Chapter 1

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

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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)

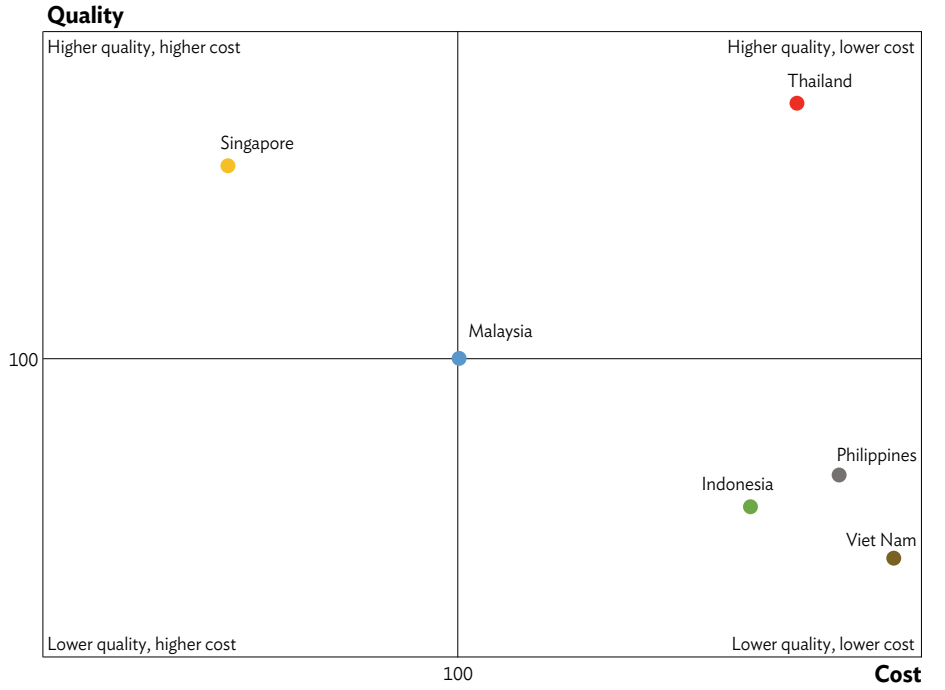
Group	Industry	ASEAN-6 Total	Indonesia	Singapore	Viet Nam	Malaysia	Thailand	Philipines
Global innovation for local markets	Chemicals	9	5	13	14	5	6	2
	Motor vehicles and components	9	13	<1	3	3	42	3
	Other transport equipment	6	2	4	4	20	2	9
	Electrical machinery	6	2	3	6	20	3	7
	Machinery, equipment, appliances	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

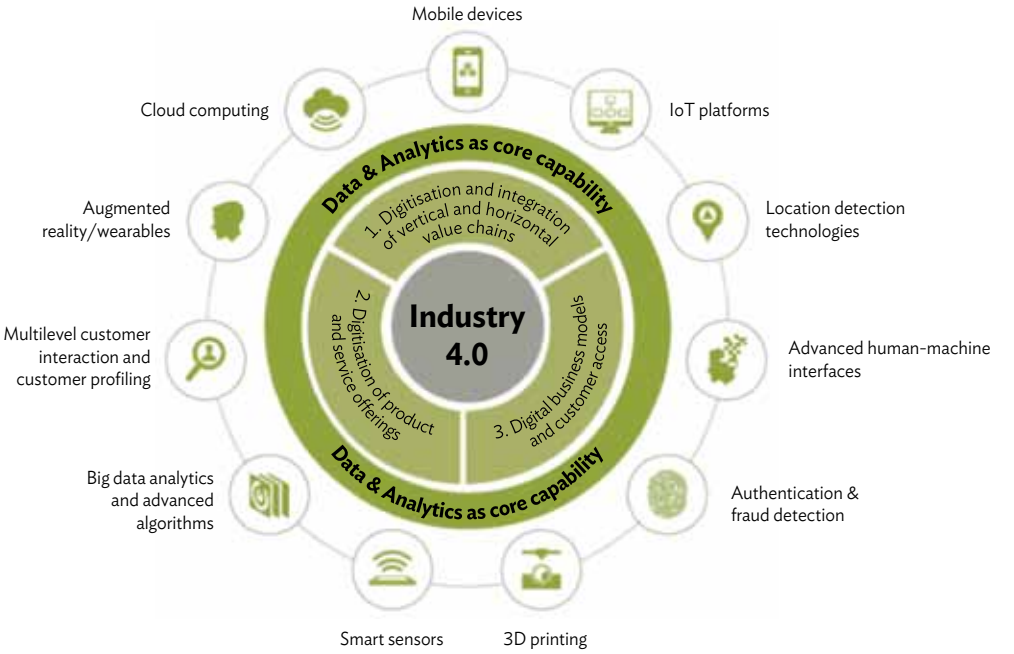
Industry 4.0 is often cited as the fourth major upheaval in modern manufacturing, following the lean revolution in the 1970s, the out-sourcing phenomenon of the 1990s, and the automation that took off in the 2000s (Roland Berger, 2014). It is also defined as the next phase of powerful technologies that 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.

