Industry 4.0: Empowering ASEAN for the Circular Economy

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FOREWORD

The circular economy represents a fundamental and necessary alternative to the linear take–make–consume–dispose economic model that currently predominates industrial production systems in Asia. This old model has brought unprecedented economic growth and welfare, but has run its course. Drastically new economic models are needed wherein material inputs and waste generation are minimised through eco-design, recycling and reusing of products, new business models, and new technologies. Products and production systems need to be designed for circularity, materials need to be efficiently processed, and waste needs to be sorted and recycled. Interactive platforms need to be set up that enable people and product connectivity. The value chain needs to be revisited in terms of its circularity function, and customers provided with services rather than throwaway products. This requires a change in mentality – a different way of looking at and organising our production and consumption processes.

Using Industry 4.0 is crucial to make this transition from a linear to a circular economy happen. Industry 4.0 refers to a set of diverse and complex automation processes that are currently being used in the industry from the internet of things and 3D printing to artificial intelligence, cloud computing, machine-to-machine communication, etc. Increasingly, Industry 4.0 technologies should be used to catalyse and facilitate the transition from a linear economic model to a circular one. This requires closer cooperation between the research, technological, and business communities and the creation of an enabling policy, and an institutional, business, and financial environment that will make this cooperation possible.

Major entry points to forward the integration of these two rapidly evolving technological and business fields are resource use and management and waste management: the beginning and the end of the circular economy model. Raw material extraction, processing, and production companies can use Industry 4.0 technologies more efficiently, while the same technologies can be used for more efficient resource management and turning waste into 'new' raw material, closing the material cycle.

This 'closing of the material cycle', using in an optimal manner the developments of Industry 4.0, will not happen by itself, at least not at the speed needed to transform our economies to conform to the requirements of the Sustainable Development Goals (SDG) such as SDG 9 – sustainable industrialisation – and SDG 12 –sustainable consumption and production. Major policy changes at the business level, and local, national, and international governance levels are needed that include the exchange of expertise at an inter-regional and inter-continental level, development of infrastructure and business activities, with a strong role for eco-innovative small and medium-sized enterprises and the shift from waste thinking to materials management for circularity. We cannot have a circular economy without the 4th Industrial Revolution, and we cannot have a socially useful and sustainable 4th Industrial Revolution without advancing the circular economy.

The chapters in this volume show the key opportunities as well as challenges in embracing the two concepts in the context of the fast-growing emerging economies of ASEAN. Transforming the challenges into opportunities requires the participation of the full breadth of society and actions in nations, sectors, supply chains, and cities. Major trend corrections are needed to get the regionally integrated economies on a pathway towards circularity that is aided by Industry 4.0. The contributing chapters identify key levers and point to inconvenient truths that provide systemic challenges for moving to circularity by the middle of the 21st century.

This book is published as part of ERIA's effort to disseminate knowledge products that can be used to promote industrial restructuring in ASEAN and East Asia. I am confident that it will help countries to identify policy challenges and opportunities associated with a new wave of industrial revolutions and greater integration of the emerging best practices into the economies of ASEAN and East Asia.

Hidetoshi Nishimura
President
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LIST OF ABBREVIATIONS

3Rs	reuse, reduce, and recycle
AEC	ASEAN Economic Community
AI	artificial intelligence
APASTI	ASEAN Plan of Action on Science, Technology, and Innovation
ASAPSMED	ASEAN Strategic Action Plan for SME Development
ASEAN	Association of Southeast Asian Nations
CLMV	Cambodia, Lao People's Democratic Republic, Myanmar, and Viet Nam
CPPS	cyber-physical production systems
E&S	ecological and sustainable
EU	European Union
GCI	Global Competitiveness Index
GDP	gross domestic product
ICT	information and communications technology
IoT	internet of things
IT	information technology
ITS	intelligent transportation system
ITU	International Telecommunication Union
MNC	multinational corporation
MSME	micro, small, and medium enterprise
PBOC	People's Bank of China
PPP	public–private partnership
R&D	research and development
RFID	radio frequency identification
SCMIT	Sub-Committee on Microelectronics and Information Technology
SCP	sustainable consumption and production
SME	small to medium-sized enterprise
STI	science, technology, and innovation
WSN	wireless sensor network

Chapter 1

Industry 4.0: What Does It Mean for the Circular Economy in ASEAN?

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The Association of Southeast Asian Nations (ASEAN) encompasses Brunei, Cambodia, Indonesia, the Lao People's Democratic Republic (Lao PDR), Malaysia, Myanmar, the Philippines, Singapore, Thailand, and Viet Nam. These countries are at vastly different stages of development but all sharing immense growth potential. ASEAN is already a manufacturing hub, accounting for nearly 5% of global manufacturing in value-added term, with dominant shares in sectors such as automobiles, electronics, chemicals, textiles, food and beverages, and metal resources.

Recent studies indicate the following three trends would stimulate substantial industrial growth in ASEAN countries: the implementation of the ASEAN Economic Community (AEC) integration plan, which aims to increase intra-regional and global trade (ERIA, 2014; ADB, 2014); the application of big data and the internet of things (IoT), both disruptive technologies where many ASEAN manufacturing industries lag behind their multinational counterparts (ISEAS, 2005; RIS, 2014); and achieving improved resource efficiency and recycling rates (UNEP, 2012; ERIA, 2015), which is directly related to competitiveness.

1. Understanding the Industrial Competitiveness of ASEAN

ASEAN is a dynamic market made up of 600 million people with diverse industrial and investment landscapes. The AEC, which came into force in 2016 and with extensions granted to Cambodia, Lao PDR, Myanmar, and Viet Nam, is premised on the free flow of goods, services, labour, and investment. It is aimed to create three important components: a single market and production base, a highly competitive economic region comprising countries of equitable economic development, and a region fully integrated into the global economy. ASEAN's commitment to the AEC represents high aspirations for integration and industrial competitiveness. What started as a straightforward push to merely lower formal trade barriers has evolved into a vision of a dynamic and unified market, one that as a manufacturing base has the potential to compete with other large neighbouring economies like China and India.

At the core of this community lies a unique approach of open regionalism that has served as the catalyst for wider industrial agglomeration across East Asia. This dividend of openness to economic integration, combined with trade and other reforms within the economic bloc, has stimulated strong economic growth (ERIA, 2016). In the past decade, regional gross domestic product doubled from US$1.3 trillion (2007) to US$2.6 trillion (2017) (EMF, 2017). Prosperity, driven by export-led growth, keeps rising with a per capita gross domestic product of US$5,000 a year and the population with an income of more than US$5,000 per year is estimated to grow from 300 million in 2015 to 400 million in 2020 (World Bank, 2018), making ASEAN one of the world's most important consumer markets for raw materials and finished products.

The foreign direct investment that flows into six major ASEAN economies – Indonesia, Malaysia, the Philippines, Singapore, Thailand, and Viet Nam, which together account for more than 95% of regional gross domestic product – shows several drivers of competitiveness. For example, competitiveness for the chemicals and automobile sectors is characterised by innovations, research and development (R&D) spending, and a global manufacturing strategy that usually entails regional supply chain and production networks. Table 1 shows that manufacturing-related foreign direct investment for the six ASEAN countries, totalling US$225 billion between 2009 to 2016, is centred on global innovation for local markets (34%), regional processing (28%), and energy-intensive commodities (27%).

Table 1. Competitiveness of the ASEAN Manufacturing Sector

Percentage of manufacturing-related FDI by sector (2009–2016)

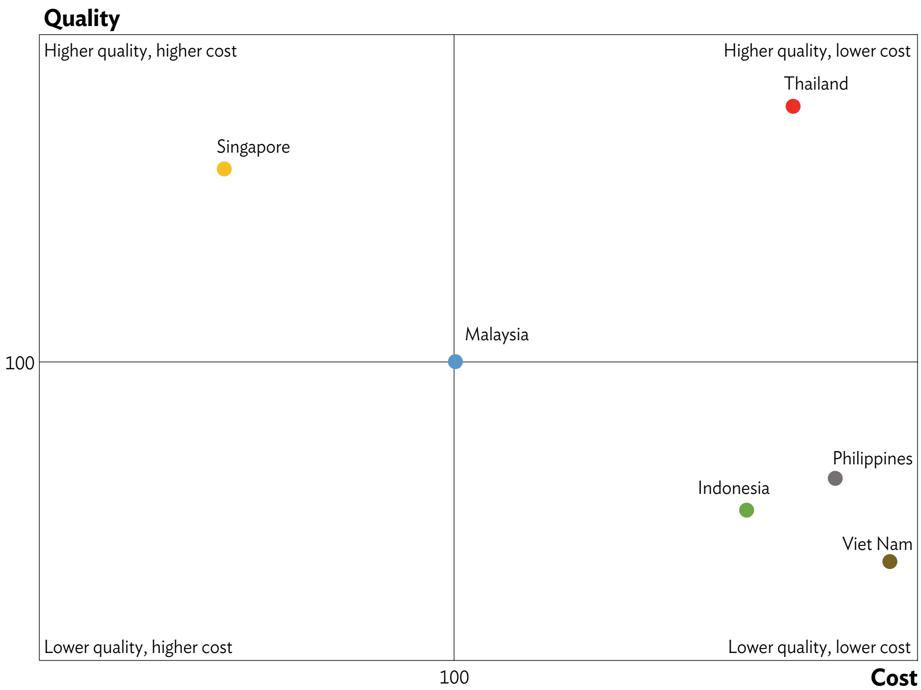
Group	Industry	ASEAN-6 Total	Indonesia	Singapore	Viet Nam	Malaysia	Thailand	Philipines
Global innovation for local markets	Chemicals	9	5	13	14	5	6	2
	Motor vehicles and components	9	13	<1	3	3	42	3
	Other transport equipment	6	2	4	4	20	2	9
	Electrical machinery	6	2	3	6	20	3	7
	Machinery, equipment, appliances	4	1	4	6	6	6	4
Regional processing	Rubber and plastics products	5	8	2	1	5	14	2
	Fabricated metal products	8	14	3	9	6	9	4
	Food, beverage, and tobacco	14	7	38	9	3	5	14
	Printing and publishing	<1	<1	<1	<1	<1	<1	<1
Energy-resource-intensive commodities	Wood products	<1	<1	<1	<1	<1	<1	<1
	Refined petroleum, coke, nuclear	6	<1	2	26	1	<1	<1
	Paper and pulp	1	<1	<1	1	2	<1	<1
	Mineral-based products	8	19	5	1	6	1	17
	Basic metals	12	23	1	14	14	2	13
Global technologies/ innovators	Computers and office machinery	3	2	3	<1	1	5	11
	innovators	5	<1	15	1	4	3	11
	Medical, precision, and optical	2	<1	6	1	3	1	1
Labour-intensive tradable	Textiles, apparel, leather	1	2	<1	2	<1	<1	<1
	Furniture, jewelry, toys, other	<1	<1	<1	<1	<1	<1	<1
Total		100	100	100	100	100	100	100
Total, US$ Bn		225	61	56	45	32	21	10

ASEAN = Association of Southeast Asian Nations, Bn = billion, FDI = foreign direct investment.

Source: World Bank Data Base: https://data.worldbank.org/indicator/BX.KLT.DINV.CD.WD

The competitiveness index, which uses a detailed database of several indicators weighted by the importance to cost and revenue base for selected sectors, such as the automobile sector, shows quality factors such as talent pool, internet access for improved connectivity, current ecosystem, or linkages to resource recycling, makes countries an attractive location (Figure 1). Generally, the productivity growth in manufacturing has been respectable in ASEAN countries. On the other hand, there is substantial room for increasing quality with less cost. Within ASEAN, Singapore and Malaysia have seen an increase in quality of growth, while emerging economies like Indonesia, the Philippines, and Viet Nam take advantage of low-cost production to improve growth conditions although the quality remains at comparatively low level. Alongside its many successes, ASEAN faces considerable challenges. Arguably, the most momentous challenge is how to keep pace with the fast technological advancement happening in the rest of the world. In practice, quality considerations, innovations, and technology absorption are more important when considering the future growth of ASEAN industries (EIU, 2016). In the manufacturing sectors, the use of new approaches such as big data, IoT, and material recycling could improve demand forecasting and production planning, leading to better quality and higher profit margins (WEF, 2017).

Figure 1. Positioning of ASEAN Countries in Terms of Competitiveness



Source: Based on calculations from World Bank, 2016; McKinsey Global Institute, 2014; and United Nations, 2014.

2. Industry 4.0: Finding Frontier Productive Value for ASEAN

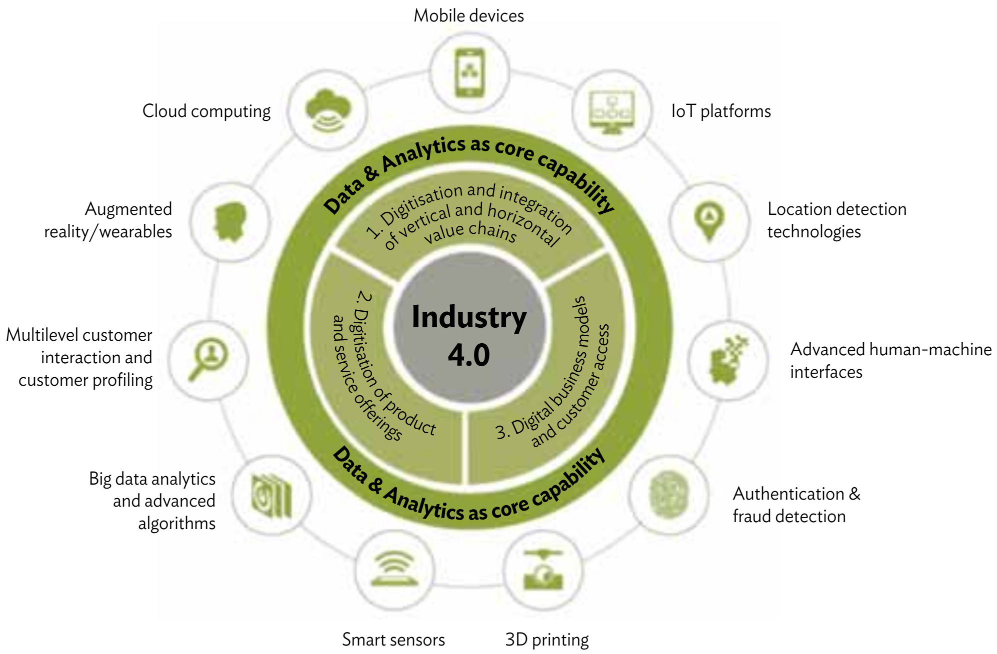
Industry 4.0 is often cited as the fourth major upheaval in modern manufacturing, following the lean revolution in the 1970s, the out-sourcing phenomenon of the 1990s, and the automation that took off in the 2000s (Roland Berger, 2014). It is also defined as the next phase of powerful technologies that have strong potential to step up competitiveness and create differentiated products. New digitally enabled technologies include advances in production equipment such as 3D printing, advanced robotics, smart finished products such as connected cars and home appliance systems using IoT, advanced analytics such as big data analytics and analytics across the global value chain, human–machine interfaces such as picking technology using augmented reality and artificial intelligence, etc.

In some part of the advanced economies like Japan and Germany, these technologies are changing the way by which industrial processes are designed and serviced. In combination, these technologies can create value by connecting individuals and machines, making it possible to generate, securely organise, and draw insights from vast data on production systems and networks (Kolberg and Zuhlke, 2015). They hold the potential for positive change, making production process more cost efficient. They will facilitate innovation and can improve the top line of business. For example, aggregation and analysis of data across a product's life cycle can increase the uptime of manufacturing unit, reduce time to market, and make it possible to understand the most favoured consumers for a particular product. They also get production innovation as an exercise of analysing, testing, and responding to hard data and robust simulations (Bagheri et al., 2015).

The Industry 4.0 concept is already proving its potential to create global value chains at points beyond the design phase. For example, soft drinks producer Coca Cola applied a flexible packaging process in its 'Share a Coke' campaign, in which firms collaborated throughout the global supply chain and helped increase the company's soft drink volumes across the world markets (Isaiah, 2015). German automaker Daimler has a rolled out 'Mercedes me' scheme, which, amongst other features, tracks the usage of key automotive parts to help service automobiles more effectively. It is important that opportunities for Industry 4.0 are not just for big corporations. Small and medium-sized enterprises, for example, are using some internet-based wholesale programmes, such as Alibaba, as a digital distribution platform to scale up their productivity and consumer markets (Sommer, 2015).

These and many other changes are certain to be far reaching, affecting the future manufacturing capacity and competitiveness of industries in ASEAN. But the pace of change will also have profound impact. The advent of production networks and their automation has resulted in the outright replacement of about 40%–50% industrial equipment (Thorbecke, Lamberte, and Komoto, 2013). One kind of lost value that is sure of interest to manufacturers is process effectiveness that comes with Industry 4.0. Essentially, it offers new tools for smarter energy consumption, use of alternate materials, greater information storage or intelligent lots, and real time productivity optimisation. There are several choices, levers, and values, which include but are not limited to digitalisation of vertical and horizontal value chains, application of IoT in product and service offerings, and new business models that use data analytics as a core capability (Figure 2).

Figure 2. Industry 4.0 Framework and Contributing Digital Technologies



IOT = internet of things.

Source: PricewaterhouseCoopers, 2017.

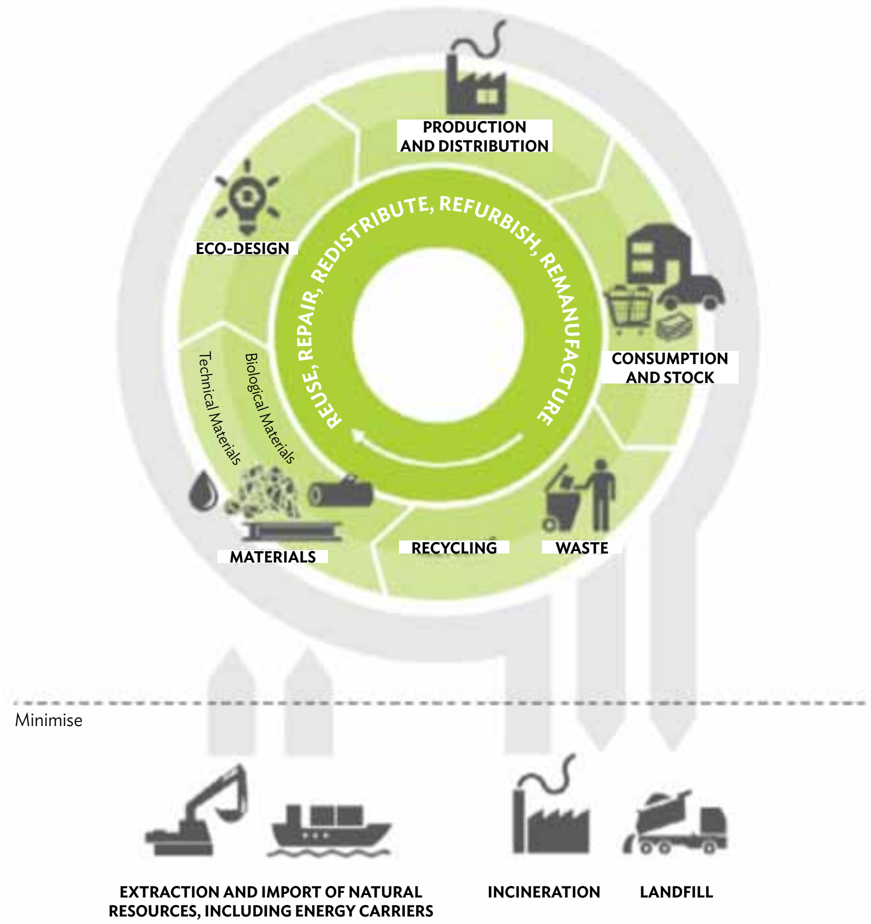
3. The Circular Economy: Motivating Competitiveness Through Resource Efficiency

The circular economy is an umbrella term used for industrial process and business models that do not generate waste but instead reuse natural resources repeatedly. At its core, the circular business is about economics and competitiveness. Its approach to resource efficiency integrates cleaner production and industrial ecology in a border system, encompassing industrial firms or network of firms to support resource optimisation (Di Maio and Rem, 2015). At the firm level, higher resource efficiency is sought through the 3R: reduce consumption of resources, reuse resources, and recycle the by-products. Sustainable product and process designs are important circular economy plans. In such a business model, instead of selling products to consumers, companies can retain ownership of the physical products and consumers only pay for the use they derive from them. This spurs firms to make their inventory of assets as thin as possible. An example of this is an action by tyre manufacturer Bridgestone, which sells mileage, not tyres, to customers (Mouri, 2016). When a tyre is no longer roadworthy, Bridgestone simply replaces it for clients. The manufacturer retreads, repairs, and regrooves the old tyres in its workshops.

At a national level, countries can boost industrial competitiveness by supporting a shift towards a new industrial process that minimises waste and focuses instead on resource recovery (Park, Sarkis, and Wu, 2010). The set of new technologies under Industry 4.0 framework has data analytics as a core capability to speed up this transition. This is because the circular economy, with its focus on recycling, innovation, and skills development, is inherently more labour intensive than the linear industrial production model of 'take, make, waste' but uses less energy and raw materials.

In comparison to ASEAN, companies and the governments in Japan, Europe, and the United States (US) have taken a more proactive approach to embrace the circular economy. The European Union (EU), for example, passed in 2017 a circular economy package that includes various laws on reducing waste, and sustainable manufacturing, with 5R components of reuse, repair, redistribute, refurbish, and remanufacture, as shown in Figure 3. By this systemic approach, the circular economy has the ambition to minimise material usage per unit of functionality and to manage materials in the system in such a way that losses and emissions are minimised. In many ASEAN countries, resource-use policy is typically based on 3R: reuse, reduce, recycle. The circular economy adds upstream measures (in product design, for example) to this 3R principle. But they have very valid reasons for adopting 5R framework conditions.

Figure 3. A Simplified Model of the Circular Economy



Source: European Environment Agency, 2016.

Over decades, since the boom of new industrialisation, ASEAN adopted export-led growth, which has enhanced living standards and brought new wealth to industries and comfort to policymakers in shaping their economic modernisation. Embedded deep within the take-make-waste tradition of linear economy are negative consequences ranging from depletion of natural resources, social inequality, and worsening of the risks and effects of climate change (ADB and ADBI, 2014).

This flawed linear model is no longer fit for ASEAN, which has also become the fastest growing region in term of resource consumption. Breaking down products into their individual materials and using them to make new products or other energy streams is a cheap and effective solution (Genovese et al., 2015). By reusing existing materials, firms can avoid the hassles and cost of procuring new raw materials. The circular economy model, where ownership of good is not transferred to customers at all, is the most profitable business model as it guarantees recovery of all the materials, and is thus protected from sudden spikes in commodity prices (UNEP, 2017).

The introduction of the circular economy will generate at firm level new technological and non-technological needs. The concepts of change in ownership and material management, both at consumer and business levels, generate a need for introducing new business concepts, such as products as service, sharing platforms, peer-to-peer interactions, and industrial symbiosis (Cullen, 2017). Many of these are based on the availability of efficient information and communications tools such as apps, websites, consumer and user platforms, and customer-driven databases.

The circular economy concept has made headways in some companies. Ricoh, a global maker of office machines, produces a brand of office copiers and printers that maximise reusability of products and components while minimising the use of raw materials. Products returned from their leasing contracts are inspected, dismantled, and taken through an extensive refurbishing process that includes replacing components and updating software before they re-enter the market. By designing the components to be reused or recycled in its facilities, Ricoh reduces the need for new materials in production and creates a tight closed loop of use that allows it to employ fewer materials, and less energy, labor, and capital.

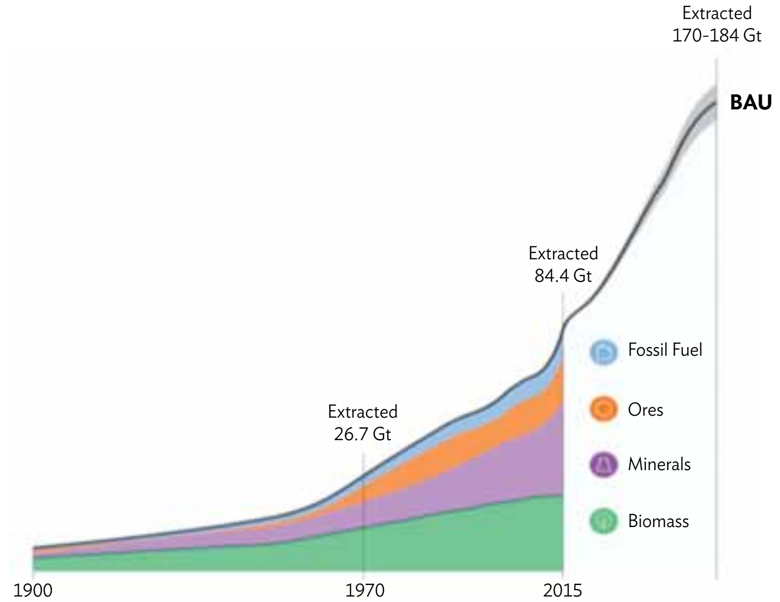
Regulations stimulate business innovations. Inspired by Japanese and German recycling laws, China formed a circular economy initiative in 2008 which is supposed to set new levels of competitiveness for its economy (Su et al., 2013). Unlike the EU, ASEAN lacks formal direct policies but has a long legacy of finding ways to reuse goods and reduce wastes. For example, the first jeepneys, a common mode of transport in the Philippines, were refurbished military jeeps left behind by the US forces after World War II. Localised services such as garments repair and automobile tyre restoration are developed industries in many countries of ASEAN without any legally binding and measurable targets than in advanced economies.

4. Empowering ASEAN for Industry 4.0 and the Circular Economy

A lot of hope has been built up around Industry 4.0 and circular economy notions over the last few years, creating awareness amongst policymakers and company executives, and contributing significantly to the rejuvenation of industries in the ASEAN context. In view of this, industry leaders in advanced economies remain optimistic overall and see the transition to Industry 4.0 and the circular economy as a unique opportunity to gain global competitiveness, consumer confidence, and environmental integrity.

In truth, momentum is already building in Asia. Almost 2 decades into the 21st century, ASEAN, along with China and India, has emerged as the world's largest consumer of minerals, ores, biomass, and fuels. As Figure 4 indicates, over the last 40 years, the use of these materials almost tripled from 26.7 billion tonnes in 1970 to 84.7 billion tonnes in 2017 (UNEP, 2017). Demands for resources and energy continue to expand in line with the region's industrialisation, rapid urbanisation, and accelerated economic growth. Without alternate models of growth and appropriate planning, consumed materials and resources may ultimately end up as wastes and pollutants, imparting negative impacts to the economy.

Figure 4. Global Trend in Extraction of Materials, Fossil Fuels, Ores, and Biomass



BAU: Business-as-usual, Gt: Gigatonnes (equal to billion tonnes).
Source: United Nations Environment Programme, 2017.

In a circular economic system, resources are to be kept at the highest possible level of functionality at all times. This goes beyond just waste, requiring that natural resources are managed efficiently and sustainably throughout their life cycles. Ecodesign, innovation, product sharing, waste prevention, and waste recycling are all important in a circular economy. At the same time, material losses through landfills and incineration will be reduced, although these may continue to play a much-reduced role in safely removing hazardous substances from the biosphere and recovering energy from non-recyclable waste. Several concepts of the circular economy and visualisations of its operational principles exist. They can empower ASEAN to create economic and environmental co-benefits, as the dependency on extraction and imports declines in parallel with a reduction in emissions. Thus, the circular economy generates new opportunities and needs for business. These can be grouped according to the following archetypes where each represents a specific business focus as the main entry point for developing a circular business model (EIT Raw Materials, 2017).

- relationship with customer: providing a service instead of a product
- product or process: circular product or process design
- relationship with the value network: building circular value networks
- sustainable identity: circularity as a unique selling proposition

In most cases, a company will combine elements of each archetype in its business approach. However, looking from an industrial perspective, the circular economy generates technological needs in manufacturing, processing, identification, and recycling of materials and products. The main needs are advanced collection, sorting and recycling technologies; efficient materials processing technologies; production technologies that support design for circularity; and interactive platforms for enhanced connectivity.

These needs are to be covered by robotics, analytics and artificial intelligence, sensors and connectivity, machine learning, and human–machine interfaces. All these technologies can typically be designated as Industry 4.0. Until now, the frameworks of Industry 4.0 and the circular economy have not been connected in theory, practice, policy initiatives, and research programmes.

Nevertheless, the term Industry 4.0 is applied to a group of rapid transformations in the design, manufacture, operation, and service of manufacturing systems. The term originated in Germany but developments in other Asian countries have resulted in other labels, such as smart factories, the industrial internet of things, smart industry, or advanced manufacturing. The European Parliament's briefing 'Digitalisation for productivity and growth' mentions that Industry 4.0 builds upon a number of six new technology developments (Table 2). Similarly, Lacy & Rutqvist (2015) has identified 10 digital, engineering, and hybrid technologies that will enable the transformation of the current linear economy into a circular one.

Table 2. **Technological Developments for Industry 4.0 and the Circular Economy**

Technological developments for Industry 4.0
Information and communications technology
Cyber-physical systems
Network communications - internet of things (IoT)
Simulation
Advanced data analytics
Robots, augmented reality, and intelligent tools for support of human workers

Ten disruptive technologies for the circular economy
Mobile technology
Machine-to-machine communication
Cloud computing
Social media for business
Big data analytics
Modular design technology
Advanced recycling technology
Life and material science technology
Trace and return systems
3D Printing

Source: Authors.

On the other hand, PriceWaterhouseCoopers (2017) presents a framework for Industry 4.0 based on the following elements: digital business models and customer access, digitalisation of product and service offerings, and digitalisation and integration of vertical and horizontal value chains.

If these elements are compared, it is striking that similar concepts emerge. Both the circular economy and Industry 4.0 are based on new product and process offerings, an integration of value chains, and a change in the approach of customers.

From this perspective, it becomes clear that Industry 4.0 and circular economy at least share common levers of change. Circular economy is considered a driver for envisioning the sustainable industry while Industry 4.0 provides the driver for circular innovation.

A sustainable industrial system should be designed and run to the needs of the society it serves. The Industry 4.0 for circular economy is, therefore, to be an agenda with a measurable impact framework that extends beyond mere enhancement of resource efficiency. As a multi-stakeholder model, it should boast capacity and capability of firms to serve the industry and societal needs of ASEAN by embracing the power of entrepreneurship, innovation, and collaboration. The radical and holistic interconnectedness of Industry 4.0 and circular economy means it is both aspirational and responsible. The transition and integration of Industry 4.0 and the circular economy call for intellectual rigor and collective innovation in system design, combined with resolute determination. They also challenge the ASEAN industry to exhibit leadership.

Several barriers to the growth of Industry 4.0 in the circular economy could also be identified, which include the fact that the region's markets are not yet saturated or mature. In saturated markets, product sales hit a peak and can increase no further unless governments set new targets for eco-efficiency and companies improve the product significantly. But this is not the case in ASEAN, where economic growth is driving ever-increasing growth in demand for use of raw materials. Industrial innovation and waste prevention are not a political priority amongst the region's lawmakers, who are preoccupied with other developmental priorities. Breaking ingrained consumer habits is also difficult. Misaligned economic incentives dot the industrial landscape, making it hard to create, capture, and redistribute resource efficiency value. Customers and governments, as the largest consumers, for instance, are used to evaluating the costs of products at the point of sale, even if more expensive but longer lasting products and services would be more economical in the long run. Ingrained habits with top management in companies also thwart changes. Senior executives always worry about the higher levels of capital needed to replace old production systems, as well as the friction of moving from familiar and proven old approaches.

Ultimately, the systematic nature of challenges means that individual corporate actions, while necessary, will not suffice to create the transition needed at a scale. The real payoff will come only when all stakeholders, business community, policymakers, and researchers come together to reconceive the concepts as appropriate to the region, device key strategies, and make support policies.

To take stock of these complex and diverse developments in this field and shed light on why some players are making progress while others are not, we draw upon, in this book, global knowledge to present and discuss its relevance to ASEAN economies along the following dimensions.

- Perception: To what extent have global awareness and ASEAN attitudes towards Industry 4.0 and the circular economy evolved over the years?
- Progress: How much progress have countries and companies made in implementing the key levers of Industry 4.0 and the circular economy in an integrated way?
- Problems: What are the perceived key barriers to implementation of such an integrated concept in ASEAN countries and companies?

5. Value Pools of Integrating the Circular Economy and Industry 4.0

ASEAN as a region has economically grown faster and more integrated, but there are increasing signs of underdevelopment in resource efficiency and technological advancement. A fresh perspective for industrial transformation of ASEAN could be offered if it is built upon the notion of Industry 4.0 and the circular economy. This is discussed in this book under the value proposition themes of global economic transition and next industrial evolutionary acts, finding economic values and capturing firm competitiveness, understanding the risks and adverse social impacts, financing essentials of integrated strategies, managing the transition through multilevel governance system, and regional architecture for decades ahead.

A main motivation for having this value pool analysis is that while it links up the levers of two emerging concepts, it shifts the attention from a vague end goal to stimulating a transformation process and making corrective steps to systemic challenges. Both convey the message that formation of a system-wide approach that takes into account sectoral interaction as well as complex relationship between technologies, institutions, and economies is needed.

5.1 Global Economic Transition and Next Industrial Evolutionary Acts

Traditionally, the manufacturing and resource-use sectors in ASEAN are driven and dominated by large corporations and small and medium-sized enterprises (SMEs) in their value chains. This is mostly linked to high capital expenditure intensity, long payback periods of investment, and rather low fungibility of assets in operation. However, new digital technologies, business model innovations, and regulatory changes have the potential to transform the competitiveness landscape of these sectors. A competitive resource-efficiency paradigm with value pools around new digital technologies will increase the efficiency of resource supply and reduce waste and material usage, such as those related to Industry 4.0-type technologies for manufacturing and raw material-processing companies; advanced sorting, dismantling, and recycling technologies; waste management for electronic waste, precious, and specialty metals; and new usage models that shift products to services, or virtualise or redistribute products.

The inherent strength of ASEAN economies allows an effective move towards a resource efficiency economy that is supported by technological innovations. Several studies recognise not only the need for more efficient management of resources in view of increasing consumption patterns but also the inherent strength of ASEAN economies concerning recovery and recycling as well as digital technologies. The combination of both must allow a direct move towards effective circular systems, avoiding linear system lock-ins (EMF, 2017).

Table 3 presents the contributing value levers and technologies for business creation in the different steps of the material value chain. It shows that digitalisation technologies are central in this.

Naturally, incumbent players would be rather slow in exploiting such newly arising opportunities. Start-ups, not having the need to defend legacy business, are generally more agile in this field. The relatively limited number of viable new ventures in the resource-use sector compared to the economic potential, however, indicates market barriers that impede entry or scale-up of new Industry 4.0 technologies and circular ventures. Such barriers include high upfront capital and specialised knowledge requirements, market-specific trading patterns, and market reflexivity. Altogether, these result in high underlying volatility and risk with regards to new venture business.

Table 3. Value Levers for Business Creation Across the Material Value Chain

	Extraction 1	Processing 2	Manufacturing 3	Usage 4	Recycling 5
Value lever	**Increase mining efficiency**	**Increase processing yield**	**Optimise product design & waste**	**Shift in usage models**	**Increase recovery share**
Startup/SME value pools	*Digital mining technologies* Software, services, and digital equipment to better understand resource base, optimise materials/ equipment flow, and optimise failure and safety rates	*Digital processing technologies* Software, services and digital equipment to optimise materials flow, automate and monitor processes, and optimise failure and safety rates	*Digital manufacturing technologies* Software, services, and digital equipment to better understand resource base, optimise materials/ equipment flow, and optimise failure and safety rates	*New business models* New usage models that shift product-to-service (e.g. sharing models), virtualise products or reuse/ redistribute existing products	*Recycling technologies* Leverage data analytics and advanced robotics to automate complex recycling processes Capacity expansion Business cases along secondary material supply chain are becoming viable due to shift in regulation, prices, technologies
Examples	Sensors, remote steering equipment, geological modelling, predictive maintenance	Material flow software, remote steering, augmented reality, predictive maintenance	Virtual product design software, rapid prototyping solutions, augmented reality	Car sharing, energy sharing, pay-as-you-use appliances	Take-back platforms, urban mining, automated e-waste recycling

SME = small and medium-sized enterprise.
Source: Authors.

The manufacturing industry forms the breeding ground for new digital production technologies. The transition towards advanced manufacturing systems also entails a differentiation of the product offerings and a further integration of the full product value chain. If competitiveness and sustainability principles are integrated into this evolution, the sector will be a strong enabler to realise sustainable development.

Hence, the manufacturing and raw materials industry needs to refocus its future approaches in increasing productivity. Technology diversification and modernisation are the basis for resilience in the sector, which needs to shift away from maximising material supply to providing the right material for the right product at the right place. Coupling this technology modernisation idea to the principles of the circular economy leads to a different approach for sourcing and management of materials.

When focusing specifically on businesses, SMEs play a very important role in facilitating transformation along value chains. Businesses that are able to anticipate this transformation can increase their market access, value creation, and business growth along with increased operational resilience.

The introduction of Industry 4.0 will be a determining factor for the future of the manufacturing sector. Material management will no longer be merely a logistic concept. In current practice, waste collection services are already optimised using manual labour and mobility vehicles. The introduction of sensoring, identification, and tracing that allows data collection on the flow and destination of goods and components is a technical and economic possibility. Data analysis and intelligence, together with IoT, will enable the mapping of materials and initiate a new range of material management services.

The results of an industry survey by the International Solid Waste Association (2017) on the future of the waste industry and Industry 4.0 show that new biodegradable materials and sensors technologies will have the highest impact on products. To drive and allow this impact, development and investment in big data and artificial intelligence are necessary. These are not yet in the comfort zone for ASEAN business. The main impact areas already identified by the sector are redesign of products and changed recycling practices.

In waste sorting and material processing, the introduction of advanced characterisation techniques and robots may revolutionise the current practice. The introduction of large-scale sorting installations will enable the production of higher-value recovery materials and the production of new higher-grade secondary products. It will impact waste collection and recycling schemes and allow strong progress in material recycling and current landfilling practice.

5.2 Finding Economic Values and Capturing Firm Competitiveness

Characterised by new technologies using physical, digital, and biological potentials, Industry 4.0 will impact at an unprecedented rate on resource use and industries. On the one hand, academia and policymakers still see high uncertainty amongst industries of what implementation of Industry 4.0 and the circular economy really requires of them, and many are still struggling to even get started. On the other hand, several pioneering companies have moved relatively fast in adjusting their portfolios towards the new concepts. There are also manufacturers who report some progress, especially when moving beyond these umbrella terms and focusing on valuable, business-specific applications (Kim and Kim, 2016; Geng et al., 2013).

Practical cases show the use of robotics in disassembly of products and as enabler for repair, refurbishment, and remanufacturing. These techniques stimulate industries to enlarge their focus from materials only to the products and the herein contained components and materials. The use of advanced characterisation techniques in combination with big data analytics and machine learning brings new capacities for sorting processes, with production of higher quality materials for recycling. Smart data could enable several new opportunities and support overall differentiation and customer retention (Wijkman and Skanberg, 2016).

Product lifetime extension is an important economic value of circular business as it generates economic value and materials savings. The product-system design approach should consider both forward and reverse logistics as well as a new value proposition that is based in maximised customer utility via multiple product lives.

Companies that have been pioneering the digital era, such as Google and IBM, are driving the development of new technologies to enable the circular economy. Data management and connectivity, machine learning, and artificial intelligence are finding their way from process optimisation in industry towards optimisation of product and waste management systems. Robust, traceable materials information management is an enabler for machine learning for future product designs. The use of an open innovation approach in production technologies, such as 3D printing, results in improved accessibility of the technologies and speeds up progress in material efficiency and dematerialisation.

New companies can provide database services to manufacturing industry and allow the development of circular material streams in which companies have better access to specific recycled materials. Big data, artificial intelligence, and block chain can accelerate transition into the circular economy by delivering viable business model and value connection between waste creators, waste processors, and remanufacturers. The use of ICT-enabled apps at local level allows for better collection practices and reduction of littering through citizen involvement.

The imperative for industry is to embrace a technology-driven product design approach that considers both forward and reverse logistics as well as a new value proposition that is based on maximised customer utility via multiple product service lives. The imperative for governments is to enable and optimise value retention within the system, which requires investment in the development of efficient reverse-logistics infrastructure, incentives for increased participation rates and value-retention capacity, and alleviation of regulatory-based barriers to circular processes and products (UNEP, 2017).

Increased productivity could unleash an additional US$200 billion–US$625 billion in annual economic impact by 2030 (Krausman et al., 2017). It will also provide high value for individuals not held by traditional measures.

Innovative and agile start-ups and SMEs with no need to defend legacy business are widely entering the circular economy and Industry 4.0 field by providing new digital platforms and disruptive service solutions to maximise the value of products and materials. Partnerships between established and small companies hold great promise for disruptive new solutions.

New technologies will create new ways for citizens to connect to each other, to trade with each other, and to access environment-friendly services currently not available. Small and medium-sized enterprises are the backbones of ASEAN economies. Between 89% and 99% of enterprises within ASEAN are SMEs and they provide 52%–97% employment in member states. They are also important source of innovation. Many SMEs, however, are limited in their ability to grow because of lack of access to finance and business services and information, and constrained access to markets beyond their immediate neighbourhood. The rise of digital market places and non-services can empower SMEs to trade their raw materials and wastes in ways unimaginable. Technologies such as block chain will revolutionise logistics, enabling small firms to interact on a trust basis without having to meet each other. At present, the value of e-commerce in ASEAN stands at US$9 billion or about US$14 per person. In China, the value is US$426 billion or US$327 per person, illustrating the size of the potential (WEF, 2015).

Integrating Industry 4.0 with the circular economy can offer opportunities for leapfrogging. It creates the opportunity for least developing countries of ASEAN – Cambodia, Lao PDR, Myanmar, and Viet Nam – to bypass the traditional phase of industrial development and resource conservation. With clever policies, ASEAN could become a global leader in some selected technologies through smart, regionally harmonised regulations. Some ASEAN nations, notably Indonesia, the Philippines, and Malaysia, are archipelagic and physical connectivity has long been a concern for economic development. Equally, some ASEAN countries like Lao PDR, Cambodia, and Myanmar have large rural populations and rural industries that have yet to benefit from the technologies of the first and second industrial revolutions. Given the high cost of moving goods and labour, Industry 4.0 technologies may be particularly advantageous in the context of agro-industries. Moreover, recent calculation suggests that 40% of the land in six ASEAN countries is suffering from severe or very severe industry-induced degradation. With economic growth projected to grow 8% a year in the next six years (EMF, 2017), pressure for resource conservation will increase substantially. Artificial intelligence, drones, and remote sensing offer opportunities to monitor industry, agriculture, and fisheries activities much more effectively.

5.3 Understanding the Risks and Adverse Social Impacts

Industrialisation within many ASEAN countries has been on the supply of relatively low-cost and low-skilled labour that attracts foreign investment. However, technologies such as artificial intelligence and robotics will decree the competitiveness of low-cost and low-skilled labour. Equally, 3D printing will transform the nature of manufacturing. Today, with the advent of production networks, many goods are made at decentralised locations operating at scale and producing standardised products. In the future, 3D printing may mean that products are produced locally, next to demand, on a highly customised basis. That means waste management and recycling options are mostly localised rather than cross-boundary.

Industry 4.0 technologies are also rapidly increasing jobs that can be performed better and faster by machines rather than by people. While these may reduce costs and raise productivity, they will also threaten jobs, and some members of ASEAN will be more affected than others. The immediate threats are to low-skilled, repetitive jobs such as those by assembly line workers. But services jobs are also at risk, threatening to undermine regional success stories such as the rise of the business-process outsourcing sector. In a survey by the World Economic Forum, the largest employers in 10 industries and 15 economies believed that complex problem-solving skills will be more in demand compared to technical jobs (Table 4).

Table 4. **Skills Demand in 2025**

Skills Demand	Recognised Sector
Cognitive abilities	15%
System skills	17%
Complex problem solving	36%
Content skills	10%
Process skills	18%
Social skills	19%
Resource management skills	13%
Technical skills	12%
Physical abilities	4%

Source: World Economic Forum, 2015.

Every revolution creates fears over job losses. This applies to Industry 4.0 as well. In the past, however, new waste management operations generally led to more jobs being created through growth of new recycling industries. The outlook is less positive under Industry 4.0. The International Labour Organization (ILO) (2016) estimates that 56% of jobs in five ASEAN countries – Cambodia, Indonesia, Viet Nam, Thailand, and the Philippines – are at high risk of automation in the next few decades. At the same time, the workforce in ASEAN is forecast to grow by 11,000 new workers every day for the next 15 years (ILO, 2016). In the short time, at least, it is likely that unemployment will increase. This could lead to high numbers of economic migrants within ASEAN and increasing inequality. Retraining and skills development may cushion the impact of automation, but they will not prevent deep shocks.

Although Industry 4.0 for the circular economy promises to empower ASEAN SMEs, it may create difficulties for larger businesses. This becomes true for types of companies that require scale to be competitive, such as banks and online businesses. The spread of digital networks means that the economics of online business no longer experience diminishing returns to scale. An additional customer or user has almost zero marginal cost and instead delivers ever greater value through the impact of network effects. On the other hand, as more and more devices, sensors, and machines are connected through the internet, the potential for damage and cyber attacks will be rising significantly. The likely annual cost to the global economy from cybercrime is between US$375 billion and US$575 billion (Reuters, 2014).

5.4 Financing Essentials of Integrated Strategies

Financial inclusion and access to finance are key determinants of the success of Industry 4.0 and circular economy notions. ASEAN has banking and financial systems to provide services to retail as well as business customers. However, the penetration of formal financial systems has limitations.

The vision, possibilities, and roadmaps looking into the future of the circular economy must look into some key areas that can slow the pace of integration across sectors. First, pioneering examples of activities supporting Industry 4.0 are primarily in large firms. In the opposite side of the spectrum are SMEs that often provide inputs and components or services along complex supply chains. SMEs are, by definition, fragile entities with a high bankruptcy in the market but still accounting for more than 80% of establishments creating employment. One key factor hindering the circular economy innovation in SMEs is access to finance. This is likely to continue.

Second, the industry-installed technology capacity will change gradually and a sweeping change is not expected to overcome entire production systems. The change is likely to follow a pattern of 'discrete islands of change', that is, one machine here, a software there, one or two materials further there, etc. The challenge will be to keep up the pace of upscaling these changes in the industrial and services landscape that need to be continually financed.

Third, the circular economy is likely to ride on the shoulders of Industry 4.0, not the other way around. Thus, the circular economy would depend to a large extent on the success of the digitalisation of industry and the connectivity and interoperability of platforms, which need innovative financing.

Fourth, connectivity and interoperability of platforms requires large efforts to achieve a new generation and a confluence of standards along vertical and horizontal integration within industry. This connectivity concerns not only the technical hurdles, but also the alignment of business models that would unlock current legacy systems. Efficiency gains can only be reached through smooth alignment of innovation and standards/policy. This is a necessary requirement for providing a stable basis for financing.

5.5 Managing the Transition Through Multilevel Governance System

The integration of Industry 4.0 with the circular economy will not only affect the priorities and issues of policymaking but will also require a new approach to how these policies are created and implemented. Given the significance of the complementarities and the speed at which this integration is unfolding, it will be critical for ASEAN leaders to think creatively about how they can upgrade crafting policy, setting standards, and writing regulations at a regional or global scale. Otherwise, ASEAN may well find itself on the wrong side of developmental reset. The traditional models of crafting policy, regulations, and standards have been relatively linear, time consuming, and top-down in approach. Today, the imperatives of Industry 4.0 and the circular economy demand a different set of guiding principles of multilevel governance.

A combination of legislative approach and establishment of necessary infrastructure and restructuring of services is key in this respect. Collaboration and sharing of expertise amongst different regions will allow capacity building for local policymakers. This can happen at regional level. But lessons can also be learnt and expertise shared between the continents. A local stakeholder platform involving representatives from policy, industry, research, and society is a strong driver to enable and smoothen the implementation of successful integration.

Governance bodies and committees, regulators, and policymakers must be flexible to respond to changing circumstances without losing sight of the overarching goals and values the legislation is designed to support. As technologies evolve, regulators must have the ability to correct their course in real time. Part of adopting a more agile and flexible approach to policymaking is the need to be both more experimental and iterative. Rather than running long time-consuming process for setting rules and standards, policymaking will need to develop ideas quickly, implement these in experimental settings, learn lessons quickly, and steer feedback into the rule-making process. Building institutions that can link local-scale experiments in different countries could provide faster way of designing regional regulations. It suggests a bottom-up approach.

Digitalisation and Industry 4.0 technologies help companies move into new production systems, alternative product approaches, and ultimately into the circular economy. Data sciences support companies to optimise material flows and manage the circular value chain. In this regard, past regional government initiatives for resource efficiency show success on a strong stakeholder involvement and close collaboration between research, industry, society and government. There are three key conditions for such successful stakeholder involvement: a shared ambition based on strong drivers, a single focal point acting as a fly wheel, and engagement and willingness to act on all levels.

A first important mind shift, needed for the collective approach, is to move the focus from waste management to resources efficiency. The systemic change can be initiated by innovative SMEs. Such newcomers need specific coaching, enabling conditions, and financial support.

The young generation is seen to embrace Industry 4.0 and the circular economy in a natural way. They show increased participation in sharing and leasing systems, community platforms, and are stepping away from product-ownership focus. This holds great promise for the implementation of a digitally enabled circular economy.

Truly effective policymaking for a circular economy must consider the above potentials and input of all stakeholders. The ASEAN approach of consultation, compromise, and consensus as well as open regionalism makes it ideal for enabling the development of regional regulations and legislations that can open the doors to global phenomenon while maintaining the values and principles of the communities and countries.

5.6 Regional Architecture for Decades Ahead

A new industrial revolution based on digital technology does not recognise national boundaries but can help manage national and cross-boundary issues. Regionally coordinated approaches will help ASEAN capture the opportunities and manage the challenges that accompany Industry 4.0 through very different channels.
Big data will be the foundation for Industry 4.0 and thus all new circular technologies to be built on it. Of particular impact is the ability to transfer and access data across borders. Individuals, companies, and governments will increasingly rely on the ability to move, process, and store data and reap the benefits. Combining different types of data and reusing existing data allow for an exponential increase in the creation of economic and social benefits. Conversely, any attempts to lock data away and erect barriers to accessing them will reduce the ability of companies and individuals to thrive in a new era. ASEAN countries must think deeply about how it can encourage data to flow without friction and barriers. Cross-border flow of data may also bring challenges related to personal, factory, and sensitive information such as financial transactions and quality standards. Issues of security, privacy, and intellectual property rights are of paramount concern.

In the future AEC landscape under Industry 4.0, the charter of free trade will be shifting away from physical goods towards virtual goods. Rather than importing and exporting finished goods, companies may instead sell blueprints and designs, with customers using 3D printers to manufacture spare parts on board. These trends, if they gain momentum, will have profound implication for industrial and waste management policy in ASEAN. Important questions will be emerging around who sets regional and environmental safety standards and how they are enforced. If, for example, a consumer in one country sources a virtual product from another country, prints it locally, and causes toxic waste, who is liable?

Innovative SMEs and start-ups will be critical in capturing new opportunities offered by Industry 4.0. Many ASEAN countries already have innovation hubs and incubators at national level. To be competitive, however, new businesses will need to operate at scale and reach it rapidly. ASEAN should think about how to connect national incubators to regional innovation networks and to overlay regional businesses and financial services to help SMEs operate across ASEAN. This regional network would open doors to new opportunities, nurture the cross fertilisation of ideas between countries and industries, and support the exploration of complementarities between countries.

The Adelaide 3R Declaration was signed during the Seventh Regional 3R Forum that was held on 2-4 November 2016. The forum aimed to promote the circular economy to achieve resource-efficient societies in Asia and the Pacific under the 2030 Agenda for sustainable development. In this declaration, all of the ASEAN countries that signed express their willingness to strengthen the coordination to adopt and implement circular economy plans; and a whole-of-value chain approach, strategies, and tools to reduce, reuse, and recycle natural resources in production, consumption, and other life cycle stages. Industrial sectors have the opportunity to take up this agenda to redefine their approach at regional level. Countries and companies need to assess their preparedness for Industry 4.0 and evaluate the possible ways for this in a coordinated manner.

Countering job losses and disruption from Industry 4.0 and the circular economy will require a transformation of educational systems. The skills needed to thrive will centre not only on technical capabilities but also on creativity and innovative problem solving. Given the dynamic change needed in the job market, workers must expect to have several careers rather than just one, which calls for a deep commitment to adult training and lifelong learning, not just early life education. Much of the response from policymakers plays out at the national level, but there is important regional dimension too: online education opportunities beyond their borders. Equally, expansion of existing credit transfer systems amongst ASEAN universities would help to build cross-border personal and professional networks, which will be crucial for the future work force.

All of the issues discussed here will demand a regional architecture to governance, coordinated policy, and harmonised regulations. This will require regional leaders to assess the past experiences on regional cooperation and the common values shared by a highly diverse group of cultures and to craft protocols that ensure the shared values of people-centred approach.

Those value pool analyses also illustrate the required innovation along the production value chain. Different companies will introduce their successful implementation of new technology for circular business. While acknowledging the progress made on the past technological and resource efficiency front over the last few decades, this book looks to those future prospects. The chapters in the book consider what impact the context-oriented solutions of Industry 4.0 and the circular economy will have on the region and how ASEAN can continue to thrive. The chapters in the book are organised into 13 thematic sections, summarised in Table 5. They take a broader look at the opportunities and challenges and argue for a set of key proactive actions that decision makers can make while adopting the new approaches.

Table 5. Value Pools for Industry 4.0 and the Circular Economy in ASEAN

Group	Industry 4.0	Circular Economy
Global Economic Transitions and Next Evolutionary Industrial Acts	**The evolution of Industry 4.0 and its impact on the knowledge base for the circular economy** • Industrial production today needs to engage in the circular economy to overcome unsustainable production and consumption problems while making its transition to Industry 4.0, where integrated systems and cyber-physical systems allow more flexible and efficient production. • The circular economy is essentially held back by the lack of information, which causes failure of recycling markets, inefficient treatment of waste and lack of trustworthy quality standards, and has lately been slowed down by a slack in waste-related research and development. • Industry 4.0 is a powerful enabler of the circular economy, by means of digitising information and integrating systems, enabling business models for collaborative consumption as well as selling of function versus ownership, but needs to be controlled for its impact on traditional value chains and social implications, for example, on quality standards and workers' rights. • To work as enabler, Industry 4.0 needs to be used as a tool to achieve high-level recycling targets, and therefore necessitates adequate measurement and monitoring of recycling rates. • New business models illustrate the potential Industry 4.0 applications in the circular economy when supported by governments and business, and allow ASEAN to cater to its specific development characteristics and issues while taking part in a global perspective of material and information flows which takes into account global interdependencies.	**Evolutionary acts and global economic transition: progress of circular economy in ASEAN** • ASEAN has achieved important economic growth and transitions since its inception but remains a region with disparities in economic development and a linear economy model necessarily constrained by resource availability. • Global industrial development has moved towards prioritising sustainable development, culminating in the concept of the circular economy, which is integrated with economic, social, and environmental objectives. • The value drivers of the circular economy (augmentation of length of use, utility, looping, and regeneration of resources) are exploited through business models including the circular input model, resource recovery model, product life extension model, sharing platforms models, and produce as a service model. • Industry 4.0, which consists in reforming supply chains through extensive use of ICT and intelligent assets, presents an opportunity to digitalise the circular economy. • There are disparities in ASEAN's preparation to implement such concepts, which should be remedied by policies such as the ones included in the AEC Blueprint 2025, as well as national support for the transition.

Group	Industry 4.0	Circular Economy
Finding Economic Values and Capturing Firm Competitiveness	**Industry 4.0 and the internet of things, maximising economic benefits and firm competitiveness** • Industry 4.0 is based on automation technology, cyber-physical systems with an interface for human interaction, and using the internet of things as well as big data to streamline production and create smart factories. • Industry 4.0 gives access to economic benefits (cost reduction, flexibility, stability, and increased turnover) through optimisation of productivity of resources, assets and labour, forecasting the markets better to allow efficient management of inventories as well as bettering services (including after-sale). • Within Industry 4.0, competitiveness is achieved through horizontal and vertical integration of value chains, as well as efficient end-to-end engineering of products. • Industry 4.0 opens up new opportunities for business through leveraging disruptive technologies and innovations, such as platforms, as-a-service-business, intellectual property rights, and data-driven businesses. • Major challenges to Industry 4.0 include the importance of privacy and data protection, the inclusion of SMEs in the transition, and the adaptation of education systems to contend with new qualification demands for employees. • ASEAN needs to take advantage of this opportunity through finding and implementing a clear vision towards Industry 4.0, effectively identifying policy priorities, and closing skill gaps in addition to cooperating with other regions.	**An assessment of Vietnamese firms for their readiness to adopt the circular economy** • Viet Nam has been a fast-growing economy but is paying the price in pollution and resource depletion, making the circular economy concept an attractive solution. • Survey shows that Vietnamese firms' managers are conscious of their use of resources and understand the 3R framework (reduce, reuse, recycle) but are not aware of the concept of the circular economy and rarely put in place environmental corporate social responsibility initiatives. • The Political, Economic, Social and Technological (PEST) analysis framework shows implementation of sustainable development policies, albeit without explicitly naming the circular economy, a favourable economic context due to sustained growth and high reliance on raw materials, a population that is young, literate, fond of consumption products and environmental values, but generally unaware of green products, and finally an important lack of investment in technological innovation. • Case studies show that some Vietnamese companies have been able to take advantage of circular economy business models: the circular supplies models, the product-as-service business model, and the platform-sharing model . • Barriers to firms' involvement in the circular economy include business culture privileging quantity over quality, a lack of specific government support and legislation, a lack of finance compared to the high cost of green innovation, as well as constraints in technology innovation.

Group	Industry 4.0	Circular Economy
Understanding the Risks and Adverse Social Impacts	**Mitigating the risks and adverse impacts in implementing IoT services.** • IoT aims to connect the world seamlessly through information and communications technology's precise monitoring of assets, in order to achieve autonomous production operation by controlling and optimising processes. • From the demand side, the technology acceptance model points to ease of use, usefulness, and perceived risks as major factors, all of which are closely linked to value creation, social implications, and environmental impacts of the IoT technology. • From the supply side, IoT can provide firms with competitive advantage on internal processes, external connections, and business model creation, but attention needs to be paid to technical requirements as well as social and environmental impacts of implementation. • IoT can be used to further the circular economy as evidenced by the creation of smart waste recycling systems and intelligent transportation systems. • Policy implications for IoT implementation include understanding and differentiating the four functions of IoT, monitoring the factors of acceptance of technology, the new values and concerns created, the use of IoT for firms' competitive advantage as well as putting down standards to ground change on. .	**Mitigation of the adverse impact of the circular economy: implementation and the role of government** • The circular economy has already started spreading improvements of waste management and recycling but needs more visionary practices such as new product lifecycle supply chains and business models to create a restorative industrial economy modelled on living systems. • Important practical steps for countries and companies include best practice and knowledge sharing, smart regulation to guide and encourage private initiatives, standardisation of technology standards, raising public awareness through certifications or labelling, and support for developing countries' transition. • Several business models have appeared in ASEAN: circular supplies (Omni United), resource recovery (Tes-Amm), product life extension (Sustainable Manufacturing Centre), sharing platforms (Tripid), and product as a service (Sunlabob); and in the region, China and its Dalian pilot study provide an example of large-scale circular economy implementation. • The circular economy has positive economic, operational, and strategic impacts due to decoupling growth and resource inputs but needs to face technological, legal, economic, and behavioural obstacles as well as heightened complexity of the international supply chain. • The government is particularly needed to change the end-of-pipe approach to waste management, recognise value of waste, and implement better waste reduction and waste handling, which requires collaboration of central and local governments as well as use of public–private partnership schemes. • The circular economy can also be applied on a city scale, creating 'smart cities' which are needed in the face of rapid urbanisation.

Group	Industry 4.0	Circular Economy
The Financing Essentials of Integrated Strategies	**Innovation of finance for Industry 4.0 in ASEAN** • Industry 4.0 brings both opportunities and threats to ASEAN, which means the region has to adapt their growing financial market to the specificities of investment in Industry 4.0 for ASEAN and put in place innovative finance systems. • Crowd finance, which collects small money into a sizable investment, has been a growing source of finance due to the creation and spread of internet platforms, but needs to overcome problems of scamming and wrong estimation of costs or technology, possibly through establishment of a public–private platform in which public funds match private funds engaged. • Venture capital, which is investment in high-risk high-return projects, is mostly limited to Singapore as far as ASEAN is concerned, but has been successfully supported by the public sector in Japan in the case of Japan Asia Investment Co. (JAIC), Japan Industrial Partners (JIP), and Innovation Network Corporation of Japan (INCJ), providing advantages in mobilising private finance, sourcing as well as evaluation of market and technology. • Industry finance was commonly used for post-World War II reconstruction and has since then declined, but could be revived because its low immediate returns, long-term approach is best fitted to the restructuration of industry which Industry 4.0 demands. • Green finance and carbon finance are attempts to monetise 'green benefit' such as CO_2 emission reductions, which will be monitored more precisely in the near future through IoT and other Industry 4.0 processes. • ASEAN should focus on utilising the above-mentioned financial tools, furthering and controlling public-private partnerships mechanisms, and setting up a common knowledge platform to share best practices.	**Establishing green finance system to support the circular economy** • The circular economy needs policy to internalise externalities in the economy and push capital towards the production of cleaner goods, which governments can achieve through 'greening' financing policy tools such as the bank system, the capital market, and capacity building. • From a developed country's perspective, the history of green finance has led to many innovative financial services such as 'green' securitisation and indices, credit and banks, funds and indices, venture capital and private equity, bonds and insurance, as well as carbon finance, supply chain finance, and the application of the Equator Principles. • Several actors are important in creating this 'greening': the governments for incentivising green finance, financial institutions for creating innovative finance services, the media and related actors for promoting environmental awakening and regulation, and the green investors that need to be brought together in a network. • China exemplifies the experience of establishing green finance in a developing country due to successful environmental policies and the circular economy pilot projects, but lacks private engagement such as financing and insurances, as well as overall internal knowledge and skills, for example, related to Environmental and Social Risk Management. • Drawing on those experiences, ASEAN countries can enhance access to financial resources by 'greening' different financial institutions, mobilising capital through special mechanisms that foster private investment, enhancing capacity building with special regards to the basic financial infrastructure, and fostering international cooperation and international financing channels

Group	Industry 4.0	Circular Economy
Managing the Transition through Multilevel Governance Systems	**Managing the transition to Industry 4.0 through multilevel governance systems** • Transitioning to a circular economy using Industry 4.0 requires policy and institutions to be dynamic to foster innovations, and stable to attract investment. • Whereas majoritarian democracies are usually considered to implement innovation faster, consensus democracies could be the most appropriate framework for this transition as the corporatist institutional structure frames negotiations between political and societal actors, and the requirement for consensus creates a broader base of support for policies and a coordinated market economy system. • Moreover, the integration of a country in a framework beyond nation-states plays a role, as societal actors can advocate for issues absent from national agendas, and institutions gain independence from national political events, making them more stable. • Germany is taking the lead on the concept of Industry 4.0, focusing on innovations such as cyber-physical systems, but also minding the societal aspects of the concept by investing in human capital and facilitating access to funding for innovative start-up businesses. • Industry 4.0, associated with the circular economy project, can go beyond economic benefits and contribute to reaching numerous social and environmental objectives, thereby creating a strong coalition of support in the community, if to this effect it involves from early on veto players, stakeholders, and the public whose participation insures durability through political vicissitudes.	**Managing the transition through multilevel governance** • The circular economic model, which aims for an economy without an impact on the environment, and Industry 4.0, the use of intelligent assets to this aim, both represent alternative economic growth models requiring multilevel governance to be effectively implemented. • Strongly influenced by the leadership of Germany and Japan, China and India are examples of policy and governance approach to implementing the circular economy model, despite Industry 4.0 having no policy space of its own in the latter but important convergence points even in nascent form. • Both the circular economy and Industry 4.0 need to be thought of in the context of inclusive growth, and their social dimension understood, for example, in guiding them to support struggling populations and traditional practices. • Multi-governance at macro, meso, and micro level is possible when implementing the circular economy as a new industrial paradigm with the participation of the international community as well as national public institutions and stakeholders, and using Industry 4.0 as a way to provide competitiveness with the engagement of actors all the way to the civil society, guaranteeing inclusive growth. • The cooperation of governmental actors at the macro level and private actors at meso and micro level can help establish precedents, invest in the innovation needed to transition into both concepts, and educate consumers to inform and empower them.

Group	Industry 4.0
Readiness of Industry 4.0 in the Circular Economy: Regional Architecture for the Decades Ahead	**Enhancing regional architecture for innovation to promote the transformation to Industry 4.0** • Industry 4.0 relies on cyber-physical production systems to integrate production and manage the supply chain, including using IoT technology which breaks down the barrier between the physical and digital worlds. • Case studies of the smart factory and additive printing show that Industry 4.0 can also curb waste and play a role in the implementation of the circular economy since it can be flexibly applied to a diversity of related domains such as climate change, disaster management, etc. • As a region growing more integrated, ASEAN can hope to leapfrog into Industry 4.0, and by using the Roland Berger Readiness Index and Manufacturing Share methodology, the authors find four clusters of countries: potential innovators (Singapore, Malaysia), efficiency seekers (Indonesia, the Philippines, Thailand), mid-term transitioners (Viet Nam) and slow movers (Cambodia, Lao PDR, Myanmar). • To accelerate transition, the authors suggest that ASEAN countries should move backwards up Caputo et al.'s model of innovation, from incremental innovations to architectural, then modular and finally radical innovation, their priority step depending on existing levels of intellectual capital (human, relational, and structural capital) in the country. • ASEAN can develop needed skills in all four characteristics of Industry 4.0, supported by government measures, regional cooperation mechanisms and action plans, as well as pioneers actors in the field such as Japan and Germany.

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Chapter 2

Connecting Sustainable Lifestyles, Industry 4.0, and the Circular Economy

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Concepts at the interface between society and economics, such as sustainable development, Industry 4.0, and the circular economy have often been addressed in singularity by the business sector, by academia, and policy (Romero and Noran, 2015). The questions that arise are whether and how they complement one another. Could the integration of Industry 4.0 and the circular economy result in a further strengthening of the extractive, 'linear' economy or will it enable the decoupling of resource consumption from economic development and accelerate the transition towards the circular economy? Could an interface between Industry 4.0 and the concept of the circular economy unleash new gains in productivity and efficiency? How do we address societal uncertainties related to the integration of Industry 4.0 and the circular economy, for example, through the concept of multilevel governance systems? And what will be the challenges and role of the ASEAN region in this context?

This chapter addresses the interfaces between sustainable development, Industry 4.0, and the circular economy and whether productivity increases could provide an impetus for economic growth, providing examples with a view to better understand the prospects and impacts for the ASEAN region.

The chapter addresses the questions:

- Whether Industry 4.0 is ready for circular economy integration? Can the integration of Industry 4.0 and the circular economy lead to a reduced use of resources during both production and use and or consumption?
- How can the interface between Industry 4.0 and the circular economy look like? Can Industry 4.0 be regarded as a facilitator for the circular economy and thus enable closed loop systems?
- How much progress have the European region and the Asian region made in implementing the concepts of Industry 4.0 and the circular economy?
- What are enabling factors and or key barriers to implementation of such an integrated concept in the ASEAN region?,
- Can multilevel governance systems be a tool to turn this vision into reality? What are the policy implications for the ASEAN region and what kind of conclusion and recommendations can be drawn?

1. Introduction

Global awareness and attitudes towards the greening of both the economy and society have evolved since 1992 when the first United Nations Conference on Environment and Development in Rio de Janeiro called upon national governments to develop strategies for sustainable development. The goal of shaping the new foundation for the world's future – a world economy that is based on a cleaner, more sustainable production and consumption pattern, providing economic models for countries and societies to build wealthier and happier lives – has never been nearer (Buhr, 2015). The commitments of the major world economies to the post-2015 Development Agenda, the recent sustainable development goals, and the Paris Accord on Climate Change ensure that new political, economic, and trade arrangements between nations and the trading blocs are created, evolving into greener drivers of development. This, in turn, creates challenges and opportunities for all other nations (Richard,2005; von Stechow et al., 2015; Zhang and Wen, 2008).

The advantages of a transition to a resource-efficient and ultimately a regenerative circular economy have been acknowledged by governments, private sector, and civil society (Stern et al., 2002). Innovation and a systemic transition in the use and recovery of resources are needed to ensure future jobs and competitiveness; outline potential pathways in innovation, investment, and regulation; tackle harmful subsidies; increase opportunities for new business models; and set clear targets (Aghion et al., 2005).

Economic growth has long focused on the linear 'take, make, dispose' model (George, Lin, and Chen, 2015). On the back of the digital revolution, a circular alternative which enables an effective flow of materials, energy, labour, and information so that natural and social capital can be rebuilt, is emerging (Bundesministerium für Bildung und Forschung, 2015).

The circular economy is an economic model where the value of products, materials, and resources is maintained in the economy for as long as possible and where waste generation is minimised. The transition to a circular economy involves a fundamental change, which means rethinking the way products are designed, produced, consumed, and brought back into the value chain (Bilitewski, 2012).

Another new model to unlock the potential for more reuse, remanufacturing, and recycling of products, and for sometimes unconventional business models, derives from modern communication tools (Romero and Noran, 2015). The key to achieving this model is the internet of things (IoT) and the role of intelligent products. Digital technologies and devices can sense, store, and communicate information about themselves and their surroundings. Experts are describing this as the fourth industrial revolution or Industry 4.0 – a so-called fusion of technologies that blurs the lines between the physical, digital, and biological spheres (Dombrowski and Wagner, 2014).

Linking Industry 4.0 and the circular economy can help unlock creativity through the convergence of the digital and natural worlds, an intersection which could define how we govern and innovate. By decoupling economic value creation from resource consumption, the World Economic Forum in 2016 talked about a 'trillion-dollar opportunity' (Dutta, Geiger, and Lanvin, 2016). Understanding and harnessing the potential of this 'fourth industrial revolution' for society, the economy, and the environment, and relating it to the concept of a circular economy will be the goal. Industry 4.0 and IoT will be the glue that links material items which are being consumed with the changes in consumer behaviour, allowing recovery, material separation, and remanufacturing (Kagermann, 2014).

One of the key elements why advanced economies have only limited growth rates is that traditional efforts to make production processes more efficient have already been implemented to a large degree. Recent studies show that the concept of Industry 4.0 could increase productivity tremendously (Rüßmann et al., 2015). In Industry 4.0, the product itself will become the carrier of knowledge and information, which opens new business opportunities (Brettel et al., 2014). The resulting potentials of increases on productivity are impressive.

2. Can the Integration of Industry 4.0 and the Circular Economy Lead to a Reduced Use of Resources?

Industry 1.0 was based on the introduction of mechanical production equipment driven by water and steam power. Industry 2.0 was based on mass production achieved by division of labour and use of electrical energy. Industry 3.0 was based on the use of electronics and information technology to further automate production. Now, Industry 4.0, in a material-reliant industrial economy, is being based on the use of cyber-physical systems with the notion of connectivity as the 'new' relationship (Faller and Feldmüller, 2015).

The widespread adoption by the manufacturing industry around the world of information and communications technology (ICT) is paving the way for disruptive approaches to development, production, and the entire logistics chain. This networking within an 'IoT, services, data, and people' will transform the future of manufacturing (Wang et al., 2016). Industry 4.0 is on its way to become a fourth industrial revolution with four main characteristics:

- Vertical networking of smart production systems, such as smart factories and smart products; and the networking of smart logistics, production, marketing, services, with a strong needs-oriented, individualised, and customer-specific production operation.
- Horizontal integration by means of a new generation of global value-creation networks, including integration of business partners and customers, and new business and cooperation models across countries and continents.
- Through-engineering throughout the entire value chain, taking in not only the production process but also the end products – that is, the entire product life cycle.
- Acceleration through exponential technologies such as sensor technology and massive computing power.

Integrated analysis and use of data are the key capabilities for the industrial internet. Today, the efficient analysis and use of data is of great significance. Companies believe that the ability to analyse data will be critical to their business model in 5 years. These companies primarily focus on the efficient exchange of data within their own value chain, the digital labelling of the products, and the use of real time data to steer their production.

Digitisation of the product and service portfolio of businesses is the key to sustainable corporate success. A mechanically perfect product will no longer be enough to withstand international competition. Therefore, it is expected that most European manufacturers will have achieved a high degree of digitisation of their product and service portfolio within 5 years.

The fourth industrial revolution – characterised by the increasing digitisation and interconnection of products, value chains, and business models – has arrived in the European industrial sector, including manufacturing and engineering, automotive and process industries, as well as the electronics and electrical systems, and information and communications industries. The digital transition will lead to a significant transformation of the business sectors that will require considerable investment. It is estimated that the share of investments in Industry 4.0 solutions will account for more than 50% of planned capital investments for the next 5 years. German industry will invest a total of €40 billion in Industry 4.0 every year by 2020 (Bundesministerium für Wirtschaft und Energie, 2014). Applying the same investment level to the European industrial sector, the annual investments would be as high as €140 billion per annum.

These investments must be used along the entire value chain to achieve maximum success. In 5 years, more than 80% of companies will have digitised their value chains – one-quarter of the companies already achieved a high degree of digitisation of their value chains. However, thus far, only individual units and isolated applications have been mostly automated and digitised. The business sector expects that 86% of the horizontal and 80% of the vertical value chains will have a high degree of digitisation by 2020 and will therefore be closely integrated (Buhr, 2015).

The industrial internet increases productivity and resource efficiency, with an 18% increase in efficiency within 5 years. The industrial sector is required to produce ever larger quantities using fewer raw materials and less energy. The industrial internet allows higher productivity and resource efficiency and thus creates the conditions for sustainable and efficient production. The companies surveyed anticipate an average efficiency increase of 3.3% per year across all industry sectors due to the digitisation of value chains. This amounts to a total of 18% in the next 5 years. They expect annual savings of 2.6% with respect to cost reduction.

The industrial internet paves the way for new digital business models. The industrial internet will have a lasting effect on existing business models and will also generate new, digital – often disruptive – business models. The focal point of this trend comprises increasing customer benefits through a growing range of value solutions (instead of products) and increased networking with customers and partners. The unique quality of the digital change lies in the rapid acceleration of the speed of change. Disruptive innovations will also cause industry sectors like the information and communications industry to sustainably transform within a short period (Schulte, 2013).

Horizontal cooperation allows for improved satisfaction of customer needs. European companies have understood that closer cooperation with value chain partners – combined with increased horizontal interconnection – is of great significance. Its importance will further grow in the context of Industry 4.0 considering increased digitisation, particularly where new, digital business models should be established.

The industrial internet holds various challenges. The focus is on high investment levels and often unclear business cases for new industrial internet applications. Furthermore, sufficient skills to meet the needs of the digital world must be ensured. Binding standards must also be defined and tasks in information technology security should be solved (Finn and Wright, 2016). Policymakers and industrial associations need to address these latter challenges by advocating uniform industrial standards at a European or international level and promoting efficient rules for data security and data protection.

Digitised products and services generate approximately €110 billion of additional revenues per year for the European industry. Companies which have already digitised their product portfolio have grown above average in the past 3 years. Companies even expect sales to rise by more than 20%. In total, this amounts to an average incremental sales increase of 2.5% per annum. Compared to all industrial companies in the five core industry sectors, this is equivalent to an annual sales potential of more than €30 billion for Germany and reaches up to €110 billion of additional revenues for the European industry in total.

The European example indicates that, as a result of Europe's primary resource dependency, Europe increasingly faces the limitations of a linear economy, which is the lost value of materials and products, scarcity of resources, volatile prices, waste generation, environmental degradation, and climate change (Tukker, 2015). It comes as no surprise that the European Commission and Parliament developed a policy package to create a 'Resource Efficient Europe' (European Commission, 2011). The European

Environmental Research and Innovation Policy aims to support the transition to a circular economy in Europe, define and drive the implementation of a transformative agenda to green the economy, and to achieve sustainable development. The policy debate so far has focused on waste management, which is the second half of the cycle, and only limited efforts have been done to address the first half, which is eco-design (Bagheri et al., 2015).

Employment in the eco-innovation sector continued to increase during the recession, from 3.0 – 4.2 million jobs (2002–2011), with 20% growth in the recession years (2007–2011). The European Union (EU) holds a third of the global market, which is worth a €1trillion, and it is expected to double by 2020 (European Commission, 2012).

Digital innovations in social, mobile, analytics, cloud, and machine-to-machine communication (M2M) are especially effective in connecting physical and digital channels, and in connecting customers more broadly and deeply than ever before.

- Mobile: Mobile technology spurs the adoption of circular business models by enabling universal and low-cost access to data and applications. As consumption behaviour goes mobile and online, it reduces the need for physical resources ranging from paper and entertainment to stores.
- M2M communication: Machines capable of communicating with one another are not new. M2M technology has long been used in factory control systems and vehicle telematics. But we are about to reach a critical mass for mainstream M2M use as wireless network coverage expands worldwide.
- Cloud computing: Dematerialisation – the process of replacing something physical with a digital alternative – has placed some industries (travel agents, music stores, and newspapers) on the endangered species list. Cloud computing is key to dematerialisation, along with mobile and social technologies.
- Social: While social media started as a way for people to find and connect with friends and family, it has evolved into so much more. Social technology is fundamental to sharing. It reduces the cost of setting up sharing platforms as it allows businesses to tap into existing social networks. It makes it cheaper and quicker for companies to receive consumer feedback to help improve offerings.
- Big data analytics: In a circular economy, many companies will generate their revenues from product use instead of sales, and growth will rely on how good they are understanding and catering to product use behaviour. This means companies need to monitor and analyse data in entirely new ways. Complex analytics is especially important for the circular supply chain, sharing platform, and product as service business models.

- Modular design technology: Modular design technology is not only revolutionising how products function but also the length and nature of customers' relationships with those products. When a modularly designed product breaks, only the defective part is replaced or repaired, keeping the product relevant to its users longer and extending its overall product life cycle.
- Advanced recycling technology: Recycling is not new and it has benefited from a great deal of innovations and some significant rapid returns on foothills of the coming changes. Initially, circular business model innovation was driven by start-ups. Now, large multinationals are making serious moves as well. This is illustrated by a joint Accenture and United Nations Global Compact study which found one-third of global chief executive officers actively seeking to employ circular economy investments. Because of the advances in recycling and its increased efficiency, more and more companies are turning to the circular economy as a source of growth.
- Life and material sciences technology: Life and material sciences play a key role in driving input substitution at a large scale. Ongoing innovation in this field will lead to new circular material input options. It will also bring on new ways to alter output so they can be used as inputs.
- Trace and return systems: Trace and return systems support circular business models by making it more cost effective to collect used products to service, repair, recover, reuse, refurbish, or recycle them through, for example, efficient and effective material sorting machines.
- Three-dimensional (3D) printing: 3D printing is steadily evolving to become a major player in the manufacturing world. It has also become one of the major drivers of circular business models. It facilitates repairing by making it possible to directly print suitable parts with the exact geometry. It also creates opportunities for circular inputs – inputs that are biodegradable or infinitely recyclable models.

The new business models offer the business sector options for embracing the circular economy. But it would not be possible to scale many of these business models without the support of the innovative technologies mentioned above.

Table 1. Interactions of the Circular Economy and Intelligent Asset Value Drivers and Examples of Value Creation Opportunities

Circular Economy Value Drivers	Knowledge of location of the asset	Knowledge of the condition of the asset	Knowledge of availability of the asset
Extending the use cycle length of an asset	• Guided replacement service of broken components to extend asset use cycle • Optimised route planning to avoid vehicle wear	• Predictive maintenance and replacement of failing components prior to asset failure • Changed use patterns to minimise wear	• Improved product design from granular usage information • Optimised sizing, supply, and maintenance in energy systems from detailed use patterns
Increasing **utilisation** of an asset or resource	• Route planning to reduce driving time and improve utilisation rate • Swift localisation of shared assets	• Minimised downtime through to predictive maintenance • Precise use of input factors (e.g. fertiliser and pesticide) in agriculture	• Automated connection of available shared asset with next user • Transparency of available space (e.g. parking) to reduce waste (e.g. congestion)
Looping/cascading an asset through additional use cycles	• Enhanced reverse logistics planning • Automated localisation of durable goods and materials on secondary markets	• Predictive and effective remanufacturing • Accurate asset valuation by comparison with other assets • Accurate decision making for future loops (e.g. remanufacture vs. recycle)	• Improved recovery and reuse/ repurposing of assets that are no longer in use • Digital marketplace for locally supplied secondary materials

Source: Ellen Mc Arthur Foundation, 2016.

3. The Prospects of the Circular Economy for the European and Asian Regions

The traditional linear ‘take, make, dispose’ industrial processes and the lifestyles that feed on them deplete finite reserves and create products that end up in landfills or incinerators (Roy et al., 2012). In contrast, the circular economy stands for an industrial economy that produces no waste and pollution, by design or intention, and has two types of material flows: biological nutrients designed to re-enter the biosphere safely, and technical nutrients designed to circulate at high quality in the production system without entering the biosphere (Ashby, 2016).

Transitioning to the circular economy presents an opportunity to organise production and consumption. At its essence, the circular economy represents a new way of looking at the relationships between markets, customers, and natural resources. The lens through which it is viewed is disruptive to new business models powered by new technology breakthroughs, particularly Industry 4.0.

Digitalisation disrupts the way of production and consumption through innovative business models established by innovative technologies. Blended together, the circular economy, innovative new business models, and digital revolution represent an opportunity to create a competitive advantage.

Research indicates a US$4.5 trillion reward for performing circular economy business models by 2030, stemming from the elimination of ‘waste’ and recognising that everything has a value, moving from efficiency to effectiveness in the way we manage inputs and outputs, and by forging a bond with consumers through product returns and customer engagement.

Global industry leaders as well as innovative start-ups are already beginning to reap huge rewards by tapping into these opportunities. The world’s economy has generated unprecedented wealth over the past century. Part of the success is attributable to continuous improvements in resource productivity. At the same time, resource productivity remains hugely underexploited as a source of wealth, competitiveness, and renewal in the Asian context.

In Europe, it is estimated that resource productivity could grow by up to 3% annually. This would generate a primary-resource benefit of as much as €0.6 trillion per year by 2030 to Europe’s economies. In addition, it would generate €1.2 trillion in non-resource and externality benefits, bringing the annual total benefits to around €1.8

trillion compared with today. This would translate into a gross domestic product (GDP) increase of as much as seven percentage points relative to the current development scenario, with an additional positive impact on employment.

Europe's economy remains very resource dependent. Views differ on how to address this against an economic backdrop of low and jobless growth as well as the struggle to reinvigorate competitiveness and absorb massive technological change. Proponents of the circular economy argue that it offers Europe a major opportunity to increase resource productivity, decrease resource dependence and waste, and increase employment and growth. They maintain that a circular system would improve competitiveness and unleash innovation, and they see abundant circular opportunities that are inherently profitable but remain uncaptured. Others argue that European companies are already capturing most of the economically attractive opportunities to recycle, remanufacture, and reuse. They maintain that reaching higher levels of circularity would involve an economic cost that Europe cannot afford when companies are already struggling with high resource prices. They further point out the high economic and political costs of the transition.

A circular economy vision enabled by the technology revolution would allow the Asian region to grow resource productivity. The circular economy concept was introduced in China to address environmental degradation and resource scarcity associated with rapid economic development. China has implemented the circular economy strategy as a means of conserving water, materials, energy, and land. China faces several challenges that, until recently, have held back complete implementation. These include lack of incentives for older industries to 'green' their operations, lack of financial support to expand the circular economy concept, and a broad-based need for heightened public awareness and participation in circular economy initiatives. Although circular economy initiatives have been successful in China, more is possible and more is needed.

The programme 'Made in China 2025' announced in 2015 aims to bring China on an equal footing with the Western industrial nations with respect to Industry 4.0. The ambition is for China to become the world's leading industrial power by the time it turns 100 in 2049. China remains on the fast track – from 2013 to 2015, Chinese inventors registered more than 2,500 patents for Industry 4.0-enabling technologies. In the United States (US), this number was 1,065 and in Germany, 441. With respect to patent quality, researchers believe that China has outperformed the US and Germany. Nevertheless, China is still in the early days with respect to the implementation of Industry 4.0 – 35 % of companies have not yet concerned themselves with the subject.

The 'Industry 4.0 index' for China indicated that companies in China are looking to seize the opportunities presented by digitalisation and networking. Most importantly, the subject of the smart factory is on the agenda for at least half of Chinese industrial companies.

4. Shaping the Link Between Industry 4.0 and the Circular Economy

The current views on Industry 4.0 focus mainly on production processes, its impact on supply chains and business-to-business relationships, and its transformative potential for different industry sectors. We now have to shift the attention to consumers and related sustainable lifestyle opportunities and ask ourselves the following questions:

- Can Industry 4.0 lead to a reduced use of resources during both production and use and/or consumption?
- Will smarter and decentralised production strengthen regional and local consumption and value creation?
- Can Industry 4.0 be regarded as a facilitator for the circular economy and thus enable closed loop systems?
- Will transparency along the supply chain increase and support more conscious consumption patterns?

Connecting Industry 4.0 and the concept of circular economy is a vision which could unleash new gains in productivity and efficiency. As a prerequisite for linking the circular economy and Industry 4.0, products need to be designed in such a way that its components can communicate through simple 'If This Then That' commands, which would provide simple connections between products (Kolberg and Zühlke, 2015). The future of automation will be tied to the rise of the Why IP, instead of the Who IP, and thus provide the foundation to accelerate the IoT revolution and to achieve a transformational economic-wide impact in manufacturing, innovation, and global competitiveness.

On one hand, all parts must be digitally interlinked. Companies that are not able to deliver interactive components will become suppliers of low-value parts and can easily be replaced by other suppliers. These are small suppliers who have grown with intelligent products. This represents a shift from rigid, centralised factory control systems to decentralised intelligence (Chituc and Restivo, 2009). These will network with one another in an intelligent way, carry out their own configuration with minimal effort, and independently meet the varying requirements of production orders.

There is an impression that Industry 4.0 focuses on automation and computerisation; yet, at the centre of Industry 4.0 are the conceptualisations, designs of the products, and production rules and parameters. This provides the opportunity to link Industry 4.0 and the concept of the circular economy. Instead of end-of-the-pipe production of waste as in previous industrial concepts (Industry 1.0 to Industry 3.0), the conscious design of the product in Industry 4.0 provides the opportunity to link to the concept of the circular economy which has the design of products in its forefront instead of the concept of recycling (Allwood, 2014).

