Chapter 8

The Digital Economy in Singapore

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Chapter 8
The Digital Economy in Singapore

Simon Tay, Rohini Nambiar, and Janessa Kong

1. Introduction

In this essay, we discuss how best to balance the growth of Singapore's digital economy with environmental concerns, with a focus on two areas: the physical-digital infrastructure of data centres and the growth of e-commerce.

These elements of the digital economy are important and of general concern to many countries. For Singapore, they are essential. The country's digital economy has already experienced rapid growth, with considerable future demand. At the same time, Singapore has undertaken obligations to help address climate change by stepping up its nationally determined contribution (NDC) under the Paris Agreement, even as the country is acknowledged to have limited resources for renewable energy. The growth of the digital economy holds much potential as it can be integral towards successfully implementing sustainability standards and incorporating sustainability through various frameworks.

In undertaking this work, we rely on policy analyses from our earlier digital-green report (Kong and Wau, 2023) and from interviews with stakeholders. The essay will put forward several policy suggestions that aim to enable Singapore to grow its digital economy whilst limiting carbon emissions and improving its environmental record. These recommendations include upgrading grid infrastructure and capacity, investing in technologies to reduce carbon footprints, improving waste management, and prioritising the development of green and digital skills.

2. Context for a Green and Digital Economy

Singapore is one of the most advanced economies in the region and has been consistently recognised as a leader in the digital economy. Looking ahead, the digital economy is expected to grow to US$30 billion by 2025 (EDB, 2022; Tech for Good Institute, 2023), further enhancing Singapore's overall competitiveness.[1] According to a 2024 study by the Capgemini Research Institute, investments in digital transformation are projected to yield the highest returns for organisations in Singapore over the next 5 years, with the estimated annual return on investment expected to grow from 6% in 2023 to 17% by 2028. This is significantly higher than the current global average return of 4% and the projected 14% yield in 2028 (SBR, 2024b).

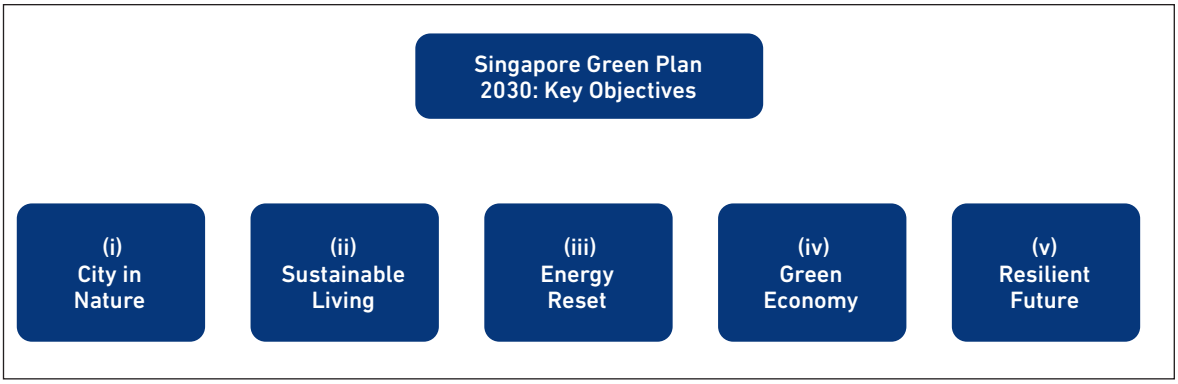
The country's well-developed digital infrastructure and extensive island-wide internet connectivity underpin its growth in the digital domain (IMDA, 2023c). Since the 1980s, the government has proactively invested in the infrastructure required for digital technology adoption through policy initiatives such as the National Computerisation Programme (1981) and the National IT Plan (1986). To date, the country boasts the highest median fixed broadband download speed in the world (Low, 2022), well-developed digital infrastructure, and high levels of digital education and training (Yip, 2019). Approximately 99% of households have internet access, 90% of individuals have computer access, and the mobile penetration rate stands at 170% (IMDA, 2023c). In 2023, the country ranked third globally in digital competitiveness (Chia, 2023). It is evident that the government's initiatives have positioned the country to effectively leverage and grow its digital economy.