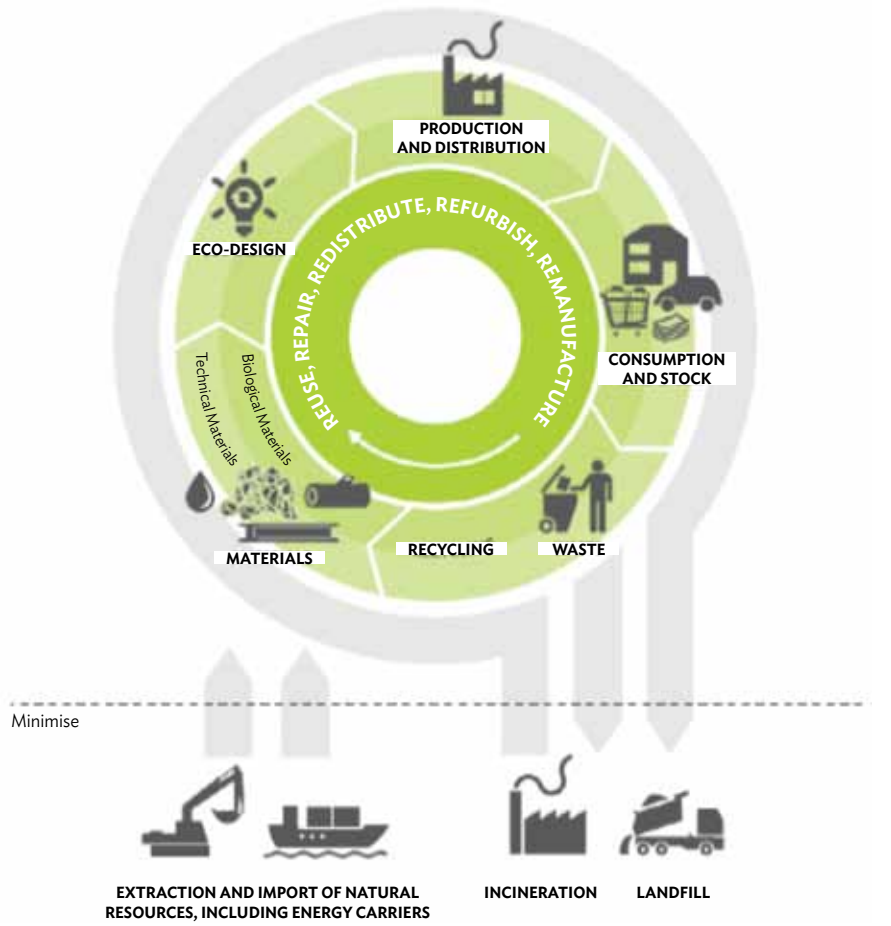
3. The Circular Economy: Motivating Competitiveness Through Resource Efficiency

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.

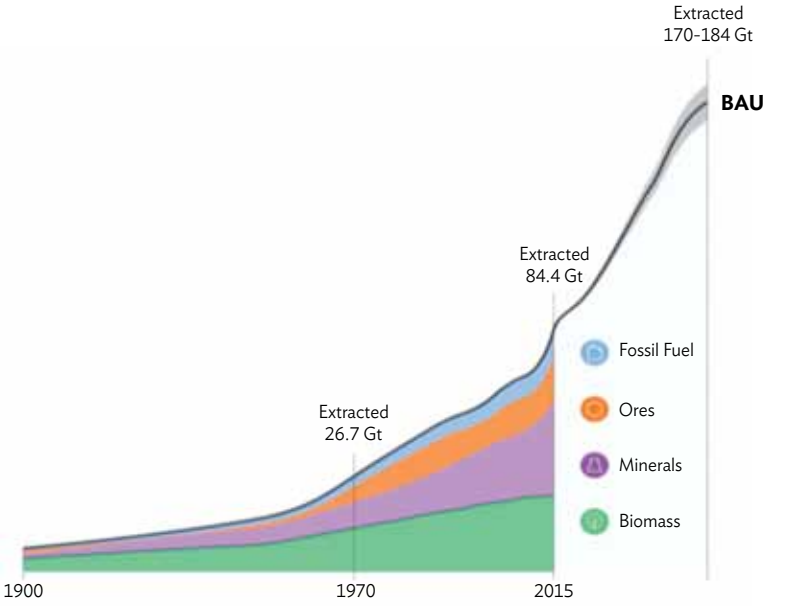
Regulations stimulate business innovations. Inspired by Japanese and German recycling laws, China formed a circular economy initiative in 2008 which is supposed to set new levels of competitiveness for its economy (Su et al., 2013). Unlike the EU, ASEAN lacks formal direct policies but has a long legacy 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	Processing	Manufacturing	Usage	Recycling
	1	2	3	4	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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