Industry 4.0 facilitates the vision and execution of 'smart factories' (Li et al., 2015). Within the modular, structured smart factories of Industry 4.0, cyber-physical systems monitor physical processes, create a virtual copy of the physical world, and make decentralised decisions (Wang et al., 2016). With IoT, cyber-physical systems communicate and cooperate with each other and with humans in real time and, via the internet of services, both internal and cross-organisational services are offered and utilised by participants of the value chain (Wang et al., 2016).

Companies that are not able to deliver interactive components will become suppliers of low-value parts and can easily be replaced by other suppliers. Small suppliers have understood to grow with intelligent products. This represents a shift from rigid, centralised factory control systems to decentralised intelligence (Chituc and Restivo, 2009). These will network with one another in an intelligent way, carry out their own configuration with minimal effort, and independently meet the varying requirements of production orders.

The crucial question that emerges is whether linking Industry 4.0 and the circular economy will lead to an acceleration of the extractive 'linear' economy of today, or it will enable the relative decoupling of resource consumption from economic development and accelerate the transition towards the circular economy. Circular economy drivers include extending the useful life and maximising the utilisation of assets, and regenerating natural capital. Industry 4.0 drivers include collating knowledge about the asset's location, condition, and availability. A broad range of opportunities emerges when these value drivers are being paired.

In Industry 4.0, individual workpieces will themselves determine what production installations they need to provide. In a linked system of the circular economy and Industry 4.0, the design of the product would allow the immediate recognition of those products and their components, and thus provide an impetus for a shift away from traditional recycling processes and towards the initial founding principles of the circular economy. Instead of the end-of-the-pipe production of wastes as in previous industrial concepts, the conscious design of a product in Industry 4.0 would link with the concept of the circular economy, which has the design of products in its forefront instead of the concept of recycling (Dalhammar, 2016).

The resources for linking the concepts of Industry 4.0 and the circular economy are readily available to help companies transition to Industry 4.0 and to connect elements of the circular economy across enterprises, value chains, and customers for improved performance. As a prerequisite for linking the circular economy and Industry 4.0, products need to be designed in such a way that its components could communicate through simple 'If This Then That' commands which would provide simple connections between products and the circular economy. The future of automation will be tied to the rise of the Why IP and thus provide the foundation to accelerate the IoT revolution, thus achieving a transformational economic-wide impact in manufacturing, innovation, and global competitiveness (Gao et al., 2015; Lin et al., 2015).

Companies such as Bosch, Dell, and Intel have joined forces with a German start-up named Relayr to create an IoT accelerator starter kit. The kit enables fast and cost-effective creation of industrial grade IoT solutions such as early developments to connect the circular economy and IoT. All the components and expertise needed to develop respective IoT solutions, such as sensors, configured hardware, and programmes to visualise the data are included. The Relayr kit allows one to create models which could be upgraded with a cloud installation to full-scale deployment.

Companies seeking the circular advantage will be required to develop new business models that are free of the constraints of linear zero-sum thinking.

Circular supply chain: When a company needs resources that are scarce or environmentally destructive, it can either pay more or find alternative resources (Ying and Li-Jun, 2012). The circular supply chain introduces fully renewable, recyclable, or biodegradable materials that can be used in consecutive life cycles to reduce costs and increase predictability and control. One example is CRAiLAR Technologies Inc., a company that produces renewable biomass resources using flax and hemp to create fibres as good as cotton without environmental impact.

Recovery and recycling: The recovery and recycling model creates production and consumption systems in which everything that used to be considered waste is revived for other uses (Allwood, 2014). Companies either recover end-of-life products to recapture and reuse valuable materials, energies, and components or they reclaim waste and by-products from a production process. Procter & Gamble Company operates 45 facilities on a zero-waste basis.

Product life-extension: This means shifting from merely selling things to actively keeping them alive and relevant (Du et al., 2015). It also means moving customers from transactions to relationships, tailoring upgrades, and alterations to specific needs. Through its refurbishment business, Dell Inc. Computers takes back old equipment and resells units when possible.

Sharing platform: In developed economies, up to 80% of the appliances of individual consumers are used only once a month. The sharing economy model, which is increasingly assisted by new forms of digital technology, forges new relationships and business opportunities for consumers, companies, and micro-entrepreneurs who rent, share, swap, or lend their idle goods (Cohen and Muñoz, 2016). Fewer resources go into making products that are infrequently used, and consumers have a new way to both make and save money. Examples of a growing field include Uber Inc., Airbnb Inc. and Lyft Inc.

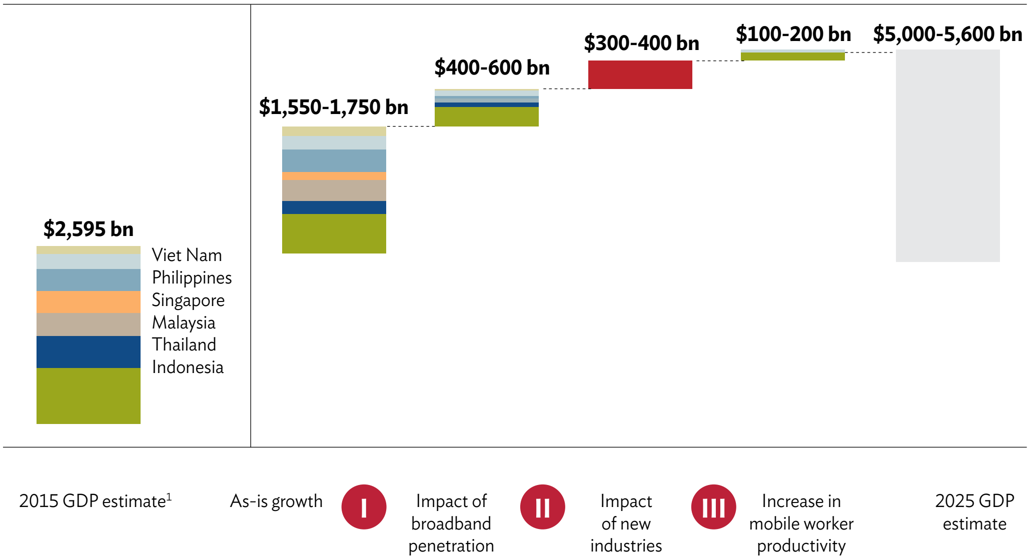
Product as a service: What if manufacturers and retailers bore the 'total cost of ownership?' Many would immediately adjust their focus to longevity, reliability, and reusability. When consumers lease or pay for products by use through the product as a service model, the business model fundamentally shifts in a good way. Performance trumps volume, durability tops disposability, and companies have an opportunity to build new relationships with consumers. Koninklijke Philips NV is using 'lighting as a service' to charge by output instead of unit sales.

5. The Prospect of Linking Industry 4.0 and the Circular Economy in the ASEAN Region

ASEAN has an opportunity to leapfrog to the forefront of the fast-moving global digital economy. Many of the fundamentals are already in place in the region. It has robust economy, generating US$2.5 trillion GDP and growing at 6% per year; literate population of more than 600 million people, with 40% under 30 years of age; smart phone penetration of around 35% and growing rapidly; well-developed ICT cluster with a track record of innovation and investment in new technology; and renewed sense of optimism and urgency for economic integration with the implementation of the ASEAN Economic Community, which pledges to promote free movement of goods, services, investment, skilled labour, and free flow of capital.

The ASEAN digital economy currently generates approximately US$150 billion in revenues per year. Connectivity and online services are the biggest components, each accounting for 35%–40% of overall revenues. The user interface (including devices, systems, and software) constitutes the third largest segment, accounting for close to 20% of revenues. However, these elements are growing at very different speeds. For example, connectivity revenues are expected to grow just 3%–5% per year, whereas online services are likely to grow at more than 15% compound annual growth rate over the next 5 years (Figure 1).

Figure 1. ASEAN's Digital Economy's Potential to Add an Incremental US$1 Trillion in Gross Domestic Product by 2025



bn = billion, GDP = gross domestic product.

[1] Based on current prices; uses 2015 as baseline to project future real GDP growth; as-is growth based on 5-year GDP forecasts.

Source: The ASEAN Digital Revolution – AT Kearney, 2016.

Major trends in the digital economy – the advent of the multiple screen environment, social networking, growth in big data and augmented reality, personalised advertising, and the rise of the cloud – will drive the 50% compound annual growth rate to 60% in data traffic in the future.

ASEAN's vibrant economy, favourable demographics, ICT investments, and ongoing economic integration have laid the foundation for the region to become a global leader in the digital economy. If ASEAN were a single country, with a combined GDP of US$2.5 trillion, it would be among the largest economies in the world, behind only the US, China, Japan, Germany, the United Kingdom, and France. The six largest economies in ASEAN, (Indonesia, Thailand, Malaysia, Singapore, the Philippines, and Viet Nam) contribute 99% of the total ASEAN GDP. Economists project GDP to grow at about 9% from 2015 to 2020, which falls between GDP growth forecasts for China and India.

ASEAN is home to more than 628 million people – around 10% of the world's population. The literacy rate is high at 94%. Some 40% of its citizens are under 30 years of age and are digital natives. This generation is learning to champion disruptive thinking and is primed to innovate.

ASEAN's ICT sector has evolved at a phenomenal pace in the past few years. ICT investment, which amounted to more than US$100 billion in 2014, is now growing at more than 15% annually. Indonesia alone has set aside US$150 billion for ICT investments over the next 3 years.

Moreover, the implementation of the ASEAN Economic Community, which pledges to promote free movement of goods, services, investment, skilled labour, and capital, has created a renewed sense of optimism and urgency for economic integration in the region. Growing integration should help the region's nascent digital economy realise greater economies of scale.

There remains a significant digital divide within ASEAN. Singapore is the only country in the top 10 of the United Nations ICT Index and the top 20 of the Economist Intelligence Unit Digital Economy ranking. ASEAN is not a monolithic bloc; there are three distinct groups of nations within the region:

- ASEAN 1 (Malaysia and Singapore) – matches the performance of developed countries but still lags in spectrum availability, innovation environment, regulatory environment, and digital literacy.
- ASEAN 2 (Thailand, Indonesia, and the Philippines) – displays significant gaps in market competitiveness, spectrum availability per operator, and regulatory environment.
- ASEAN 3 (Viet Nam, Myanmar, and Cambodia) – underperforms its ASEAN peers in all categories except regulatory environment.

In ASEAN member countries, the policy enablers for a digital economy have not kept pace with those in the EU. Policy enablers have two facets. First, each individual country must have the right regulations in place to support the digital economy. This entails ensuring that critical enablers, such as sustainable market structures, supportive spectrum policies, privacy laws, digital signature laws, data protection, and incentives are in place to support universal broadband access, mobile financial services, e-commerce, and other key areas of the digital economy. Second, these policies need to be extended and harmonised across the economic community to create a single digital market.

Table 2. Digital Progress in the European Union and the ASEAN Region

	European Union	ASEAN
Region-wide digital vision	• Single digital agenda defined by seven growth pillars with 111 action items • Digital Economy and Society Index ranks EU countries across five segments and metrics	• e-ASEAN framework agreement consists of high-level guidelines, only no actions defined • Limited ranking and tracking to evaluate progress
Consumer protection (privacy, cybersecurity)	• EU-wide common privacy initiatives established by EU Data Protection Directive and ePrivacy Directive • Cybersecurity identified as regional priority under Single Digital Agenda (Pillar III), supported by 14 EU-wide action items	• Only three countries (Myanmar, Singapore, and the Philippines) have privacy laws in place • Cybersecurity addressed under 2/6 of the ASEAN ICT Masterplan 2015 strategic thrusts but no consensus on KPI targets or actions
Development of e-commerce and MFS	• Mobile only banks are operational, including Fidor bank, Number 26 (Germany) Hello bank (BNP-group France • Efforts underway to have an EU-wide payments platform	• ASEAN-wide initiatives to create regional mobile-payment systems are limited • Current initiatives are limited to traditional payment systems
Digital public services	• Large-scale pilots for EU-wide public services • e-ID: access another country's citizens' ID and information • eHealth: Interoperability between national health systems to check benefits anywhere in EU • Progress is regularly tacked and measured	• Statement of intent expressed in high-level framework agreement • No regional actions, monitoring, or ranking mechanisms to ascertain progress in digital public services
Industry structure (definition of digital, OTT)	• EC plans to increase telecommunications regulations with common rules covering OTT players and cable operators	• No comprehensive ASEAN-wide regulations on OTT players • No distinct approach to regulate operators vs. OTT

ASEAN = Association of Southeast Asian Nations, BNP = BNP Paribas Bank, EC= European Commission, e-ID = electronic identification, EU = European Union, ICT = information and communications technology, KPI = key performance indicators, MFS = mobile financial services, OTT = over the top content.

Sources: European Commission: Digital agenda for Europe; press reports: A.T. Kearney analysis.

Industry 4.0 might potentiate a threat to ASEAN economies. Recently, the World Bank has been trying to estimate the potential threat by using the Frey-Osborne approach. The results indicate that the relocation of industrial production from rich to poorer countries was just a stopover on the way to automation. Like the disruptive innovation of fracking in the oil and gas industry, which will allow producers in the USA to define prices for oil and gas and which led to a whole new set of small and medium-sized companies, Industry 4.0 has the potential to return the definition of industrial production away from Asia. This may create opportunities for Southeast Asian countries to participate in this process and/or to switch into an even higher gear such as linking Industry 4.0. to the circular economy.

The industrial internet is already a key subject in the industry and this trend will become increasingly more important in the future (Wang et al., 2016). However, companies in the ASEAN region should take on numerous challenges for the successful and timely implementation of digital concepts. In this respect, the expected high investment levels and the often unclear cost benefits for new Industry 4.0 applications remain limiting factors. Many companies have not yet developed specific plans for the implementation of Industry 4.0 solutions and have also not made any larger investments. This is because the solutions are new for many companies and require significant internal adjustments. The quantification of potentials is also complex and diverse. There is an urgent need for more transparency and an exchange of experience across industry sectors (Buhr, 2015).

Employee qualification is an important topic across all industry sectors (OECD, 2017). The digital change will alter requirements for employees across all steps of the value chain – from development on through production to sales. Processes and business models will become more agile and data-based, and require completely new employee skills and qualifications. The need for software developers and data analysts in industry will once again significantly increase, which requires appropriate training and education programmes.

So far, ASEAN (as a single community) is behind its global peers in the digital economy, yet it has the potential to enter the top five digital economies in the world by 2025. Moreover, the implementation of a radical digital agenda could add US$1 trillion to the region's GDP over the next 10 years. A decade from now, ASEAN's manufacturing sector is likely to have embraced Industry 4.0 technologies.

6. Perceived Key Barriers to the Implementation of an Integrated Industry 4.0 and the Circular Economy Concept in ASEAN

There are several major roadblocks standing between ASEAN and an advanced digital economy and society. To bring about a full digital revolution, the following barriers will need to be addressed: weak business case for building broadband, regulations inhibiting innovation in mobile financial services and e-commerce, low consumer awareness and trust which hinder the uptake of digital services, no single digital market, and limited supply of local content, primarily due to a weak local digital ecosystem.

Gaps in the policy enablers required to support devices, networks, and applications mean that many ASEAN member countries are lagging behind the potential of innovative sectors associated with the digital economy such as mobile financial services, e-commerce, and cloud services (OECD, 2017).

Still, the ASEAN region has the potential to leapfrog other countries and rank as an elite global digital economy. A true digital revolution will transform ASEAN by 2025. Singapore, Malaysia, and Thailand would be in the top 20 of the global digital rankings, while all other ASEAN countries would be ranked in the top 40 worldwide. Achieving this ambition would go hand in hand with delivering a substantial increase in GDP across the 10-nation bloc. Transforming ASEAN into a global digital economy powerhouse could potentially generate an additional US$1 trillion in GDP over the next 10 years. Realising this goal will require a joint effort and a shared vision across ASEAN. The uplift to GDP will be driven by three major factors: an increase in broadband penetration, higher worker productivity, and new digital industries such as e-commerce and mobile financial services.

Digitisation is not limited to ICT industries. It is also disrupting traditional industries. It involves three key elements: digitising product and service offerings (for example, remote health monitoring), digitising customer engagement (for example, digital channel for sales and digital self-serve channels), and digitising internal operations to increase productivity (for example, digitising the sales force). As labour costs rise in the manufacturing and engineering sectors, digitisation will help ASEAN move up the economic value chain. Technology sensors and devices are being integrated into equipment and machinery through IoT, while advances in computational ability are enabling the analysis of huge information (big data) related to production, logistics, and sales. In the future, factories will be far more flexible than today in terms of producing individual products and achieving higher efficiency. Manufacturing will be faster, lower-cost, and higher-quality

Over the next decade, Industry 4.0 will emerge in Southeast Asia, aided by support from far-sighted business and political leaders. Industry 4.0 consists of the intelligent networking of product development and production, logistics, customers, and beyond. We will begin to see intelligent machines and smart factories that will bring about the fourth industrial revolution. The resulting revolution in ASEAN's manufacturing sector will increase the region's productivity and competitiveness, while lowering unemployment rates and creating higher-wage jobs.

Discrete manufacturing industries, from automotive to electrical and electronics, will all benefit from the operational efficiencies reaped from new technologies. In Singapore and Malaysia, high-value product manufacturing, such as printed electronics and miniaturisation, could undergo a high degree of automation and optimisation. These sectors will be among the first to integrate Industry 4.0 into their production platforms.

A true single digital market requires member states to align their digital visions and strategies to create a single, borderless digital market and harmonised digital regulations.

ASEAN is quite far from realising this ideal. Only three countries – Singapore, Malaysia, and the Philippines – have a mature and comprehensive digital strategy. Indonesia has an ICT master plan focused primarily on connectivity until 2016, with a subsequent focus on creating Indonesia Digital. Thailand's and Viet Nam's digital strategies were works in progress as of September 2015, with only high-level information available at the time of writing. Cambodia's and Brunei's digital strategies are quite nascent, with Brunei Darussalam focusing mostly on digital government.

Harmonisation of regulations needs to begin from the top down. This does not mean creating the same laws in different countries. But there is a need for a common standard that applies to digital services in ASEAN, like the EU's privacy directive or the streamlined sales tax system in the USA for cross-state e-commerce transactions. Today, different ASEAN countries are taking very different approaches to infrastructure, spectrum sharing, and spectrum trading, while the maturity of cybersecurity and data protection policies varies significantly from country to country.

There are five steps policymakers can take to eliminate the roadblocks described in the previous section: pursue universal mobile broadband access; accelerate innovation in mobile financial services, e-commerce, and connected cities; enhance trust and security in ASEAN's digital economy; strengthen the local digital economy; and foster digital innovation within ASEAN.

7. Turning the Vision into Reality: Multilevel Governance Systems

Turning the vision into reality at the society level is a challenge. Policymakers and industrial associations thus need to provide a framework for the transition using models that have been proven to significantly reduce costs while improving business capabilities (Foray and Raffo, 2014; and Qin, 2015).

Managing the process of linking Industry 4.0 and the circular economy could follow the multilevel governance practice in the EU, often described with the term subsidiarity (Weidenfeld, 2010). The analysis of societal complexity clarifies that uncertainties, non-linear processes of change and innovation, and emergence of systemic changes are important features of future economic transformation.

Over the last decades, a shift from the centralised government-based nation-state towards liberalised market-based and decentralised decision-making structures could be observed. Due to societal developments, the power of central governments to make policies and implement these policies has decreased, leading to increasingly diffused policy-making structures and processes that are stratified across sub-national, national, and supra-national levels of government (Wainstein and Bumpus, 2016).

There is an increasing degree of consensus that traditional forms of governance are not suitable for challenges with a high degree of complexity. Both classical top-down management as well as laissez faire approaches have proven to be ineffective management mechanisms to generate sustainable solutions for complex tasks, such as sustainable development, which has to consider the adverse side effects of modernisation and fundamentally redefine its own dynamics and workings, implying a new paradigm on managing economic and technology development (Winkelbach and Walter, 2015).

This means that understanding complexity is a means of leverage. Greater insight into the dynamics of a complex adaptive societal system leads to improved insight into the feasibility of directing and influencing it. Over the last decade, the policymaking process has been changing fundamentally because of the European integration, which has led to a multilevel governance structure whereby, at each level, different actors are involved in the decision-making process.

This development has led to multilevel participatory decision-making structures in which, for example, cities and regions are dealing directly with EU institutions, non-government organisations, and businesses that are involved in the development of policies, and top-down decisions are limited to the politically most controversial issues. But governance has also become common practice at the regional scale, where the influence of non-governmental organisations, business, and science slowly become part of policymaking (Bernauer et al., 2016).

Obviously, these need to be considered when conceptualising the management of the process of linking Industry 4.0 and the circular economy. While classical and top-down forms of management, steering, and organisation still have a function in modern society, the complexity of the tasks requires additional strategies and approaches (Allen et al., 2011).

8. Recommendations and Next Steps

The ASEAN region is both complex and diverse. Its political and cultural differences and variations in economic behaviour make it one of the most challenging regions for businesses to operate in. But ASEAN countries are moving in the right direction, striving to sharpen overall competitiveness through closer international collaboration. This integration will begin to drive positive change.

ASEAN member countries would be well advised to consider a comprehensive overhaul of both its domestic and cross-border (regional) regulations, addressing both supply-side and demand-side objectives. On the supply side, countries within ASEAN should strive to strengthen the business case for investment in digital infrastructure, revisit regulations for key sectors (such as financial services), and boost the local digital ecosystem. On the demand side, ASEAN countries should create a single digital market and take steps to aggressively expand access to broadband. If ASEAN can implement these policies effectively, realising this opportunity should be a top priority for the new ASEAN Economic Community.

The ASEAN region should accelerate the shift towards a circular economy by launching four efforts. Shifting to the new model starts with acknowledging the systemic nature of the change. All sectors and policy domains will be affected, and aligned action is required. Such a shared agenda could contain four building blocks: ASEAN-wide quest for learning, research, and opportunity identification; development of a value-preserving materials backbone – a core requirement for strengthening ASEAN's European industrial competitiveness; initiatives at the ASEAN, national, and city levels to enable inherently profitable circular-business opportunities to materialise at scale; and development of a new, more integrated governance system to steer the regional economy towards greater resource productivity, employment, and competitiveness.

The ASEAN region should regularly monitor the extent to which ASEAN companies have already positioned themselves in relation to this digital transformation and the opportunities that the switch to Industry 4.0 offers them. The very first step is to establish an independent ASEAN Digital Economy Promotion Board to consist of country representatives, industry experts, and key opinion leaders. This board will provide strategic direction, guidance, and advice to the ASEAN Economic Community and its member governments.

The independent advisory board should be responsible for oversight of the future state of digital and communications in ASEAN. The role and responsibilities of the board should reflect ASEAN's vision of the digital economy, while ensuring economic policies within ASEAN support the development of digital products and services. Its area of focus should include the fixed and mobile telecommunications landscape, spectrum, and future sectors such as Industry 4.0 and the circular economy.

The board should also monitor and measure ASEAN's and its members' performance to make sure they are on course to make the necessary changes. An example is the EU's Digital Economy and Society Index which summarises relevant indicators on Europe's digital performance and tracks the evolution of the EU member states' digital competitiveness. ASEAN should consider establishing a similar index.

The board should also enable easy sharing and exchanging of best practices, learnings, and information across countries, governments, and operators.

The factors to be monitored are:

- Competitiveness: Digital transformation to Industry 4.0 will increase their competitiveness. The digital transformation to Industry 4.0 will have an impact right across both local and global value chains in low-cost as well as high-cost ASEAN countries.
- Opportunities and risks: Industry 4.0 represents several major opportunities for the ASEAN region. It will open new ways for companies to integrate their customers' needs and preferences into their development and production processes, including via direct data-sharing with their machinery. It will also make it easier to analyse machine data, helping to enhance quality and avoid faults in the production process. In terms of risks, digital transformation to Industry 4.0 could further increase the already heightened cyber risk to the manufacturing industry.
- Human resources: The ASEAN region might have all the staff they need to make the digital transformation to Industry 4.0. If the digital transformation to Industry 4.0 is to be successful, however, it is essential that businesses in the ASEAN region continue to invest in appropriate skills and an excellent information technology infrastructure.
- Develop potential for individual business segments: Research and development, procurement and purchasing, production and warehousing, and logistics are currently at the heart of the digital transformation to Industry 4.0, while sales and services segments have the greatest potential to benefit from it. In these segments, individualised solutions have the capacity to take manufacturing into a whole new era of customisation and provide a window of opportunity for the ASEAN region. This will require the sector to switch from the 'push into the market' of better products for their customers to an individualised understanding of customers' needs and specialised industry-specific solutions.
- Use the impetus from exponential technologies such as 3D printing to accelerate the transformation of the manufacturing industry in the ASEAN region to Industry 4.0. To assist the ASEAN business community to manage the transformation to Industry 4.0, it needs to continue to address the following four major characteristics: vertical networking, horizontal integration, through-engineering, and exponential technologies.

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Chapter 3

Evolutionary Acts and Global Economic Transition: Progress of the Circular Economy in ASEAN

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1. Introduction

The Association of Southeast Asian Nations (ASEAN) region has a huge market of US$3.6 trillion with a population of 622 million. Industry and service sectors play key roles in the gross domestic product (GDP) of its member nations.

Figure 1 illustrates the importance of the industrial sector in the GDP of ASEAN nations. Currently, 30%–50% of national GDP is linked to the industrial sector and is expected to grow further. The ASEAN model for economic growth, characterised by accelerated industrialisation through free trade and foreign direct investment (FDI) with a regional production network, has been successful. As projected by Nielsen (2015), 55% of the population (400 million) will be elevated to the middle-class level[1] by 2020 compared to the 28% (190 million) in 2012. This implies that more resources and energy will be needed to meet the increasing production capacity and consumer demand in lieu of the rising purchasing power of the people in ASEAN.

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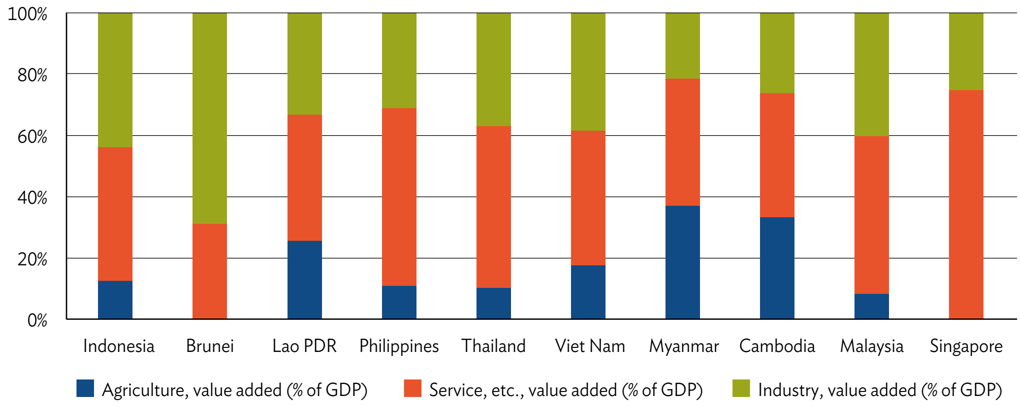
1 Middle-class level is defined as people having a daily disposable income of US$16–US$100.

Figure 1. ASEAN GDP by Sector



ASEAN = Association of Southeast Asian Nations, GDP = gross domestic product, Lao PDR = Lao People's Democratic Republic.
Source: ASEAN, 2015.

ASEAN is a diverse region comprising 10 countries, each at different stages of development. The linear approach of growth – 'take-make-use-dispose' – has been the trend for most countries in ASEAN. Singapore, ranked second in the Global Competitiveness Index (GCI)[2], has moved up from linear approach to the circular economy. As reported by the National Environment Agency of Singapore, only 2% of Singapore's waste is finally disposed in landfills while 60% is recycled and 38% is incinerated to produce renewable energy. Indonesia, which has the highest GDP in ASEAN, disposes 69% of its waste in landfills (Jong, 2015). As resources become scarcer and more expensive in future, there is an urgent need to transition to a circular economy in ASEAN.

[2] The World Economic Forum annually publishes the Global Competitiveness Index (GCI), which ranks the competitiveness of around 140 economies. GCI rank is based on both static and dynamic components (termed as 'pillar' in GCI) which include institutional capacity, infrastructure, microeconomic environment, health and primary education, higher education and training, goods market efficiency, labour market efficiency, financial market development, technological readiness, market size, business sophistication, and innovation.

The current efforts to attain sustainable economy in ASEAN countries, which focus on optimised use of resources, are limited to the 3Rs – reuse, reduce, and recycle. The circular economy, however, is not limited to the 3Rs. Developed countries like Germany and Japan have already recognised this concept where used resources are moved in a closed loop. The circular economy focuses on increasing material efficiency and resource productivity. It implies producing more GDP with minimum use of resources, particularly virgin resources. The circular economy thus requires recognising waste as resources. Unlike the 3Rs, the circular economy also extends to a conceptual business model, which helps synchronise the materials and resources flow in the supply chain to minimise or eradicate the need for resource consumption. One such business model, initiated by Philips, successfully broke the paradigm of owning a product to utilise its value and moved to a new paradigm where people can only own the value of the product. This sort of business hugely focuses on increasing the lifespan of the products. Although the 3Rs are part of the circular economy, the opportunities and potentials of the circular economy are far beyond the 3Rs.

Moving one step ahead of the circular economy is the Industrial Revolution 4.0 (Industry 4.0), which has emerged in the last few years to revolutionise the efficiencies of industries. Industry 4.0 targets minimising the use of labour and optimising the use of resources through the use of technologies. Through robots, big data management systems, cyber-physical systems (CPS), and the like, Industry 4.0 can achieve its goal of reducing dependence on unskilled and semi-skilled labour force. Industry 4.0 is an alternative way for industries to maximise their profit while increasing the efficient use of resources. However, under the ASEAN context, which thrives on the unskilled and semi-skilled labour force, the way forward with Industry 4.0 is still not clear. The ASEAN region further lacks the technological competitiveness to absorb Industry 4.0 and is still struggling to gain more control on its supply chain.

2. Economic Resilience and Evolution in the ASEAN Region

Apart from establishing regional stability, ASEAN was formed to primarily boost the economy of its member states through integration. One key milestone of ASEAN was the adoption of the ASEAN Economic Community (AEC) Blueprint in 2007, followed by the formal establishment of the AEC on 31 December 2015. AEC Blueprint 2015 is built on the following pillars: single market and production base, competitive economic region, equitable economic development, and integration into global economy. These interlinked pillars are mainly focused on elimination of trade tariff; free flow of goods, services, investments, skilled labour, and capital; establishment of common framework, standards, and cooperation across several areas; improvement of transport connectivity amongst ASEAN countries; development of a coherent external economic relationship; and enhancing sharing in the global supply network (ASEAN, 2015a).

The mid-term review of the AEC Blueprint by the Economic Research Institute for ASEAN and East Asia in 2012 highlighted the key achievements of the AEC Blueprint 2015 in areas like free trade, single window, free flow of investments, and the like. The Common Effective Preferential Tariff, the implementing mechanism of the vision for the ASEAN Free Trade Area, is significantly reduced in the ASEAN region. The number of items with zero tariff rose from 40% in 2000 to 99.11% in 2012 for six ASEAN nations. Considerable progress was also achieved in the implementation of the ASEAN Single Window policy. This is the heart of AEC 2015, which is aimed at facilitating the trade. The policy aims to speed up the process of cargo clearance from customs. Only five nations currently have the National Single Window policy (Indonesia, Thailand, the Philippines, Malaysia, and Singapore), although only Singapore executes an effective Single Window approach. Viet Nam is on the way to implementing the ASEAN Single Window policy while Cambodia, the Lao People's Democratic Republic (PDR), and Myanmar are still behind. The implementation of AEC 2015 also resulted in the improvement of the free flow of investment within the ASEAN region. However, AEC 2015 failed at establishing and implementing trade standards, mutual recognition agreements, and movement of professional service providers.

The economy of the ASEAN region almost doubled from US$1.33 trillion in 2007 to US$2.57 trillion in 2014 and its per capita GDP increased by 76% at the same time. These quantify the success of AEC 2015. The ASEAN economy grew to be the third largest in Asia and the seventh largest in the world in 2014 (ASEAN, 2015b). The ASEAN region also gathered 11% of the total foreign direct investment inflow in 2014, making it one of the potential markets for global investment. The foreign direct investment was only 5% back in 2007 when the AEC Blueprint was just initiated (ASEAN, 2015b).

At the end of the AEC Blueprint 2015, the AEC decided to move forward with the AEC Blueprint 2025 for networking and building a competitive, innovative, highly integrated, and contestable ASEAN (ASEAN, 2015c). The AEC Blueprint 2025 is based on the following pillars: highly integrated and cohesive economy; competitive, innovative, and dynamic ASEAN; enhanced connectivity and sectoral cooperation; resilient, inclusive, people-oriented, and people-centred ASEAN; and global ASEAN. ASEAN's growth is predicted to grow at 5.2% over 2015–2020 (OECD, 2016) and to be the fourth largest in the world by 2050 (Vinayak, Thompson, and Tonby, 2014).

However, these gains are not equitably divided amongst ASEAN member nations (Table 1). Indonesia, with an enormous GDP of about US$872 billion, accounts for nearly 35% of the total ASEAN economy. Similarly, Indonesia, Thailand, the Philippines, Malaysia, Singapore, and Viet Nam occupy 95% of ASEAN's economic wealth, while Myanmar, Cambodia, and Lao PDR are moving at a tremendous rate. ASEAN nations are at different stages of economic growth and the variance can be seen in their GDP and per capita GDP. Similarly, the level of industrial contribution to GDP also differs. Brunei Darussalam, Indonesia, Thailand, and Malaysia are more inclined towards the industries whereas Singapore and the Philippines are more inclined towards the service economy. Cambodia, Lao PDR, Myanmar, and Viet Nam (CLMV) are still struggling to escalate their production. Domestic material consumption, which refers to the raw material extracted in a nation and all the physical imports after deducting the physical exports, is a suitable indicator for resource consumption. The domestic material consumption for Singapore and Malaysia is also seen to be significantly higher than the other ASEAN nations. Among the CLMV nations, Viet Nam has a higher domestic material consumption with 8.5 tonnes/capita, while Myanmar consumes the least resources.

Table 1. Economic Status of ASEAN Member Countries and their Resource Consumption

Country	GDP Growth Rate (%)*	GDP (in US$ Billion) Per Annum*	Per Capita GDP at Current Price (US$)**	Industrial Contribution to GDP (%) (2013)*	DMC (tonne)***	Per capita DMC (tonne/capita)***
Indonesia	5.0	872	3,467	42.6	1,822,839	7.5
Thailand	0.9	373	5,678	36.9	577,912	8.6
Malaysia	6.0	313	10,420	39.8	448,861	15.9
Philippines	6.1	299	2,707	31.3	374,549	4.0
Singapore	2.9	293	55,182	25.1	161,737	31.8
Viet Nam	6.0	198	1,909	33.2	755,956	8.5
Myanmar	8.5	65	916	21.3	208,498	4.0
Cambodia	7.1	17	1,047	25.6	83,073	5.8
Lao PDR	7.5	12	1,505	33.2	NA	NA
Brunei Darussalam	-2.3	11	39,679	68.24	3,128	7.9

DMC = domestic material consumption, Lao PDR = Lao People's Democratic Republic, NA = not available.

Sources: *Work Development Indicators, 2014; ** ASEAN Economic Community Chart Book 2014; *** Dittrich, 2014.

ASEAN accounts for 7% of global exports and is the fourth largest exporting region in the world after the European Union (EU), United States, and China. The manufacturing capabilities of this region are also diverse and different member countries specialise in different sectors. Table 2 shows the manufacturing capabilities of this region are also diverse.

Table 2. Globally Recognised Major Industries of ASEAN Member Countries

Country	Recognised Sector
Viet Nam	textile and apparel, leather, shoes
Singapore	electronics, service industry
Malaysia	electronics, palm oil
Thailand	vehicle and automotive-parts exporters
Indonesia	palm oil, coal, cocoa, tin
Philippines	agricultural products, business process outsourcing
Brunei Darussalam	natural gas, oil

DMC = domestic material consumption, Lao PDR = Lao People's Democratic Republic, NA = not available.

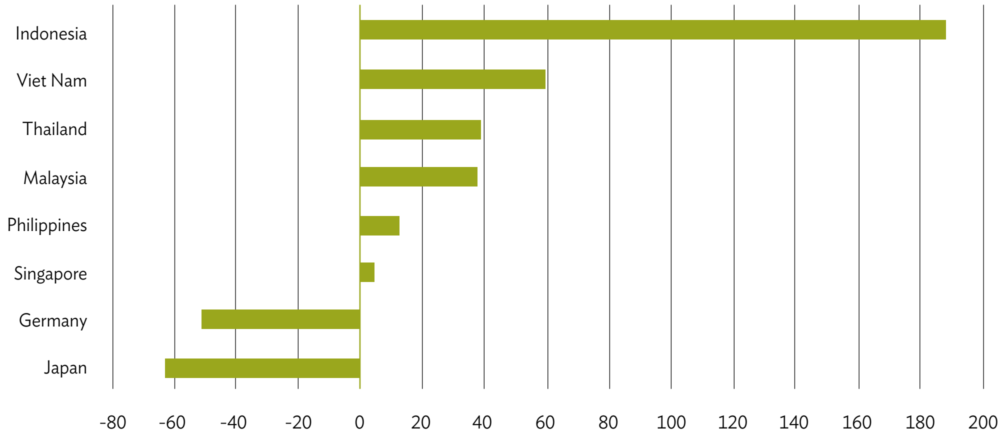
Sources: *Work Development Indicators, 2014; ** ASEAN Economic Community Chart Book 2014; *** Dittrich, 2014.

3. Linear Economy and its Limits to Growth

Though ASEAN member nations have achieved rapid economic growth, this was attained at a significant environmental cost. As can be seen in Figure 2, total cumulative CO_2 emissions in Singapore, the Philippines, Malaysia, Thailand, Viet Nam, and Indonesia increased between 2007–2011, while CO_2 emissions decreased in Germany and Japan during the same time interval. The increase in CO_2 emissions can be attributed to the increase in industrial activities and resource consumption. It also signifies the trend in linear economy, which focuses on the 'take-make-use-dispose' principle. The ASEAN economy is based on the principle of linear economy where the resources flow from 'cradle to grave'. 'Cradle to grave' flow implies that the resources flow from extraction of minerals to the landfill after production and consumption of the materials.

However, if this linear economy continues, two earths will be needed to meet human consumption needs by 2030 as estimated by the United Nations. Resources have been abundantly exploited to raise the GDP of nations. About 65 billion tonnes of raw materials entered the economy and resource demands are expected to soar to 82 billion tonnes by 2020 (Ellen MacArthur Foundation, 2012). Therefore, the linear economy model is not sustainable, and ASEAN must transition to a model like that of Japan and Germany.

Figure 2. Change in CO_2 Emissions Per Annum in Million Tonnes, 2007–2011



CO_2 = carbon dioxide.
Source: World Development Indicators, 2016.

Figure 2 demonstrates the difference in annual CO_2 emissions between 2007 and 2011. Japan and Germany, which have moved forward with stringent laws and market-based policies, have managed to develop new technologies and business models, and enhanced resource use efficiency with considerable reduction in the annual CO_2 emissions. However, for the ASEAN6 region (Indonesia, Thailand, Malaysia, Viet Nam, the Philippines, and Singapore), which accounts for over 95% of ASEAN's wealth, Figure 2 shows that the economic growth and resource consumption are coupled, as the increase in GDP is also followed by an increase in annual CO_2 emissions. Indonesia increased its CO_2 emissions by 188.4 million tonnes (MT) in 2011 compared to its annual CO_2 emissions in 2007. Indonesia emits the highest amount of CO_2 in the ASEAN region. Similarly, Viet Nam, Thailand, Malaysia, the Philippines, and Singapore increased their annual CO_2 emissions by 59.3MT, 38.3MT, 37.6MT, 12.3MT, and 4.2MT, respectively, compared to the 2007 emissions. However, in the same year, Japan and Germany reduced their annual CO_2 emissions by 63MT and 51MT, respectively, compared to their CO_2 emission levels in 2007.

CO_2 emissions are related to resource consumption. Resource extraction, processing, production, use, and disposal are all linked to energy consumption, which leads to the emission of CO_2 as well as other greenhouse gases. CO_2 has been widely used to quantify resource use efficiency, which advocates minimum use of energy and resources or, alternatively, minimise CO_2 emissions to do the same activity (e.g. extraction, production, use, disposal, and the like). Linear economy disregards this cost and is focused on the economic gain.

3.1 Constraints to Linear Economy

The linear economy has undoubtedly assisted the ASEAN economy to grow. However, it has limits and sustainable growth is not possible with this economic development model as there is an end to resources use. Some aspects of linear economy that trigger the need for the circular economy for ASEAN are as follows:

3.1.1 Inefficient resource consumption along the supply chain

Linear economy excessively produces waste, which ultimately end up in landfills. Wastes are created throughout its supply chain – from mineral extraction, production, transportation, packaging, etc. However, sometimes, the supply chains are much more complex like in the case of the food supply chain where the wastes are produced from each component of the supply chain. The constrained approach of linear economy simply deals with the 'take-make-use-dispose' approach, which might not be resource efficient.

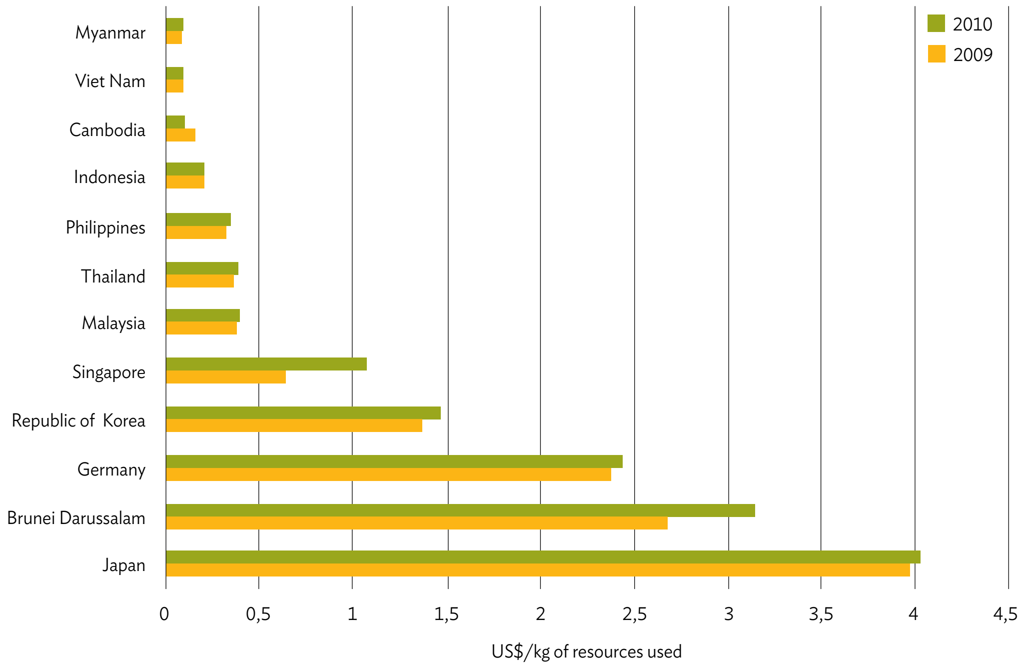
The Food and Agricultural Organization of the United Nations estimated a massive food loss of 1.3 billion tonnes, which accounts for one-third of the current food production (FAO, 2011). The Food and Agricultural Organization further estimated that 42% of fruits and vegetables and up to 30% of grains produced in Asia and the Pacific region are lost between production and the market. Food waste created by consumers is only a small fraction of this supply chain. These losses occur due to the following reasons in the supply chain: lack of technological advancements in harvesting techniques, pests during handling and storage, lack of efficient processing plants, and lack of logistics and data on customer demands.

Waste generation in the supply chain is inevitable in the conventional linear approach. This calls for an alternative that uses the principles of the circular economy to reduce waste generation and to improve efficiency throughout the supply chain.

3.1.2 Low resource productivity

ASEAN Member States have low resource productivity. Resource productivity indicates the effectiveness of the resources used for generation of wealth. Higher resource productivity not only signifies higher per capita income or GDP of a nation but also depicts minimal environmental impact.

Figure 3. Resource Productivity of ASEAN Countries



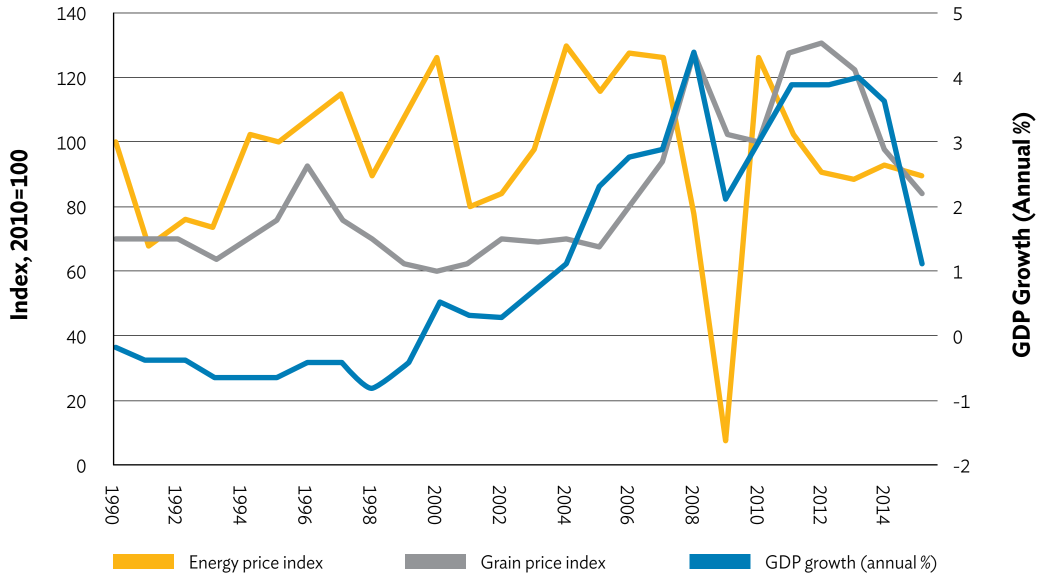
ASEAN = Association of Southeast Asian Nations, kg = kilogram.
Sources: Wirtschafts Universität Wien, 2014; Global Material Flows Database.

Figure 3 illustrates the low resource productivity of the ASEAN region, except Singapore and Brunei Darussalam. Japan and Germany have stringent rules, regulations, and policies as well as a vibrant private sector and strong research and development (R&D) system to support the circular economy, resulting in higher resource productivity.

3.1.3 Vulnerability due to mounting commodity price

The linear approach to growth demands the use of virgin raw materials. This dependence on virgin resources makes the company vulnerable to price hikes. The circular economy aims at decoupling the economy from excessive resources consumption. Thus, it is necessary for the ASEAN region to explore ways to reuse and recycle the used materials.

Figure 4. Comparative Analysis of Commodity Price and GDP Growth World Development Indicators (1990-2014)



GDP = gross domestic product.

Source: Based on UN Comtrade data.

The figure above shows the comparison between the GDP growth rate and the price of two commodities (energy and grain). Energy price index and grain price index refer to the basket of these commodities or all its sub-categories. As seen in the graph, the GDP growth rate seems to have a direct relationship with the fluctuating price of commodities. A stronger relationship can be seen in 2009 where the fall in the global GDP was marked by the decline in the energy and grain price indices. Similarly, when the global economy collapsed in 2015, energy and grain price indices also crashed.

4. Evolution of the Circular Economy

With depleting resources and increasing rate of carbon emission becoming global problems, an economically viable solution that promotes conservation and optimal use of environmental resources is an essential agenda for any nation. The major sector to be considered for such advancement is the industrial sector, which depends largely on the use of natural resources and economic growth. This sector consumes significant amount of natural resources and produces by-products that have no further use in the production process but are to be disposed as waste. A current linear model, which is based on the generation of more wealth by consuming more resources, is questionable from the point of view of competitiveness and sustainability.

With innovative technologies and smart business models, one of the prominent solutions to resource scarcity is to circulate these wastes in a closed loop in the form of material symbiosis between companies and production processes (Andersen, 2007). This principle of loop closing with the aid of new technologies, production models, and green entrepreneurship is termed as 'circular economy', and was first introduced in German and Swedish environmental policies (Yuan, Bi, and Moriguchi, 2006).

4.1. Evolution from Linear Economy to Circular Economy

Figure 5 presents the stages of global industrial development. During the early industrial development stages, environmental problems were addressed by considering all pollution issues that could be solved through the dilution approach. Regulatory and associated policy instruments were progressively developed later, aimed at controlling and enabling the manufacturing sector to deal with environmental impacts downstream, with emphasis on end-of-pipe waste treatment.

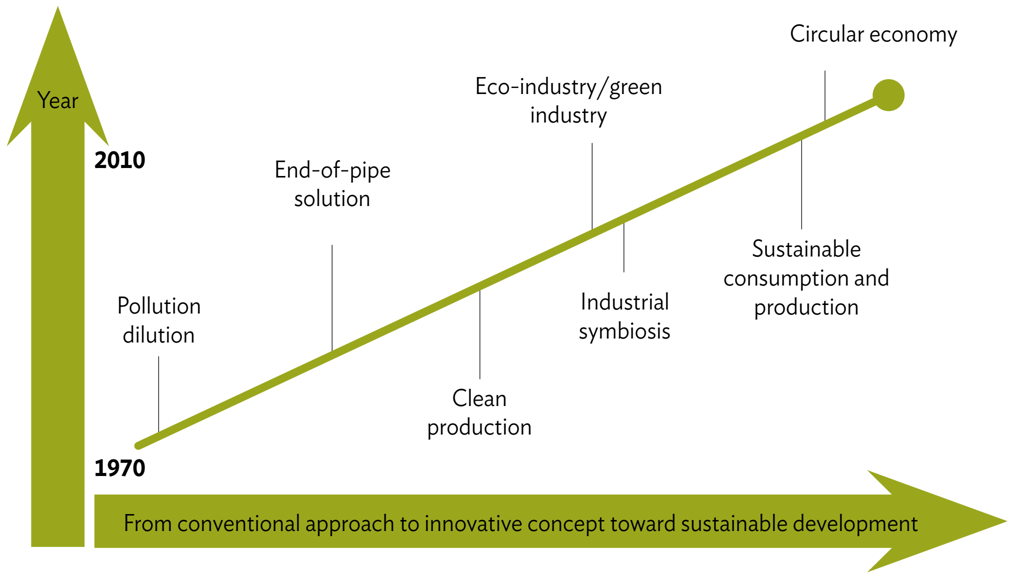
In the 1980s, cleaner production was the next response to pollution management, which moved beyond the traditional concept of pollution dilution and treatment. The changes intended to decrease waste production, minimise the resources used, and increase the efficiency of the production processes. Cleaner production looked at the waste and pollution created by the industries from the modular approach and emphasised the improvement of each module.

However, these approaches did not have a holistic view, lacked integrated policy support, and often failed to penetrate the supply chain and emerging production networks. The investments made in pollution control and infrastructure focused either on the eradication of pollution or on the improvement of resource and energy efficiencies. These solutions did not aim at eradicating the need for virgin natural resources and were based on the linear model of resource consumption. Thus, with the rising population and needs, consumption and pollution invariably increased.

Sustainable consumption and production (SCP), as defined by the Oslo Symposium in 1994, is about 'the use of services and related products, which respond to basic needs and bring a better quality of life while minimising the use of natural resources and toxic materials as well as the emission of wastes and pollutants over the life cycle of the service or product so as not to jeopardise the needs of further generations'. SCP was indeed the first attempt to manage waste in the supply chain. It focused on consuming the goods and reducing the creation of wastes in a sustainable way.

In the 2000s, the circular economy became the next step towards transforming the vicious into a virtuous cycle. The circular economy calls for an innovative supply chain and business model that eliminates waste by designing products in such a way that resources can be used in a cyclical way rather than being disposed in landfills. Furthermore, the circular economy concept integrates all upstream and downstream processes/flows throughout the economic value chain (facilitate materials in cyclical flow).

Figure 5. Development of Environmental and Resource Management Approach by Industrial Sector



Source: Authors.

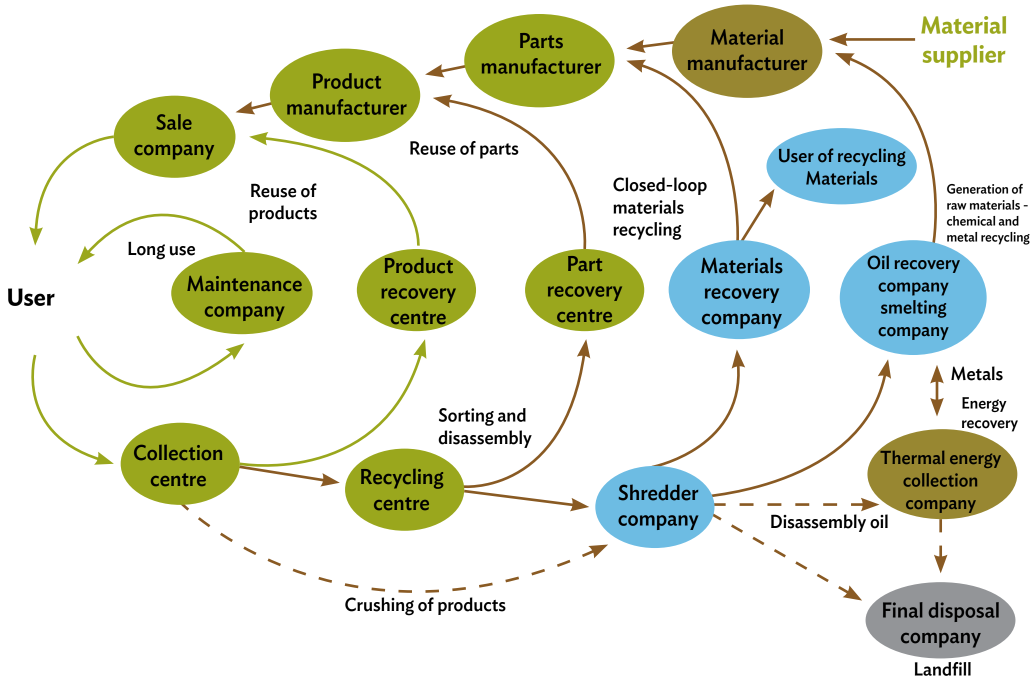
The circular economy is based on a win-win philosophy where both economy and environment can be sustained in a healthy way (Geng and Doberstein, 2008). It focuses on the following objectives: economic (accelerate growth), social (job creation and employment), and environmental (reduce pollution and greenhouse gas [GHG] emissions). It puts emphasis on the most efficient use of resources and recycling as well as environmental protection (UNEP, 2014). The circular economy is described in terms of an industrial system that replaces the 'end-of-life' concept by restoration and regeneration through intention. By redesigning products, services, or processes, it aims to transform wastes or discarded materials into productive and reusable products through closed-loop systems (Sempels and Hoffmann, 2013; Ellen MacArthur Foundation, 2013).

4.2 Contents of the Circular Economy

Several definitions of the circular economy have been proposed in the literature. The Ellen MacArthur Foundation (2013) highlighted that the circular economy is a restorative system which aims at careful management of material flows. It looks to eradicate waste through careful designs and minimise the use of resources by considering everything (including waste) in the economy as a valuable resource. The concept advocates the need for functional service, selling the use of the product rather than the product, effective take-back arrangements for products which have reached their 'end-of-life', and the proliferation of product and business models which generate durable products, and facilitate disassembly and refurbishment.

A practical example of the circular economy can be illustrated by Ricoh's Comet Circle (see Figure 6). The system of material flow puts priority on the inner loop based on designing for long use, reuse/repair; design for easy sorting; and disassembly. The next priority is given to recycling.

Figure 6. Example of the Circular Economy (Ricoh's Comet Circle)



Source: Ricoh Group.

The cradle-to-cradle philosophy, based on the circular economy principle, classifies all materials used in production processes around two kinds of metabolism: the biological and the technical. The biological nutrient is a material or a product initially designed to reintegrate the natural cycle, and the technical nutrient is a non-biodegradable material that can be recovered and reintroduced into a closed-loop production cycle, without loss of quality. Further, 'waste does not exist when the biological and technical components (or materials) of a product are designed by intention to fit within a biological or technical materials cycle, designed for disassembly and repurposing' (Ellen MacArthur Foundation, 2013).

4.3 Need for the Circular Economy

The World Economic Forum estimates that only 20% of the total global materials, valued at US$3.2 trillion, are recovered, while 80% is lost to the 'take-make-use-dispose' model. The concept of the circular economy is recognised as an alternative approach to transform the linear system into a more sustainable approach based on circular cycles (called the closed loop). The circular economy concept is gaining more attention recently as it will potentially help reduce resource extraction and waste streams, minimise environmental impacts, and support organisations to move towards sustainable development.

One of the key advantages of the circular economy is that it focuses on reducing dependency on the resource market, which reduces a country's or company's vulnerability to costs. Unlike in the past century, resource prices are soaring, and this trend will continue for the next 20 years (Dobbs et al., 2011). Thus, a more resilient economy that is not centred on energy and use of virgin materials is essential. The circular economy, which evolves around the same concept, focuses on the usage of materials through reuse, refurbishment, remanufacturing, and recycling. Apart from reducing vulnerability from macroeconomic shock, the circular economy also reduces pressure on the environment and minimises the environmental cost. Economically, it also creates jobs as a new sector has evolved.

The carpet giant Interface successfully runs a programme called Network Philippines, which buys discarded fishing nets from local communities and recycles it into fresh carpet tiles. Apart from reducing its dependence on virgin resources, social and environmental benefits are embedded in this business model. Nylon, which is made from petrochemicals, is used for production of fishing net. For decades, nylon was considered unrecyclable until the groundbreaking discovery by Econyl Corporation in 2011. Econyl's regenerative system is capable of recycling fishing nets into nylon yarn (raw material for carpet manufacturers).

In the Philippines, discarded nylon fishing nets continue to injure and even kill marine life. These globally discarded fish nets cumulate around 10% of the total marine wastes (Macfadyen, Huntington, and Cappell, 2009). Interface explored the opportunity of utilising these discarded nets as raw material through the formation of Network Philippines, which is the association of Interface, Aquafil, and the Zoological Society of London (see Figure 7).

Figure 7. Network Philippines

SPFTC = Southern Partners and Fairtrade Center Inc., ZSL = Zoological Society of London.
Source: Authors.

Under this business model, the seller gets paid for the nets which initially threatened marine life. The collected nets are exported to Aquafil which applies its technology to convert it into a raw material (nylon yarn) for the Interface manufacturing process. This kind of business model and technological innovation not only helps companies meet the sustainability need but also motivates the community to participate in the circular economy.

The circular economy has been considered an important tool to attain the resource efficiency agenda established under the Europe 2020 Strategy for smart, sustainable, and inclusive growth. The circular economy has also been recognised as China's national regulatory policy priority, and the Chinese government has introduced numerous regulations to support and build its implementation. Under the circular economy package, Europe has targeted to achieve 70% recycling by 2030 and put a ban on sending recyclable materials to landfills by 2025 (EU Commission, 2014). Asian countries like Japan, the Republic of Korea, and Taiwan have also introduced the circular economy in their policies and have demanded that manufacturers recycle 75% of their annual production. The practice of circular economy has also been seen at the industrial level in Asia.

The industrial and business sectors have a very significant influence on the transformation of the linear system to a more sustainable model of development, particularly in the way companies design how their products are manufactured, the decision on what materials are used, and the structure of their operational business practices, from procurement until the end of product's lifetime. The industrial sector has become increasingly proactive in contributing to sustainable development due to multilateral environmental agreements, international trade agreements, and national environmental regulations and pressures. Companies now need to be more careful and proactive in environmental regulations; the circular economy not only solves environmental issues but also makes business profitable.

4.4 Value Drivers of the Circular Economy

Value drivers are the entities that give the product or service of companies more competitive advantage. They add value that is recognisable and appealing to the consumers. This can be capitalised as they differentiate the product or service from the competitor's product. The circular economy value drivers are marketable as the consumers are progressively moving towards 'green consumerism', which demands the inclusion of social and environmental costs in the product or products. The circular economy value drivers, which focus on prolonging the usage of a product, recirculating the resources, and increasing the regenerative capacity through effective product design, are easily capitalised in the form of Ecolabels, certifications, and the like, which are clear and lucid to the consumers. The ability to upgrade and use the product for longer time also adds value to the product and these value drivers are mostly observed in the electronics market where consumers regularly upgrade, for instance, their mobile phones. Some of the value drivers of the circular economy that the consumers can benefit from or can be advertised from the perspective of green consumerism are as shown in Table 3.

Table 3. Value Drivers of the Circular Economy and Associated Consumer Benefits

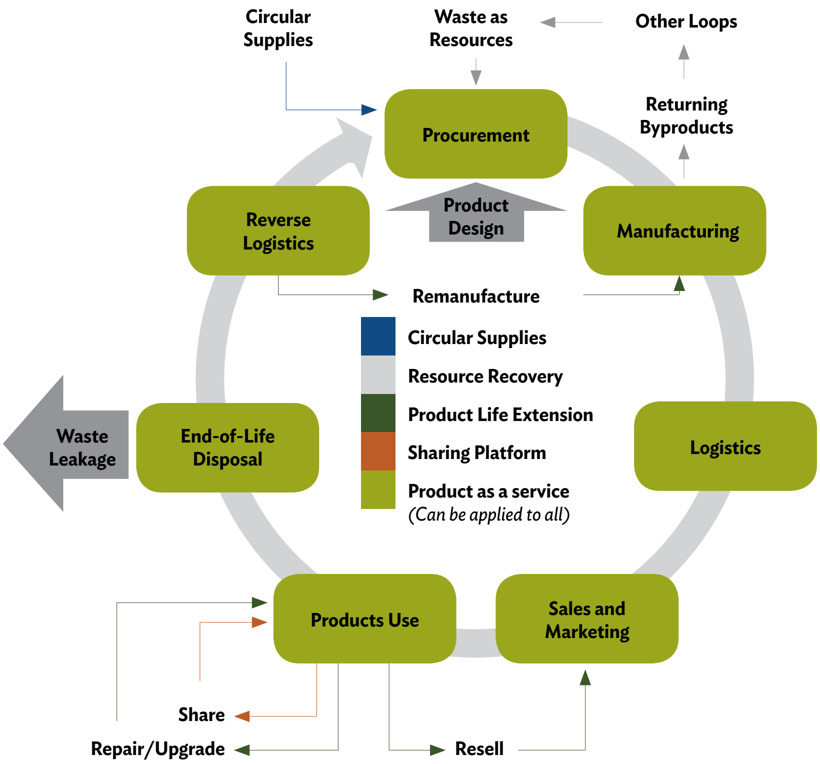
Value Drivers	Method
Extending the length of use cycle of an asset	• designing to last long • designing for easy recyclability • designing for easy repair and upgrade • including clear guidance for maintenance
Increasing the utilisation of an asset or resource	• increasing the sharing of assets • increasing resource productivity • limiting the negative externalities
Looping or cascading an asset through additional use cycles	• reusing of the material • recycling of used material for use as raw materials • refurbishment of the assets
Regenerating natural capital	• returning the biological nutrient back to land • avoiding topsoil erosion • regenerating the nutrients of soil • maintaining marine ecosystem

Source: Authors.

4.5 Circular Economy Business Models

Companies in ASEAN are becoming increasingly aware of the merits of the circular economy for their businesses and the collateral benefits it can bring. The circular economy not only provides companies the opportunity to be greener but it also generates revenue for the companies' sustainable growth. The business model adopted by the companies can be divided into five categories (as illustrated in Figure 8).

Figure 8. Circular Economy Business Model



Source: Modified from Accenture, 2015.

4.5.1 Circular input model

Under this business model, limited resources are replaced by fully renewable, recyclable, and biodegradable resources in the supply chain. It aims to decrease a company's dependence on valuable resources and vulnerability to the rising prices of scarce resources by using recycled materials.

Greenpac, a Singapore-based company that designs and manufactures packaging systems, has adopted the circular input model where packaging materials are designed for recyclability. Their 'revolutionary systems concept packaging' solution uses oriented strand boards and water-based glue to do away with the use of nails, which can sometimes destroy the product. It is the world's first nail-free wooden packaging design that is 100% reusable and recyclable. The new design also saves 60% of the material and therefore reduces the weight of packaging, saves transport costs, and reduces carbon emission (Greenpac Environmental Packaging, 2008).

Under the circular input model, resources are moved along the loop. One example is the use of tyre waste for the manufacturing of shoe outsoles. The tyre and footwear industries are the largest users of raw rubber. Recycling the used rubber from tyres into footwear can reduce the resource consumption and increase resource efficiency. Omni United, a Singapore-based tyre manufacturing industry, and Timberland, a footwear company in the United States (US), explored this link and have partnered to manufacture tyres that can be easily recycled at the end-of-life into crumb rubber to be used by Timberland for making shoe outsoles (Ecobusiness, 2014).

4.5.2 Resource recovery

This business model targets to improve technology and capabilities to efficiently eliminate material loss in the supply chain. It targets to recover and reuse resources for the next cycle through recycling, industrial symbiosis, and cradle-to-cradle design.

Wongpanit is a waste management company that has pioneered the resource recovery principle in Thailand. Wongpanit is spread throughout the nation and has more than 900 branches spread all over the country. The company is continuously growing as waste generation is inevitable. The largest waste recycling plant of Wongpanit is located in Ayutthaya (the ancient capital of Thailand) and it recycles 100 tonnes of wastes a day. The recycled materials mostly include metal, paper, glass, plastic, waste tyres, hazardous waste, food residues, electronic waste, expanded polystyrene foam, and many more. Wongpanit has managed to increase the public interest in waste management by buying waste from the user. It has also collaborated with the government to promote separation of waste materials at the source. Moreover, the company offers capacity-building training programmes as well as provides job opportunities to disadvantaged people.

PT Enviro Pallets, a US company based in Bali, Indonesia, came up with an innovative business model where the plastic wastes from the island are processed to produce shipping pallets. The company buys plastic waste from the local waste collectors at a minimum of US$0.09 per kilogram, creating jobs for many and improving the environment (Richardson, 2015).

4.5.3 Product life extension

This business model deals with designing a product that can be repaired, upgraded, remanufactured, and remarketed with ease. Under this business model, a product is designed to have a prolonged lifetime to avoid ending up too early in the waste stream.

The product life extension business model has already been initiated by multinational companies like Philips and Optus. The Dutch electric equipment giant, Royal Philips, has a new healthcare imaging system refurbishment facility in the Netherlands that refurbishes x-ray, magnetic resonance imaging, nuclear medicine, and ultrasound systems; and extends their product lives. Similarly, Optus, the Australian telecommunications provider, through its sustainable asset-disposal initiative, sold its entire set of outdated inventories to users who will be using them for their own business or to sustainable recyclers. This kind of business model increases the product life and decreases the need for landfills. It is economically rewarding as well (Accenture, 2015).

4.5.4 Sharing platforms

This business model is centred around sharing the products and assets amongst companies to minimise the need for owning a product. Through this model, the productivity of a resource can be enhanced and the resource consumption can be decreased.

With the launch of sharing platforms like Airbnb (home sharing) and Uber (car sharing), the sharing business model is gaining momentum. It is also gaining popularity in the ASEAN region. Tripid, a ride-sharing service based in the Philippines, connects drivers and passengers headed the same way. This platform helps create a community of drivers and passengers who opt to share rides with others while also allowing users to act as drivers for others looking for a ride. The sharing platform has spread to the food sector. Malaysia-based Plate Culture allows homes to host a meal in their own kitchen. The menu and prices can be easily uploaded on the site where home meal lovers can find such a place to eat their meal. Similarly, sharing platforms like Waste Is Not Waste in Singapore enables business and companies to sell their waste to the right buyers. In addition to selling the product, the platform also provides companies the option to trade their wastes.

4.5.5 Produce as a service

This business model is a paradigm shift from the conventional thinking of owning a product. Under this business model, customers pay for the performance of the product. This model is attractive for companies that wish to reduce their operational costs by outsourcing more eligible businesses for services.

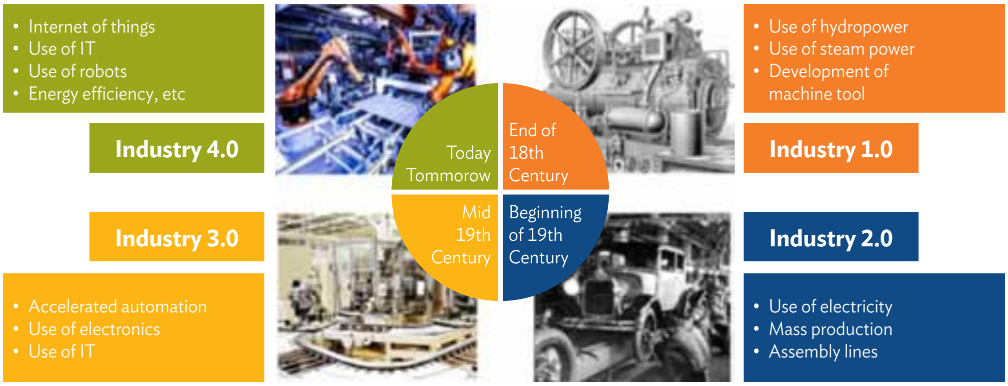
Sunlabob is a solar enterprise based in Lao PDR which has initiated this business model to light rural areas in the country. Sunlabob created a solar lamp renting business where people can rent a solar lamp on a daily or weekly basis. This lighting as a service business model is affordable for the villagers who cannot buy the expensive solar panels and lights but have enough money to borrow the service rather than buy the product. It also ensures better maintenance and efficiency of the equipment as the service providers are obliged to maintain the quality of their service. This kind of business model is resource efficient as it reduces the resource consumption and increases the reliability of the service. The lighting of the famous Dragon Bridge in Da Nang, Viet Nam, runs under the same business model where Philips sells the light rather than the bulbs. Philips is responsible for lighting this landmark and charges for the service, which gives it liberty to sustainably manage its resources for better performance. This type of business model can motivate as well as offer economic benefits to the business/firm/company to prolong its product life cycle by proper maintenance and refurbishment, thus increasing the resource efficiency.

5. Digitising the Circular Economy: Industry 4.0

Figure 9 presents the evolution of Industry 4.0. ASEAN manufacturing can be strongly associated with Industry 1.0, which is based on the use of hydropower, system power, and machine tool. Industry 2.0 is associated with mass production based on the division of labour using renewable energy. Industry 2.0 was followed by Industrial 3.0, wherein electronics, information and communications technology (ICT), and robots played a key role in the atomisation of the production line.

Moving one step ahead of the circular economy is Industry 4.0, which focuses on the use of intelligent assets (robots, internet of things, ICT, and others). Through effective use of intelligent assets, Industry 4.0 aims to make the production line of the industrial system 'cyber efficient'. Industry 4.0 refers to the digital transformation of the design, manufacturing, operation, and service of the manufacturing systems and products.

Figure 9. Evolution of Industry 4.0



IT = information technology.

Source: Authors.

5.1 Characteristics of Industry 4.0

Industry 4.0 relies on the use of ICT in the supply chain. It not only focuses on making the production more efficient but also tries to make the system efficient outside the company boundary. Industry 4.0 focuses on the vertical networking of the production system, logistics, marketing, and services. It targets the customer's needs and is capable of customised production at a lower cost, with improved resource efficiency than the conventional system. It also accounts for the end-of-life of the goods and works on life cycle approach. It further targets the use of intelligent assets that can significantly cut production, transportation, and distribution costs.

The comparative advantages on different mechanism, technology, and uses in Industry 4.0 is shown in Table 4.

Table 4. Mechanism, Technology, Uses, and Comparative Advantages of Industry 4.0

Mechanism	Technology	Use	Advantages
CPS	ICT, sensors, intelligent robots, and 3D printing	Monitor and control production	Minimise the creation of waste and the production cost. The production process is more resource efficient as it is automated.
Network communications	Wireless and internet technology	Synchronise machines, products, and people	Production process can be changed at short notice. There is more control over the machines and the process is more efficient.
Remote monitoring	Robots and skilled labour	Remote monitoring of problems	As the production process can be remotely monitored and the problem can be remotely solved, there is less usage of unskilled and semi-skilled workforce.
Big data management	Simulation and modelling	Prediction of consumer behaviour	Better forecast of demand can potentially reduce the inventory and the probability of wastage of the manufactured good.
Energy efficiency and decentralisation	Use of renewable energy and recycled resources	Staying resilient to the vulnerabilities	Reduces the need for virgin resources. As the environmental costs are indirectly reduced due to the principle of energy and resource efficiency, Industry 4.0 can add green value to the products.

3D = three-dimensional, CPS = cyber-physical systems, ICT = information and communications technology.

Source: Authors.

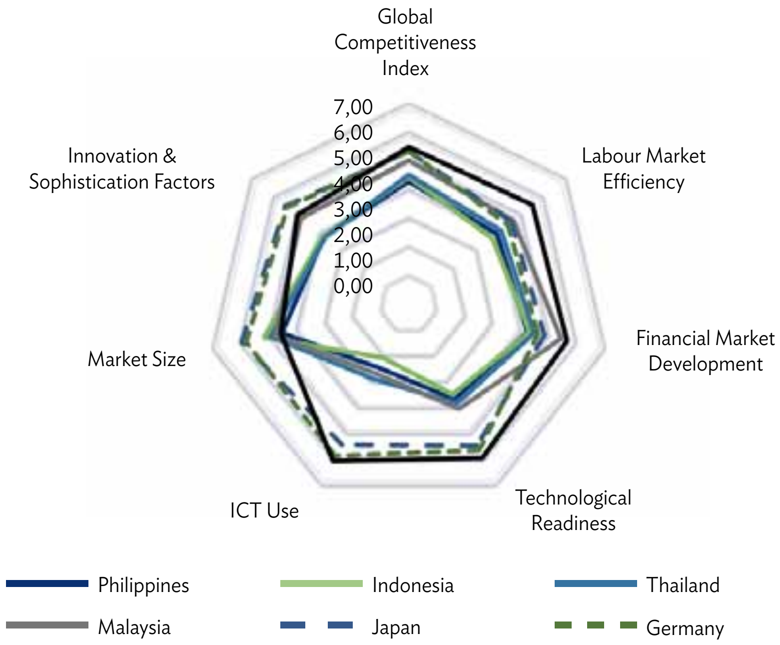
5.2 Positioning of ASEAN Members in Preparedness for the Circular Economy and Industry 4.0

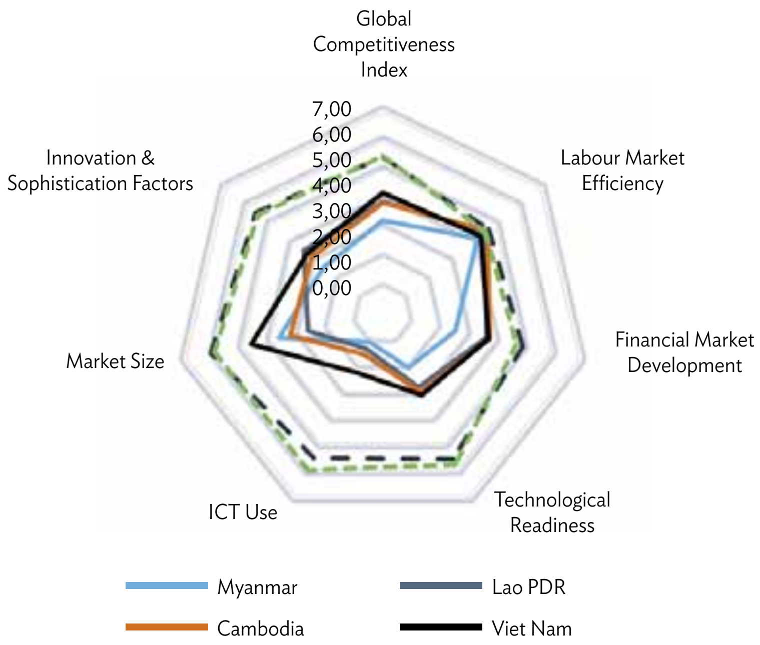
The Global Competitiveness Index (GCI) was used to clarify ASEAN's position in the context of its performance, capabilities, and preparedness. The Global Competitiveness Report 2014–2015, which analyses the GCIs of countries, analyses and ranks 140 countries according to their competitiveness. It measures institutions, policies, and factors that can lead to economic growth and is based on theoretical and empirical research. GCI consists of 110 variables organised into 12 pillars. These pillars measure the following sub-indices: basic requirements, efficiency enhancers, and innovation and sophistication. These sub-indices, pillars, and variables use a scale from 1 to 7, where 1 means least competitive and 7 means highly competitive. Two-thirds of the scaling of the variables of the GCI is done through executive opinion surveys while one-third comes from publicly available reliable sources or databases.

However, for purposes of analysing ASEAN in terms of its capability to absorb the circular economy and Industry 4.0, the GCI scale has four pillars of the sub-index efficiency enhancer (labour market efficiency, financial market development, technological readiness, and market size); one sub-index of innovation and sophistication factors; and one variable of efficiency enhancer, i.e. ICT use, which falls under the technological readiness pillar that has been used in Figure 10. Japan and Germany, which have been reported to be flourishing with the circular economy and Industry 4.0, have also been analysed for benchmarking ASEAN.

CLMV countries are marginally behind Japan and Germany as seen in Figure 10. In the ASEAN6, Singapore is as competitive as Japan and Germany, but has constraints in terms of market size. Other ASEAN6 nations are more or less at the same scale and need a lot of improvement in their technology, labour efficiency, and innovation to compete with the developed economies. ICT use in the ASEAN region (except for Singapore) needs a huge improvement and needs to be supported well by policies.

Figure 10. ASEAN Position in the Global Context (Above ASEAN6 and Below CLMV)





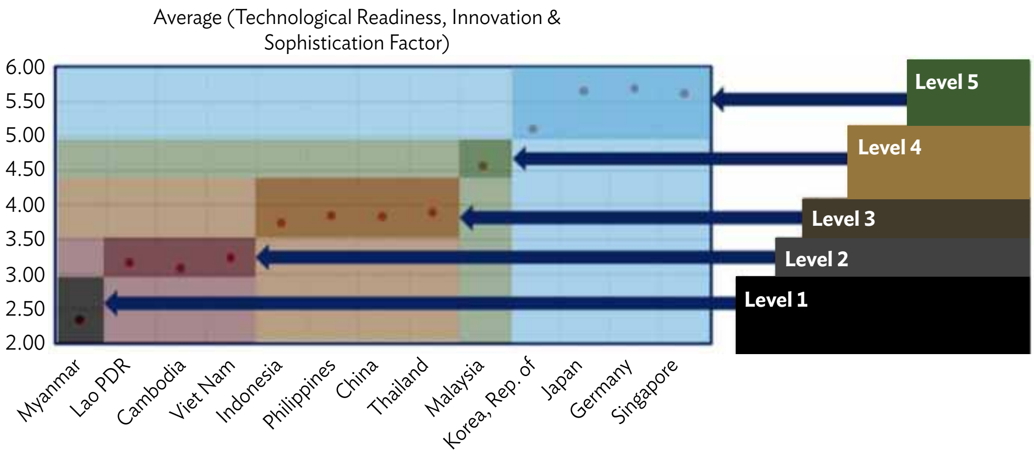
CLMV = Cambodia, Lao PDR, Myanmar, and Viet Nam, ICT = information and communications technology, Lao PDR = Lao People's Democratic Republic.

Source: Authors.

Narrowing down our analysis to Industry 4.0, which is more related to innovations and technology, Figure 11 ranks ASEAN's potential for Industry 4.0 in terms of its average technological readiness, and innovation and sophistication factors. The GCI for technological readiness measures the flexibility and potential of the nation to capitalise on the technologies to enhance the productivity of industries. This pillar gives special emphasis to the use of ICT to improve the performance and efficiency of the industrial system (Schwab and Sala-i-Martin, 2015). Similarly, the innovation and sophistication factors measure the business network of the country, the companies' operations and strategies, and the capacity to innovate. The innovative and sophistication factor signifies the research and development capacity, strategy, and policies of the economy that thrive on innovating new products and services to stay competitive in the market.

In Figure 11, Myanmar almost has no potential for Industry 4.0. Cambodia, Lao PDR, and Viet Nam also have the least potential. Singapore is highly competitive with other developed economies like Japan and Germany, and has the potential for Industry 4.0. Malaysia tends to have medium potential while Indonesia, the Philippines, and Thailand have low potential for Industry 4.0.

Figure 11. ASEAN Potential for Industry 4.0



ASEAN = Association of Southeast Asian Nations, Lao PDR = Lao People's Democratic Republic.
Source: Authors.

ASEAN countries need to progress swiftly to catch up with developed nations in terms of technology and innovation. The research and development sector should be strengthened with suitable policies and strategies.

5.3 Impact on ASEAN Economy

One of the competitive advantages of the ASEAN region lies in the existence of cheap labour force, which includes semi-skilled and unskilled workforce. Advanced nations, whose technologies need cheap labour, usually find the ASEAN region profitable for production of their goods. However, with the evolution of technology, Industry 4.0 is targeting to increase the labour productivity through massive exploitation of technology. It aims to eradicate the need for semi-skilled and unskilled workforce, which is otherwise the selling point of ASEAN countries. CLMV will be the most affected ASEAN countries as they tend to attract more multinationals and their economies are trending towards the industrial evolution.

As shown in Table 2, ASEAN nations excel in different sectors, most of which are labour intensive. Multinational companies that have the technology but need cheap labour can flourish in the politically stable ASEAN region, which is open to foreign direct investment. The footwear industry in Viet Nam plays a crucial role in its economy. Viet Nam exported footwear worth of US$12 billion in 2015 (Asia Pacific Leather Fair (APLF), 2016), which represented a significant portion of its total exports. Around

US$2 billion worth of goods reached the EU market in the same year. However, these industries exist in the ASEAN region because of cheap labour. Now, with the emerging possibility of mechanised production, the ASEAN market is in danger of losing its competitive advantage to the intelligent assets that do away with the need for labour.

Adidas, a German shoe manufacturing industry, manufactures its goods in Viet Nam using cheap labour. Adidas shut down its production in Germany 20 years ago due to high labour costs. However, with the evolution of robots and advancement in production technology, Germany is set to start a new shoe manufacturing factory back home since a robot-based production unit will produce shoes more quickly. Germany is further planning to set up more shoe factories in the US and Britain or France in the future. Resource efficiency, no doubt, can be better achieved with Industry 4.0 but at the cost of loss of jobs, which a developing economy like most economies in ASEAN is vulnerable to.

Germany is a pioneer of Industry 4.0 and has several policies that drive the revolution of Industry 4.0. Some of the strategies, policies, and projects for the evolution of Industry 4.0 are as shown in Table 5.

Table 5. German Policy Drivers of Industry 4.0

High-Tech Strategy 2020	Aimed at establishing Germany as the lead provider of scientific and technological solutions to issues in climate/energy, health/nutrition, mobility, security, and communication
Lead Market for CPS 2020	Under the national Industry 4.0 project, Germany targets to be the lead provider of CPS by 2020
Agenda CPS	Aimed at promoting R&D to shape technological revolution and to be the lead market and provider, in competition with other industrial and technological players
ICT 2020: Research for Innovations – IT Systems for INDUSTRIE 4.0	Fund research on ICT in complex systems (e.g. embedded systems), new business processes, and production methods as well as the internet of things and services.
Autonomics for INDUSTRIE 4.0	Contribute to the implementation of goals set out in the High-Tech Strategy 2020
RES-COM	Target automatised conservation of resources through application of highly interconnected and integrated sensor-actuator systems

CPS = cyber-physical systems, ICT = information and communications technology, R&D = research and development.
Source: Authors.

The EU further plans to increase its manufacturing from 15.4% to 20% by 2020. Under this scenario, the future of economies relying on labour-intensive production like the ASEAN region is unpredictable. The ASEAN region thus needs to promote micro, small, and medium enterprises (MSMEs) to move towards Industry 4.0 and to stay competitive with the large companies that have higher potential for Industry 4.0. The circular economy, which presents the innovative business model, and which has the potential for creating jobs based on resource circulation in the loop, could trade-off with the jobs lost due to Industry 4.0. However, detailed research and analysis, and a farsighted vision are needed for ASEAN.

6. Policies Supporting the Circular Economy in the ASEAN Region

6.1. ASEAN Policy: AEC Blueprint 2025

After the conclusion of the AEC Blueprint 2015, remarkable success was seen in economic growth in ASEAN. However, this growth did not consider environmental sustainability and the developments were achieved at the cost of resources and energy use. Linear approach to growth was observed and the principles of the circular economy were not adopted.

AEC Blueprint 2025 attempts to address the need for resource efficient technology, energy efficiency, and sustainability. The clauses that will impact both the circular economy and Industry 4.0 in the ASEAN region are as shown in Table 6.

Table 6. Strategic Measures Adopted in the AEC Blueprint 2025

Clause Number	Strategic Measures	CE	IE
B4: Productivity-driven growth, Innovation, Research & Development, and Technology Commercialisation	Strengthen the competitiveness of the MSME sector through the application of science and technology	•	•
	Support the development of highly mobile, intelligent, and creative human resources that thrive on knowledge creation and application	•	•
	Focus support on the development of research and technology parks; joint corporate, government and/or university research laboratories; research and development centres; and similar science and technology institutions and centres	•	•
	Share information sharing and promote networking to stimulate ideas and creativity at business-level	•	

Clause Number	Strategic Measures	CE	IE
B.8: Sustainable Economic Development	Foster policies supportive of renewable energy and set collective targets accordingly	•	
	Develop a framework to utilise low-carbon technologies with international support	•	
	Promote the use of biofuels for transportation: Free trade in biofuels within the region, and investment in research and development on third-generation biofuels	•	
	Promote good agriculture practices to minimise the negative effects on natural resources such as soil, forest, and water; and reduce GHG	•	
C.2: Information and Communications Technology	Innovation: Support ICT innovations and entrepreneurship as well as new technological developments such as smart city, and big data and analytics		•
	Human capital development: Strengthen the professional development of the ICT workforce in the region		•
	New media and content industry: Encourage the growth and use of e-services and new media in the region		•
C.4: Energy	Increase the component of renewable energy to a mutually agreed percentage by 2020	•	
	Reduce energy intensity in ASEAN by 20% as a medium-term target in 2020 and 30% as a long-term target in 2025, based on 2005 level	•	
C.5: Food, Agriculture, and Forestry	Enable sustainable production and equitable distribution	•	
	Increase resilience to climate change, natural disasters, and other shocks	•	
	Improve productivity, technology, and product quality to ensure product safety, quality, and compliance with global market standards	•	•
	Promote sustainable forest management	•	
	Develop and promote ASEAN as an organic food production base, including striving to achieve international standards	•	
C.8: Minerals	Promote environmentally and socially sustainable mineral development	•	
D.1: Strengthening the role of MSMEs	Promote productivity, technology, and innovation through measures to enhance MSME productivity by understanding key trends in productivity	•	•
	Build industry clusters through industrial linkages and promote technology	•	
	Build capabilities to foster industry clustering	•	
	Promote innovation as a key competitive advantage through technology use and application to business and business-academia linkages		•

ASEAN = Association of Southeast Asian Nations, AEC = ASEAN Economic Community, CE = circular economy, GHG = greenhouse gas, IE = Industry 4.0, MSME = micro, small, and medium-sized enterprises.