Additional initiatives are planned. The Infocomm Media Development Authority (IMDA), the lead government agency in this sector, has released several frameworks to further promote the country's digital growth, such as the Digital Economy Framework for Action and the Digital Connectivity Blueprint (DCB). The DCB outlines the government's plans to strengthen and future-proof digital infrastructure, focusing on soft, hard, and physical-digital infrastructure (IMDA, 2023a). Of relevance to our essay, the DCB identifies 'designing for sustainability' as a key priority. Notably, the government has actively considered the impact of digital infrastructure on carbon emissions, ensuring that the growth of digital economy does not impede progress in the country's long-term climate commitments.

[1] For example, the country performs well on International Institute for Management Development (IMD's) world competitiveness ranking, in particular receiving fourth place on the 2022 IMD World Digital Competitiveness Ranking, IMD, 'World Digital Competitiveness Ranking – IMD', www.imd.org, 2022, https://www.imd.org/centers/wcc/world-competitiveness-center/rankings/world-digital-competitiveness-ranking/.

Singapore has set specific guidelines for its vision of sustainable development, many of which are elaborated in the Singapore Green Plan 2030 (Singapore Green Plan 2030, n.d.). Unveiled in 2021, the plan looks broadly at the following five objectives, including goals for an 'energy reset' and hopes to grow a 'green economy'.

Figure 8.1. Singapore Green Plan 2030



Source: Singapore Green Plan 2030 (n.d.), https://www.greenplan.gov.sg./

3. Overview of Data Centre Landscape in Singapore

Data centres (DCs) are a cornerstone of the digital economy. As centralised facilities that store, process, and disseminate large amounts of data, DCs provide the essential digital infrastructure required to support digital services and platforms. Today, most businesses increasingly rely on data centres for their day-to-day operations. The rising demand for digital goods and services has intensified the need for more efficient data processing and storage solutions. With the increasing adoption of emerging technologies such as 5G, artificial intelligence (AI), machine learning (ML), and blockchain, data storage needs will increase, leading to increased demand for DCs.

Accounting for 60% of DC demand in Asia-Pacific, Singapore is a top location for DCs in the region (Cushman and Wakefield, 2023). According to the annual Global Data Centre Market Comparison report by Cushman & Wakefield, Singapore's attractiveness stems from its strong ecosystem, fibre connectivity, growing demand, and availability of major cloud services. As of January 2022, Singapore was hosting more than 70 operational DCs (Abdullah, 2023), which collectively consume approximately 7% of the country's total electricity. Driven by the digital economy growth in the region, Singapore's DC market is expected to exceed 1 gigawatt (GW) by 2024 (Rad, 2023), making it the biggest DC market in Southeast Asia and the fourth biggest in the world (SBR, 2024a).

Recognising the substantial amount of energy required to power DCs, the government has imposed stricter standards for DC providers. Whilst existing frameworks like the Green Data Centre Standard (SS564) (2013) IMDA, 2023b) and Green Mark for Data Centres (2012) (BCA and IMDA, 2012) set benchmarks for energy efficiency and outline best practices for the industry, greater intervention was required to align the growth of DCs with Singapore's climate commitments.

In 2019, the government imposed a 3-year moratorium on new DCs to reassess its long-term sustainability strategy. This led to the introduction of new criteria for DCs, including a minimum power usage effectiveness of at least 1.3, the harnessing of renewable energy sources, or investment in energy-efficient and decarbonisation technologies, strengthening Singapore's international connectivity and contributing to the country's broader economic objectives (IMDA, 2022). A pilot exercise led by the IMDA and Economic Development Board called the 'Data Centre-Call for Application (DC-CFA)' (IMDA, 2022) was announced in July 2022 after extensive consultation with the DC industry to define new parameters for new DC construction. The pilot awarded 80 megawatts (MW) of additional capacity to four DC operators—Equinix, GDS, Microsoft, and an AirTrunk-ByteDance consortium (IMDA, 2023e) —all of which obtained platinum certification under the Building Construction Authority (BCA)-IMDA Green Mark for New Data Centres (BCA and IMDA, 2019), amongst other criteria.