Source: Authors.

Table 6 presents the strategies (which can be linked to the circular economy and Industry 4.0) that ASEAN member countries will be adopting to ensure a sustainable economy until 2025, as published in the AEC Blueprint 2025. These strategies are aligned with the circular economy and Industry 4.0 and focus on technological advancement in MSMEs through science and technology and R&D, development of highly skilled human resources, increase in R&D, increase in the usage of renewable energy, low-carbon technology and biofuels, reduction in GHG emission through good agricultural practices, innovation in ICT, management of big data, elevation of e-service industries, improvement in resource productivity, development of ASEAN as the hub for organic farming, sustainable and environment-friendly mineral extraction, development of industrial clusters, and promotion of innovation for economic growth.

One of the highlights of AEC 2025 is the focus on the supporting role that ASEAN claims to provide for the technological advancement of MSMEs. The use of ICT, big data analysis, e-services, and advanced technology could push MSMEs closer to Industry 4.0. The development of industrial clusters and fostering of human resources and skills in this sector can also help ASEAN move towards the circular economy. Although these strategies fall under the periphery of the circular economy and Industry 4.0, the AEC Blueprint 2025 has not recognised the circular economy or Industry 4.0 as a whole.

6.2. National Policy

National policy and strategies play a crucial role in promoting the circular economy and Industry 4.0. However, ASEAN countries presently lack clear policies and strategies for the advancement of the circular economy and Industry 4.0. Some of the policies that ensure 3Rs and resource circulation in ASEAN are presented in Table 7. These policies could be the guiding principles for the development of individual national policies on the circular economy and Industry 4.0.

Table 7. Policy Development on the 3Rs and Resource Circulation in Asia

Country	3Rs and Resource Circulation Policy Development
Malaysia	**The 2007 Solid Waste and Public Cleaning Management Act (2007):** The responsibility for solid waste management was transferred from local governments to the central government. The 3R principles were introduced. Privatisation of waste management is encouraged.
	The Five-year Plan 2011–2015 calls for increasing the rate of resources recovery from household wastes, from 15% to 25% by 2015.
	The Eleventh Malaysia Plan 2016–2020 highlights the importance of pursuing 'Green Growth' for sustainability and resilience.
	The National SCP Blueprint 2016 to 2030 provides pathways for SCP to cover the circular economy.
	The Global Cleantech Innovation Programme of the Malaysian Industry-Government Group for High Technology, in collaboration with the United Nations Industrial Development Organization, is an annual competition and accelerator-based programme that aims to identify, fund, and nurture Malaysian start-ups in clean technologies.
Philippines	**The Ecological Solid Waste Management Act (2001)** introduced the 3R principle. All municipalities are required to achieve 25% diversion of solid waste (recycling and reduction) by 2006. Recycling rate in 2010 was 33%.
	The National Solid Waste Management Commission coordinates, at the national level, the ministries and other related parties in improving solid waste management (inaugurated in 2001).
	The National Framework Plan for the Informal Waste Sector in Solid Waste Management (2009) was established to support the formulation of a 3R national strategy. It is an action plan for improving the conditions of the informal sector engaged in solid waste management.
	The Philippine Developmental Plan 2011–2016 increased the waste diversion rate from 33% in 2010 to 50% in 2016.
Thailand	**The take-back programme for used products** started for containers and packaging, used lead-acid batteries, mobile phones, and batteries, in cooperation with the manufacturers and retailers. The take-back of fluorescent lamps is also in place, in cooperation with the Japan External Trade Organization.
	The initiation of a recycling-oriented society has been implemented in more than 200 communities through the 3Rs. In some communities, a 30%–50% or more reduction in waste generation was achieved.
	The Industries Waste Exchange Program registered over 450 firms by 2005.
	The National Economic and Social Development Plan 2017–2021 has policies like zero-waste society, green industry cluster, sustainable agriculture, promoting reusing and recycling, supporting factory owners to move forward with the green supply chain/green value chain.

Country	3Rs and Resource Circulation Policy Development
Lao PDR	**The 8th 5-year National Socio-Economic Development Plan 2016–2020 (waiting for approval from the National Assembly)** includes: • green and clean city development; and • green and sustainable urban development through waste reduction and integrated waste water refreshment system.
	Vision 2030, 10-Year Strategy 2016–2025, and 5-Year Work Plan of Natural Resources and Environment Sector provide for the: • participation in green growth to achieve sustainable development; • support of green productivity, and reduction of natural resources consumption in the industrial and tourism sectors, and households; and • reduction of impacts on environment from development and investment activities (e.g. reduction of CO_2 emission from transportation sector, and the like).
Viet Nam	**3R-related laws and policies:** Under the 2005 Law on Environmental Protection, 14 decisions were taken in relation to 3R and solid waste management. Decree No. 57 on integrated solid waste management in 2007; and Decision No. 1440 on planning/construction of solid waste management facilities in three central economic regions until 2020 in 2008.
	The 3R National Strategy (approved by the prime minister) targets 30% recycling of collected waste; 30% separation-at-source rate for households, and 70% for firms for 2020.
	The National Strategy on Cleaner Production in Industry Toward 2020.
	National Programmes on Sustainable Consumption and Production (NPSCP) for the period 2011–2020, with Vision 2030.
Cambodia	**The Green Growth Roadmap**, endorsed in 2009, outlines a framework for environmentally sustainable and socially inclusive development and growth in Cambodia. The master plan is currently being developed.
Singapore	**The 3R Guidebook for Hotels**, prepared by the National Environment Agency and the Singapore Hotel Association, offers a step-by-step and practical guide on planning and implementing 3R programmes.
	The 3R Guidebook for Shopping Malls, prepared by the National Environment Agency, offers guidelines to help shopping malls improve their current waste management practices, and identify opportunities for 3R. These guidelines focus on minimising the need for disposal of waste by shopping malls.
	The Sustainable Singapore Blueprint 2015 has strategies for smart city, 3R, energy, and water-efficient household appliances. It has clearly mentioned the need to use 3R on resources due to limited landfill spaces.
Indonesia	**The Waste Management Law No. 18/ 2008** focuses on waste reduction, recycling, reuse, and treatment as resources, extended producer responsibility, etc. The country has a weak policy for 3R and resource circulation.
Myanmar	Relevant rules and regulations are yet to be framed (UNCRD, 2013).
Brunei Darussalam	Recycling in Brunei Darussalam is still in the infancy stage and the country faces many challenges (UNCRD, 2013). It lacks proper institutional policies for 3R. The hazardous oil and gas industrial materials are mostly exported to the United Kingdom and Germany.

3R = reuse, reduce, and recycle, Lao PDR = Lao People's Democratic Republic, SCP = sustainable consumption and production

Source: Adapted from Hotta.

7. Conclusion

While companies are key to fostering the shift to a circular economy, governments also play an important role. To successfully tackle a systemic reshaping of the production and consumption model that has dominated the past two centuries, a tight alignment of supply, demand, and policy is required. This means that governments must use their powers to shape market conditions at the national and even at the global level to create the right conditions for change. This also means adopting the circular economy in their own substantial organisations and supply chains through areas like public procurement.

The ASEAN industrial sector believes that it is only through greater government intervention at global, national, and local levels that they can sustainably move from sporadic, incremental advances to collective and transformative impacts. They also want clear policies and regulations that can provide long-term investment stability to accelerate the pace of change and greater investment. They are calling for active intervention by governments and policymakers, in collaboration with business, to align public policy with sustainability at global, national, and local levels.

The governments of ASEAN member countries, irrespective of their developmental stage and industrial structure, have a role in not only providing supporting measures for the circular economy but also in improving the acquisition and application of knowledge on the circular economy. The AEC and the ASEAN Socio-Cultural Community can play vital role in knowledge networking through various measures such as raising awareness on the benefits of the circular economy, exchanging knowledge and networking, providing support and appropriate incentive schemes for collaboration across the ministries, fostering network supporters, and bringing together actors. Regional knowledge institutes like the Economic Research Institute for ASEAN and East Asia and the Asian Institute of Technology can act as facilitators and moderators of networking and knowledge exchange.

To accelerate the concept of the circular economy within ASEAN countries, policymakers must design and implement policies that are conducive to innovation and drive dynamic growth. Some governments are taking preliminary steps to that end. For instance, the Singapore Packaging Agreement, a joint initiative between the government, the private sector, and non-governmental organisations to reduce packaging waste from consumer products and the supply chain, has saved US$20 million over five years on locally consumed products. To promote the circular economy concept, greater focus should be oriented towards manufacturing sectors where competitiveness can be easily seen. In CLMV, national governments should prioritise capacity-building activities that are linked to increasing the technical competence of the labour force, especially in the service sector. The respective governments can also play an active role in the strategic clustering of industries in certain regions. Innovative eco-industrial clusters, which have been viewed as engines of regional growth, are networks of independent firms, local universities, and community actors. The governments can create favourable conditions for innovative clustering and linking them to value-adding production chains. By introducing incentives at the local level in the form of social community funds, providing strategic information on circular economy targets, and sponsoring industry–community–university partnership, the governments can help operationalise the circular economy at the local level.

The EU has been the world's leader in regulatory innovation to promote sustainable growth. The European Resource Efficiency Platform provides policy recommendations and actions to help member states move to a circular economy and, in the process, reduce the total material requirements of its economy by 17%–24%, thus boosting the GDP and creating between 1.4 and 2.8 million jobs (European Commission, 2014). In the US, for example, the circular economy is supported by the 'bio-preferred' public procurement programme, which aims to increase the development, purchase, and use of bio-based products, through the procurement preference of federal agencies and their contractors, and voluntary product certification and labelling for consumers. These are valuable examples that ASEAN leaders could consider either on a regional or country basis.

Governments in general still need to make greater and more rapid progress in creating a policy environment that nurtures circular business models. Policies like shifting taxation from labour to resources, setting specific recycling targets for industries, making companies responsible for products throughout their life cycle, implementing tax premiums for the use of regenerated resources, and creating an international standard definition of wastes, and the like are needed to make circular thinking the de facto way of doing business in the future. Governments can serve as catalysts for circular economy innovation and as role models in adopting circular business models, reducing their own reliance on natural resources in the materials they purchase.

During the next decade and beyond, industrial production will be increasingly disaggregated and codified through the internet of things. Since the internet and communication technologies can overcome constraints of time and distance, the creation of virtual organisations, networks of lead firms, and independent institutions is warranted to facilitate the sharing of information and good practices for integration into the circular economy. Through intensive communications and interactions, a virtual organisation at ASEAN level can increase the ability to transfer strategic know-how and competence within and across networks, supporting the circular economy.

In this era of global competition, regional economic integration, and local environmental considerations, the determinants of success of economies depend upon the harnessing of the full potentials of national innovation systems. To improve innovative capacity and competitiveness, ASEAN should focus its industrial, environmental, and research policies on the importance of the strategic integration of circular economy and Industry 4.0. The current knowledge networking in ASEAN often takes place spontaneously in the market, without significant government support. Thus, there is a need for shift towards direct support through public–private partnerships to achieve the targets of circular economy.

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Chapter 4

The Evolution of Industry 4.0 and its Impact on the Knowledge Base for the Circular Economy

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1. Introduction

For decades, growth in wealth and well-being, especially in Europe, has been based on the increasing and unsustainable use of resources (Bringezu and Bleischwitz, 2009; EC, 2011). To address scarcities of supply and sustainability challenges, more efficient methods of turning waste into secondary resources are required. Such methods should avoid the common 'downcycling' of materials, in which the quality of the material is reduced with each cycle (Velis and Brunner, 2013).

Overcoming these unsustainable patterns of consumption and production will, among other things, require a radical transition of waste management towards an integrated element of the circular economy. For a long time, such concepts of keeping materials in closed circuits have been seen in local and national contexts only. Historically, waste policy has been considered as a responsibility of local governments or councils. Accordingly, the regulative framework that has emerged aims at preventing environmental burdens on-site (Kranert and Cord-Landwehr, 2010).

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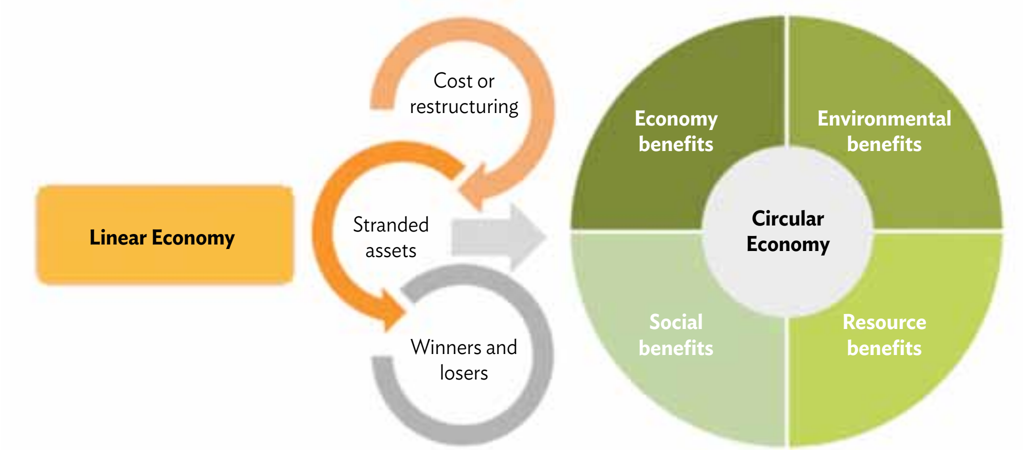
The concept of circular economy has recently gained attraction in European policymaking as a positive and solutions-based perspective for achieving economic development amid increasing environmental constraints (EEA, 2016; EASAC, 2015). The term is often very differently interpreted by the European Commission as an economy 'where the value of products, materials, and resources is maintained in the economy for as long as possible, and the generation of waste is minimised' (EC, 2015: 2). It is viewed as an essential contribution to the efforts of the European Union (EU) to develop a sustainable, low-carbon, resource-efficient, and, from an economic point of view, competitive economy. Figure 1 also shows the transition towards the circular economy concept applied in the EU. This is reflected, for example, in Europe's 7th Environment Action Programme, which identifies the need for a framework that gives appropriate signals to producers and consumers to promote resource efficiency and the circular economy. It is also increasingly seen as a business opportunity, for example, through the efforts of the Ellen MacArthur Foundation. Moreover, European countries increasingly indicate the circular economy as a political priority. In December 2015, the European Commission published its new strategy, 'Closing the loop – An EU action plan for the circular economy', which aims to support the transition to a circular economy in the EU (Wilts, 2016). The action plan sets out several initiatives that address all stages of the life cycle, combined with concrete targets on waste and the development of a monitoring framework.

Figure 1. The Transition Towards a Circular Economy



Source: European Environment Agency, 2016.

The current knowledge base, however, is rather fragmented. An improved 'transformative literacy' (Schneidewind, 2013) is needed, especially in terms of better insight into various aspects of system dynamics, such as production structures and functions, consumption dynamics, finance and fiscal mechanisms, and trigger pathways for technological and social innovations. This links to another new and dynamic policy field, the emergence of Industry 4.0, which is the comprehensive transformation of the whole sphere of industrial production through merging digital technology and the internet with conventional industry (European Parliament, 2015). In 2012, in response to this decline in the relative importance of industry, the European Commission set a target that manufacturing should represent 20% of the total value added in the EU by 2020. While some observers find this goal overly ambitious, many believe that we are on the brink of a new industrial revolution – Industry 4.0 – which could boost the productivity and value added of European industries and stimulate economic growth.

This paper aims to analyse a few of the synergies and challenges that might occur at the interface of these radical innovation pathways, especially regarding the availability and provision of data, information, and knowledge as crucial aspects in both concepts. Given this, the paper asks how the emergence and evolution of the Industry 4.0 concept transforms the waste management sector, influences the transition towards a circular economy, and creates synergies with sustainable resource management. The evolution and key elements of Industry 4.0 are outlined in Section 2. Section 3 discusses the role of information that would be required to transform traditional waste management into a circular economy and thus develop the analytical framework for this paper. Section 4 analyses existing case studies on how Industry 4.0 might contribute. The final section draws conclusions regarding the further need for research and policy formulation.

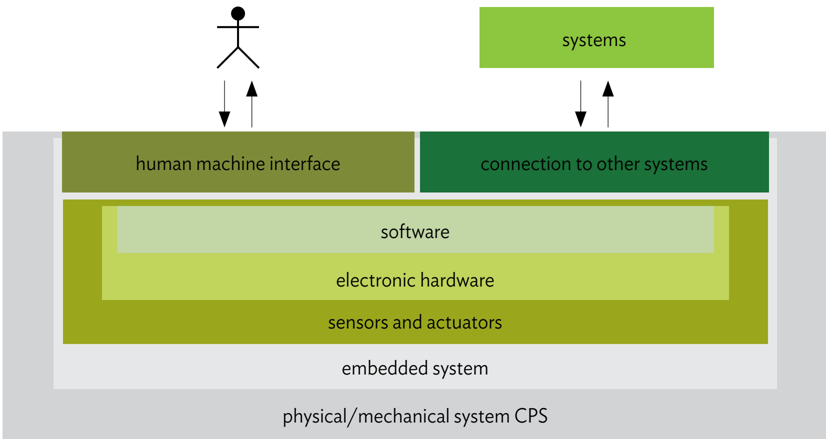
2. Evolution of the Industry 4.0 Concept

To understand the concept of Industry 4.0, it is helpful to analyse the evolution of previous industrial revolutions. All of them were triggered by technical innovations, such as the introduction of water- and steam-powered mechanical manufacturing at the end of the 18th century, the division of labour at the beginning of the 20th century, and the introduction of programmable logic controllers for automation purposes in manufacturing in the 1970s. According to Brettel et al. (2014), the upcoming industrial revolution will be triggered by the internet, which allows communication between humans and machines in large networks (Figure 2).

Alongside technological innovation, the organisational structure of industrial production has undergone several major shifts in the past to face the changing markets. Industrial production started with the transformation from craft production to mass production, with strict division of labour and standardisation. On a seller market with production as the major bottleneck, the organisational structure was focused on increasing outputs and productivity, disregarding variations in customer needs. As market saturation increased, markets transformed into buyers' markets and forced manufacturing companies towards product differentiation. To raise effectiveness at growing product varieties, lean production has become very popular as it allows eliminating waste along the value chain. The internet has been identified as a powerful instrument to manage distributed systems.

In future manufacturing, factories will have to cope with the need for rapid product development, flexible production, as well as complex environments. Within the factory of the future, also considered as a smart factory, new integrated systems will enable the communication between humans, machines, and products. As they can acquire and process data, they can self-control certain tasks and interact with humans via interfaces. In a smart manufacturing environment, intelligent and customised products comprise knowledge of their manufacturing process and consumer application, and independently lead their way through the supply chain. The resolution of the automation pyramid towards self-controlling systems leads to an extreme amount of data, which can be extracted, visualised, and used for end-to-end engineering. Individualised production, horizontal integration in collaborative networks, and end-to-end digital integration are key aspects of this transformative process that will radically change cyber-physical systems.

Figure 2. Interaction Between Humans and Machines via Cyber-Physical Systems



CPS = cyber-physical systems.
Source: Brettel et al., 2014.

According to an extensive survey conducted by the Laboratory for Machine Tools and Production Engineering in Aachen, over 90% of managers from the German manufacturing industry have high interest in resolving the dilemma between scale and scope (Brettel et al., 2014). The establishment of product families is seen to be the primary means to incorporate flexibility into mass production as product design and development usually represent only 5%–10% but determines more that 80% of the costs of a product. Hence, the desired flexibility of a product family must be determined at a very early stage. However, as the benefit of flexibility is difficult to quantify, it is generally not included in a classical investment analysis of new machinery. The lack of powerful information technology systems and their integration with each other, inadequate employee knowledge of production processes, and lack of change efforts within the company are key deficits that could be addressed and overcome by Industry 4.0 concepts. In the context of rapid manufacturing, industry experts see not only great potentials but also considerable obstacles to replace conventional production technologies.

In the future, new forms of cooperation will allow businesses to flexibly allocate production capacity within a value chain. To do so, information needs to be accessible throughout collaborative networks, which has a lot of potential for conflicts. Companies usually refuse to disclose information about their production processes and cost structures to their partners to maintain a strong bargaining position. However, 45% of all German manufacturing enterprises adjust their capacity through outsourcing of jobs (Stich, Kompa, and Meier, 2011).

To overcome trust issues, dominant market forces like major original equipment manufacturers from the automotive industry need to structure entire value chains and urge suppliers to share information. An illustrative example is the electronic devices sector with a highly global supply chain where information about the specific raw material content is not passed on because it could allow competitors to draw conclusions on production and cost structures. But unless one party sees a direct benefit, exchange of information often fails due to a lack of willingness to bear costs, which others benefit from. The following section will illustrate this conceptual challenge using the example of the aspired transition towards a circular economy.

3. Information Requirements for the Circular Economy

The starting point for our consideration is the hypothesis that the lacking recovery of raw materials contained in end-of-life products in global material cycles is driven by knowledge problems and transaction costs (OECD, 2006; Wilts, 2016). On the one hand, recycling markets have failed to work properly because of asymmetrical distribution of information between recyclers and industry purchasing secondary raw materials, which has been impairing efficient agreements, e.g. plastic recycling rates are below economically optimal levels because it would be costly for buyers to confirm the quality of the product as stated by the seller, and even the smallest contamination could significantly lower the value of the material for the recycling process. On the other hand, governments also lack sufficient information that would be needed to correct the existing market failure in an optimal way through direct regulation.

Neither governments nor enterprises have the knowledge required to initiate and implement long-term changes towards sustainability. Thus, it is necessary to develop joint mechanisms, considering strategic interests and options for action (Bleischwitz, 2004; de Bruijn and Tukker, 2002; Grin, Rotmans, and Schot, 2010). Such integrated approaches for an 'industrial transformation go beyond the notion of eco-efficiency and beyond the domain of individual actors. It is about system innovation, both technological and institutional' (de Bruijn and Tukker, 2002: 8).

3.1. Conceptual Interlinkages Between Waste and Information Flows

On a conceptual level, the classification of specific products or materials as 'waste' is highly dependent on the availability of reliable information. Due to uncertainties regarding the quality of specific material flows, economic actors, based on their personal risk perception, can consider them as waste. Based on the analysis of international recycling markets, Johnstone and de Tilly have drawn conclusions on market inefficiencies that negatively influence recycling levels (OECD, 2006). Beyond traditional market failures like externalisation of environmental costs, information availability seems to play a crucial role. In contrast to primary resources, the quality of secondary resources is much more difficult, time-consuming, and costly to assess. Minimal contaminations can significantly change the value of metal scrap if it is no longer suitable for a recycling process, or it might even turn into hazardous waste.

In reality, waste management information on the material composition of products is almost non-existent or it gets lost alongside the recycling chain (Reuter et al., 2013).

Even if information regarding the quality of waste flows exists, it is asymmetrically distributed. Akerlof described how lack of information on end-of-life vehicles leads to a decreasing price level for such discarded products due to an adverse selection of market participants, which might eventually lead to a breakdown of the business model due to too high transaction costs for the confirmation of information (Akerlof, 1970).

It is striking that commercial waste streams lose a significant share of their value the moment they leave the company just because the available information become less reliable. Today, knowledge on waste quality and material composition of waste streams is mainly tacit, often bound to specific persons, and often not publicly available because it could allow competitors to gain insights into production technologies. This obviously leads to massive obstacles for closing material loops, e.g. the so-called industrial symbiosis concepts. The economic relevance of such transaction costs can be assessed based on price differences. Taking the example of plastic waste, it was shown that based on the availability of information, diverging price levels of up to a factor 10 have been reported (OECD, 2006). Thus, overcoming knowledge deficits becomes an independent regulatory objective – not as a sufficient but as a necessary precondition to improve market efficiency. Against this background, the Industry 4.0 concept of integrating information flows could be the cornerstone of a future circular economy that would contribute to innovation and competitiveness. Overcoming information-based market failures could increase the optimal level of material recycling, lead to additional investments into high-quality recycling technologies as well as research and development, and consequently support innovation capacities in this sector.

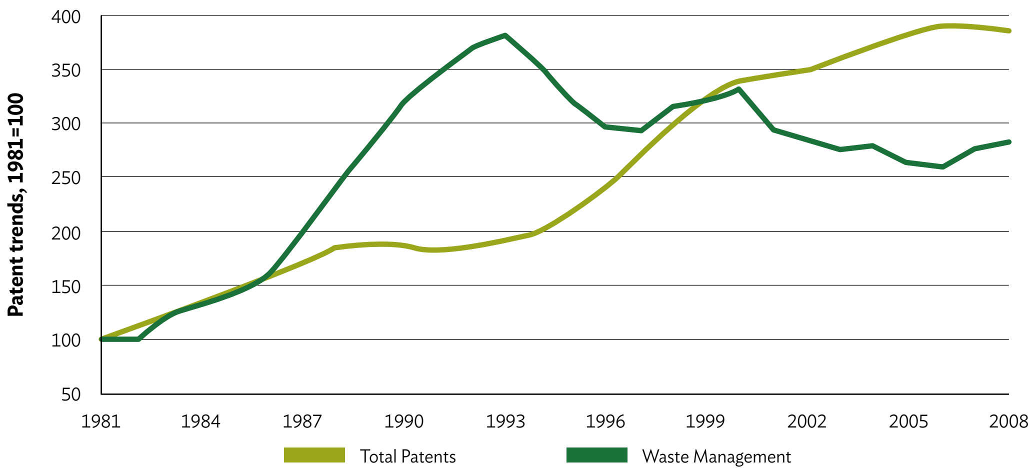
3.2. Reality of Waste Management

The necessity of such innovative concepts is highlighted by the reality of waste management in Europe. In contrast to the expressed political intention to transform Europe into a 'recycling society', the reality still shows a different picture. In 2011, total waste production in the EU amounted to about 2.5 billion tonnes. During the last 2 decades, solid waste streams have been massively diverted from landfill towards recycling and recovery. However, only 40% of waste generated in the EU had been recycled. The rest had been sent to landfills (37%) or incinerated (23%). About 500 million tonnes of materials could have been recycled or reused in the EU. The failure to recycle materials represents an environmental and possibly an economic loss (EC, 2015).

Innovation patterns in this sector have been analysed as part of a European research project on 'Environmental Macro Indicators for Innovation' coordinated by the

Wuppertal Institute, Climate and Energy. The outcomes highlight the importance of the integration of the circular economy and Industry 4.0. Extensive patent analysis in EU25 countries shows a clear decrease in waste-related innovations (see Figure 3). Innovation peaked in the 1990s when several new waste policies had been introduced. Similar policy-driven innovation patterns can be observed in the waste sector in Europe and worldwide. Due to increased level of data availability, improved quality of data, and reduced transaction costs for quality assessments, Industry 4.0 could be an important enabler to revive research and development in this sector, leading to a higher level of relevant eco-innovations for a circular economy.

Figure 3. Number of Patent Application Fields at the EPO by EU25 Countries Total Patents and Waste Patents, 3-year Moving Average (1981 = 100)



EPO = European Patent Office, EU = European Union.
Source: Wilts et al., 2015.

4. Industry 4.0 as an Enabler of a Circular Economy

The transition to a circular economy requires fundamental changes in many different areas of the current socio-economic system. Although it is a complex process that is difficult to predict, several crucial areas of change can be identified in technical, economic, and social domains, with a focus on the enabling factors that guide and accelerate the transition process. Industry 4.0 and the application of information and communications technology to digitise information and integrate systems at all stages of product creation and use (including logistics and supply), both inside companies and across company boundaries, can be considered as a key enabler for this development. Obviously, different factors need to act simultaneously to create reinforcing effects, and they all require the support of adequate policy frameworks and interventions (Wilts, 2016). The following section will give some concrete examples on how these elements will have to interact.

4.1. Industry 4.0-Based Business Models

One of the most powerful enablers of the circular economy are business model innovations based on web-based applications. Business models that successfully incorporate circular economy principles have a direct and lasting effect on the economic system. Most of these models relate to the functions of a product instead of its physical ownership (Ölundh and Ritzén, 2001; Mont, 2002). The following types can be distinguished: product-oriented services, which are centred on product sales, including additional services such as maintenance and take-back agreements; user-oriented services, which are based on product leases, rentals, sharing, and pooling; and result-oriented services, which provide specific outcomes, such as the creation of a pleasant climate in offices (Tukker and Tischner, 2006).

From an economic perspective, these models can improve customer loyalty, increase market share through product differentiation, scale up the value of used products leading to reduced costs, and bring new technologies to the market (Baines et al., 2007; EMF, 2013). In addition, service-based business models provide transparency for customers about the costs of the whole use phase, whereas uncertainties exist about costs of maintenance, repair, and replacement in purchase-based models. Nevertheless, these models may trigger negative economic and social impacts on traditional value chains, as they reduce the need for new materials and products. Environmental benefits can be observed in terms of reducing resource use and environmental impacts through the substitution of products with services. However, rebound effects, such as increased demand for a service because it costs less than ownership, could arise. Without the adaptation of policy frameworks, many innovative business models will not be able to compete with existing linear ones, or they might lose some or all their benefits when scaling up.

Another option with a clear role for solutions based on information and communications technology within Industry 4.0 is collaborative consumption, which is based on sharing, swapping, bartering, trading, or leasing products and other assets such as land or time (Botsman and Rogers, 2010). While such peer-to-peer interactions have long been practised on a local scale, they have developed into a different dimension through online sharing marketplaces where the demand for certain assets, products, or services is matched with their supply, usually through consumer-to-consumer channels.

Some involve fees for individual transactions while others are only open to registered fee-paying members, and some, typically smaller and often local schemes, are cost-free for users. One example is the hugely successful Airbnb model, which allows people to rent rooms and apartments. A 2014 global online survey showed that 54% of European respondents were willing to share or rent out their possessions for money, while 44% were happy to rent goods and services from others (Nielsen, 2014). This suggests that this model has considerable potential.

Positive economic effects include consumer access to a broader selection of products and services without incurring the liabilities and risks associated with ownership. While outcomes for citizens are generally positive, traditional businesses could experience losses in the form of lower sales, while governments might have to re-examine fiscal rules to guard against diminishing tax revenues.

Environmental benefits include a decrease in the use of natural resources, energy, and emissions throughout production and consumption cycles based on longer or more intensive use of existing products. Annual economic benefits of increased reuse have been estimated at about €360 billion for Europe alone (EMF/McKinsey, 2015). This, however, might trigger negative environmental impacts by promoting the longer use of inefficient appliances, or an increase in mobility (Leismann et al., 2013) through, for example, car sharing or low-price access to holiday accommodation.

Social effects can be measured through enhanced social interaction and cohesion as well as job creation. While the net effect on the creation of new jobs is unknown, companies organising collaborative consumption stimulate micro-entrepreneurship among the public (Dervojeda et al., 2013). The rapid growth of some internet-based consumer-to-consumer platforms has sparked discussion about fair competition, safety, risk allocation, and workers' rights, triggering the creation of specific legislative frameworks. Issues of concern that might require regulation when collaborative consumption is scaled up include taxation, property rights, avoiding the creation of informal sectors in the economy, and insurance.

Uptake of collaborative consumption is also influenced by cultural factors (e.g. historic experiences of forced collectivisation) and increased personal wealth (more assets to share), although interest in sharing might, for economic reasons, be higher in less well-off regions of Europe. Overall, the effects of collaborative consumption business models depend on the exact set-up of the model, including whether they are oriented towards profit or non-profit.

4.2. Industry 4.0 as an Enabler of an Actual Circular Economy

Despite the current emphasis on recycling, the concept has limits and is just a means to achieve higher level targets; it is not a goal in itself (Velis and Brunner, 2013). The main benefit of recycling is environmental protection, decreasing the need to mine and produce virgin materials, and reducing energy requirements and large-scale emissions. Against this background, there is an urgent need to measure recycling on a more sustainable basis. The integration of value chains and material flows with Industry 4.0 provides the option to measure progress towards a circular economy.

A recycling metric must be based on clear definitions of inputs and outputs, considering the time axis and material stocks along this time axis. Furthermore, the different qualities and constituents of materials must be considered. Plastics and metals are composed of numerous additives and alloying metals. When recycling targets are defined, these mixtures require individual attention to yield optimum and balanced economic, environmental, and resource solutions. The recent United Nations Environment Programme International Resource Panel Report on metal recycling has taken a similar perspective by pointing out the limits of a material-centric approach that worked in the past for base metals but increasingly fails for complex products, production processes, and value chains. The report says: 'However, thanks to the increasingly sustainability enabling technological advancement of the 21st century, products have become increasingly complex, mixing almost any imaginable metal or other material. Recycling these products became increasingly difficult as trying to recover one material would often destroy or scatter another, and it became clear that we needed a product-centric approach' (Reuter et al., 2013: 23). Embedded system production technologies and smart production processes, as part of Industry 4.0, will pave the way to a new technological age, which will radically transform industry and production value chains and enable completely new options to maintain the embedded value of materials and components in products – inter alia by remanufacturing, high-quality recycling, or dematerialisation (GTAI, 2015).

4.3. Experiences with Industry 4.0 in the Circular Economy

Despite the practical and conceptual challenges outlined above, several innovative entrepreneurs and pioneers have initiated start-ups and business models that aim to link Industry 4.0 and the circular economy. The examples presented below – waste electrical and electronic equipment (WEEE), construction and demolition waste, and household waste – are three of the fastest growing waste streams.

4.3.1. Radio frequency identification in WEEE

Despite the increased political focus on WEEE, the recovery, especially of critical raw materials, is still surprisingly low (EC, 2015). Major inefficiencies in the collection and treatment of WEEE stem from product-specific information gaps, leading to inadequate recovery or recycling of valuable materials. Radio frequency identification is an auto-identification system that could enhance potential benefits due to higher recovery rates for resource intensive materials in the current waste management system. Within the framework of smart product labelling, specific WEEE and their components are marked with transponders and individual identification numbers. This allows a product's identification throughout the entire life cycle without necessarily touching or seeing it. By being connected to a database, further information about material compositions, whether they are toxic or hazardous, and components are made available. The implementation of this technology allows a transparent identification of heterogeneous waste streams like WEEE by enabling adequate process optimisation of treatment, making it more flexible and product-specific. It also offers producer-specific cost analysis that sets incentives for a better product design (Löhle, 2013). The radio frequency identification technology therefore contributes to a more circular economy by offering the following potentials (Löhle and Urban, 2011):

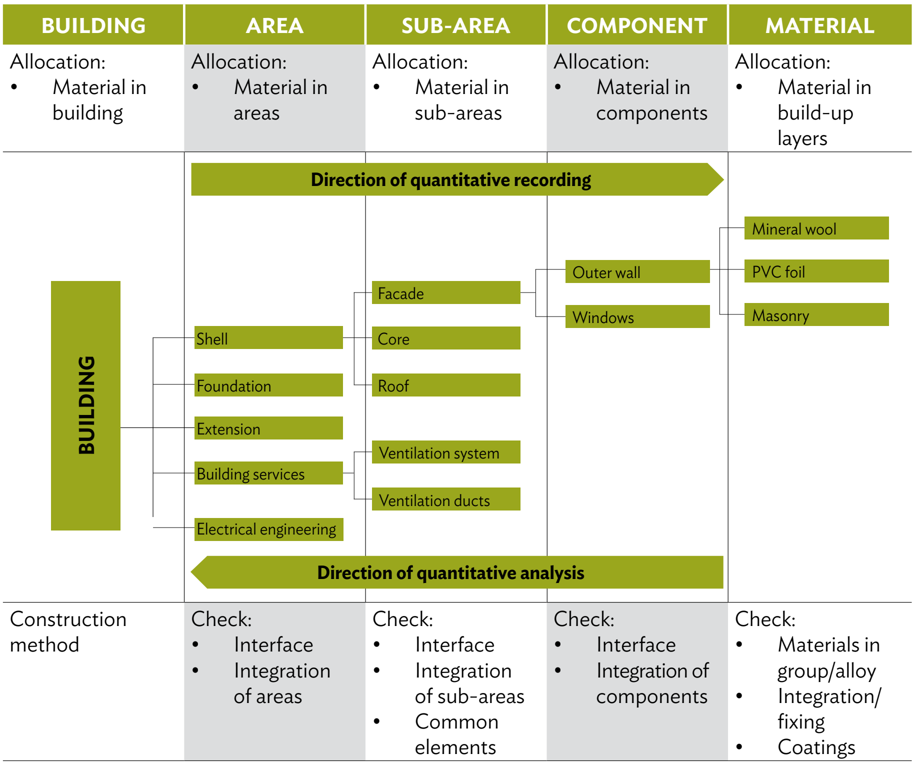
- categorisation of end-of-life products regarding materials, toxic components, environmental risks, or recyclable materials;
- provision of information about age, type, and requirements for reuse;
- provision of information about economically feasible dismantling or recycling strategies;
- provision of information about waste characteristics regarding treatment;
- provision of information and visualisation of dismantling instructions;
- data collection for material quantities and accounting; and
- support for deposit and leasing systems.

4.3.2. Building pass

A second potential field of application of Industry 4.0 solutions could be 'urban mining', the increased use of secondary raw materials, especially from buildings and infrastructures. Due to high uncertainties about future generation and demand, and especially information-related transaction costs for raw material contents and qualities, the construction and demolition waste sector is mainly characterised by down-cycling processes. Several actors, especially in Austria and Belgium, aim to address this issue by web-based 'building passes', an information system about the material characteristics of a building, containing necessary information about optimum low-waste management of building materials throughout the whole life cycle. It should document building activities, used materials, and technical equipment, e.g. heating, water, or electricity systems; and recommended maintenance measures. It is also a basis for the ecological evaluation of the building and provides an optimisation of deconstruction at the end of its life.

A building pass can help inform new building owners about the distribution of (hazardous) components within the building, facilitate detection of hazardous materials, simplify the planning of demolition, and create the preconditions for an efficient deconstruction process with high recovery and recycling rates. Furthermore, it provides a base for careful election of eco-friendly, recyclable building materials. Therefore, a building pass is especially valuable for demolition companies. Regarding the waste stream of construction and demolition, a building pass could increase the recycling rate for construction waste, improve the recycling quality, extend the useful life of a building, and substantially reduce waste generation of non-metallic minerals and metals (Reisinger et al., 2014). Web-based cadastres offer the possibility of identifying, quantifying, evaluating, and visualising relevant anthropogenic deposits with urban mining potential.

Figure 4. Example of a Building Pass



PVC = polyvinyl chloride.

Source: Adapted from Markova et al., 2010.

As can be seen in Figure 4, a building pass encompasses all building levels from the broader area to the individual materials. The aim is not to assess buildings or materials, but to receive qualitative and quantitative information about materials in any building. The focus therefore is on the location in the building, potential interfaces, material type, and how it is connected to other components (glued, screwed, and the like). The main parameters include structural elements (areas, sub-areas, components, and materials) and their relevant interactions that are crucial for recording, assigning, and evaluating information. Documentation is divided into two phases: quantitative recording, which is top-down; and quantitative analysis, which is bottom-up (Markova et al., 2010).

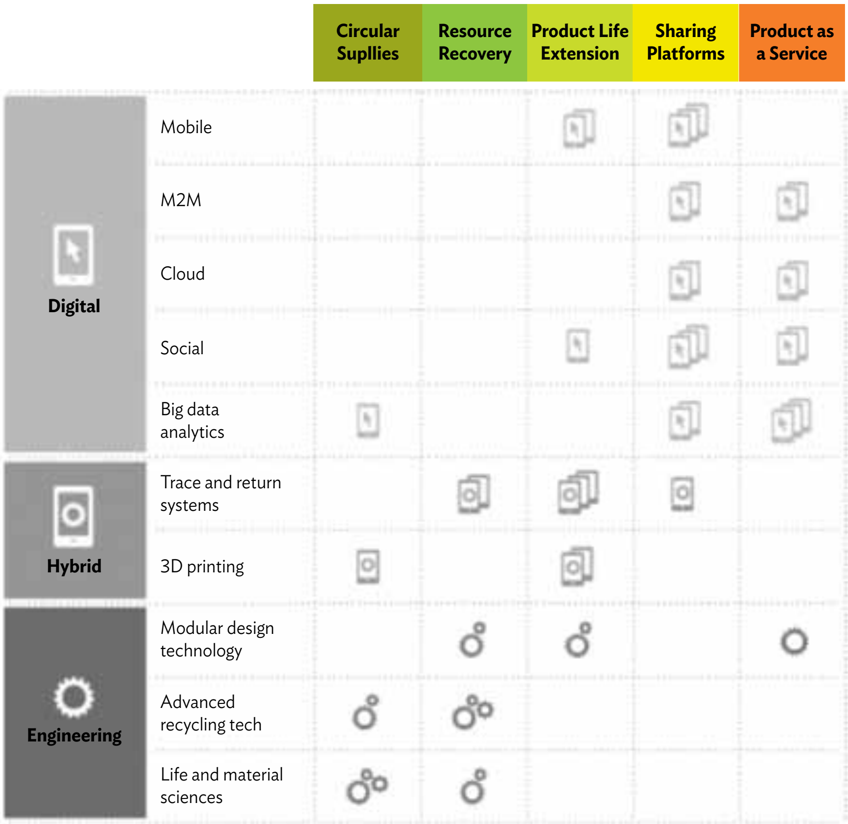
4.3.3. Rubicon Global: cloud-based waste management

A key driver for Industry 4.0 will be the emergence of lucrative business models. One example is Rubicon Global in the United States, a provider of a cloud-based waste management platform. On this platform, customers can manage and track waste and recycling metrics to monitor the progress towards environmental sustainability. The company does not provide treatment services itself but offers haulers the opportunity to connect their businesses on a national scale. First, companies sign up with the network, which enables haulers to compete for the business. Rubicon informs the winning bidder, who then provides the fleet for waste pickup. Through the global positioning system tracking within Rubicon's application, the waste's route is tracked from pickup to final drop-off where waste is processed into recycled materials, which are then sold on the cloud-powered auction site. The application also automatically organises all payments between haulers, customers, processors, and buyers. According to Rubicon, this system should help save costs, keep waste from being sent to landfills, and achieve sustainability goals within corporations (Rubicon, 2018). Five years after receiving US$5 million seed funding, the company is now estimated to be worth about US$1 billion.

4.4. Industry 4.0 Models for the Circular Economy

New business models offer companies powerful options for embracing the circular economy. Almost all of them would not be possible without the support of innovative new technologies, especially Industry 4.0-based digital ones such as social, mobile, analytics, cloud, and machine-to-machine technologies (e.g. the wirelessly connected internet of things, not just people). Designing value chains to embed circular business models all the way through to the customer's use and return is a major new frontier for the digital world, which revolutionises levels of service and flexibility as the physical and digital worlds merge and products start to flow between users, markets, and life cycles at very low transaction costs. Figure 5 identifies 10 disruptive technologies commonly used by the leading circular economy companies. These technologies fall into three categories: digital (information technology), engineering (physical technology), and a hybrid of the two.

Figure 5. Disruptive Technologies Used by Pioneers to Launch and Operate Circular Business Models with Speed and Scale



3D = three-dimensional, M2M = machine-to-machine.

Source: de Boer, 2015.

5. Conclusion and Outlook

The three examples highlight the market and eco-innovation potentials that could be generated by Industry 4.0 applications in the waste sector, especially in an integrated circular economy. They underline the issue of information requirements that can be the main entry point for web-based solutions if they manage to link. So far, the production and consumption phases are completely disconnected with the end-of-life phase of materials and products. This issue can be of specific importance for the ASEAN countries that face steeply increasing levels of waste generation and a direct link between economic development and the amount of wasted resources.

Forward-looking governments and business organisations are increasingly analysing policy options and their potential impacts, aiming to create favourable conditions for a circular economy (De Groene Zaak, 2015; EMF, 2015). At the EU level, the European Commission's recent circular economy package (EC, 2015) and the European innovation partnership on raw materials (EC, 2012) both aim to enable circular economy approaches, while the EU's Horizon 2020 research and innovation programme is set to invest around €941 million throughout 2018–2020 into the EU industry, with the aim of supporting circular economy approaches (EC, 2017). At the same time, several EU member states sponsor Industry 4.0-related initiatives, including Germany, Italy, France, and the United Kingdom, which represent the largest industrial sectors by value added in the EU. Since 2010, the German government has contributed €200 million to the 'Industrie 4.0' initiative (one of the 10 projects in the German High-Tech Strategy 2020 Action Plan) to encourage the development of smart factories (European Parliament, 2015). Unfortunately, these initiatives are rather decoupled from attempts to support the transition towards a circular economy. Against this background, the Economic Research Institute for ASEAN and East Asia initiative to look for potential synergies and trade-offs between Industry 4.0 and the circular economy is of special importance, especially regarding the alignment of national/regional strategies, research and development, and financing structures in both areas.

As outlined in a recent study on ASEAN countries and companies operating in the region with their specific development challenges, particularly vulnerable ecosystems, increasing demand for higher living standards, and rapidly growing population, the resource shortage is more pressing and a circular economy approach is urgently needed (de Boer, 2015). The study describes how these challenges in the next two decades could translate into, on a global scale, trillion-dollar losses for companies and countries whose growth remains tied to the use of scarce and virgin natural resources (de Boer, 2015). Without further action, the ASEAN countries would have to bear a big proportion. At the same time, infrastructure in several regions is yet to develop, making it challenging on the one hand but also possible to leverage latest technological progress to leapfrog the old development models on the other hand. It is crucial for ASEAN to look beyond the old 'take, make, and waste' models and to adopt alternative models of growth to ensure long-term sustainability.

Another important factor in this analysis is the global perspective of material and information flows. Decreased dependence on imports of strategic resources may be an explicit objective of the circular economy, but European as well as ASEAN production-consumption systems depend on such imports and will not operate in isolation. It is crucial to understand the environmental pressures that arise along the value chain where these pressures will be critically felt and how a transition to a circular economy may influence those pressures. Only then can policy efforts be targeted at resources and actors where the economic, environmental, and social benefits of circular economy approaches are greatest. So far, European policies are mostly targeted at impacts that occur within Europe at the production and end-of-life stages of systems. For ASEAN countries, this offers significant potentials for innovative and integrated strategies. As international trade laws limit intervention options, policy generally relies on consumption-oriented approaches, such as eco-labels, to influence the impacts of production abroad.

ASEAN and global businesses increasingly work towards sustainable value chains. Obviously, Industry 4.0 can neither be a national nor just a European or an ASEAN project. Considering global interdependencies alongside global supply chains, completely new governance approaches will be necessary to link these fields on different spatial levels. A closer coordination of circular economy and Industry 4.0 strategies between the ASEAN countries and the EU could be beneficial. A second aspect with clear benefits for ASEAN countries would be a strengthened focus on Industry 4.0 linked to the circular economy in financial cooperation schemes as well as access to finance for inter-company cooperation.

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Chapter 5

Maximising Economic Benefits and Firm Competitiveness

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1. Introduction

The world economy is on the cusp of the fourth industrial revolution. Driven by the internet, the real and the virtual worlds merge together to form the internet of things (IoT). This development is of utmost importance, especially for the manufacturing industry. Production comes together with the latest information and communications technology, and the digitalisation of economy and society changes the way things are produced in a permanent way (BMBF, 2016; GTAI, 2014).

The notion 'Industry 4.0' (derived from the German term 'Industrie 4.0') was mentioned for the first time in public at the Hannover trade fair in Germany in 2011 (Kagermann et al., 2016). The initiative that followed, set by the Federal Ministry of Education and Research, Germany (Bundesministerium für Bildung und Forschung, BMBF), was intended to encourage the German manufacturing industry to prepare for the future of production (BMBF, 2016). Since 2012, BMBF has been promoting various projects worth more than €120 million in the context of Industry 4.0, with industry, researchers, and policymakers working closely together (BMBF, 2015).

The digital transformation of the industry is accelerated by exponentially growing technologies like intelligent robots, autonomous drones, sensors, and three-dimensional (3D)-printing. Due to this technology-driven change, whole firms and their industrial processes need to adapt so as not to be left behind by their competitors. An early adaption to this new environment will increase their competitiveness in the future. This adaption goes beyond the automation of production, which has already been taking place since the early 1970s. Through the proper application of recent information and communications technology, the boundaries between the real and virtual worlds increasingly disappear and cyber-physical systems (CPS) emerge. In the future, there will be online networks of communicating machines, linking information technology (IT) with mechanical and electronic components (Deloitte, 2015). Out of that, interlinked and self-operating production systems or even totally re-engineered value chains can arise (GTAI, 2014).

The concept of Industry 4.0 is also widely known across Europe and the United States (US). In Germany, for example, there is an initiative called the pan-European partnership for the 'factories of the future', which aims to help European manufacturing companies adapt to the global competitive pressures by developing necessary key technologies. A budget of €1.15 billion has been allocated for it from 2014 to 2020 (European Commission, 2013). In the US, the Industrial Internet Consortium aims to accelerate the growth of the industrial internet by bringing organisations and technologies together to prepare for the upcoming revolution (Industrial Internet Consortium, 2016). Between these organisations, there is close cooperation to ensure global standards. For example, the American Industrial Internet Consortium is working closely together with the German 'Plattform Industrie 4.0' to create an international framework to ensure consistent rules and norms (Giersberg, 2016).

According to the vision of Industry 4.0, the future of production could look like the following. There will be communications via software and networks over the whole vertical value chain (product development, production, and services). Smart machines will exchange information and instructions in real time with smart products as well as with individuals across the whole value chain and the overall product life cycle (PLC). Through sensors and control elements, machines will be able to link plants, fleets, networks, and human beings. The machines will continually share information about current stock levels, problems, faults, and changes in orders or demand levels. Furthermore, processes and deadlines are coordinated to raise efficiency and throughput times are optimised. Consequently, we experience an increase in quality throughout the whole PLC. In total, this will create a production system with autonomous control and optimisation (Siemens 2014b; Deloitte, 2015).

Companies that are aware of this development in the manufacturing landscape and invest in all the technologies coming along will be able to profit from the enormous potential of optimisation in logistics and production, and could be part of totally new business models (Kagermann, Lukas, and Wahlster, 2016). But Industry 4.0 not only changes how things are produced but also have strong influence on the operative and strategic performance management through greater flexibility and decentralisation (Sauter, Bode, and Kittelberger, 2015).

Through digital transformation, there is an expected additional potential of value creation in Europe of about €250 billion per year (Roland Berger Strategy Consultants, 2015). Based on this enormous potential, there is consensus within (at least) the German industry that Industry 4.0-related topics have to be on the management agenda of each company and have to be considered with respect to strategic planning over the coming years (Roland Berger Strategy Consultants, 2015; Koch et al., 2014).

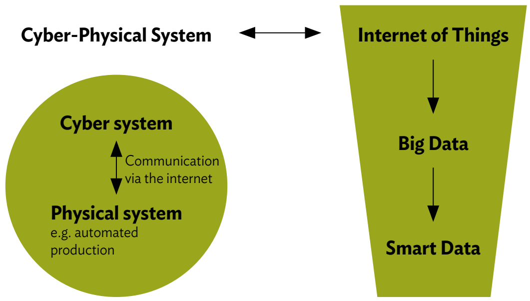
Beyond all competitive advantages through, for example, improvement of efficiency and flexibility, which come along with the implementation of Industry 4.0, efficient uses of resources should also be considered. Production processes within Industry 4.0 should be seen as holistic balanced circuits, which guide and shape the new industrial production (Arbeitskreis Industrie 4.0, 2013). Environmental pollution and shrinking resources have incrementally increased pressure on industrial businesses. These circumstances force manufacturing industries to cope with the pressure of environmental regulations set by governments, the challenges in resource price volatility because resources get scarce, and risks in resource supply. Therefore, a rethinking of the conventional linear economy (take, make, dispose) takes place, and the concept of a circular economy emerges. A circular economy could be the solution to harmonise ambitions for economic growth and environmental protection, where it is understood as a realisation of a closed-loop material flow in the whole economic system (Lieder and Rashid, 2015). Here, the development towards Industry 4.0 provides immense opportunities for the realisation of sustainable, eco-friendly, and resource-saving manufacturing (Stock and Seliger, 2016). For example, IoT and wireless technologies can be used to monitor emissions to supervise air quality, the collection of recyclable materials, and the reuse of packaging resources and electronic parts. The disposal of electronic parts, for example, could be advanced by using radio-frequency identification technology to identify electronic subcomponents of personal computers, mobile phones, and other consumer electronics products to increase the reuse of these scarce resources and reduce waste. Furthermore, radio-frequency identification technology enables a greater visibility into the supply chain, which makes it possible for companies to, for example, efficiently track and manage inventories, consequently reducing unnecessary transportation requirements and fuel usage (Sundmaeker et al., 2010).

The main purpose of this chapter is to explain the potential effects of Industry 4.0 on creating economic value and increasing competitiveness of corporations. In addition to the analysis of the benefits of Industry 4.0, the opportunities to create a circular economy through Industry 4.0 will be studied. For a proper discussion of the topic, some definitions of key terms will be introduced before addressing the main theme of economic benefits and competitiveness, and its consequences for Industry 4.0. This analysis will be followed by a description of new Industry 4.0-related business opportunities and business models, and their impacts on a circular economy. Since even the Industry 4.0-pioneer countries are still in the early stages of Industry 4.0 imagination, creation, and implementation, some key challenges and obstacles on the visionary concepts are discussed. An approach to the transfer to the specific situation of the various Association of Southeast Asian Nations (ASEAN) countries is briefly proposed at the last part of the chapter.

2. Definitions

Industry 4.0 is still based on automation technology (e.g. robots), but these technologies are now connected via sensors and other control elements that link the real and the virtual worlds forming CPS. These CPSs are then able to cross-link all productive entities to each other through the internet. This communication of physical objects without any human interaction is known as IoT. The huge amount of data that arise out of that interaction (big data) could be stored in clouds and should then be converted into smart data to filter the information really needed and to evaluate the generated data in a proper way (see Figure 1). If we take all these technologies together, we will be able to form the smart, digital factories of the future.

Figure 1. Interplay of Components Used Within Industry 4.0



Notes: Cyber systems, together with physical systems, form the so-called cyber-physical systems, which can communicate via the internet. Through small embedded devices (e.g. radio-frequency chips) within physical systems, objects become 'intelligent'. The communication of these smart objects without human interaction is known as the internet of things. The huge amounts of data recorded within these processes are called big data, which must be converted into smart data for proper use. All these concepts are the basis for the upcoming industrial revolution called 'Industry 4.0', where smart factories are producing smart products in a self-organised manner.

Source: Author´s own representation (Hedwig Werthmann).

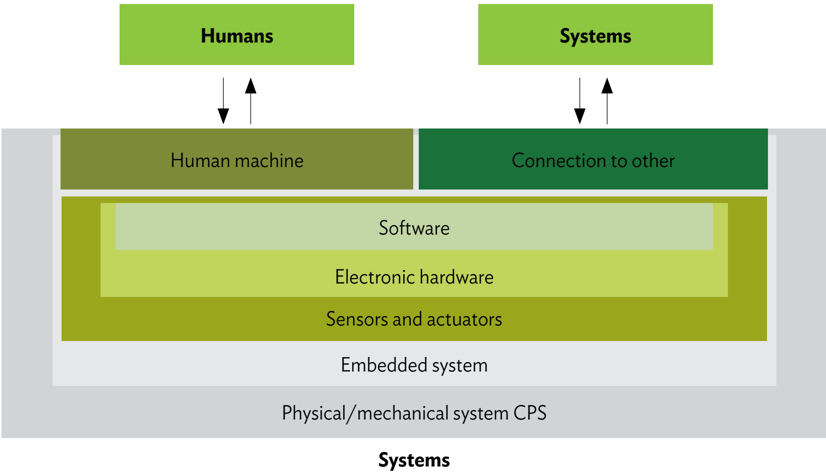
All these concepts, which are important to Industry 4.0, are explained in more detail in the following subsections.

2.1 Cyber-Physical Systems

A CPS describes the technological basis of information technology in combination with the physical world. This means that they connect information technology with mechanical and electronic elements. These systems of collaborating computational entities are therefore in a steady intensive connection with the surrounding physical world and its on-going processes (Monostori, 2014). Therefore, open, cross-linked systems arise, which can collect data in various situations in the physical world. In addition, they interpret data and make them available. Furthermore, these systems can react via actuator systems to processes within the physical world and can therefore influence the behaviour of equipment, things, and services (Geisberger and Broy, 2012). CPSs, which provide and use data at the same time, are intelligently linked with each other and are continuously interchanging data via virtual networks (like clouds), making data available via the internet. These CPSs can also be used within manufacturing systems, where the intelligent cross-linking is, for example, realised by embedded sensors, processors, software, and connectivity in products, coupled with a product cloud in which product data is stored and analysed. These data can be used to improve product functionality and performance (Stock and Seliger, 2016).

CPSs can also behave as human-to-machine interfaces, or it can support machines to interact with the products (see Figure 2). Therefore, a CPS enables development across all levels of production, from processes through machines up to production and logistic networks, where manufacturing systems can interact and operate in a self-organised and decentralised manner (Monostori, 2014; Brettel et al., 2014).

Figure 2. **Interaction Between Humans and Machines in Cyber-physical Systems**



CPS= cyber-physical system.

Notes: Cyber-physical systems consisting of physical/mechanical systems with embedded software using sensors and actuators to record, store, and evaluate data, can connect the real and virtual worlds. To ensure communication between users and, for example, production plants, there are man-machine interfaces, as well as interfaces between the systems itself (e.g. machine-to-machine interaction, product-machine interaction). The elements of CPS can control tasks in an autonomous manner and are able to interact with humans via interfaces.

Sources: Authors' representation based on Monostori, 2014; Brettel et al., 2014.

Recent developments have resulted in higher availability and affordability of sensors, data acquisition systems, and computer networks, and changed the competitive landscape of the current manufacturing industries. More factories are constrained to implement high-technology methodologies to stay competitive and up-to-date. Therefore, the ever growing use of sensors and networked machines has resulted in the continuous generation of high-volume data, which is known as big data (Lee, Bagheri, and Kao, 2015). But CPSs do not only have the potential to change the manufacturing landscape; it also has enormous potential to change every aspect of life. Ideas such as autonomous cars, intelligent buildings, smart electric grid, 3-D printing, and robotic surgery are just some selected practical examples that have already emerged (Monostori, 2014).

2.2 The Internet of Things

The notion 'internet of things' was mentioned for the first time by Kevin Aston in 1999 (Pande and Padwalkar, 2014). According to his definition, computers and, consequently, the internet are dependent on humans for information. Humans capture and create most information available in the internet. Therefore, information available is based on ideas, not on things. His vision was:

> If we had computers that knew everything there was to know about things – using data they gathered without any help from us – we would be able to track and count everything, and greatly reduce waste, loss, and cost. We would know when things needed replacing, repairing or recalling, and whether they were fresh or past their best (Ashton, 2009).

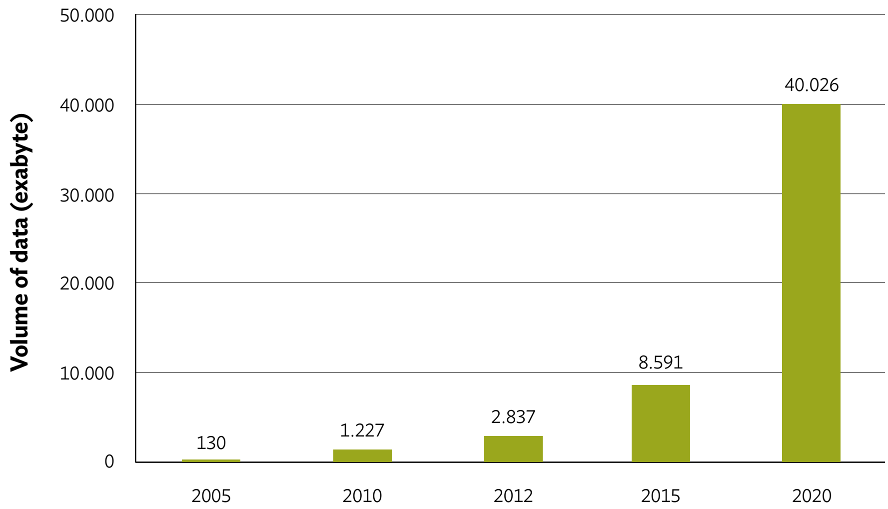
To reach that level, humans must empower computers to obtain information from surrounding things. This will be possible through embedded radio-frequency identification and sensor network technologies in our surrounding environment. Consequently, there will be an omnipresent interlink of persons, things, and machines at any time – enabled by IoT. The result will be enormous amounts of data, which have to be stored, processed, and presented in an efficient and easily interpretable form. Cloud computing can provide the virtual infrastructure for such utility computing, which integrates monitoring and storage devices as well as analytical tools (Gubbi et al., 2013). Companies and organisations have several ways to explain IoT. But it is commonly described as an 'ecosystem of technologies monitoring the status of physical objects, capturing meaningful data, and communicating that information through networks to software applications' (Thrasher, 2014). The recurring topics in all definitions of IoT include smart objects, machine-to-machine communication, and radio frequency technologies (Thrasher, 2014).

Through IoT, it is possible to connect everyday objects to remotely determine their state via information systems, which continuously collect up-to-date information on these physical objects and processes. It is like billions of objects will report and receive data without human interaction. IoT is exploding. Therefore, the total number of connectable things will be increasing from 7% of the total objects in 2013 to 15% by 2020 (EMC2, 2014). This enables many aspects of the real, physical world to be monitored in detail and at low cost. Using these technologies within 'the future of manufacturing' (Industry 4.0), would allow a better understanding of production processes as well as a more efficient control and management of these processes. As a consequence, the ability to react to events in the physical world in an automatic, fast, and informed way is gained, which will ease the optimisation of processes and the handling of complex situations (Friedemann and Floerkemeir, 2010).

2.3 From Big Data to Smart Data

The set of data worldwide is exploding. In 2005, there were 130 exabytes (10^{18} bytes) available (Webel, 2016). In 2012, it was already 2,837 exabytes and in 2020, experts expect it to increase to about 40,000 exabytes (Heuring, 2015; Statista.com, 2016; see Figure 3).

Figure 3. **Growth in Data Amount Until 2020**



Notes: Prediction is based on the volume of the yearly generated digital amount of data worldwide between 2005 and 2020 (numbers in exabytes).

Source: Authors' representation based on Statista.com, 2016.

Different sources give different figures on the increase in the volume of generated data over the coming years. But there is a clear consensus that the amount of data will increase dramatically across the following years.

Through Industry 4.0 applications, there is a change in the whole industrial value chain through increasing digitalisation and networking. The huge and continuously produced amount of data through the growing use of sensors, networked machines in CPS, and the development towards an industry with smart factories is called big data.

These sensor-generated, networked data from a wide variety of sources are therefore unstructured. To use these data to, for example, generate forecasts and enable companies to take fact-based decisions, it is important to consolidate and evaluate these data in an intelligent way (Sauter, Bode, and Kittelberger, 2015). Consequently, companies must face the challenge of developing smart predictive informatic tools to manage big data. Within this approach, it is important to think about information retrieval, representation, and the interpretation of data with special regard to security aspects, thereby achieving transparency and productivity (Monostori, 2014; Lee, Kao, and Yang, 2014). In the age of digitalisation and IoT, businesses are collecting more data than they know what to do with. To convert this bulk of data into useful information, it is necessary to reduce their complexity when structuring the information. Then these data have to be evaluated in a proper way to be used for knowledge advances and decision-making throughout the whole PLC (Stock and Seliger, 2016). If this challenge succeeds, then smart factories producing smart products with the aid of CPSs, collecting smart data at each step of production will be enabled to self-organise each required manufacturing step throughout the whole production process or even the whole value chain.

2.4 The Smart Factory

How the smart factory of the future will look like, no one knows exactly. But a probable scenario would be that machines and products will organise the production, supply chains will arrange themselves, and orders will convert to information needed for production to start the manufacturing process. This means the originating product itself will guide the process of production, supervise the environment through its embedded sensors, and react to disturbances with counteractions. This may become a reality when using the technologies described in the previous subsections above. There are some existing advanced factories that are deemed to be part of the most modern production sites in the world. We are in the midst of the fourth industrial revolution. Hence, these plants show the direction of where to go in the future.

Examples of these sites are the Siemens' electronics plant in Amberg, Germany, which produces Simatic programmable logic controls (Siemens, 2014a), and Festo`s technology plant in Scharnhausen, Germany (Festo AG and Co. KG, 2015), which is a pioneer in putting into practice Industry 4.0. Within Festo's technology plant, employees cooperate in safe interaction with flexible robots, energy systems track all energy flows in real-time, and new working tools detect and rectify machine faults directly on-site.

Within the electronics plant of Siemens, products and machines are already communicating with each other. IT processes are optimised with a minimal error rate and products regulate their production on their own. The result is impressive. By using a constant production area and only slight changes in numbers of employees, the production site has octuplicated its production volume. This means man and machine are eight times more productive compared to 20 years ago. In addition, the defect rate could be kept to a minimum. Production quality is at 99.99885%, and a series of test stations detect the few defects that occur (Siemens, 2014a).

As we can see from these examples, smart factories will make the growing complexity of manufacturing processes manageable and ensure that production can be attractive, sustainable, and profitable at the same time.

In evaluating the readiness of European countries to Industry 4.0, Roland Berger identified Germany, Finland, Sweden, Ireland, and Austria as frontrunners; and, Belgium, the Netherlands, Denmark, the United Kingdom, and France as 'potentialists' with high Industry 4.0 readiness but rather small manufacturing share (Roland Berger Strategy Consultants, 2014).

In comparison to corporations in the US, German industry is seen to be strong in the systems level of sensors, actuators, and data collection. Until recently, there were concerns that Germany has deficits in data security and data analysis. However, German industry has strengthened its position through the creation of an Industrial Data Space, which is a joint industry effort, coordinated by the German research network Fraunhofer-Society as a neutral entity. China is also interested to follow the Industrial Data Space (Marx and Neugebauer, 2016).

Asian countries have been inspired by Germany with its Industry 4.0 initiative. Following that Industry 4.0 effort, the powerful industry association Keidanren in Japan has created a new initiative called Super Smart Society, also called Society 5.0 (Welter, 2016).

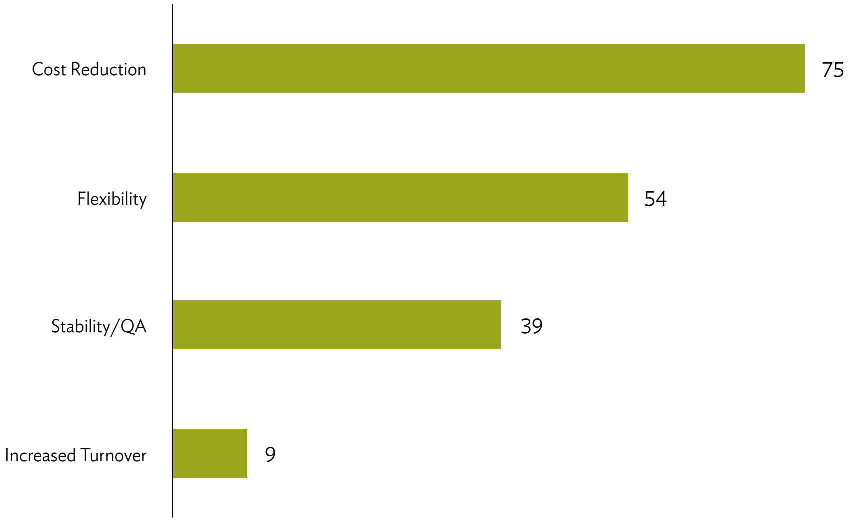
3. Economic Benefits and Improved Competitiveness Within Industry 4.0

In this chapter, economic benefits, which can be achieved when using Industry 4.0 technologies, will be explained. Researchers and strategy consulting firms indicate various value drivers. When looking at these value drivers and trying to optimise and work with them, there is high potential to accomplish economic improvement within business and manufacturing processes. Furthermore, there will be a demonstration of three dimensions to work with, according to which companies can gain competitive advantage by implementing what was learned when looking at these value drivers.

3.1 Economic Benefits

The users of Industry 4.0 technologies expect four major economic benefits in the future compared to companies not taking part in the upcoming industrial revolution (see Figure 4). The main driving force to apply Industry 4.0 is seen within the possibility of reducing costs, which can be realised through an increase in the degree of automation and efficiency. The cost-reducing goal is followed by an increase in flexibility, which allows companies to react quickly to changes in orders and capacities, and respond to increasingly individualised customer demands. Furthermore, intelligent maintenance concepts (e.g. predictive maintenance) are expected to increase stability and improve quality. As a fourth economic benefit, an increase in turnover is expected through incremental efficiency in business as well as manufacturing processes and by entering new markets (Sauter, Bode, and Kittelberger, 2015).

Figure 4. Potential Benefits of Industry 4.0 Applications



QA = quality assurance

Note: The number of multiple answers possible is 112.

Source: Authors' representation based on Sauter, Bode, and Kittelberger, 2015.

According to McKinsey`s Digital Compass, there are eight value drivers, creating value for companies and customers. Using these value drivers, it is possible to describe in more depth economic benefits for companies applying Industry 4.0 concepts. These value drivers will explain how they impact the performance of companies concerning Industry 4.0, having in mind the objective to maximise value (McKinsey, 2015).

In a world of perfect information, it is possible to manufacture more efficiently, to use fewer resources while getting the same results as before. and production becomes more flexible. Consequently, smaller production batches are possible. Such efficiency improvements can also be used for the implementation of a circular economy, even though this might only be the starting point for more radical circular economy innovations in the coming years.

When using all information provided by Industry 4.0 technologies, companies can harness this at each step of value creation across the entire PLC. In the following subsections, concrete value drivers are described across the whole value chain/PLC, where Industry 4.0 technologies can be used to optimise business processes to become more efficient and productive. Besides the efficiency perspective, potentials for reaching a circular economy are indicated.

3.2 Using Resources and Optimising Processes

The possibilities to improve processes and the consumption of materials when using the concepts of Industry 4.0 are versatile. It is possible to decrease material costs by less defective goods and optimise processes (in speed or yield) via the use of CPS, which allows the observation of processes in real time. Through these technologies, it will be possible to react to events in the physical world in an automatic and fast way. Therefore, the improvement in manufacturing processes, including the optimisation of material consumption, will drive value and will make it possible to increase productivity by 3%-5% (McKinsey, 2015; see Figure 5).

The cross-linking of value-creation networks in Industry 4.0 provides new opportunities for implementing closed-loop PLCs and the so-called industrial symbiosis in a circular economy. Efficient coordination of the product, material, energy, and water flows throughout the PLC as well as between different factories can be realised. PLCs with closed loops help keep products in life cycles of multiple use phases with remanufacturing or reuse in between (Stock and Seliger, 2016). Industrial symbiosis is described as the (cross-company) cooperation of different factories for realising a competitive advantage by trading and exchanging products, materials, energy, water (Chertow, 2007), and smart data on a local level (Stock and Seliger, 2016).

3.3 Utilisation of Assets

The optimal use of a company's machinery park is supported by Industry 4.0-based technologies, which enable, for example, predictive maintenance. Through the permanent monitoring of machinery conditions, it becomes possible to reduce machine downtimes or changeover times by an early detection of possible problems and continuous maintenance. The avoidance and early correction of defects can therefore save costs and drive production throughput, which consequently drives value (McKinsey, 2015). Based on analyses, the use of predictive maintenance decreases total machine downtime by 30%–50% and increases machine life by 20%–40% (see Figure 5).

In a circular economy, manufacturing equipment in factories is often a capital good with a long use phase of up to 20 or more years. Retrofitting enables an easy and cost-efficient way of upgrading existing manufacturing equipment with sensor and actuator systems as well as related control logics to overcome the heterogeneity of equipment in factories (Spath et al., 2013). Retrofitting can thus be used as an approach for realising a CPS throughout a value-creation module, such as a factory, with already existing manufacturing equipment. This extends the use phase or facilitates the application in a new use phase of the manufacturing equipment and can essentially contribute to the economic and environmental dimensions of sustainability. It is particularly suitable for small- and medium-sized enterprises, being a low-cost alternative to the new procurement of manufacturing equipment (Stock and Seliger, 2016).

The same applies to the finished product to be developed. The approach for the sustainable design of products in Industry 4.0 focuses on the realisation of closed-loop life cycles for products by enabling the reuse and remanufacturing of the specific product or by applying cradle-to-cradle principles, also called circular economy. Different approaches also focus on designing for the well-being of the consumer. These concepts can be supported by the application of identification systems, e.g. recovering the core for remanufacturing, or applying new additional services to the product for achieving a higher level of well-being for the customer (Stock and Seliger, 2016).

3.4 Labour Productivity

An increase in the productivity of labour can significantly drive value. The improvement of labour productivity can be realised by using the new technologies of Industry 4.0, which make it possible, for example, to reduce waiting times between different production steps in manufacturing or to accelerate the research and development (R&D) process (e.g. through 3D printing). Furthermore, the burden or complexity of tasks can increase the speed of manual production steps executed by workers (McKinsey, 2015). Examples of such assistance within production processes are Etalex, a Canadian manufacturer of warehouse furniture, and the German company Festo, where human–robot collaborations work in close proximity to each other (Universal Robots, 2016; Festo AG & Co. KG, 2015). Through this technology, Etalex was able to increase sales by about 40% with the same number of employees (see Figure 5).

Humans will still be the organisers of value creation in Industry 4.0 (VDI/VDE and GMA, 2014). To cope with the social challenge in Industry 4.0 in a sustainable way, the training efficiency of workers can be improved by combining new information and communications technology, increasing the intrinsic motivation and fostering creativity by establishing new CPS-based approaches of work organisation and design, and increasing the extrinsic motivation by implementing individual incentive systems for the worker, e.g. by taking into account the smart data within the PLC for providing individual feedback mechanisms (Stock and Seliger, 2016).

3.5 Management of Inventories

Proper management of inventories is very important, because too much inventory leads to huge capital costs. By applying Industry 4.0 levers, drivers of excess inventories can be targeted by addressing problems like unreliable demand planning and overproduction (McKinsey, 2015). Through intelligent technologies like systems which automatically reorder, if necessary, costs for inventory holding can be reduced by 20%–50% (see Figure 5).

Regarding the circular economy, the benefits of such a reduction in inventory are reductions in energy needs for the proper storage of the inventory as well as less waste created by materials turning old or outdated due to technical progress.

3.6 Quality Improvement

Industry 4.0 facilitates the improvement of product and process qualities by using real-time problem solving, advanced process control, or real-time error corrections to decrease unstable manufacturing processes, rework, and extra costs (McKinsey, 2015). By using these approaches, cost saving related to suboptimal quality of about 10%–20% could be achieved (see Figure 5). As described in section 2.4 on the smart factor, Siemens was able to decrease the defect rate to a minimum, and a production quality of 99.99885% could be reached through the use of advanced technologies emerging with the fourth industrial revolution (Siemens, 2014a).

A sustainable-oriented decentralised organisation for a circular economy in a smart factory focuses on the efficient allocation of products, materials, energy, and water by taking into account the dynamic constraints of CPS, e.g. the smart logistics, smart grid, self-sufficient supply, or customer (Stock and Seliger, 2016). Such a concept towards a holistic resource efficiency in the sense of a circular economy is being described as one of the essential advantages of Industry 4.0 (Kagermann, Lukas, and Wahlster, 2015).

3.7 Match of Supply and Demand

To prevent waste by unnecessary inventory and storage costs, a perfect understanding of customer demand in terms of quantity and product features leads to a much better predictability through new possibilities like crowd forecasting based on advanced analytics (McKinsey, 2015). The use of such technologies to optimise the match of supply and actual demand can increase the accuracy of demand forecasting to more than 85% (see Figure 5).

Accurate demand forecasts lead to reductions in waste and, therefore, to a smoothly operating circular economy. In developed countries, this topic already caught the attention of the public as food is being dumped by retailers while at the same time people in other parts of the world do not have sufficient food supply.

3.8 Reducing Time to Market

Being the first supplier of a new product in the market can create value in terms of increased revenues and less competition. New technologies emerging with Industry 4.0, which enable faster and cheaper R&D processes, for example, concurrent engineering or rapid prototyping by using 3D-printing, can significantly reduce the time to market (McKinsey, 2015). Typically, the use of such technologies within R&D processes can reduce the time to market by 30%–50% (see Figure 5). Local Motors is already using this approach to drive value. It produces cars almost completely through 3D printing. They were able to reduce the development cycle from about 7 years to only 1 year, consequently reducing their R&D costs massively (Local Motors, 2015, Werner, 2015).

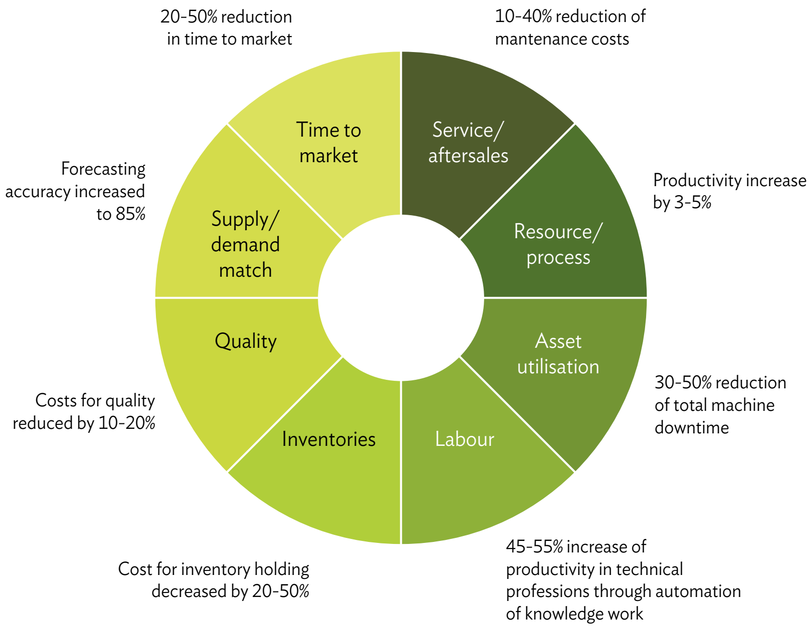
Reducing time to market also means faster learning if a product or process turns out to be less suitable for the circular economy. This means that the continuous improvement cycles are accelerated through the latest technology and practices to implement a circular economy.

3.9 Service and Aftersales

The sustainable design of processes addresses the holistic resource efficiency approach of Industry 4.0 by designing appropriate manufacturing process chains or by using new technologies (Stock and Seliger, 2016).

Innovative services lead to new possibilities of repairing products and to the chance to keep them operational longer. Manufacturing of products can be more cost effective when machines get a longer operational time, supported by maintenance services and repairs, e.g. through remote maintenance. In this case, it is possible to carry out error diagnosis and even repair without the necessity of a technician visiting the site (McKinsey, 2015). Average maintenance costs could be reduced by about 10%–40% through remote and predictive maintenance (see Figure 5).

Figure 5. Indicative Quantification of the Eight Value Drivers



Source: Authors' own representation based on McKinsey, 2015.

All eight value drivers are showing high improvement potentials within already existing production systems enabled by Industry 4.0. Which one of these value drivers will have the highest room for improvement is strongly dependent on the firm itself as well as the industry the company is operating in. To activate these value drivers and really exploit the potential they offer, it is necessary to prepare the company along three dimensions to get ready to take part in the fourth industrial revolution.

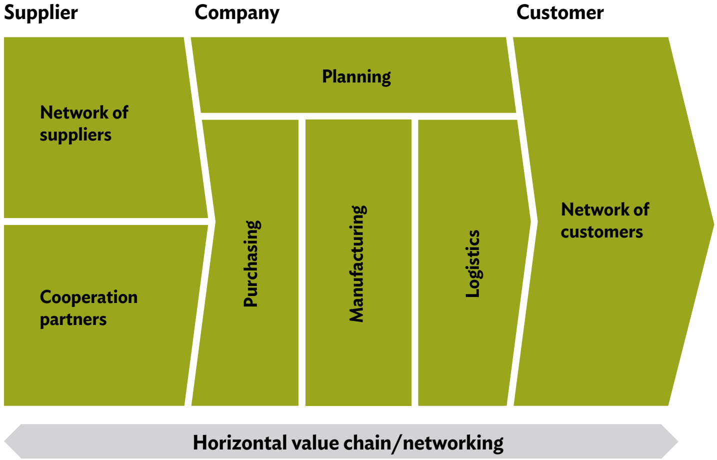
3.10 Improving Competitiveness Within Industry 4.0

The paradigm of Industry 4.0 is basically outlined by three dimensions: the horizontal integration across the entire value creation network; the end-to-end engineering across the whole PLC; and the vertical integration and networked manufacturing systems (Stock and Seliger, 2016; Acatech, 2013; Deloitte, 2015). To deliver the goals of Industry 4.0 and gain improved competitiveness, the features of the three dimensions described in the following subsections should be implemented.

3.11 Horizontal Integration

Horizontal integration characterises the cross-company and company-internal smart networking and digitalisation throughout the value chain of a PLC and between value chains of neighbouring PLCs (Stock and Seliger, 2016). The digitalisation of the horizontal value chain integrates and optimises the flow of information and goods from the customer over the whole corporation to the point of the supplier and vice versa (see Figure 6). Within this approach, all company-internal areas (e.g. purchasing, production, and logistics) will be connected and regulated together with all external partners as part of value creation (Koch et al., 2014).

Figure 6. Horizontal Value Chain



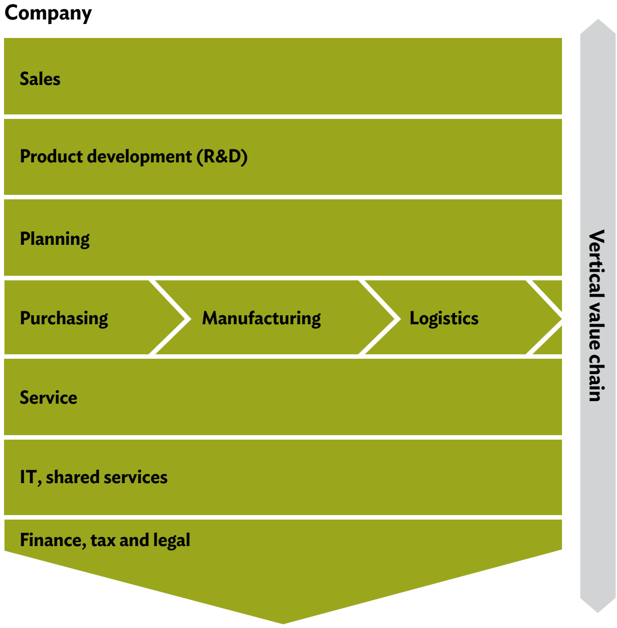
Note: Horizontal integration across value creation networks/supply networks.
Source: Authors' own representation based on Koch et al., 2014.

As the complexity of products and processes increase with Industry 4.0, concepts such as collaborative manufacturing and collaborative development environments are becoming important, especially for companies with limited resources like small and medium-sized enterprises. Within these collaborative networks, risks and resources can be shared and, consequently, the range of market opportunities can be expanded. Therefore, it is easier to adapt to volatile markets within such cross-company networks. But to reach an increased productivity within these inter-company value chains and networks, companies and their employees must communicate with various departments across company boundaries very efficiently. The prerequisite for the global optimisation of the production processes within or across company boundaries is the availability of product data throughout the entire network. To maintain global competitive advantage, companies will have to focus on their core competencies while outsourcing other activities within the network (Brettel et al., 2014).

3.12 Vertical Integration

Vertical integration specifies the intelligent cross-linking and digitalisation within the different hierarchical levels of a value chain. This will enable digital order processes and customer-specific product development, where an automated transfer of data into an integrated planning and manufacturing system can be assured. Furthermore, the associated value chain activities such as marketing and sales or technology development are integrated (Koch et al., 2014; Stock and Seliger, 2016; see Figure 7).

Figure 7. Vertical Value Chain



IT = information technology, R&D = research and development.
Note: vertical integration and connected production systems.
Source: Authors' own representation based on Koch et al., 2014.

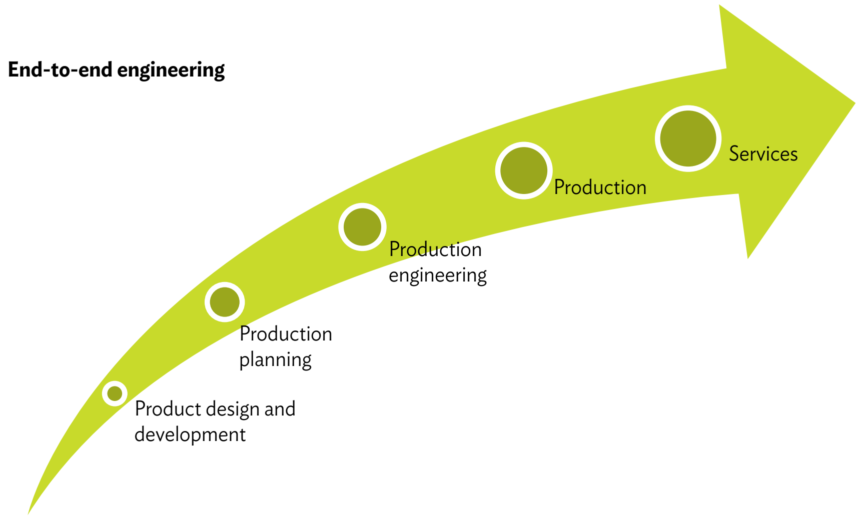
With vertical integration, it becomes possible to have flexible and reconfigurable production structures, which can be adapted to each specific customer order or even to changing market requirements. These features are key enablers for manufacturers to stay competitive within highly volatile markets and it will allow them to reach fast and fault-free production (Stock and Seliger, 2016).

As better availability and integrated use of all relevant data through the cross-linking of all products, entities, and companies that are part of the value creation process are the base for Industry 4.0, the digitalisation of value chains is a premise to all companies to sustain their competitive ability. According to a study conducted by Strategy& and PricewaterhouseCoopers, where they interviewed 235 German companies, the digitalisation of value chains will increase tremendously within the following 5 years (Koch et al., 2014).

3.13 End-to-End Engineering

End-to-end engineering describes the intelligent cross-linking and digitalisation throughout the whole PLC, from the procurement of raw materials to the use of the product till its end of life (Stock and Seliger, 2016). This integrated engineering along the whole value chain promises high optimisation potential. Under this type of engineering, all entities that are part of the engineering process will be provided with real-time information. The advantage is that it encompasses both the manufacturing process and the manufactured product (see Figure 8).

Figure 8. End-to-End Engineering



Note: Digital patency of the engineering across the whole value chain
Source: Authors' own representation based on Acatech, 2013.

4. New Business Opportunities and Business Models

In Chapter 3, the value drivers of Industry 4.0 were described with a rather narrow focus on economic benefits through improved efficiency and cost reductions, and other improvements related to the existing business model. There are ways of creating new markets by reinventing the way things are done. They can be seen beyond pure competitiveness, as new market opportunities (Blue Oceans) can be discovered beyond traditional markets with high levels of competition (Red Oceans). Existing business models will change and new disruptive digital business models enabling, for example, mass customisation will emerge. Similar to the concept of re-engineering, business models and concepts can be imagined in a radically different way, based on the new possibilities of Industry 4.0.

In Industry 4.0, new evolving business models are highly driven by smart data for offering new services. This development can be exploited for the creation of new sustainable business models. Sustainable business models significantly create positive impacts or reduce negative impacts for the environment or society (Bocken et al., 2014). They can even fundamentally contribute to solving an environmental or social problem (Schaltegger and Wagner, 2011). In addition, sustainable business models are necessarily characterised by competitiveness in the long run (Schaltegger and Wagner, 2011). In this context, selling the functionality and accessibility of products instead of only selling the tangible products will be a leading concept (Stock and Seliger, 2016).

This creative and disruptive process can be imagined at an early stage of development, even though there are already four new types of business models emerging. All four of them are leveraging disruptive technologies and providing opportunities for current and new players.

1. Platform models have in common products, services, and information that are exchanged on predefined communication streams. Further, there is the option for an interaction platform in the function of a marketplace, which means the technological conditions are provided to connect various parties and coordinate those transactions. Another category is called the technology platform or ecosystem. In this case, the company is facilitating the further development of other company's own technologies or products.
2. As-a-service-business model means that organisations are moving from selling equipment to a pay-by-usage model. In this case, machinery equipment is in the factory of the manufacturer, paid per use and not as a one-off payment, and not owned by that company. Another less radical shift in the role is related to a subscription-based model, which ensures recurring revenues for the provider of the service (continuous revenues instead of one-off payments, as well as pay-by-usage which can transform fixed costs into variable costs).
3. Intellectual property rights-based business models follow the idea of generating value from their proprietary data or intellectual property of the corporation. This could be through licensing fees or by providing add-on services to the core product (example, systems, application, and products consulting services in addition to software revenues).

4. Data-driven business models are new ways of gathering and using data that can be leveraged by using a data-driven business model. The two main approaches to such models are either direct or indirect. Google is an example of a direct monetisation of data, as the primary product creates the data that is further analysed and used for target advertising. The indirect use of the data refers to the insights from the data to identify and target specific customer needs and characteristics. Examples could be pricing micro-segmentation or use-specific machine maintenance plans (McKinsey, 2015).

In a circular economy, all four new categories of business models provide opportunities to generate growth in revenues and employment for people without the linear increase in physical materials consumed. Improvement in the usage of data, machinery equipment, software, and other resources can reduce the need for such limited resources and reduce the ecological footprint of production.

Furthermore, jobs eliminated by Industry 4.0 can be counter-balanced by new job opportunities in the new business models. This refers to the social dimension of sustainability.

Case example: A European example for Industry 4.0 implementation for the circular economy is Elanders Group, a printing and fulfilment company with headquarters in Sweden. It also has strong operations in Germany and other countries throughout the world. Elanders calls itself a specialist in information management and distribution. The company offers cost-efficient and innovative solutions that meet customers' needs for printed materials both locally and globally. Elanders has developed advanced, user-friendly and internet-based order platforms that streamline the process of order to delivery and enable customised just-in-time or sequenced deliveries (Elanders Group, 2016a). Furthermore, Elanders is one of the few companies in the graphics industry that can follow multinational customers over country borders and offer comprehensive solutions that include printed matters and other related services such as kitting and packing or just-in-time and sequence deliveries. Facilities in Brazil, China, Hungary, India, and Italy are good examples of how Elanders has followed its customers out into the world. Some of its core products are manuals and marketing materials, personalised prints, and print-on-demand. Small batch digital printing of user manuals for the permanently increasing product variety of the automotive industry is an example of improvements in efficiency, reduction of inventory levels, and reduction of waste through outdated or inadequately configured user manuals. Rather than producing a large-volume mass-printing product at price levels of a commodity, Elanders has changed to a business model that follows the just-in-time production needs of the automotive industry (Elanders Group, 2016b). Such business models could be also transferred to 3D printing, where the digital printing products will be substituted by 3D customised products.

5. Challenges and Obstacles When Implementing Technologies of Industry 4.0

There are some obstacles and challenges to the implementation of emerging technologies in the context of Industry 4.0, like the need for qualified personnel (e.g. specialists for data analysis), concerns about data security (cybersecurity), and the need for global uniform standards (Koch et al., 2014).

By using technologies like IoT, these wireless smart devices face threats from the proliferation and sharing of data. Therefore, deciding a common strategy and policy for the future is a priority for the European Union (EU). There is concern about the privacy of citizens through the use of, for instance, wireless medicards or passports with built-in chips, as well as concern about the misuse of sensitive or secret data, for example, production parameters from manufacturing companies (Sundmaeker et al., 2010). The saving and sharing of data through, for example, cloud systems, and the networking and integration of several different companies through value networks will comprise a lot of risks such as industrial espionage, attacks by hackers, and data theft, which could have a devastating impact on Industry 4.0. Therefore, companies need an appropriate cybersecurity strategy and a set of common standards such that partnerships can become a reality without bearing too much risk for its participants (Deloitte, 2015). Companies, the German government, and research institutes are aware of these threats. Consequently, there are collaborations where standardisation and security are under development. One example is the Industrial Data Space, which enables a reliable exchange of data with common rules for all firms. This initiative aims to create a secure data space and develops guidelines for the certification, standardisation, and utilisation of data (Industrial Data Space e.V., 2016).

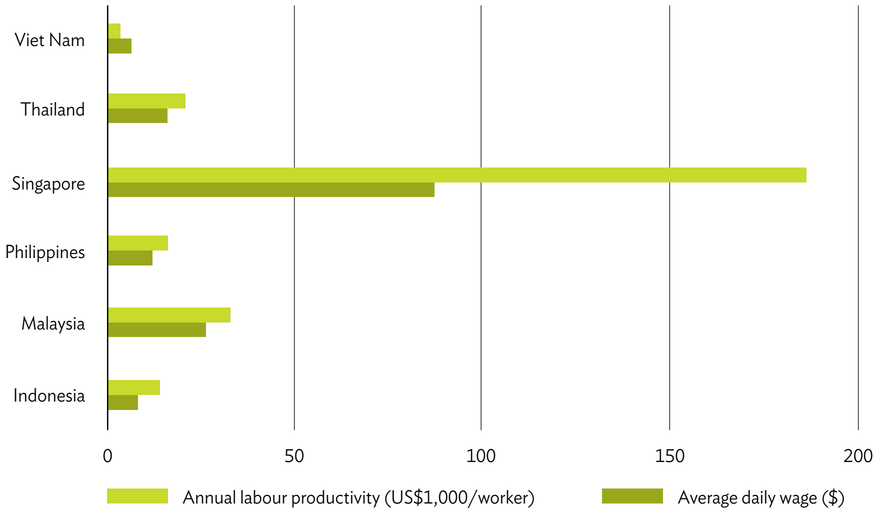
In addition to doubts about data security, the high investments and vague economic feasibility for new Industry 4.0 applications represent a challenge for many firms, especially small and medium-sized enterprises. Also, many German companies do not have prepared concrete implementation plans because they avoid the extensive and complex transformations that will come up with the forthcoming industrial revolution. Therefore, there is a need for more transparency and intersectoral exchange of experiences (Koch et al., 2014).

In line with Industry 4.0, there will also be a change in the required qualifications of employees (Koch et al., 2014). On the one hand, there will be less heavy and repetitive work in future manufacturing systems as this work will be transferred to the manufacturing system itself (e.g. robots). On the other hand, there will be more skilled work needed as production becomes increasingly autonomous and agile. That is why there is a higher need for creative working processes like strategic planning or R&D because there will be new skills required to introduce and implement all new and innovative business opportunities offered by Industry 4.0 (Deloitte, 2015). For these more complex tasks, good qualifications are needed, which can be implemented already into prospective education. One can think about a more interdisciplinary education system, where pupils already get familiarised with techniques and information technology needed for a digitalised professional life. In addition, workers whose tasks are now done by robots should be further trained to be able to carry out more complex tasks, take over more responsibilities, and act on their own initiatives (Acatech, 2013). A more recent study of Acatech claims that the strengths of Germany can be seen in the areas of sustainability, training and education, market access, and security. Also, a lot had been done recently on standardisation. However, according to the authors, the creation of digital business models and the spirit of pioneering those are missing in Germany. Access to capital and the experience to develop user-friendly products are further challenges for Germany (Acatech, RWTH Aachen, Universität Paderborn, 2016).

6. ASEAN and Industry 4.0

ASEAN encompasses 10 economies that are at vastly different stages of development, and is already a major manufacturing hub. It has a window of opportunity to capture a greater share of global manufacturing, especially for multinationals that are seeking a lower cost base. The availability of low-cost labour in Cambodia, Indonesia, Lao People's Democratic Republic, Myanmar, and Viet Nam can be a competitive advantage. The average cost of labour is about US$7/day in Viet Nam and US$9/day in Indonesia. However, the advantage of low labour costs in these countries is undermined by weak output per worker (see Figure 9).

Figure 9. **ASEAN's Labour Cost and Productivity**



Source: Authors' own representation based on APO, 2015.

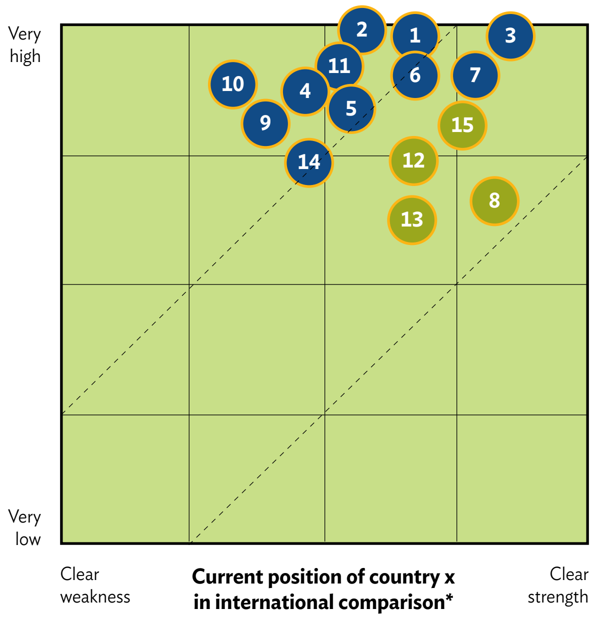
To stay competitive and accessible in an increasingly connected and collaborative global supply chain, and to move towards a digital society and the related economic benefits, ASEAN countries need to identify their specific vision regarding Industry 4.0. Key questions to be addressed are: How can they be a competitive player? Should less-developed countries do something in between or step-by-step? What are country-specific drivers towards Industry 4.0?

Considering that both highly industrialised countries (e.g. Singapore) and much less industrialised countries (e.g. Cambodia and Myanmar) are ASEAN member countries, the current initial situation of ASEAN countries for Industry 4.0 is quite diverse. The policy community also has concern about the relatively high share of the agricultural sector and the lower share of the manufacturing sector (Kathiravale, 2016). Therefore, a careful analysis of the status quo for each country would need to be done. In addition, a vision of a desirable future state should be created and key areas of action to focus on must be identified. Based on the results, new business models for the value creation from waste materials can be designed by managing waste holistically and increasing coordination of waste management via a waste management platform (Kathiravale, 2016). State-of-the-art Industry 4.0 technology can be used for an efficient and effective monitoring and management of waste processes rather than implementing processes with a high degree of bureaucratic overhead.

A good methodological basis for analysis is provided by the recent study of Acatech, which is based on interviews with experts in 13 countries (Acatech, RWTH Aachen, Universität Paderborn, 2016). A total of 15 areas of focus for successful implementation of a desired future state were identified. This study suggests that four out of those 15 areas are indicating that the country is on the right track. The other 11 are areas in which there is a need to focus action on in the very near future. Figure 10 illustrates the results for the example of Germany (Acatech, RWTH Aachen, Universität Paderborn, 2016).

Figure 10. Future Importance of Focus Theme

Example of Germany



Focus themes

1. Security
2. Standards, migration, and interoperability
3. Sustainability
4. Usability
5. Field data collection and analysis
6. Material and information flow
7. Education and qualification
8. Societal acceptance of production
9. Pioneer spirit
10. Business models
11. Organisational culture and flexibility
12. Degree of internationalisation
13. Political support and restrictions
14. Access to capital
15. Access to markets of demand and supply

Note: Critical focus themes indicate needs for action. Items coloured green are not considered for focused action.
Source: Authors' own representation based on Acatech, RWTH Aachen, Universität Paderborn, 2016.

Depending on the degree of technological maturity of a country as well as on the comparative labour cost versus the cost and accessibility of capital, the optimal implementation of Industry 4.0 solutions can be quite different. While a high degree of automation might be most useful in high-labour-cost countries like Singapore, less automation might be more competitive and suitable in lower-labour-cost countries like Myanmar or Cambodia. Nevertheless, labour will need to be documented and monitored by sensors providing data to the smart data system. For this purpose, augmented reality devices like smart glasses (e.g. Google glasses) can compensate for deficits in the skill levels of employees, improve quality and efficiency of operations, and document manual processes to reach the target of seamlessly traced production processes for smart data analysis. Such tracking of manual processes can help production suppliers in ASEAN region fulfil the documentation needs for sustainability reports of global brands, as required, for example, in the textile and shoe industries (e.g. Nike, Adidas, and Hugo Boss).

In manufacturing, technologies like IoT could increase profit margins and reduce costs, potentially creating US$20 billion to US$45 billion of annual impact on ASEAN by 2030 (Woetzel et al., 2014). The use of IoT could improve demand for forecasting and production planning, leading to better customer service and higher profit margin. Most of the ASEAN participants in the recent workshop on Industry 4.0 conducted by the Economic Research Institute for ASEAN and East Asia mentioned that they are optimistic about Industry 4.0's ability to improve forecast accuracy that could increase revenue and resource efficiency. On the cost side, analysing detailed real time data on everything, from supplier's inventory and shipments in transit to downstream consumer demand, allows manufacturing companies to tighten inventory control and maximise production capacity. However, many manufacturing companies in ASEAN are still behind in applying the available IoT for their operations. Beyond awareness of opportunities, skill gaps appear to be an important barrier. Companies will need to recruit or groom three types of talents: workers with deep analytical skills to execute IoT, managers and analysts who know how to request and consume these analyses, and technology support personnel focused on implementation.

On the implementation of a business model for the circular economy, we can look at the example of Fuji Xerox Asia Pacific. Its project for a sustainable value chain shows how the company is transforming its operations in ASEAN from a printer manufacturer to a document services and communications solutions provider. By looking at the value chain in a holistic way, the corporation intends to reduce paper use and provide green monitoring and reporting for its customers. This is done by digital alternatives to paper like DokuWorks, by introducing scanning and workflow technologies, and by providing mobile solutions. To reach a greener, smarter, and more efficient workplace, the company is working with people, processes, and technology (Fuji Xerox Asia Pacific, 2016). One element of the circular economy helps to minimise the economic impact of resource scarcity. Considering history's most dramatic resource demand shock and emerging signs of resource scarcity, improving materials productivity is a crucial response at a company level and a self-preserving reflex at a market level.

Industry 4.0 will be having a similar groundbreaking impact on our lives and work, business models, and technologies like industrialisation, mass production, and automation. To become more competitive and an attractive economic region for business partners throughout the world, ASEAN member countries need to consider creating a similar initiative as the 'platform Industrie 4.0' in Germany. It would be helpful for ASEAN member countries to learn from other economies throughout the world and to identify suitable standards, adjust, and develop them together in a regionally suitable way. By working together, not each country would have to invest in this on its own. ASEAN could expand collaboration with other regions like the EU and the US that are cooperating together. This would also improve and speed up communication between policy, industry, science, and education to get recommended actions implemented in a timely manner and included into the extremely important education of future generations of employees, managers, and leaders at all levels. For developing economies like Indonesia, Thailand, the Philippines, and Malaysia (Ramanathan, 2016), the digital economy will enable them to connect to multinational firms' production networks. With less legacy infrastructure and fewer investments in maintaining older technologies, some of them can leapfrog towards more efficient technology rather than upgrade existing equipment.

Nevertheless, we must keep in mind that the introduction of such technology needs to be the end – not the beginning – of a well-considered chain of thoughts and actions. It means powerful IT systems need well-structured processes, which implement a corporate strategy and a successful business model. Strategies and business models have to target future potentials for success (Acatech, RWTH Aachen, Universität Paderborn, 2016).

Given ASEAN's unique context, several IoT technologies will be attractive for certain sectors but less relevant for the region. Many ASEAN member countries (with notable exception of Singapore) are starting from a relatively low base in terms of digital infrastructure, adoption, and innovation. The Readiness Index shows that only Singapore, Malaysia, and Brunei are amongst the world's top 50 countries for the quality of their digital environment and the extent of their technology usage. While it highlights the challenges ahead, it implies that the opportunity for technology-driven growth is larger for ASEAN than advanced economies.

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Chapter 6

An Assessment of Vietnamese Firms' Readiness to Adopt a Circular Economy

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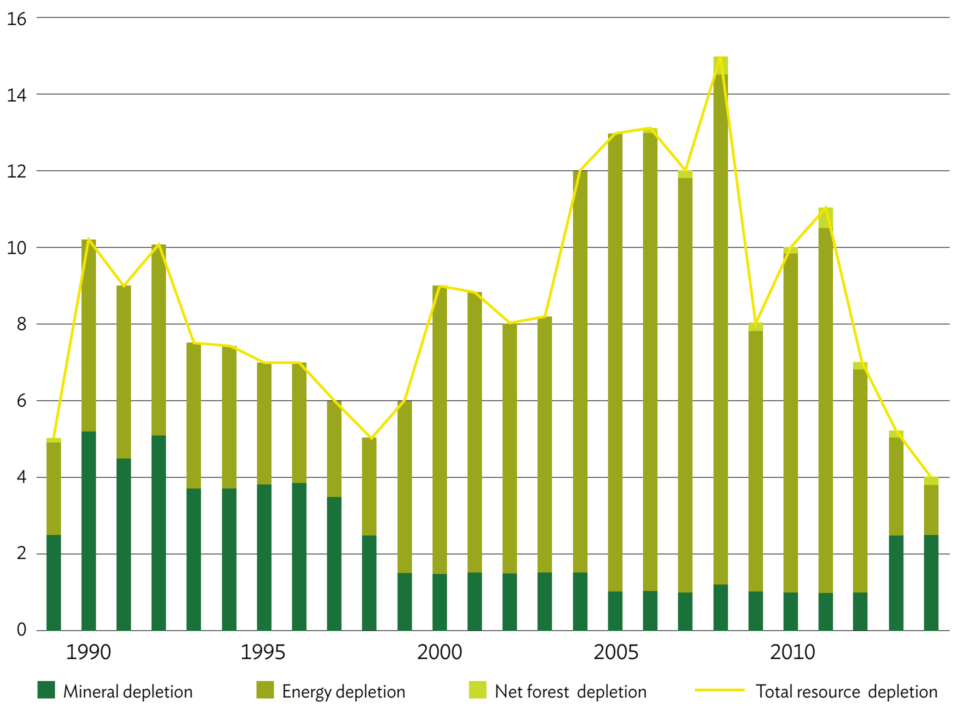
1. Introduction

Viet Nam is a development success story. It has been amongst the fastest growing economies in the world, with an annual economic growth average of 5.5% per year since the 1990s, 6.4% growth average per year in the 2000s, and continued strength with an estimated gross domestic product growth rate of 6.7% in 2015 (World Bank, 2015). Viet Nam's economy has extraordinarily come a long way in a short time. Today, it faces complex challenges that require a transition to a better development model (Breu et al., 2012) Viet Nam's economy is highly dependent on foreign direct investment (FDI), not only in terms of industrial production (FDI accounted for 50% in 2014) or exports (70% in 2014), but also in terms of ownership structure (almost 100% of enterprises have foreign capital and only 17% of the total number of FDI projects by the end of 2014 were joint venture projects with local investors) ([Tho, 2015]). Viet Nam also has very weak linkages between FDI and domestic enterprises. The main reason for such situation is that Vietnamese domestic enterprises are unable to supply qualified components and intermediate goods to FDI businesses (Tho, 2015). This situation may split the economy of Viet Nam into two separate areas – the FDI sector and the domestic sector – which may deter the spread of the FDI sector's technology and business knowledge to the entire economy (Tho, 2015). Moreover, according to the standards of the World Bank, Viet Nam has become a low middle-income country as its per capita income surpassed US$1,000 in 2008 and reached US$2,000 in 2015. In this context, Viet Nam's economy is still low and its enterprises have generally weak competition capacity and management ability. Thus, it can be said that without strong reforms, Viet Nam may fall into the low middle-income trap. These are some of the major challenges in Viet Nam's economy at present.

Viet Nam's rapid growth also came with a price (Ni et al., 2015). For over three decades, many production sectors were formed and developed, and there was an increased need for commodities, materials, and energy to boost national socio-economic development. This has resulted in depletion of natural resources, pollution in urban areas, and generation of solid wastes (Ni et al., 2015). Environmental pollution from urban and industrial wastewater leaves waterways toxic, while urban water and air pollution are beginning to pose serious health hazards, especially near Hanoi and Ho Chi Minh City, and particularly for children (World Bank Group, Ministry of Planning and Investment, 2016). Exacerbating the risks is rapidly growing energy consumption, increasingly reliant on coal-powered electricity generation. In recent years, Viet Nam's increase in greenhouse gas emissions has been one of the world's fastest (World Bank Group, Ministry of Planning and Investment, 2016).

Figure 1. Status of Natural Resources Depletion in Viet Nam 1988– 2014

Unit % of gross national income



Notes: Natural resources depletion is the sum of net forest depletion, energy depletion, and mineral depletion. Net forest depletion is unit resource rents times the excess of round wood harvest over natural growth. Energy depletion is the ratio of the value of the stock of energy resources to the remaining reserve lifetimes (capped at 25 years). It covers coal, crude oil, and natural gas. Mineral depletion is the ratio of the value of the stock of mineral resources to the remaining reserve lifetime (capped at 25 years). It covers tin, gold, lead, zinc, iron, copper, nickel, silver, bauxite, and phosphate (World Bank, 2015).

Source: World Bank, 2015.

Figure 1 shows the natural resources depletion (percentage of gross national income) in Viet Nam for 25 years. The highest peak was 14.82%, followed by a downward trend until 2014 with 3.97%, except in 2011 where depletion was recorded at 11.12%. At present, Viet Nam is facing serious air pollution problems in big cities such as Hanoi and Ho Chi Minh. Sea pollution is also a serious problem for Viet Nam. Forest resources have also been depleted by mining and furniture-making activities, causing floods and disasters.

Based on the origin of waste generation, 46% of solid waste is produced in urban areas; 17% come from industrial production, rural solid waste, and waste released by craft villages; and the remaining percentage comes from the medical sector (VEA, 2013). A World Economic Forum research in 2013 indicated that Viet Nam is amongst the 10 countries that have the lowest air quality that critically impacts human health. Waste problems have become stressful environmental, social, and economic issues that the government and people must cope with.

The pollution in Viet Nam is expected to get worse if the current pattern of industrialisation continues and no further control on the environment is activated. For air pollution nearly half of nitrogen dioxide emission is due to industrial development while sulfur dioxide emission is caused by industry (Clean Air Initiative for Asian Cities, 2010). These two substances are hazardous to both human health and the environment. According to a 2015 report by the Vietnamese government, there were 815 violations of environmental protection regulations in 2010, 393 of which incurred a total fine of D100 billion. In 2015, there were 10,900 violations of environmental protection regulations, of which 4,600 were fined a total of D358 billion. The number of violations was 17,000 (Lam, 2016).

In a circular economy, waste from factories would become a valuable input to other processes. Rather than being disposed, defunct products could be repaired, reused, or upgraded (Preston, 2012). Many countries and regions such as Germany, Japan, the European Union (EU), the United States (US), and France have launched circular economy plans (Geng et al., 2008; Albertini, 2014). The circular economy concept is especially considered and experimented in the EU where it is deemed to help reduce environmental pressures in Europe and beyond and minimise the continent's high and increasing dependence on imports. This dependence is increasingly becoming a source of vulnerability. Growing global competition for natural resources has contributed to marked increases in price levels and volatility. Circular economy strategies could thus result in considerable cost savings, increasing the competitiveness of Europe's industry while delivering net benefits in terms of job opportunities (EEA, 2016). Circular economy seems to be an essential solution for Viet Nam so it can continue to serve the growing energy and resource demands in the domestic market while at the same time decrease the pressures from waste, pollution, and climate change.

The Vietnamese people in general and Vietnamese enterprises are active and flexible agents that take advantage of spillover and learning effects from experiences of advanced countries to increase the economic value and improve competitiveness of their companies. They also follow new international development concepts/trends. However, there is a big gap between good ideas and the real possibility of implementing the proposed concepts/trends due to lack of infrastructure and human resource capabilities and finance availability, and weak cooperation between different sectors of the economy in pursuing joint goals.

Is it possible and profitable for Vietnamese firms to apply circular economy in Viet Nam? This chapter aims to answer this question by exploring the possibility of applying circular economy in Vietnamese firms using the Political, Economic, Social, and Technological (PEST) model and considering the current perception of Vietnamese entrepreneurs about circular economy. This chapter also focuses on the economic values and firms' competitiveness gained from applying circular economy business models to prove the profitability of the concept. Some successful case studies with innovative circular business models (conducted by the Business Model Canvas) will be given as proofs of the concept. Barriers and challenges are analysed in this chapter, along with suggestions for potential solutions and information provided for further study on the implementation of circular economy in Viet Nam's economy.

2. Assessing the Possibility of Vietnamese Firms Applying Circular Economy

To examine the possibility of Vietnamese firms applying circular economy even when empirical data is lacking, the authors examined firms' awareness and behaviours towards circular economy by conducting a survey of 500 enterprises, and applying the PEST tool to analyse the business environment in Viet Nam.

The concept of no-waste production was very popular in Viet Nam during the 20th century, when agriculture was the country's main industry. At that time, there was a concept similar to circular economy called the V-A-C model, which stands for *vuòn* (garden), *ao* (pond), and *chuông* (cage). This was applied in agricultural activities only, the idea being that the three factors would work smoothly with each other so that the outputs, including waste, from one process would become inputs to the other. The model was able to cover the biological materials circle of the circular economy butterfly diagram. However, after Doi Moi (1986), waves of industrialisation and urbanisation placed the country in a different situation, covering economic, social, and cultural elements. It also transitioned the whole country from a poor agricultural country to one of the most active producers of the world, focusing on light industries and processing services. Through Doi Moi, people's incomes increased and the average living standard improved such that the society became more specialised and not many people were working in paddies anymore. The introduction of advanced farming tools from foreign countries also helped speed up the progress of social specialisation. However, the abundance of assets and variety of choices in the market strongly reduced the V-A-C model as well as the natural materials recycling system from the upstream. Consequently, the biological materials circle in agricultural production was neglected for years. Nowadays, with the use of chemicals (fertilisers, pesticides) in farming, Vietnamese farmers not only break the natural circle of materials but also release more waste, even toxic waste, to the environment.

Viet Nam, like many other developing countries, has achieved very little in closing the mechanical materials circle due to its dependence on investors' technology. According to the Vietnam Environment Administration report (2014), waste reduction in production, services, and consumption is still almost neglected. However, related terms in circular economy such as cradle-to-cradle, resource efficiency, renewable energy, and cleaner production have been popularised across various industries in Viet Nam by the Vietnamese government and some development programmes. Many companies have applied cleaner production technologies and activities in their factories, although the number is still modest (less than 30% of the total companies all over Viet Nam). Recycling activities in Viet Nam today mainly depend on micro enterprises, which currently use poor tools and outdated technologies to process waste through the waste collection network of garbage buyers. Most companies that participated in the survey have not used recycled materials as inputs for production. Nor do they collect renewable end-of-life materials from their own products for recycling. Therefore, although Vietnamese firms have a good awareness of concepts related to circular economy, the application or intention to apply these concepts is still limited and not popular.

2.1. Firms' Awareness of Circular Economy Concepts

Since there are no empirical data on Vietnamese enterprises' awareness of circular economy concepts, the authors conducted a survey on this issue using a sample of 500 enterprises operating in a variety of industries in Viet Nam. We received 152 usable responses. We reached the samples through the Viet Nam Social Enterprises Network, the Creative Enterprises Club, and the Viet Nam Entrepreneurs Association. We also arranged in-depth interviews with nine enterprises. Respondents' characteristics are shown in Table 1.

Table 1. Characteristics of the Respondents

Characteristics	Frequency	Percentage
Gender		
Male	115	76.5%
Female	37	23.5%
Educational level		
College	10	6.3%
University	57	37.5%
Higher study	85	56.3%
Industry type		
Food processing	54	35.5%
Textile manufacturing	23	15.1%
Furniture manufacturing	26	17.1%
Steel manufacturing	1	0.7%
Ceramic manufacturing	27	17.7%
Cosmetics manufacturing	1	0.7%
Research and development service	20	13.1%
Positions in the organisation		
Marketing department deputy	20	13.3%
Production manager	51	33.3%
CEO	41	26.7%
CFO	40	26.7%

CEO = chief executive officer, CFO = chief financial officer.

Source: Authors' questionnaire and survey results.

The multiple-choice questions from the survey were the main data sources for the analysis. Since the awareness and behaviours of firms towards developing a circular economy are multidimensional constructs (Liu and Bai, 2014), the study should have involved specifying the construct domain, generating items, collecting data, and purifying measures, in addition to assessing reliability and validity. However, under the limited scope and timeframe of the project, we directly used the primary data to imply the actual status of firms' awareness and behaviours towards applying circular economy in their businesses.

Table 2. The Questionnaire

Question purpose	Questions
Awareness	1. Have you heard of circular economy?
	2. Do you know any other concepts of sustainable development? a. CP b. SCP c. Resource efficiency d. Renewable energy e. Green growth f. 3Rs
	3. Do you agree that circular economy can be applied in Viet Nam as a business ethic?
	4. Does your firm have willingness to: a. recycle waste within the factory b. use inputs from recycled materials c. collect used products of the company from the market to re-produce.
Behaviour	5. Has your firm used recycled materials as inputs?
	6. Does your firm apply CP technology?
	7. Has your firm worked with professional recycling companies?
	8. How much percentage of your products can be recycled or renewed?
	9. Has your firm minimised the use of materials form natural resources?

3Rs = reduce, reuse, recycle; CP = cleaner production; SCP = sustainable production and consumption.

Source: Authors.

Data were collected through emails, phone calls, or social network. A total of 152 usable responses were received.

The interview included 17 questions, six were about general information on the company and its current business model, 10 were closed questions focusing on the research purposes, and one was an open question. The 10 interview questions were:

(i) Have you heard about the circular economy concept?
(ii) Do you follow the trend of circular economy?
(iii) Have you heard about Industry 4.0?
(iv) Do you care about processing wastes?
(v) Do you intend to solve waste problems within your production process?
(vi) Do you know of any stakeholder in your product value chain who can help solve the waste or resource efficiency issues?
(vii) Do you work with any stakeholders in your product value chain who can help solve the waste or resource efficiency issues?
(viii) Do you intend to invest in cleaner production (CP) technology?
(ix) Do you intend to switch to sustainable energy?
(x) Does your company operate any social responsibility activity?

The open question was:
(xi) Do you have any suggestions to improve circular economy awareness and practice amongst Vietnamese firms? (All the respondents answered 'no' to this question.)

Almost all surveyed companies (96.2%) understand how hard the challenges caused by natural resources scarcity and climate changes are, and how price increases of raw materials and pollution will affect their revenue, threaten their business growth, and decrease their competitiveness in the market. They also understand that they are getting into a big risk given the context that many free trade agreements (FTAs) such as the ASEAN Economic Community, Trans-Pacific Partnership, and the like will take place soon, making the market more and more intensely competitive.

Moreover, the survey results showed that 82% of companies assumed that the three most significant production costs for them are labour (50%), materials procurement (35%), and fossil energy consumption (15%). Therefore, they are afraid that their company revenues would be vulnerable if one of the three factors would increase its price dramatically given increasing resource scarcity. However, these firms are still quite unclear about the possible ways to deal with the current situation towards building a sustainable business in the long term. They are not willing to innovate their business models either. According to the survey result, 78.8% of the firms' managers do not have a perception on the concept of circular economy, which explains why they have no action plan towards implementing circular economy in their business models.

About 13.3% of the firms know about some related concepts such as sustainable production and consumption, CP, cradle-to-cradle, and resource efficiency. However, their practice towards applying these concepts in businesses are very limited, particularly for CP, which has several national action programmes sponsored by the Vietnamese government. Another survey, conducted by the Ministry of Industry and Trade in 2014, showed that only 2,509 enterprises, equivalent to 28% of industrial production units across the country, were aware of the concept. This result was far lower than the initial objective of the National Action Programs.

Regarding the 'reduce, reuse, recycle' (3R) concept, 90% of the firms have clear understanding of the 3R and the environmental corporate social responsibility concepts. However, the survey revealed that a modest number of firms (21%) implemented corporate social responsibility as one of their main activities and recorded their expenses for such activities in the company's financial balance. About 62% of the responses assumed that their products had more than 40% of materials that were recyclable after use, and about 2% of which could be renewed. In reality, only 36 companies or 25% intend to collect the renewable materials for recycling/reproduction. Only one company operating in the cosmetics industry collected used packaging materials, relying on the voluntary actions of their customers to give back packaging boxes after use through the company's distribution systems, though the scale was small. This is because there is no effective collection channels in Viet Nam to help companies take their renewable elements back and Vietnamese consumers do not have the habit of separating wastes at source nor return recyclable wastes to producers through their distribution channel or by any other channels (Dao, Downs, and Delauer, 2013).

2.2. Firms' Behaviour Towards Circular Economy Concepts

The survey results showed that 75% of the participants have never procured recycled materials as inputs for their production process. Among them, 80% had no idea about a recycling facility that could provide suitable secondary materials to fit their production needs. The other 25% who responded affirmatively imported plastic granulates, the same recycled material. Processing waste after production (recycling/exchanging materials) also presented the same scenario, with 75% of the respondents stating that they had never cooperated with a professional waste processing company to find solutions for their production wastes. This may be because every industrial park in Viet Nam has its own landfill or a waste processing partner who collects unsegregated waste and either incinerates or sends them to landfills. Moreover, based on our experience, some recycling companies face many difficulties and costly procedures in securing a licence to process wastes of companies.

Outside of industrial zones, some micro enterprises process wastes at household level through a collection system of individual garbage buyers and collectors. There are some households, mostly in rural areas, that separate recyclable wastes such as plastics, paper, metals, and the like to sell to garbage buyers. Through this system, recyclable and reusable materials are collected separately and delivered to recycling facilities in craft villages. These craft villages, which recycle paper, plastics, metals, etc. from household wastes, are strongly developed and have contributed to job creation, poverty reduction, and improving people's incomes and lives. Statistics in 2003 showed that about 52,000 tonnes of plastics and 735,000 tonnes of waste metals were recycled by those craft villages in the north. However, most recycling technologies used by craft villages are out of date and have caused serious pollution that impairs people's health and lives (Yap et al., 2013).

In terms of compost production from household garbage, the number of compost production facilities is too small and thinly distributed in some big cities. The compost market has not been really developed and people still prefer to use chemical fertilisers for crop production. Despite the recent development and application of new technologies, which have been proven to be effective in recycling and treating solid wastes, the replication of these models and technologies in the entire country still requires a much larger investment from the government and the communities.

Based on our survey, nearly 50% of the survey participants (70 enterprises) have applied at least one CP technology in their factories. Moreover, 25% said that they had planned to apply cleaner technology but lacked financial resources. We believe that if these companies knew about the preferred financial loans for applying cleaner technology provided by the National Financial Ministry and the Ministry of Industry and Commerce, they would be ready to take one more step to CP. The other 25% of companies that had never applied cleaner technology were in rural areas or operate in craft villages.
On a national scale, according to a much wider survey conducted by the Viet Nam Environment Administration (VEA) in 2014, only about 200 out of 200,000 enterprises (0.01%) have been applying the CP approach, which is very effective in reducing wastes in production activities (VEA, 2014). The Ministry of Industry and Trade undertook another baseline survey of CP implementation against the objectives of the Strategy on Cleaner Production in Industry from August 2010 to February 2015. The survey was conducted in 63 provincial branches of the Department of Industry and Trade and 9,012 industrial production units in Viet Nam.

The findings from the survey are summarised in Table 3.

Table 3. **Cleaner Production Implementation Status in Viet Nam in Achieving National Strategic Objectives**

Strategy's Objective	Objective during		Situation in 2010	Situation in 2015
	2010–2015	2016–2020		
Percentage of industrial production units aware of CP application benefits	50%	90%	28%	55%
Percentage of industrial production units applying CP and able to cut down the consumption of energy, fuel, and raw materials per product unit	25%	50%	11%	24%
Level of reducing consumption of energy, fuel, and raw materials per product unit	5%–8%	8%–13%	Varying	Raw materials, chemicals: 1%–92%
				Water: 1%–99%
				Coal: 2%–98%
				DO: 1%–70%
				Electricity: 1%–68%
				Biomass fuels (firewood, rice husks): 3%–61%
				FO: 7%–43%
				Gasoline: 5%–34%
				Gas: 3%–30%
Percentage of medium-sized and large enterprises having focal points responsible for CP on-site	–	90%	–	
Percentage of full-time DoIT employees fully capable of providing guidance and advice on CP application	70%	90%	18%	73%

CP = cleaner production, DoIT = Department of Industry and Trade, DO = diesel oil, FO = fuel oils.

Source: (Ministry of Industry and Trade, Viet Nam, 2010-2015).

At the time of the survey, CP had been applied in 1,031 enterprises, equivalent to 11% of industrial production units nationwide. Among those, 309 enterprises (equivalent to 3% of the surveyed enterprises) reduced their fuel and material consumption by 5%–8%, meeting the strategy objective in the first period.

CP is widely applied and it reduced 5% of energy and material consumption per product unit in all industrial sectors. The textile and cement-brick-porcelain sectors have the largest number of enterprises applying CP (84 enterprises by each sector). Of these, 16 enterprises from the textile sector and 36 enterprises from the cement–brick–porcelain sector reduced their energy and material consumption by 5%.

3. Examining the Possibility of Applying Circular Economy at Firm Level: Application of PEST tool

3.1 Introduction to PEST Tool and its Application

Political, Economic, Social, and Technological (PEST) analysis is an important tool used for market and environmental analysis and to support the strategic decision-making of a company. It is very useful for understanding market growth or decline, business position, and potential and direction for operations (Narayanan, 2001).

PEST analysis describes the framework of macro-environmental factors used in the environmental scanning component of strategic management. The different macro-environmental overviews provided by the PEST analysis are important inputs that a company must take into consideration when conducting business strategy and planning. It is regarded as effective in long-term strategic planning and works from a macroeconomic perspective. The political, economic, social, and technological factors allow firms to get a deeper understanding of the market trends (FME team, 2013).

3.1.1. The application of PEST tool in this chapter

In applying the PEST tool, we examined the external factors in Viet Nam's business environment to see if they encourage or discourage Vietnamese firms to implement circular economy in Viet Nam.

Political factors	Economic factors
Political factors are basically how the government intervenes in the economy. Specifically, in this chapter, political factors will cover the stability of the Vietnamese political environment, focusing on the existing policy framework relating to green growth as well as environmental laws and trade policies, to see if the Vietnamese government commits to sustainable economic development. Hence, it will examine if the convergence of political factors in Viet Nam is good for the implementation of circular economy in Viet Nam or not.	Economic factors include economic growth, interest rates, exchange rates, inflation rate, and market prices of raw materials and energy, which greatly affect how businesses operate and make decisions. These factors will reflect if the circular economy concept is applicable for Vietnamese firms to apply at firm level. It also examines if the circular economy concept would increase the risks for applied firms or vice-versa by considering the transaction cost for circular economy.
Social factors	**Technological factors**
Social factors involve trends in population, domestic markets, culture, and demographics to see if the market is ready for the application of circular economy with new sustainable consumption habits. The service industry in Viet Nam will also be examined. The circular economy concept will be considered to see the benefits it can bring to the Vietnamese society, including both local wealth creation and environmental benefits.	Technology is a crucial component of any business as it determines whether it can increase productivity and compete in the market. In this chapter, the analysis will focus on research and development as well as technology transferring activities to develop better sustainable technologies. Existing types of current technology and innovation systems will be considered to find their benefits to apply the circular economy concept at firm level.

3.2. Examining External Factors that Affect the Application of the Circular Economy at Firm Level

Viet Nam has advantageous conditions in terms of its policy, economy, society (available market), and technology to develop the circular economy concept. The policy framework of Viet Nam has covered many important target groups of green growth such as resource efficiency, renewable energy, sustainable consumption, and CP. All its supporting policies aim to contribute to economic restructuring for the transformation of the growth model towards better sustainability by improving the productivity, efficiency, and competitiveness at company level. Although the political system is still weak, causing different policies that overwhelm each other, and the implementation/enforcement efforts become complicated and ineffective, the economic, social, and technological factors seem to positively respond to the green development pathway with remarkable results.

The PEST analysis below shows that Viet Nam's business environment and market are quite ready and attractive for enterprises to implement the circular economy concept at firm level.

3.2.1. Policies support the development of the circular economy

In a region of the world where some countries remain vulnerable to political and economic instability, Viet Nam has benefited from its stable government and social structure (Ernst and Young Viet Nam, 2013). Therefore, the Vietnamese political environment is considered safe for operating businesses.

Regarding the political environment, Viet Nam has an extensive legal framework that supports scientific activities, innovation, and technology transfer towards a better sustainable development in various industries. It also has an open trade political framework, with FTAs with developed countries, and sustainable production and consumption policies. These will be considered to see how they affect the circular economy concept application in Viet Nam.

In this section, the authors give an overview of these policies to prove that circular economy can also be encouraged in Viet Nam as it is the umbrella term for all other sustainable production and consumption activities.

3.2.2. Policies on CP

CP issues have been put on the political agenda in this century. Viet Nam's prime minister has issued the 'strategy on cleaner industrial production to 2020' in his Decision 1419/QD-TTg on 7 September 2009. The overall objective of the policy is to observe CP in all industrial production establishments to improve the use of natural resources, materials, and fuels; minimise emissions and curb pollution; protect and improve the quality of environment and human health; and secure sustainable development. To achieve this, government offices have issued many activities such as communications solutions to improve awareness; solutions relating to organisations, management, mechanism, and policy; technical support, human resource training, and international cooperation; and investment and financial solutions.

In terms of resource efficiency, the National Assembly promulgated the Law on Economical and Efficient Use of Energy on 17 June 2010, pursuant to the 1992 Constitution of the Socialist Republic of Viet Nam, which was amended and supplemented under Resolution No. 51/2001/QH10. This law aims to state management policies on the economical and efficient use of energy at firm level in Viet Nam, particularly the application of measures to use energy economically and efficiently for socio-economic development; the provision of financial support and energy subsidy and other necessary incentives to promote economical and efficient use of energy; the increase of investment in scientific research, development, and application of advanced technologies using renewable energy; the encouragement to use energy-saving devices and equipment, eliminating back-dated technologies and low energy yield devices and equipment; and the encouragement to develop counselling services and rational investment in information dissemination, education, and support for organisations, households, and individuals to use energy economically and efficiently.

The renewable energy issues, a concern since early 2007, have been addressed by the prime minister with the issuance of Viet Nam's national energy development strategy 2020, with 2050 vision, on 27 December 2007. Its overall objective is to contribute to successfully fulfilling the tasks set in the Communist Party of Viet Nam's socio-economic development strategy. The overall objectives of the national energy development strategy are to assure national energy security, contributing to firmly maintaining security and defense and developing an independent and self-reliant economy; supply adequate high-quality energy for socio-economic development; exploit and use domestic energy resources in a rational and efficient manner; diversify forms of investment and business in the energy domain and develop an energy market conducive to fair competition; boost the development of new and renewable energies, bio-energy, and nuclear power to meet the requirements of socio-economic development, especially in deep-lying, remote, and border areas and offshore islands; and develop the energy sector in a quick, efficient, and sustainable manner in line with environmental protection.

3.2.3. Policies on sustainable development vision

Many policies encourage sustainable production at firm level in Viet Nam. Based on the Viet Nam 2035 vision report by the World Bank and the Ministry of Investment and Planning (2016), growing economic prosperity in accordance with the protection of environmental sustainability is one of the three main pillars to establish a sustainable economy in Viet Nam. This must-have vision was first mentioned in 2012, when Viet Nam's prime minister issued Sustainable Development Strategy 2011–2020, which sought to maintain sustainable economic growth; gradually carry out green growth, develop clean renewable energies, and ensure the development of low-carbon economy as well as guarantee national energy security; gradually implement market-oriented energy prices; gradually raise the ratio of clean and renewable energy in the energy consumption structure; design an environmental-economic cost accounting system and add environment and social aspects to the system of national accounts; pursue sustainable development in the industrial sector with professional structure, environmentally friendly technology and equipment; proactively prevent and handle industrial pollution; develop 'green industry'; give priority to the development of sectors, technologies, and products that are environmentally friendly and speed up high-technological development in big cities; gradually formulate environmental industry; intensify mass application of CP to increase the efficiency of natural resources, materials, energy, and water while reducing emissions and pollution rate; and protect the quality of the environment and people's health for sustainable development (Viet Nam Government Portal, 2012).

3.2.4. Policies on establishing eco-industrial parks

In August 2014, the prime minister approved the project 'Implementation of eco-industrial park initiative for sustainable industrial zones in Viet Nam'. The objectives of Decision No. 1526/QD-TTg are to strengthen the transfer, application, and dissemination of technologies and CP methods to reduce hazardous wastes, greenhouse gas emissions as well as water pollutants; and to better manage chemicals in industrial zones in Viet Nam (Ministry of Planning and Investment, 2014). The project led to some specific results:

- Issued several policies and regulations that meet the criteria of eco-industrial park in the fields of industrial park planning and management, environmental pollution control, industrial pollution in the industrial zones, responsibility and investment support methods of the stakeholders for investing in clean-technology activities, and low carbon emissions of the industrial park businesses, encouraging the participation of many firms to the eco-industrial park ideas.
- Strengthened the planning and management of eco-industrial parks for the industrial park management agencies at central and local levels.
- Strengthened the technical capacity for technology transfer and application of clean technologies and low carbon emission, safe production methods, and effective use of resources for the management agencies of industrial zones and businesses in the industrial parks such as industrial zones in the provinces of Binh Duong and Quang Ngai; industrial zone for high-tech companies in the cities of Ho Chi Minh, Hanoi, and Bac Ninh; software industrial zone in Ho Chi Minh city and so on.
- Identified potential businesses in the industrial park that can participate in clean technology applications, low carbon emissions, and technical solutions to use resources effectively and develop projects to strengthen community capacity.
- Converted model projects into eco-industrial parks.
- Increased community awareness about ecological industrial zone development.

3.2.5. Policies on sustainable production and consumption

On 11 January 2016, the prime minister issued the National Action Program on Sustainable Production and Consumption through 2020, with a Vision Toward 2030, through Decision No. 76/QD-TTg. The overall objectives of the national action programme are to gradually change production models and consumption towards enhancing efficiency of resources and energy; increase the use of raw materials, renewable energy, environment-friendly products; reduce, reuse, and recycle waste; and maintain the sustainability of the ecosystem at all stages in product life cycle (PLC) from extraction of raw materials to the production, processing, distribution, consumption, and disposal of products.

This policy states clear specific objectives through each period, encouraging Vietnamese firms to innovate to strive for the same goal of developing a sustainable production and consumption society in which both producers and consumers are key players to decide the result of the action programme.

The Vietnamese government also issues new laws on environmental protection with more strict regulations and higher responsibility level for companies whose operation activities may harm the environment. The most significant change is the issuance of by the prime minister of the new law on environment protection, Decision No. 55/2014/QH13, on 23 June 2014. This law hastens environment protection especially in manufacturing, trading, and service provision within economic zones, high-technology zones, and other business zones.

3.2.6. Active and open policies on international trade and international integrations

Viet Nam became a member of the World Trade Organization in 2007. Since then, Vietnamese manufacturers have not only approached many export markets with fewer restrictions and lower tariffs but have also gained many benefits from improving access to imports of cheaper raw materials and semi-processed inputs as Viet Nam's import tariffs drop. The active participation of Viet Nam in many cross-border FTAs is also a competitive advantage that contributes to the development of the economy and creates good conditions for enterprises to improve their competitiveness through spillover effects and learning effects from FDI projects. Viet Nam now has economic relations with 224 countries and territories. According to the Viet Nam Chamber of Commerce and Industry, Viet Nam signed 12 FTAs, including the Trans-Pacific Partnership, and ASEAN, ASEAN–India, ASEAN–Australia/New Zealand, ASEAN–Korea, ASEAN–Japan, ASEAN–China, Viet Nam–Japan, Viet Nam–Chile, Viet Nam–Korea, Viet Nam–Eurasian Economic Union, and Viet Nam–EU free trade agreements. These international integrations usually go along with strict regulations and limitations on environmental activities and technological added value within products, which force the domestic companies to change production processes and improve productivity as well as product quality to meet the common environmental requirements of these agreements. These types of markets bring good opportunities for Vietnamese enterprises to approach new markets (customers) by innovating business models, creating new products/services, and following the world production and consumption trends, including circular economy. The intense competition with foreign competitors already following the world trends and global standards also creates pressure on Vietnamese companies to improve themselves via learning effects, hence encouraging the whole industry to adopt global economic trends. To utilise the advantages of these FTAs, the country should continue to improve the regulation systems and reform the institutions. The Vietnamese government should continue to complete institutions related to ownership and development of economic sectors as well as business types and improve policies to boost the growth of enterprises and the synchronous development of all kinds of market (Hoa, 2016).

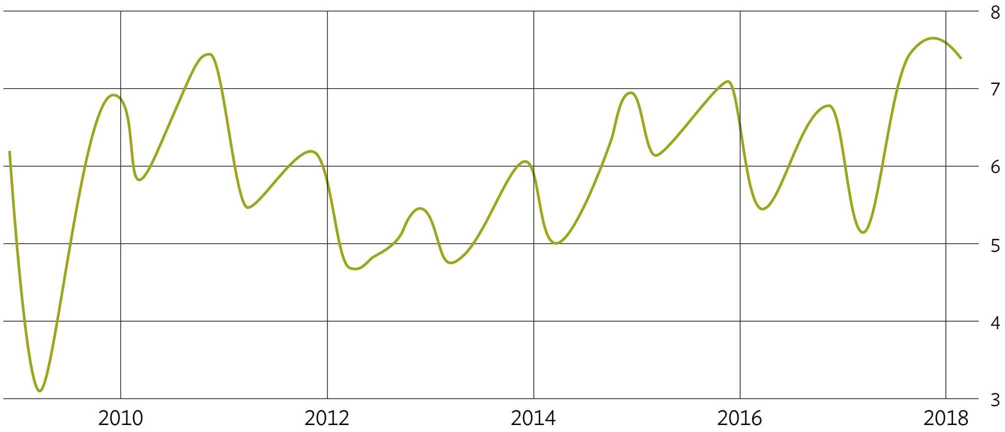
Many cross-border FTAs between Viet Nam and the global south countries, such as the Trans-Pacific Partnership, Viet Nam–EU, etc., as well as between Viet Nam and ASEAN countries such as the ASEAN Economic Community, ASEAN+, etc., have shown convergence of political factors committing to the sustainable development in the long term in Viet Nam. Therefore, circular economy, as a new effective concept of doing business in a sustainable way, should absolutely be encouraged by the development of the political framework of Viet Nam.

4. Prevalent Economic Factors

Viet Nam is at the top of the gross domestic product growth leader board in Southeast Asia-based on FDI and the private sector (Uyen, 2015).

According to the General Statistics Office of Viet Nam, 2017, the country has achieved a relatively stable high speed of economic growth. In 2017, Viet Nam witnessed an economic growth of 6.8%, exceeding the target set by the National Assembly. In 2018, the government targeted 7% growth (Figure 2).

Figure 2. Viet Nam's GDP Annual Growth Rate



GDP = gross domestic product.

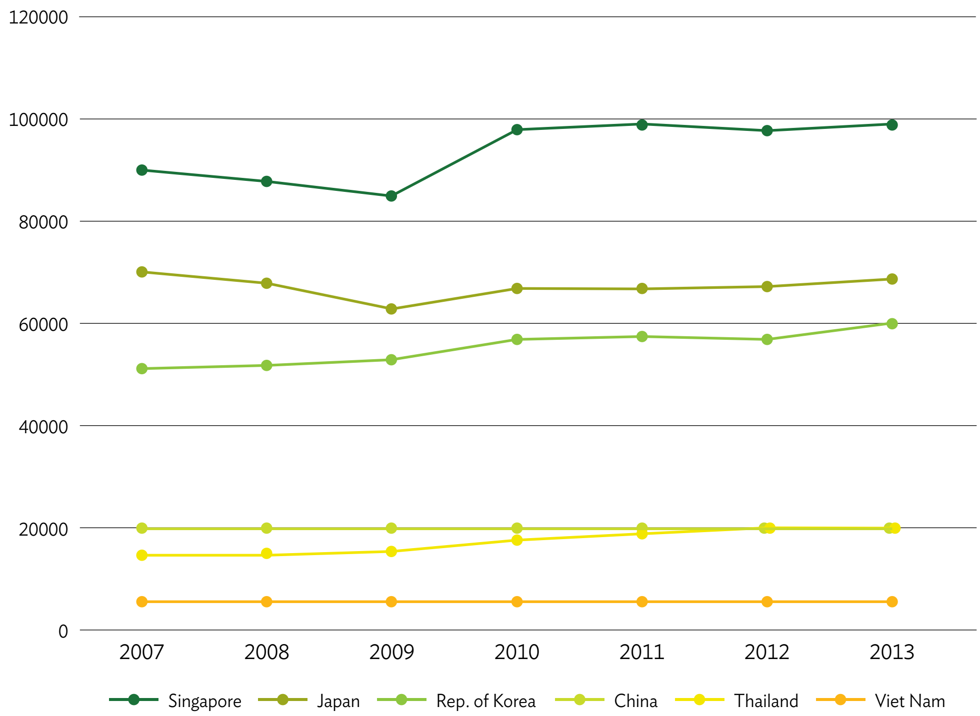
Source: Graph – tradingeconomics.com; Data – General Statistics Office of Viet Nam.

In recent years, inflation and interest rates in Viet Nam fell dramatically while a relatively high growth was seen in its exports. In addition, the macro-economy continues to be kept stable, with inflation constrained at 4% while FDI growth is expected to increase the amount of FDI disbursement to more than US$17 billion (State Bank of Viet Nam, 2015) .

Viet Nam also retains a 'measured depreciation' of the dong over the years. The Bank of Viet Nam devalued the Vietnamese currency three times in 2015, pushing the dong down nearly 6% against the US dollar (Varathan, 2015). That move brought advantages to Vietnamese enterprises, especially exporters.

In terms of labour cost, although Viet Nam's current monthly minimum wage of US$96–US$138 seems to remain wage-competitive in comparison to the minimum wages of other Asian countries such as Cambodia (US$121.90), China (US$135.43–US$296.96), and Thailand (US$265.68) (Shira, 2015), it does not reflect the exact labour cost in Viet Nam because the average productivity of Vietnamese workers is still low and the added value created by Vietnamese workers is low as well. Viet Nam's productivity is still considered below the regional average (see Figure 3). As of 2013, the productivity of a Vietnamese worker was US$5,440, whereas it was 2.8 times higher in Singapore, which recorded a productivity of US$98,720 or 18 times higher (Phuong, 2016). This situation urges Vietnamese enterprises to consider circular economy, which encourage them to apply new business models, processing technologies, as well as creative and utilised product designs to decrease production cost while increasing the value added of each selling unit, so that they will be free from depending on the productivity of the domestic labour market.

Figure 3. **Productivity of Asian Countries**



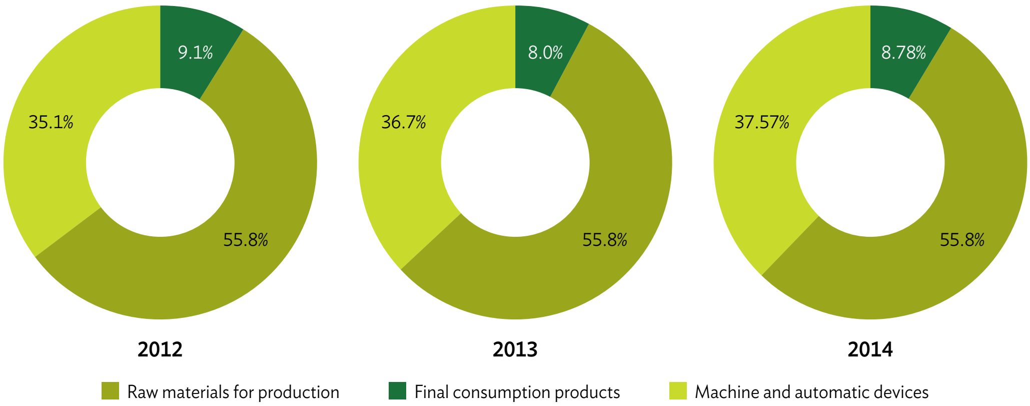
Source: Asian Productivity Organization, databook 2015.

In conclusion, Viet Nam has a very active and dynamic economic environment that performs a high rate of economic growth, operates a competitive market with various trading partners from different countries, and provides an advantageous depreciation currency system.

Therefore, the Vietnamese economy has many domestic advantages in terms of stable economic growth, with low risks to apply the circular economy trend. It can also get the chance to develop circular economy models and sell innovative products in huge common markets under the advantageous conditions set in the free trade deals between Viet Nam and foreign countries such as the EU, the US, Japan, the Republic of Korea, and ASEAN.

Besides these encouraging factors, there are also many existing situations and challenges that force Vietnamese enterprises to consider circular economy as a solution to reform their companies and the way they do business. Currently, due to underdeveloped auxiliary industry, Viet Nam's industry mainly focuses on providing processing services operated by labour-intensive business models. Only some 300 Vietnamese enterprises are qualified to participate in the global supply chain but most of these only provide spare parts and have not been involved in main production (Dione, 2017). This leads to the high dependence of domestic enterprises on imported raw materials for production. According to the Viet Nam Ministry of Industry and Trade, more than half of the imported goods in Viet Nam are raw materials for production (see Figure 4). Most of the imports are from China, ASEAN countries, and Middle East countries. Therefore, Viet Nam's economy is extremely vulnerable to changes in prices of raw materials as well as exchange rate fluctuations.

Figure 4. Viet Nam's Import Structure in 2012, 2013, and 2014



Source: The Ministry of Industry and Trade, Viet Nam, 2015.

Viet Nam is facing energy shortage challenges. Imported energy could account for 37.5% of its total supplies in 2025 and more than half (58.5%) in 2035 (Embassy of Denmark, 2017). Viet Nam's demand for electricity has increased dramatically over the last 10 years while its electricity generation still depends on thermal coal. More than 80% of the total electricity comes from thermal coal while the other 20% is shared by hydropower and gas. The dependence on thermal coal is intended to continue in the next 10 years, with more than 50% electricity yield planned to be generated by thermal coal (Vietnam Sustainable Energy Association, 2016). In the vision to 2035, the forecast for total final energy demand in the business-as-usual (BAU) scenario is nearly 2.5 times higher than in 2015. In 2035, energy consumption in the transportation sector (covering 27.5%) is projected to achieve the highest growth (5.7% per year), while the industrial sector (covering 45.3%) is expected to see growth of 5.0% per year in the period 2016–2030 (Embassy of Denmark, 2017). This will surely put domestic enterprises under pressure from rising prices of electricity.

The above challenges show the vulnerability of Vietnamese enterprises to changing prices of raw materials and energy now and in the future. However, these difficulties strongly motivate Vietnamese enterprises to innovate their business and operational models towards smarter and more sustainable ways. In this case, the circular economy concept can be considered a very good choice for them to help save materials and energy, and hence reduce both production costs and dependence on imported raw materials.

With the existing 301 focused industrial parks and company clusters along the country, the transaction cost for the company and a group of companies in a cluster switching to the circular economy concept is not high.

Therefore, Viet Nam's economic factors now and in the future are very supportive of Vietnamese companies adopting the circular economy concept.

5. Social Factors Affecting the Application of Circular Economy in Viet Nam: The Consumers' Consumption Behaviours Towards the Circular Economy Value

Viet Nam is an emerging and potential market for new and innovative products. Its population is approximately 91.7 million, with 70% aged between 15 and 64, and this is expected to continue (World Bank, 2015). According to the Ministry of Education and Training of Viet Nam, the country's literacy rate also reached 97.3% by the end of 2015. Moreover, the number of consumers in middle-income class are predicted to double in size between 2014 and 2020, from 12 million to 33 million people (Amcham Viet Nam, 2017). These factors will spur the demand for greater selective choices in products, brands, and product categories (Deloitte, 2014), which require products of high quality, sophisticated design, and better environmental friendliness.

The tertiary sector of Viet Nam's economy has been growing very fast over the last decades, especially for business services and retail services. Although the service industry only officially appeared in Viet Nam after Doi Moi due to the manipulation of state-owned enterprises under the previous subsidy regime (1976–1986), it still achieved incredible breakthrough developments and significantly contributed to the dynamic economic development nationwide, especially after Viet Nam joined the World Trade Organization in 2007. The service sector is quite varied and helpful, including banking and finance, insurance, logistics, consulting services, legal services, tourism, retailing services, and some offshore services such as data analysis, business process outsourcing, and information technology. In 2015, the share of the services sector in the national GDP was 44%. This was its highest share compared to the industry (39%)

and agriculture (17%) sectors (Viet Nam GSO, 2016). The development of the service sector also promotes the development of the infrastructure system in Viet Nam. Hence, it creates many social positive effects and increases the attractiveness of the domestic business environment. The retail sector in Viet Nam is also dramatically developing, growing at a healthy double-digit rate of approximately 10% year-on-year in 2013, regardless of the global economic slowdown in that year, beating the neighbor economies of Malaysia (7%), the Philippines (7%), Singapore (3%), and Thailand (1%) (Deloitte Southeast Asia, 2014). Recently, Viet Nam's retail sector achieved impressive growth of about $129.6 billion in 2017, up 10.6% from 2016 (Bradstreet, 2018). These achievements have been drawn by Viet Nam young population, of which 70% are aged between 15-64 years old and 64% are females, who are most involved in shopping and day-to-day consumption decisions (World Bank G. , 2018). The business environment for consumption products in Viet Nam is thus very efficiently supported and highly competitive.

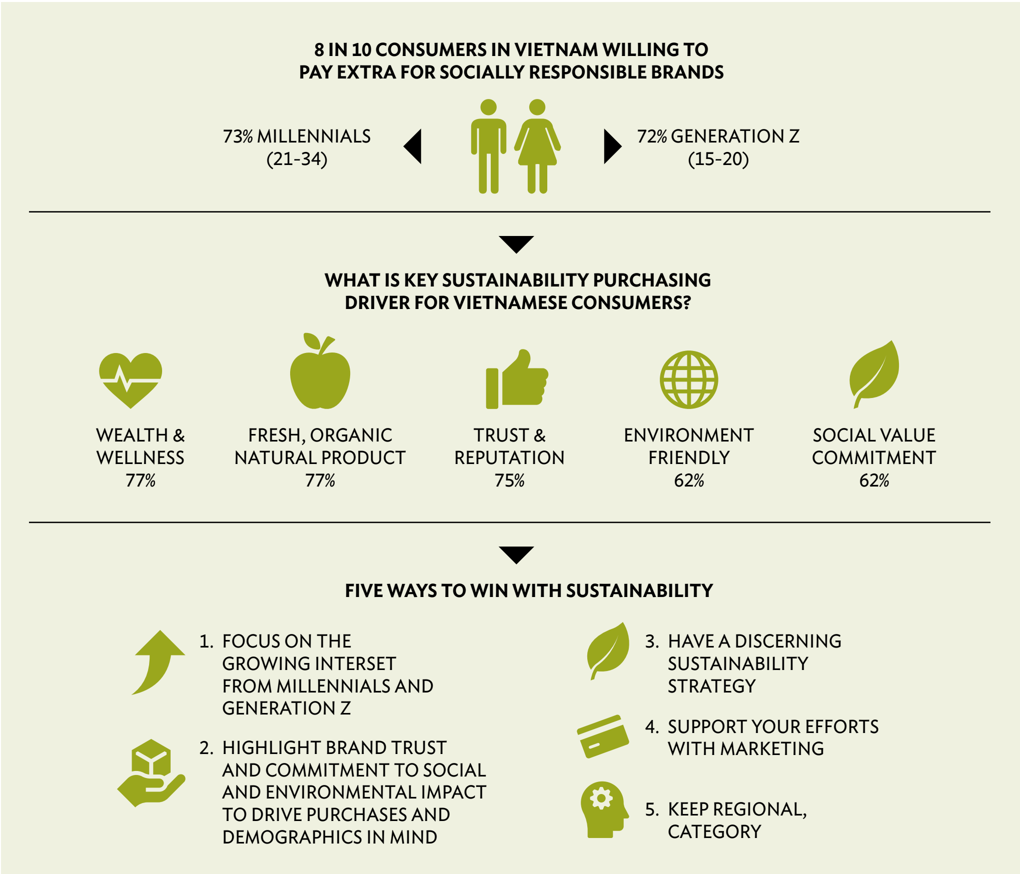
Powered by huge waves of FDIs and FTAs as well as the promising prospects offered by the new cross-border FTAs such as the Trans-Pacific Partnership, the ASEAN Economic Community, the EU–Viet Nam Free Trade Agreement, etc., ASEAN countries are more likely to keep more foreign investors interested in them. FDIs that flowed into the tertiary sector of Viet Nam's economy was 32.6% of the total number of projects by 2015 (Viet Nam GSO, 2016) and soared by 6.3% year-on-year by May 2016 (Viet Nam GSO, 2016).

The above evidence proves that the Vietnamese market has a great potential and is dynamic and profitable not only for Vietnamese enterprises but also for future FDIs.

The environmentally preferred purchasing, often referred to as 'green purchasing', is an emerging global trend. This trend is considered as a strategic alternative for all stakeholders in society to promote the sustainable development of the global production chain with the active involvement of consumers. Although this approach is still at its infancy in Viet Nam, Vietnamese consumers have recently demonstrated, especially in big cities, their environmental concerns, as evidenced by the increase in purchase of green products, which can save energy and water spending while at the same time reducing the environmental impact (Giang and Tran, 2014). The market for green/sustainable products in Viet Nam has high potentials. Nielsen conducted in 2014 a comparison of countries in the ASEAN region (Figure 5) and found that Vietnamese consumers lead in having a social spirit towards sustainable development. The report also found that consumers in Southeast Asia exceed consumers in other areas in terms of the willingness to pay more for products/services that are committed to sustainable development.

The report (Nielsen, 2014) shows that nearly nine out of 10 consumers (86%) surveyed in Viet Nam are willing to pay more for products/services with commitment to sustainable development (compared to 73% in the 2014 survey). This is also the general trend in other countries in the region such as the Philippines (83%), Thailand (79%), and Indonesia (78%). The figure for the whole of Southeast Asia is 80%.

Figure 5. Vietnamese Consumers' Behaviours Towards Sustainable Consumption

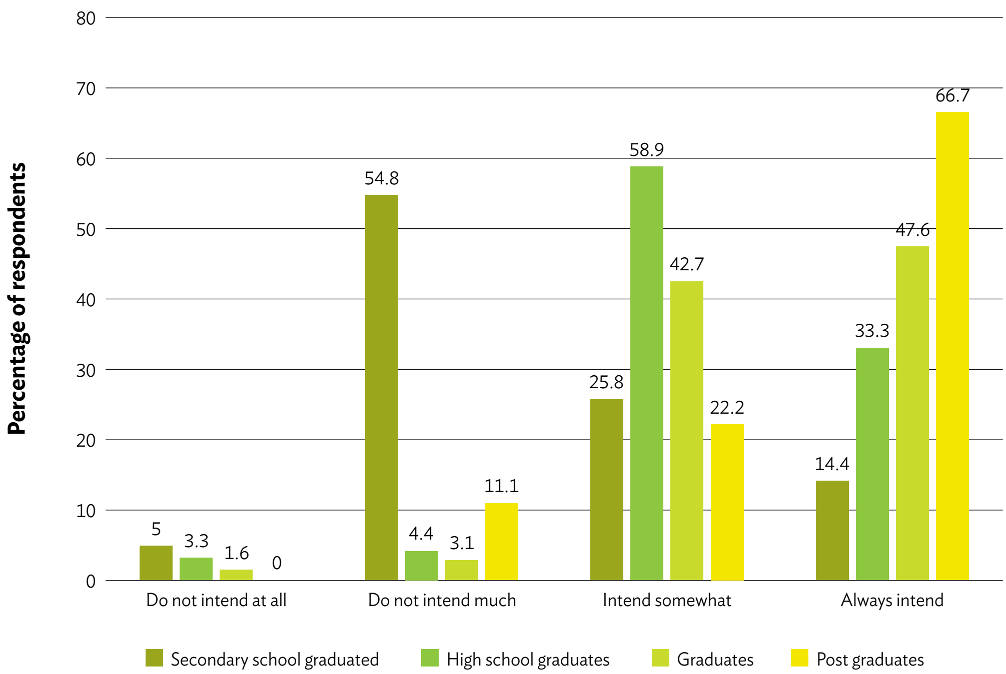


Source: Nielsen, 2014.

The report also points out that the youth sector is the sector most concerned about sustainability and that affects the sale of products/services committed to sustainable development. Specifically, over 73% of global consumers aged 21–34 (millennials) and 72% of consumers aged 15–20 (Generation Z) are willing to pay more to buy products/services with commitment to sustainable development. According to the Nielsen report, sales of products with sustainable development commitments increased by 4% globally compared to the 2014 figure.

However, since green products (eco-products) are relatively new for Vietnamese people and the choices limited for green products in the market, the use of sustainable products or eco-products is not popular or obvious in Viet Nam. The results of a survey by Giang and Tran in 2014 on the consumption of green electronic products show that more than 75% of the 263 respondents have never bought a green electronic product before and more than 50% of the respondents do not care whether the electronic products are green or not (Giang and Tran, 2014). According to another survey, conducted by Hai and Mai in 2012, with 315 participants, there is a new trend of consuming eco-products in three big cities (Hanoi, Ho Chi Minh, and Da Nang). The trend shows that only consumers with a high level of education are more concerned about environmental issues and have sufficient knowledge of eco-products and green purchasing. The others have limited understanding of eco-products. As a result, consumers with different levels of education differ in their purchase of green products or eco-products.

Figure 6. Intention to Buy Eco-products



Source: Hai and Mai, 2012.

The research also shows there are several more important factors that consumers consider when making an eco-product purchase. These include descriptions on products, and information from television and the internet. Graduates and post-graduates seem to consider all factors when making a purchase.

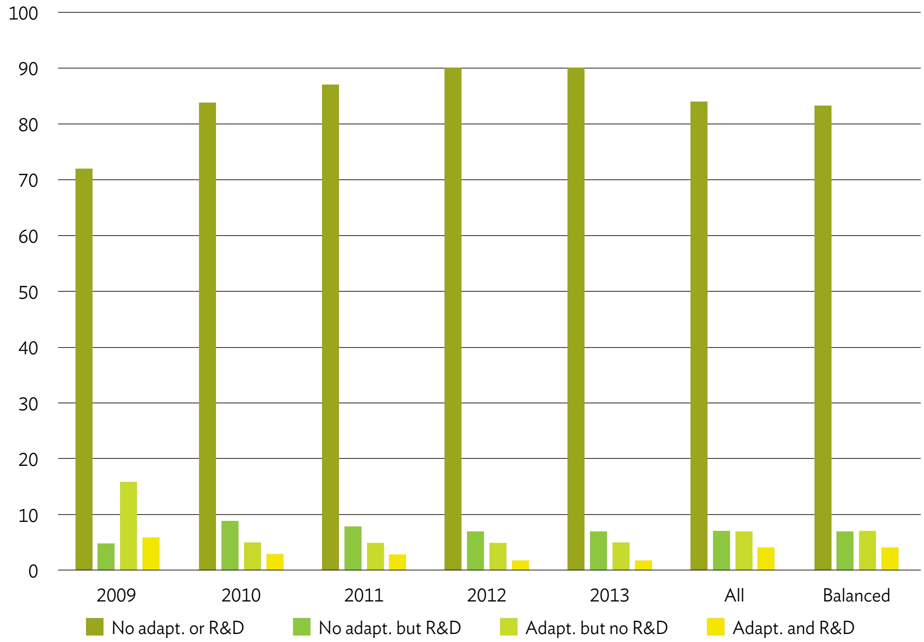
These prove that the market potential for innovative, sustainable, and high value added products, such as the ones with circular economy characteristics, is indeed very large and possible in Viet Nam. There is, therefore, much room for Vietnamese companies to apply the circular economy concept to their business model as an innovation advantage (or what can be referred to as first-mover advantage) to promote their products and grasp the large potential market shares in Viet Nam, against foreign competitors.

6. Technological Development Trends: What is the Progress of Technology Innovation Towards Circular Economy?

Although Viet Nam's policy framework seems to bring pull factors to encourage firms to apply circular economy in their business model, particularly to new advanced and clean technology in production processes, and the market is gradually following sustainable consumption trends, not many firms invest in innovating (researching and developing new technology) or adapting (receiving technology transfer from other organisations) new clean and advanced technologies.

According to the 2009-2013, Technology Competitiveness Survey of around 7,000 companies about research and adaptation on technology, most companies do not engage in any technology research and development (R&D) or adaptation activities (depicted in Figure 7). Only 7% of firms pursue either R&D or adaptation, while 3% of firms operate both R&D and adaptation to innovate their production chain.

Figure 7. **Share of Firms Doing Research on and Adaptation of Technology (Unit in %)**



Adapt. = Adaptation, R&D = research and development.

Source: General Statistics Office, Viet Nam, 2015.

We noticed a declining trend in adaptation and R&D activities, with adaptation declining sharply from 16% in 2009 to 3% in 2013. R&D activities have returned to 5% after peaking at 8% in 2010. Overall, 83% of firms do not have an adaptation or R&D strategy. Complementary with the goals of increasing the productivity of the Vietnamese manufacturing sector, the findings presented so far suggest that industrial policies have not offered strong enough support for firms to invest in adaptation of technology as it appears to be more costly in the short run. With productivity gains attributed to advanced technologies, it is possible that greater policy support of adaptation would lead to increased productivity, hence the competitiveness amongst manufacturing enterprises.

In terms of Industry 4.0, despite Viet Nam having at least three high-technology industrial parks, none of the companies operating there is of Vietnamese ownership. All the industrial parks have been built so far to attract foreign high-technology companies as well as FDI for high-technology development. These industrial zones were established with the vision that Vietnamese enterprises can take advantage of the horizontal and vertical technology transfer as well as improve the capacity of Vietnamese engineers. Therefore, it is very hard to conclude that the development of Industry 4.0 in Viet Nam is ready to be the foundation for circular economy development.

7. Profitability of Circular Economy: Finding Economic Values and Firm Competitiveness of Circular Economy Through Case Studies

7.1 Indicators to Assess the Economic Values and Competitiveness of a Firm in Circular Economy

In this chapter, we used the definition of a firm's economic value from *The Principles of Microeconomics* by Gregory Mankiw, which states that 'economic value is assessed based on the people's preferences, represented by the maximum amount a consumer is willing to pay for an item in a free market and the trade-off value, which is the amount of time or value of the other item an individual will sacrifice to get that item.' Therefore, we examined the economic value of a firm based on its ability to generate revenue, business growth rate, and market share volume.

Definitions differ, but normally, firm competitiveness is defined as the ability to face competition and to be successful when faced with competition. Competitiveness would then be the ability to sell products that meet demand requirements (price, quality, and quantity) and, at the same time, ensure profits over time to enable the firm to thrive. Competition may be within domestic markets (firms or sectors in the same country are compared with each other) or international (comparisons are made between countries). Competitiveness is therefore a relative measure. It is also a broad concept and there is no definitive agreement on how to measure it precisely. To assess a firm's competitiveness in circular economy, we used the following characteristics:

- possesses new innovative/creative solutions to the market: ability to gain market share at high speed;
- minimises production cost: focuses on the ability to avoid the hassles and to procure new raw materials, labour, capital, and energy; and
- the business model is flexible to sudden spike of commodity price.

Applying the circularity calculator tool developed by the Ellen MacArthur Foundation, we calculated the economic impact of moving to a circular system at the product level in five case studies. In addition, we included quantitative data on the business result of these companies to prove their economic values and firm competitiveness gained from circular economy.

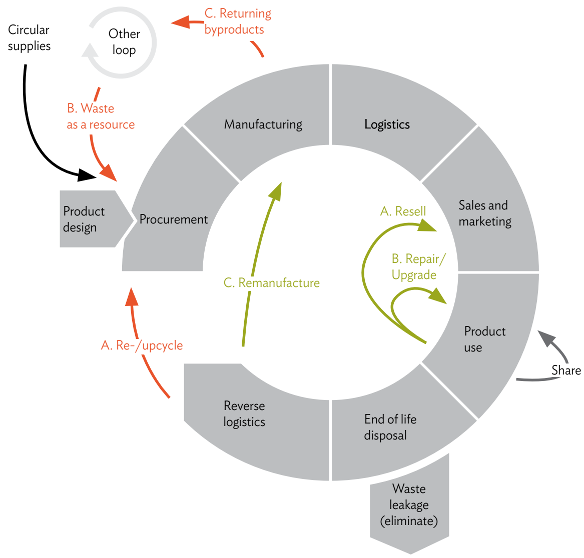
7.2. Finding Economic Values and Capturing Competitiveness of Enterprises Applying Circular Business Models in Viet Nam

Though not many companies acknowledge knowing exactly the term circular economy, a variety of circular business models in Viet Nam have been proven to not only improve firms' economic value and competitiveness but also to generate many good externals for society as well as the environment.

According to the five business models of circular economy identified in the 2014 Accenture report *Circular Advantage* by the National Zero Waste Council Circular Economy Working Group, different types of circular business models exist in Viet Nam.

Figure 8. The Five Business Models of Circular Economy

- **Circular Supplies:** Provide renewable energy, bio based or fully recyclable input material to replace single-lifecycle inputs.
- **Resource Recovery:** Recover useful resources/ energy out of disposed products
- **Product Life Extension:** Extend working lifecycle of products and components by repairing, upgrading and reselling
- **Sharing Platform:** Enable increased utilization rate of products by making possible sgared use/ access/ownership
- **Product as a Service:** Offer product access and retain ownership to internalize benefits of circular resource productivity
- **Can be applied to product flows in any part of the value chain*



Source: Accenture, 2014.

Case Study 1: Circular Supplies Business Model: Hamona Limited Company – How a coconut fruit can decouple the relationship between high growth rate and environmental pollution

The company name Hamona is an abbreviation of 'Harmony with Mother Nature' and is inspired by the strong willingness of the circular economy to build a good business, gaining high revenue while not harming nature, and helping the environment, particularly the natural sources of the company, to be more healthy and sustainable. It is one of the big success stories that prove the possibility of decoupling economic development without destroying the environment.

Hamona Ltd. was founded in 2013, with fresh coconuts as its main product, processed through bio-technology without affecting its natural taste and using no package (except for the reusable plastic tray for delivery purposes). It has 50 employees, of which 80% are local labourers.

Hamona operates a very innovative business model. It signs farming contracts with coconut farmers in Ben Tre and Tra Vinh provinces, provides technical support and financial services to farmers so they can follow the GLOBAL G.A.P. cultivating standard, and then buys all the coconut fruits from contracting farms at stable prices all year long. After processing, the by-products are collected and processed to make clean soil and organic fertilisers to be returned to the coconut farms. Hamona also provides financial services to farmers to encourage them to build ecosystems under the coconut shade, such as growing beans, chickens, and bees to maintain the natural biodiversity, develop the natural enemies of harmful insects, and utilise by-products to make fertilisers and increase the productivity of coconut trees. This activity also helps to increase the income for farmers, especially in between two coconut harvesting seasons. To avoid monopoly, Hamona's contract with farmers only lasts for a year. Hamona's main revenue comes from selling the processed coconut to wholesalers in domestic markets and the US.

After two years of implementing the business model, Hamona has signed contracts with more than 550 coconut farms in Ben Tre and Tra Vinh provinces. Their revenues increased by more than three times from US$50,000 per year in 2014 to US$250,000 at the end of March 2016. Its exports–domestic sales ratio was recorded as 60:40 in 2016. Its strategic goals in the next three years are to build a coconut farm network of more than 2,000 households to assure stable and high-quality raw materials, successfully establish export markets in Japan and the Republic of Korea, and create jobs for more than 2,000 women in the Mekong Delta area.

In terms of competitiveness, Hamona surpasses its competitors in innovative and varied high-quality products from coconut, in close relationship with a firm network of GLOBAL G.A.P. coconut farms and the addition of value over the product value chain. Moreover, Hamona has the first-mover advantage in the market in terms of processing fresh coconut by applying bio-technology. Hamona differentiates its products as the most natural and fresh coconut water without preservatives, additives, and chemicals. Hamona also has competitive advantage over cafés in that it serves fresh juices in convenience stores. Customers can bring Hamona's coconut anywhere, drink fresh coconut water anytime they want without paying any service fees. Moreover, Hamona implements corporate social responsibility by contributing to the leasing of financial funds for farmers.

Case Study 2: Product as a Service: The Case of Viet Lien

The Viet Lien Investment and Commerce Limited Company (hereinafter called Viet Lien) was founded in 2005 with a factory located in the guava-growing area and new community tourism site of Cu Khoi Ward, Long Bien District, in Hanoi. It has 38 employees producing dried guava tea and guava bio-dishwashing soap that are sold all over the country. Its average annual revenue, entirely from the domestic market, is about US$620,200 per year. Viet Lien's products have always been the first choice of Vietnamese women because of their safety, quality, unique use experience, and reasonable prices. However, in the last 7 years, the use of chemical fertilisers and toxic pesticides in local guava farms has become worse, resulting in the accumulation of toxic materials in Viet Lien's products. As a result, the sale of its products dramatically decreased, with sale activities facing great difficulties. Moreover, soil erosion and insect attacks on their farms occur more frequently and more severely. Consequently, the price of the raw material supplies of Viet Lien (guava fruit and guava leaves) increased while their quality and quantity decreased. This situation forced Viet Lien to innovate its business model, develop high-quality supplies, and find new markets.

In October 2015, Viet Lien applied a new innovative business model, where farmers are both the customers and key suppliers of the company. It provides services for farmers in processing their standard guava raw materials into guava tea and guava bio-dishwashing soap under the local brand name Cu Khoi Guava. It also continues to sell processing products from safe and tasty guava to the domestic market. To operate this business model, the company works with local government representatives (particularly agricultural development officers) to operate technical hubs that provide technical support, cultivation consultancy, and non-chemical agricultural inputs such as organic fertilisers, bio-pesticides, and the like. These technical hubs help enable farmers to cultivate their guava farms safely while increasing the productivity of guava trees and protecting farmers' health. Consultancy fees and revenues from agricultural input sales are returned to the local government to improve the infrastructure that serves guava cultivation in the areas. The company also signs service-providing contracts with farmers to ensure their commitment. To scale up the model and gain more revenue, Viet Lien also invests in R&D activities to introduce more products from guava materials to the market.

With this open business model, Viet Lien gains sustainable income from processing services for farmers while maintaining the environment clean and sustainable. The business is expected to break even after two years, double its sales revenue in the next three years, and gain stable point at about US$1,500,000 per year. Farmers can gain more knowledge and techniques in cultivating high-quality guava while gaining much higher revenue from selling guava-processed products to tourists participating in community tourism in the area.

With this business model, Viet Lien has achieved extraordinary competitive edge over its competitors in the tea processing industry as well as in the chemistry industry as it is a pioneer in providing processing services to farmers. Further, it can take advantage of having a local brand name, and increase the quality of raw materials, farmers' income, and the company's revenue. Farm contracting with this business model also protects the company from the variable prices of raw material and minimise inventory in the company. It also helps many stakeholders in the local areas develop more sustainably. In its proposed strategies for 2020, Viet Lien aims to shift its guava farm in Cu Khoi from chemical base to eco-agricultural base, which meets the GLOBAL G.A.P. cultivating standard.

Case Study 3: Sharing Platform: The Case of Dichung

Dichung is a social enterprise that provides a convenient platform on the web to solve the transporting needs of its customers. It connects people who need a ride with others who want to share empty seats in their vehicles. The goal is to create a ride-sharing culture in Viet Nam, where the company acts as the middleperson, bringing users (riders and drivers) together and overcoming barriers to be able to share vehicles. It also works with transport companies that provide standardised ride-sharing services (taxi-sharing, van pools) via a business-to-business-to-customer platform (dichungtaxi.com), which helps companies collect extra customers and commodities to utilise empty seats in their vehicles.

Established in 2010, Dichung has successfully engaged 20 business customers (70% of which are airport taxi companies and the other 30% are truck taxi service companies) all over Viet Nam to use the dichungtaxi.com platform. In the period 2010–2016, the platform provides an average of 500 shared rides from cities to airports and vice-versa every day, earning €147,100 per year. There have also been 233,770 success rides between vehicles' owners and passengers, technically matched by the dichung.vn platform. From 2014 to 2016, Dichung has popularised its mobile application with more than 200,000 users (both share-riders and drivers) in Hanoi and Ho Chi Minh cities, and an average revenue of €90,000 per year from advertising and registration fees.

To develop its customer database, Dichung runs a marketing campaign aimed at students, officers, travellers, and tourists. The company has also set up a volunteer team providing free ride sharing for people with disabilities. Unlike Grab Taxi and Uber Taxi, which subsidise drivers and give them economic incentives to make money from using their apps and working like taxi drivers without any tax burden and social responsibility, Dichung focuses on utilising empty seats in individual vehicles and taxis only. This means that Dichung helps drivers save on fuel costs and reduce transportation cost for share-riders based on their willingness to match and not for any profit purposes.

Over the last eight years (2010–2018), the innovative business model of Dichung has helped drivers of private vehicles, and taxis and truck taxis to save D17,337,962,675 in total, reduce 1,562,218 kg of CO_2 emissions, reduce travel cost for passengers, and reduce traffic jams (dichung.vn, 2018). Still, Dichung operates at a very low cost as it provides motor ride and taxi sharing without owning any motorbikes or cars.

Case Study 4: Circular Supplies Business Model: Elegance Company Ltd., for Research & Development, Manufacturing, and Services – How a gasification cook stove can decouple the relationship between high growth rate and environmental pollution

Founded in May 2011, Elegance Ltd. focuses on R&D, testing, and manufacturing heating devices using renewable energy sources. The main products of Elegance are gasification cook stoves for households, which are designed according to the principle of biomass gasification technology. Basically, the biomass gas stove converts biomass into syngas and then mixes this combustible gas with air for burning like gas cookers. The stove can adjust the amount of gas generated, thus it can adjust the power of the flame. Biomass fuel is much cheaper than the more popular liquefied petroleum gas. Elegance also produces biomass gasification boilers for industrial use, industrial solar heating dryers, as well as hybrid solar-gasification systems for non-wood material drying.