Concurrently, IMDA has been exploring policy initiatives to support sustainability efforts amongst DC providers and their respective ecosystems. Most recently, IMDA announced a new sustainability standard for DCs operating in tropical climates, allowing them to increase their operating temperatures to 26 degrees Celsius and above. The agency is also working with the BCA to update the Green Mark Scheme for DCs (IMDA, 2023d). This new standard was established under the DCB on 5 June 2023 (IMDA, 2023a), which identified developing a 'Roadmap for Growth of new Green Data Centres' as a priority.

The government's approach has relied on consulting industry partners and other stakeholders in the ecosystem. In developing the new sustainability standard, a working group comprising domain and technical experts from industry, academia, and government agencies was formed, and a pilot trial was conducted with DC operators in Singapore to ensure that this standard is achievable (IMDA, 2023a). Frequent consultations with stakeholders have ensured that new standards and regulations remain feasible, whilst pilot exercises, trials, and test-bedding of new technologies with industry partners during pilots have enabled the government to adopt policies and explore new solutions for increasing DC operational efficiency. These solutions include AI and ML computing, green software, and low-carbon technology.

4. Challenges in Pursuing Sustainable Data Centre Growth

Singapore faces a significant challenge in balancing the rising demand for DCs with its commitment to achieving net-zero emissions by 2050. According to a Keppel DC representative, Singapore's aggregate capacity demand will exceed 3,000 MW by 2030 (Suruga, 2023), far above the current 60 MW of capacity officially allocated per year (Chong, 2022). Although the government is trying to increase generation capacity (C. Tan, 2023c), the key challenge lies in achieving this whilst fulfilling the country's net-zero commitment (NCCS, 2022). Thus, in addition to adopting solutions such as liquid cooling and using AI and ML to reduce energy consumption, DC providers will require access to renewable sources of energy and carbon offsets to ensure the industry's sustainable growth. However, Singapore faces a limited supply of renewable energy within the country and lacks certified carbon credits and established carbon markets in the region.

4.1. Limited Supply of Renewable Energy

Power generation accounts for 40% of Singapore's carbon emissions, making decarbonisation in this sector considerably difficult. Given Singapore's size and resource constraints, renewable sources of energy account for only 2.9% of total electricity generated (Andres, 2023). Alternative energy sources such as wind, tidal, and biomass are not scalable, given the country's natural limitations. The government has identified 'four switches' to decarbonise the power sector: solar, regional power grids, low-carbon alternatives, and natural gas (EMA, n.d.-a). Whilst progress has been made in each switch, current projects remain inadequate to meet Singapore's projected energy demand, estimated at 10.1–11.7 GW, by 2028 (C. Tan, 2023b).

The current target for solar energy is to achieve a 2 GW-peak by 2030, which would meet only around 3% of the country's projected total electricity demand (Andres, 2023). Solar, albeit the most viable energy alternative, is not land-efficient and will not drastically change Singapore's energy mix without unprecedented technological advancements.

Singapore has set targets to increase low-carbon electricity import capacity to 4 GW by 2035 (EMA, n.d.-b). Projects such as the Lao People's Democratic Republic (Lao PDR)–Thailand–Malaysia–Singapore Power Integration Project (LTMS-PIP) (EMA, 2022), which currently pipes 100 MW of hydroelectric energy from Lao PDR to Singapore, serve as a proof-of-concept for multilateral cross-border electricity trade and set out Singapore's intentions to develop the Association of Southeast Asian Nations (ASEAN) Power Grid (APG). Whilst such trials strengthen regional grid architecture and test the viability of cross-border power trade, the long-term implementation of these contracts remains tenuous without a commitment to indefinite collaboration. The involvement of multiple stakeholder groups with differing interests across member states adds further complexity to the approval process.

Singapore's ambitious National Hydrogen Strategy aims to complement and diversify the power mix of available solar, imported green energy, and other low-carbon energy sources. Hydrogen could potentially supply up to half of Singapore's power needs by 2050 and will be pivotal in shifting away from natural gas (MTI, n.d.). However, this depends on how quickly hydrogen technology develops and whether undisrupted supply chains for hydrogen can be established to meet demand.