The new cooking solution that Elegance brings to low-income people is a clean, cheap, safe, and handy cooking stove. After 6 years of research, Elegance has mastered the biomass gasification technology for a minimum scale. The company's gasification has reached the world's highest performance of 57% efficiency, recorded in 2016. The exhaust gases from the stove are also very clean, classified under Tier 4, the cleanest level of the Global Alliance Cook Stoves' standards.

Elegance sells gasification cooking stoves and their changeable modules to local dealers who distribute the stoves and provide maintenance services in the community. The company also transfers biomass pellet-making machines to local cooperatives and provides pellet-processing service for farmers. With this system, farmers can actively collect agricultural by-products (straw, rice husk, corn cob, and the like) as well as biomass wastes (tree branches and the like) and buy processing services from cooperatives to make their own energy source (biomass pellets) at very low cost.

Elegance's strategic goals in the next three years are to gain US$600,000 revenue per year by building 50 product-service systems all over Viet Nam, focusing on rural areas where 70% of the Vietnamese population live, to assure stable supply and consumption of sustainable products (gasification cooking stoves, biomass pellets). It also aims to successfully export to the Lao People's Democratic Republic, Cambodia, and Myanmar, create jobs for more than 150 low-income people, and liberate 2,000 women in the Mekong Delta area from unhealthy cooking habits. It also aims to protect low-income people from agro-waste hazards and air pollution risks.

Elegance surpasses its competitors in innovative and varied high-quality products, applied gasification technology, and having close relationship with local communities. The company also has the first-mover advantage in the market in terms of creating clean, convenient, and very low-cost cooking devices using renewable energy, gaining competitive advantage over other types of products.

The case studies above are just some of the cases that prove the concept of circular economy in Viet Nam and the profitable ways to apply circular economy in the current context. The significant notion in this section is that four out of five company case studies apply eco-innovation tools to develop their business model towards the concept of circular economy in Viet Nam. Circular economies innovate their business models by considering the whole value chain of their products, take advantage of the chain by cooperating with a variety of related stakeholders, and reduce wastes and CO_2 emissions not only within the factory processing line but in every possible activity along the products' value chain. Hence, the companies aim to increase business revenue and improve business sustainability by reducing production costs, using resources more efficiently, reducing waste or turning waste into products, outsourcing specialised activities to other stakeholders; and maximising profits by accessing new market, innovating new products, and building a firm brand name.

8. Barriers and Challenges for Vietnamese Enterprises to Overcome

Although perceptions on circular economy and related concepts are quite popular amongst Vietnamese firms and some successful initiatives prove the profitability of the circular economy concept in Viet Nam, numerous barriers can still hamper its implementation today. These barriers are listed and analysed below.

8.1 Business Environmental Culture

Viet Nam's economic growth was mainly based on quantitative rather than qualitative development, using high fuel and energy consumption as well as labour-intensive models in making products, thereby hurting the environment. The natural resources in Viet Nam are extracted using poor and outdated technology, posing damages and extreme pollution to the ecosystem around the mining areas. The consumption of natural resources, both in industries and society, are irrational and uncontrolled, which threatens not only the living conditions of the Vietnamese people but also the sustainability of the environment. Sustainable and environmentally friendly industries are largely underdeveloped until now. Consumption demand in Viet Nam quadrupled in the past decade due to incredibly strong economic development and population boom (the population of Viet Nam is approximately 91 million, 70% of which is at working age). Consequently, the demand for more energy spiked and there is more wasteful and ineffective use of energy, proven by the fact that fuel consumption per product in Viet Nam is 1.5 to 1.7 times higher than in Thailand and Malaysia. Escalating energy prices also contribute to production costs, and products and services have become costly, which in turn undermine business efficiency, competitiveness, and profit margins (Dat and Tuong, 2013).

8.2. Lack of Effective Support and Legislation from Government

Although the economic structure of Viet Nam has shifted towards industrialisation and modernisation, energy-intensive and natural resources-intensive industries are still popular. Most of these are state-owned companies that are too big to change and rely on outdated and ineffective technologies.

As the Vietnamese economy is accelerating, it is difficult to either cut down fuel consumption or use alternative fuels, such as wind power. This process will reduce growth in the short term and affect employment, income, and welfare (Dat and Tuong, 2013).

Moreover, the application of sustainable consumption and production ideas and the implementation of green policies are not concrete and sufficient to generate positive and disruptive results in a large scale. The weak and unclear policy framework, consistent with the complicated government system, results in weak enforcement and ineffective operations. The reasons for these are the lack of cooperation between different government offices in implementing related actions, the infrastructures and firms are not ready for the changes, the government does not have good enough incentives in both policies and finances to encourage more firms to participate, corruption, and global economy changes. Growth model transformation also remains slow and coordination amongst agencies and departments in transition is ineffective. The goals of economic development and the goals of protecting the environment are conflicting. All these are major challenges hindering green and sustainable growth in Viet Nam. These potential ideas for a better sustainable development are not interesting to enterprises and not many enterprises are willing to innovate their current business model by applying the given concepts.

8.3. Lack of Finance

The cost of green (or no-waste) innovation has been extensively considered in literatures as one of the major barriers to the adoption of sustainability practices by SMEs (Vasilenko and Arbačiauskas, 2012; Lawrence et al., 2006; Trianni and Cango, 2012). The upfront costs of any type of investment and the anticipated pay-back period are particularly important for SMEs, which are generally more sensitive to additional financial costs resulting from green business activities compared to large enterprises (Oakdene Hollins, 2011; Rademaekers, Asaad, and Berg, 2011).

Financial resource is also one of the fundamental barriers to the application of circular economy (and other types of green growth) in Viet Nam. About 90% of enterprises in Viet Nam are SMEs, of which technology investment only accounts for 1%–3% of total revenue annually. Therefore, the government should have clear policies to support business investment in clean technology, especially tax policy, funding incentive, or interest rate support. The World Bank has said that the financial mechanism should be more clearly defined in the Viet Nam Green Growth Strategy, especially incentives for the private sector, because there should be more involvement of this sector in this strategy (UNIDO, 2012).

8.4. Constraints on Firms' Economic Performance

Technological progress raises the potential for economic growth by increasing the availability of a wider number of new products and production processes for which the role of private sector investment in innovation and new technologies cannot be overemphasised. While firms may be aware of the benefits of innovation, they may lack the capacity and resources to put in place technological improvements such as updating equipment and machinery.

The General Statistics Organization of Viet Nam conducted a technological competitiveness survey of 7,000 enterprises in Viet Nam from 2010 to2014. Firms were asked to assess constraints to the economic performance they face on a 10-point scale and the overview of the scores is shown in Figure 9.

Figure 9. Constraints on Firms' Economic Performance

Source: General Statistics Office of Viet Nam, 2015.

Figure 9 shows an overview of the constraints faced by firms in improving their economic performance, which are the reasons that discourage them from investing in innovation or applying new technologies. First to note is that financial constraints dominate at any time of the survey, with the average score of six for all years. The second significant constraint of the company is the skills level of labour, followed by limited access to equipment. However, firms do not seem gravely constrained by labour availability, or deficiencies in transport and communication infrastructures.

Figure 9 reveals that the most important constraints faced by Vietnamese firms remain unsolved for years, regardless of how many supporting policies have been issued.

9. Conclusions

The results of the PEST analysis and the survey on the factors proving the potential of applying circular economy in Viet Nam show that Viet Nam is ready for circular economy. Although there is only a small number of firms that are aware of the concept of circular economy, a large proportion of firms already know about the concepts relating to circular economy such as CP, sustainable production and production, resource efficiency, and the like.

The implementation of existing plans and actions towards developing circular economy is still inefficient and slow. However, many case studies have shown that by innovating the business model at the firm level, Vietnamese firms can gain high economic value and competitiveness to develop the business and gain more revenue.

To gain the advantages of circular economy in Viet Nam and learn experiences from pioneering companies, Vietnamese firms should consider the whole value chain to find opportunities for innovating their business models. Building capacity and increasing productivity, especially the creative ability of employees and stakeholders along the value chain, are also necessary for companies to successfully apply circular economy for long term. Lastly, there must be a strong commitment to the long-term sustainable strategies and plans to ensure the development of circular economy business models and convince investors to help scale up the good ideas.

To ensure green growth in Viet Nam, the government should be more decisive in accelerating economic restructuring, focusing on intra-industry structural change in favour of lower-carbon sectors, especially resource efficiency and renewable energy industries.

Local government bodies should also raise awareness and enhance coordination amongst ministries, taking motivational policies towards sustainable growth goals.

Moreover, attracting foreign investment is not only about attracting foreign capital but also about attracting the technology and their management skills so that Vietnamese firms can use the spillover and learning effects from international enterprises in developing their business model.

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Chapter 7

Establishing Green Finance System to Support the Circular Economy

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1. Introduction

For years, pioneers in sustainability have been talking about concepts such as 'closed-loop' and 'cradle-to-cradle', which are focused on bringing individual products and processes into a more circular life cycle. This life cycle concept has been evolving, from individual companies to an entire circular economy. It is an inevitable choice in realising economic growth and effective utilisation of resources to develop a circular economy. The transformation towards a circular economy will entail a lot of costs, such as research and development and capital investments, wasted capital and stranded assets, subsidies for new products to the market, as well as public spending on green infrastructures. The British government has estimated that the creation of a completely effective recycling and recovery system will cost about GBP 13 billion. Scaling up to Europe, the cost will be GBP 110 billion. Providing effective financial support mechanisms and systems can meet the financial needs of circular economy industrialisation. The relationship between finance and circular economy development is very close. Industrial transformation of the circular economy needs green financial support oriented to the market. The upfront costs of investment and the anticipated payback period are more sensitive to additional finance resulting from green innovation and green business activities. Studies have shown that lack of green finance resources is one of the major barriers to establishing and managing a recycling scheme. Meanwhile, the development of the circular economy industry is also favourable for promoting reform and innovation in the financial sector. Financing policy is an effective booster and important guarantee for promoting the circular economy development and transformation of an economy to a development mode. It is also a key link for nurturing and developing the circular economy. Taking the banking financial institution as an example, financial support on the circular economy can be increased and cost pressure of enterprises can be relieved by lowering the interest rate, extending the credit period, increasing the loan amount, and relaxing repayment conditions. Meanwhile, investment behaviour that does not comply with the principle of the circular economy can be restricted by not providing loans, raising interest rates, and mandatory repayment. It supports the circular economy from another level.

We now have the global Sustainable Development Goals, which target an annual investment pipeline measured in trillions of dollars to end poverty and marry increased prosperity with social inclusion and environmental regeneration. We also have the Paris Agreement on Climate Change, which signals the shift to a low and ultimately net zero carbon economy and stresses the urgency of improving resilience to mobilised financial institutions and regulators in novel ways. However, the current financial system in Association of Southeast Asian Nations (ASEAN) countries lacks the environmental function. Thus, building a healthy market-oriented environment and a green financing system to support the circular economy has a profound social background and practical significance for accelerating the establishment of resource-saving society, improving quality and efficiency in economic growth, and promoting sustainable development of the national economy.

2. Theoretical Framework

One of the basic assumptions of classical microeconomic theory is that companies will seek to maximise profits. However, the market prices for some of these input materials and output products do not fully reflect the externalities of their production and consumption. Internalising the externalities so that production of polluting products falls and production of cleaner products rises calls for the following sets of policy measures:

- increase the investment return of green projects by increasing the revenues for cleaner products, lowering their taxes, or reducing real risks and costs of production, thus kindling firms' enthusiasm to invest in green-related industries;
- lower shareholders' expectations on the return on their investments in polluting projects by reducing perverse subsidies and raising taxes on pollution, and raising the costs through lender liability and mandatory disclosures; and

- increase environmental awareness and responsiveness amongst investors, companies, and consumers through risk assessment and information disclosure for companies and financial institutions on the environmental impact of their investment projects, etc. Consumers play a vital role in the market equilibrium mechanisms that determine market price. Therefore, to influence market price and reduce externalities, efforts should be made to change their consumer preferences.

The purpose of these policy measures is to internalise the environmental costs and curb investment activities with excessive environmental risks through financial means to protect the ecological environment and optimise economic growth. Thus, it calls for a green financial system. A 'green finance system' refers to a series of policies, institutional arrangements, and related infrastructure building. The main source of capital towards the circular economy can be divided into three categories: public capital, private capital, and hybrid funds. All kinds of capital flow to green fields mainly through development banks, United Nations agencies, and capital market channels. The green financial system was rapidly extended in the world with the push for green economic development. The following may be included in the financial support for promoting the circular economy:

- financial institutions may encourage corporations to engage in environment-friendly management and socially responsible investments;
- banks may reflect on the emission of environmental pollutants and greenhouse gases as well as the efficiency of energy usage during investment and loan review stage;
- capital market may form green funds and offer incentives, or develop green industry stock indices and green management performance indices;
- revitalisation of private investment on the construction of foundation facilities;
- strengthening of public notice systems on the green management information of companies and expansion of financial support for green companies; and
- formation of green finance infrastructures to improve the general public's awareness of green finance or to cultivate professionals related to the industry.

The relevant financing policy tools and acting mechanisms are summarised in Table 1.

Table 1. Financing Policy Tools and Acting Mechanisms

Financing Policy Tools		Main Benefits and Acting Mechanisms
Greening Bank System	Discounted Green Loans	Reduce the cost of funding for green projects.
	Lender Liability	Strengthen the social responsibilities of investors; impede the availability of funds for polluting projects by increasing their financing costs.
	Green Banks	Increase the return on green investment and reduce the investment risk and cost of private capital for green projects by leveraging the economies of scale and specialised services and operations.
Greening Capital Market	Green IPO	Facilitate efforts by green companies to raise funds; indirectly reduce financing costs.
	Green Bonds	Reduce the cost of funding for green projects.
	Green Funds	Build up the economies of scale and specialised green services and operations; reduce the cost of green investment.
	Green Equity Indices	Indirectly reduce the investment costs of green projects by channelling more funds into green industries.
	Green Insurance	Expose environmental risks through insurance policies, which indirectly increases the costs of polluting projects and discourages investment in such projects.
Green Capacity Building	Carbon Markets	Drive down the cost of emission reductions through market mechanisms.
	Green Ratings	Reveal environmental risks; reduce the investments in polluting projects by increasing their costs; reduce the financing costs of green projects and foster more of these projects by showing their positive externalities.
	Environmental Cost Database	Increase the accessibility of environmental information and reduce the cost of environmental impact studies.
	Green Investor Network	Increase investor companies' preference for green projects through pressure from institutional investors; increase investors' preference for green projects through online educational programmes.
	Compulsory Disclosure	Encourage (discourage) companies to invest in green (polluting) projects by emphasising greater corporate social responsibilities.

IPO = initial public offering.

Source: Author.

3. Financing Practices and Experiences from Developed Countries' Perspective

Estimates indicate that around US$1 trillion of additional investment is needed annually up to 2030 to establish new green infrastructures in energy, transport, buildings, and industry. Such an amount, which is reasonably modest at roughly 1.5% of global gross domestic product, is in addition to the need to mobilise US$5 trillion a year for the underlying investment. Even if this investment target can be met, there are still trillions of dollars of polluting investments that need to be addressed. Developed countries have already accumulated rich experiences in developing green finance-related institutional arrangements and financial products.

3.1 Overview of the Financing Policy that Promotes Green Finance Internationally

In 1974, the first social and ecological bank, Gemeinschaftsbank für Leihen und Schenken Bank (GLS Bank), was founded in Germany to provide preferential loans for cultural, social, and ecological projects. It currently finances around 23,000 projects and businesses. In 1980, the United States enacted the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 and established a superfund to finance the cleanup of sites contaminated with hazardous substances and pollutants.

In 1992, The United Nations Environment Programme Finance Initiative was established. It comprised two core initiatives, the Financial Institutions Initiative and the Insurance Industry Initiative, each based on a statement of commitment to sound environmental and sustainability management principles, endorsed by supporting companies. The United Nations Environment Programme Finance Initiative collaborates with commercial and investment banks, insurance and reinsurance companies, fund managers, multilateral development banks, and venture capital funds.

In June 2003, the International Finance Corporation launched the Equator Principles, which were initially implemented by 10 leading international banks in seven countries, including Citibank, Citigroup, ABN AMRO, Barclays, and WestLB. The Equator Principles are a set of environmental and social benchmarks for managing environmental and social issues in development project finance globally (Equator Principles Association, 2013).

Since then, green finance began to flourish and gradually formed a huge system with diversified markets and increasing green products and services. Commercial banks, investment banks, trusts, insurance companies, and private investors actively participate in the green financial market. Consumers are witnessing a flood of new financial products and services geared towards rewarding and/or stimulating environmentally sustainable behaviour and practices. The following is a brief overview of the financing policies that promote green finance internationally.

The Equator Principles. The Equator Principles require financial institutions to assess the environmental and social implications of projects proposed for financing, and only finance those that demonstrate compliance with social and environmental standards. In July 2006, the Equator Principles were revised, increasing their scope and strengthening their processes.

Green securitisation. Properly functioning capital markets ensure the efficient operation of businesses and the economy in a globally competitive marketplace by providing appropriate reputational and financial incentives, and efficiency in controlling pollution emissions given its appropriate monitoring and enforcement as a market mechanism. The earliest attempt at introducing securities based on natural disasters was the end of 1992, when the Chicago Board of Trade developed catastrophe futures and call spread options. Currently, a variety of innovative environmental securitisation techniques have begun to emerge, including green initial public offerings, green bonds, eco-securitisation pilot programmes, and green mortgage-backed securities.

Green credit and green banks. The shift in banks' strategies and actions towards sustainability is underway, not only amongst smaller alternative and cooperative banks but also amongst diversified financial service providers, asset management firms, and insurance companies. Many western financial institutions have answered to market demand and developed green credit products with preferential loan limits, lending rates, and loan application processes catered to enterprises, individuals, and families. Several banks have created service divisions or teams dedicated to large-scale renewable energy project finances, such as Rabobank International's Project Financing Department, Barclay's Natural Resources Team, and West LB's Global Energy Team. Beyond financing, green banks also undertake a variety of non-finance market development activities to facilitate turnkey, easy-to-use clean energy finance and adoption solutions. For example, the United Kingdom's (UK) Green Investment Bank was initially a policy bank funded by the government, and now is an independent financial entity, renamed the Green Investment Group (GIG), offering both technical and financial expertise on green infrastructure investments. The Japan Bank for International Cooperation, a government-owned bank, is implementing part of Japan's climate change policies by providing finance together with private banks.

Green funds and indices. The Netherland's Green Fund Scheme is an example of government's support for banks financing green growth. The programme consists of three parts: green projects, green institutions, and tax incentives. The government provides funds to green projects at low cost by taking full advantage of banks' financial intermediary functions. There are also some environmental indices-related funds. An environmental stock market index aims to provide a quantitative measure of the environmental damage caused by the companies in an index. Broad-based indices of stocks generally use extensive environmental, social, and governance criteria, and scoring systems to select companies that are 'leaders' in social and environmental responsibility. Examples include the FTSE4Good series, the BM&FBovespa Corporate Sustainability Index, the FTSE/JSE Responsible Investment Index Series , the NASDAQ OMX GES Sustainability Nordic Index, the Wienerhill Sustainability Index, and some sector-specific indices focusing specifically on companies that provide solutions to sustainability challenges, i.e. the Financial Times Stock Exchange's Environmental Technology Index series, Deutsche's DAXglobal Alternative Energy Index, the NASDAQ OMX Clean Edge Global Wind Energy Index, and the New York Stock Exchange Arca Cleantech Index. These are frequently linked to exchange-traded funds. By October 2008, these funds had over US$42 billion in assets under management, with a dominated volume of US$7.3 billion venture capital/private equity investment.

Green venture capital and private equity. Venture capital and private equity investments are an important source of financing for innovative entrepreneurial firms and can significantly accelerate the market diffusion of new technologies (Bürer and Wüstenhagen, 2009). There has recently been increasing attention to 'cleantech', an investment category which consists of renewable energy technologies such as solar energy, wave energy, and biofuels, as well as a collection of other sustainability related subsectors (Usher, 2008 cited in Bürer and Wüstenhagen, 2009). The past few years have seen an explosion of interest in clean energy by venture investors, attracted by the size of the markets that will be created.

Green bonds. Green bonds are instruments which tie the proceeds of a bond issue to environmentally friendly investments. In 2007, the European Investment Bank issued the first climate-related bonds (EIB, 2013). In 2010, the International Finance Corporation launched a green bond programme to help catalyse the market and unlock investment for private sector projects that support renewable energy and energy efficiency. Since then, green financial markets started to flourish. In March 2015, the International Capital Market Association published Green Bond Principles, enabling capital-raising and investments for new and existing projects with environmental benefits. Recent activities indicate that the market for green bonds is developing rapidly. The global green bonds market amounted to over US$40 billion in 2015, with issuers including the World Bank, commercial banks, corporations, and municipalities from all over the world.

Green insurance. The purpose of this type of insurance is to form insurance funds for the prevention and restoration of ecological accidents and other types of accidents. It typically encompasses two product areas: insurance products, which differentiate insurance premiums based on environmentally related characteristics; and those specifically tailored for clean technology and emission-reducing activities. In 1990, the German government passed the Environmental Liability Act, which requires the compulsory insurance of 96 sectors (including, amongst others, thermal power, mining, and petroleum) across 10 major industries. Examples of green insurance products include green auto insurance and green home insurance, and the like.

Carbon finance. Key elements of carbon finance include carbon trading, carbon finance, carbon funds, and carbon-related financial derivatives. To date, carbon market products and services have largely been found in Europe, driven by the January 2005 implementation of the European Union's Emissions Trading Scheme. Other trading markets include the Chicago Climate Exchange, the Keidanren Voluntary Action Plan in Japan, the New South Wales Greenhouse Gas Reduction Scheme in Australia, the New Zealand Emissions Trading Scheme, and many others. Collaboration between multilateral development banks and private financial institutions has led to the emergence of a variety of carbon funds to help finance greenhouse gas emission reduction projects to curb climate change. Financial institutions have introduced many derivative products based on carbon emission rights as they become more intertwined with the carbon trading market.

Supply chain financing. Supply chain financing is one area where versatility and scalability are possible, making it a great starting point in building a more circular economy. The industry chain connects supply enterprises, manufacturing enterprises, distribution enterprises, retail enterprises, and even all users, and provides financing services for numerous enterprises in the industry chain. Continuous appreciation of the whole industry chain is realised through functional division and cooperation of relevant enterprises. The International Chamber of Commerce and its Banking Commission are currently focusing on the establishment of new financial solutions that will enable corporations to maintain a resilient supply chain.

3.2 Experiences and Implications

3.2.1 Governments should play a positive and vital role in promoting environmental sustainability and green finance in the earlier stages.

In terms of the financial channels and tools introduced above, the government has played a positive role in promoting green finance in three aspects: policy incentives, subsidies, and preferential loans. In the UK, for example, to meet the huge investment gap in climate change, a green bank was created in 2012 by the government to attract private funds to finance the private sector's investments related to environmental preservation and improvement. It is the world's first investment bank dedicated to greening the economy, with a government funding of US$5 billion. The Green Investment Bank invests in innovative, environmentally friendly areas where there is lack of support from private markets. Four-fifths of the value of its investments is divided between four main priority sectors: offshore wind, waste recycling and energy from waste, non-domestic energy efficiency, and support for the government's Green Deal, which was launched in January 2012 with the aim of improving the energy efficiency of more than 14 million homes by 2020. As its parliament stated, the mission of the bank is a key component to accelerate the UK's transition to a greener economy, and to create an enduring institution operating independently of government. As well as providing finance, government initiatives also aim to remove the information and green technology barriers by managing risks, simplifying processes, and building the skills and experience in these projects. As of January 2014, the Green Investment Bank had committed US$ 0.9 billion to mobilise US$ 4.2 billion when fully deployed, a ratio of private-to-public investment of 3:1. The Green Bond Principles is another example. The green bond market is relatively young but rapidly expanding, growing from US$0.4 billion of new issuances in 2008 to nearly US$42 billion in 2015, with a total of US$118 trillion green bonds currently outstanding. There is no separate legal framework under which green bonds are issued. A new Green Finance Initiative was launched by the City of London in 2016, supported by both the Treasury and the Department of Energy and Climate Change, with the aim of promoting London 'as a leading global centre for green financial services'.

Another example is the United States (US). In 2008, the US committed to develop a green economy through addressing climate change, developing new energy, and improving energy saving and efficiency. In 2009, the US proposed an independent, tax-exempt green bank, with an initial capitalisation of US$10 billion through the issuance of green bonds by the US Department of Treasury. The principal charge of the green bank is to assist in the financing of qualified clean energy projects and qualified energy efficiency projects.

3.2.2. Financial institutions, especially banks, play a vital role in prompting green finance.

Given their intermediary role in the economy and far-reaching customer base, international banks are well-positioned to benefit from the design and marketing of new green products and services. Globally, international banks are starting to see the top line money-making reality of delivering sustainability to corporate and retail clients. They define clear roles and responsibility at the board of director or supervisory board levels and establish teams or committees to build and promote green credit activities. Moreover, they set up and improve policies, systems, and processes for environmental and social risk management, and establish working mechanisms conducive to green credit innovation to boost innovation of green credit processes, products, and services. For example, Citi, Standard Chartered, and HSBC make public financial commitments of their green financial products and services; JPMorgen and Mizuho embed basic ecological and sustainable (E&S) principles directly into its credit management policy. At present, more than 80 financial institutions in 35 countries have officially adopted the Equator Principles, representing more than 90% of global project finances. Over 200 financial institutions worldwide report their E&S performance using or referencing the Global Reporting Initiative framework. By 2005, the majority of the leading European banks had debt portfolios that contained committed lines to finance renewable energy assets.

Banks have also started to employ innovative financing arrangements for large-scale clean fuel and renewable energy projects. Banks also established a capital base for environmental projects through specialised private equity units focused on clean energy growth markets and investment opportunities. Some banks have taken steps towards participating in the growing carbon market, including US banks Goldman Sachs, Merrill Lynch, JP Morgan, Morgan Stanley, and several European banks, HSBC, Barclays Capital, Fortis, and ABN AMRO. They employ a range of financing approaches to improve portfolio diversification, secure opportunities, and hedge risks.

In 2014, the Green Bond Principles were developed with guidance from issuers, investors, and environmental groups. These principles serve as voluntary guidelines that recommend transparency and disclosure, and promote integrity in the development of the green bond market by clarifying the approach for issuance of a green bond. It will provide greater certainty to the market, which could increase financing opportunities for renewable energy, energy efficiency, clean transportation, sustainable water management, and climate change adaptation projects. In 2014, the Green Bond Principles had been signed by 25 major investment banks that facilitate green bond issues.

3.2.3. Environmental awakening and regulation will build momentum for the green products and service innovation, and expose new business opportunities.

The relatively high level of environmental awareness and government support for environmental sustainability in Europe and the US has driven the ever-growing consumer demand for eco-friendly products and services. Higher levels of media coverage about various environmental challenges, along with multinational environmental campaigns and outreach initiatives, have helped improve the general public's understanding (UNEP FI, 2007).

In Europe, proactive governmental regulatory actions, such as the European CO_2 Emissions Trading Scheme, German feed-in-tariffs for renewable energy, and Dutch Green Funds, provide price certainty in environmental markets and significantly stimulate demand for green products and services amongst bank clients. Organisations that have the foresight and capacity to tap into this desire of consumers to achieve positive environmental change may experience benefits ranging from improved corporate image to increased growth and competitiveness in the marketplace. The Comprehensive Environmental Response, Compensation, and Liability Act of 1980, which was passed in 1980 in the US, requires the lender to assume liabilities if the business operation, production, and waste disposal of its borrower would cause pollution. The United Nations' Principles for Responsible Investment require investors to report on the status of implementation of the network's principles on an annual basis and make their reports and evaluation documents accessible for external review.

3.2.4. Building networks for green institutional investors help facilitate the inclusion of environmental considerations in the investment decision-making process.

The Investor Network on Climate Risk, established in 2003, includes 100 large-scale investors managing US$11 trillion of assets. The Institutional Investors Group on Climate Change, which was founded in 2001 and currently has 80 members, publishes the carbon emissions data of 2,500 institutions (companies) from 30 countries and their potential commercial risks.

4. Financing Practices and Experiences of Developing Countries: China's Case

4.1 Circular Economy Promotion in China

Facing significant natural resource consumption, environmental degradation, and public frustration, the Chinese government has considered ecological modernisation, green growth, and low carbon development with a national circular economy strategy. The leadership developed a 50-year plan to address sustainable growth objectives and challenges. Important steps include the passage and implementation of the Cleaner Production Promotion Law in 2003, the commitment of US$1.2 billion in science and technology investment for sustainable development by the Ministry of Science and Technology, and the adoption of the Circular Economy Promotion Law in 2009, which outlined national plans for safe urban municipal solid waste treatment, energy savings, and emissions reduction.

To promote the circular economy at a larger scale, and build a resource-saving and environment-friendly society, the Notice on Policies, Measures and Opinions of Investment and Financing to Support the Development of the Circular Economy was issued on 19 April 2010. It is the first macroeconomic policy guidance document promoting the development of the circular economy since the implementation of the Circular Economy Promotion Law of the People's Republic of China in 2008, which puts forward specific measures to support the development of the circular economy. The data showed that the Ministry of Science and Technology continuously increased research support to key and common technology, developing the circular economy during 2006–2008; science and technology investment in the field was increased every year; and support range also continuously expanded.

In China's 12th five-year plan, energy conservation and pollution control take high priority on the agenda. The 10 key environmental protection projects in the 11th five-year plan was adjusted to eight in the 12th five-year plan by reducing main pollutant emissions and improving people's livelihood. The key preferred environmental protection areas include:

- **major pollutants reduction** such as sewage treatment, sludge treatment, desulphurisation, and denitrification;
- **living environment improvement** such as water/air/soil quality improvement;
- **environmental protection in rural areas** such as non-point source pollution control from agriculture;
- **ecological preservation** such as nature reserve development and biodiversity conservation;

- **environment risk prevention** such as prevention and control of heavy metal/ hazardous chemicals pollution and persistent organic pollutants;
- **nuclear safety** such as nuclear safety systems/technology development and radiation monitoring;
- **environmental infrastructure** such as waste treatment facilities development and projects on water supply security; and
- **environmental monitoring** capability development and talent training.

In August 2012, the State Council cleared 10 out of 12 key energy-saving and emission-reduction projects under the five-year plan of energy-saving and emissions reduction, including the demonstration of energy-saving technology industry and the circular economy demonstration.

These environmental protection projects can be divided into three categories. The first are the resources recycling projects with obvious economic benefit, as well as the government pricing or government subsidies, and rewards that can be directly given to the enterprise, such as urban sewage treatment facilities construction, garbage disposal facilities construction, and power plant desulphurisation facilities construction projects. The second category of projects with no short-term economic benefits mainly include the vast number of industrial pollution prevention, ecological protection, and so on. The third category of projects with indirect economic benefits include industrial resource efficiency improvement, land reclamation, etc.

4.2 Current Investment Pathway and Potential Finance Gap

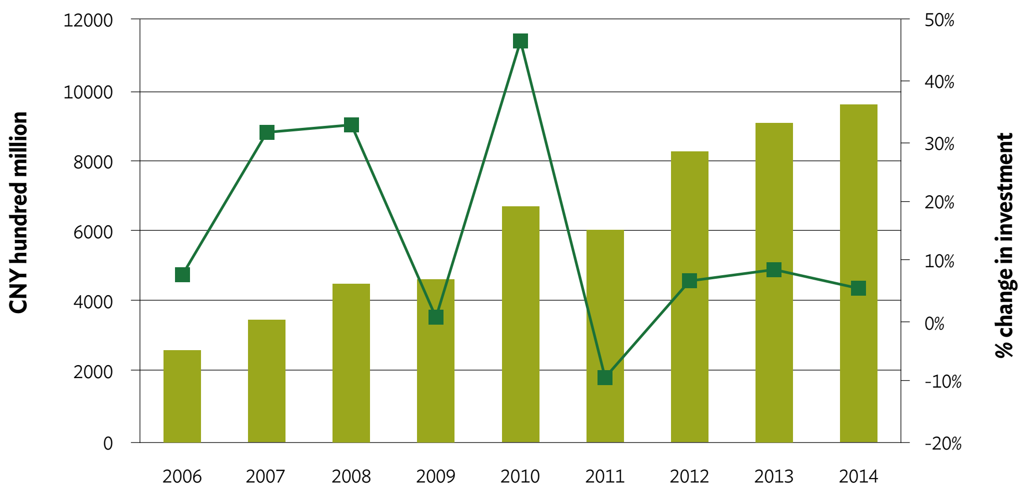
To meet the financing demand, the 12th five-year plan states that China is seeking around CNY3.4 trillion of investments to protect its environment, with around CNY1.5 trillion to be injected first into eight types of 'green' projects, double than in the 11th five-year plan. The government also launched a series of environmentally friendly policies in a bid to encourage the development of 'green' industries. Some of these policies include:

- offering incentives to enterprises engaged in sewage treatment, sludge treatment, desulphurisation, gentrification, and waste disposal;
- improving the pollution charging system to increase the cost of high-pollution production;
- encouraging bank loan issuance to 'green' projects; and
- increasing the portion of 'green' products on the government's procurement list.

In accordance with relevant plans in specific areas, urban sewage treatment and recycling facilities in country construction planning had an investment of about CNY30 billion, and urban life garbage disposal facilities construction investment was nearly CNY2,636 billion. This represented a 37.0% and 14.1% growth, respectively, from the actual investment in the 11th five-year plan. Pipeline construction for sewage treatment received CNY2,173 billion investment, while garbage disposal facilities construction received CNY44.3 billion, representing 56.8% and 65.6% growth, respectively. The government also introduced market mechanisms such as establishing low-carbon product standards, an energy labelling system for consumer products, and carbon trading pilot programmes.

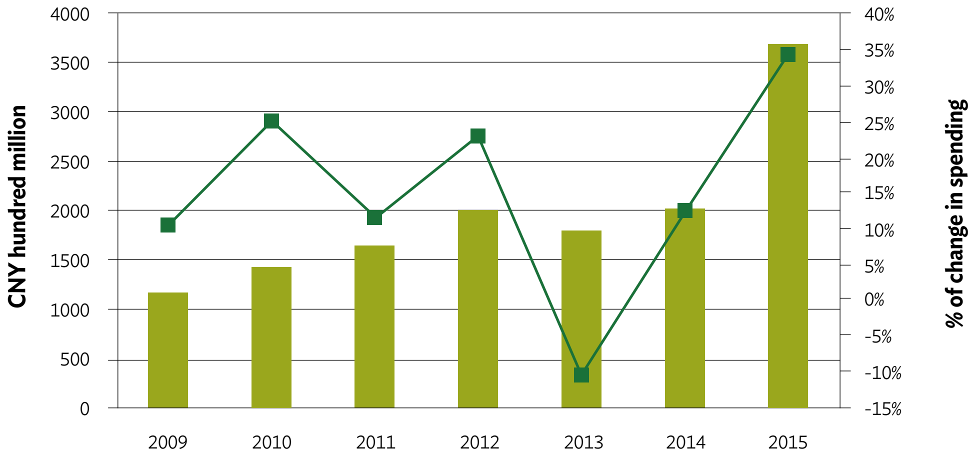
In 2014, the national environmental pollution treatment investment was CNY957.6 billion, up by 6% from the previous year (see Figure 1). In December 2015, spending on energy conservation and environmental protection in China was more than CNY370 billion (see Figure 2). According to the Ministry of Environmental Protection, during the 12th five-year plan, environmental protection-related investment reached CNY3.4 trillion, of which CNY1.5 trillion will be allocated to eight key projects. Total final investment is expected to exceed CNY5 trillion.

Figure 1. National Environmental Pollution Control Investment and Growth
(2006–2014, CNY hundred million)



Source: Based on dataset from the Ministry of Finance, China.

Figure 2. **Spending on Energy Conservation and Environmental Protection in China**
(2009–2015, CNY hundred million)



Source: Based on dataset from the Ministry of Finance, China.

To demonstrate the efficiency and applicability of these plans, the state has made substantial investments in circular economy-oriented pilot projects, including the application of clean production techniques in specific sectors, and municipal and regional eco-industrial developments. Most circular pilot project cities have met or exceeded the targets set. Beijing has achieved a 62% reduction in energy consumption per GDP in 2010, a 45% increase in the rate of treated wastewater recycling, and a 45% reduction in consumption per capita from 2005. Other cities such as Dalian, Shanghai, and Tianjin have attained more modest improvements so far, but trends are similar. Now, China is a pioneer in the global green investment market, with a green finance mechanism gradually taking shape. In December 2015, China became the first country to issue official rules on green bonds (Kidney and Oliver, 2014). Both Shenzhen Stock Exchange and Shanghai Stock Exchange rolled out pilot corporate green bonds in March and April 2016, while the People's Bank of China (PBOC) is mulling over developing green bonds services for local markets. According to a report by credit rating agency Moody's, China replaced the US as the top issuer of green bonds in the first quarter of 2016, with US$7.9 billion of green bonds issued in Q1, nearly half of the global total.

The China Banking Regulatory Commission has instructed Chinese banks with on and off balance sheet assets worth over CNY1.6 trillion to disclose 12 key indicators according to the Basel Committee of Banking Supervision. Some of these banks are Industrial and Commercial Bank of China, Bank of China, Agricultural Bank of China, China Construction Bank, Bank of Communications, and China CITIC Bank. Banks are required to disclose claims on liabilities to other financial institutions, outstanding securities, or other financial instruments, cross-border assets, and liabilities, amongst others.

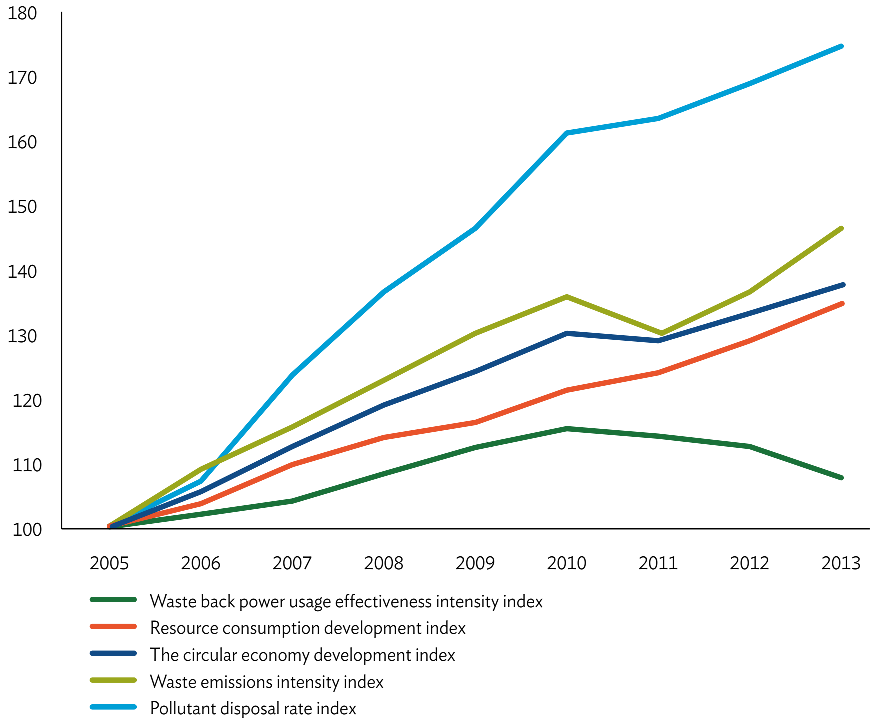
The Ministry of Environmental Protection has blacklisted products that contain high pollution risks. The list includes 722 products and 92 crafts, and the ministry has provided the information to government bodies such as PBOC and the ministries of commerce and finance. The list aims to educate companies and organisations to identify toxic products and consider the implications in the production, safety supervision, decision-making, use, manufacturing, or export of those items. The Shanghai Stock Exchange has established the Listed Companies' Information Disclosure Consultation Committee, which will be responsible for increasing regulatory supervision over listed companies. Furthermore, Greenovation Hub has launched a series of new reports assessing China's latest efforts to prioritise environmental issues through carbon trading, bank lending, and mining regulations. China is substantially improving its environment (see Table 2). The circular economy has undergone great progress in terms of different circular economy development indices (see Figure 3). The next step is for the Chinese government to aid the legitimacy of economic and environmental decisions concerning resource use and trade, including the development of a circular-economy-oriented indicator system (e.g. energy indicators, considering all available energy input directly or indirectly required to generate a product). However, there is still a lot to do, ranging from policy, to ideas and products.

Table 2. Environment and Protection: Achievement and Goals

Measure	Targeted decrease in total output (%)	
	2005–2010	2011–2015
Chemical oxygen demand	12.45	8
Ammonia	–	10
Sulphur dioxide	14.29	8
Nitrogen oxides	–	10
Measure	**Targeted water/air quality improvements (↑↓%)**	
	2005–2010	**2011–2015**
Area of polluted surface water	↓ 8.4	↓ 2.7
Area of quality surface water	↑ 14	↑ 5
Portion of country-level cities with quality air	↑ 2.6	↑ 8

Source: Based on Ministry of Environment Protection, China.

Figure 3. **China's Circular Economy Development Index in 2005–2013 (%)**



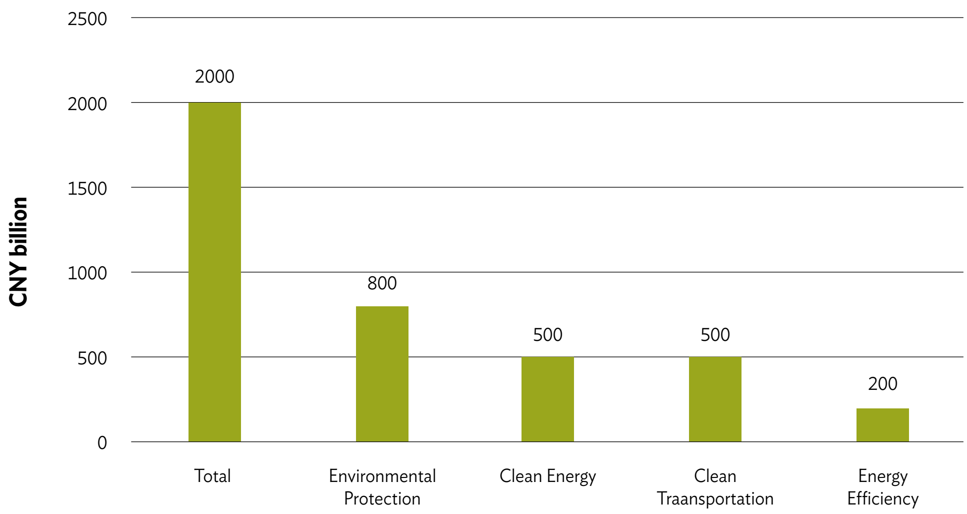
Source: Based on data from the Ministry of Environment Protection, China.

The finance gap is still huge. According to the modelling of the Energy Research Institute, China's total financing need for de-carbonising its energy industry and for energy efficiency (for industry, building, and transportation) under a 2-degree Celsius scenario will reach CNY2.8251 trillion (US$453 billion) per annum in 2030. As the annual average climate finance from 2008 to 2012 in China was only CNY546 billion (US$87.6 billion), the gap could potentially reach CNY2.3 trillion (US$370 billion) by 2030. According to the latest estimates of a research conducted by PBOC,[1] achieving the targets of moving towards a green economic development and building an ecological civilisation requires an annual investment in the green sector of at least CNY3 trillion during the period 2015–2022, and CNY2 trillion (US$320 billion or more than 3% of GDP) for the next 5 years (2015–2020). Only 7% of current financing in China could be currently described as 'green'. Given that provision of finance reached about

1 Estimate based on (1) The 12th Five-Year Environmental Protection Plan and the Ministry of Environmental Protection, (2) the Plan on Water Pollution Prevention and Control (issued in 2014, total investment planned at CNY2 trillion), (3) the Plan on Air Pollution Prevention and Control (issued in 2014, total investment planned at CNY1.7 trillion), (4) China Railway Annual Report (a fixed investment of CNY800 billion is planned for 2014; realized investment in 2013 was CNY663.8 billion), (5) the Renewable Energy Policy Network (in 2013, China's investment in wind, solar, and other renewable energy projects (excluding natural gas) was US$56.3 billion, or approximately CNY350 billion), and (6) Bloomberg (China's investment in renewable energies (excluding natural gas) was US$67.7 billion in 2012, or CNY420 billion).

CNY10 trillion in 2015, the public investment alone is far from sufficient. Since the growth rates of government expenditure and fiscal revenue have both declined in recent years, the government can only be expected to contribute around 10%–15% of all green investment, while private capital will need to contribute the remaining 85%–90%.

Figure 4. China's Green Investment Needs During 2015–2020



Source: People's Bank of China, Green Finance Task Force Report, 2015.

4.3 Experience and Implications

The enthusiasm of enterprises to enter the national pilot range is very high, but the enterprises that can enter the pilot range is limited.

Enterprises are needed to implement and promote the circular economy. At present, China's pricing system does not fully reflect the negative externalities of polluting projects and the positive externalities of green projects. The latest data from the National Statistics Bureau shows that private enterprises have occupied over 90% of national corporations in China; that the circular economy industry mainly depends on inter-corporation and private lending to support few high-margin items; and that support from banks is quite limited. Loan investments of main commercial banks on relevant industries of the circular economy only account for 7% of total green investments. A significant portion of banks' lending portfolio consists of loans to state-owned enterprises, which are dominant in most traditional industrial sectors such as steel, base metals, and chemicals. The strategic emerging sectors such as clean energy and high-technology manufacturing receive more than 70% of bank lending (Szamosszegi and Kyle, 2011).

It also lacks financial guarantees and insurance for private financing. For example, in the energy services sector, contract energy management operations largely depend on specialised energy services companies to make a profit. But most of them are small to medium-sized enterprises, with few assets, poor management, and relatively low financial quality. They have little money to lend, and the majority have never dealt with banks. Project funds lack liquidity owing to the long recycling time, so energy service companies must bear the costs. Consequently, commercial energy-saving project loans are difficult to obtain from banks.

Understanding how to restrict excessive investments in polluting sectors and incentivise private investments in green industries, as well as how to use limited government funding to leverage several times more in private investment, will be the key to promoting circular economy development and building an 'institutional system for ecological civilization'. This is also a major challenge that confronts China's economic restructuring.

4.3.1 Lack of effective financial system safeguards although the state strengthens financial support efforts

China is still far from having an ideal green financial regime and the volumes required to meet the demand for green investment. Although the government actively promoted marketisation in the field of sewage and garbage disposal for many years because of its strong public welfare, the majority of projects were still financed by government investment.

In terms of the 2012 Wind Database, bank loans are currently the primary source of external finance to enterprises in China, which is 2.7 times more than financing from issuing stocks or bonds in the capital market. PBOC has policies relating to green finance since the 1990s, limiting lending to polluting and energy-intensive industries. Later, in 2007, the China Banking Regulatory Commission put forward guidelines for green lending. Several years later, the commission announced that it would release guidelines on green credit ratings. China's Environmental Pollution Liability Insurance system was also relatively early on the scene, and is subject to ongoing improvement. While these efforts are not yet mature, they are on the table and markets are preparing to react. Opportunities for green building, for example, present major challenges for the financial sector. Commercial banks have difficulty pricing energy savings as an asset. Investors are still not comfortable with factoring water and energy performance into property-pricing decisions. Property investors need clear guidelines for green investment. Home buyers want to cut their energy costs and ensure good air quality for their children. City officials want to limit the expenditure of resources for public infrastructure. All these expectations must be part of green finance assessments.

As stressed by the decisions of the Central Committee of the Communist Party of China on several major issues concerning the comprehensive deepening of reform adopted at the Third Plenum of the 18th Communist Party of China Congress (CPC Central Committee, 2012), efforts must be made to establish 'a systematic and full-fledged institutional system of ecological civilization for the protection of eco-environment,' and 'a market-based mechanism that channels private capital investments to the protection of eco-environment'. The General Office of the State Council on the Implementation of Third Party Governance of Environmental Pollution (State Council, 2014) also stipulates that 'the People's Bank of China, the China Banking Regulatory Commission, the China Securities Regulatory Commission, and the China Insurance Regulatory Commission work together with the government agencies to formulate financial policies that support the development of environmental service industry'. The No.12 Opinions of the State Council on Accelerating the Ecological Civilization Construction' (State Council, 2015) puts 'green' into the core of modernisation, and takes 'green development, cycle development, and low carbon development' as the basic way towards the ecological civilisation of China.

4.3.2. Lack of E&S for most Chinese banks

Most Chinese banks choose to focus on issues directly related to government policy, including limiting the growth of 'high-pollution, energy-intensive, and over capacity' industries, improving energy efficiency of necessary industries, and developing renewable energy. For example, China's Industrial Bank, Shanghai Pudong Development Bank, China Development Bank, China Merchants Bank, etc. have all established a dedicated 'sustainable finance' team. The portfolio of green credit products across banks is diverse, catering to different sectors and regions. Several banks that already have interest in green finance actively identified clients at risk. The Shanghai Pudong Development Bank uses E&S risk management as an indicator to assess the performance of local branches for loans made to clients. Many banks recognise the lack of knowledge and skills internally and the need to improve this through formal and informal methods like training programmes and meetings with banks with best practices.

But only a few banks are taking the lead to develop green finance. The Industrial Bank of China is the first Chinese Equator Principles bank and is recognised as the 'greenest Chinese bank'. The Shanghai Pudong Development Bank is publicly recognised as a leader in green finance. For most banks, profitability is a key factor that they consider if they should go for further commitment on green finance since this concept is still at an early stage. The relatively low share of green credit compared to the overall loan portfolio means training on E&S issues is not a high priority for many banks.

Most domestic banks rely on environmental impact assessment reports by borrowers to assess risks. In rare cases, banks have specific E&S in place. 'One-vote veto' is fully implemented across the banking sector, but additional assessment on E&S issues and post-loan monitoring are not common at present. Leading international banks' compliance and performance monitoring efforts may vary depending on the nature of the transaction. Failure to effectively identify and control E&S risks could lead to financial, legal, and reputational damage to both the company and the bank (PwC HK, 2013).

In addition, the financial regulatory authorities have no specific industry standards for low-carbon industries, lack detailed instructions, and have no environmental risk-rating standards for projects. These have made green credit policy too unclear for implementation at an operational level.

4.3.3. Lack of financial guarantees and insurance for private financing

As an example, contract energy management operations largely depend on specialised energy services companies to make a profit. But most of them are small to medium-sized enterprises, with few assets, poor management, and relatively low financial quality. They have little money to lend, and the majority have never dealt with banks. Project funds lack liquidity owing to the long recycling time, so energy service companies must bear the costs. Consequently, commercial energy-saving project loans are difficult to obtain from banks.

4.3.4 Lack of capacity, training, and knowledge of financial institutions in E&S issues

Technical capacity and skills in non-technical aspects such as managerial and senior level engagement are important factors that will help drive the expansion of green finance. Furthermore, the legal system is still behind. Legislation does not impose strict enough penalties, including newly released regulations. Enforcement is also ineffective and the cost and pricing of environmental impacts are still problematic. The negative cost of pollution and emissions is not factored into economic statistics.

In addition, in China, statistics on investments and financing have not been established. Most data about circular economy investments take environmental-protection investments as reference basis. Also, data on environmental protection and circular economy investments are often mixed. Investments and financing policies on environment protection mainly focus on environment protection and not the circular economy. Thus, environmental-protection investments and financing policies only help the implementation of the circular economy to some degree. Some environmental-protection investments can be attributed to investments on the circular economy. Although some environmental-protection investments have the environmental-protection effect, they do not fall under the scope of the circular economy in a strict sense. Due to the lack of accurate statistical data on the circular economy, the preparation of policy for the circular economy lacks accurate data support and scientific basis, which undoubtedly brings many difficulties for guiding and promoting the development of the circular economy.

Green finance requires additional screening of E&S risks and knowledge of emerging projects. The new opportunities for green finance are therefore associated with extra costs to banks. Due to the lack of green finance information and data disclosure, it is hard to find direct quantitative linkages between green finance practices and financial performances in Chinese banks.

5. Establishing Green Finance System to Support the Circular Economy: Policy Recommendations for ASEAN Countries

Guided by the foregoing framework and drawing on international practices and experiences to promote green finance, the ASEAN governments must prepare the following finance-related policies:

- formation of financial resources and capital support for green economy and green industry;
- development of diversified financial products and services to support green growth;
- revitalisation of private investment on the construction of foundation facilities;
- strengthening of public notice systems on green management information of companies and expansion of financial support for green companies;
- enhancement of capabilities to support green finance; and
- promotion of global cooperation.

5.1 Broaden and Enhance the Formation of Financial Resources and Capital Support for Circular Economy Projects through Innovation

Compared to financial institutions in developed countries, financial institutions in developing countries generally lack green finance experience, especially when introducing E&S to the traditional financial business. Governments need to provide the corresponding training and technical support, and even preferential fiscal arrangements and taxation to promote the market access.

Greening the banking system. The role of bank lending in financing industrial transformations means that promoting green finance is an important lever to ensure that countries can meet their environmental target. The role of the government and regulator will also be crucial in shaping the lending decisions of commercial banks. Banks need to demonstrate that they are acting in an environmentally sensitive way. The greening of the banking system also needs further clarification to guide and explain the terminology and, more importantly, propose a framework and standard protocols for E&S risk management across the whole lending activities for banks to use. Lender liability for environmental pollution by borrowers should be introduced, and environmental liability insurance should be mandatory for selected industries. Transparency in the implementation of the Green Credit Policy and Guidelines needs to be enhanced. If banks' standards and performance are publicly defined, reported, and accessible, companies will be able to build trust with stakeholders and demonstrate their management of social and environmental issues.

Greening the capital market. Capital markets can react positively to the announcement of rewards and explicit recognition of superior environmental performance. Currently, the capital markets manage trillions of dollars that could be directed towards a green economy. Public and private institutional investors, banks, and insurance companies are increasingly looking at portfolios that minimise environmental, social, and governance risks, while capitalising on emerging green technologies. While in many ASEAN countries, the capital market is less developed, financing through the capital market for green industries is limited. In this sense, it is necessary for some Asian countries to study the successful experience by introducing new varieties of product innovation and trading market, gradually forming perfect multilevel capital market system, and, to further improve present enforcement of issuing conditions, release information on disclosure procedures, provision for supervision and management, and legal liability. The governments can harness market forces of capital market by introducing structured programmes to release firm-specific information about environmental performance. Stock exchanges would mandate investor-relevant environmental reporting and encourage the development of green indices and linked exchange-traded funds. (Another form of a public disclosure mechanism is the Global Reporting Initiative). This iniative invites voluntary participation of stakeholders outside the regulatory public institutions of the country to implement the industrial environmental evaluation.

Creation of a new green investment bank. Governments can actively explore and encourage the creation of new green banks, funded mostly by private capital, then introduce practices and experiences in green financing from the eco-finance business divisions of more established commercial banks. A new green bank will provide at least five major benefits. First, it will enhance the public's confidence and risk preference for green projects and help steer more public funds. Second, a new green bank can easily adopt the Equator Principles from its inception and match international best practice in environmental principles and risk management. Third, innovative financing methods for targeted industry sectors and market needs will be implemented more easily. Fourth, countries will have a much more flexible ownership structure to attract private investors. Fifth, a specialised green bank can outperform normal commercial banks in controlling risks and non-performing loans, as seen from experiences of other countries.

Encourage innovative financing by supporting discounted green loans, issuing green bonds, green funds, improving the mechanism of green initial public offerings, green bonds, and other finance innovations. Green bonds are debt instruments that associate the proceeds of a bond issue to environmental or social activities, creating ring-fenced debt finance for green investments. China and India, pioneers in Asia's nascent green bond market, are expected to be prominent drivers of regional issuance over the coming years given their governments' ambitious targets on building renewable energy capacity. What governments need to do is encourage incentives for buyers on a set of green bond guidelines. Green funds will serve as the platform through which private capital can converge into professionally managed green investments and provide an important supplement to green credits. Furthermore, leasing finance is a powerful and flexible tool with which to finance sustainable energy equipment. Leasing energy-saving and emission-reduction technology and equipment was the solution used for Beijing's Chaoyang District and it established a 'green role model' in China. Another example is energy management contracts. Energy management contracts will affect the focus of the eight predetermined, high energy-consuming industries, including steel, cement, metallurgy, coke, calcium carbide, coal, glass, and power. Moreover, carbon finance is a new branch of environmental finance. The market for the purchase of carbon has grown exponentially since its conception in 1996.

Setting up a network of financial institutions and other stakeholders. Financial institutions can become familiar with the entire product value chain by partnering with contractors and manufacturers to offer green financial products; can align green financial product and service development with federal, provincial, state, regional, or municipal environmental and energy policies, targets or incentives; and can collaborate with environment-focused non-governmental organisations and academic groups to design and offer green financial products. It is also necessary to set up a network of green investment banks and groups of commercial banks.

5.2 Some Special Mechanisms are Needed to Further Boost Lending and Risk-taking Capacity for Higher Risk Circular Economy Projects with the Aim of Mobilising Private Capital

Giving innovative small businesses access to the stock market. Governments should encourage and support resource recycling enterprises to meet the conditions for domestic and foreign listing and refinancing, actively develop credit innovation products that are relevant to the circular economy, and broaden guarantee range and innovate guarantee schemes. Regulatory authorities can list the approved public offerings and 'green' channels to accelerate the financing of green measures in the capital market. Greater disclosure of environment risks to investors is necessary as well. In the US, Japan, and Europe, the second board markets serve as one of the main mechanisms for the exit of green industry funds from their investors. Similarly, Asian countries should hasten their pace in lowering the listing criteria and transaction costs of the Growth Enterprises Market Board, improve the transparency and regulation of the market, and implement strict delisting regimes.

Offering financial guarantees or insurance to help remove barriers to private investment. Financial guarantees or insurance can be provided by governments, normally through government-owned or -controlled corporations, central banks, ministries, or other government departments; national, multinational, or multilateral export credit agencies; and private sector guarantors or insurers. Several public finance instruments can help remove barriers to private investments, such as loan guarantees, which enable borrowers to obtain lower interest rates, as the lender is protected against default; or mixed-equity funds, which lower the risks for private equity investors, including public capital in the fund. The need for a modern grid infrastructure is an example of when private capital must be mobilised along with government infrastructure spending. The use of 'green' mortgages for green buildings could help finance energy-efficient houses, enabling homeowners to pay the accrued energy savings over time. The People's Bank of China can launch financing pilot programmes for commercial banks, technology service providers, and companies that need energy-saving innovation. Some of this money will be allocated as non-performing loans, and local governments can join in offering funds.

Creating green funds to encourage private capital. The government can encourage creating green industry funds through public–private partnership (PPP) arrangements. The level of government involvement in a green industry fund should depend on the nature of the fund. PPP green industry funds can be thought of as an innovative extension of the traditional PPP model. First, they can enjoy the favourable policies applicable to individual PPP projects. Second, as an innovation, PPP green industry funds can possess characteristics typical of PPP arrangements, which will make them significantly different from other industry funds. For green start-up companies, green industry funds will have difficulty pulling their funding support from these companies.

Encourage innovative business models in the circular economy, especially supply chain finance. Supply chain financing means commercial banks connect core enterprises with upstream and downstream enterprises through expanding services of core enterprises, from raw material purchase, intermediate products, finished products to the delivery of the products to consumers through sales networks. Innovative business models are needed to allow better access to products, components, and materials during and within the post-usage loops. Business model innovation will be critical to mainstreaming the uptake of the circular economy principle in more business-to-business setups, and in business-to-customer setups. Industry chain financing can break through traditional loan modes. The service is not oriented to producers, manufacturers, sellers, and other independent enterprises in the industry chain in the market. Thus, large core enterprises in the supply chain can provide larger financial support for the industry chain. Therefore, industry chain financing services can make small and medium-sized enterprises enter the credit system. Meanwhile, industry chain financing can mobilise commercial banks to research and develop more financial products to improve operation initiatives and flexibility as well as the profit space of commercial financial institutions. It is required to actively improve credit rating mechanisms implemented for small and medium-sized enterprises according to distinct characteristics of small and medium-sized enterprises.

5.3 Enhancing the Basic Financial Infrastructure and Capacity Building

For a full-scale market to develop, solid foundations need to be in place, including a framework of definitions and standards, institutions, and capacity for assessment, and networks and platforms for trading.

The first problem facing most Asian countries is information asymmetry between industry and the financial sector. Most financial institutions tend not to evaluate green performance of firms. Green certification, a green rating system, and environmental information disclosure are examples for serving this purpose. Efforts should be made to investigate the pathways and degrees of the impact of green factors on sovereign governments, local governments, and corporate rating.

Moreover, carbon and pollution trading markets are important financial infrastructures for the promotion of emissions abatement at lower costs and with higher efficiency. National legislation and top-level design should be strengthened and optimised to accelerate the development of a national carbon trading market, set appropriate cap and trade mechanisms, fully leverage price incentive to polluters, and increase market liquidity. For key river systems and air-pollutant monitoring regions, governments should establish trial programmes that allow pollution rights trading across administrative divisions, and implement a system for regular evaluation and adjustment that links total regional pollutant emission with the carrying capacity of the local environment.

Furthermore, governments can promote the use of circular economy development indices that orient the capital market to the circular economy industry. Financial institutions can publish greener and sustainability stock indices with reference to successful earlier experiences to expedite the development of relevant investment products. Exchanges and index companies may provide platforms for realising sustainability indices and information.

It is also necessary to constantly increase the information volume of the database, starting with listed companies and major polluters. Based on publicly disclosed environmental information or corporate social responsibility reports, the inputs of environmental cost accounting can be arrived at (such as the categories, emissions, and local emission pricing of various pollutants) and the environmental costs of companies can be calculated and included in the database. With growing public demand for the disclosure of environmental information, more enterprises can be included in the database over time.

Increasing the environmental and social responsibility of regulators, financial institutions, investors, and consumers is also necessary. Firms need to be more aggressive and innovative in introducing green management. Firms should invest in green management and seek competitive advantage through achieving green management. It is also necessary to improve environmental experts' inspections of listed companies, training mechanisms, evaluation mechanisms, and incentive mechanisms; and linkage to environmental protection departments, the securities information regulator, and the local environmental protection department regulator, and others. The professionals in green finance should be educated. The experts in banks and capital markets need to have professional knowledge about socially responsible investing investment, carbon trading, and carbon tax.

Governments also need to accelerate the formation of legal infrastructures by, for example, setting up a national compulsory green insurance system and promulgating regulations on the compulsory pollution liability insurance. Countries including the US, Germany, and Russia have enforced compulsory insurance requirements for enterprises or equipment with high environmental risks. Singapore and Taiwan have also promoted the green insurance market during the early stages of their development through compulsory insurance requirements. Stock exchanges should formulate rules on compulsory environmental information disclosure, identify environmental information as an indispensable component of corporate information disclosure, and formulate compulsory rules of environmental information disclosure.

5.4 Encourage International Cooperation, and Widen International Financing Channels

Some international banks such as the Asian Development Bank have already started the green business in Asian countries. The World Bank Group has a wide range of concessional financing instruments that can cover the incremental costs and risks associated with low-carbon investments (World Bank, 2016). Examples include the Global Environment Facility projects for energy efficiency, renewable energy, new clean energy technology, and sustainable transport projects; the Carbon Partnership Facility to generate a flow of carbon credits for up to 10 years after 2012; the Clean Technology Fund towards clean technologies; and the Strategic Climate Fund to support targeted programmes with dedicated funding to pilot new approaches with potential for scaled-up, transformational action aimed at a specific climate change challenge or sectoral response. The International Finance Corporation, a member of the World Bank Group, also provides direct debt and equity financing.

The Green Climate Fund, founded within the framework of the United Nations Framework Convention on Climate Change, is a mechanism to transfer money from the developed to the developing world to assist the developing countries in adaptation and mitigation practices to counter climate change. Its objective is to raise US$100 billion a year by 2020. The long-term financing of the Green Climate Fund aims to raise US$100 billion per year by 2020.

Further, large venture capital/private equity and funds are beginning to look for low-carbon investments. The past few years have seen an explosion of interest in clean energy by venture investors. New Energy Finance has identified over 1,500 separate venture and private equity groups, all searching for the clean energy equivalent of Cisco, Dell, Amazon, or Google. Wind is the most mature clean energy technology and it accounts for more than one third of capacity investment, more than either nuclear or hydroelectric power. Solar energy is the fastest-growing sector. The P8, an initiative of the Cambridge Programme for Sustainability Leadership and HRH Prince of Wales's Business and Environment Programme, is a group of senior leaders from some of the world's largest public pension funds, working together to contribute to take the lead in the move towards a low carbon economy. The P8 started as a group of eight of the largest pension funds and now involves 10 leading global pension funds and sovereign wealth funds, including representatives from Europe, Asia, Australasia, and North America. They are working closely with development agencies and multilateral development banks to identify specific investment opportunities.

In this sense, the governments can assist the local finance projects by coordinating with international and local financial institutions, and use the multilateral development banks' knowledge-sharing platform to speed up international knowledge transfer and learn international advanced management experiences and technology. For this, it is necessary to strengthen the capacity of government officials to help enterprises realise these potential international alternative financial products. Governments can encourage commercial banks to strengthen the cooperation with domestic and international finance intermediaries to jointly explore the development of green finance market and learn from the cooperation.

6. Conclusions

The development of the circular economy is not only beneficial to the effective protection of the ecology and the sustainable exploitation of the resource but also to the adjustment and upgrade of the industrial framework. The circular economy is characterised by low consumption, low discharge, and high efficiency. Policy financing is an effective booster and important guarantee for promoting the circular economy development and transformation of an economy to development mode.

However, in most Asian countries, because the circular economy is a long-term project and has a wide involving range and higher technical research and development investment, fund demand is quite huge and financing for small and middle-sized enterprises is especially difficult. Taking China as an example, its current thcircular economy industry mainly depends on inter-corporation and private lending to support few high-margin items, and operation of the project with general margin is struggling. Meanwhile, limited by policy and mechanisms and worrying about risk and reward, private capital cannot always be injected into the booming industry market.

Given the financing challenges to develop the circular economy, we suggest that a green financial system that supports the circular economy in ASEAN countries should have the following characteristics:

First, the establishment of a sound green financing mechanism will be a systemic project that requires the coordination amongst central authorities, local governments, financial institutions, and enterprises. In the process, governments have a key role to play in strengthening domestic policy frameworks, better aligning and reforming policies across the regulatory spectrum to overcome barriers to green investment, and providing an enabling environment that can attract both domestic and international investments. Three types of policies and mechanisms can be designed: increase returns to the circular economy projects; reduce returns to polluting projects; and increase investor, corporate, and consumer responsiveness to these signals.

Second, enable direct long-term investment and sustained financing by encouraging new green financing channels and financial products innovation. In prompting the greening of existing banking channels to green credits, governments can consider the creation of a new green investment banks by undertaking huge capacity-building exercises across relevant institutions. The capital market shift, the evolution of market instruments such as carbon finance, and green stimulus funds established in response to the economic slowdown are opening spaces for financing a transformation. For this, regulators and key market players need to promote the development of the global green bond market and improve the consistency of green bond standards to develop environmental information disclosures for publicly traded entities and develop environmental stress testing by financial sectors and/or firms.

Third, innovation to scale up institutional investment and large-scale private investment needs to be mobilised to close the funding gap. To steer private capital to the circular industry, a series of policies, institutional arrangements, and related infrastructure building are necessary. Green bonds are an optional policy because, as typically tax-exempt bonds, they are issued by federally qualified organisations and target institutional and retail investors and, therefore, can help raise additional funds from consumers and the private sector rather than from general taxation.

Fourth, international cooperation and knowledge sharing is crucial. International organisations, national banks, institutional investors, and banking associations can enhance cooperation to promote the adoption of high environmental standards by lending institutions around the world and enhance their ability to conduct green investments. National governments should actively nurture intermediaries, including the trading platforms, consulting, assessment, legal, accounting, and other intermediaries' services, to cultivate and improve the cultivation of the right to participate in green finance.

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Chapter 8

Mitigating the Risks and Adverse Impacts of Implementing Services for the Internet of Things

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1. Introduction

Information and communications technology (ICT) has been the primary source of several innovations in modern human society. Since the 1970s, the advent of personal computer, the internet, and smart phone has changed human life enormously, and other new ICTs will keep changing the human world in the future. The internet of things (IoT) is considered the next source for information technology-generating innovation. Even if IoT has huge potentials to improve human life, we must introduce new technology effectively and prevent any negative impacts. We need to maximise the benefits from using new technology and minimise the risks arising from its use. More careful examination of the implementation process should be studied. The aim of this chapter is to analyse both the benefits and risks from implementing new technology, and to prepare for its best use.

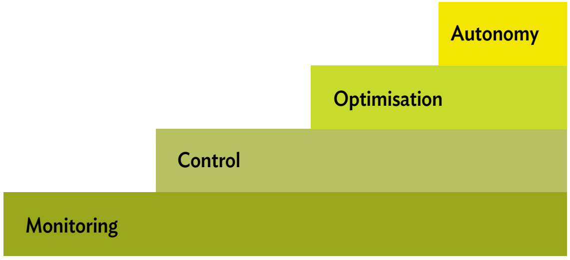
Our study first reviewed the positive and negative impacts of the introduction of IoT services. When new technology is introduced in our lives, we gain not only many benefits but also some negative outcomes. We will try to explain these positive and negative impacts of the implementation of IoT-based services from both the demand side and the supply side. The demand side usually represents customers and markets, and the supply side usually represents corporations. Next, we will discuss how we can manage this technological change to maximise the benefits and minimise the adverse outcomes. We will also analyse two cases where IoT is implemented to improve circular economy. These cases are the waste recycling system management and the intelligent transportation system (ITS) management. Through these case analyses, the benefits and risks coming from IoT implementation will be re-examined.

2. Basic Characteristics of Internet of Things

Information technology has influenced human life and organisation management very much. Personal computers were introduced in the 1970s and the internet opened a new era in telecommunication in the 1990s. Smart phones made mobile communication common since 2010. The current leading technologies in ICT are IoT, big data, location-based technology, cloud computing, and many more. The most important technology amongst these is IoT. Many applications using IoT are being considered and we will face many changes in our everyday life from the usage of IoT. IoT is expected to innovate human lives in areas such as home electronics, healthcare service, transportation, and manufacturing processes. IoT and the internet of everything (IoE) paint a vision of a seamlessly connected world where interconnected devices collect and share our most practical data to improve the functionality of products, the efficiency of homes and workplaces, the infrastructures of cities, and, fundamentally, the overall integration of our lives. But there are also hidden or lesser-known risks.

Porter (2014) explains four basic functions of IoT as shown in Figure 1. The first function is monitoring. Sensors and external data sources enable the comprehensive monitoring of many things such as the product's condition, the external environment, and the product's operation and usage. Next, we can control the processes. Software embedded in the product or in the cloud enables control of product functions and personalisation of the user experience. Third, we want to optimise the processes. Monitoring and control capabilities enable algorithms that optimise the production process and use to enhance production performance and allow predictive diagnostics, services, and repair. Lastly, we can expect an autonomous production operation. The manufacturing system can coordinate various operations and enhance the quality of the process. Self-diagnosis will also be possible. The innovation from using IoT comes from these four functions of IoT. These functions can be applied in most areas of human life and create many benefits.

Figure 1. **Capabilities of IoT Services**



IoT = internet of things.
Source: Porter, 2014.

One example of the application of IoT is the streetlights. When IoT is applied in streetlights, they monitor the darkness of the street automatically. Through sensor technology, the streetlight can send the signal to the central system when it becomes dark on the streets. This is the role of monitoring in the new system. After the central system receives the signal about the darkness on the streets, it can turn the lights on or off. From the automatic monitoring and control functions, the system can minimise the time to turn on the lights and the energy consumption. This can achieve the optimal condition for the operation of streetlights. Lastly, every process in monitoring, control, and optimisation is performed automatically. There is no human intervention in the entire process. The autonomy is achieved in the system. The use of IoT in providing these four functions can be limitless. These IoT applications can be possible in any area of human life and create new values to human society.

3. Impacts of IoT-based Services on the Demand side

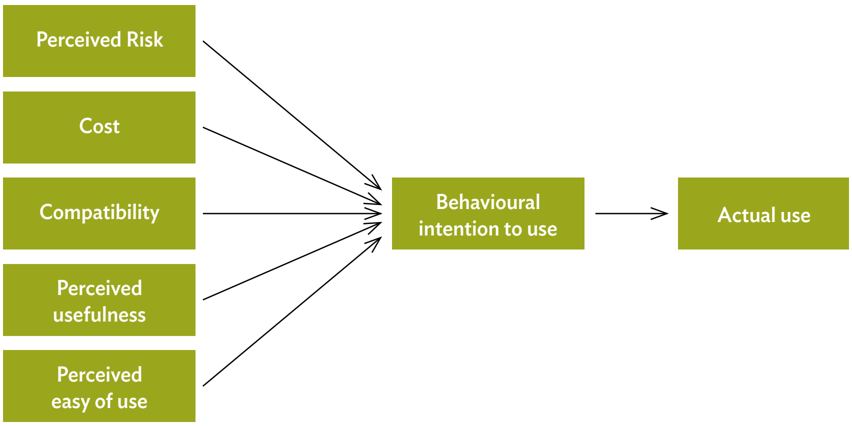
This chapter will consider the impacts of IoT on both the demand and supply sides. Demand side means the markets and consumers of IoT-based services and supply side means the corporate sector that supplies the services. We want to answer what sorts of positive effects can be made on consumers and markets from the implementation of IoT-based innovations and what will be the negative outcomes. Table 3 summarises the positive benefits and negative outcomes of the impacts of IoT- based services on the demand side.

3.1. Technology Acceptance Model

To determine the attitude of buyers in markets when a new product or service using new information technology is introduced, Davis (1989) suggested the technology acceptance model (TAM), which has two factors: recognised ease of use and recognised usefulness. After Davis (1989) presented this model, many scholars searched the diverse determinants to make technological innovation accepted in a market. Figures 2 and 3 show a revised or extended TAM.

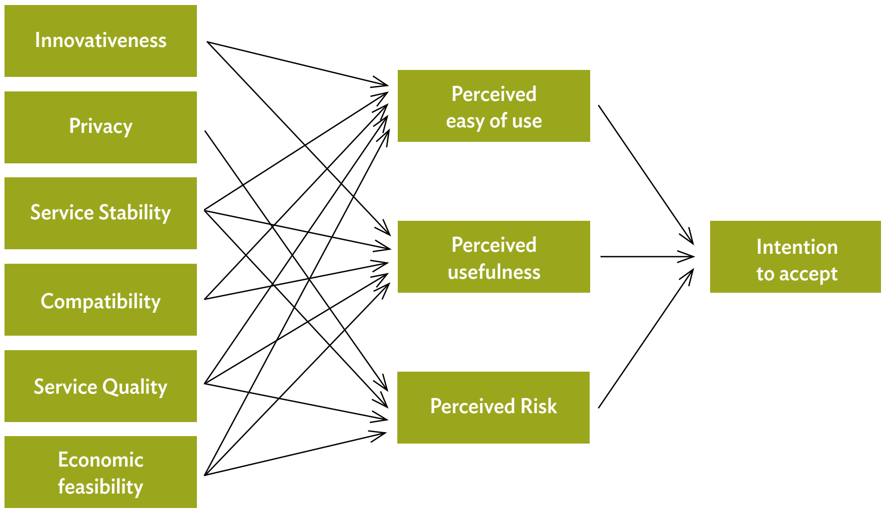
We need to consider several factors when we make a new product or service using IoT based on TAM. IoT will be applied in many areas in our lives, but whether the new services will be accepted in the market is determined by factors identified in TAM. Originally, TAM considered two factors that determine the acceptance of new technology: ease of use and usefulness. Consumers need to recognise that this new technology is useful in their lives and create new value, and that they can easily use it. There are many start-ups considering new business models with IoT usage and these two factors must be in the centre of the start-up manager's mind. Another important factor is economic feasibility. Even if a new product or service is very innovative, the high price can be an obstacle to be a successful business. It is true that IoT is a very innovative technology, but there are many requirements to consider for its acceptance in the market.

Figure 2. Technology Acceptance Model



Source: Davis, 1989.

Figure 3. Extended Technology Acceptance Model



Source: Legrisa, Inghamb, and Collerette, 2003.

The difficulty of acceptance in the market can be seen in the case of a smart farm in the Republic of Korea (Kim, Jung, and Lee, 2016). Even if a smart farm provides many kinds of benefits, it is not widely accepted in the Republic of Korea. There are various obstacles to delay the introduction of smart farms in the Republic of Korea. A smart farm is also a very potent area for using IoT. Table 1 shows three steps in the development of a smart farm. Agriculture information technology 1.0 (Agriculture 1.0) means automation in the production process. By using various machines, we can automate the production processes. The machines automatically cut flowers, move them, and make bundles. In Agriculture 2.0, we monitor the conditions by sensors and distribute the information through electronic communication network. We can control the temperature of the greenhouse even from a foreign country. In Agriculture 3.0, we use big data technology. We collect data from farmers and analyse the optimal production condition and share it amongst the farmers.

Table 1. Agriculture IT Development Process

Agriculture IT 1.0) Agriculture Automation	(Agriculture IT 2.0) Smart Farm	(Agriculture IT 3.0) IoT Platform Propagate
• Increasing the crop productivity and quality standardisation	• Monitor and control the crop cultural environment	• Disruptive innovation realisation
• Reduction of manpower	• Provide safety food	• Various connected farm
• Raise agriculture value added	• Climate change response	• Information sharing between users
• Partial control of the crop cultural environment	• Forecast market demand	• Low initial installation cost
	• Enclosed type	• Leading in agriculture IT
	• Low penetration rate because of high cost	

IT = information technology, IoT = internet of things.

Source: Asuming–Brempong, 2004.

The benefits from smart farms are summarised as follows. First, we can reduce the labour cost. A successful example is found in the flower production of the Netherlands where the impact of agriculture automation is very clear. For example, the minimum production size to realise scale of economy in the production of flowers in the Netherlands is at least 30 hectares. Second, we can improve productivity and quality. Agriculture production is not limited by the climate condition, and production is possible all throughout the year. Data can be collected from many farms and the optimal production condition can be calculated. This optimal solution can be shared amongst farms. Third, the early participants in smart farms can have first-mover advantage in this area. As ICT advances, the scope of smart farms will extend and the country with the first-mover advantage in smart farms will lead agriculture in the future. In some regions such as Eastern Europe or Middle East where the climate is not adequate for agriculture production, the adoption of smart farms is critical. Fourth, smart farms make agriculture production less restricted by external environmental conditions such as land, temperature, carbon dioxide, and many more. Light-emitting diode lighting can replace sunlight and water can be automatically supplied. The temperature inside greenhouses is controlled by the automatic opening of the ceiling. Typhoon, drought, flood, and insects cannot affect production, and the forecast of future production becomes possible.

But there are also some obstacles in building smart farms. An important challenge in introducing smart farms is the resistance from farmers. The introduction of new technology usually faces resistance or inertia from users. The interviews with owners of two successful smart farms in the Republic of Korea revealed that many farmers do not have positive attitude towards smart farms (Kim, Jung, and Lee, 2016). In the Republic of Korea, some large corporations intended to participate in agriculture production and they wanted to introduce large-scale production with new technologies. Most of these firms faced strong resistance from farmers and gave up their ambitious plans. Another critical hurdle is efficiency. The construction cost of a smart farm is so huge that it is not easy for a farmer to do it. Even if the possible benefits of smart farms are huge, their spread in the Republic of Korea is very limited due to the obstacles mentioned above.

We reviewed the factors that influence the acceptance of IoT technology on the demand side. We also investigated the impacts of IoT on the technical, social, and environmental aspects on the demand side.

3.2. Technical Aspects

Value creation and improved life. New treatments and materials can be developed by new IoT devices and sensors, and new values to customers can be created. One example of the new treatment is the e-healthcare device. Medtronics, a healthcare vendor in the United States (US), announced that its research prototype for a smart phone application will predict hypoglycaemic events in diabetes patients three hours in advance (Vermesan and Friess, 2013). In this process, the various requirements of customers are reflected on the new IoT products and services. The healthcare application of Medtronics is designed to provide relevant, real-time insights, and coaching to help people improve their ability to understand the impact of daily activities on their diabetes and adjust these as needed. Personalised diabetes management is also possible from the application of Watson's cognitive computing power to data from Medtronic's wearable medical devices, including insulin pumps and continuous glucose-monitoring devices. Those customised products and services provide easy-to-use and convenient technology.

Security and privacy. Previous research suggests that consumers are likely to put high value on cybersecurity. Many consumers require that data security professionals be hired and work in their organisations. As many kinds of IoT products and services are introduced in the marketplace, data security is likely to become a critical component. For example, e-healthcare applications need to consider data discovery and classification. All healthcare organisations must try to install secure IoT devices in their systems. Yet, according to more than 7,000 global IT and cyber security professionals, IoT device manufacturers are not supplying sufficient security measures.

System credibility. A remote patient-monitoring programme can collect from a remote site a wide range of health data such as vital signs, weight, blood pressure, blood sugar, blood oxygen levels, heart rate, and electrocardiograms. Health professionals can remotely monitor and treat patients based on this collected information. But those personal data may have two issues: privacy and the risk of data inaccuracies (Baliamoune–Lutz, 2003). Data are transmitted to health professionals in facilities such as monitoring centres in primary care settings, hospitals and intensive care units, skilled nursing facilities, and centralised off-site case management programmes. However, the probability of transmitting inaccurate data raises the possibility of incorrect treatment. The disclosure of personal information is also a critical issue.

3.3. Social Aspects

Increased connectedness. Basically, IoT means the connection amongst many things through sensors and digital network. Many kinds of information can be created and delivered to people. We can receive many kinds of data such as natural conditions, safety, and locations from remote places. IoT can increase globalisation through the improvement of transportation and communication technologies. IoT devices and sensors can support a hyper-connected ecosystem through smart phone usage (Friess, 2013). There is seamless connected technology through long-term evolution or 4G to 5G with higher data transmission capacity.

Upgrade of social function. The introduction of IoT can offer many valuable products and services, which would be impossible without IoT. New technology such as IoT can improve the function of society. For example, financial technology or fin-tech in China is being boosted to overcome its current inconvenient and outdated banking system. Therefore, IoT can upgrade China's current banking system and offer the future financial system to the Chinese. IoT technology can facilitate human progress and suitable social systems (Shin, 2014).

Social inequality. In addition to security issues, IoT services can deepen the inequality in our society and increase unemployment rate due to information gaps. Isolation of communication may occur between people and things. The advancement of technology can make the production system in a society more efficient and increase the total amount of wealth in society. But the increased wealth in society can be concentrated in a limited number of people. Another adverse effect is that the social norm can be changed from the introduction of new technology. The speed of wealth creation is different between people with information and people without information due to the social value of information and knowledge.

Job loss. Many experts are concerned that technological progress in ICT may bring about job loss. IoT and artificial intelligence can affect employment (Lohr, 2012). The World Economic Forum reports that robots will cut 25% of jobs in 4 years in the US. This report was based on a survey of senior executives from 350 companies across nine industries in 15 of the world's largest economies. Many experts warn that substitution of machinery for human labour from using artificial intelligence may lead to job loss (The Economist, 2016). Our past experiences showed that mass production during the second industrial revolution and the automation that occurred during the third industrial revolution led to both job loss and creation. We can expect this to happen again when we face the fourth industrial revolution and hyperconnected society. What matters is not only the job loss but also the wage gap coming from information and technology asymmetry. The importance of effective education and training should be considered to adapt successfully to the technology environment. Now is the time to prepare for a new employment framework, new legislation, and welfare system, and we should not waste one century again.

3.4. Environmental Aspects

Monitoring of environmental symptoms. The monitoring capability of IoT can be used to detect our environments (Fantana et al., 2013). We can monitor the significance of pollution and degradation in natural environments. Some places are difficult to be approached and protected by men. Deep seas, high skies, and deep valleys are examples. Remote monitoring and control makes possible more effective management of natural environments. Cook and Das (2007) report that we can monitor our environment by using physical sensor and make the information available over the communication layer. A database storing environmental information is a useful technique.

Environmental protection. In today's society, environmental protection is considered very important. IoT can be a tool to further reduce carbon emission and improve resource circularity to protect the environment. Now, economic prosperity and environmental protection are stressed at the same time. The innovative functions of IoT make these two objectives easily achievable. IoT can help reduce waste from the demand side. A region has diverse sources of wastes. In the agricultural region, the wastes from livestock excretion can be transformed to biogas and biogas can generate clean energy. In this process, we expect energy reduction. This technology reduces energy consumption and minimises the waste discharge. Efficiency in energy source minimises environmental pollution and represents a positive side of the circular economy.

Environmental harm. We can also recognise the adverse effects of IoT in the environment. It can raise environmental harm through heavy metal, radiation, and chemical disasters. The sensor of IoT consists of electromagnetic elements. Around 26 billion sensors and terminals of IoT system will be deployed in 2020 based on Gartner forecasting reports. We will face the problem of wastes from those unused sensors and terminals. It is not sure if these wastes would be recycled. The United Nations estimated in 2013 that 53 million tonnes of new electrical and electronic equipment and e-waste will be stacked in the increasing return to scale pattern. Therefore, we have a joint effort by the United Nations such as the Stopping the E-waste Problem Initiative, which can suggest ways to reuse and recycle those hazardous substances.

Table 2. Impacts of IoT on the Demand Side

	Positive Benefits	Negative Outcomes
Technical Aspects	1. Qualitative requirements are reflected on new products 2. Development of new materials 3. New treatment available 4. Ease of technology tool 5. Technical feasibility 6. Ease of technology	1. Privacy 2. Cybersecurity weakness 3. Standardisation of technology 4. Risk of data inaccuracies 5. Significant investment in the system 6. Information disclosure 7. Waste of resources to maintain the system trust 8. Complexity to have compatibility
Social Impact	1. Ease of transportation and means of working 2. Changes in lifestyle pursuit 3. Increased connectedness 4. Upgrade of social system	1. New social norms amendment 2. Lack of humanity in technology advances 3. Traffic accidents (AI unmanned car error) 4. Job loss 5. Social inequality
Environmental Aspects	1. Technology powered by clean energy 2. Environmental pollution monitoring 3. Resource savings and sustainability 4. Efficiency of energy resources 5. Minimising waste discharge	1. Increased wastes from electronics 2. Environmental harm (heavy metals, radiation, and chemical disasters)

AI = artificial intelligence, IoT = internet of things.

Sources: Palensky and Dietrich, 2011; Baliamoune-Lutz, 2003.