4.2. Availability of Certified Carbon Credits

Due to the limited supply of renewable energy in Singapore, most DC providers typically purchase international renewable energy certificates (RECs) or carbon credits to offset their emissions. However, the long-term feasibility of purchasing RECs is questionable, as they do not contribute to Singapore's NDC (EPA, 2018). There is a global shortage of carbon credits that qualify as internationally traded mitigation options under Article 6 of the Paris Agreement.[2] This scarcity of high-quality carbon credits is one of the reasons why companies in carbon-intensive industries focus on deploying energy-saving and efficiency technologies to reduce their carbon footprint, with carbon credits deemed a last-mile tool to achieve their decarbonisation targets.

Voluntary carbon markets (VCMs) will be pivotal in offsetting emissions generated in the region. However, VCMs are nascent and bolstered by companies at the forefront of decarbonisation efforts, as most countries in the region do not have a stated carbon price or a carbon tax. Whilst it is unlikely that a uniform carbon price will be applied across ASEAN, several countries are looking to implement some form of carbon tax in the coming years as they develop and revise national roadmaps to meet their Paris commitments. Recognising ASEAN's potential as a carbon credit production powerhouse, four VCMs have either been either opened or announced in the region: Climate Impact X (CIX) in Singapore (Fogarty, 2023), Bursa Carbon Exchange (BCX) in Malaysia (A. L. Tan, 2022), FTIX in Thailand (Tanakasempipat, 2022), and IDXCarbon Exchange in Indonesia (ST, 2023). As nature-based solution projects gain momentum in the region, increased investment in resources to develop robust auditing and verification systems will be needed to ensure the legitimacy and quality of carbon credits.

5. E-commerce and Delivery Services

5.1. Growth of E-commerce

E-commerce is a rapidly growing component of Singapore's digital economy. In 2021, e-commerce sales reached US$8 billion (Choo, 2022), with gross merchandise volume expected to rise to US$9.8 billion by 2025 (ITA, n.d.). Over 3 million Singaporeans are now active e-commerce users, with the average shopper registering the largest basket size in the region (ITA, 2022).

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[2] Article 6 of the Paris Agreement recognises that some parties choose to pursue voluntary cooperation in the implementation of their NDCs to allow for higher mitigation ambition and to promote sustainable development.

The coronavirus disease (COVID-19) pandemic contributed to the uptick in e-commerce, compelling many retailers to move their businesses online. Popular online platforms saw a surge in the number of monthly web visits as consumers shopped online more frequently (Kriwangko, 2021). Shopee, an online retail giant, saw an increase of nearly 10 million platform visits in 2019–2022 (Statista, 2023). Given its current trajectory, it is expected that e-commerce sales will reach US$14 billion by 2027 (Choo, 2022).

Alongside the growth in e-commerce, food delivery platforms and services grew significantly. Well-known food delivery platforms such as FoodPanda and Deliveroo have seen sustained increases in user numbers long after the pandemic, with the convenience and accessibility of such platforms sustaining this trend (Heng, 2022). Singapore's online food delivery market is currently valued at approximately US$1.5 billion, with analysts predicting that the number of users will reach 3.69 million by 2027 (Ting, 2023).

6. Challenges in Pursuing Sustainability in E-commerce

Due to increasing sales in e-commerce and food delivery services, the amount of packaging used has skyrocketed, exacerbating Singapore's waste and greenhouse gas emissions.

6.1. Increase in Packaging Waste

The ease of online ordering and doorstep deliveries has led to an explosion in consumption and, consequently, in excessive packaging waste. Packaging used for delivery accounts for 45% of carbon emissions in the e-commerce supply chain (Diego Fernandez et al., 2021) and dominates the amount of plastic waste generated in Singapore (Fidelity International, 2021).