4. Impact of IoT on the Supply Side

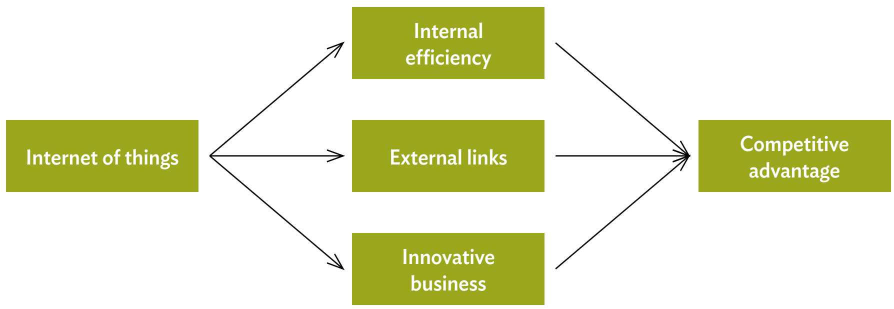
IoT can be effectively utilised in most industries and this will change the value chain of corporations. In some firms, IoT can be a new source to create competitive advantages, but new technological environments coming from IoT can provide competitive threats too. The following technologies are new environments for firms.

- The communications environment will be 1,000 times faster than the 5G or 4G Long-Term-Evolution (LTE) to accommodate the amount of data increase;
- The data centre must be built to prepare for the era of big data. Big data is generated in the digital environment. Its scale is vast and has a short life cycle. It includes large-scale numerical data as well as text and image data; and
- Sensors to measure temperature, humidity, heat, gas, light, ultrasound, motion, and sound generate different types of information.

4.1. IoT and the Competitive Advantage of Firms

Traditionally, ICT improves the competitiveness of firms through three paths: internal efficiency, external links, and innovative businesses. We want to review how these three paths contribute to corporate competitiveness through the implementation of IoT. It can make the internal processes in an organisation cheaper and faster and, as result, make these processes more efficient. Firms can also connect with external institutions more easily through IoT technology and, therefore, information flow from and to the outside of the firm increases significantly. As a new technology IoT offers the possibility of new business models; valuable business models developed through IoT can provide new growth opportunities to firms.

Figure 4. Competitive Impacts of IoT in Firms



IoT = internet of things.

Source: Powell and Dent-Micallef (1997).

Three sources of competitive advantage from the use of ICT can be applied to IoT. Will the adoption of IoT in corporate management bring about internal efficiency, external links, and innovative business? Can some other competitive advantages be created from the introduction of IoT? An example of IoT application in corporate management is Industry 4.0. The following are discussions about the concept and effects of Industry 4.0. From the description of Industry 4.0 below, internal efficiency, external link, and new businesses can be realised from the development of smart factories through Industry 4.0.

Industry 4.0 is the current trend of automation and data exchange in manufacturing technologies. It includes cyber-physical systems, IoT, and cloud computing. Industry 4.0 creates what has been called a 'smart factory'. Within the modular structured smart factories, cyber-physical systems monitor physical processes, create a virtual copy of the physical world, and make decentralised decisions. Through IoT, cyber-physical systems communicate and cooperate with each other and with humans in real time. Also, via the internet of services, both internal and cross-organisational services are offered and used by participants in the value chain.

Some examples of Industry 4.0 are machines that can predict failures and trigger maintenance processes autonomously or self-organised logistics, which react to unexpected changes in production. According to Davis (1989), 'it is highly likely that the world of production will become more and more networked until everything is interlinked with everything else'. While this sounds like a fair assumption and the driving force behind IoT, it also means that the complexity of production and supplier networks will grow enormously. Networks and processes have so far been limited to one factory. But in an Industry 4.0 scenario, these boundaries of individual factories will most likely no longer exist. Instead, they will be lifted to interconnect multiple factories or even geographical regions.

There are differences between a typical traditional factory and an Industry 4.0 factory. In the current industry environment, providing high-end quality service or product with the least cost is the key to success and industrial factories are trying to achieve as much performance as possible to increase their profit as well as their reputation. This way, various data sources are available to provide worthwhile information about different aspects of the factory. In this stage, the use of data to understand current operating conditions and detect faults and failures is an important topic for research. For example, in production, various commercial tools are available to provide overall equipment effectiveness information to factory management to highlight the root causes of problems and possible faults in the system. In contrast, in an Industry 4.0 factory, in addition to condition monitoring and fault diagnosis, components and systems have selfawareness and self-predictiveness, which will provide management with more insight on the status of the factory. Furthermore, peer-to-peer comparison and fusion of health information from various components provide a precise health prediction in component and system levels, and force factory management to trigger the required maintenance at the best possible time to reach just-in-time maintenance and gain near zero downtime.

4.2. Technical Aspect

Changed strategy and processes. IoT projects require long-term investment. Three out of four IoT projects can more than double over the current budget requirement due to various problems. As the scale of the project is large and complex, the budget increases, exceeding a certain point. Some projects should be harmonised with existing projects or budget and be weakened due to integration with existing processes. Even after solving the problem of time span and budget, companies are faced with human resource allocation issues. Most human resource allocation problems are critical for the stable introduction of new technologies model. It is very complex because a new business model requires a change in the process and culture of firms.

Technological standard. Technology standard is a very critical issue during the global spread process of IoT. Firms are very interested in capturing a dominant position and leading the standard. IoT standardisation is divided into areas: IoT platform/services and IoT devices. Standardisation issues discussed through the internet system, which is the 3rd Generation Partnership Project, the European Telecommunications Standard Institute, and the Institute of Electrical and Electronics Engineers, include a global mobile telecommunications standards body that has been operating since 2005. The world's leading standardisation organisations promoting technology standards aim to have minimal impact on the current mobile users' devices that are already optimised in IoT services.

Cyber protection and security. Enterprises try to maintain a cyber-secure workplace and provide data protection. IoT can potentially collect data from all places around us consistently. Data integration will play a key role in the decision-making process of individuals and businesses and will be important for verifying identity in medical diagnostics and protecting the environment. Eventually, extensive discussions about the role of government for individual privacy safeguards will be necessary. IoT security problems increased costs for annual security budget. Cybersecurity companies and service providers continue to customise security solutions even for small companies. Gordon and Loeb (2002) proposed how much investment is required to protect from security threats. Firms should plan huge investments to respond to cyberattacks.

4.3. Social Aspect

Change in industry structure. There can be a change in the scope of industries. Industry structures change when new technology is introduced and there is a shift in customer needs. Porter (1980) explained that industry structure is determined by five forces such as rivalry amongst existing competitors, threat of substitute, threat of new entrants, bargaining power of suppliers, and bargaining power of buyers. IoT as a new technology may change these five forces and cause a new industry structure. A changed industry structure can lead to different profit potentials and attractiveness of the industry. Corporations should modify their strategies to respond to a new industry structure.

Change in laws and regulations. Changes in laws and regulations are required for the successful implementation of new IoT services. Sometimes, the introduction of new services created by IoT may be delayed due to the existing regulation environments. For example, many new services, which can be possible by using drones, are illegal in the Republic of Korea and the government considers amendments to laws to accept the new services. Security vulnerabilities in IoT could be the target of hacking incidents, and new laws and regulations must be made to prevent the security risks (Lewis, 2002).

Improved corporate social responsibility. IoT may increase the social role of corporations. Currently, corporate social responsibility is being emphasised in the world and most corporate managers consider sustainable management significantly as one their top priorities. IoT can help private and public organisations contribute to society in many ways.

4.4. Environmental Aspect

The major issue is whether the use of IoT in many areas will increase pollution or improve environment protection. We will search many ways to apply IoT for sustainable development, resource efficiency, and air pollution prevention. IoT is expected to become a valuable tool to create a circular economy and pursue green growth in the future.

Environmental management. Today, corporations are pressed to pursue sustainability.[1] To achieve sustainability, more corporate social responsibility is expected, and environmental monitoring and protection has become a major social performance indicator of private firms. IoT can help firms play these roles by offering increased

[1] From management theory, sustainability includes socially responsible behaviours, ethics, and environmental protection. The concept of circular economy or green economy is part of environmental protection.

connectivity with outside environments. Corporations are evaluated through their social performance and environmental protection activities, as well as economic performance. Because IoT can help companies fulfil their social contributions, the importance of social and environmental performance in evaluating firms can be strengthened.

Proactive response. When a firm is forced to participate in social contribution and environmental protection, many successful firms tend to respond to the pressure more proactively. Proactive response seems to lead to better impact on corporate performance than does the passive response. IoT can become an effective tool with which firms can make proactive responses.

Table 3. Socio-technical Environmental Effects of IoT on the Supply Side

	Positive Benefits	Negative Outcomes
Technical Aspects	1. Research and development, and commercialisation 2. Technology standardisation 3. Changed strategies and processes	1. Technical dependence 2. Network attack/ heavy network traffic
Social Impact	1. Knowledge acquisition 2 Convergence of industries 3. Industrial development	1. National destruction 2. Revision of laws and regulations
Environmental Aspects	1. Industrial development, 2. Economic development 3. Minimised environmental pollution 4. Resource savings 5. Efficient energy resources	1. Natural environment pollution 2. Biological hazards: genetically modified micro-organisms 3. Ecosystem degradation by biological pollution (bio-pollution) which artificially manipulates life

IoT = internet of things.

Source: Authors' own framework using previous Socio-Technical and Environmental Aspects Stefik, 2000.

5. Cases of IoT Adoption for The Circular Economy

5.1. Lessons Learnt from a Smart Waste Recycling System

The first case is the smart waste recycling system. The system itself can leverage raw data from food waste with new smart waste recycling systems from a combination of biotechnology and high technology. With the new high-technology recycling system created by Redmond, a start-up in Washington state, retail shops, grocery stores, and restaurants can not only recycle their wastes conveniently but can also track many data. WISErg ('wise' + 'erg', a unit of work), a hybrid technology company that manages urban-generated organics, was established to reduce inventory loss, give businesses insight about the root causes of food waste, and prevent excess overstock of the restaurant business. This system can help cut down more than 40 million tonnes of food, otherwise thrown away every year in the US, and boost the bottom lines of food businesses. One example is The Harvester where biotechnology meets high technology. This is a nutrient recovery system that turns food scraps that might otherwise be destined for landfills into high-grade fertiliser. Introduced in 2011, the machine consists of a closet-sized garbage disposal and a cylindrical tank. It employs a proprietary oxidative conversion process. It grinds up organic wastes and quickly turns them into liquid that will be stored in a tank and later refined into nutrient-rich fertiliser. While composting is a good solution for organic waste from many kinds of food, it is still a problem that food waste will end up in landfills. This system can be a solution to this problem.

The second example of an IoT waste management system are the smart trash cans as seen on Figure 5, provided by BigBelly Inc. The company uses IoT to add wireless communication capability to the bins. It has a smart version of a high-value product through the trash cans. An IoT-based version that could also communicate real-time data would become much more versatile and much more valuable. It operates with a real-time monitoring system through the CLEAN Management Console while generating actual waste. This system allows the monitoring and testing of the fullness of bins automatically. Trash collections can be done on time based on real time data transferred from the system.

Figure 5. **The BigBelly's Trash Cans**

Source: https://bigbelly.com/

For the city to select this public service, the company offers managed service options to perform the analysis and management of the device. These trash cans can dramatically increase the speed and efficiency of the recycling programmes of the city. The intelligence system provides the infrastructure to support ongoing waste management and time scheduling for the manpower. Therefore, it uses new resources to support the expanded additional recycling programmes. CLEAN can make the necessary changes to create a more effective public recycling programme. The company reports that its system installed in Philadelphia[2] is the best example of how effective the system can be used.

In the Korean example, the government introduced a volume-based waste fee system that can reduce the domestic waste itself. The government started to sell the waste bags by volume. A few years later, the consciousness of citizens in waste management slowly changed and they have been looking for ways to make a positive impact on the world. In addition, they have several types of waste fee systems by food waste and business waste. After the smart waste management system was introduced, more and more citizens have become interested and have tried to find ways to decrease their waste.

2 BigBelly Co. Ltd., Philadelphia started with 210 recycling containers in 2009 and each bin collected 225 pounds of recyclables monthly on average, resulting in 23.5 tonnes of materials diverted from landfills. The city gets US$50 per tonne from the recycling and avoids the US$63 landfill tipping fee, with a total benefit to the city of $113 per tonne or US$2,599 per month.

5.2. Lessons Learned from the Intelligent Transportation System (ITS) case

ICT and sensor networks have the potential to contribute to increased efficiency in freight and passenger transport, as well as the potential to reduce transportation overall. On the one hand, increased use of ICT can avoid freight and passenger transport through better virtualisation, digitisation, and teleworking. Digital content is delivered electronically, and virtual conferences and teleworking reduce passenger transport. On the other hand, increased use of ICT can contribute to better management of transport routes and traffic, higher safety, time, and cost savings as well as reductions in carbon dioxide emissions.

Sensors and sensor networks play a vital role in increasing transport efficiency. For example, sensor technology contributes to the better tracking of goods and vehicles, which might result in a lower level of inventories and energy savings from less inventory infrastructure as well as reduced need for transportation. Further, sensors and sensor networks are pivotal parts of many ITSs.

An ITS can be defined differently at different institution. ITS Canada defines it as 'the application of advanced and emerging technologies (computers, sensors, control, communications, and electronic devices) in transportation to save lives, time, money, energy, and the environment'(Intelligent Transportation System Society of Canada, 2012). ITS is categorised into intelligent infrastructure and intelligent vehicles (see Table 4). Many of these applications are based on sensors and sensor networks. In the field of intelligent infrastructure, sensors in pavements are used for road traffic monitoring systems to measure the intensity and fluidity of traffic (vehicle count sensors) and to provide information for the control of traffic lights. These sensors are also able to detect whether, for example, public buses are approaching so that the green phase of traffic lights can be extended, allowing buses to keep their schedules. They also transmit information to update public transport panels. New sensor applications include intermittent bus lanes. In addition, sensors are used for motorway tolling purposes wherein they detect vehicle radio-frequency identification tags and retrieve the required information. Sensors also monitor the state of physical infrastructures such as bridges by detecting vibrations and displacements.

Table 4. Structure of ITS

Intelligent Transportation Systems		
Intelligent Infrastuctures		
Arterial and Freeway Management • Traffic Signal Control, Lane Management • Surveillance, Enforcement	**Crash Prevention and Safety** • Warning Systems • Pedestrian Safety	**Traffic Incident Management** • Surveillance, Detection • Response, Clearance
Emergency Management • Hazardous Material Management • Emergency Medical Services	**Electronic Payment and Pricing** • Toll Collection • Multi-Use Payment	**Roadway Operations** • Asset Management • Work Zone Management
Transit Management • Operations and Fleet Management • Transportation Demand Management	**Traveller Infromation** • Pre-trip and En-route Information • Tourism and Events	**Road Weather Information** • Surveillance and Prediction • Traffic Control
Infromation Management • Infromation Warehousing Services • Archived Data Management	**Commercial Vehicle Operations** • Carrier Operations, Fleet Management • Credentials Administration	**Intermodel Freight** • Freight and Asset Tracking • International Border Crossing
Intelligent Vehicle		
Collision Avoidance • Obstacle Detection • Collision-Avoidance Sensor Technologies	**Driver Assistance** • Navigation, Route Guidance • On-Board Monitoring	**Collision Notification** • Advanced Automated Collision Notification • In-Vehicle Crash Sensor

ITS = intelligent transport systems.

Source: Miles, 2014.

6. Conclusion and Implications

We examined several theoretical frameworks to understand the impacts and risks from IoT implementation. Porter (2014) explained four basic functions of IoT, and TAM shows what factors influence the successful acceptance of IoT-based services in the market. IoT can improve corporate competitiveness through internal efficiency, external links, and innovative businesses. We also summarised the impacts of IoT in three areas: technical aspect, social aspect, and environmental aspect. A smart waste recycling system and an intelligent transportation system were presented as examples of IoT adoption to improve the circular economy. These two systems are still in their early stage and more efforts should be made to be successful cases for the circular economy.

6.1 Theoretical Implications

Based on the discussions about the various issues arising in the implementation of IoT, the theoretical implications can be summarised as follows. These can be questions to be explored in future researches.

- The services using IoT can have four basic functions such as monitoring, control, optimisation, and autonomy. These functions can be applied to most areas of our lives. We can expect these four functions to help implement the circular economy. In smart trash cans or intelligent transport systems, these four functions can be realised.

  We can create many kinds of IoT applications. While some applications involve all these four functions, others may only have a few of them. What function amongst the four is most important and most used can be studied in future research.

- TAM shows what factors are important to make a new service using IoT that is accepted in markets successfully. TAM suggests many factors such as ease of use, usefulness, compatibility, enjoyment, and many more. Many business models that will use IoT will be developed, but only a few of them can be accepted in the market. From using smart trash cans or intelligent transportation systems, what kinds of benefits can users acquire? They should be able to use them very easily and experience new values from them. Otherwise, users will not accept them.

  We can study both determinants and outcomes of new IoT services. While Davis (1989) suggested ease of use and usefulness as determinants, many other factors affecting the successful acceptance of IoT services in markets can be found. For example, when the wearable smart watch device was introduced in the market, what factors significantly influenced its success? The seminal work of Davis (1989) was done for a personal computer environment. A little bit different explanation is possible for the IoT environment.

- IoT services will create new values and improve human life. However, security/privacy and system credibility have come up as new concerns about the use IoT-related services. Also, while social connectedness will be increased, job loss due to new innovative systems is a significant concern as well. Environmental protection and monitoring can be improved through IoT services. Smart waste systems can have significant impacts on the clean-up of our environment, and in ITS, the security issue is very important.

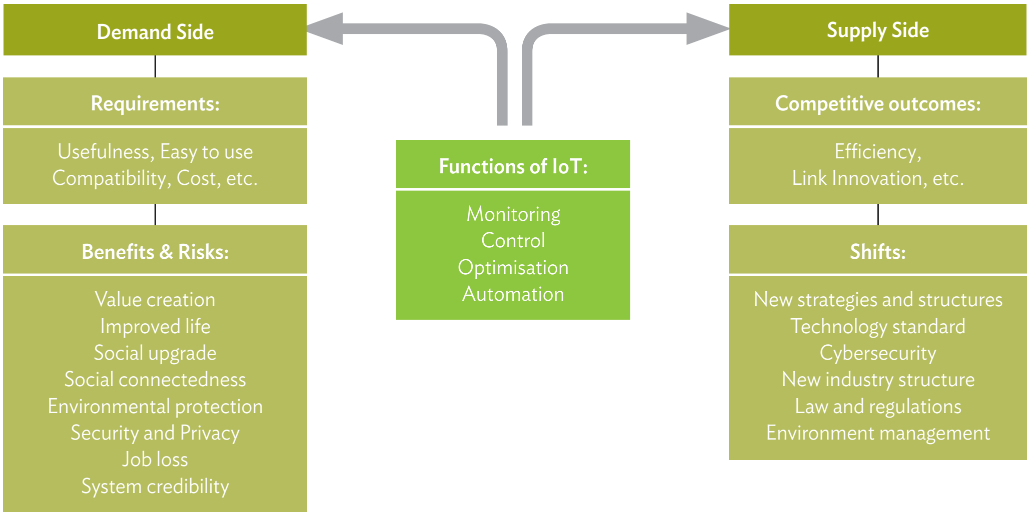
We can have both benefits and risks from using IoT services. Deeper analysis is required for both benefits and risks from IoT services implementation. Benefits such as increased connectedness and environment protection should be maximised, and the risks of security/privacy and job loss should be carefully scrutinised and prevented. Various tools to increase social connectedness by IoT services should be considered and the solutions to prevent job loss from the automation and to guarantee human prosperity should also be studied.

- Generally, the effective use of ICT can provide firms with diverse competitive advantages such as internal efficiency, external links, and new businesses. IoT applications in corporate management such as Industry 4.0 can reduce costs, increase connections with outside stakeholders, and offer new growth opportunities by creating new business models. When firms adopt IoT for resource recycling or environmental protection, this decision should improve their competitiveness. Smart waste management or smart transportation can be a new business opportunity for many corporations.

  Corporations are searching many innovative ways to use IoT. Corporate managers should have vision about the kind of competitive edge they will achieve from the use of IoT services. We can also analyse diverse conditions that enlarge or reduce the competitive benefits from IoT services.

- After introducing many IoT-based systems, processes and strategies in corporations will be changed. Even corporate culture can be changed due to new innovative systems. Technology standard in IoT is a very critical issue for firms that intend to participate in this area and decide to be the lead firm in the marketplace. Industry structure can also be changed and mergers amongst industries can happen. With improved environmental monitoring, sustainability management will be more stressed. The introduction of new technology such as IoT brings about significant changes in corporate organisations. There should be many researches about the impacts of IoT on organisations and how to deal with the changes successfully.

Figure 6. An Integrative Model



IoT = internet of things.
Source: Authors.

6.2 Policy Implications in the ASEAN Context

The concepts of IoT, Industry 4.0, and circular economy were developed in advanced economies such as the European Union and the United States. Industry 4.0 is about the picture of the future factories and the circular economy is an alternative to a past economic development model of linear economy. The Association of Southeast Asian Nations (ASEAN) countries are less developed economies and have different institutional environments from western countries. Therefore, ASEAN countries must find different solutions to achieve Industry 4.0 and the circular economy. ASEAN countries must build the foundation for Industry 4.0 and the circular economy based on their own situations.

One typical response is mere imitation to western countries. Based on institution theory (Meyer and Rowan, 1977; DiMaggio and Powel, 1983), leaders of societies or organisations make their decisions to follow outside pressure. This gives the leaders legitimacy and support from accepting the outside pressure. Government officials in ASEAN countries may face many pressures to reflect the concept of Industry 4.0 and the circular economy in their policies. Usually, it is not easy to develop a model for Industry 4.0 and the circular economy that fits a country's situation. We need a more creative approach for each ASEAN country to adapt to the new environment of Industry 4.0 and the circular economy.

To develop solutions reflecting each country's situation, Porter (1990) suggests that at least four dimensions be considered: factor condition, demand condition, supporting and relating industries, and firms and rivalry. These four factors usually explain what kinds of efforts should be made to make an industry competitive. From the framework of Porter (1990), we can list the following policy considerations for ASEAN countries.

- ***Factor condition:*** Labour is the most important input factor. Adequate education and training to prepare for Industry 4.0 and the circular economy are required. A big concern in ASEAN is that because most manufacturing processes will be automated, and the importance of cheap labour will be decreased, the production base of western multinational corporations in ASEAN will move back to their countries.

- ***Demand condition:*** Customer education is very important to make firms and governments realise the necessity of changes to new paradigms. The factor condition above is about technology of people, but demand condition is about the attitude of people. To achieve a circular economy, the commitment of ordinary people is very significant.

- ***Relating and supporting industry:*** This means the overall social infrastructure to accept Industry 4.0 and the circular economy. Financing, law/regulation, transportation/communication, democracy, and market economy are the examples. Most ASEAN countries have inferior situations in these infrastructures.

- ***Firms and rivalry:*** In pursuing both the circular economy and Industry 4.0, the role of the corporation is critical. The strategies, corporate culture, and corporate structure can influence how Industry 4.0 and the circular economy will be shaped in the region.

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Chapter 9

Mitigating the Adverse Impacts of the Circular Economy: Implementation and Role of Governments

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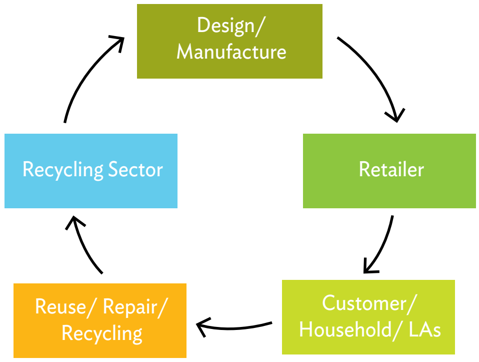
1. Introduction

The idea of a circular economy has its roots in industrial ecology, which explains the industrial economy and its processes as a human ecosystem. It involves the industrial system along the lines of an ecosystem, recognising the efficiency of resource cycling in the natural environment. The concept of a circular approach to the economy is the direction for society to move away from the 'take-make-dispose' process. Recently, many companies have noticed that this linear system increases their exposure to risks – most notably, higher resource prices and supply disruptions.

Many countries, including emerging economies, have had impressive environmental improvements in the past 2 decades. However, the overriding global patterns of production, consumption, and trade remain dangerously unstable (Preston, 2012). To cope with the issue, the United Nations Conference on Sustainable Development (RIO+20) in June 2012 renewed its focus on pursuing important activities to reduce resource and environmental stress.

The circular economy is an alternative to the traditional linear economy (make, use, dispose) where we keep resources in use for as long as possible, extract the maximum value from them while in use, then recover and regenerate products and materials at the end of each service life, as shown in Figure 1. The more complex process of the circular economy in industry is shown in the circular economy butterfly diagram.[1]

Figure 1. Simple Pattern of the Circular Economy



LAs = Local Authorities.

Source: WRAP and the Circular Economy. http://www.wrap.org.uk/content/wrap-and-circular-economy.

The waste and resources sector in the United Kingdom has been actively following the butterfly diagram approach, particularly in the outer circles (recycling, composting, anaerobic digestion, and the like), and some progress is being gained towards improvements in material recycling such as improving recycle quality and moving from down-cycling to closed-loop recycling. However, the more visionary aspects of the circular economy, involving new product life cycle supply chains and new business models that focus on the elimination of waste in the traditional sense, could avoid the waste and resources sector in its current form. Therefore, other circular economy activities such as repair, refurbishment, and remanufacture are not significant in the waste and resources sector now but could become so in the coming years (Chartered Institution of Waste Management, 2014).

[1] The diagram shows the value recovery for biological and technical materials. The drive to move the material composition of consumables from technical towards biological nutrients, and to have those flow through different applications before extracting valuable feedstock and finally reintroducing their nutrients into the biosphere, rounds out the core principles of a restorative circular economy through the economic system. The diagram shows a range of different processes and material flows in a circular economy (Ellen MacArthur and McKinsey & Company, 2014, p.24).

An industrial economy that is restorative by intention aims to rely on renewable energy; minimises, tracks, and hopefully eliminates the use of toxic chemicals; and eradicates waste through careful design. The term goes beyond the mechanics of production and consumption of goods and services in the areas that it seeks to redefine (examples include rebuilding capital, including social and natural, and the shift from consumers to users). The concept of the circular economy is grounded on the study of non-linear systems, particularly living systems (Ellen MacArthur Foundation, and McKinsey & Company, 2014). It includes activities that contribute to zero waste, but with a greater focus on the flow and ownership of materials in the economy and keeping materials in use for as long as possible. The circular economy also requires water and energy to come from renewable resources and that biological materials, such as food waste, are returned to the soil (Natural Scotland, 2013).

This chapter aims to elaborate on the extent that the Association of Southeast Asian Nations (ASEAN) countries, particularly Indonesia, can implement a circular economy. The two major contributions of this chapter are determining the role of governments and their relationships with the private sector in implementing a circular economy, and how to mitigate the risks and social impacts of a circular economy.

2. Progress in Implementing the Circular Economy

The circular economy presents many challenges to the way we think about, design, use, and handle products and the resources that they are made from. For those just beginning the journey, the implementation of basic, well-known waste management practices is a necessity. For those that are well along, openness to experimentation and innovation is key to creating new processes, practices, products, and markets.

It is critical that the local and regional waste management systems designed and built today are adaptable and flexible enough to become the regional circular material management systems of tomorrow, as development along the maturity curve cannot be radically short-circuited. City waste-reduction strategies are also essential (Zero Waste, Net Positive, and the Circular Economy, 2013).

Preston (2012) suggested that countries and companies could take several practical steps in pursuit of a circular economy. Some of these selected steps are as follows:

i. *Best practice and knowledge-sharing*. Companies with commitments to the circular economy or related concepts are already explaining the benefits to the industry and investors. Industry bodies can play a key role in facilitating dialogues between leaders of circular economy and other companies that stand to gain from making the transition.
ii. *Smart regulation*. Innovation and practice related to the circular economy will be led by the private sector when investment is abundant. Governments have a crucial role to play in areas such as support for innovation, setting the conditions for investments, and encouraging business-to-business and business-to-university linkages. The mix of policies will vary according to country and economic conditions, particularly the extent of market liberalisation.
iii. *Standardisation*. Technology standards can play a critical role in accelerating innovation in an industry by removing bottlenecks and encouraging economies of scale.
iv. *Raising public awareness*. A certification or labelling system for circular economy products will help build awareness amongst consumers, encourage rapid uptake by companies, and reward leading companies.
v. *Support for developing countries*. Many developing countries will need help with the transition to a circular economy. Multilateral development banks could target additional support towards circular economy investments.

Preston's ideas for countries and companies to implement a circular economy could be followed by Indonesia and other ASEAN countries, subject to credible regulations and government interventions to promote a circular economy.

2.1. The Circular Economy Model in ASEAN and China

Accenture (2015) identified the following five business models that could be implemented in ASEAN: circular supplies, resource recovery, product life extension, sharing platform, and product as a service.

Circular Supplies. The first model that Accenture proposed is the circular supplies business model. This model is based on supplying fully renewable, recyclable, or biodegradable resource inputs that strengthen circular production and consumption systems. Companies attempt to replace linear resource approaches by cutting waste and removing inefficiencies. For example, tyre manufacturer Omni United in Singapore has tied up with US footwear company Timberland to make a special line of tyres that can be easily recycled at end of life into crumb rubber. The rubber is then used by Timberland for making shoe outsoles.

Resource Recovery: Recover useful resources/energy out of disposed products or by-products. This model enables a company to eliminate material leakage and maximise economic value of product return flows. Singapore's waste management company Tes-Amm connects seamlessly with its clients' manufacturing processes to help dispose electronics scrap. Another example is PT Enviro Pallets located in Bali, Indonesia, that processes plastic waste to create shipping pallets. Offering up to Rp500 (US$0.05) per kilogram of plastic waste effectively incentivises locals to help clean up rivers, beaches, and grounds from mounds of plastic rubbish, and use these containers for feedstock. With this clever business model, the company aims to process 30% of plastic waste generated on the island.

Product Life Extension: Extend the working life cycle of products and components by repairing, upgrading, and reselling. In Singapore, the Sustainable Manufacturing Centre (established in 2009) and the Advanced Remanufacturing and Technology Centre (launched in 2012) have been working with companies to improve the longevity of products through topics such as green manufacturing, remanufacturing, repair and restoration, and product verification.

Sharing Platforms: Enable increased utilisation rate of products by making possible shared use/access/ownership. The sharing platforms business model promotes a platform for collaboration amongst product users, either individuals or organisations. These facilitate the sharing of overcapacity or underutilisation and increases productivity. Car sharing is one of the earliest sharing platform models. Tripid, a ride-sharing service based in the Philippines, connects drivers and passengers headed the same way. This platform helps create a community of drivers and passengers who opt to share rides with others, while also allowing users to act as drivers for others looking for a ride.

Product as a Service: The product as a service business model offers an alternative to the traditional model of buy and own. Products are used by one or many customers through a lease or pay-for-use arrangement. Sunlabob, a solar enterprise based out of Lao People's Democratic Republic (Lao PDR), has created a service-based approach to sustainable lighting in rural areas. Meanwhile ASEAN countries may select one or more business models created by Accenture (2015). Indonesia may focus on how to manage e-waste and get potential benefits from electronic waste.

China is the third country engaged in serious efforts to implement a circular economy on a large scale. The Chinese government likes to retain competitiveness and intends to initially introduce the circular economy framework on a smaller scale through several pilot studies so that it has a better basis for assessing its large scale and full coverage in the longer run. This policy is like economic liberalisation, which started with coastal free economic zones (Heshmati, 2015).

The limited existing evidence on the implementation of the circular economy in practice in China suggests that consensus has been reached on the concept of the circular economy, which in many ways resonates with the concept of industrial ecology. This concept emphasises the benefits of reusing and recycling residual waste materials. It includes energy, water, different byproducts, as well as knowledge (Jacobsen, 2006; Park, Sarkis, and Wu, 2010).

Dalian city in China is an important pilot study where the circular economy strategy was implemented during 2006–2010 (Table 1). The characteristics of the city's industrial and business area and the local government's initiatives led to the aspiration of transforming it into a leading environment-friendly city. The strategy had several objectives, including further improving resource-use efficiency and improving the level of material reuse and recycling, and recovering solid waste and waste water.

Table 1. Key Circular Economy Indicators in Dalian (2005–2010) and Goals Set in 2006

Dimension	Indicators	Actual 2005	Actual 2010	Goal by 2010	% Change in Goals	% Change in Actual
Resource efficiency	Energy consumption per GDP (standard coal, tonnes/104)	1.0	0.8	0.8	-21	-21
	Energy consumption per unit of industrial value added (standard coal, tonnes/104 RMB)	1.6	1.2	1.2	-27	-27
	Water consumption [per unit of industrial value added (tonnes/104 RMB)	37.5	18.0	26.2	-15	-52
	Water consumption per capita (m^3 per year)	186.9	62.1	-	-	-67
Waste discharge	Municipal waste generation per capita (kg/year)	163.7	136.4	-	-	-17
Waste treatment	Rate of municipal waste water treatment	73	90	90	17	17
	Rate of safe disposal of municipal solid waste, %	80	100	98	18	20
Waste reclamation	Rate of treated waste water recycling, %	10	42	35	25	32
	Rate of industrial solid waste reclamation %	62	96	75	13	34

GDP = gross domestic product, kg = kilogram, m^3 = cubic metre, RMB = renminbi.

Note: Municipal waste include waste from both industrial and residential sources.

Source: Dalian Municipality, 2006, Liaoning Statistical Yearbook, 2006, 2011.

The iron and steel industry is an energy-intensive and highly polluting industry in China. Ma et al. (2014) investigated the mode of the circular economy in this industry in China. A case study of private enterprises in Wu'an city shows significant improvements but there is much room for additional environmental quality improvements. Another energy-intensive and polluting industry is the papermaking industry. Li and Ma (2015) investigated how Guangdong Silver Island Lake Papermaking Park realises cleaner production and sustainable development by the circular economy through inter-industry resource integration.

ASEAN countries, including Indonesia can implement a circular economy based on the 3R principles of material use, i.e. reduce, reuse, and recycle. These principles are introduced in both production and consumption areas. Both areas are important as the flow of materials and energy penetrates them.

3. Risks and Adverse Impacts of the Circular Economy

The industrial model, which is also described as a 'take-make-waste' approach, is one main driver of the challenge of sustainability. As circular economy is a concept that claims to be more in line with the cyclical nature of earth and acknowledges the interconnectedness of economy and environment, it can potentially address the sustainability challenge by reducing resource extraction and waste streams.

To mitigate the adverse impacts of the circular economy, we can focus on its benefit to the economy. These benefits are not purely operational but also strategic; not just for industry but also for customers; and serve as sources of both efficiency and innovation.

The circular economy is about creating new value chains that decouple growth from the use of scarce and linear resource inputs. For instance, a company could promote using 'lasting' resources to break the link between scarcity and economic activity by using only inputs that can be continuously reused, reprocessed, or renewed for productive use (e.g. renewable energy, biomaterials, or fully recycled/recyclable resources).

Economies will benefit from the existence of the circular economy through significant net material savings, mitigation of volatility and supply risks, driving innovation and job creation, regeneration and improved land productivity, and paving the way to a strong economy (Ellen MacArthur Foundation, and McKinsey & Company, 2014).

Significant net materials savings. Based on detailed product-level modelling, the circular economy represents a net materials cost savings opportunity of US$340 billion–US$380 billion per annum at a European Union (EU) level of 'transition scenario', and US$520 billion–US$630 billion per annum for an 'advanced scenario'.

Mitigation of price volatility and supply risks. The net materials savings would shift the cost curve for various raw materials downward. For steel, the global net materials savings could add up to more than 100 million tonnes of iron in 2025.

Innovation and job creation. Adopting more circular business models would bring significant benefits, including improved innovation, across the economy. The circular economy might bring greater local employment, especially in entry-level and semi-skilled jobs.

Regeneration at work for land productivity and soil health. The circular economy will reduce the need for replenishment of soil with additional nutrients by moving more biological materials through anaerobic digestion or composting process, and then back into the soil.

Paving the way to strong economy. The circular approach offers developed economies a way to strong growth, reducing dependency on resource markets and reducing exposure to resource price shocks. Importantly, any increase in materials productivity is likely to have a positive impact on economic development beyond the effects of circularity on specific sectors.

Subsidies. Subsidies that encourage excessive use of resources need to be removed and all externalities should be incorporated into the price of resources and energy.

Significant upfront investment cost. At the macro level, a successful circular economy would raise growth and reduce vulnerability to resource-price shocks. But in the short term, there will inevitably be significant upfront investment costs and risks. Therefore, clear, strong, and predicable policy frameworks will be crucial to encourage investments.

Betchel, Boiko, and Volkel (2013) found that the main barriers or risks in the circular economy are on technological, legal, economic, and behavioural levels, i.e. the difficulty to change mindsets. Technological barriers refer to processes and technologies needed to establish closed loops and create technical and biological materials cycles. Legal barriers refer to the management of products, materials, and waste. Economic barriers refer to the complexities between regulations and business operations (e.g. regulations connected to packaging), international discrepancies, and outdated status of regulations. Finally, a successful transformation to a circular model involves a new way of thinking, acting, plus communicating with others in the chain. However, an internal reluctance to move away from business as usual and to challenge current paradigms in a corporation is another risk.

Complexities in the international supply chain may hinder the implementation of the circular economy. In a circular economy, the supply chain must be recognised so that information and materials flow in both directions to facilitate reuse and remanufacturing. The other risk is the lack of consumer enthusiasm. For example, consumers need to understand and value what is the concept of a cradle-to-cradle product.

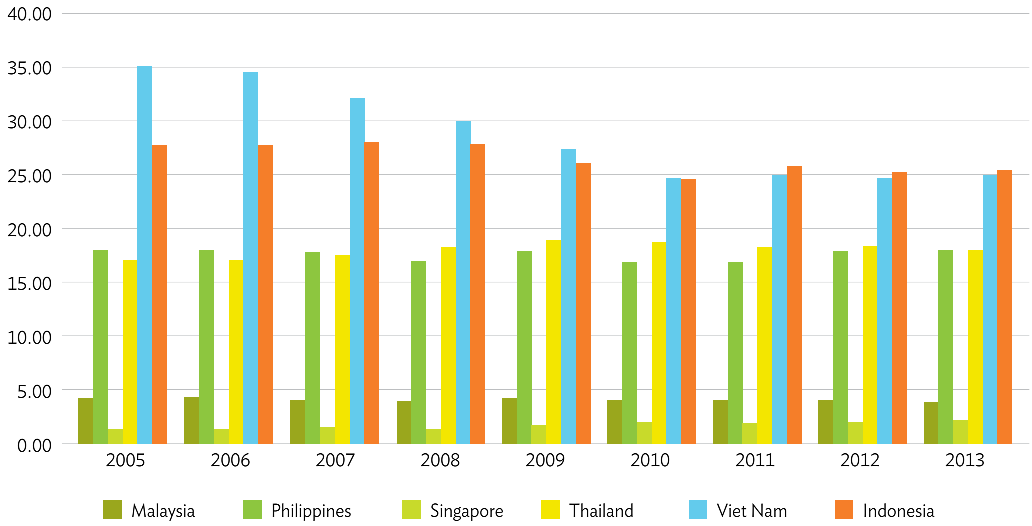
Rock et al. (2016) explored the impacts on business of moves towards a circular economy. The possible negative impacts of a move to a circular economy include reduced demand for virgin raw materials, changes to demand for employment in raw material production sectors and new product manufacturing, and stranded assets.

4. Role of Government and Waste Management

The considerable increase in Indonesia's population has increased the volume of waste. Furthermore, the consumption pattern in the community has significantly contributed to the production of various waste such as waste with hazardous packaging and/or waste that do not easily decompose by natural process. So far, the people still consider waste as unusable remnants, not as beneficial resources. In waste management, the community still depends on end-of-pipe approach, i.e. waste is collected, transported to, and disposed at the final waste processing. The end-of-pipe approach to waste management should be changed by a new paradigm of waste management. The new paradigm considers waste to have an economic value and could be utilised as energy, compost, fertiliser, or industrial raw material. Waste management is carried out comprehensively: from the upstream, before a product potentially becomes waste, to the downstream or the stage where products are used to produce waste and would return to the environment safely.

Amongst selected ASEAN countries, Viet Nam contributed the highest combustible renewables and waste from 2005 to 2009. However, since 2010, Viet Nam and Indonesia have almost similar amounts of combustible waste. Combustible renewables and waste comprise solid biomass, liquid biomass, biogas, industrial waste, and municipal waste.

Figure 2. **Combustible Renewables and Waste**
(% of total energy)



Source: Author's compilation; World Development Indicators (WDI), World Bank, 2015. Measured as a percentage of total energy use – IEA Statistics © OECD/IEA 2014 http://www.iea.org/stats/index.asp subject to https://www.iea.org/t&c/termsandconditions/

The new paradigm of waste management is implemented with waste reduction and waste handling. Waste reduction includes limitation activities, reusability, and recycling, while waste handling includes segregation, collection, transportation, processing, and final processing. Rapid economic growth in Asia and the increasing transboundary movement of secondary resources will increasingly require both 3R activities in each country and appropriate control of international material cycles.

Developing countries are seeing rapid growth in the generation of waste, including electrical and electronic equipment or electronic waste (e-waste), agricultural biomass waste, and plastic waste. Effective and efficient management of waste, including the application of 3R, is an essential element for promoting sustainable patterns of consumption and production.

Integrated solid waste management and recovery of useful materials or energy from waste streams is an effective approach to enhance resource efficiency while reducing the adverse environmental impacts caused by waste disposal.

The potential revenue from recycling of sorted recyclable waste based on primary data on the quantity of recyclable waste from households and the selling prices of recyclable materials obtained from field surveys in Jakarta are shown in Table 2.

Table 2. Potential Revenue from Recycling, Jakarta (2013)

Waste Category	Subcategory	Average Selling Price (US$ per kg)	Average Quantity Sold per household (kg per month)	Revenue Potential (US$ per annum-million
Paper and Cardboard	Newspaper	0.17	3.57	14.68
	Magazine	0.21	1.75	8.87
	Carton boxes	0.25	4.43	27.13
Plastic	Refuse plastic sacks	0.33	1	8.12
	Plastic bottles	0.27	1.75	11.62
Metal		0.45	1.04	11.53
Glass		0.23	1.36	7.67
Textiles	Used clothes and fabrics	1.04	1	25.32
TOTAL		**2.95**	**15.9**	**114.94**

kg = kilogram.

Source: Household Solid Waste Management in Jakarta, Indonesia: A Socio-Economic Evaluation.

The Medium-Term Development Plan (RPJMN) Indonesia 2015–2019 clearly states that solid waste and poisonous toxic and hazardous waste substances could be reduced by about 755.6 million tonnes in 5 years. It also states that solid waste could be reduced by about 85 million tonnes in 5 years through the extended producer responsibility programme. The Government provided US$31.2 million to the reduction of waste programme in 2016 (Table 3).

Table 3. Programmes/Activities Related to Waste in 2016 and 5-year Planning (2015–2019)

No.	Programmes/Activities	Target 2016	Allocation 2016	Executing Agency
1.	Garbage, and poisonous toxic and hazardous waste substances		US$31.2 million (Rp405.7 billion)	Ministry of Environment
	Total garbage (solid waste) is 124.6 million tonnes from 380 cities			
	Total hazardous and poisonous toxic waste substance is around 755.6 million tonnes in five years	52,98 million tonnes		
	Reduction of solid waste (garbage) by 85 million tonnes during five years through extended producer responsibility .	300 million tonnes		
	Reduction of solid waste (garbage) by 124.1 tonnes during 5 years through recycling centres (capacity 20 tonnes per day)	30 million tonnes		

Source: Medium-Term Development Plan (RPJMN) Indonesia, 2015–2019; Government Action Plan (RKP) 2016.

Regarding waste management, the Government of Indonesia issued Act No. 18 of 2008. The management of waste is conducted based on the principle of responsibility, sustainability, profitability, justice, awareness, togetherness, safety, security, and economic value.

The objective of the management of waste is to increase public health and environmental quality as well as to utilise waste as an energy source. The Act also explains the separation in the management of waste between the central government and the local government.

The tasks of the central government and the local government are as follows:
i. developing and increasing the public awareness on waste management;
ii. conducting research, developing technology for reducing and handling of waste;
iii. facilitating, developing, and conducting efforts to reduce, handle, and utilise waste;
iv. carrying out waste management and facilitation in providing the facility and infrastructure for waste management;
v. encouraging and facilitating the enhancement of the benefit of waste management outcomes;
vi. facilitating the application of specific local technologies in the local community in reducing and handling of waste; and
vii. conducting coordination amongst government institutions, society, and industry towards an integrated waste management.

In carrying out waste management, every level of government has authority to manage waste. The central government has the authority to:
i. stipulate national policy and strategy of waste management;
ii. stipulate norms, standards, procedures, and criteria for waste management;
iii. facilitate and conduct cooperation amongst local governments, partnerships, and networks for waste management;
iv. conduct coordination, development, and monitoring of local government performance in waste management; and
v. stipulate policy for dispute settlement in waste management amongst regions.

The provincial government has the authority to:
i. stipulate policy and strategy for waste management in line with the government policy;
ii. facilitate cooperation between regions within one province, partnership, and network for waste management;
iii. conduct coordination, development, and monitoring of district and municipality performance in waste management; and
iv. facilitate for dispute settlement in waste management amongst districts/municipalities within one province.

Finally, the district/municipality governments have the authority to:

a. stipulate policy and strategy for waste management based on national and provincial policies;
b. carry out waste management at district/municipality levels in line with the norm, standard, procedure, and criteria stipulated by the government;
c. carry out development and monitoring of other agencies' performance in waste management;
d. determine the location of the temporary collection site, integrated waste treatment site, and/or final waste processing site;
e. carry out monitoring and evaluation every 6 months within 20 years on open dumping systems' final waste processing sites that have been closed; and
f. issue and carry out a waste management emergency response system in line with their authority.

The Act also states that every producer should label or put a symbol on the packaging and/or the product regarding waste disposal and handling. The producers are obliged to manage the packaging of their products and indicate those that are difficult or cannot be decomposed.

In terms of administrative sanctions, the head of the district/mayor could impose administrative sanctions on waste operators who violate the regulations stipulated in their licence. The administrative sanction could be an imposition of fee/fine and/or permit withdrawal.

Financing and Compensation for Waste

Financing and compensation for waste in Indonesia is clear. The central and local governments are obliged to finance the implementation of waste management. The budget should be provided under the national budget and the local government budget. For example, the Ministry of Environment allocated US$31.2 million in 2016 for managing garbage and poisonous toxic and hazardous waste substances (Government Action Plan, 2016). In 2016, the Badan Pengusahaan Kawasan Perdagangan Bebas dan Pelabuhan Bebas Batam (BPKPBPB) or the Batam Free Trade Zone and Free Port Authority provided US$0.1 million (Rp0.98 billion) budget for supporting the waste activities of local governments, particularly the city government of Batam which supports the Batam Free Trade Zone Authority.

Furthermore, the central and local governments, including the provincial and district/municipality levels, could provide compensation to a person who suffers from the negative impact of waste handling activities. Compensation includes relocation, environmental rehabilitation, and health and medication costs (Waste Management Act, 2008).
To implement Act No. 18 of 2008, the government issued Government Regulation (PP) No. 101 of 2014 [2] on the management of toxic and hazardous waste substances. This regulation regulates the management and disposal procedures for toxic and hazardous waste substances. In general, it covers:

i. methods of identifying, reducing, storing, collecting, transporting, utilising, processing, and hoarding hazardous waste;
ii. procedures for dumping hazardous waste into the open sea or land;
iii. risk mitigation and emergency responses to address environmental pollution caused by hazardous waste; and
iv. sanctions for non-compliance.

This regulation is of relevance to producers, importers, exporters, and managers of hazardous waste.[2]

In terms of specific waste like e-waste, Indonesia is still developing the specific e-waste regulation that covers e-waste from household and industry sources. The coverage of recycling of e-waste is still limited. The locations and number of industries that recycle e-waste are also limited (Table 4).

Table 4. Recycling of E-waste (2013)

Location	No. of Industries	Kind of Collection
Batam Island	1	Rejected small parts of electronic components, plastic-waste, used printed circuit boards, computer monitors, electronics, and electronic parts (only dismantled items and those that can be used as raw materials in smelter industries)
Central Java	2	Dry cell batteries collection and smelters
West java	3	All e-waste materials (only collection; the waste is exported or goes to smelter industries and other smelter industries in Jakarta)
Tangerang	1	All e-waste (only collection)
Central Java	1	Used monitors (stop processing of cathode ray tube for reuse since 2011)

Source: Ministry of Environment, Indonesia, 2013, 3rd Global E-Waste Management, San Francisco.

[2] The 2014 Regulation repeals and replaces the 1999 Regulation and has been in force since 17 October 2014.

Compared to other selected countries in Asia and ASEAN, Table 5 indicates regulation from countries to manage e-waste.

Table 5. Recycling of E-waste (2013)

Country	Items	Regulation	Brief Explanation
China	TV sets, refrigerators washing machines, air conditioners, personal computers	Management for e-waste Management of recycling of home appliances and electronics	Distributors (retailers) have responsibility for collection and then transiting to recyclers.
Japan	TV sets, refrigerators, washing machines, air conditioners	Home Appliances Recycling Law (enacted 1998 and enforced 2001)	Retailers are obliged to accept appliances discarded by consumers. Manufacturers are obliged to take these from retailers and to implement measures for reusing and recycling. Retailers and manufacturers can charge consumers for collecting, transporting, and recycling their discarded appliances.
	Personal computers (both for business and household use)	Law for the Promotion of Effective Utilization of Resources (2001 for business PCs, 2003 for household PCs)	Manufacturers are obliged to accept discarded PCs for recycling. Recycling fees are added to the sales prices.
Rep. of Korea	TV sets, refrigerators, washing machines, air conditioners, personal computers (2003), vehicles equipment, mobile phones (2005)	Extended Producer Responsibility in Recycling Law (2003)	Government allocates mandatory quantity for recycling every year. Manufacturers must pay the standard expenses to recycling bodies per item.
Taiwan	Waste home appliances (TV sets, refrigerators, washing machines, air conditioners), and waste IT products (PCs, monitors, printers, notebooks) as due recycled waste	Waste Disposal Act (amended 1998)	Producers should take financial responsibility only (not physical responsibility). Producers submit recycling-clearance disposal fee to the recycling management bodies.
Philippines	Consumer electronics (radios, stereos, TV sets, and many others) and white goods (stoves, refrigerators, dishwashers, washing machines, dryers, and the like)	Solid Waste Management Act of 2000 (RA 9003)	Consumer electronics and white goods are classified as special waste requiring separate handling from other residential and commercial waste.

IT = information technology, PC = personal computer, RA = Republic Act, TV = television.

Source: Mater, 2006.

The public–private partnership (PPP) scheme is an alternative to finance waste management in ASEAN countries, including Indonesia. Municipal waste management and recycling contracts may follow procurement methods under a PPP scheme (Zen and Regan, 2015).

The government of Indonesia and the ASEAN countries should support the major technologies necessary for a circular economy, including waste management, through accurately identified key technological areas and projects in line with current medium- and long-term requirements, and some initiatives to improve the public awareness and participation activities related to the concept of a circular economy such as television promotions, newsletters, exhibitions, and workshops, which should be carried out periodically.

4.1. Public–Private Partnerships[3] in Waste Management

The recent regulation regarding the PPP scheme in Indonesia is Presidential Regulation No. 38 of 2015 regarding cooperation between government and business entities in infrastructure provision. The infrastructure relates to economic and social infrastructures. Some types of economic and social infrastructures include transportation, roads, water resources and irrigation, drinking water, centralised waste water management systems, local waste water management systems, and other economic infrastructures including waste management infrastructure systems.

The PT Sarana Multi Infrastruktur (Persero) (PT SMI) is an infrastructure financing company that was established on 26 February 2009. PT SMI plays an active role in facilitating infrastructure financing as well as in preparing projects and providing advice for infrastructure projects in Indonesia. PT SMI performs these functions through partnerships with private and/or multilateral financial institutions in PPP projects. PT SMI can serve as a catalyst in accelerating infrastructure development in Indonesia. Sectors that can be financed by PT SMI include toll roads and bridges, transportation, oil and gas, telecommunications, and other social and economic infrastructure including waste management.

One of the projects under PT SMI is the waste management project in Batam in 2014. The project aimed to overcome waste management in Batam City. The project included how to collect, carry, and end waste dump.

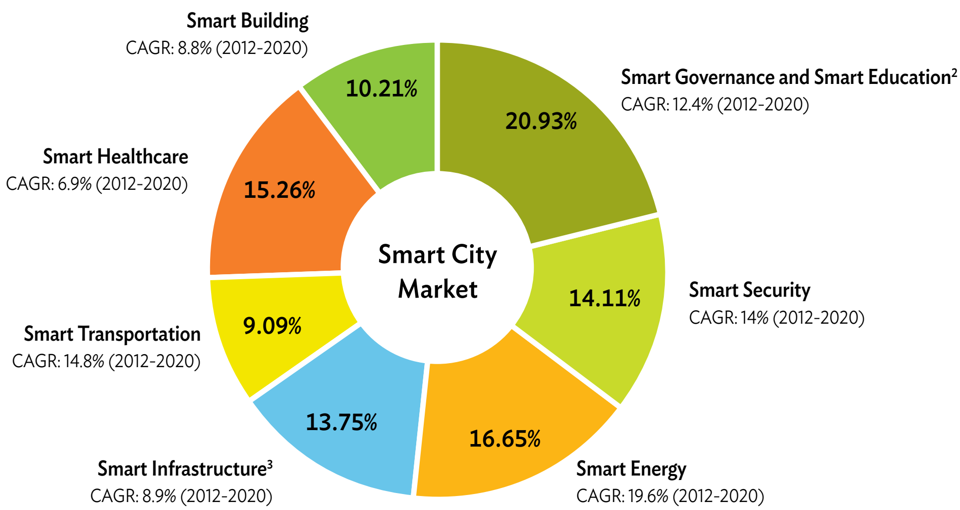
[3] Public–private partnership is the cooperation between the government and a business entity in infrastructure provision for the public interest in accordance with the specification previously determined by the minister/head of institution/head of region/state-owned enterprise/regional-owned enterprise, which partially or fully uses the business entity's resources, with particular concern for the allocation of risk between the parties.
Source: Presidential Regulation No. 38 of 2015.

4.2. Smart City

The application of the circular economy concept at a city scale is fundamental to creating a smart city (Circulate, 2015). A holistic understanding of the circular economy tries to balance material and energy exchanges between nature and society, and within society itself, then working towards eco-effectiveness and long-term resilience.

Urban conglomerations compete to attain 'global city' or 'world city' status by attracting big corporations to establish headquarters in their city. The global smart city concept reached Indonesia and it launched the Smart City Index in March 2015. It was initiated to answer challenges around how to wisely manage a city and increase residents' welfare and quality of life. The index emphasised that rural–urban migration was an inevitable trend and would make cities ever denser. The World Bank pointed out that 2025 will see the peak of Indonesia's urbanisation, with 57% of the population living in cities. Currently, the population living in cities is 52%.

Figure 3. Smart City by Segment,[1] Global 2020



CAGR = compound annual growth rate.

Notes: The graph represents the market share of each segment in the smart city market.

1 These numbers represent the entire smart solutions eco-system in each segment for both urban and non-urban panoramas.

2 Smart Education includes eLearning services for schools, universities, enterprises, and government entities.

3 Other Smart Infrastructures such as sensor networks for digital management of water utilities are not included in other segments.

Sources: Indonesia International Smart City 2016 Expo and Forum -IISMEX, 2016.

A smart city may create enormous business opportunities with a market value of US$1.5 trillion in 2020. Smart governance and smart education, smart energy, and smart security may contribute 20.9%, 16%, and 14.1%, respectively, to total global market.

Indonesia introduced the Smart City Index in 2015 by applying the main criteria: economic conditions (smart economy), social interaction between the public and administration supported by information technology (smart society), and environment (smart environment).

Indonesia's Smart City Index has been implemented and smart cities are being developed in 98 cities, which have attracted big industry players to invest and contribute to the country. Smart City Index 2015 has eights indicators: smart information and communications technology, smart development planning, smart green open space, smart transportation, smart waste management, smart water management, smart building, and smart energy.

Fifteen cities were selected amongst 93 cities to receive the Smart City Award 2015. The five winning cities with more than 1 million residents are Depok, Bandung, Semarang, Surabaya, and Tangerang.[4] Bandung was one of the finalists in the World Smart City Awards 2015.[5]

Bandung Smart City. Bandung's population is estimated to reach 4.1 million by 2030. With rapid urbanisation, the city is starting to face several challenges such as traffic congestion, rising crime rates, waste management, air pollution, and housing shortages.

The local government may increase the budget for its smart city programme, from Rp25 billion (US$1.8 million) in 2015 to Rp100 billion (US$7.3 million) in 2016. The budget may be used to build up the city's digital infrastructure.[6]

Bandung Command Centre [7]

In 2015, the government launched and built the Bandung Command Center at a cost of Rp27 billion (US$2 million). The centre is a state-of-the-art facility that monitors and manages city operations. It consists of 26 monitors, a control room, an operator room, and a meeting room.

4 For populations between 200,000 and 1 million, the winners were Balikpapan, Pontianak, Yogyakarta, and Surakarta. For the fewer than 200,000 residents category, the winners were Madiun, Malang, Mojokerto, Bontang, and Salatiga.

5 Bandung competed with Buenos Aires, Argentina; Curitiba, Brazil; Dubai, United Arab Emirates; Moscow, Russia; and Peterborough, United Kingdom.

6 Over the years, the city government has installed about 5,000 free wi-fi hotspots across the city and has set a target to install up to 40,000 hotspots to provide more citizens with access to free connectivity.

7 http://www.enterpriseinnovation.net/article/bandungs-smart-city-initiatives-246675038 (accessed 21 May 2016).

E-Government Initiatives

The Bandung administration is currently working to launch various e-government initiatives to provide public services more effectively.[8]

Bandung Technopolis

To attract foreign investment and develop Bandung into a centre of entrepreneurship, the city government has started the construction of Bandung Technopolis, a satellite city which may serve as the centre of Indonesia's technology industry. It is located in Gedebage, South Bandung, and has a planned investment of US$800 million.

Jakarta Smart City

The Jakarta administration launched the Jakarta Smart City programme in 2014 to establish a technology-based service for the residents (Jakarta Post, 2016).The city introduced the Jakarta Smart City website (http://smartcity.jakarta.go.id) and smartphone applications (Qlue)[9] for residents and the Cepat Respon Opini Publik Jakarta for civil servants and officials.

The Jakarta Smart City Lounge at the city hall provides facilities to support the implementation of Jakarta Smart City.

The Jakarta provincial government already allocated Rp30 billion for the smart city project in 2015. About 60% of the budget may be allocated for infrastructure and 40% for operation costs and human resources.

8 There are plans to build 1,000 government applications by 2017 to ease the strain on bureaucracy and provide digital government services to citizens. The city now has 320 applications and the remaining 680 applications will be built by a new team of programmers hired by the government.

9 Qlue is a crowd-sourcing smartphone application that enables users to report various incidents such as flood, crime, fire, or waste, and city officials will respond through the Cepat Respon Opini Publik Jakarta smartphone application. Civil servants and officials nearest to the reported incident will be detected through their smartphones and must respond to the report.

5. Conclusion and Recommendations

This chapter examines the extent to which ASEAN countries, particularly Indonesia, are implementing the circular economy. How much progress have countries, including Indonesia, made in implementing the concept of the circular economy. What is the role of government in mitigating the risks and social impacts of the circular economy? For those just beginning the journey, the implementation of basic, well-known waste management practices is a necessity to implement a circular economy through the R3 waste activities – reduce, reuse, and recycle.

Some countries in Asia have policies to mitigate e-waste. Indonesia is still developing specific regulations to manage e-waste. Law No. 18 of 2008 and Government Regulation No. 101 of 2014 are policies issued by the Government of Indonesia to manage waste. However, both regulations do not manage how to control specific waste, i.e. e-waste.

The implementation of a smart city may be an initial step to implement Industry 4.0. One of Indonesia's smart cities, Bandung, was one of six finalists for the Global Smart City Award 2015.

Economies will benefit from the circular economy through significant net material savings, mitigation of volatility and supply risks, drivers for innovation and job creation, regeneration and improved land productivity, and path to a strong economy.

Some of the recommendations that may be taken to support the circular economy are as follows:

i. strengthen waste management policies and regulations to implement the circular economy;
ii. improve the 3Rs – reduce, reuse, and recycle – through the involvement of the private sector, local and central governments in ASEAN countries;
iii. establish clear regulations and law enforcement regulations to manage e-waste at national, regional, and municipal levels, as well as incentive systems to encourage electronic producers with extended producer responsibility;
iv. establish smart cities and other activities that involve full cyber technology for a better life as an initial step to support the circular economy and Industry 4.0 in selected ASEAN countries;
v. continue to support the major technologies necessary for the circular economy; and
vi. undertake initiatives to improve public awareness and participation in activities related to the concept of the circular economy in ASEAN countries.

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Chapter 10

Innovation of Finance for Industry 4.0 in ASEAN

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1. Introduction

Industry 4.0 was proposed in October 2012 by the Industry-Science Research Alliance of Germany (Iwamoto, 2015). Its key technologies are digitalisation, data processing, and the internet; and it is a typical example of the internet of things (IoT). Industry 4.0 or IoT for industry is an irreversible megatrend in industry and will improve production efficiency through the optimisation of production processes. Its impact is not limited on the supply side but on the demand side, too, through the reduction of the loss of products by responding to demand precisely and on time. It will also push the transformation to circular economy and improve international competitiveness.

This is an irreversible global trend and the Association of Southeast Asian Nations (ASEAN) countries will be affected, both by risks and opportunities. This chapter focuses on the need for finance to realise the benefit of IoT innovation.

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2. Industry 4.0 and ASEAN

2.1. Nature of Industry 4.0

The benefits of Industry 4.0 are:

> **Improvement of productivity through the optimisation of processes**
Industry 4.0, which connects and optimises various production processes at manufacturing facilities through the internet, can reduce wasteful energy, materials, and resources consumption. Furthermore, it can reduce the number of workers by using the digital control system, which is based on the know-how and experience of skilled workers, accumulated as a database. It is also able to scale down the production facility through outsourcing (Hongo, 2016b).

> **Reduction of loss of products**
Demand for products can be predicted precisely and timely through the monitoring of various elements of the supply and demand chain such as sales through the point of sales system and the forecast of weather or other natural circumstance. Thus, it reduces the number of unused products. A well-known case is food loss. Annual food loss in the United States (US) and Japan is about 30 million tonnes and 6 million tonnes, respectively. The 6 million tonnes loss in Japan is equivalent to annual food demand from Tokyo with 13 million people.

> **Acceleration of innovation**

i. Removal of the bottleneck of the supply chain for production
Industry 4.0 can remove the bottleneck of supporting industry. For instance, when innovative products and services are proposed, designed, and planned by an entrepreneur, production capability is a barrier for commercialisation. Industry 4.0 and other IoT technologies will improve the access to producers and global supply chains and reduce the barriers for entry.

ii. Reduction of uncertainty in market
IoT will digitalise consumer behaviour and store the data in a database. Innovators can access potential demand directly and quickly. Thus, the IoT can reduce the uncertainty in demand.

iii. Flexibility to natural circumstances, e.g. weather forecast

Natural environments influence demand and supply. For instance, we may catch the change of ice cream sales immediately through an online system at retail shops (like point of sale) and increase its supply. If we forecast weather conditions precisely, we can respond to the demand more flexibly. This may improve quality of services, increase profit, and reduce waste. Sensor technology, particularly satellite remote sensing technology, is improving every year and observation data are accumulating. This will be the seed of innovation. It is crucial for combining the natural science, social, and economic data.

2.2. Opportunities or Threats to the ASEAN Economy

Canon, a leading Japanese camera and digital office equipment supplier, announced that it will start its fully automated factory in Japan in 2018. Canon shifted its manufacturing factory from Japan to other Asian countries after the 1990s for lower labour costs. But labour cost is no longer a critical factor with the robotics and computerised manufacturing system. Adidas, a German-based, world top brand for sports gear, also spoke about a plan to withdraw the manufacturing of its products in Asia and take it back to Germany.

When the share of labour cost is not a critical production factor, it is natural that companies will relocate their production base near their head office to connect research and development, marketing, and investment. Industry 4.0 will thus accelerate the home country regression of industry.

The other new trend is higher value of services by software. Panasonic, as a home appliance supplier, is keen to develop an online service system using its digital equipment and products. An example is the railway maintenance checking system using tablet terminals. Industry 4.0 will lower the barrier for new entrants to manufacturing and, at the same time, increase the value of network base service. Manufacturers take efforts to reduce production cost by Industry 4.0 and develop new fields through the internet and digitalisation as their long-term strategy. Assemblers have been at the top of the industry pyramid but they are losing their influence over the supply chain. System integrators are gaining more influence.

Industrialised countries will greatly benefit from Industry 4.0 because productivities and competitiveness will improve and there will be less dependence on labour cost. ASEAN economies may experience serious negative impacts by the relocation of manufacturing facilities but, at the same time, Industry 4.0 may help them 'leapfrog' their development by improving their access to knowledge and experiences, which are digitalised and stocked by industrialised countries. Industry 4.0 provides a big chance to small- and medium-sized companies and companies without manufacturing facilities too. Industry 4.0 is a serious threat but a big opportunity too. How to avoid the risk of Industry 4.0 and how to use this opportunity is a very critical agenda for ASEAN. A key is finance to support these projects and companies.

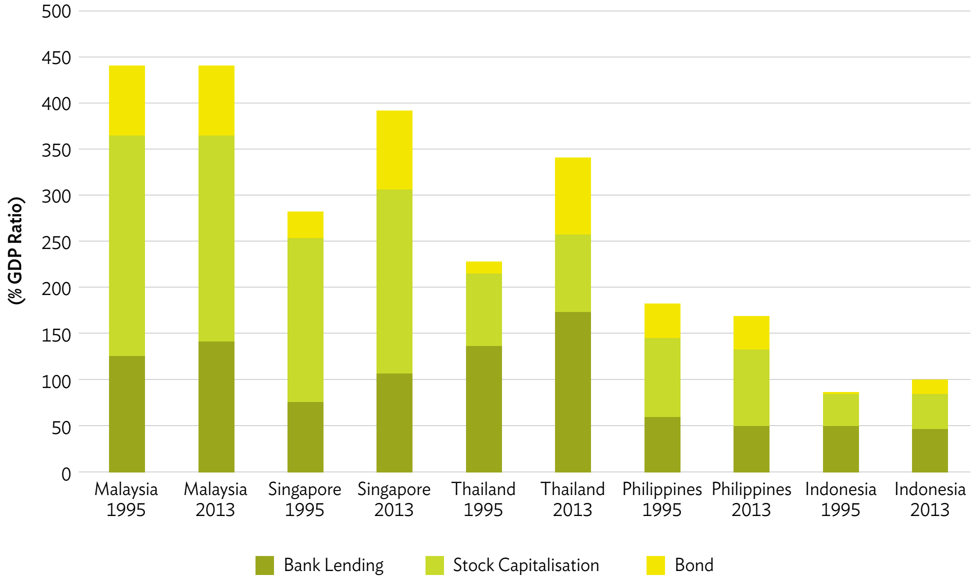
3. Modality of Finance – Innovation of Finance

3.1. Finance Market in ASEAN in General

Projects and businesses under Industry 4.0 have characteristics different from conventional projects. Thus, there is a need to develop suitable finance. Financial innovation is a condition for the development of Industry 4.0 in ASEAN economies.

ASEAN economies are growing. Their gross domestic product increased to US$2,400 billion in 2013 from US$666 billion in 1995 (up 260%), and their per capita gross domestic product also increased to US$12,291 from US$5,772 (up 130%). As well as economic growth, the financial market in ASEAN is growing. The ratio of bank lending, stock capitalisation, and bond issuing to gross domestic product in 2013 increased to 406% in Malaysia, 389% in Singapore, and 338% in Thailand as depicted in Figure 1. Domestic financial markets play more important roles in providing finance to the industry sector, even making long-term finance available. For instance, for large-scale photovoltaic power generation projects in Thailand, local finance was provided for 15 years because revenue from the project is guaranteed by the feed-in tariff system and financial risk is very low. In general, the finance market is growing and several options are becoming available.

Figure 1. **Financial Market in ASEAN**



ASEAN = Association of Southeast Asian Nations, GDP = gross domestic product.
Source: Daiwa Institute of Research.

However, access to finance for industrial investment and high-risk investment projects is still not well developed. Particularly for small- and medium-scaled companies and entrepreneurs, access to finance is limited. Innovative finance is needed for projects and companies under Industry 4.0 because their risks and return profiles are different from conventional projects.

These differences are summarised as follows:

- New products and services: Industry 4.0 is creating new products and services, and their markets are not confirmed. Conventional financial due diligence is unlikely to evaluate these projects properly.
- Small and medium-sized enterprises and ventures: Small and medium-sized enterprises and ventures are expected to be drivers of Industry 4.0 projects. Commercial banks are unlikely to support these projects because they are too small and do not have enough track record of borrowing.
- Engagement of many companies: More companies, including small-scaled companies, are involved in a project and burden of due diligence is bigger than that of conventional project.

We may use various finance models, like crowd finance, venture capital, industry finance, and green finance, for supporting Industry 4.0 but innovation of these finance models is needed too.

3.2. Crowd Finance

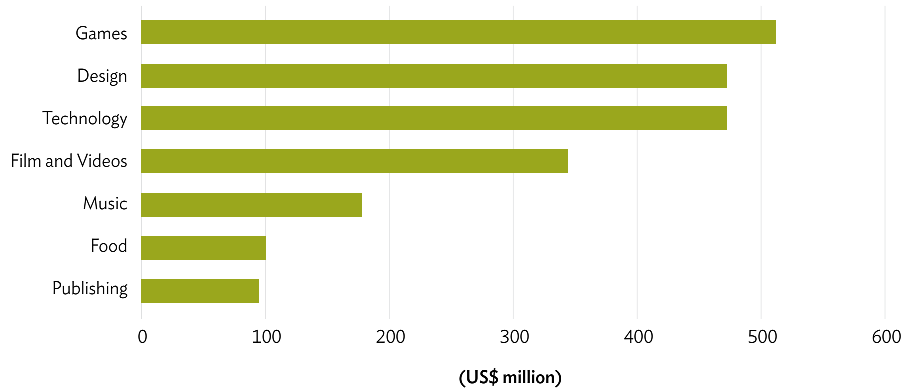
3.2.1. General

Crowd finance is defined as 'the collection of small money from numerous people (crowd) for a specific purpose'. This concept has a long history. A famous example is the Statue of Liberty in New York, which was constructed through donations from several French people for the celebration of the 100th anniversary of independence of the United States (US). The installation cost was funded by donations from the people of New York.

The diffusion of the internet and other IoT technologies will make this approach easier and it is suited to crowd funding. A typical project is a social-related one – poverty alleviation, for instance – or one that provides opportunities for education or medical services.

Crowd funding is also applicable for the development of new products. The largest crowd funding service provider in the world is Kickstarter in the US. More than 11 million people have participated in this and US$2.5 billion have been collected. It covers 15 categories and many are arts related. Technology is the second biggest category and US$467 million for 4,506 projects have been collected, which is depicted in Figure 2.

Figure 2. Kickstarter – World's Largest Crowd Funding Service Provider



Source: Kickstarter, 2016.

3.2.2. Cases of new product development

An example of funding for new product development is the compact and portable DJ mixing machine. The proposal was made by the potential user of this product and this is what they wanted. This is a typical demand-oriented product and more funds were collected than its budget (over-subscribed) because its products were what potential clients wanted to have and applications of the first product were developed following the success of the first model. Investors receive this product and are provided the right to buy additional units at a discounted price. Investors enjoy both products and the financial return.

The demand for the compact and portable DJ mixing machine was not confirmed by conventional manufacturers and, even if it was confirmed, it was unlikely to be produced because its market was too small. Hence, a new but niche market is developed by crowd funding.

Another example is the compact laser processing machine. This machine is common in industry and is of very high standard and expensive. This was proposed by potential customers who wanted a product with reasonable cost and performance. The planned budget was ¥1 million but the collected fund was over ¥46 million. Funding was 46 times bigger than the demand. This is a niche market and unlikely to be developed by a conventional manufacturer.

Both cases are scaled-down products that have not been developed by conventional manufacturers. A key for the success of these products is connecting potential demand and supply directly. The platform also arranges funding. The arrangement of the market, manufacture, and finance would be at one platform, and the procedure for investment decision is cut short.

Figure 3. **Crowd-Funding Cases**

Laser Processing Machine
Programme: Laser processing machine
Planned funding amount: ¥1 million
Collecting funding: ¥6 million
Reward: Discount purchase
Remarks: Initial program was completed but continued for the development of the attachment to the machine.

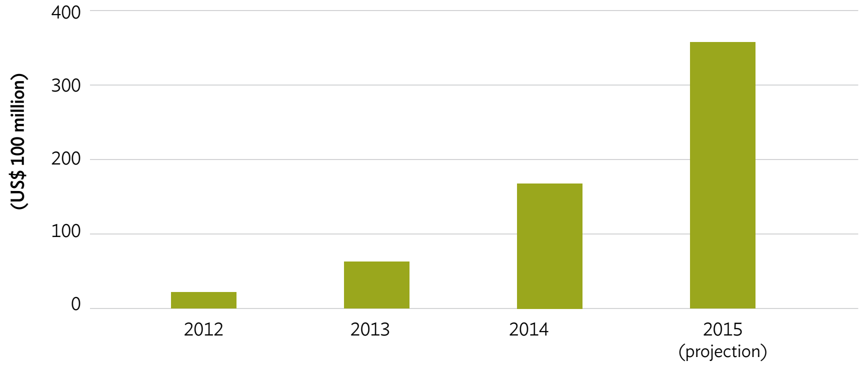
Source: Readyfor, 2016.

DJ Mixing Machine
Programme: Portable DJ Mixing Machine
Planned funding: ¥34 million
Investment: Several investment courses are prepared, from ¥27,800 to ¥79,800
Investors can purchase the machine with different discount prices
Remarks: Investors participating in the program are users of machines. Crowd funding supports not only funding but also marketing.

Source: Makuake, 2016.

The crowd funding market grew from US$2.7 billion in 2012 to US$16.2 billion in 2014. The leading market is the US, as shown in Figure 4.

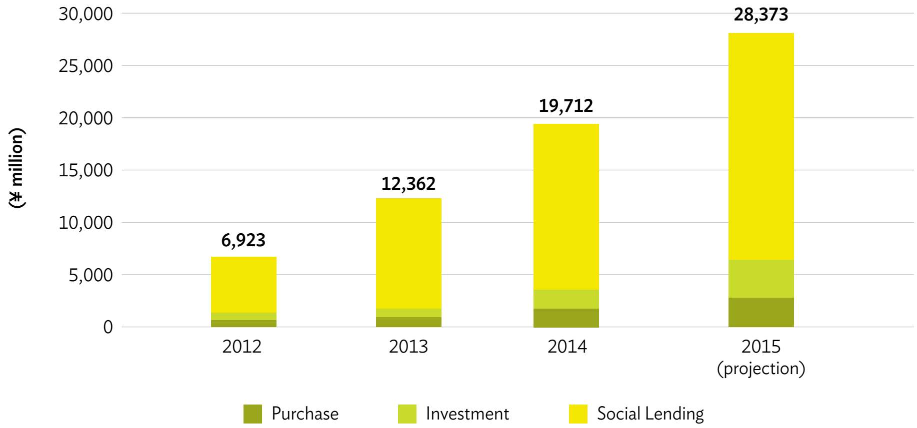
Figure 4. Global Crowd Funding Market



Source: Mitsubishi UFJ Trust Bank, 2015.

Crowd funding is spreading to many countries. The Japanese market is growing and market leaders are mostly internet service companies. The Financial Instruments and the Exchange Act was revised in 2014 to improve the investment climate through crowd funding (Mitsubishi UFJ Trust Bank, 2015). Figure 5 shows the growth of the crowd funding market in Japan from 2012 to 2014 with the 2015 growth projection.

Figure 5. Growth of Crowd Funding Market in Japan



Source: Yano Economic Institute.

3.2.3. Application and improvements

Crowd funding can be developed with a financial option for commercial projects, including Industry 4.0 projects. Sometimes the delivery of the product is delayed and, in the worst case, the plan may be suspended. We should learn lessons for further development.

> *Scams or fake projects*
  It is easy to start funding for projects, but the risk of scams or fake projects cannot be excluded. In many platforms, a proposal is screened by the platform and developed together with the curator. Thus, the ability of the curator is important.

> *Technology evaluation*
  Proposals that are demand or technology oriented should be reviewed by experts or manufacturers to reduce technology risk.

> *Cost estimation*
  Sometimes, cost estimation is not done properly and cost overrun occurs. Experts in finance due diligence should review this to reduce the risk.

Crowd funding is still in the very early stages and has a big room for improvement. In addition to the three lessons above, we must consider ways to scale up the mobilisation of funds by applying crowd funding for projects under Industry 4.0.

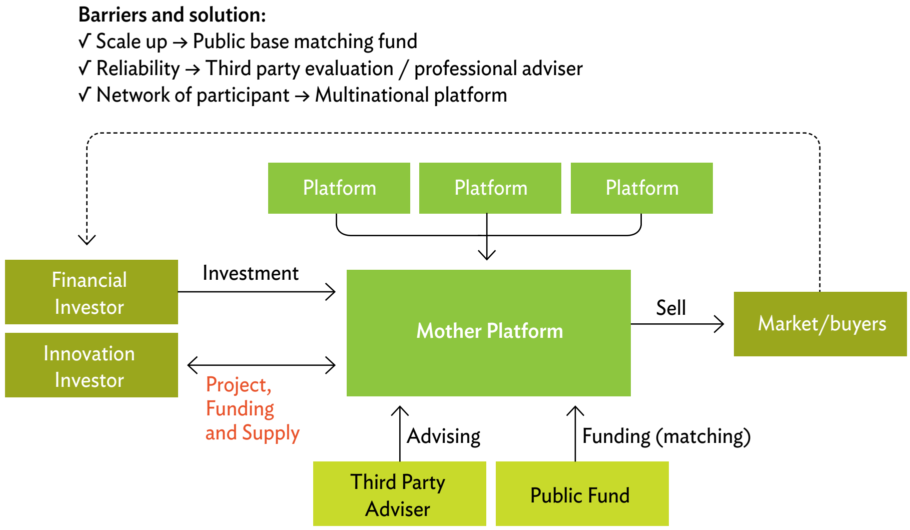
One idea is having a public–private platform. The conceptual model is presented in Figure 6.

> A new platform will be established by public and private funds. This is the mother platform and it will have a partnership agreement with private crowd funding operators.

> The proposal by a private platform is submitted to the mother platform for review. The mother platform shall use advices from the advisory committee composed of experts to improve the review quality.

> Once the mother platform accepts the proposal, the mother platform will invest in the project together with the partner platform. Their investment amount depends on the amount of private fund. For instance, using 'one-to-one' leverage ratio. This is a kind of matching fund.

Figure 6. Recommendations on Advanced Crowd Funding for Industry 4.0



Source: Author.

3.3. Venture Capital

3.3.1. General

Venture capital is characterised as funds for investing in higher-return projects or companies, although the risk is high. Funds are invested in technology innovations and small-scaled companies with high-potential technology or unique products, and companies that need to restructure the business model for further growth. Private equity is a similar type of financial model. In general, private equity invests in a company that will nearly undergo floatation, while venture capital invests in the early stage of the company and project. Also, private equity is a financial investment which engages a corporate management. Some funds are a combination of these two types.

Many funds, including venture capital, private equity, and infrastructure funds, are in Singapore. Singapore is the regional hub of funds because of the following:

- Accumulation of capital stock for investment, particularly cross-border transactions.
- Information hub. Various companies and people, including finance, trading, and industry, from China, India, Japan, the US and the European Union, in addition to ASEAN countries, are based in Singapore.

- Technology. In addition to local technology, Singapore invites research and development centres from various countries by using incentives.

Singapore is an exceptional case in Asia and, in general, venture capital is not active in ASEAN countries.

3.3.2. Japan Asia Investment Co., Ltd.

Japan Asia Investment Co., Ltd. (JAIC) is a fund that invests in China and Japan. Its typical approach is not only providing funds but also engaging in corporate management ('hands-on'). JAIC invests in companies that aim to increase their corporate value and monetise their increased value through initial public offerings.

JAIC changes its business model from time to time in response to changes in the business environment. It was established in 1981 with the participation of 102 Japanese companies such as banks, trading companies, and lending industry, through the initiative of the Ministry of Finance. During its early stage, the Overseas Economic Cooperation Fund, as an official development assistance agency and now part of the Japan International Cooperation Agency (JICA, 2008a), participated as a big shareholder by inviting more private participation to JAIC ('cornerstone investor'). It exited when many private companies joined JAIC. JAIC's target was investment in infrastructure projects. After the Overseas Economic Cooperation Fund's exit (fully privatised) in the 1990s and 2000s, it shifted to industrial projects in ASEAN following the growth of the ASEAN industry. Its clients were local companies in addition to local Japanese subsidiaries in ASEAN. JAIC invested in the early stage of the project and near floatation. An example is a Singapore-based company which planned to develop and supply light-emitting diode lighting systems for fishing boats. The product was commercialised and succeeded to attain initial public offering. JAIC invested through both venture capital and private equity, and many of its investments reached until exit, followed by the growth of the ASEAN economy. JAIC was interested in both venture capital and private equity but did not have many venture capital projects because, in many cases, the projects were small and not enough upside value was expected.

However, JAIC's business model could not be continued. The Asian initial public offerings market shrunk during the financial crisis in 2008 and its cash flow position deteriorated rapidly. It was obliged to sell its assets to survive the crisis – they chose balanced contraction. JAIC received a Hong Kong-based fund as their major shareholder. It prioritised its country and its investments shifted to China and Japan, not ASEAN.

3.3.3. Japan Industry Partners Inc.

The next case is Japan Industry Partners Inc. (JIP). JIP was established in 2002 through the support of the former Industrial Bank of Japan (IBJ), which is now integrated with Mizuho Bank. The funder of JIP is someone from IBJ who has rich experiences in the restructuring of companies and supporting emerging companies. JIP's typical approach is to provide funds for the initial cost necessary to carve out a part of the business operation from a large-scale company, or merger of small-scaled business that has big growth potentials. Then, it intervenes in the corporate management, particularly marketing strategy. JIP will realise a return on its investment through initial public offerings or bilateral equity participation. It invested in Vaio personal computers, which was carved out from Sony, in BIGLOBE (computer portal site), which was carved out from the laser machine centre of NEC, and many others.

The share of Mizuho Bank (IBJ) was around 30% at the start of its business but it has been reduced to less than 10%.

The lessons from JIP are as follows:

- Financial support from bank
  Initial funding is critical because it takes time to recover the investment and it gives confidence to the proposal of the company. The reliability of JIP was supported by the expectation that IBJ, as a leading bank, will support it if additional funding for JIP is needed.
- Sourcing ability
  Networks amongst industry and access to potential clients are also crucial. The funder of JIP has long experience in industrial finance and his experience is valuable to the fund's marketing and operation.
- Market
  Engagement to restructure may realise big returns but its risk is so high and it takes time. Leading banks, like the three mega-banks in Japan, tend not to be interested in such investments. This is a niche market and JIP can avoid the competition with powerful competitors.

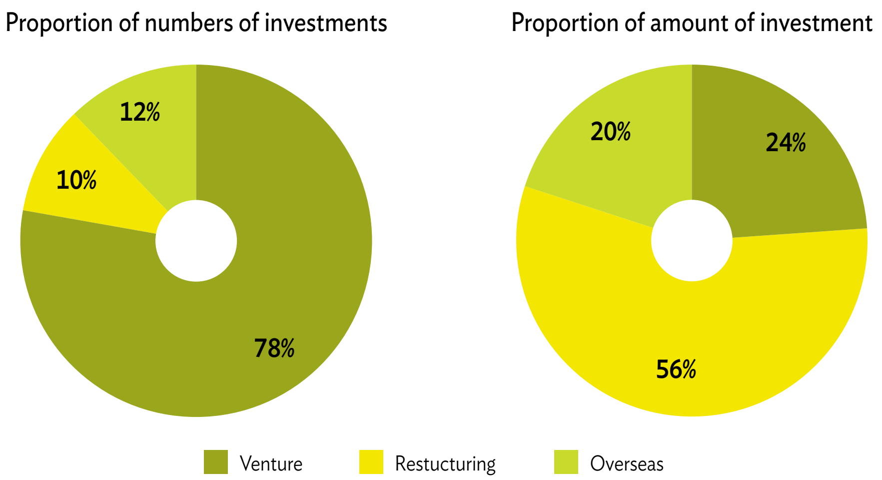
However, there are still some concerns and/or barriers. These are:

- **Financial position**
  Financial position is, in general, not strong compared with large commercial banks, and it may face a difficult situation when the finance market is depressed. A key for success is to keep sufficient financial position for surviving the economic cycle, which is about 7–10 years.
- **Staff**
  Engagement is a big burden for the fund in terms of human resources and it will limit the number of projects. Thus, securing experienced staff and maintaining the quality of the staff is important.

3.3.4. Innovation Network Cooperation of Japan

The third case is the Innovation Network Cooperation of Japan (INCJ) (INCJ, 2016). INCJ was established in 2009 and it aims to accelerate innovation, mobilisation of unused technology, and improvement of international competitiveness by restructuring the industry. INCJ supports a variety of businesses, including large manufacturing companies, small and medium-sized enterprises, ventures, and academia. It can finance both venture capital and private equity types of industrial projects.

Figure 7. Investment by INCJ



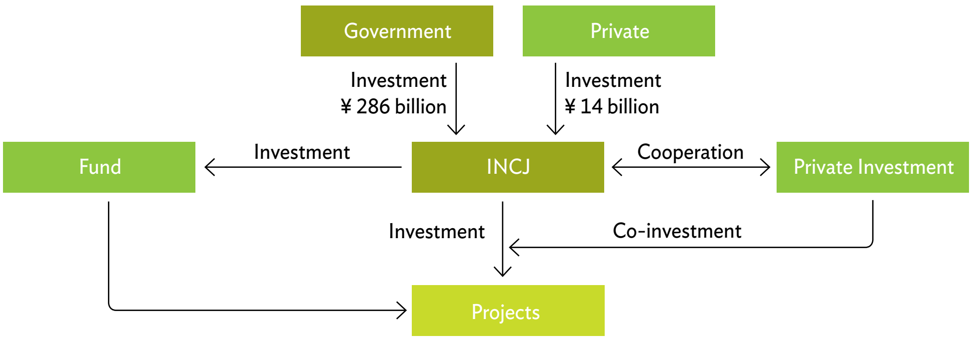
INCJ = Innovation Network Corporation of Japan.
Source: Innovation Network Corporation of Japan.

INCJ was initiated by the Japanese government, which provided ¥286 billion (95% of equity[1]). Private companies provided ¥14 billion. In addition to equity participation, the government provided a guarantee commitment up to ¥1.8 trillion for INCJ's financial operation. However, INCJ's style of operation is like the operations of private funds, and many staff are recruited from the private sector.

INCJ has a big funding capacity. In terms of its finance, 79% is venture capital and 9.7% is private equity. In terms of finance amount, 23.9% is for venture and 55.7% is for private equity (see figure 7). The average size of venture capital is ¥2.5 billion but private equity is ¥46.3 billion. The average size of venture capital by INCJ is small compared with private equity, but it is bigger than the average of venture capital in Japan (less than ¥100,000).

High sourcing ability is another strong point of INCJ because INCJ is neutral to all industrial groups and has close connections with a government technology agency. Three-dimensional (3D) robotics is a good example of strong sourcing capacity. The New Energy and Industrial Technology Development Organization, a government-owned research and development support agency, supports the research and development of 3D robotics through a Japanese university, and introduces products to INCJ for commercialisation.

Figure 8. Innovation Network Corporation of Japan (Public–Private Venture Capital Fund)



INCJ = Innovation Network Cooperation of Japan.

Notes: Innovation Network Cooperation of Japan invests in innovation technology in addition to financing infrastructure projects. For example, 3D media for industry robots, smart metre, e-publications, microwave for chemical processing, and many more.

Source: Prepared by author using INCJ's web information, 2016.

[1] The Japanese government invests through the Fiscal Investment and Loan Program Special Account. In addition to the investment, INCJ provides ¥1.8-trillion guarantee for the operation of INCJ.

INCJ also funds private venture capital funds. An example is its participation in the venture capital fund of Ricoh (digital devices company), Omron (digital device for medical service company) and Sumitomo Mitsui Banking Corporation (bank). This is a 'fund of funds' approach and it improves the investment performance of companies/projects using private venture capital. The scheme of the public-private venture capital fund by INCJ is depicted in Figure 8.

INCJ also finances infrastructure projects that have low return ratios and longer investment periods. This is to blend the different risks and return profile, and may improve the stability of the balance sheet of the fund.

Venture capital, private equity, and other fund approaches could be an option for supporting projects under Industry 4.0 because funds can take higher risks and may play a supplemental role of conventional commercial banks' financing, which, in general, are conservative to take higher risks. However, its weak points are initial fund raising, financial capacity during operation period, and technology evaluation capacity. An option to cover the weakness and enhance the strong points is a public–private approach.

Lessons learnt from public sector involvement of JAIC and INCJ

- Cornerstone investor and leverage function
  The Overseas Economic Cooperation Fund was a cornerstone investor for inviting private capital to JAIC. The share of private funds in INCJ is not so high but INCJ provides finance to projects with private finance (co-finance), or through private funds (back finance). This is the leverage function too. Both are effective to mobilise private finance.
- Sourcing
  Sourcing is very critical element for a successful outcome. The public sector is recognised as neutral to all companies and industry groups, and it also has good access to projects and the technology information of the public sector. More project information is expected to be supplied too. On the other hand, companies that are not familiar with the public sector tend to hesitate to consult with the public sector directly. Thus, the window for first contact should be improved.
- Technology and market evaluation
  The public sector is good at analysing the mid- and long-term future and overview of the market, although the private sector is good at in-depth evaluation for a specific segment. The combination of the public and private sectors is thus effective for improving analysis.
- Additional finance support
  The government provides big volumes of guarantee and this may improve the credibility of funds. Backstop finance can make the financial situation stable and improve access to market funding.

- **Conflict between national and commercial interests**
  INCJ, as a public driven fund, has a special mission to comply with government policy, for instance, support the strategically important company and technology along with government policy. However, private shareholders focus on securing fair and sufficient returns for risk management. Balance is important. A technical solution is separate accounting in response to special missions.

3.4. Industry Finance

3.4.1. General

The ASEAN financial market is growing, but major players in project financing are commercial banks, which collect funds through deposits and provides short-term finances, like 2–3 years' maturity. However, industrial projects, particularly capital-intensive investments, require long-term finance like 5–7 years for manufacturing projects or over 10 years for energy-related projects.

An option for filling the gap is industry finance and we can see a good case in Japan.

3.4.2. Industry Bank of Japan

Industrial finance was very active during Japan's restoration from the damage of World War II and its high economic growth from the mid-1950s to 1970s. A critical barrier to restoration and economic growth was the shortage of finance, particularly long-term finance. Japan had a bottleneck of current account balance because it needed to import energy and resources, and the trade account became a deficit when domestic production was increased. The finance market was chronically tight, and access to long-term finance was very critical for industry.

After World War II, the Japanese government restructured the financial sector and transformed it into three categories: short-term finance (commercial bank), long-term finance (industry and mortgage finances), and public finance (infra-development and trade finances). Three long-term finance banks were established by reorganising the special banks during the pre-war period. They were privatised but were provided special articles of corporation (mission of bank) and status for issuing long-term bonds (IBJ, 2002).

IBJ, now Mizuho Bank, focused on financing the industry sector and provided finance not only for conventional heavy industries like steel, cement, and power, particularly after the restoration from war, but also new rising industries like automobiles, petrochemicals, semiconductors, and electronics.

A unique feature of IBJ was that it had an industry research department. IBJ analysed not only companies but also the industrial sector, whether it has growth potential and whether it may contribute to the Japanese economy. Then, IBJ provided finance following the analysis of each industry potential. It analysed corporate risk based on the project cash flow and/or the mortgage on the factory of the borrower to be financed, while most of the banks relied on collateral like real estate or financial assets. This was called 'project-based finance' compared with 'collateral-based corporate finance' and financing to small or early-stage companies. IBJ took care of these small and early-stage companies, particularly when the Japanese economy was in recession. In many cases, companies, soon after the start of the business, could not have strong a balance sheet and they were vulnerable to the economic turbulence. Therefore, this approach was very supportive of the Start-up Company and new and advanced approaches at that time.

IBJ played an important role in the restructuring of the sector for further growth, and it seconded its skilled bank staff to these companies in addition to the financial support. The merger of Nissan and Price Motor (now Nissan) and Nippon Steel by Yahata Steel and Fuji Steel (now Nippon Steel and Sumitomo Metal) are well-known cases.

IBJ's corporate message was to 'grow with industry'. A combination of long-term investment finance, sector potential analysis, and engagement in the management was its business model. Deutsche Bank had a similar business model. The role of IBJ in Japan was reduced and disappeared due to the merger of city banks because funding capacity was increased and various finance services became available.

We have learnt many lessons from IBJ that are useful in designing new industry finance to projects under Industry 4.0. These include:

Strengths

> Cash flow-based finance

IBJ provided finance based on the cash flow of the project or mortgage on the factory, and its decision was pushed by the sector analysis. This approach was effective for the company at the start-up period.

- Long-term finance
  Industry projects need long-term finance but this is not easy for commercial banks because their funding is mostly from deposits or shorter funding sources. Special permission for issuing long-term bonds at tight market was effective for getting long-term funding.
- Independence from industry group
  IBJ was neutral to all industry groups and could fairly evaluate the growth potential of the sector. Independence brings benefit to both IBJ and the industry.

Change of business circumstances

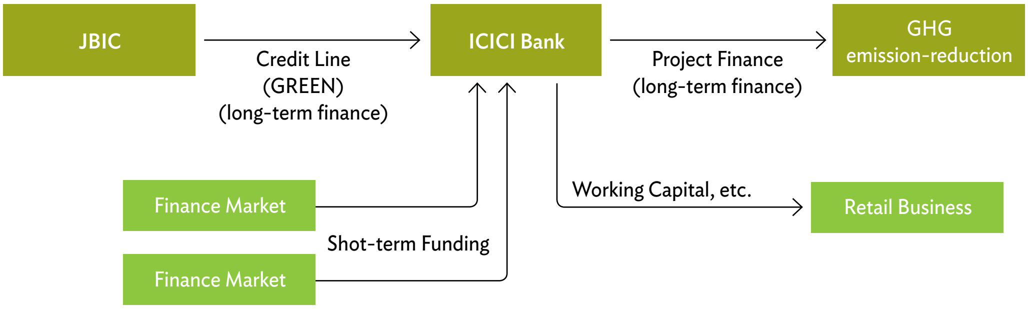
- Slowdown of economic growth
  Investment in industry projects, including emerging companies, was decreased due to the slowdown in the economic growth of Japan. The demand for industry finance was reduced and banks shifted to financing the real estate business in the late 1980s, then the bubble boom was over in the early 1990s.
- Development of capital market
  Due to the accumulation of financial stock, in the 1980s, commercial banks increased long-term financing although their major funding source was deposits (asset and liability management was not seriously considered). Competition between long-term finance banks and commercial banks intensified and finally, in 2007, the special status for issuing long-term bonds was abolished.
- Capacity of bank (human resources and financial resources)
  Long-term finance banks could issue long-term bonds at a tight financial market but the retail business was limited to taking care of competition amongst banks. Their capacities were limited by both human resources and financial resources, and when they competed with commercial banks, limited capacity became a serious handicap.
- Return on investment
  The return on investment for long-term finance is, in general, not so high. This is a big concern when they tap on the capital market for funding because low return on investment leads to the low financial rating of these banks. This is a structural bottleneck of the industrial finance.

Recently, due to the low economic growth in Japan, small and medium-sized companies are expected to lead or stimulate the revitalisation of the Japanese economy. They have unique technology, capability for developing new market, and high growth potential, but their businesses lack finance. Large-scale companies can enjoy good access to finance because their financial risk is not high, and they can offer collateral if they are asked. However, the typical characteristic of funding demand by small and medium-sized companies is 'middle risk and middle return'. This market is the air pocket of financial services and the function of industrial finance is needed in Japan. This is the 'renaissance of industrial finance'.

3.4.3. Industrial Credit and Investment Corporation Ltd. of India

Industrial finance is not yet common in Asia and the exceptional cases are the Republic of Korea and India. The Industrial Credit and Investment Corporation Ltd. of India (ICICI) was established as an industrial finance bank but is now focusing on retail business. One of the weak points of the bank is long-term funding. ICICI borrows long-term funds from the Japan Bank for International Cooperation to support CO_2 emission-reduction projects, including energy efficiency and renewable projects (JICA, 2008b). This approach will reduce barriers to the availability of long-term funds.

Figure 9. Case of India, ICICI



GHG = greenhouse gas, ICICI= Industrial Credit and Investment Corporation Ltd. of India,

JBIC = Japan Bank for International Cooperation.

Notes: In 1955, the Industrial Credit and Investment Corporation Ltd. of India (ICICI), was established by the World Bank, the government of India, and the Indian industry for mid- and long-term project finance in India.

In 1994, ICICI Bank was established as a subsidiary of ICICI.

ICICI Banks shifted to multi functions from a development bank, but still provides finance for longer-term investments.

JBIC provides long-term finance (credit line) to support greenhouse gas emission-reduction projects, which need longer-term financing. There is a gap between demand and supply of long-term finance in India.

Source: Author.

Financing of projects under Industry 4.0 has some similarities with funding projects during high economic growth periods in areas such as project cash flow-based finance, sector approach for risk analysis, restructuring of the company (merger, integration, spin off, and the like), and long-term relationship with the borrower. Industry finance could be an option for supporting Industry 4.0, provided that some modifications and improvements are introduced.

3.5. Green Finance and Carbon Finance

Institutional investors who manage several funds at the global market are aware of the opportunities of projects and technologies for circular economy as well as the risk of global environment constraints. They are seeking new investment frontiers and varieties of 'green' finance initiatives such as green loans, green bonds, green funds, and green ratings. However, their concern is how to monetise 'green benefit'. 'Green benefit', which is in the most advanced stage for monetisation amongst 'green', is carbon dioxide (CO_2) emission reduction.

At the annual Conference of the Parties in Paris (COP21) in December 2015, the parties agreed to keep the temperature rise well below 2 degrees Celsius and to balance the anthropogenic emission and removal in the second half of the 21st century. Clearly, the additional cost will be charged to CO_2 emission. In other words, it will provide commercial value to CO_2 emission reduction. Projects under Industry 4.0 will receive additional incentives or funding when they contribute to CO_2 emission reduction.

The carbon market, the clean development mechanism under the United Nations Framework Convention on Climate Change, the Joint Credit Mechanism of Japan, the China Certified Emission Reduction, and other mechanisms have been prepared and implemented, but a concern is the demand for credits. Table 1 presents various management bodies of applied carbon markets across the countries. More than 180 countries submitted CO_2 emissions reduction targets (INDC[2]) at COP21 (Hongo, 2016a) but their implementation and monitoring mechanisms have not been determined. For the time being, the actual demand for credits is small and limited, and it takes more time for emerging actual demand.

[2] Intended Nationally Determined Contributions. As of 18 April 2016, 190 countries had submitted Nationally Determined Contributions.

This also has a technical issue. CO_2 credits and the reduction amount need to be calculated and verified in accordance with the United Nations Framework Convention on Climate Change's *Handbook on Measurement, Reporting and Verification for Developing Country Parties*. A typical reduction project is renewable energy use and energy saving through investments in equipment. However, IoT will reduce emissions through more channels like factory optimisation (production optimisation), reduction of waste (optimisation of demand and supply), or behaviour change (change of sense of values). A new methodology for evaluating CO_2 emissions reduction through IoT should be developed.

Table 1. Carbon Markets

Management Body	Outline
UNFCCC	CDM is being implemented but there is little demand. Under the Paris Agreement, Article 6, 'UN Centralized Approach' and 'Cooperative Market Approach' as international transfer mechanisms of emission reduction are considered.
International Aviation (CORSIA)	Offset mechanism is adopted for carbon neutral growth and will be available in 2021. However, early action (credit purchase before 2020) is considered.
EU ETS	Implemented from 2005. The biggest market revitalisation is planned.
US and Canada	No nationwide scheme now but subnational scheme, such as California and Quebec, is operational. Inter-state cooperation is active.
China	Seven pilot ETS are being implemented and C-CER is being developed. In December 2017, start of national ETS was announced.
Japan	Domestic and international offset credits scheme is being implemented (J-Credit and JCM).
Republic of Korea	ETS has started. International offset credit is planned after 2021.

C-CER = China Certified Emission Reduction, CDM = clean development mechanism, ETS = Emission Trading Scheme, EU ETS = European Union Emission Trading Scheme, JCM = joint credit mechanism, UNFCCC = United Nations Framework Convention on Climate Change, US = United States.

Source: Author.

4. Discussion for Future Works

4.1. Recommended Finance Option

Industry 4.0 or IoT for industry is an irreversible trend and is becoming a big stream. It provides an opportunity for ASEAN, although it poses a serious threat too. The key to utilising this opportunity and avoiding or reducing negative impacts is finance. The ASEAN financial market is growing and various financial services are becoming available. But projects under Industry 4.0 have different characteristics, like 'high risk, high return', and 'down scaling', and, therefore, innovations in financing are needed. Four finance instruments are recommended: industrial finance, venture capital, crowd finance, and green finance and carbon finance.

4.2. Public–Private Approach

The market of Industry 4.0 or IoT for industry is growing rapidly, and finance options should be prepared as quickly as possible. One way to fast track the development of these options is through public–private partnership. ASEAN member governments are recommended to take the actions below.

i. funding support, e.g. providing initial funds for the establishment of new financial vehicles;
ii. tax benefit, e.g. tax exemption from return on investments through innovative finance;
iii. legal setting, e.g. financial regulation for crowd financing (improve investment climate by setting proper financial discipline);
iv. phaseout policy (exit policy) for public money, e.g. conditions for withdrawal of public funds from public–private institutions for reducing the burden of tax payers and keeping level playing fields; and
v. rationale by economics; carbon price for removing externality.

4.3. ASEAN Knowledge Platform

These policies and measures shall be harmonised and shared amongst ASEAN members under the second phase of the ASEAN integration. I recommend that the Economic Research Institute for ASEAN and East Asia set up knowledge platforms for advocating the necessity of innovation in finance and the harmonisation of finance through local and international experts, such as academics and businesses from various fields such as technology, energy, and finance; and encouraging continuous policy dialogues with financial institutions and policymakers.

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Chapter 11

Managing the Transition to Industry 4.0 through Multilevel Governance Systems

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1. Introduction

A fourth industrial revolution may provide great opportunities for Southeast Asia as it combines managing growing pressures on resources and the environment and takes advantages of a transition to a resource-efficient and ultimately regenerative circular economy. This is increasingly being acknowledged by governments, the private sector, and civil society. However, leapfrogging to a circular economy is not trivial. A systemic transition is needed in the use and recovery of resources in the economy, ensuring future jobs and competitiveness; outlining potential pathways in innovation and investment regulation; tackling harmful subsidies; increasing opportunities for new business models; and setting clear targets.

This chapter outlines some of the opportunities for innovation policies using examples from Germany and the European Union (EU). In that context, the chapter will also highlight some barriers and opportunities in a multilevel governance system.

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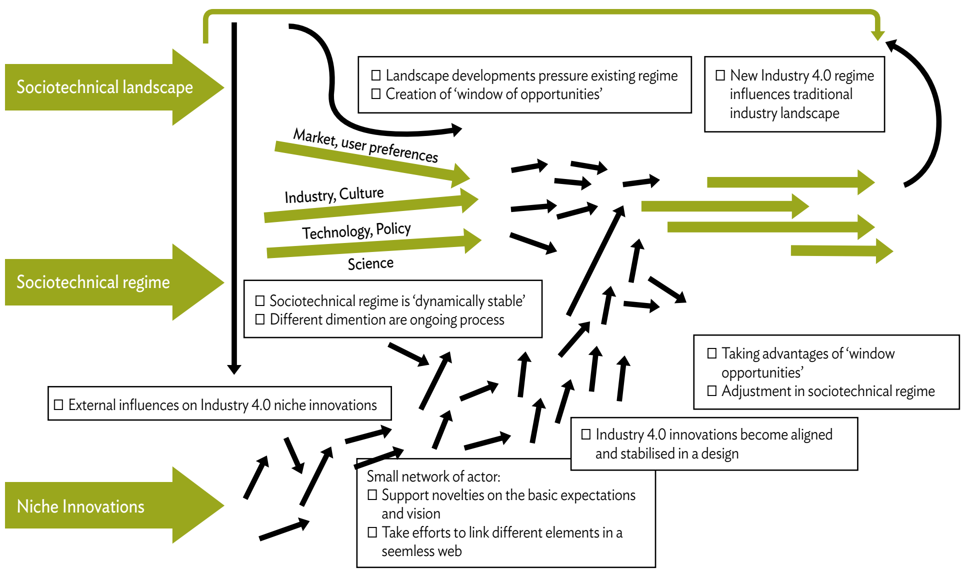
2. Transition towards a Sustainable Industry 4.0

Countries are different and the institutions that define these differences are described by several scholars using different approaches and definitions. This section explores some political science theories in innovation and industry policy. There are several studies examining the influence of the concepts of corporatism, coordinated market economy, consensus democracy, epistemic communities, and European integration on policy performance (Bernauer and Koubi, 2008; Haas, 1999; Neumayer, 2003; Scruggs, 1999). This section will compare some of the key institutional indicators with the ability of countries to move towards an Industry 4.0 approach. It aims to shed some light on the transferability of related innovation and industrial policies to Southeast Asia.

Transitioning from Industry 4.0 innovation niches to a mature circular economy landscape is a complex and challenging process that requires a policy and institutional environment that is dynamic, which is vital to enable innovations, but is also stable, which is essential to attract investments. Transition towards an Industry 4.0-led circular economy would be considered a radical shift towards a different economic system. The scope of the change requires innovations that range from technological breakthroughs to longer-term changes within the existing regime, all of which are gradually emerging through the sociotechnical system (Geels, 2002, 2011).

Figure 1. Transition Process of Industry 4.0 Innovations



Source: Based on Geels, 2002.

2.2 Consensus-focused Institutions as Enablers for Industrial Transitions

A central element of many consensus democracies is a corporatist institutional structure that allows a more coordinated approach to policymaking with a small number of large peak organisations (Goldthorpe, 1984). This closed-shop approach enables the formation of epistemic communities as it substantially limits the number of players that need to be convinced. The comparative advantage of consensus democracies also relates to a number of other elements that characterise these countries, such as the 'shadow of state regulation' (Scruggs, 1999) and a broad acceptance of government regulations due to a history of strong penetration of the state in areas such as the labour market and social policy (Woldendorp, 1997). The institutional structures of a consensus democracy are the primary drivers behind political stability and continuity that create better industrial and innovation policies over the long term, which are vital for a transition to Industry 4.0 (Lundqvist, 1980; McGuire and Olson, 1996). Corporatist institutional arrangements are characterised by a strong relationship between large encompassing groups that enable decision makers to negotiate policy in a way that is distinctively different from policymaking in pluralist, majoritarian democracies (Hall and Soskice, 2001). These groups are integrated into the policy process in a corporatist country and broaden the basis of policies, which create a high level of continuity that is required for long-term investments (Lehmbruch and Schmitter, 1982). This coalition building locks groups into certain policy directions that further enhance policy progress, which is almost self-reinforcing (Katzenstein, 1978).

The institutions that enable a broader consensus amongst political groups and societal actors are described by several scholars using different approaches and definitions. Democratic systems can largely be divided into two major categories: majoritarian and consensus democracies (Crepaz, 1995; Lijphard, 1999). Majoritarian systems are characterised by the concentration of power in one party and minimal winning majority cabinets, a two-party system, non-proportional election systems, interest organisation pluralism, centralised forms of government, unicameral parliaments, constitutional flexibility, absence of judicial review, and executive control of the central bank. Consensus democracies, on the other hand, are characterised by a coalition government, balance between executive and legislative powers, proportional representation, interest group corporatism, federalism, bicameralism, constitutional rigidity, judicial review, and independence of the central bank (Lijphart, 1999). Note that these combinations are not a definitive list of characteristics but an indication of typical elements of countries that can be described as majoritarian or consensus democracies. Due to its characteristics, it could be argued that majoritarian democracies, such as the United States, Australia, and the United Kingdom are decisive and are able to implement innovation policies faster than their consensus-focused counterparts (Lah, 2017a).

2.2 Reliability as a Factor of Success for Innovation Policy

A decisive factor of success for innovation policy is the reliability of the policy environment over the long term. This challenges the theory that majoritarian democracies are more effective and argues that consensus-orientated democracies are more likely to be successful in moving towards sustainable development and a circular economy over the long term. It is argued that consensus democracies are even more responsive and decisive than majoritarian systems, at least over the longer term, because of the more coordinated interaction with societal actors (Lah, 2017b). This positive impact on the stability of the policy environment depends on a number of elements that are characteristic of a corporatist country, for example, comparatively encompassing interest groups, the 'shadow of state regulation', and a broad acceptance of government regulations due to a history of strong penetration of the state in areas such as the labour market and social policy (Scruggs, 1999).

The institutional structures of a consensus democracy are the primary drivers behind political stability and continuity. Corporatist institutional arrangements are characterised by a strong relationship between large encompassing interest organisations that enables decision makers to negotiate policy in a way that is distinctively different from policymaking in pluralist, majoritarian democracies. There is still a debate about corporatism creating more positive impacts, particularly on socio-economic performance (Schmidt, 1982; Cameron, 1984), than negative impacts (Therborn, 1987). Corporatist institutional interaction is characterised by less collective protests and strikes (Schmitter, 1981), which indicate political stability, but no definitive answer can be translated into the Southeast Asian context. However, engagement and coordination of key societal actors clearly help create a lasting partnership and coalition on which transition to Industry 4.0 in Association of Southeast Asian Nations (ASEAN) member countries can be built.

It can be claimed that corporatism is beneficial for innovation policy development and outcomes, but here it is argued that it is only if the encompassing groups have vital interests that foster environmentally sustainable policies. These groups are integrated into the policy process in a corporatist country and broaden the basis of policies, which create a high level of continuity that is required for long-term investments. This coalition building locks groups into certain policy directions that further enhance policy progress, which is almost self-reinforcing (Katzenstein, 1977, 1987). A similar effect is expected from consensus democracies and coordinated market economies.

2.3 European Integration as a Driver of Industry 4.0

A high level of integration into a framework beyond the nation state acts as an additional factor for policy continuity, which helps in the transition towards Industry 4.0 in the case of the EU. It also results in policy action and may enhance policy implementation as outcomes are externally monitored. The interrelations between European and domestic politics and policies create a new dimension for societal and political actors. The European level opens new opportunities, but potentially also constraints, to pursue specific political interests. This provides societal actors with an opportunity to advocate for, for example, innovation policies, even if this issue has no or little priority in the domestic political agenda.

Even more importantly, there are formal institutions in the EU, which provide the opportunities for innovation policy initiatives. They also create a policy environment that is less dependent on national elections and hence, less likely to become subject to radical change after an election (Weidenfeld, 2010). The 'logic of appropriateness' (March and Olsen, 1998) and processes of persuasion in the EU are mediated by the influence of change agents who persuade others to adjust national interests to the overarching European framework and the European political culture, which aim for political consensus and cost-sharing (Börzel and Risse, 2009). The EU influences directly and indirectly the innovation and industrial policies of its member states (Jordan, 2001; Vogel, 2003; Boerzel and Risse, 2009). Due to its supranational character, the EU is a significant policy driver, which acts as a contributing factor to more political continuity. While the ASEAN framework has no supranational character, a common research and innovation framework for Southeast Asia may at least help pursue ideas collectively and on a more consistent and longer-term basis, which may eventually feed into national policy processes.

2.4 Institutions that Enable a Transition Towards Industry 4.0

Consensual political institutions as outlined by Lijphart and Crepaz (1991) cited in Lah (2017a) may lead to higher levels of policy continuity, which, in turn, would have positive effects on industrial transition processes. This approach also adopts the theoretical concept of 'encompassing organisations' (Olson, 1982) and examines the relationships between political and societal actors and their ability or inability to negotiate policies that are based on broad majorities in both politics and society. Crepaz (1991) cited in Lah (2017a) argues that multiparty coalition governments with proportional representation and negotiation power are more effective in lowering unemployment and inflation, hence creating a more favourable socio-economic environment. Crepaz (1995) and Lijphard (1999) provide conceptual frameworks and supporting evidence that governments with consensual, inclusive, and accommodative constitutional structures and wider popular cabinet support act more politically responsible than more majoritarian, exclusionary, and adversarial countries.

In countries with corporatist institutional structures, major policy issues are negotiated in a concerted effort by organised interests. Studies in this domain usually focus on the interaction between unions and employer organisations to negotiate socio-economic policies. Policy coordination amongst organised interests facilitates favourable policy outcomes, which, in this study, relates to high levels of energy efficiency and low levels of greenhouse gas emissions. According to this, a high level of corporatism may influence the implementation and improvement of policies with a long-term focus. There are several elements that may support this. For example, comparatively encompassing interest groups, a consensual social partnership, the 'shadow of state regulation', and a broad acceptance of government regulations due to a history of strong penetration of the state in areas such as the labour market and social policy (Scruggs, 1999). Interest groups are integrated into the policy process in a corporatist country and they broaden the basis of policies, which create a high level of continuity that is required for long-term investments. This coalition building locks groups into certain policy directions that further enhance policy progress, which is almost self-reinforcing (Katzenstein, 1977). As a response to the economic downturn, high unemployment, and inflation rates triggered by the oil price shocks in the 1970s, several countries with open economy used corporatist structures to cope with increasing policy pressures (Goldthorpe, 1984; Katzenstein, 1977; Woldendorp, 1997).

The concept of coordinated market economies is very similar to the general concept of corporatism, as it relies on formal institutions to regulate the market and coordinate the interaction of firms and firm relations with suppliers, customers, and employees (Hall and Soskice, 2001). Coordinated market economies can be characterised as having long-term relations between key actors in the economy. The focus in research has been the relationship between trade unions and employer associations. These long-term, cooperative relations provide coordinated market economies with a comparative advantage that positively affects the policy continuity and policy capability of a country as corporatist structures do.

Hall and Soskice (2001) argue that the hands-off policy approach and uncoordinated interaction between policymakers, and economic and societal actors, which characterise liberal market economies, put these countries on a relative disadvantage compared with coordinated market economies. The strong interlinks between industry, banks, government, and non-governmental organisations in coordinated market economies are considered to cause inertia, but also continuity and policy stability (Amable, 2003; Streeck and Yamamura, 2001). The analysis of the potential relationship between carbon intensity and continuity and coherence indicators gives some indications of clusters of countries that represent certain institutional arrangements and governance structures.

3. Industry 4.0 Innovation Policy: Examples from Germany

The concept of Industry 4.0 originated from Germany and it aims to generate greater productivity through resource efficiency and investments in people and technology (Buhr, 2015). The German approach to Industry 4.0 is to boost human-orientated development as much as technological development. Industry 4.0 is seen as a sociotechnical system that will not outsource workers but will broaden its work spectrum and offer access to knowledge and training. Technological innovation needs to focus on easy access and operation for consumers, interconnectedness, and individualisation of products. The efficiency of resources can be planned, developed, monitored, and optimised (BMBF, 2015). These areas of action are a priority for the German government – open standards for networking; automation of complex systems; widespread broadband infrastructure; safety, privacy, and security; clarification of work organisation for people; continued education; legal framework; and resource efficiency. A clear focus of the government on standards, legal regulations, and financial incentives or facilitations, is crucial for the successful implementation of Industry 4.0.

The German Federal Government sees Industry 4.0 as a central part of a future plan to lead the economy into a sustainable future and maintain Germany´s role as a global economic powerhouse. Several innovation policy and infrastructure initiatives started to enable this transition, for example, by investing in the interconnectedness of the virtual and physical worlds to a cyber-physical system (CPS). These CPSs will have intelligent sensors to interact with their environment and self-assess products, machines, and equipment to optimise and self-regulate (BMWE, 2014).

Germany is a place for innovation and industry, with about 15 million jobs that are directly linked to production. To keep businesses in the country, industry needs to evolve and change. The value of Industry 4.0 for the economy will lead to higher quality and productivity, increased flexibility, standardisation of development processes, as well as quicker production to bring products on the market (BMWE, 2014). The focus for the German government is on:

i. the expansion of high technology sectors, for which the federal government will promote the development of autonomous systems, smart services, and digitalisation of medical-related systems;
ii. the establishment of platforms to manage big data and make it more consumer friendly;
iii. the investment in people and their training in high technology sectors; and
iv. the investment in medium-sized companies (BMBF, 2016).

One of the main driving factors for the development and support for Industry 4.0 is the economic value that it can bring and the necessity to develop resource efficient production ways and products. For example, a BMBF-funded project develops a resource conserving production chain with zero-waste-production. This is one goal to keep the need for limited resources as low as possible and to create a circular economy in which all products can be produced efficiently and reused afterwards. Intelligent systems will be able to provide relevant data for life cycle management at any time and in any location, which will be necessary for increased efficiency and waste reduction. Intelligent systems will provide policymakers with reliable data to develop an optimised sustainable recycling circle (Velis and Brunner, 2013).[1] Government policies need to mirror this development and adapt existing policies to accommodate innovation and ensure sustainability safeguards.

3.1 Governance and National Innovation Systems in Germany

The German government sees an active role for itself in the transition to the fourth industrial revolution. It sees its role in creating an innovation-friendly environment and fair competition within the international actors, as well as 'financing possibilities' (Die Bundesregierung, 2016).

The German Federal Government sees the need to accelerate the launch of start-up companies to facilitate market access, which needs a regulatory framework and industry standard that enable innovation. Traditionally, Germany's industry works within a 'closed innovation' circle, which means that no technical invention will be spread outside the company. Yet, Industry 4.0 will change this towards an 'open innovation' strategy, which means to circulate ideas, innovations, and skills sets (Buhr, 2015). Cohen and Levinthal (1990) spoke about 'absorptive capacity', which means the power of policy instruments to promote this openness and enhanced networking (Cohen and Levinthal, 1990). This has to start with educational changes, promoting interaction, network building, and funding inter-disciplinary projects or the transfer of research from funded projects (Buhr, 2015). The German government is funding companies that can profit from the digitalisation of their industry and will especially support small and medium-sized enterprises to apply Industry 4.0 approaches.

[1] http://www.res-com-projekt.de/index.php/home_DE.html

3.2 Investing in Industry 4.0 Innovations, Examples from Germany

Investing in research and innovation can make a vital contribution to the transition to an Industry 4.0. The German Federal Ministry for Research and Education plays an active role in this by funding a range of research projects geared towards innovations for an Industry 4.0. The following section briefly summarises some of the recent projects in this area.

The research project BaZMod (component-specific machine configuration in production by cyber-physical additions) developed an integrated strategy, which can communicate between the tool and its environment (time frame: 3 years, volume: €4,040,000). The intelligent documentation of machines, which will, with increased digitalisation, only be done by machines in the future (time frame: 3 years, volume: €3,704,000). The intelligent network in production is another example of German government funding, which will be necessary with increased consumer requirement and the need for resource efficiency (time frame: 3 years, volume: €11,100,000). To achieve a timely knowledge of production to be able to influence events, the research project eApps4Production will provide knowledge and information in real time, which CPSs can access (time frame: 3 years, volume: €3,656,000). Intelligent cooperation and networking is important when working in production to create flexible and small-amount production parts (time frame: 3 years, volume: €4,234,000). To react flexibly to increased or decreased capacity needs, the KapaflexCy project will enable industry to plan in a timely and flexible manner the use of staff (time frame: 3 years, volume: €5,560,000). To react quickly to changes in production, the production machines must be changed. This will be done through a standardised system and developed by the research project KARIS PRO (time frame: 3 years, volume: €5,057,000). To be able to create CPSs, all disciplines of production must be synchronised, such as mechanics, electric, informatics, and the like (time frame: 3 years, volume: €4,364,000). The research project metamoFAB is creating the change towards an intelligent industry within the companies itself, which means the development of a connected industry with itself and others (time frame: three years, volume: €4,500,000) (BMBF, 2015). The development stages of Industry 4.0 vary from pilot-phase initiatives to market-ready companies. As part of a federal programme to support Industry 4.0 companies, 249 businesses identified themselves as taking an Industry 4.0 approach. The following sections show some illustrative examples.

F&M Maschinenbau in Berlin has started to use intelligent software solutions to enable employees to organise their work more efficiently and to prioritise the orders intelligently, taking third party deliveries into account. Barcodes at every station help further to deploy personal, more efficient, and open-sourced hardware, which guarantee low cost.[2] Another example is PRO-OPT, a big data production optimiser for smart ecosystems. It helps to collect volumes of generated data and develop an integrative modelling approach, which models along with the restrictions on their use and quality. The secure data can be further analysed by the companies involved and integrated into its own processes.[3] The sHub for smart motors has been successfully integrated in the HIPERFACE DSL company in Baden-Wurttemberg. This element can be integrated at the motor of a production machine and predict the next necessary maintenance, hence avoid an unplanned machinery shutdown.[4] The company Bayer developed a management system for a modern light-emitting diode street lighting called 'Intelligent City 2.0', which works through an internet-connected cloud software CityTouch Light Wave and communicates with light-emitting diode light bulbs independently. The illuminance can be controlled according to the individual lighting situation. The intelligent software can find any fault in the light bulbs and automatically sends a report; it follows a programmed protocol to ensure the operation continues safely.[5]

3.3 Funding for Innovation Start-ups

It can be challenging for small start-up businesses with weak financial security or history to attract investment or find start capital. The German government wants to help these companies through a special funding strategy and tax exemption. Start-up businesses are necessary for a successful implementation of Industry 4.0 in Germany and they will get initial capital through various programmes like INVEST – Zuschuss für Wagniskapital (grant for venture capital), a start-up funding programme for science (EXIST) (BMWE, 2016). The German government is also exploring funding options from crowd investing or crowd funding and will support society to organise itself.

The first important step towards Industry 4.0 is to create a fast internet access because one core factor of Industry 4.0 is the connection between real and virtual realities to ensure smooth data exchange (Wirtschaftsrat Deutschland, 2013). This increased data exchange entails some pitfalls for data security for companies and individuals. It is especially important to secure personal data from third parties without the consent of the person,

[2] http://www.plattform-i40.de/I40/Redaktion/DE/Anwendungsbeispiele/239-auftragsverwaltung-als-basis-zur-schrittweisen-einfuehrung-von-industrie-4-0-komponenten-f-m-maschinenbau-gbr/beitrag-auftragsverwaltung-als-basis-zur-schrittweisen-einfuehrung-von-industrie-4-0-komponenten-f-m-maschinenbau-gbr.html

[3] http://www.plattform-i40.de/I40/Redaktion/DE/Anwendungsbeispiele/298-dsa-daten-systemtechnik-pro-opt/beitrag-dsa-daten-systemtechnik-pro-opt.html

[4] http://www.plattform-i40.de/I40/Redaktion/DE/Anwendungsbeispiele/230-shub-enabler-for-smart-motors/beitrag-shub-enabler-for-smart-motors.html

[5] http://www.plattform-i40.de/I40/Redaktion/DE/Anwendungsbeispiele/200-intelligent-city-2-0/beitrag-intelligent-city-2-0.html

as well as to secure business-related data. In such cases, the government must legally protect the security of data within the new area of Industry 4.0. The international uniform data protection laws create insecurity, and uniform laws, at least for the EU, have to be provided (Wirtschaftsrat Deutschland, 2013). However, these standards and laws must be enforced abroad as well. Security and intellectual property rights are also important considering the increased digitalisation and the potential security issue from manipulation or data loss. The government is responsible for providing secure infrastructure and formulating standardised data security for the EU or the international community (Wirtschaftsrat Deutschland, 2013).

3.4 Investing in Human Capital and Innovative Start-ups

The introduction of CPSs will permanently change the relationships between people, manufacturing, and the kind of work that people are used to. The change towards Industry 4.0 needs to address the quality of the products as well as the satisfaction of the people, their health, and the related knowledge and competence development of workers (Botthof and Bovenschulte, 2009). The digitalisation of production can potentially bring many positive results for workers: flexible work time, balance between family and work, and easier integration of elderlies or disabled people. Yet, without supervision and the right policies, Industry 4.0 could also become more stressful for people or a means to exclude many (Buhr, 2015).

One task of government and industry is to create an environment in which people's motor skills are not replaced by intellectual machines; they can also develop their thinking, association, and sensory skills. These human capabilities will never entirely be replaced by machines (Spath et al., 2013). Yet these skills must be developed, especially the necessary creative potential and systematic competences required to efficiently use it. Machines should primarily be employed to replace repetitive work to relieve the worker.

Labour organisations could be replaced in the process of digitalisation and new industrialisation. Which form they will take in the future is less clear. One scenario could be a small group of experts, which has the qualification and knowledge about the whole process to make all important decisions, while others suggest a swamp organisation in which workers act as a collective (Hirsch-Kreinsen, 2014). Both scenarios need trained and educated people at the centre and it is partly the government's responsibility to enhance people's abilities and knowledge through training and education.

5. Co-benefits and Coalitions to Support Innovation

5.1 Potential Co-benefits of Industry 4.0 Innovations

Industry 4.0 strategies that help achieve economic, social, and environmental policy objectives can have a far more extensive overall impact on sustainable development and rely on broader political support than business innovations that only deliver economic benefits. Only a few studies have examined the total cost of industry, including air pollution, environmental degradation, and social issues, and the total potential benefits of policies and programmes that reduce these negative impacts. When developing business cases for Industry 4.0 innovations, an assessment of the wider societal benefits that may be high on the agenda of important policy actors and stakeholders may help strengthen the case to find additional support for the implementation. Energy security, access to jobs and markets, affordability, air quality, health, and climate change are all powerful policy objectives that need to be considered when designing Industry 4.0 innovations that are geared towards a high level of synergies and co-benefits.

5.2 Coalition Building Potential of Circular Economy Approaches

Boosting Industry 4.0 innovations and supporting the transition towards a circular economy are complex and multifaceted activities. Policy interventions in this sector can have unintended positive and negative consequences as they rarely only affect one objective. For example, air quality measures may affect resource or energy efficiency negatively or vice-versa. Linking and packaging policies are therefore vital to generate synergies and co-benefits between measures. These provide a basis for coalitions that can align different veto players. An integrated policy approach can help overcome implementation barriers, minimise rebound effects, and create the basis for coalitions amongst key political actors and societal stakeholders.

There is a growing number of examples of successfully implemented Industry 4.0 innovations and policies that provide substantial economic opportunities and other sustainable development benefits. Only an integrated approach can achieve economic outcomes that benefit society entirely and help reach international climate change and sustainable development goals.

Different people, groups, and institutions may have different priorities. For example, some may be motivated by economic objectives and others by social equity or environmental objectives. The diverse benefits offered by a comprehensive or integrated measure can help build broad community support. The nature of integrated circular economy policies is that they address several objectives simultaneously, which generates synergies and helps create coalitions. The political and institutional contexts in which policies are being pursued are vital factors for the success or failure of implementation (Jänicke, 1992). Institutional aspects, such as the presence or absence of an environment ministry at the national level or an environment department at the local level and their respective roles in the process as well as their legal power, budget, and political influences are likely to affect the implementation of (primarily) sustainability-related measures (Jänicke, 2002).

Support from diverse businesses, political actors, stakeholders, and the public is vital for the success of innovation policies and circular economy strategies. A societal perspective and the incorporation of sustainable development objectives are vital steps in forging coalitions and building public support. The policy environment, the context in which decisions are made, is vital for the success of the take-up and implementation of Industry 4.0 measures (Justen et. al., 2014). This context includes not only socio-economic but also political aspects, considering the institutional structures of countries. The combination of business and policy objectives can help build coalitions but can also increase the risk of failure of the package if one measure faces strong opposition, which can be overcome if the process is managed carefully. A core element of success is the involvement at an early stage of potential veto players and the incorporation of their policy objectives in the agenda setting (Tsebelis and Garrett, 1996).

Veto players are political actors who have distinctive roles in the policy process and can put a hold on an initiative. Typical veto players are finance ministries and parliaments with legislative prerogatives. This is a substantially different role from stakeholders who have vested interests in a policy process but do not have the (legal) power stop it. However, both groups need to be involved in the process to successfully implement a measure. Public participation can help ensure stability and support beyond political parties. There is a causal relationship between policy objectives, agenda setting, institutional structures, and policy outcomes (Tsebelis, 2002 and Lijphart, 1984 cited in Lah [2017c]). The synergies explored in this paper provide a basis for the inclusion of veto players into the policy process, which is vital for the uptake of Industry 4.0 innovations.

6. Discussion and Conclusion

Transition towards Industry 4.0 requires a consensus on the need for policy intervention and a strategic, coherent, and stable operating environment. Policy interventions in the various sectors that make up Industry 4.0 require a clear political vision to drive change rather than to follow it. This requires a strong political commitment to bring Industry 4.0 on the policy agenda and to remain in place as transition relies on investments for long-term change. This policy environment prevails in the EU and some of its member states where a mixture of national and supranational institutional structures ensures a relatively high level of continuity that can mitigate political volatility to a certain extent and foster policy coherence through integration. Copying singular measures or adopting isolated technologies will not help in the transition towards Industry 4.0 in Southeast Asia. What is needed is a common approach amongst ASEAN countries and a commitment from each of the member states to bring a common vision into national policies. An ideal first step in that direction would be setting up a joint ASEAN research framework programme that identifies policies and technologies that can help Southeast Asian countries develop into sustainable societies with innovative and productive industrial economies.

Considering that significant and diverse benefits can be gained from Industry 4.0 innovations that increase resource efficiency, their uptake is far lower than economically justified. Shifting to a circular economy pathway requires substantial reforms and investments into innovations. Many of these are options that provide significant economic, social, and environmental co-benefits and can therefore conserve energy, resources, and reduce emissions cost effectively. Because of their significant and diverse benefits, they offer opportunities to build coalitions involving many different stakeholders with various interests. This is true for Europe and Southeast Asia. This can help build support and strengthen the political case for the shift towards a circular economy. Successful strategies need to be integrated across policy areas, regions, and levels of government in close cooperation with innovators, start-ups, and traditional industries.

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Chapter 12

Managing the Transition through Multilevel Governance

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1. The Circular Economy and Industry 4.0 – Towards a Sustainable New Industrial Paradigm

1.1 Transitioning to an Alternative Economic Growth Path

The discourse on the circular economy originated in the early 1970s[1] and it is now gaining significant traction as an alternative model that could alleviate and potentially even counteract major global environmental challenges, including climate change, natural resource scarcity, and critical ecosystem degradation. These environmental threats are largely the result of the proliferation of the linear economy – an industrial system that converts natural resources into waste via production (Murray, Skene, and Haynes, 2015).

Advanced economies, particularly in Europe, are now seriously considering the circular economy as they begin to encounter greater price volatility, scarcity, and vulnerability in natural resource supply chains. The World Economic Forum is advancing the circular economy as a new industrial system (World Economic Forum, 2014b) while the Ellen MacArthur Foundation foreshadows that it could be the next major European political economy project after the creation of its internal market (Ellen MacArthur Foundation and McKinsey Center for Business and Environment, 2015).

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1 With the publication of the landmark Limits to Growth study by Meadows et al. and Walter Stahel articulating the 'cradle-to-cradle' concept and the first vision of a closed-loop economy (CIRAIG, 2015).

Its major proponents are also seriously considering its prospects in the developing world. Indeed, emerging economies could potentially leapfrog directly into this economic model, given their ripe opportunities to establish and implement circular systems in developing their manufacturing bases (World Economic Forum, 2014a).

1.2 The Circular Economic Model

The circular economy is a new and evolving school of thought that still requires careful debate and consideration in formulating a fitting definition that will allow real benefits for both the economy and society. In broad terms, this concept envisages an economy that has no net effect on the environment, restoring any damage in resource acquisition and minimising waste generation in manufacturing and the product life cycle (Murray, Skene, and Haynes, 2015).

Circular goods are either consumable or durable. Consumables are not environmentally harmful and can be safely returned to the biosphere. Durables contain technical nutrients that cannot biodegrade and must be designed for reuse. Ideally, recyclable products require limited redesign (if any) before they can be reused (harnessing the power of the inner circle); maximise opportunities for recycling and prolong each stage of reuse (the power of circling longer); diversify use across value chains to reduce demand for virgin materials (the power of cascaded use); and harness the collection of uncontaminated material streams (the power of pure inputs) (World Economic Forum, 2014b). Taken to its full conclusion, the circular economy could radically transform the built environment and transport our existing food systems (Ellen MacArthur Foundation and McKinsey Center for Business and Environment, 2015).

Transitioning towards a circular economy could have profound industrial and social implications, particularly in terms of providing an enabling environment for the pervasive emergence of new service, leasing, sharing, and collaborative business models. Product ownership gives way to product stewardship, and manufacturers will begin to resemble service providers. The circular economy will also create a new breed of 'prosumers' – consumers who are directly involved in lending, swapping, or selling their spare or idle capacity.

1.3 Harnessing the Circular Economy through Industry 4.0

Many leading circular economists regard the emerging Industry 4.0 revolution as a profound tool to mainstream the circular economy. Indeed, in our rapidly changing technological landscape, 'things that were products can become services ... Information that was impossible to know can now be tracked ... one of the greatest impacts will be in the 'circular economy', the idea that natural resources are used in an effective and sustainable manner'.[2]

The proliferation of intelligent assets and greater connectivity inherently complement the circular economy. They could reconfigure our existing energy infrastructure,[3] the built environment,[4] waste management,[5] and natural resource management.[6] They could also herald a more comprehensive transition towards a service or leasing-oriented economy as they provide platforms for the popular growth of these new business models.

1.4 The Role of Multilevel Governance in Driving a New Economic Transition

Convincing states, particularly emerging economies and developing countries, on the merits of transitioning to a the circular economy is a challenging task, particularly since no successful macroeconomic state precedent can be directly followed. In this regard, progressive multilevel governance will play a seminal role, as a shift of this kind requires strategic approaches to create linkages to overcome the existing system and its entrenched path dependencies (Grin, 2008).

Ostensibly, circular economy is normatively aligned with multilevel governance in that it requires implementation at all levels to function as intended, and warrants significant

2 Kenneth Cukier, Data Editor, cited in Ellen MacArthur Foundation, 2016.

3 Intelligent assets are already being used to improve efficiency in energy consumption and are now creating greater transparency in usage. They could improve renewable energy efficiency and have supported its growth in the developing world (Ellen MacArthur Foundation, 2016).

4 Intelligent assets can create a built environment that is flexible and modifiable. They are already being used to optimise energy efficiency in buildings. They can facilitate the predictive maintenance of the urban infrastructure and offer a platform for the secondary materials market (Ellen MacArthur Foundation, 2016).

5 Intelligent assets substantially advance the ability to track products worldwide as well as their condition, thereby optimising resource management on a global scale. Better data collection on waste could assist municipalities in launching successful incentives to reduce waste and improve recycling (Ellen MacArthur Foundation, 2016).

6 Sensing technology and precision agriculture could transform agricultural production, reducing the use of inputs that cause negative externalities and facilitate natural capital regeneration (Ellen MacArthur Foundation, 2016).

cooperation between governments, civil society, and private actors (CIRAIG, 2015). Multilevel governance is also instrumental for Industry 4.0 to be fully harnessed towards the circular economy. While the technology revolution, developing on its own, should improve resource productivity, it is not likely to generate systemic environmental solutions without intervention. Moreover, given the comparatively slow nature of systemic change (in contrast with rapid changes and innovation at product level), there is a very real risk that new technologies will not be integrated effectively towards the structural development of a circular economy (Ellen MacArthur Foundation and McKinsey Center for Business and Environment, 2015). The formulation of multilevel governance approaches must also be tailored to the specific challenges that emerging economies like India and countries within the ASEAN community face to enable them to leapfrog into a circular development path.

2. Existing Policy and Governance Approaches to The Circular Economy in Different Countries

2.1 An Emerging Public Policy Discourse in India

Although India has a low per capita consumption of natural resources, it ranks third in ecological footprint after China and the United States (WWF, 2016), strengthening the case even further for a macro-level circular transition. However, the circular economy still inhabits a relatively niche policy space in India and is generally considered in the context of new approaches towards waste management. In this regard, the status of the circular economy in India is similar to that of many other ASEAN countries that have not yet formulated a coherent vision for the circular economy and tend to approach it predominantly from a waste management perspective.

Fly ash utilisation is often cited as one of India's most significant circular policy initiatives as shown in the case study in Box 1.

Box 1. Fly Ash Waste in India: A Case Study

India generates enormous amounts of fly ash waste.[A] Its utilisation by the building and construction sector has mainly been promoted through government policy measures. The Fly Ash Notification of 1999,[B] originally established an ambitious 100% utilisation target within 9 years (or 15 years for old power plants), while power plants were required to make fly ash freely available for a minimum of 10 years.

This notification was amended in 2003, 2009, and 2016. In 2003, the radius capturing construction activities that should use ash-based products was expanded from 50 to 100 kilometres of a thermal power plant.[C] The 2009 amendments specified the minimum content of fly ash to be used in bricks and other construction materials. They also postponed the 100% utilisation deadline to 2014 (allowing a 5-year grace period to achieve full utilisation).[D]

The latest 2016 amendments further expanded the radius capturing construction activities to 300 kilometres. Power plants must now 'inventorise' and regularly update their fly ash stock online, and bear the cost of transportation to manufacturers within a 100-kilometre radius. They are also responsible for establishing ash production facilities within or near their premises. The use of ash-based products is mandated in cities with a population of 1,000,000 or more, as well as for government programmes with a built-up area over 1,000 square feet.[E]

These regulatory measures achieved 55% ash utilisation by 2015 (Central Electricity Authority, 2015). They were generally effective when fly ash is economical. For example, there has been a significant uptake from the cement industry, which currently represents half of the demand for fly ash-based products (Central Electricity Authority, 2015). Fly ash is generally a popular raw material for cement manufacturers as it is cheaper than limestone. However, there has not been much penetration within the brick-making industry. Although it is offered freely, it is difficult for brick makers to access as they must either bear the cost of transportation or purchase it through traders. In addition, these measures do not incentivise brick makers to invest in transitioning to the manufacturing of ash-based products. The 2016 amendments could improve existing utilisation levels by addressing the problem of transportation logistics, promoting the development of more power plant-based production facilities (particularly near cities), and expanding the requirement to use fly ash materials in smaller cities and government projects.

A Approximately 184 million tonnes were generated in 2014–2015, while 300 million tonnes are projected by 2021 (Bhushan et al., 2015).

B Utilisation of Fly Ash from Coal or Lignite -Based Thermal Power Plants, Notification under the Environment (Protection Act) 1986, Ministry of Environment and Forests, New Delhi, 14 September 1999, http://envfor.nic.in/legis/hsm/flyash.html

C Notification, Ministry of Environment and Forests, New Delhi, 27 August 2003, http://envfor.nic.in/legis/hsm/so979(e).pdf

D Notification, Ministry of Environment and Forests, New Delhi, 3 November 2009, http://dste.puducherry.gov.in/Flyash_notification2009.pdf

E Notification, Ministry of Environment, Forests and Climate Change, New Delhi, 25 January 2016, http://www.moef.nic.in/sites/default/files/fly%20ash%20amendment%202016.pdf

Source: Author.

Apart from fly ash, there have been other recent government initiatives in the direction of the circular economy, although these are being implemented in an ad hoc fashion (largely due to the absence of a consolidated national policy in this area). These include:

Clean India Mission: The national Clean India Mission has catalysed the development of circular waste management initiatives by local bodies. For example, the city of Pune in Maharashtra, India, has implemented Zero Garbage Pune, which is directed towards eliminating the need for landfills, adding value to waste, and creating a paradigm shift from mere disposal to the treatment of garbage as a renewable resource (Kumar, K., 2015).

Introducing the White Industries Concept: In March 2016, India's Ministry of Environment, Forest and Climate Change announced a new category of practically non-polluting white industries. This notification also re-categorises existing industries based on their pollution load. The purpose of the white categorisation is to dispense with the need for environmental clearances to foster the growth of non-polluting industries, and to assist them obtain finance from lending institutions. The re-categorisation of existing industries according to their pollution load seeks to encourage more progressive industries to adopt cleaner technologies and generate fewer pollutants.[7]

Zero Liquid Discharge: This policy (where industrial and municipal wastewater output is reused instead of disposed into a waterbody) is gradually being introduced in different industrial sectors (with a draft notification issued for the textiles industry in December 2015), and as part of the national strategy to rehabilitate the Ganga. In early 2016, the government also amended the power tariff policy to mandate the use of sewage wastewater by thermal power plants within 50 kilometres of a sewage treatment plant.[8] This policy should significantly improve the water efficiency of the thermal power sector, which consumes approximately 22 billion cubic metres of water, almost half of India's total domestic needs (Bhushan et al., 2015).

Amendments to the 2016 Waste Management Legislation: The government has introduced a suite of amendments to existing legislation advancing the circular economy in waste management. The most significant circular features of these new laws are shown in Box 2.

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7 Press Information Bureau, Government of India, Ministry of Environment and Forests, 5 March 2016, http://pib.nic.in/newsite/PrintRelease.aspx?relid=137373

8 Press Information Bureau, Government of India, Cabinet, 20 January 2016, http://pib.nic.in/newsite/PrintRelease.aspx?relid=134630

Box 2. New Waste Management Legislation

E-Waste: Introducing the principle of extended producer responsibility (under which manufacturers and producers are responsible for collecting and channelising e-waste for disposal), and prescribing collection targets.[A]

Plastic Waste: Introducing the principle of extended producer responsibility (channelising recyclable plastic waste to a registered recycler) and encouraging urban local authorities to promote the use of plastic waste for the construction of roads and energy recovery.[B] The introduction of these new rules is timely, considering that India's plastic production is growing at 2.5 times the rate of India's gross domestic product (GDP) (Narain and Sambyal, 2016).

Municipal Solid Waste: Representing India's largest waste stream, the new rules mandate segregation at source, channelising waste to wealth through recovery, reuse, and recycling. They introduce a collect back scheme for non-biodegradable packaging waste. Biodegradable waste must be composted or treated through bio-methanation. Waste processing facilities should be set up in cities with a population of 1,000,000 or more (Sambyal, 2016). The new rules also promote the development of waste to energy plants, requiring that non-recyclable waste with high calorific value should be used directly for energy production or for preparing refuse-derived fuel (Narain and Sambyal, 2016).

Construction and Demolition Waste: This is a newly designated waste category. Local bodies must now use 10% –20% of this waste in municipal and government contracts. Large generators are responsible for segregating this waste, and must pay for its transportation, collection, processing, and disposal.

[A] E-waste (Management) Rules, 2016, Ministry of Environment, Forest and Climate Change, Government of India, 23 March 2016, http://www.moef.gov.in/sites/default/files/EWM%20Rules%202016%20english%20 23.03.2016.pdf (accessed 22 April 2018).

[B] Plastic Waste Management Rules, 2016, Ministry of Environment, Forest and Climate Change, Government of India, 18 March 2016, http://www.moef.gov.in/sites/default/files/PWM%20Rules%2C%202016.pdf (accessed 22 April 2018).

Source: Author.

Existing Circular Initiatives in Business and Industry

Indian businesses and industrial sectors are now beginning to seriously consider the circular economy. In many respects, circular practices are attractive, not only because they are more sustainable but also because they make sound business sense.

Significantly, the Tata Group has announced a sustainability policy embedding a product life-cycle approach, which commits to natural and social capital valuation. Reduce, reuse, and recycle offer a competitive advantage and Tata companies are encouraged to explore the possibilities of product life-cycle management (with Jaguar Land Rover and

Tata Motors taking significant steps in this area).[9] The Mahindra Group is participating in The Climate Group's EP 100, committing to double its energy productivity by 2030. Each business within the group undertakes materiality analyses to formulate its own sustainability roadmap. The Birla Group has pledged to eliminate wood sourced from sustainable forests. Novelis, a Birla subsidiary, is now celebrated for rapidly dropping its dependence on bauxite mining and primary aluminium and using 53% of recyclable inputs. Novelis maintains that there is a strong business case for the circular economy. Indeed, the resource crunch has exposed the vulnerability of existing linear supply chains (Karunakaran, 2016).

Some Indian industries are voluntarily adopting circular practices. For example, since 2001, the paper industry has substantially reduced its need for virgin wood and chemicals and has improved its energy and water productivity (Bhati and Sangeetha, 2014). Apart from being the largest user of fly ash, the cement industry is also exploring co-processing different types and streams of waste material as fuel (Confederation of Indian Industry, 2011). The Indian sugar industry is now beginning to use integrated units in sugar mills, which enable the use of waste for co-generation, and ethanol and fertiliser production.

The Circular Economy: An Indian Cultural Tradition

Although advanced economies tend to approach the circular economy as a new economic model, it is already a familiar practice in many developing countries, including India. Indeed, despite the limited formal policy recognition of the circular economy, India, like many ASEAN countries, may already have a sociocultural ethos that, in contrast with advanced economies, is more inclined towards the circular economy.

India's Ministry of Environment, Forest and Climate Change recently documented existing, traditional climate friendly practices in India that are consistent with the circular economy (MoEFCC, 2015).[10] Significantly, India has a thriving informal recycling network. In fact, the concept of frugal innovation (developing scalable innovative low-cost solutions) that is now becoming popular in advanced economies originated in India where there is a strong

9 Tata Sustainability Group, Waste, http://www.tatasustainability.com/waste.aspx

10 Culturally, Indians are inclined towards needs-based consumption. Simple, sustainable consumption values are imbibed from a young age. Approximately 40% of households are vegetarian. Non-motorised transport (such as pedal rickshaws) is still prevalent in Indian cities (representing 40%–50% of the modal share in mega cities). Traditional building practices such as solar passive orientation, mud-based thermal insulation chequered windows, and large courtyards for natural ventilation are practices designed for comfort in harmony with natural surroundings. Traditional houses use materials such as bamboo, stones, and clay. These materials are not only suitable for the local climate but reduce cement consumption and material transport.

recycling tradition and where people are accustomed to doing more with less. However, the challenge will be to maintain this existing ethos, which is now at risk of becoming displaced as these countries pursue economic development through a linear pathway.

2.2 The Circular Economy in Other Emerging and Advanced Economies

Perhaps, one of the reasons the circular economy remains a peripheral discourse in India and the ASEAN region is the comparatively few and still evolving governance models to support its implementation.

2.2.1 The Circular economy in China

Ironically, although circular economy is predominantly an advanced economic discourse, China has the most sophisticated governance and implementation model. Amongst other things, China established a fund to convert industrial parks into eco-industrial agglomerations along with tax breaks for the reuse sector (Mathews and Tan, 2016). China also enacted the Circular Economy Promotion Law, which is designed to influence behaviour at the micro,[11] meso,[12] and macro[13] levels to achieve a recycling-oriented society (Murray, Skene, and Haynes, 2015). It was even upgraded to a national development strategy in China's 12th Five-Year Plan.[14]

In 2012, the National Development and Reform Commission called for 50% of national industrial parks and 30% of provincial parks to complete circular economy transformation initiatives by 2015, with the aim of achieving close to zero discharge of pollutants. In 2013, the State Council released a national strategy for achieving the circular economy – the first such strategy in the world – including establishing targets for energy productivity, water productivity, and for the recycling industry to reach CNY1 trillion (Mathews and Tan, 2016). The National Development and Reform Commission also invited academic and policy experts to develop circular economy indicators aimed at the macro and meso levels, which measure resource output, consumption and utilisation, waste, pollution, and emissions (Murray, Skene, and Haynes, 2015).

11 Wherein companies are encouraged to develop eco-design and cleaner production approaches (Murray, Skene, and Haynes, 2015).
12 Promoting regional development and the natural environment (Murray, Skene, and Haynes, 2015).
13 Promoting eco-cities and sustainable production and consumption (Murray, Skene, and Haynes, 2015).
14 Including objectives such as reusing 72% of industrial solid waste and raising resource productivity; and introducing 10 major programmes focusing on recycling industrial wastes, converting industrial parks, remanufacturing, urban mining, the development of waste-collection and recycling systems, 100 demonstration cities and 1,000 demonstration enterprises or industrial parks (Mathews and Tan, 2016).

2.2.2 The Circular economy in Germany and Japan

Although China is ostensibly the leader in circular economy implementation, it has been greatly influenced by both Germany and Japan (Mathews and Tan, 2016). Germany's National Sustainability Strategy of 2002 prescribes, amongst other things, ambitious targets to double its raw material productivity and its energy productivity by 2020 (with reference to 1994 and 1990 baselines respectively).[15] Germany has also implemented ProgRess, a national resource efficiency programme. ProgRess II is an updated version of the programme that was passed by the Cabinet in March 2016, which relevantly seeks to safeguard the sustainable supply of raw materials, enhance resource efficiency in production and consumption, and expand a resource efficient circular economy.[16] It also supplements the national raw material productivity target with additional indicators and includes a series of circular economy-related indicators and targets.

Diminishing solid waste landfill capacity initially catalysed Germany's waste management and recycling policies and legislation. In 1991, Germany passed the Ordinance on the Avoidance of Packaging Waste[17] (the first of its kind in Europe), which was followed in 1994 by the Closed Substance Cycle Waste Management Act, Germany's principal circular economy legislation (Davis and Hall, 2006). Significantly, it establishes the principles of the circular economy and waste hierarchy, and enshrines the prioritisation of waste prevention over reuse, recycling, energy recovery, and disposal, while setting specific recycling targets (Sum of Us, 2016).[18] However, although Germany is arguably the global leader in this area, it has not yet made significant inroads with respect to the recirculation of secondary materials and the promotion of circular product design (Wilts, 2016).

The circular economy also arose from resource scarcity in Japan. Its first transformation was to reduce its dependency on oil as its primary energy source and improve the energy efficiency of its industries (World Economic Forum, 2014b).

15 Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety, General Information Sustainable Development, http://www.bmub.bund.de/en/topics/strategy-legislation/sustainability/general-information/

16 Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety, The German Resource Efficiency Programme II Summary, http://www.bmub.bund.de/fileadmin/Daten_BMU/Download_PDF/Ressourceneffizienz/the_german_resource_efficiency_programme_summary_ii_bf.pdf

17 Imposing a system of extended producer responsibility for packaging waste, compelling producers and retailers to take back packaging waste, and pay for waste treatment via the Green Point system, wherein producers pay in advance for the treatment of their packaging waste (Sum of Us, 2016).

18 At least 65% of paper, metal, plastic, and glass, and at least 70% of construction and demolition materials should be recycled by 2020 (Sum of Us, 2016).

Like Germany, it has implemented a series of waste management legislation since the early 1990s. Its most significant is the Law for the Promotion of Effective Utilisation of Resources, enacted in 2000, which is aimed at waste minimisation by consumers and producers alike and covers the entire product life cycle.[19] It has also developed indicators and established targets with respect to material productivity, circularity usage rate, and landfilling amount (Ministry of Economy, Trade and Industry, 2016). Strong, complementary education and public awareness campaigns were also initiated, directed at changing not just economic behaviour but also social behaviour to reinforce and cultivate the circular economy as a social transition (Ji, Zhang, and Hao, 2012).

2.2.3 The Circular economy in the European Union

In December 2015, the European Union (EU) adopted a circular economy package. This package consists of an EU action plan and timelines addressing the full product life cycle from production, consumption, and waste management, and the market for secondary raw materials. It also includes revised legislative proposals on waste, establishing reduction targets and an ambitious and credible path for long-term waste management and recycling (European Commission, n.d.).

3. The Emergence of Industry 4.0 in India

3.1 A Nascent Public Policy Discourse

Although still an emerging concept, Industry 4.0 heralds a new industrial era where smart devices assume major control over manufacturing and distribution. Existing cyber-physical production systems are sophisticated enough to tell machines how they should be processed; processes now govern themselves in a decentralised, modular system; and smart embedded devices start working together wirelessly, either directly or via the internet cloud – the internet of things (IoT) – to revolutionise production. Rigid, centralised factory control systems give way to decentralised intelligence as machine-to-machine communication hits the shop floor (ABB, 2014).

[19] Ibid.

India was the official partner country for the Industry 4.0-themed Hannover Messe in April 2016. India's participation was based on the 'Make in India' theme (launched by the government of India)[20] and a joint Indo–German workshop was convened on Innovation Partnership through Industry 4.0. India's Ministry of Heavy Industry entered two memoranda of understanding with German entities to develop cooperation, technology transfer, and innovation in the manufacturing sector. India also announced that it would leverage its reputed information technology industry to transform manufacturing, not only in India, but also at the global scale, with new concepts such as smart factory, artificial intelligence and IoT, which is projected to be worth US$15 billion for India by 2020.[21]

Despite the inherent opportunities for Industry 4.0, its implementation faces several challenges in India and other ASEAN countries. For example, the cost of energy could be a deterrent to using technologies such as automation in heavy manufacturing (Ranjan, 2016). Significantly, India risks falling behind in terms of its international competitiveness, particularly as Gartner estimates that the global opportunity for IoT alone could reach US$1.9 trillion by 2020 (of which India's share will be relatively minor) (Gartner, 2013). India and many countries within the ASEAN community will need to prioritise building their domestic capabilities in Industry 4.0. This will include developing a domestic IoT industry, robust data security infrastructure, competent security services, as well as education and skills training (Lanvers, 2015).

3.2 Early Signs of Industry 4.0 Transition

India is now positioning itself as an attractive destination for foreign investment, providing international opportunities for setting up new plants and processes in line with Industry 4.0. Table 1 shows sectors that attract the inflows of the FDI Equity in India in the 2013-2016 period. Havells, Godrej, and Bosch are already shifting their operations to India (Lanvers, 2015). However, there are signs that the Industry 4.0 transition has already begun. Pertinently, foreign investment is increasingly directed at the information technology and services sectors (sectors which are ostensibly the most inclined towards Industry 4.0):

20 A national initiative seeking to transform India into a global manufacturing and design hub, http://www.makeinindia.com/about

21 Press Information Bureau, Government of India, Ministry of Heavy Industries and Public Enterprises, 26 April 2016, http://pib.nic.in/newsite/PrintRelease.aspx?relid=142220 India has already launched the Cyber Physical Systems Innovation Hub. The Ministry of Communication and Information Technology has committed ₹ 17.6 (1 crore = 10 million rupee, 17.6 crore = US$ 2.6 million) to develop prototypes and a hub for testing out projects, focusing predominantly on smart buildings.

Table 1. Sectors Attracting Highest FDI Equity Inflows
(Amount in ₹ [crore] and US$ in million)

Sector	2013–14	2014–15	2015–16
Services Sector*	₹ 13,294 US$ (2,225)	27,369 (4,443)	45,415 (6,889)
Construction Development: Townships, Housing, and Built-Up Infrastructure	7,508 (1,226)	4,652 (769)	727 (113)
Computer Software and Hardware	6,896 (1,126)	14,162 (2,296)	38,351 (5,904)
Telecommunications (Radio Paging, Cellular Mobile, and Basic Telephone Services)	7,987 (1,307)	17,372 (2,895)	8,637 (1,324)
Automobile Industry	9,027 (1,517)	16,760 (2,726)	16,437 (2,527)
Drugs and Pharmaceuticals	7,191 (1,279)	9,052 (1,498)	4,975 (754)
Chemicals (Other Than Fertilisers)	4,738 (878)	4,658 (763)	9,664 (1,470)
Trading	8,191 (1,343)	16,755 (2,728)	25,244 (3,845)
Power	6,519 (1,066)	4,296 (707)	5,662 (869)
Hotel and Tourism	2,949 (486)	4,740 (777)	8,761 (1,333)

FDI = foreign direct investment.

Note: *Services sector includes financial, banking, insurance, non-financial/business, outsourcing, research and development, courier, and technology testing and analysis.

Source: FDI Statistics, Department of Industrial Policy and Promotion, Ministry of Commerce and Industry, Government of India, 2016. http://dipp.nic.in/English/Publications/FDI_Statistics/2016/FDI_FactSheet_JanuaryFebruaryMarch2016.pdf

Bosch is already planning to roll out Industry 4.0 in its Indian plants. It has more than 100 pilot projects underway and aims to implement connected production in its 14 manufacturing locations across India by 2018 (ETAuto, 2015). GE has opened its US$200-million multi-modal facility in Chakan (which can manufacture a wide range of products throughout all the company's divisions) that could completely revolutionise how its products are manufactured (Grunewald, 2016). Godrej is already using an intelligent plant framework to run its factory floors, while Mahindra & Mahindra and Tata Motors are using robots to build car body frames (Krishna, 2016). The Indian Institute of Science is developing India's first smart factory in Bengalaru. This project is expected to be revolutionary for India in terms of creating fully autonomous, thinking, and sensing factory operations (Kumar C., 2016).

3.3 Prospects for Integration with the Circular Economy

Policymakers at the highest level acknowledge the importance of Industry 4.0 for India. They believe that it will contribute to productivity gains, revenue growth, employment, and investment (Chitravanshi, 2016). In contrast, there is no equivalent recognition or willingness to evolve from a linear to circular growth path through Industry 4.0, even though both are potentially highly disruptive transformations. This swift embrace of Industry 4.0 is perhaps symptomatic of how the technology revolution does not warrant the same socio-economic paradigm shift that the circular economy does. Moreover, conventional national accounting mechanisms such as GDP are deficient in properly capturing the scope of economic growth opportunities inherent in the circular economy for policymakers to consider this model more seriously.

However, there are some discrete areas of convergence between Industry 4.0 and the circular economy in India. The most obvious example is the Smart Cities Mission. Arguably, this integration is an inherent feature of the smart cities concept, rather than a result of deliberate planning by policymakers. The apparent circular elements of this initiative include requiring solar power to deliver at least 10% of energy requirements, planning for solid waste management, waste water recycling and rain water harvesting, smart metering, the promotion of non-motorised transport, intelligent traffic management, and energy-efficient street lighting. In addition, at least 80% of buildings should be energy efficient and green buildings (Ministry of Urban Development, 2015).

Earlier, the government shortlisted 20 cities under this programme. In May 2016, 13 more cities were added. However, it remains to be seen how far these cities will authentically imbibe characteristics of a circular economy. Of the 33 smart city winners, 21 have already decided not to follow the requirement of 80% energy efficiency in buildings, while there has been an excessive emphasis on 24-hour water supply and comparatively little attention given to water efficiency and sufficiency (Somvanshi, 2016).

4. Facilitating Inclusive Growth?

While there is much excitement about the potential for Industry 4.0 to substantially unleash the circular economy, it is imperative to position this debate within the broader context of the principle of sustainable development in an emerging economy or developing country scenario. The principle of sustainable development consists of economic, environmental, and social aspects. Human well-being lies at the very heart of this principle. Ideally, rural communities and poor people should be the prime economic beneficiaries in developing countries (CIRAIG, 2015).

The circular economy originally emerged as a business- and industry-oriented discourse relating to resource efficiency. While it is often advanced as an important mechanism to promote sustainable development, it is not necessarily synonymous with inclusive growth. In fact, contemporary literature on the circular economy is virtually silent on the social dimension of sustainable development (Murray, Skene, and Haynes, 2015).

While current economic policies may enable the shifting of Industry 4.0-style manufacturing operations to India, it is questionable whether the proliferation of Indian smart factories will substantively promote the human aspect of sustainable development. Although they are economic and environmentally efficient models of production, they are not likely to deliver substantial employment opportunities in a country with a labour force that far exceeds its employment growth. The World Economic Forum predicts that the fourth industrial revolution could lead to the loss of over five million jobs worldwide in 15 major developed and emerging economies, including India and ASEAN countries (Cann, 2016).

This does not imply that India should discourage Industry 4.0. If anything, the prevailing linear model has only deepened existing inequalities. In this regard, there are huge merits in transitioning to an economic model that is more sustainable. However, policymakers will need to ensure that the economic growth delivered by Industry 4.0 is somehow harnessed towards uplifting the poor, considering that they represent a majority of India's population and are not likely to immediately benefit from this transition. They will also need to develop complementary policies on reskilling and retraining to better prepare its labour force for this transition.

Despite the general concern over the future of jobs, the enormous potential for the progressive deployment of Industry 4.0 should not be overlooked. Indeed, these technologies may be ideal for economies with aging populations, and in labour sectors that traditionally have high occupational health and safety risks. Potentially, the use of intelligent assets in India to accurately inventorise its waste could radically catalyse the growth of India's recycling sector, a sector which remains largely untapped and lacks government recognition as an industry but which could be worth up to US$13 billion by 2025 (Dixit, 2016). Precision agriculture is another area where Industry 4.0 could substantially improve the livelihoods of small-scale farmers and the sustainability of existing agricultural practices (Rajvanshi, 2015). It could also create more jobs in the services sector for which obtaining the relevant skills may not be too demanding (such as the emergence of app-based car-riding services).

There are already some compelling examples of the deployment of Industry 4.0 to support inclusive growth in India. For example, Amul India (the world's largest dairy cooperative) has been using advanced automation and control systems since 2008 to enable the aggregation, processing, and distribution of milk, preventing millions of litres from perishing. This has supported both Amul's growth and improved the livelihood of its farmers, enabling them to keep pace with growing demand for milk produce (ABB, 2014). Similarly, the Akshaya Patra Foundation has leveraged technology to feed daily 1.3 million children in government-run schools across 10 states. This initiative has not only contributed to the alleviation of child hunger, but has improved school attendance (Seaver, 2012). Sigma Fraudenberg NOK has opened a state-of-the-art plant in Basma, Punjab, which will employ 2,000 skilled and semi-skilled workers, approximately 50% of them are women from nearby towns and villages (Mathur, 2015).

Intriguingly, the digital economy is also reviving traditional circular practices in India. For example, a substantial market has now emerged through e-commerce for cow dung cakes, which is providing a valuable source of supplementary income for women in villages (Ganesan, 2016). There is also a growing trend of philanthropic crowdfunding emerging in India (as donors can make a significant difference to people's lives by contributing even small amounts of money).[22]

Indian start-ups, which progressively combine Industry 4.0 with the circular economy, are now emerging. Below are a few of the kinds of progressive initiatives that have emerged in this space:

[22] For example, crowdfunding enabled farmers to build a canal in a village in Western India, provided boarding and education to children orphaned by farmer suicides, as well as refurbished old shoes to provide footwear for the underprivileged (Rai, 2016).

Box 3. Examples of Progressive Initiative for Industry 4.0 and Circular Economy in the Indian start-ups

Kabadiwalla Connect is an online information service that works with stakeholders in the informal waste ecosystem, using information technology to help collectors get better prices for their materials, connect to new customers and markets, and optimise logistics across the value chain. They connect communities to their local scrap dealer, helping them sell their recyclable waste easily. Going forward, they will explore new ways, through technology, to send more recyclable (and upcyclable) materials into local scrap-dealer networks, and track how much materials are being recycled at the neighbourhood level (Vardhan, 2015).

Protoprint is a social enterprise that empowers urban waste pickers with low-cost, distributed technology to produce 3D printer filament from the plastic waste they collect. It is currently pioneering an ethical, fair-trade filament production process, which aims to leverage the existing gap in the market for recycled filament (as most filament is produced from virgin polylactic acid plastic and acrylonitrile butadiene styrene plastic).

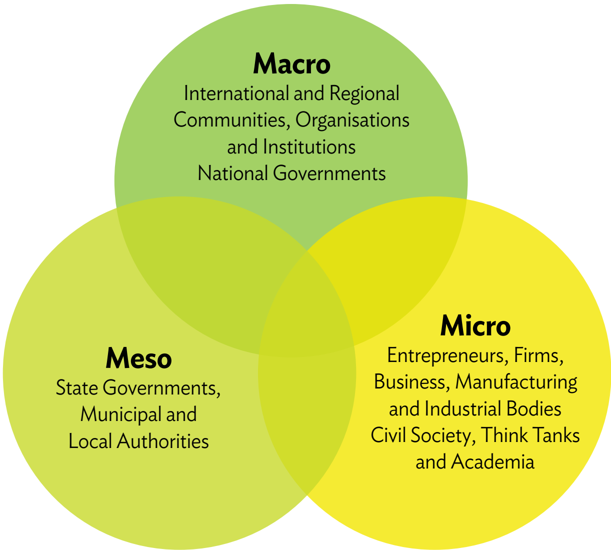
EM3 Agri Services makes high-end technology affordable and accessible to Indian farmers by offering its services on a pay per use basis. They are currently exploring the scope of offering even more cutting-edge technologies (such as soil testing, pest tracking, and other remote sensing technologies that can detect plant health) through the pay per use model (Goyal, 2016).

skyTran is a path-breaking public transport technology using levitating, pod-like vehicles on elevated guideways, which could increase the speed of travel sixfold. Co-founded by an Indian engineer, the technology is now being developed in collaboration with NASA. It is being proposed in many countries around the world, including India, where it will be piloted in a few states including Kerala. If successful, it could augur a new era in public transportation that alleviates air pollution and congestion.

5. Implications for Multilevel Governance in India and the ASEAN Region

While Industry 4.0 and the circular economy are complementary discourses, they may not always interact and combine organically. Accordingly, multilevel governance will play a crucial role in coordinating their strategic integration.

Figure 1. Multilevel Governance and Key Actors



Source: Author.

While relevant actors and change-makers are associated with different tiers of multilevel governance (as identified in Figure 1), Table 2 exemplifies how such transitions occur through dynamic interlinkages and interactions between multiple developments at all three levels (Grin, 2008).

Table 2. Multilevel Governance – Key Actors and Their Roles

Levels	Actors	Strategic Approaches, Measures, and Initiatives			
Macro	International and Regional Communities, Organisations, and Institutions	Promote a circular economy discourse. Encourage the formulation of regional and national policies on the circular economy and Industry 4.0.	Fund and implement strategic and replicable pilot projects.	Facilitate knowledge sharing and technology transfer.	Fund pioneering projects with the potential to scale up the circular economy.
	National Governments	Develop national circular economy policies and initiatives (including indicators) supported by Industry 4.0. Develop guidelines for the adoption of new technologies.	Strengthen domestic capabilities in Industry 4.0.	Support R&D and innovation. Establish research collaborations exploring the scope for the circular economy through Industry 4.0.	Incentivise the adoption of circular and collaborative practices in industry and business.
Meso	State Governments, and Municipal and Local Authorities	Develop complementary circular economy policies.	Educate the local community about the circular economy.	Fund and provide infrastructure support to local innovators.	Encourage and facilitate the implementation of strategic and replicable pilot projects.
Micro	Entrepreneurs, Firms, Corporate, Manufacturing, and Industrial Bodies	Drive innovation. Undertake R&D.	Establish and implement circularity practices.	Showcase and disseminate circular precedents supported by new technologies.	Participate in research collaborations with government and academia.
	Civil Society, Think Tanks, and Academia	Influence public policy development. Popularise the circular economy and its potential in the digital revolution.	Educate consumers about sustainable production and consumption.	Promote the deployment of new technologies to advance sustainable development and inclusive growth.	Harness the collective voice of consumers to reform linear production chains.

R&D = research and development.

Source: Author.

5.1 Raising the Profile of the Circular Economy at the National and Regional Levels

Circular economy remains a relatively niche policy discourse in the ASEAN region. This arguably contributes to the current lack of recognition of the opportunities for Industry 4.0 to catalyse circular growth. While ASEAN countries are no doubt developing progressive policies with respect to environmental management and resource efficiency, policymakers are not yet seriously regarding the circular economy as a new industrial paradigm.

Considering the experiences in other countries (particularly China, Germany, and Japan), ambitious efforts are required at the macro level to develop holistic national circular economy policies that can drive systemic transformations and encourage the participation of key actors. Comprehensive national circular economy policies and implementation strategies must ideally address the following key components identified in Box 1, and not simply focus on waste management.

Box 4. Key Features of a National Circular Economy Policy and Programme

- Encouraging a circular product design
- Positioning resource efficiency policies in manufacturing and industry within a circular economy framework
- Facilitating secondary materials recirculation throughout the economy
- Including the circular economy as an aspect of State national planning (with particular emphasis on the urban and industrial sectors)
- Developing a waste management hierarchy in accordance with the circular economy principles
- Creating public institutions dedicated to the circular economy
- Devising circular economy indicators to establish targets and map progress
- Fostering research and development and innovation
- Driving social change towards the principles of reuse, reduce, and recycle
- Establishing platforms and working groups, bringing together stakeholders across all sections of multilevel governance to contribute their expertise on the circular economy

To date, the countries and regions that have developed circular economy policies and programmes have done so largely because of natural resource scarcity and/or environmental pressures. However, India, like many other countries within the ASEAN community, is not yet experiencing the same level of resource and environmental pressures that force economic change. In the absence of such compelling external policy drivers, elevating the circular economy discourse to a national or regional priority may be a challenge, particularly as most of these countries are immediately concerned with their economic growth.

In this regard, the international community and institutions will play an important role in promoting and disseminating the circular economy discourse as an alternative and better economic growth path. This could include developing more studies about the scope and opportunity for the circular economy, specifically at a regional or country level; increasing bilateral or multilateral exchanges on the merits and potential for the circular economy (such as the Indo–German Working Group on the Circular Economy that was established in 2015); and showcasing the circular economy as a prospective solution in international development discourse to realise the conventionally competing state commitments towards economic growth and the environment (for example, by leveraging the synergies between the circular economy and the recently adopted Sustainable Development Goals [23]).

Apart from devising new national circular economy policies, India and ASEAN countries will need to develop complementary public institutions and collaborative multi-stakeholder platforms to support its strategic implementation. For example, establishing an Office of Resource Management and relevant government postings could do much to widen awareness about circular economy opportunities and precipitate change (House of Commons Environmental Audit Committee, 2014). This will also require the creation of working groups, bringing together stakeholders across all levels to contribute their expertise to the formulation of circular economy policies. ASEAN could also develop a broad strategy and action plan to help stimulate a regional transition to the circular economy, similar to the approach taken by the EU. Currently, the circular economy is not formally recognised as a priority area with respect to ASEAN cooperation on the environment or in its action plans for key sectors such as energy, minerals, or the food, agriculture, and forestry sector (although these plans do exhibit some features that in some respects complement the circular economy).

A key aspect of developing a transformative state circular economy policy is the formulation of appropriate indicators that can establish targets and map progress, for which Industry 4.0 technologies can even be harnessed to develop more accurate and comprehensive measures. They can even be tailored to different governance levels, such as the approach taken in China.

These indicators should broadly address factors relating to the extraction and import of virgin materials, the current environmental load of economic activity and ultimate waste disposal rates, the recycling and recirculation of secondary materials throughout the economy, the uptake of circular life-cycle analyses in product design, resource efficiency in industrial and manufacturing operations, and the socio-economic transition towards a recycling-oriented society. Table 3 summarises the circular economy indicators that have been adopted in other countries and regions.

[23] In particular, the circular economy is highly relevant to Sustainable Development Goals 8 (Decent Work and Economic Growth); 9 (Industry, Innovation, and Infrastructure); 11 (Sustainable Cities and Communities); and 12 (Responsible Production and Consumption) http://www.un.org/sustainabledevelopment/sustainable-development-goals/

Table 3. Circular Economy Indicators Adopted by Other Countries and Regions

Country	Indicators
Japan	• Material productivity (material use as a proportion of GDP) • Circularity usage rate (measuring materials reused as a proportion of total materials used by the economy) • Landfilling amount (measuring how much waste is ultimately sent to landfills)
Germany	• Additional indicators have been formulated as part of ProgRess II, Germany's resource efficiency programme, supplementing the raw material productivity indicator. This will include input raw material productivity and total weight of all raw materials used in production. • In addition to recycling and recovery indicators and targets for different waste streams, two new virtual indicators are currently being developed including DERec (direct effects of recovery as a percentage of direct material input) and DIERec (direct and indirect effects of recovery as a percentage of raw material input). These indicators will be reviewed and improved in the future development of the programme, and further analyses will be developed with respect to the use of foreign natural resources to produce German imports.
China	China has introduced indicators for the meso-industrial park and macro levels, which include four categories broadly relating to: • Resource output • Resource consumption • Integrated resource utilisation • Waste disposal
European Union	• Resource efficiency • Eco innovation index • Recycling rates • Amount of municipal waste per capita • Amount of municipal waste per GDP output

GDP = gross domestic product.

Sources: Ministry of Economy, Trade and Industry, 2016; Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety, 2016; University of West England, 2012; and European Parliamentary Research Service, 2016.

Social and well-being indicators should also be developed to ensure the human aspects of the circular economy are adequately addressed. These could address such factors as employment generation, education and skills development, improvements in the environmental quality of life, and benefits to public health. Indeed, one of the criticisms of the Chinese system is the lack of assessment indicators for the social aspects of the circular economy (University of West England, 2012).

5.2 Leveraging Industry 4.0 Towards the Circular Economy

India and the ASEAN countries are certainly aware of the impending changes that Industry 4.0 will likely precipitate. Governments will play a key role in enabling or holding back new technologies (McKinsey Global Institute, 2014). In this emerging, new industrial era, Indian policymakers are preoccupied with ensuring that India remains globally competitive and exploring the synergies between key national initiatives such as Make in India and Digital India missions (which are particularly apparent in Indo–German collaboration and India's participation at the Hanover Messe in 2015).

At a macro level, it is certainly important for India and the ASEAN countries to strengthen their domestic capabilities to be competitive in the Industry 4.0 era (except, perhaps, Singapore[24]). These include developing policies and programmes that seek to bridge the digital divide; and strengthen the information and communications technology sector and data security environment (including instituting programmes in education and skills development). However, policymakers must also recognise and cultivate the profound opportunities that Industry 4.0 presents for transitioning towards a circular growth path. They must also ensure that this transition is specifically directed towards inclusive growth by establishing relevant guidelines or criteria for encouraging new technologies.[25] In this regard, micro-level actors, particularly the civil society sector, relevant think tanks, and academia (particularly circular economy and green growth advocates), will need to be proactively engaged to contribute to and help steer the national policy direction. Again, exploring Industry 4.0's inherent synergies with the Sustainable Development Goals may be a useful way of ensuring that this transition is harnessed progressively.

5.3 Establishing Compelling Circular Precedents

Perhaps, the biggest challenge in convincing emerging economies like India to transition towards a circular growth path is the lack of off-the-shelf models that they can emulate (Preston, 2012). In the absence of replicable economic models, it is imperative to establish and successfully demonstrate strategic pilot projects that leverage the synergies between Industry 4.0 and the circular economy.

Both macro-and meso-level actors, including international institutions and national and state governments, have an important role to play. For example, the International Finance Corporation's eco-cities programme (which is explicitly tailored towards using technology

24 Singapore is the only country in the top 10 of the United Nations ICT Index, and in the top 20 of the Economist Intelligence Unit Digital Economy Ranking. It is also the only ASEAN country to have been considered a 'Stand Out Country' in the Digital Evolution Index (A.T. Kearney, 2016).

25 This could include considerations such as the technology's potential for rapid adoption, how widespread the benefits and impacts will be (including impacts on people, institutions, products, and markets), whether it will have a significant economic impact, and whether it has the potential to address economic and social challenges (McKinsey Global Institute, 2014).

to support circular urban planning) could positively impact the future development of smart cities in India.[26] Similarly, the World Bank is funding the Efficient and Sustainable City Bus Service Project (which uses intelligent transport and management information systems).[27] While this project is currently being trialled in four cities, it has enormous potential for replication in smart city and urban transport planning if the trial is successful. National and regional initiatives can be taken to develop frameworks and implement replicable circular economy pilot projects such as the approach taken in China to develop eco-industrial parks circular economy pilot cities; and establish a National Pilot Eco-Industrial Park Program and National Pilot Circular Economy Zone Program (Su et al., 2013).

Appropriate technology transfer is certainly important in the demonstration and diffusion of successful circular precedents. While this aspect will be largely driven by micro-level actors at the firm level, national governments have a crucial determining role in deciding which technologies to promote. Currently, there is much interest in exploring opportunities for Industry 4.0 technology transfer between Europe (particularly Germany) and India. Arguably, a major criterion for supporting and facilitating technology transfer in Industry 4.0 should be its prospects for scaling up the circular economy and promoting inclusive growth.

The private sector will have a major role to play at the micro and meso levels. However, given the currently limited capabilities of Industry 4.0 in India and many other ASEAN countries, global corporations based in advanced economies (such as Japan) will be primarily responsible for showcasing Industry 4.0's circular economy potential. For example, Hitachi Ltd. is developing models for inter-manufacturing asset sharing as part of its broader research to develop factories of the future,[28] and is also creating a crowdsourcing platform wherein individual manufacturers can share their resources (including machinery, materials, and expert skills) as part of a symbiotic community of manufacturers.[29] The Japanese business community has also established the Industrial Value Chain Initiative, which is seeking to develop a comprehensive manufacturing ecosystem where factories no longer work in isolation but are connected to optimise production across an entire supply chain. The initiative is now seeking to promote global and borderless collaboration, extending beyond manufacturing to the services sector.[30]

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26 Significantly, the city of Bhubhaneswar in Odisha is one of the five cities chosen to be modelled as an eco-city, while it was also shortlisted in the first phase of the government's Smart Cities Mission.

27 Efficient and Sustainable City Bus Services Project of India, Projects and Operations, The World Bank http://www.worldbank.org/projects/P132418?lang=en

28 A model that proposed the sharing of manufacturing assets between factories that ordinarily work in isolation to ensure optimal utilisation, save costs, and reduce energy. Source: Presentation given by Mr. Jun Kikuchi, Senior Engineer, Planning Department, Hitachi Ltd. at a meeting of the ERIA Research Project on 'Industry 4.0: Empowering ASEAN for Circular Economy' on 6 June 2016 in Bangkok, Thailand.

29 Ibid.

30 Yasuyuki Nishioka, President, Industrial Value Chain Initiative https://www.iv-i.org/en/

More generally, firms will play an important complementary role supporting macro-level efforts to mainstream the circular economy in business and industrial practices. Encouragingly, major corporate houses in India (e.g. the Tata Group, the Birla Group, and the Mahindra Group) are beginning to implement circular practices within their organisations. Moreover, since the 1990s, industrial practices have become much more resource efficient.[31] As the circular economy discourse gains more traction in business and industry, governments should now consider further incentivising measures to generate a culture of circularity in these sectors. However, to fully reap the circular economy benefits of the Industry 4.0 revolution, the corporate and business sectors must further evolve towards developing a collaborative business and manufacturing ecosystem (such as the case of Japan) to develop optimal solutions. Governments will be required to play a critical role to catalyse and drive collaboration within and across different value chains (through initiating cutting edge research projects, facilitating consortiums, and establishing working groups).

5.4 Investing in the Circular Economy

Both the circular economy and Industry 4.0 are innovation-driven transitions. However, India's emerging, new breed of high technology, circular economy innovators have received little, if any, funding from the government.[32] More support is required from the macro-level to catalyse innovation. The Indian government is now recognising the importance of developing a robust start-up ecosystem with the announcement of the Start-up India initiative, which establishes a fund of approximately US$1.7 billion and provides incubation support. Within the ASEAN region, Singapore and Malaysia have established multiple programmes to support local start-ups (A.T. Kearney, 2016).

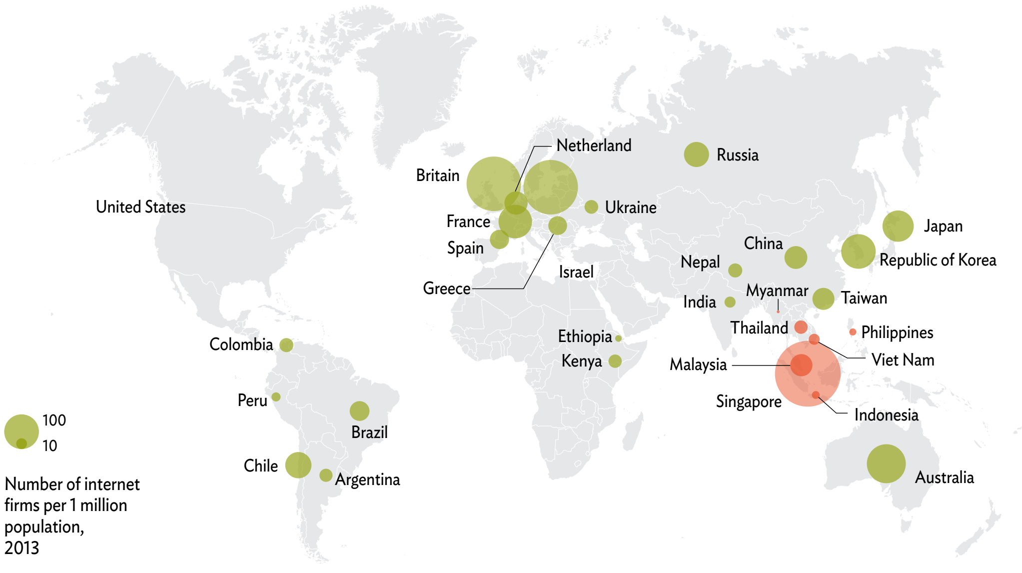
However, despite these various initiatives, the number of internet start-ups per capita in India and the ASEAN region (except Singapore) lag behind other tech hubs of the world (A.T. Kearney, 2016). While it is clearly important for governments to stimulate and support entrepreneurial activity in these countries, there should also be specific incentives for initiatives that advance the circular economy.[33] In addition, the international community should maintain and strengthen its role as an important source of seed funding, while ASEAN could consider establishing an innovation fund supporting pioneering technologies with the potential to scale up the circular economy in this region.

31 For example, the installation of pollution control devices has now become the norm, and there have been significant improvements in water and raw material efficiency (Bhushan, 2016).

32 For example, skyTran is backed by Eric Schmidt's Innovation Fund. Kabadiwalla Connect won a climate change grant from the World Economic Forum. Protoprint was supported by grants sourced from the United States of America.

33 For example, the Start-up India Action Plan currently only prioritises biotechnology as a sector http://startupindia.gov.in/actionplan.php

Figure 2. **Low Number of Internet Startups in ASEAN, except for Singapore**



Source: A.T. Kearney, 2016.

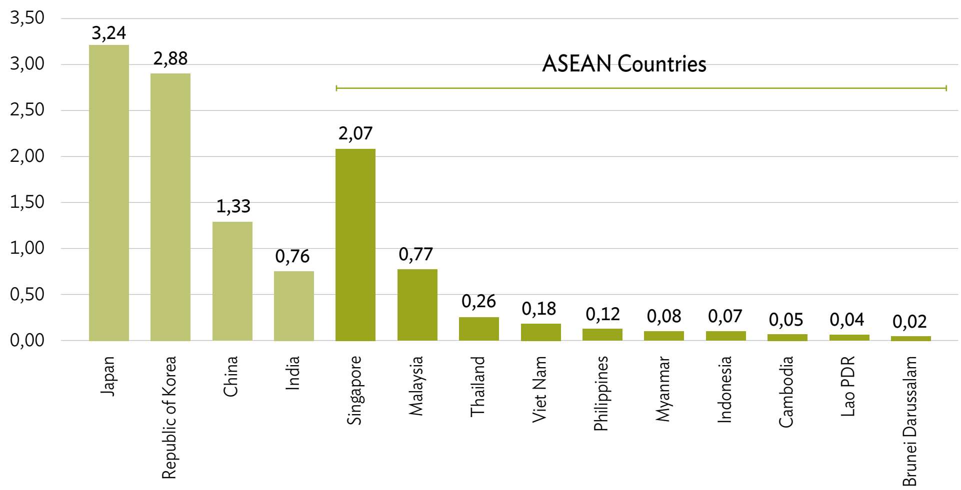
Meso actors, including states and local authorities, will also have a vital role as key enablers. For example, although the national government has recently announced the Start-up India initiative, some state governments have already played a significant role in providing support and infrastructure, stimulating the emergence of start-up ecosystems in cities such as Bengalaru and Hyderabad. However, more education and awareness about the circular economy is necessary to fully leverage the role of state and local government actors as enablers, particularly in terms of developing mindsets that are open to exploring new ideas and supporting innovation. For example, the founders of Banyan (a solid waste management high-tech start-up) encountered difficulties in dealing with urban authorities because of the general reluctance to support innovation and risk, despite the demonstrated need for an integrated solid waste management company (Vardhan, 2014). In contrast, the city of Pune designated land to Protoprint (the makers of recycled 3D filament) and its project partner SWaCH to support the development of their production lab.

Governments at all levels and micro actors (mainly civil society and think tanks) can also encourage innovation by announcing circular economy-themed competitions and challenges. Moreover, they can facilitate maker spaces and repair cafés, providing local spaces for innovation and to spread education about the circular economy. Pertinently, the repair cafés that have emerged in Europe function as important nodes for disseminating the circular economy and teaching its principles from the ground up

(Charter, 2016). While India has a growing makerspace movement (Sivaramakrishnan, 2014), it is generally focused on technological innovation rather than circular solutions.

There is also a need for more consolidated efforts between actors across all levels of multilevel governance (including government, industry, civil society, and academia) to fund and undertake research and development that explore the opportunities for leveraging Industry 4.0 towards the circular economy. Advanced economies have allocated substantial funds towards Industry 4.0 alone.[34] In contrast, no funds have been specifically dedicated by the government towards Industry 4.0 or the circular economy in India. India, like other middle-income ASEAN countries, spends only a fraction of its income on research and development (R&D).[35] These countries will need to attract more R&D investments from global corporations and the private sector, guided towards high-priority research areas relating to Industry 4.0 and the circular economy. They could also establish a public–private development fund for core technologies (McKinsey Global Institute, 2014).

Figure 3. **Average Expenditure on Research and Development (Selected Asian Countries' % Share of GDP, 1996–2013 Average)**



ASEAN = Association of Southeast Asian Nations, GDP = gross domestic product, Lao PDR = Lao People's Democratic Republic.
Source: World Development Indicators, World Databank, The World Bank.

34 For example, Germany has dedicated US$222 million to the Federal Ministry of Education on Industry 4.0, while the Obama administration has pooled together US$500 million towards smart manufacturing in the United States.

35 In the latest Union Budget for the Government of India, R&D investment towards the Department of Scientific and Industrial Research and the Department of Electronics and Information Technology represents approximately 0.6% of India's GDP.

5.5 Educating and Leveraging the Digitally Empowered Consumer

The non-governmental organisation and civil society sector has a significant role in guiding the development and popularising the circular economy, undertaking consumer education (including making consumer preferences more sustainable), and promoting the deployment of new technologies to advance sustainable development. In Europe, the French l'Institut de l'Economie Circulaire has taken a leadership role in campaigning and organising events, and the Dutch non-governmental organisation Circle Economy has been developing research partnerships with public and private enterprises (Murray, Skene, and Haynes, 2015). The Ellen MacArthur Foundation has been instrumental in revitalising international discourse on the circular economy and exploring its potential in the digital economy. However, there are no equivalent institutions in India or the ASEAN region specifically dedicated to the circular economy or exploring the social implications of new technologies. It is imperative that civil society is strengthened in this area, considering how some of these countries are rapidly urbanising. There is now a pressing need to inculcate more sustainable consumption habits in this growing population.

Intriguingly, Industry 4.0 could be an industrial transition that significantly empowers consumers. If their collective power is properly harnessed, consumers have the profound potential to reform existing patterns of production. Considering the proliferation of social and digital channels, consumers now have a significantly larger audience with whom to express their concerns and opinions about a product. They are increasingly demanding more data and accuracy about a product's performance as well as its health, environmental, and social impacts. In this regard, traditional manufacturing will need to transform from linear value chains[36] to consumer-oriented collaborative value networks[37] to respond immediately and effectively to complex and varied demand signals (Capgemini and The Consumer Goods Forum, 2015). Given this unique opportunity, civil society should be proactive in making consumers aware of their digital empowerment, and effectively utilise their collective voice to catalyse a swifter transition towards more sustainable forms of production.

36 Wherein products and information flow in a linear and sequential order from the supplier, manufacturer, retailer, and finally the consumer (Capgemini and The Consumer Goods Forum, 2015).

37 Future value networks will be based on widespread collaboration and enabled by IoT; driverless cars; smart, mobile, and wearable devices; social networks; virtual and augmented reality; 3D printing; and robotics (Capgemini and The Consumer Goods Forum, 2015).

6. Conclusion

India, like countries within the ASEAN region, has initiated some progressive steps towards the circular economy. However, these measures (primarily directed at waste management) do not go far enough to catalyse a macroeconomic transition. Moreover, given the nascent state of the circular economy discourse in these countries, there is a very real risk that the profound circular economy opportunities inherent in Industry 4.0 will be overlooked.

Multilevel governance approaches for these countries should originate primarily at the macro level with the formulation of national circular economy policies and strategies (along with appropriate indicators). Policies should be directed not just at waste management but at circular product design and manufacturing processes and the creation of a recycling-oriented society as well. These policies can also be adapted at the meso and micro levels (such as the approach taken in China).

Policies and strategies will also need to be developed with respect to Industry 4.0. While developing countries must strengthen their capabilities in Industry 4.0, they should also ensure that it is effectively deployed to support circular and inclusive growth. Guidelines for supporting the adoption of new technologies could be developed, having regard to both their circular and inclusive growth potentials, amongst other things.

Governments at the macro and meso levels and international as well as national actors should fund and facilitate pioneering circular projects involving new technologies, convene research partnerships on new technologies and the circular economy, and support the creation of a robust entrepreneurial ecosystem in this area.

Firms at the micro level must be encouraged to develop and implement circular economy practices, support R&D, and participate in multi-stakeholder research collaborations in this field. They should also showcase and disseminate new technologies that enable circular practices and solutions. Significantly, a substantial shift in corporate culture is needed. Given the opportunities now being presented by new technologies, firms will need to move beyond working in isolation and participate more collaboratively towards realising circular solutions within and between supply chains and across sectors.

Governments at the meso and micro levels and civil society actors will play an important role in popularising the circular economy discourse in their communities. Civil society and academia will also be instrumental in influencing and contributing to the public policy debate, and conducting research exploring the social implications of an Industry 4.0-enabled circular transition.

Finally, civil society actors (particularly think tanks and non-governmental organisations) will need to create a groundswell of support for the circular economy, alerting the public to its potential to unfold as a digital revolution and advancing sustainable consumption preferences within society at large. Significantly, civil society is now uniquely positioned to harness and leverage the collective voice of consumers who, perhaps now more than ever, have the profound ability to progressively reform and reshape existing production chains in this digital era.

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Chapter 13

Enhancing Regional Architecture for Innovation to Promote the Transformation to Industry 4.0

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1. Introduction

Industry 4.0 is talked about extensively as the 'fourth industrial revolution' that will have a major impact on manufacturing value chains at both local and global levels, not just in industrially advanced high-cost nations but also in less industrialised low-cost nations (Schwab, 2016). While many descriptions and definitions of Industry 4.0 exist, a simple way of looking at it at an overall level is as a 'collective term for technologies and concepts of value-chain organization' (Hermann, Pentek, and Otto, 2015). Deloitte (2015), in its study of challenges and solutions for the digital transformation and use of exponential technologies, points out that Industry 4.0 has four main characteristics: vertical networking of smart production systems through the use of cyber-physical production systems (CPPS); horizontal integration of real-time optimised global value-creation networks; cross-disciplinary through-engineering across the entire value chain and across the full life cycle of both products and customers; and acceleration of individualised solutions, flexibility, and cost savings in industrial processes through the use of exponential technologies. Hermann, Pentek, and Otto, (2015) point out that an Industry 4.0 scenario needs to take into consideration six design principles: interoperability, virtualisation, decentralisation, real-time capability, service orientation, and modularity.

* The views expressed in this chapter are those of the author and do not necessarily reflect the views of the organisations that the author is associated with. Mention of firm names, commercial products, and/or technologies are not intended to imply endorsement. The contents of the chapter are aimed to stimulate discussion on policy and practice issues and are not intended to express a judgement about the practices of the nations, firms, and other entities mentioned in the chapter.

The positive impact that Industry 4.0 can have from a circular economy perspective is that it can, if well designed and used, help to minimise the leakage of both biological and technical materials, especially the loss of materials, energy, and labour (Nguyen Stuchtey, and Zils, 2014).

However, Ubisense, a global firm specialising in location intelligence solutions, found out, through its 2014 Smart Manufacturing Technologies Survey of 252 manufacturing engineers and product designers, that 40% of manufacturers have no visibility into the real-time status of their manufacturing processes, more than 80% rely on human observation to support process-improvement initiatives, nearly 85% of quality issues can be attributed to worker errors, nearly 10% of manufacturing personnel spent considerable time daily looking for equipment and products, and over 10% of cycle time per product is non-value-added time (Ubisense, 2015). This suggests that even in industrially advanced settings, there are many barriers to Industry 4.0 that need to be overcome and that perhaps there is a need for a phased-out approach in transitioning to Industry 4.0.

The Association of Southeast Asian Nations (ASEAN) region is one of the fastest growing regions in the world, with a population of over 625 million and a combined nominal gross domestic product of over US$2.6 trillion in 2015. The possibilities of enhanced trade and technological cooperation due to the ASEAN Economic Community (AEC), the ASEAN+3 (ASEAN + China, Japan, and the Republic of Korea), and the East Asia Summit (ASEAN, ASEAN+3, and Australia, India, New Zealand, Russia, and the United States) make it attractive for the ASEAN region to leapfrog to an Industry 4.0 setting to enhance the global competitiveness of its businesses while ensuring sustainable manufacturing.

While leapfrogging to Industry 4.0 can be conceptually attractive for the ASEAN region, there could be many barriers to its adoption. A report by Roland Berger (2014) on Industry 4.0 readiness in Europe highlights the challenges faced not just at the firm level but also within the business ecosystem and the national economic setting. Based on this analysis, the report suggests that different European nations could be classified as frontrunners, potentialists, traditionalists, and hesitators with respect to transitioning to Industry 4.0. While these are terms coined by the authors, frontrunners refer to countries where leading firms in manufacturing have advanced to Industry 4.0, along with critical partners in their supply chain, supported by robust government policy initiatives to accelerate this transformation. Potentialists are nations where there is, as the name implies, high potential for an Industry 4.0 transformation and several large firms have already started applying the approaches in selected areas, but leadership at the firm level and governments need to show great commitment to enable a major transformation to be realised. Traditionalists refer to countries where, despite Industry

4.0 awareness, manufacturing has yet to incorporate it comprehensively into their strategic thinking. Hesitators are countries where the manufacturing sector, for reasons such as lack of skills or resources, is wary of embarking upon an Industry 4.0 strategy.

Clearly, the initiatives to be taken by the nations in each category to advance to Industry 4.0 would be different. Frontrunner nations, such as Germany and Sweden, would set the pace while hesitator nations would have much to do to make the transition. This study has implications for the ASEAN region since it underscores the importance of looking at interrelated aspects such as the industrial base of each nation, business conditions, information technology (IT) infrastructure, technological capability, manufacturing skill pool, government policy on sustainability and innovation, and links to the global manufacturing value chain. There could also be a concern in some of the less advanced ASEAN nations as to whether Industry 4.0 will strengthen or hurt its small and medium-sized enterprises (SMEs).

This chapter will develop a conceptual framework to examine a nation's readiness to Industry 4.0. An eclectic approach will be used to develop the framework, which will then be used to make a preliminary assessment of the Industry 4.0 readiness of the ASEAN nations. Barriers will be identified and possible initiatives that could be taken to promote the transitioning to Industry 4.0 will be examined. This examination will encompass possible arrangements that could be taken within the ASEAN region. Suggestions will also be made for further work to strengthen and refine the findings of this chapter.

2. Industry 4.0 and the Internet of Things

Today, the term Industry 4.0 is used to describe a new wave of technological advancement that Schwab (2016) refers to as the 'fourth industrial revolution'. It refers to the way in which the organisation and management of the value chain in manufacturing is undergoing a dramatic transformation (Deloitte, 2015). According to Rüßmann et al. (2015) of the Boston Consulting Group, this transformation is being driven by several foundational technological advances that enable sensors, machines, workpieces, and IT systems to be linked along a value chain beyond a single enterprise. Deloitte (2015) refers to these foundational technological advances as 'acceleration through exponential technologies'. While the broad Industry 4.0 literature (Albert, 2015; D'Aveni, 2015; Deloitte, 2015; Hermann, Pentek, and Otto, 2015; Iansiti and Lakhani, 2014; and Mohr and Khan, 2015) classifies these exponential technologies in many ways, they include the industrial internet of things (IoT), big data and analytics, simulation, advanced robotics, artificial intelligence (AI), additive manufacturing (3D printing), cloud-based software platforms, and augmented reality.

A review of literature shows there is some confusion in the use of the terms 'Industry 4.0' and 'IoT'. While Albert (2015) states that the term 'Industrie 4.0 (Industry 4.0)' was adopted by a coalition of universities, companies, labour unions, and government bodies in Germany to represent the country's vision for the future of manufacturing and is used widely in Europe, Deloitte (2015) points out that the term IoT appears to be used in the same context in the United States (US) and the English-speaking world. While both these terms recognise that manufacturing and production systems are facing a radical transformation due to advances in digital technology, Albert (2015) points out that industrial IoT and Industry 4.0 have a cause–effect relationship in the sense that industrial IoT is the basis for, and will result in, Industry 4.0.

2.1. Main Characteristics of Industry 4.0

Based on the work of Deloitte (2015) and Rüßmann (2015), it could be said that the four main characteristics of Industry 4.0 are the following:

- vertical networking of smart production systems;
- horizontal integration of global value chain systems;
- through-engineering across the entire value chain; and
- adoption of exponential technologies for individualised solutions, flexibility, and cost savings.

At the core of these main characteristics are the cyber-physical production systems (CPPS). CPPS refers to an online network of sensors, machines, workpieces, and IT systems that can extend beyond a single enterprise and encompass the entire value chain (Deloitte, 2015; Rüßmann et al., 2015). They interact with each other using standard internet-based protocols and analyse data to configure themselves, adapt to changes, and predict problems and failures (Rüßmann et al., 2015).

CPPS enables the vertical networking of smart production systems to enable factories to react rapidly to changes in demand and supply, quality fluctuations, and machinery breakdowns (Deloitte, 2015). Production performance and associated discrepancies and amendments, machinery performance, and quality issues are all recorded in real time, enabling better evidence-based response. This can enable customisation of production, facilitate lean manufacturing, and promote the effective use of total productive maintenance. A direct impact of effective vertical networking is both waste reduction and enhanced resource efficiency, both of which are central to the creation of a circular economy.

Horizontal integration of global value chains is also enabled by CPPS where the entities along the supply chain, inbound logistics, warehousing, production, warehousing, outbound logistics, marketing, sales, and after-sales service are networked to provide what Deloitte (2015) refers to as integrated transparency, high level of flexibility, traceability, and global optimisation. 'This will enable factors such as quality, time, risk, price, and environmental sustainability to be handled dynamically, in real time, and at all stages of the value chain' (Deloitte, 2015). Due to comprehensive information sharing and integrated transparency, horizontal integration of global value chains can enable waste reduction and better compliance with respect to social and environmental responsibility, thereby providing an impetus to move towards circular economy.

CPPS can also enable effective cross-disciplinary and cross-functional collaboration for through-engineering along the entire supply chain. Deloitte (2015) defines through-engineering as a seamless approach for the design, development, and manufacture of new products and services across the life cycle of both products and customers. Since product modification and new product development will require adaptation and upgrading of production systems, through-engineering through CPPS will enhance flexibility and response time by dramatically reducing lead times involved in modelling, designing, prototyping, and production system design. Adoption of new environmentally sustainable product design and production systems thus becomes feasible, thereby contributing towards the objectives of circular economy.

The use of exponential technologies such as advanced robotics, AI, 3D printing, and functional nanomaterials and nanosensors can be used to deliver individualised solutions, flexibility, and cost savings along the supply chain (Deloitte, 2015; Rüßmann et al., 2015). For instance, AI and advanced robotics have enabled the use of driverless automated guided vehicles in factories and mines; drones have been used to deliver spare parts and track inventory; and nanosensors have been used to make quality management more efficient (Deloitte, 2015). Additive manufacturing is already being used to produce customised products for special applications, and high-performance 3D printing can deliver new supply chain solutions that can reduce design, production, and delivery lead times; lower transport distances; and even lead to disintermediation of some supply chain entities (D'Aveni, 2014; Deloitte, 2015; Mohr and Khan, 2015; Rüßmann et al., 2015). Here again, the potential contribution towards circular economy is significant.

2.2. The Internet of Things

The International Telecommunication Union (ITU) defines IoT as 'a global infrastructure for the information society, enabling advanced service by interconnecting (physical and virtual) things based on existing and evolving interoperable information and communication technologies' (ITU, 2015). A simpler definition is given by Whitmore, Agarwal, and Xu, (2015) who state that 'the core concept of IoT is that everyday objects can be equipped with identifying, sensing, networking, and processing capabilities that will allow them to communicate with one another and with other devices and services over the internet to achieve some useful objective'. Minsker (2015) refers to the three 'Ds' of IoT as connecting devices, data, and development platforms. These definitions reinforce Albert's (2015) statement that, 'industry IoT is the basis for, and will result in, Industry 4.0' since without an industry IoT, there can be no CPPS.

Lee and Lee (2015) identify five essential IoT technologies that are needed for the deployment of successful IoT-based products and services:

- radio frequency identification (RFID);
- wireless sensor networks (WSN);
- middleware;
- cloud computing; and
- IoT application software.

RFIDs have been used extensively in recent years to strengthen supply chain management. It enables the automatic identification and data capture using radio waves, a tag, and a reader (Lee and Lee, 2015). Data are stored in the tags using the standard electronic product code and the tags can be active (own power supply), passive (powered by radio frequency energy transferred from the reader), and semi-passive (using their own batteries to power the microchips while also drawing power from the reader). Active RFIDs can initiate communication with a reader and are used in manufacturing, hospitals, and remote-sensing IT asset management (Lee and Lee, 2015). Passive RFIDs, which are cheaper than active RFIDs, are used extensively in supply chains for inventory tracking and management, and warehouse management.

Atzori, Iera, and Morabito, (2010) define WSNs as spatially distributed autonomous sensor-equipped devices that can monitor physical or environmental conditions and, in conjunction with RFID systems, better track the status of things such as location, temperature, and movements through appropriate network topologies and multihop communication. The range of WSN applications has increased due to significant technological advances in low-power integrated circuits that have led to the development of low-cost, low-power miniature devices (Gubbi et al., 2013). Lee and

Lee (2015) give an example of the use of WSNs in aircraft engine and wind turbine performance tracking in real time to improve preventive maintenance and reduce downtime. Luo et al. (2015) provide a comprehensive description of how a WSN can be used to monitor the real-time temperature, humidity, and physical position status of perishable goods in a cold chain, thereby ensuring quality delivery and reducing wastage. These are two examples of how IoT can contribute towards waste reduction and better utilisation of resources.

Middleware may be regarded as a software layer that lies between the operating system and applications on each side of a distributed computing system in a network output (Lee and Lee, 2015). Global Sensor Networks is an open-source sensor middleware platform that facilitates the creation and use of sensor services with hardly any programming effort (Lee and Lee, 2015).

Cloud computing is now being used extensively as an on-demand, back-end solution for handling and processing large data stream. On-demand access is provided to a pool of configurable resources such as computers, networks, servers, storage, applications, services, and software through infrastructure as a service or software as a service (Lee and Lee, 2015). The massive data handling and processing capacity provided by cloud computing in real time makes it a critical element of the IoT system. ITU (2015) points out that as confidence in the information and communications technology (ICT) infrastructure and its ability to ensure data privacy and protection increases, IoT will evolve to what it calls the 'internet of everything' where connectivity will not only be between 'people to people' and 'machines to machines', but also 'people to machines' and 'people and machines to processes'. This would require the development of a vast number of industry-oriented and user-specific IoT applications that would ensure that information and messages are received and acted upon accurately and in a timely manner (Lee and Lee, 2015). While 'machines to machines' applications may not require data visualisation, 'people-oriented' applications will require visualisation to be presented in a user-friendly format. This will require IoT applications to be built with 'intelligence' (Lee and Lee, 2015). A generic categorisation of applications for enterprise use could be monitoring, big data and analytics, and information sharing and collaboration (Lee and Lee, 2015). These generic applications are relevant to enterprises in today's interdependent global business setting. A good example is supply chain management where firms must deal effectively with suppliers at multiple tiers, customers, and logistics service providers. The impact would not only be enhanced customer satisfaction and supply chain profitability but also a massive reduction in waste and lowering of the carbon footprint of the supply chain.

3. Literature-based Case Studies of the Potential Contribution of Industry 4.0 and the Internet of Things to the Circular Economy

Industry 4.0 holds considerable promise for sustainable industrial value creation. While it is regarded as a manufacturing paradigm that is still new, emerging literature based on recent developments in the field suggest that it is possible to postulate likely impacts that Industry 4.0 can have from a circular economy perspective. This section presents two short literature-based case studies that can help demonstrate the disruptive yet beneficial impact of Industry 4.0. The first case study on 'sustainable manufacturing in Industry 4.0' illustrates the positive impacts that a 'smart factory' can have from a circular economy perspective. The second case study shows how 'additive printing', a specific technology that will be a core technology in an Industry 4.0 setting, can contribute towards a circular economy. Possible applications outside manufacturing are also summarised at the end.

3.1 Sustainable Manufacturing in Industry 4.0

At the heart of manufacturing in Industry 4.0 will be the 'smart factory' where there is vertical integration of smart production systems, horizontal integration of value chain systems, and 'end-to-end' or through-engineering across the entire value chain (Stock and Seliger, 2016; Mohr and Khan, 2015).

Stock and Seliger (2016) and Kolberg and Zühlke (2015) visualise the smart factory as consisting of a CPPS where the manufacturing equipment use sensor systems to identify and localise value creation entities such as other machines, products being made, and people. Based on the monitored 'smart data', the actuators in the equipment respond in real time to changes. Exchange of smart data between the value creation entities and the value chain is executed through the cloud. Table 1 provides a summary of the value creation factors.

Table 1. Summary Description of Value Creation Factors

Value Creation Factors	Summary Description
Equipment	Automated machine tools and robots working collaboratively with other value creation factors. These smart machines are likely to be organised into modular working stations which are error-proofed and have 'plug and produce' capability.
People	Overall decrease in the number of workers but with a high percentage of knowledge workers who will increasingly have to monitor the CPPS, engage in decentralised decision-making, and participate in through-engineering activities. Equipped with smart watches, 'smart operators' will receive, monitor, and take action in real time to prevent failures and machine downtime.
Organisation	Focus on decentralised decision-making with local information being used by workers and machines in conjunction with artificial intelligence. 'Smart planning' helps CPPS find the optimum between highest possible capacity utilisation at each work station and continuous flow of goods.
Process	Use of exponential technologies such as additive manufacturing and associated supporting technologies.
Product	Mass customisation of 'smart products' with integrated after-sales functionality and access for improved performance and lower total cost of ownership, along with inbuilt features to collect process data for analysis during and after production.

CPPS = cyber-physical production systems.

Source: Adapted from Stock and Seliger (2016); Kolberg and Zühlke (2015).

The intelligent cross-linked value creation modules in a smart factory offer the potential of sustainable use of resources such as materials, products, energy, and water. Table 2 summarises possible opportunities.

3.2 Impact of Additive Printing on Supply Chains and Supply Chain Management

The use of exponential technologies is a major characteristic of Industry 4.0. One such technology is what is known as additive printing, more popularly known as 3D printing. It is called additive printing because it adds materials rather than removes materials from a larger object, as is done in traditional manufacturing. Additive manufacturing essentially involves adding layers of fine powder or liquid sequentially. The materials used include a range of metals, plastics, and composites (Deloitte, 2015).

Four types of processes are used in additive manufacturing, each using a different additive process or additive technology described as follows (Deloitte, 2015):

- *Light polymerisation*, where a light-sensitive polymer is hardened through stereolithography, digital light processing, film transfer imaging, or polyjet process.
- *Extrusion accretion*, where a wire-shaped plastic is applied in layers by a process of fused deposition modelling or plastic jet printing.
- *Compounding of granular materials*, where a powder material is melted on to a work platform using a printer head or laser jet, using processes such as selective laser sintering, selective laser melting, direct metal laser sintering, electron beam melting, gypsum-based 3D printing, and 3D powder printing.
- *Layered lamination*, where a component is built up in layers through a laminated object manufacturing process.

Table 2. Potential Contributions of a Smart Factory towards a Circular Economy

Value Creation Factors	Summary Description
Equipment	Existing manufacturing equipment can be retrofitted with sensors, actuators, and control logics as a cost-efficient way of upgrading to reduce the heterogeneity of equipment within the factory. In addition to economic and environmental dimensions of sustainability, this could enable SMEs to move towards Industry 4.0.
People	Factory workers will become knowledge workers and, with responsibility for decentralised decision-making, will have to be extensively trained to effectively use smart data and support tools based on artificial intelligence. Work, work methods, individual feedback mechanisms, and incentives will have to be suitably designed and effectively implemented to foster intrinsic motivation and social well-being.
Organisation	If the organisation is suitably structured to foster decentralised decision-making and collaboration along the supply chain with a focus on resource conservation, then the implementation of smart grids, smart logistics, customer relationships, and other integrative approaches can promote holistic resource efficiency.
Process	The use of new technologies, such as additive printing and internally cooled tools for metal cutting, can lead to the design of resource conserving and sustainable manufacturing processes.
Product	Products can be designed based on 'cradle-to-cradle' principles. Through the adoption of exponential technologies, the application of identification systems for recovery of products for remanufacturing and real-time tracking of performance of products at the customer end, total costs of production and ownership can be reduced while promoting the sustainable use of resources.

SMEs = small and medium-sized enterprises.

Source: Adapted from Stock and Seliger, 2016.

Studies suggest that while the initial investment in 3D printing may be high, the prototypical cost curve flattens out and substantial cost savings can be made when strategically used along the supply chain (Deloitte, 2015). The major areas in a supply chain that can be impacted by 3D printing are customer relationships and product design, manufacturing, logistics, and inventory management. The impacts on a supply chain from a circular economy perspective have been examined comprehensively by Mohr and Khan (2015) based on an extensive literature review. Their conclusions are discussed below briefly.

Product design and customer relationships

- Due to the additive nature of 3D printing, product designers can customise and redesign products with a focus on attributes such as enhanced functionality and materials savings without being subject to 'design for manufacturing' constraints imposed by production facilities.
- It can also facilitate customer inclusion in the design process so that they become 'prosumers' who engage in customer co-creation.
- Closer customer involvement could also lead to redefining the 'how, where, and who' of an established supply chain, thereby making it necessary to change organisational arrangements and management priorities. For instance, it could lead to merging of design, manufacturing, and distribution.
- These new relationships and ways of working could lead to making what the customers want, when they want it, and how they want it, thereby reducing waste due to overstocking and obsolescence.

Manufacturing

- 3D printing produces less waste during production than conventional manufacturing processes, thereby contributing to a greener and more sustainable supply chain. The possibility of utilising recycled material further enhances its contribution to a circular economy.
- 3D printing replaces previously assembled parts by a single component and thus simplifies the manufacturing process significantly, leading to less parts, less movement of materials, and less assembly efforts, which lead to waste reduction and cost savings.
- The high ratio of output to volume to space occupied in a 3D manufacturing setting makes on-location production and consumption economically feasible. Locating the manufacturing facility closer to the consumer makes agile production possible, small lot production of high-technology products economically viable, and production to market lead times more competitive.

Logistics

- Since 3D printing replaces many of the assembly steps in manufacturing, it reduces process complexity and makes the flow of materials more transparent and easier to control.
- By placing manufacturing closer to the customer, warehousing could be rationalised and movement of physical goods globally can be reduced by sending electronic files to the point of production. These initiatives can reduce the demand for global transportation of physical goods, thereby significantly lowering the carbon footprint of the supply chain.

Inventory management

- Since 3D printing leads to component consolidation, it reduces the number of stock keeping units in the system and lowers the number of components to be kept in stock.
- Inventory management for 3D printing will also lead to a shift to inventory of raw materials (powders, liquids, filament coils) rather than semi-finished parts and components. Handling of these raw materials will be less complex, cheaper, and safer.

It appears from the above summary that 3D printing will certainly have a positive impact on the operations of a supply chain, from a circular economy perspective, through the reduction of waste and complexity, and the lowering of the carbon footprint of transportation. However, with the closer integration of the different entities in a supply chain, there will be concerns related to misuse of intellectual property and product liability. Identifying the skill sets needed by workers and managers in a supply chain will be another area of major concern. Furthermore, if 3D printing is likely to lead to the reshoring of currently offshored manufacturing in developing countries, then how will the low-cost workforce in these countries be affected? These aspects need careful consideration.

3.3 Possible Roles of the Internet of Things in Accelerating Development

While the focus of Industry 4.0 has been mainly on manufacturing, ITU (2015) presents other possible applications of IoT for fostering social well-being and accelerating economic development, especially in developing nations. A key area would be in health, where IoT can be used for tracking, anticipating, and mitigating the spread of infectious diseases by combining mobile positioning data with epidemiological, remote sensing, and geographic information systems data (ITU, 2015). IoT can also facilitate the widespread adoption of mobile health through which assistance can be offered to those with chronic diseases through wearable devices (ITU, 2015).

Other areas of IoT application include climate change and disaster management, precision agriculture, urban planning, electric grids, water and sanitation management, infrastructure and traffic control, and early warning for natural hazards (ITU, 2015). However, ITU cautions that all these applications cannot eventuate unless adequate and reliable ICT infrastructure is established, quality internet connectivity is widely available, and cyber-vulnerabilities are mitigated and minimised.

4. Assessing the Industry 4.0 Readiness of the ASEAN Region

ASEAN was established on 8 August 1967 in Bangkok, Thailand, with the signing of the ASEAN Declaration (Bangkok Declaration) by the founding fathers of ASEAN: Indonesia, Malaysia, the Philippines, Singapore, and Thailand (ASEAN, 2016). It was subsequently joined by Brunei Darussalam, Viet Nam, Lao People's Democratic Republic (Lao PDR), Myanmar, and Cambodia over the period 1984 to 1999, making up the 10 member states of ASEAN (ASEAN, 2016). Its aims include accelerating economic growth, social progress, and sociocultural evolution amongst its member countries, alongside the protection of regional stability as well as providing a mechanism for member countries to resolve differences peacefully.

The ASEAN region is one of the fastest growing regions in the world, with a population of over 625 million and a combined nominal gross domestic product of over US$2.6 trillion in 2015. Of the 10 ASEAN nations, Singapore and Brunei Darussalam are classified by the World Bank as high-income (non-OECD) countries; [1] Malaysia and Thailand as upper middle-income countries; Indonesia, Lao PDR, Myanmar, the Philippines, and Viet Nam as lower middle-income countries; and Cambodia as a low-income country. This suggests that there is heterogeneity amongst the member states of ASEAN from an economic development perspective.

1 As of 1 July 2016, low-income economies are defined as those with a gross national income (GNI) per capita, calculated using the World Bank Atlas method, of US$1,025 or less in 2015; lower middle-income economies are those with a GNI per capita between US$1,026 and US$4,035; upper middle-income economies are those with a GNI per capita between US$4,036 and US$12,475; and high-income economies are those with a GNI per capita of US$12,476 or more (World Bank http://www.worldbank.org/).

The possibilities of enhanced trade and technological cooperation due to the AEC, the ASEAN+3 (ASEAN + China, Japan, and the Republic of Korea), and the East Asia Summit (ASEAN, ASEAN+3, and Australia, India, New Zealand, Russia, and the United States) make it attractive for the ASEAN region to leapfrog to an Industry 4.0 setting to enhance the global competitiveness of its businesses while ensuring sustainable manufacturing. However, this will require major efforts on the part of businesses in these nations. Adopting Industry 4.0 will require changes to be made quickly and effectively in the industrial base, IT infrastructure, technological capability, technological skills, national policies on sustainability and technological development, and along the entire global manufacturing supply chain. Thus, from an Industry 4.0 transformation perspective, it is imperative that each nation assesses the current level of these critical determinants from an Industry 4.0 perspective. This assessment may be called Industry 4.0 readiness.

In the report of Roland Berger (2014), the Industry 4.0 readiness of the European Union (EU) was assessed by developing an index based on a comprehensive survey of the manufacturing sector in the EU in terms of production process sophistication, degree of automation, workforce readiness, innovation intensity, high value added, industry openness, innovation networks, and internet sophistication. These were rated on a 5-point scale and an overall 'Readiness Index' ranging from 1 to 5 (with 5 being the maximum) was developed for each nation. A matrix was then developed with the readiness index on the vertical axis and the manufacturing share as a percentage of GDP on the horizontal axis. Nations that had a high readiness index and high manufacturing share were rated as 'frontrunners'. Those with a high readiness index but low manufacturing share were termed 'potentialists', and those with a low readiness index but high manufacturing shares were called 'traditionalists'. Those with a low readiness index and low manufacturing share were referred to as 'hesitators'. Clearly, the 'frontrunners' are the Industry 4.0 champions while the 'potentialists' and 'traditionalists' must take focused action to take their industry into the next era. The 'hesitators' with unreliable industrial base and adverse economic conditions will not be able to future-proof their economies (Roland Berger, 2014).

Given the constraint that this study will not have the opportunity to undertake surveys of the manufacturing sector of the ASEAN nations, published information was used to develop an Industry 4.0 Readiness Index (I4RI) for the ASEAN nations. The Global Competitiveness Report (2015–2016) provides considerable information on the status of critical indicators of what it refers to as the 'pillars of development' of nations. To develop an I4RI for the ASEAN region, information on the following three major categories were used: basic requirements, efficiency enhancers, and business sophistication and innovation (Schwab, 2015).

The basic requirements category comprises four sub-criteria: institutions, infrastructure, macroeconomic environment, and health and primary education. These essentially constitute the foundations upon which a nation can build a stable, productive, safe, and sustainable programme of economic development based on good governance (Schwab, 2015). The Global Competitiveness Report rates nations on each of these on a score of 1 to 7, where 7 is the maximum score attainable (Schwab, 2015).

The efficiency enhancers category refers to six sub-criteria, as follows (Schwab, 2015):

1. **Higher education and training**
   The higher education and training sub-criteria focus on the development of high-level skills and continuing education
2. **Goods market efficiency**
   Goods market efficiency refers to the level of healthy competition and customer sophistication, which will drive firms to embark on a programme of continuous improvement
3. **Labour market efficiency**
   Labour market efficiency examines the level of mobility of the workforce between economic sectors as demand for skills shift and ethical treatment of workers become based on meritocracy, gender equality, and appropriate incentives
4. **Financial market development**
   Financial market development assesses the level of development of capital markets in a nation that enables the private sector to gain effective access to such sources as loans from a sound banking sector, well-regulated securities exchanges, venture capital, and other financial products
5. **Technological readiness**
   Technological readiness measures the agility with which a nation adopts existing technologies to enhance manufacturing productivity, with specific emphasis on the adoption of ICTs for fostering production efficiency and innovation to enhance competitiveness
6. **Market size**
   Market size refers to the size of local and export markets that firms in the country have access to in today's global business setting. Here again, the Global Competitiveness Report rates nations on each of these six sub-criteria on a score of 1 to 7, where 7 is the maximum score attainable (Schwab, 2015).

The business sophistication and innovation category consists of two sub-criteria: business sophistication and innovation. The business sophistication sub-criterion assesses the quality of a country's business networks and supporting industries in terms of the quantity and quality of local suppliers, the extent of their interaction, and the level of cluster formation, all of which are needed for robust and agile business relationships. The innovation sub-criterion assesses the extent to which firms in a nation can design and develop cutting-edge products and processes to maintain a competitive edge and move toward higher value-added activities. It also evaluates the strength of the innovation ecosystem in a nation. As in the case of the earlier two categories, the Global Competitiveness Report rates these two sub-criteria on a score of 1 to 7, where 7 is the maximum score attainable (Schwab, 2015).

Tables 3(a), 3(b), and 3(c) show the overall ratings of the ASEAN nations for the three categories and sub-criteria. Since the Global Competitiveness Report 2015–2016 does not provide the ratings for Brunei Darussalam, it has not been included in the analysis. The ratings of industrially advanced nations such as Germany and Japan, and some leading economies in the Asia Pacific such as Australia, China, India, and the Republic of Korea are also shown in these tables for comparison.

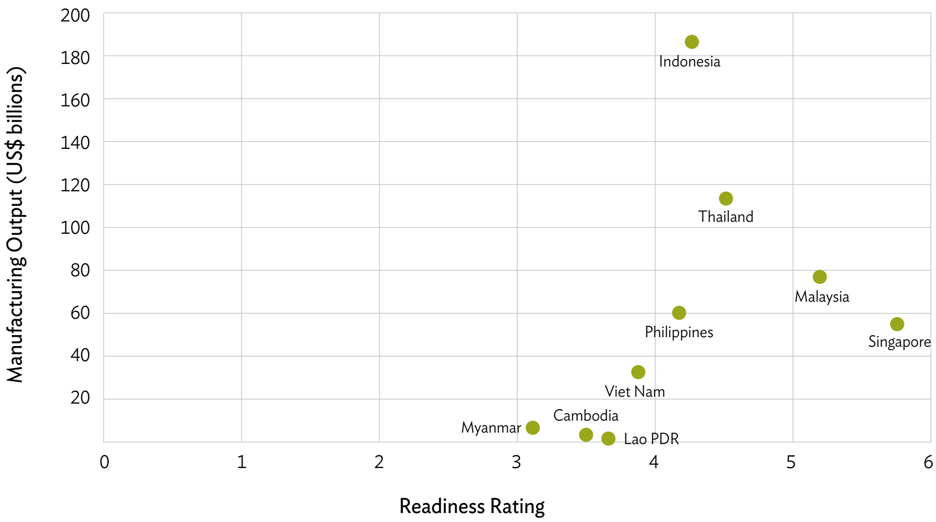
Table 4 shows an aggregate I4RI in the fifth column where the ratings of the three main categories – basic requirements, efficiency enhancers, and business sophistication and innovation – have been weighted at 20%, 50%, and 30% ratio, respectively. Similar weights have been used in the Global Competitiveness Report 2015–2016 for assessing the competitiveness index of 'innovation-driven' nations. Given that Industry 4.0 requires an innovation-driven approach, it seems reasonable to adopt the same weights to assess the I4RI of the ASEAN nations.

Table 5 shows the manufacturing output and the high-technology exports as a percentage of the manufactured exports[2] of the ASEAN nations and the comparator nations included in Tables 3, 4, and 5. These were used to develop a matrix like the ones used in the Roland Berger Readiness Index for the EU. For the sake of expository ease, these tables are presented in Appendix 1.

Figure 1 maps the I4RI and absolute manufacturing outputs of ASEAN nations. It shows that while Singapore leads in terms of I4RI, its absolute manufacturing output is less than that of Malaysia, Thailand, and Indonesia. Indonesia shows the highest level of manufacturing output followed by Thailand. The Philippines and Viet Nam rank next but with lower I4RI ratings. Myanmar, Lao PDR, and Cambodia rank low both in terms of I4RI and manufacturing output.

[2] The World Bank (2016) in its *World Development Report 2016* defines high-technology exports as products with high R&D intensity such as in aerospace, computers, pharmaceuticals, scientific instruments, and electrical machinery.

Figure 1. Industry 4.0 Readiness Hierarchy for ASEAN Based on Manufacturing Output



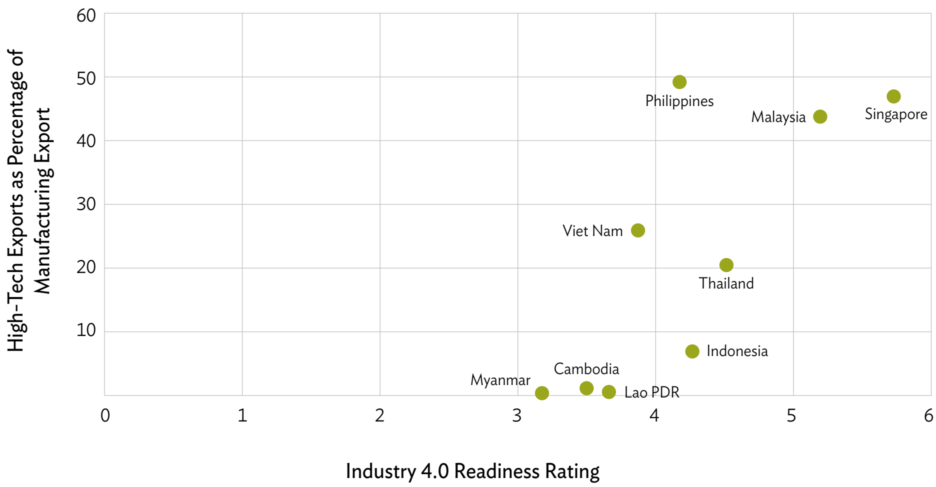
ASEAN = Association of Southeast Asian Nations, Lao PDR = Lao People's Democratic Republic.

Source: Authors.

Figure 2 maps the same nations in terms of I4RI and high-technology exports as a percentage of manufactured exports. Here too, Singapore and Malaysia rank highest followed by the Philippines, Viet Nam, Thailand, and Indonesia. Myanmar, Lao PDR, and Cambodia rank low, both in terms of I4RI and percentage of high-technology exports. A striking observation is that while Indonesia has the highest level of manufacturing output amongst all the ASEAN nations, its high-technology exports as a percentage of manufactured exports is lower than that of Singapore, Malaysia, Thailand, the Philippines, and Viet Nam.

The mapping suggests that in terms of Industry 4.0 readiness, the ASEAN countries considered in this report could be grouped into four clusters. First, Singapore and Malaysia, with their high-technology export profile could be said to be 'potential innovators for Industry 4.0'. Indonesia, the Philippines, and Thailand could be considered 'efficiency seekers through Industry 4.0'. Viet Nam, due to its lower I4RI and low manufacturing output, could be a 'medium-term Industry 4.0 transitioner', while Cambodia, Lao PDR, and Myanmar may be considered 'slow movers towards Industry 4.0'.

Figure 2. Industry 4.0 Readiness Hierarchy for ASEAN Based on High-technology Exports



ASEAN = Association of Southeast Asian Nations, Lao PDR = Lao People's Democratic Republic.
Source: Author.

Clearly, any action within ASEAN to promote Industry 4.0 must take into consideration the specific strengths and weaknesses of its member states from an Industry 4.0 perspective and not adopt a 'one size fits all' approach when formulating strategic initiatives.

5. A Conceptual Framework for Accelerating ASEAN Transition to Industry 4.0

To move into, compete, and survive, an Industry 4.0 ecosystem requires much more than machines and finance. In an Industry 4.0 setting, the key source for sustainable competitive advantage is knowledge, which may be regarded as intellectual capital (Murray et al., 2016). The three main components of intellectual capital are human capital, relational capital, and structural capital (Murray et al., 2016). As defined by Murray et al. (2016):

- Human capital refers to the set of knowledge, skills, and capacities of the workforce in an organisation aimed at achieving company objectives.

- Relational capital represents the working links and arrangements that a firm creates with its customers, employees, suppliers, universities, research and development (R&D) institutions, financing institutions, government agencies, the community, and other stakeholders.
- Structural capital refers to technologies, data, publications, procedures, and other relevant coded and non-coded knowledge owned by the company, which may or may not be protected through intellectual property laws.

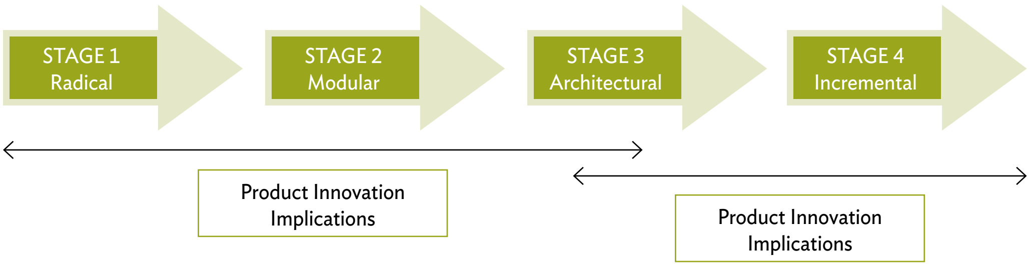
From the earlier discussion in this chapter, it is evident that IoT can play a critical role in building and sustaining these three components of intellectual capital. Murray et al. (2016) show empirically how the introduction of IoT had enhanced the intellectual capital owned by a company, named Cisco Systems Inc.

From an ASEAN perspective, intellectual capital has strategic implications. Unless firms in the manufacturing sector in ASEAN can steadily build up their intellectual capital, moving into an Industry 4.0 setting would be extremely difficult. The question is: What approach should be adopted to steadily build up the three components of intellectual capital?

A possible approach could be to adopt the model proposed by Caputo, Marzi, and Pellegrini, (2016). In their model of innovation, with specific reference to an Industry 4.0 and IoT setting, innovation in the manufacturing industry can evolve into four stages from product innovation through to process innovation as shown in Figure 3.

In Stage 1, a firm produces revolutionary and breakthrough products that have the potential to create new markets, make existing products obsolete, and change the currently prevailing paradigm that governs competition. This requires a very high level of intellectual capital within the firm, especially human and structural capital. Technology leaders are the ones that can engage in this type of innovation.

Figure 3. Evolutionary Phases of Innovation



Source: Adapted from Murray et al., 2016.

In Stage 2, the radical products are improved by improving the sub-technologies in the product and/or the linkages between them so that performance is further enhanced. This can be carried out by firms that may be called 'fast followers'. They, too, have a high level of intellectual capital. In Stage 3, architectural innovations focus on further strengthening performance by changing the nature of the interactions between the sub-technologies. This can be carried out by firms that have adaptive R&D capabilities and a substantial level of production capability. Incremental innovation in Stage 4 involves making small changes to improve both the product and the process used to make the product.

Murray et al. (2016) illustrate the model through the case of 3D printing. The four stages that they describe are summarised below.

Stage 1: An RFID tag is directly embedded in the product
This requires technologies and skills to design products with embedded readable unique identifier codes.

Stage 2: Product and printers are constantly connected
This requires considerable skills and know-how in designing, equipping, managing, and linking sensors into the manufacturing information network.

Stage 3: Products and 3D printers produce a constant flow of data
Here, the know-how gained in Stage 2 is leveraged to manage the two-way flow of data for creating a networked manufacturing system that will lead to the realisation of a 'smart factory'.

Stage 4: Produced data is used for product tracking, production planning, and strategic decision-making
Here, the emphasis is on managing the 'smart factory' and engaging in '*kaizen*' ('*kaizen*' is usually a tagline that used in the most of japanese manufacturing industry to motivate the employee to work at the best effort) to ensure that manufacturing objectives are achieved with a focus on continuous improvement. The above example suggests that, to enter an Industry 4.0 ecosystem, a firm could start by building its production capability (production planning and control, quality management, supply/procurement management, amongst others) to use additive manufacturing technology. Once this has been mastered, the firm could then move backwards to create greater value through process and product innovation. This approach is nothing new. As far back as the 1980s, Amsden (1989), in her study of the rise of the Korean steel industry, pointed out that learners do not innovate and must compete initially based on low wages, state support, high quality, and productivity. The route that must thus be pursued should

be based on transfer, absorption, and adaptation of technology. Habibie (1990), the architect of the highly publicised Indonesian aircraft industry in the 1980s and 1990s, stated that, ‘technology receivers must be prepared to implement manufacturing plans on a step-by-step basis, with the ultimate objective of eventually matching the added-value percentage obtained by the technology transferring firm’. He referred to such an approach as ‘progressive manufacturing’ and popularised the slogan, ‘begin at the end and end at the beginning’, implying that a transferee firm should start with production and move backwards to cutting-edge research.

Based on the above conceptualisation, one possible approach for the four clusters of ASEAN nations to enter the Industry 4.0 ecosystem would be as follows:

Table 6. Possible Longitudinal Entry Approaches to Industry 4.0

Clusters	Strengthening Production and Maintenance Capabilities, and Supply Chain Management	Partnering Industry 4.0 Leaders in Production and Incremental Innovation	Partnering Industry 4.0 Leaders in Architectural and Modular Innovation	Assuming Industry 4.0 Leadership
Potential Innovators (Singapore, Malaysia)	Exists at high level. Strengthen further	High priority area	Short-term priority area	Medium-term priority area
Efficiency Seekers (Indonesia, Philippines, Thailand)	Exists. Strengthen further as a matter of high priority	Short-term priority area	Medium-term priority area	Long-term priority area
Transitioner (Viet Nam)	High priority area	Medium-term priority area	Long-term priority area	Long-term priority area
Slow Movers (Cambodia, Lao PDR, Myanmar)	High priority area	Long-term priority area	Long-term priority area	Long-term priority area

Lao PDR = Lao People’s Democratic Republic.

Source: Author.

6. Discussion: Enhancing the Regional Architecture for Accelerating ASEAN Transition to Industry 4.0

The fourth wave of technological advancement in manufacturing, referred to as Industry 4.0, has the potential to confer the following substantial benefits to nations:

- Firstly, from a circular economy perspective, it can lead to waste reduction and a lower carbon footprint.
- Secondly, it can enhance the productivity of firms by reducing material and transformation costs, and through the accruing of higher value by enabling greater customisation of products.
- Thirdly, suppliers and industry partners involved in supplying machinery, sensors, materials, application software, and data services will also derive greater revenue.
- Fourthly, in high labour cost nations, reshoring of previously offshored manufacturing could enhance employment, but it is not clear how this will impact low labour cost nations with a relatively unskilled workforce. If a nation has a workforce skilled in automation, application software development, analytics and the like, new employment opportunities will become available.

However, all these will mean that enterprises will have to invest heavily to modify and modernise their production systems. Rüßmann et al. (2015) estimate that over the next 10 years, German firms will have to spend about €250 billion to incorporate Industry 4.0. In the ASEAN region, it will be necessary to invest heavily. Developing mechanisms to provide funding will be a major challenge. There is also a concern that SMEs could well become victims instead of beneficiaries of the Industry 4.0 revolution (Sommer, 2015). This could be a major concern for developing ASEAN country governments.

6.1 Intervention Needed at the Corporate and National Levels

Against this background, it would be useful to develop a preliminary set of interventions that would be needed by ASEAN nations to create an Industry 4.0 ecosystem. As explained in section 2.1 of this chapter, the four main characteristics of Industry 4.0 are the following:

- vertical networking of smart production systems;
- horizontal integration of global value chain systems;
- through-engineering across the entire value chain; and
- adoption of exponential technologies for individualised solutions, flexibility, and cost savings.

It will therefore be useful to examine the interventions that will be needed to enable the realisation of each of these attributes, and others, based on the work of Deloitte (2015), Li Xu, and Zhao, (2015), Li ,Tryfonas, and Li, (2014), Rüßmann et al. (2015), and Trequattrini et al. (2016).

Vertical networking of smart production systems

1. Strengthen networking by reducing the fragmentation of existing IT networks through the development of new solutions in partnership with suppliers of sensors, modules, control systems, communication networks, business applications, and customer-facing applications.
2. Develop specialist skills in analytics and efficient data management to generate new insights and strengthen evidence-based decision-making that will become possible due to 'big data' that will become available.
3. Develop skills in using cloud-based solutions so that decentralised networked smart-production systems can gain any time access to key data.
4. Strengthen operational efficiency (improving production processes, production planning and control, quality management, safety, total productive maintenance, and servicing) on a continuing basis.

Horizontal integration of global value chain systems

5. Develop a new business model at the edge of current businesses that will create new ways of working and utilise new skills so that, eventually, their success will lead to the model gradually extending to the rest of the business. Such an approach will reduce resistance amongst employees and avoid resentment of those who may initially be less engaged.
6. Work closely with supply chain partners, starting not just from raw material suppliers but also R&D, to gradually build a smarter and transparent supply chain that will facilitate coordination and collaboration by using data and information from a common database.
7. Smart supply chains also require the development of smart logistics arrangements across global value chain networks where autonomous technologies, flexible logistics systems, warehousing, distribution, and value-added services are seamlessly integrated. Partnering closely with logistics service providers is imperative.
8. The high levels of data sharing across entities will make it imperative to enhance data security. A service-oriented architecture for IoT requires security protection at four layers: sensing layer, network layer, service layer, and application interfaces layer (Li, Xu, and Zhao, 2015; Li, Tryfonas, and Li, 2014). This will require firms to develop a tailored risk management system and a security strategy to improve operational efficiency and security across the entire value chain.
9. Firms must develop new ways of protecting their intellectual property so that data, routines, products, and systems are protected against misappropriation and misuse.

Through-engineering across the entire value chain

10. As discussed in section 5, firms will need to develop the capacity to progressively engage in incremental, architectural, modular, and radical innovation. This needs to flow through the entire value chain, starting from customer-facing functions through to distribution, logistics, manufacturing, procurement, and design and development. The power of IT in enhancing innovative capability needs to be fully explored. For instance, data flowing from products and processes will enable innovative possibilities to be explored throughout the life cycle of a product.

Adoption of exponential technologies for individualised solutions, flexibility, and cost savings

11. This requires firms to develop horizontal and vertical technology transfer capabilities. Horizontal technology transfer refers to inter-firm commercial transfer of technologies through popular mechanisms such as purchase of plant and equipment, licensing, joint ventures, and so on. Vertical technology transfer is intra-firm and refers to commercialising technologies developed through R&D. Furthermore, firms also need to develop the ability to invest in start-ups and acquire the technologies thus developed.

Measures to be taken by governments

In addition to these interventions at the corporate level, governments in the ASEAN nations need short- and medium-term actions to strengthen the analogue complements of digital investments (World Bank, 2016). These include the following measures (World Bank, 2016; Li, Xu, and Zhao, 2015):

- Lower the barriers to digital adoption by reforming taxation and tariff regimes.
- Foster IoT standardisation with respect to security standards, communication standards, and identification standards.
- Increase competitiveness through effective regulation and enforcement, and encourage greater use of digital technologies by gradually reducing market distortions.
- Tailor 'new economy' regulations to ensure 'fair' competition (for instance, is Uber a software firm or taxi business?) and new taxation models (for instance, how to enforce value-added tax and customs regulations for 3D printing of products across countries when there is no physical crossing of national borders).
- Upgrade and continually revise education systems holistically, from foundational to tertiary education through to continuing education, to ensure the continued availability of a relevant stream of skills for the digital economy.
- Develop robust and enforceable digital safeguards and privacy policies.

6.2 Possible Regional Cooperation Mechanisms for Industry 4.0 Transformation

Section 5 outlined the possible paths that ASEAN member states could follow to build up and sustain a productive Industry 4.0 ecosystem. In this context, section 6.1 elaborated on specific interventions needed at both the national and corporate levels. Realising these, however, would pose many challenges since it requires access to knowledge (know-why, know-what, know-how, and show-how) and funds. This would require cooperation amongst many entities within the ASEAN region, supplemented by partnerships with external entities.

In 2011, the Organisation for Economic Co-operation and Development (OECD) Task Team on South–South Cooperation pointed out that, '[t]he global landscape of development cooperation has changed drastically in recent years. The era of one-way cooperation has become outdated, as countries of the South are engaging in collaborative learning models to share innovative, adaptable and cost-efficient solutions to address their development challenges' (OCED, 2011, pp.00). Knowledge sharing, which is a critical and dynamic element of South–South cooperation, is now regarded as the third pillar of development cooperation, complementing finance and technical assistance (OECD, 2011). However, when South–South cooperation is expanded creatively to include industrially advanced wealthy countries (the traditional north) through what is popularly termed the 'triangular cooperation', then greater effectiveness can be achieved (United Nations ECOSOC, 2008). This mode of cooperation could be a path that ASEAN could adopt in accelerating the region's Industry 4.0 transformation.

However, the South–South cooperation and triangular cooperation initiatives need to be implemented in a climate of cooperation based on equity, trust, mutual benefit, and long-term relations. An examination of ASEAN cooperation initiatives in the past suggests that its member nations have, over the years, worked hard to create such a climate. The ASEAN Economic Community Blueprint 2025 (AEC 2025) has three significant objectives that are of relevance to the longitudinal entry approaches to Industry 4.0 as outlined in Table 6. These are (ASEAN 2015a):

- Foster robust productivity growth through innovation, technology, and human resource development, and intensified regional R&D that is designed for commercial application to increase ASEAN's competitive edge in moving the region up the global value chains to higher technology and knowledge-intensive manufacturing and services industries.
- Promote the principles of good governance, transparency, and responsive regulatory regimes through active engagement with the private sector, community-based organisations, and other stakeholders of ASEAN.

- Widen ASEAN people-to-people, institutional, and infrastructure connectivity through ASEAN and sub-regional cooperation projects that facilitate movement of capital as well as skilled labour and talents.

Over the years, ASEAN has developed several plans of action to foster inclusive development within the region. These complement the plans developed to achieve the objectives outlined in AEC 2025. An examination of these plans suggests that there is flexibility within some of the proposed action plans to incorporate explicit efforts to foster ASEAN transition towards Industry 4.0. These efforts can be implemented through South-South cooperation and triangular cooperation with appropriate dialogue partners. In this section, some suggestions will be made based on three plans that are of most relevance to Industry 4.0.

Leveraging the ASEAN ICT Master Plan 2015

In 2015, under the auspices of the ASEAN Telecommunications and Information Technology Ministers, an ASEAN ICT Master Plan 2015 was formulated to harness ICT potential in establishing AEC (Nam et al., 2015). The specific objectives of this master plan during the period 2015–2020 are (Nam, Cham, and Halili, 2015):

- Develop ICT as an engine of growth for ASEAN countries.
- Gain recognition for ASEAN as a global ICT hub.
- Enhance the quality of life for the peoples of ASEAN.
- Contribute towards ASEAN integration.

As elaborated by Nam, Cham, and Halili, (2015), to achieve these objectives, the plan formulates three foundations supporting three pillars. The foundations are infrastructure development, human capital development, and bridging the digital divide. The pillars are economic transformation, people empowerment and engagement, and innovation.

The ASEAN ICT Master Plan thus provides a platform that can be used to promote cooperation amongst the ASEAN member nations to implement some of the interventions that have been elaborated in section 6.1. Tabor and Yoon (2015) highlight the measures taken by Indonesia and its experience in strengthening its ICT infrastructure. Similar information would be available in Singapore, Malaysia, the Philippines, Thailand, and Viet Nam, all of which would be invaluable to Cambodia, Lao PDR, and Myanmar. The exchange of ICT infrastructure building experiences and providing expertise well versed in the workings of the ASEAN region could be carried out under South–South cooperation programmes.

Leveraging the ASEAN Strategic Action Plan for SME Development

The ASEAN Strategic Action Plan for SME Development 2016–2025 (ASAPSMED 2016–2025) has five strategic goals (ASEAN, 2015b):

1. promote productivity, technology, and innovation;
2. increase access to finance;
3. enhance market access and internationalisation;
4. enhance the policy and regulatory environment; and
5. promote entrepreneurship and human capital development.

For each strategic goal, desired outcomes have been identified, and actions to achieve these have been delineated. While all five goals are important, Table 7 lists the related actions under three goals that are of higher priority from an Industry 4.0 transformation perspective.

For each identified action, a sequence of action lines should be developed to enable enterprises that are at different levels of manufacturing sophistication to choose an appropriate action line to move upwards. Referring to Table 7 – Action A-3-3, enhancing business and academia collaboration – could have sequential action lines ranging from basic to advanced, as follows:

1. Create awareness/develop skills to improve production and quality management practices.
2. Collaborate to improve manufacturing performance through low-cost automation.
3. Develop skills to improve supply chain performance and evaluate performance through approaches such as the supply chain operations eference model.
4. Set up programmes to promote collaboration amongst multinational corporations (MNCs)/large enterprises, SMEs, and academia to improve supply chain performance through IT-based initiatives.
5. Establish cooperative research programmes between MNCs, local large enterprises, SMEs, R&D centres, and academe for promoting commercial technology transfer and introduction of advanced technology from an Industry 4.0 perspective.

Table 7. **Actions Under ASAPSMED 2016–2025 to Foster Industry 4.0 Transformation**

	Desired Outcomes	Actions
A-1	Productivity will be enhanced	A-1-3: Improve production management skills
A-2	Industry clusters will be enhanced	A-2-1: Enhance industrial linkages amongst SMEs and large enterprises including MNCs
		A-2-2: Promote technology and build capabilities to foster industrial clustering
A-3	Innovation will be promoted as a key competitive advantage	A-3-1: Promote key technology usage and its application to business for innovation
		A-3-2: Enhance information on innovation support services
		A-3-3: Enhance business and academia collaboration
B-1	Institutional framework for access to finance will be developed and enhanced	B-1-1: Improve understanding and strengthen traditional financing infrastructure
		B-1-2: Improve policy environment and measures to foster alternative and non-traditional financing through increasing availability of diversified sources of private financing
		B-1-3: Strengthen export financing facilities
C-1	Support schemes for market access and integration into the global supply chain will be further developed	C-1-1: Increase information on regional and global market access and opportunities
		C-1-2: Promote partnerships with MNCs/large enterprises to increase market access and opportunities
		C-1-3: Enhance the use of e-commerce
		C-1-4: Promote adoption of international standards of quality to facilitate market access
C-2	Export capacity will be promoted	C-2-1: Establish mechanisms to assist in increasing exports

ASAPSMED 2016–2025 = ASEAN Strategic Plan for SME Development 2016–2025, MNCs = multinational corporations, SMEs = small and medium-sized enterprises.

Source: ASEAN (2015b).

Enterprises in high-income Singapore may commence action lines 4 and 5, whereas firms in low-income or lower middle-income ASEAN nations may even have to start at action line 1.

While this is meant as an illustrative example for comprehensive capacity building under ASAPSMED, it would be more appropriate to form a consortium of leading universities and R&D institutes within the ASEAN region that could deliver training programmes in specific areas of Industry 4.0, with emphasis on interventions 1 through 11 described in section 6.1 above. This consortium should work with business associations and chambers of commerce in the ASEAN region so that industry practitioners from member countries could be trained. Initially, leading universities and R&D institutes from Indonesia, Malaysia, the Philippines, Singapore, and Thailand could be used as a core in this initiative, and this can be expanded over time with the inclusion of institutions from industrially advanced nations under a triangular cooperation initiative. The emphasis in all these capacity-building initiatives should be the 'training of trainers' to ensure a multiplier effect. How this consortium would function and be funded needs to be worked out.

Leveraging the ASEAN Plan of Action on Science, Technology, and Innovation 2016–2025 (APASTI 2016–2025)

The vision of APASTI 2016–2025 is, 'A Science, Technology, and Innovation-enabled ASEAN which is innovative, competitive, vibrant, sustainable, and economically integrated' (ASEAN, 2015c). The four major thrust areas under APASTI 2016–2025 (APASTI 2016–2025) are:

- Thrust 1: Strengthen strategic collaboration amongst academia, research institutions, networks of centres of excellence, and the private sector to create an effective ecosystem for capability development, technology transfer, and commercialisation.
- Thrust 2: Enhance mobility of scientists and researchers, people-to-people connectivity, and strengthen engagement of women and youth in science, technology, and innovation (STI).
- Thrust 3: Establish innovative system and smart partnership with dialogue and other partners to nurture STI enterprises to support micro, small, and medium-sized enterprises in knowledge creation and STI applications to raise competitiveness.
- Thrust 4: Raise public awareness and strengthen STI enculturation to enhance ASEAN science and technology cooperation.

Here again, as in the case of ASAPSMED 2016–2025, while all four areas are important, thrust areas 1 and 3 are directly relevant to regional cooperation to facilitate Industry 4.0 transformation. The actions envisaged under thrust areas 1 and 3 are as follows (APASTI 2016–2025):

Thrust 1

Action 1.1: Intensify the engagement of academe, private sector, and relevant partners in the planning, implementation, and assessment of joint undertakings in human resource development, and R&D.

Action 1.2: Enhance and sustain the utilisation of the ASEAN Science and Technology Network and strengthen other science and technology networks to facilitate information sharing.

Action 1.3: Establish policy frameworks, including intellectual property rightsprotection, risk, and benefit-sharing mechanisms for collaboration and technology transfer amongst centres of excellence.

Action 1.4: Strengthen existing regional STI initiatives in priority areas including Sustainable Development Goals.

Thrust 3

Action 3.1: Establish support mechanisms such as mentorship and incentive programmes to support and nurture STI enterprises from start-up to the next competitive level of development.

Action 3.2: Engage dialogue and other strategic partners in joint undertakings on appropriate and commercially viable STI initiatives.

All these actions will, as in the case of ASAPSMED 2016–2025, require an action line hierarchy to enable inclusive Industry 4.0 capacity strengthening of ASEAN member states that are at different levels of development.

From an Industry 4.0 perspective, the Sub-Committee on Microelectronics and Information Technology (SCMIT) will have an important role to play. APASTI 2016–2025 states that 'The SCMIT seeks to develop and enhance the capabilities of ASEAN member countries' microelectronics and ICT, and its related areas from downstream to upstream technologies. The sub-committee aims to undertake research, development, capacity building, and demonstration projects in microelectronics and ICT and related areas according to the strategic thrusts' (ASEAN, 2015c). The specific objectives of SCMIT are to:

- undertake capacity building for less developed ASEAN member states;
- promote and carry out R&D technology transfer in microelectronics, ICT, and other related areas;
- foster and strengthen intra-ASEAN activities in the priority areas;
- strengthen information network/database for exchange and dissemination within and outside ASEAN; and
- strengthen institutions and centres of excellence.

The work of SCMIT is therefore critical from an Industry 4.0 perspective due to the role that it is expected to play in strengthening the IT infrastructure of ASEAN member states, which is a prerequisite for Industry 4.0 transformation.

Yet, it must be acknowledged that ASEAN firms are not yet world leaders in Industry 4.0-related technologies. Companies in Germany (for example, Siemens) and Japan (for example, NEC) are often cited as trail blazers in Industry 4.0. It would be of great value if the governments of Germany and Japan could establish centres in the ASEAN region to provide advanced training and act as a focal point for promoting business relationships between ASEAN firms and those in Germany and Japan. Both ASAPSMED 2016–2025 and APASTI 2016–2025 have sufficient flexibility to incorporate triangular cooperation in association with dialogue partners from industrially advanced nations.

A precedent case in Thailand can be cited, even though it occurred 2 decades ago. A study carried out by Cuyvers and Ramanathan (1991) shows that, in the 1970s and 1980s, the Japanese government played an important role in upgrading technical skills in Thailand by providing vocational training centres, training equipment, and fellowships. This helped the Japanese investors in Thailand since these initiatives led to the availability of a skilled pool of labour who were already influenced by the 'Japanese way of working'. The Japanese government also funded the Technological Promotion Association (Thailand–Japan) in the 1980s and 1990s, which provided advanced training in selected technical fields and in areas such as quality management for apprentices and those already employed in Japanese–Thai joint ventures.

Establishing such specialised Industry 4.0 promotion centres in ASEAN by Japan and Germany could play a very useful role in accelerating the accomplishment of the interventions outlined in section 6.1 above.

In summary, this section has essentially outlined three major cooperation mechanisms for Industry 4.0 transformation in the ASEAN region. These are:

- South–South cooperation and triangular cooperation initiatives for accelerating Industry 4.0 transformation.
- Leveraging the ASEAN ICT Master Plan 2015, the ASAPSMED 2016–2025, and the APASTI 2016–2025 to create explicit action lines to enable the inclusive incorporation of ASEAN member states in Industry 4.0 transformation.
- Establishment of advanced Industry 4.0 training and business promotion centres by leading Industry 4.0 nations such as Germany and Japan.

These recommendations need to be examined in the context of currently existing cooperation mechanisms. Such study is beyond the scope of this study. It is recommended that a detailed study of institutional mechanisms currently existing in the ASEAN be examined to assess their potential for incorporation into the Industry 4.0 regional cooperation mechanism.

7. Concluding Remarks

This chapter attempts to examine the Industry 4.0 readiness of ASEAN member countries. Basic concepts of Industry 4.0 and IoT were initially examined to establish the context within which the analysis of Industry 4.0 readiness could be carried out. As part of the examination of the basic concepts, it was also shown through literature-based case studies how Industry 4.0 could contribute towards the creation of a circular economy.

A conceptual framework was then developed for assessing the Industry 4.0 readiness of the ASEAN nations and the Industry 4.0 Readiness Index (I4RI) was computed for each ASEAN nation (except Brunei Darussalam for which comparable data were not readily available). This was then used in conjunction with manufacturing output data and high-technology exports as a percentage of manufactured exports to map the level of Industry 4.0 readiness of each ASEAN nation. The mapping showed that the ASEAN countries could be grouped into four clusters. First, Singapore and Malaysia, with their high-technology export profile, could be considered as 'potential innovators for Industry 4.0'. Indonesia, the Philippines, and Thailand could be considered as 'efficiency seekers through Industry 4.0'. Viet Nam, due to its lower I4RI and low manufacturing output, could be a 'medium-term Industry 4.0 transitioner', while Cambodia, Lao PDR, and Myanmar may be considered as 'slow movers towards Industry 4.0'.

This finding showed that any action within ASEAN to promote Industry 4.0 must take into consideration the specific strengths and weaknesses of its member states from an Industry 4.0 perspective and not adopt a 'one size fits all' approach when formulating strategic initiatives. Further analysis based on an intellectual capital framework suggested that ASEAN nations could progress towards comprehensive Industry 4.0 transition through four levels:

- Strengthening production and maintenance capabilities and supply chain management.
- Partnering Industry 4.0 leaders in production and incremental innovation.
- Partnering Industry 4.0 leaders in architectural and modular innovation.
- Assuming Industry 4.0 leadership.

Interventions needed at both the corporate and government levels to move through these four levels were then identified.

Having identified the interventions needed, three major cooperation mechanisms for Industry 4.0 transformation in the ASEAN region were proposed. These are:

- South–South cooperation and triangular cooperation initiatives for accelerating Industry 4.0 transformation.
- Leveraging the ASEAN ICT Master Plan 2015, ASAPSMED 2016–2025, and APASTI 2016–2025 to create explicit action lines to enable the inclusive incorporation of ASEAN member states in Industry 4.0 transformation.
- Establishment of advanced Industry 4.0 training and business promotion centres by leading Industry 4.0 nations such as Germany and Japan.

The modalities for implementing these cooperation mechanisms need to be examined in the context of currently existing arrangements.

A major limitation of this study is that the entire analysis is based on published information. Discussions with ASEAN experts in the field of Industry 4.0 and visits to firms in the ASEAN region that have already commenced Industry 4.0 initiatives could have substantially strengthened the content. Also, the I4RI was computed using published data. While the analysis does provide a useful start, it may be useful to conduct a survey in the ASEAN region, along the lines of the Roland Berger (2015) study carried out in Europe, to obtain more accurate insights into the Industry 4.0 readiness of the ASEAN member countries.

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Appendix 1: Basic Requirements, Efficiency Enhancers, and Business Sophistication and Innovation Ratings of ASEAN Countries

Table 3(a). Basic Requirements Ratings

Country	Institutions	Infrastructure	Macroeconomic Environment	Health and Primary Education	Overall Rating
Australia	5.3	5.7	5.6	6.6	**5.8**
China	4.1	4.7	6.5	6.1	**5.4**
Germany	5.2	6.1	6.0	6.5	**6.0**
India	4.1	3.7	4.4	5.5	**4.4**
Japan	5.5	6.2	3.7	6.7	**5.5**
Republic of Korea	3.9	5.8	6.6	6.3	**5.7**
ASEAN Countries					
Cambodia	3.3	3.2	4.8	5.4	**4.2**
Indonesia	4.1	4.2	5.5	5.6	**4.8**
Lao PDR	3.9	3.2	4.7	5.4	**4.3**
Malaysia	5.1	5.5	5.4	6.3	**5.6**
Myanmar	2.9	2.1	4.2	4.6	**3.5**
Philippines	3.8	3.4	5.7	5.5	**4.6**
Singapore	6.0	6.5	6.2	6.7	**6.4**
Thailand	3.7	4.6	5.7	5.8	**4.9**
Viet Nam	3.7	3.8	4.7	5.9	**4.5**

ASEAN = Association of Southeast Asian Nations, Lao PDR = Lao People's Democratic Republic.
The ratings are from 1 to 7, with 7 being the highest.
Brunei Darussalam is not included due to lack of data.

Source: Schwab, 2015.

Table 3(b). Efficiency Enhancers Ratings

Country	Higher Education and Training	Goods Market Efficiency	Labour Market Efficiency	Financial Market Develop ment	Technologi cal Readiness	Market Size	Overall Rating
Australia	5.8	4.8	4.5	5.4	5.6	5.1	**5.2**
China	4.3	4.4	4.5	4.1	3.7	7.0	**4.7**
Germany	5.6	4.9	4.6	4.7	6.0	6.0	**5.3**
India	3.9	4.2	3.9	4.1	2.7	6.4	**4.2**
Japan	5.4	5.2	4.8	4.7	5.7	6.1	**5.3**
Republic of Korea	5.4	4.8	4.1	3.6	5.5	5.6	**4.8**
ASEAN Countries							
Cambodia	2.8	4.2	4.5	3.9	3.0	3.0	**3.6**
Indonesia	4.5	4.4	3.7	4.2	3.5	5.7	**4.3**
Lao PDR	3.2	4.3	4.5	3.8	2.8	2.9	**3.6**
Malaysia	5.0	5.4	4.9	5.2	4.6	5.0	**5.0**
Myanmar	2.5	3.6	4.2	2.4	2.2	4.2	**3.2**
Philippines	4.5	4.2	4.1	4.2	3.9	4.9	**4.3**
Singapore	6.2	5.7	5.7	5.6	6.2	4.8	**5.7**
Thailand	4.6	4.7	4.2	4.4	4.2	5.2	**4.6**
Viet Nam	3.8	4.2	4.4	3.7	3.3	4.8	**4.0**

ASEAN = Association of Southeast Asian Nations, Lao PDR = Lao People's Democratic Republic.
The ratings are from 1 to 7, with 7 being the highest.
Brunei Darussalam is not included due to lack of data

Source: Schwab, 2015.

Table 3(c). Innovation and Business Sophistication Ratings

Country	Business Sophistication	Innovation	Overall Rating
Australia	4.7	4.5	**4.6**
China	4.3	3.9	**4.1**
Germany	5.7	5.5	**5.6**
India	4.2	3.6	**3.9**
Japan	5.8	5.5	**5.7**
Republic of Korea	4.8	4.8	**4.8**
ASEAN Countries			
Cambodia	3.4	2.7	**3.0**
Indonesia	4.3	3.9	**4.1**
Lao PDR	3.7	3.0	**3.3**
Malaysia	5.3	4.8	**5.1**
Myanmar	2.9	2.5	**2.7**
Philippines	4.3	3.5	**3.9**
Singapore	5.1	5.2	**5.2**
Thailand	4.4	3.4	**3.9**
Viet Nam	3.6	3.2	**3.4**

ASEAN = Association of Southeast Asian Nations, Lao PDR = Lao People's Democratic Republic.
Brunei Darussalam is not included due to lack of data.

Source: Schwab, 2015.

Table 4. Readiness Ratings

Country	Basic Requirements	Efficiency Enhancers	Business Sophistication and Innovation Factors	Readiness Rating 20-50-30
Australia	5.8	5.2	4.6	**5.1**
China	5.4	4.7	4.1	**4.7**
Germany	6.0	5.3	5.6	**5.5**
India	4.4	4.2	3.9	**4.2**
Japan	5.5	5.3	5.7	**5.5**
Republic of Korea	5.7	4.8	4.8	**5.0**
ASEAN Countries				
Cambodia	4.2	3.6	3.0	**3.5**
Indonesia	4.8	4.3	4.1	**4.3**
Lao PDR	4.3	3.6	3.3	**3.7**
Malaysia	5.6	5.0	5.1	**5.2**
Myanmar	3.5	3.2	2.7	**3.1**
Philippines	4.6	4.3	3.9	**4.2**
Singapore	6.4	5.7	5.2	**5.7**
Thailand	4.9	4.6	3.9	**4.5**
Viet Nam	4.5	4.0	3.4	**3.9**

ASEAN = Association of Southeast Asian Nations, Lao PDR = Lao People's Democratic Republic.
Brunei Darussalam is not included due to lack of data.

Source: Schwab, 2015.

Table 5. Profile of the Manufacturing Sector

Country	Manufacturing Output in 2014 (US$ billions)	High-Technology Exports as Percentage of Manufactured Exports
Australia	101.8	13.6
China	3,106.4	25.4
Germany	889.7	16.0
India	348.2	8.6
Japan	874.3	16.7
Republic of Korea	423.1	26.9
ASEAN Countries		
Cambodia	2.7	0.2
Indonesia	186.6	7.0
Lao PDR	1.1	-
Malaysia	77.8	43.9
Myanmar	4.5	-
Philippines	59.8	49.0
Singapore	55.4	47.2
Thailand	113.3	20.4
Viet Nam	31.7	26.9

ASEAN = Association of Southeast Asian Nations, Lao PDR = Lao People's Democratic Republic.
Brunei Darussalam is not included due to lack of data.

Source: The World Bank, 2016.