Beyond the sheer number of packages used for delivery, retailers often overpackage their goods for two reasons. First, consumers perceive that well-packaged items are secure, which is indicative of the quality of goods. Many buyers express approval of using foam and bubble wrap, even though these materials contribute to excessive and wasteful packaging (Giri, 2021). Second, sellers overpackage items to prevent damage during shipping. On average, a delivery box is dropped approximately 17 times throughout the delivery process (Mungcal et al., 2019). As up to 80% of returned items are due to damage or breakage (Harilela, 2021), adding extra layers of packaging is considered necessary to offset the costs incurred from returns.

As retailers increasingly adopt 'free return' policies to incentivise purchase, waste generation is likely to increase. The pandemic has exacerbated this, with the average return rate of 10% pre-COVID-19 rising to approximately 30% in 2020 (Deloitte, 2020). Given the increasing volume of domestic e-commerce sales, this return rate will likely be reflected in Singapore as well.

Similarly, with the popularity of food delivery in recent years, wastage from packaging and disposable cutlery has surged, a trend especially observed during the COVID-19 lockdowns in 2020. An online survey by National University of Singapore alumni revealed an estimated 20% weekly rise in takeaway orders and a 73% increase in delivered meals (BT, 2020), contributing to an additional 1,334 tonnes of waste from disposable cutlery and containers. Major ride-hailing and food delivery company Grab has acknowledged that food packaging waste is an inherent by-product of its services. In 2021, Grab reported a plastic footprint of nearly 70,000 tonnes, with approximately 166,660 tonnes of packaging waste attributed to the GrabFood delivery platform (Grab, 2022).

6.2. Higher Carbon Emissions Due to Increased Deliveries

The increase in the number of vehicles needed to fulfil last-mile deliveries has also compounded carbon emissions (Fidelity International, 2021). The World Economic Forum estimates that given the current trajectory of growth, the number of delivery vehicles in the world's largest cities will increase by 36% over this decade, resulting in a 32% rise in carbon dioxide emissions (Fidelity International, 2021). Whilst online retail theoretically consumes less energy in shipping compared with physical shopping due to economies of scale, this advantage declines precipitously when customers check out and ship items separately (Mungcal et al., 2019). With delivery routes often unoptimised for efficiency, unnecessary fuel emissions with each delivery increase.

Current Measures

In recent years, the government and industry players have acknowledged the need to adopt more sustainable practices and have developed respective plans to reduce waste and vehicle emissions.

- The National Environment Agency of Singapore (NEA) has implemented strategies under the Zero Waste Masterplan (MEWR, 2019). Since 2020, the Mandatory Packaging Reporting scheme has required suppliers to submit packaging data and its 3R (reduce, reuse, and recycle) plans to the NEA, including details on packaging materials and their corresponding weight (NEA, n.d.). NEA has implemented an e-waste management system to regulate and reduce electronic waste (NEA, 2023).

- A pilot project by the Worldwide Fund for Nature Singapore, United Overseas Bank, Singapore Post, and Better Packaging in 2022 highlighted consumer willingness to opt for reusable e-commerce packaging when given the option (Ramaniharan, 2023).

- To address vehicle emissions, Grab has introduced the 2030 Transport Sustainability Goal, which aims for all its vehicles to run on cleaner energy by 2030 (Grab Singapore, 2021). Grab has also attempted to pivot to zero-emission modes of transport, including walking and cycling, and employing more low-emission vehicles (hybrid and electric) in its rental fleet. Delivery has also become more fuel-efficient with batch delivery (Goh, 2023). GrabShare, the platform's carpooling service, pairs passengers travelling in the same direction to reduce total fuel emissions per trip. Grab has set new targets for 2023 to achieve zero packaging waste by 2040, focusing on reducing overpackaging, replacing single-use plastics with compostables, and developing long-term scalable waste collection solutions and reusable packaging (Grab, 2023).

6.3. Supply Chain Sustainability

Beyond last-mile delivery, the government has announced plans to reduce its Scope 3 emissions, which often form the bulk of companies' greenhouse gas (GHG) emissions (C. Tan, 2023b). Scope 3 emissions refer to indirect GHGs that are produced within a company's value chain. Globally, Scope 3 emissions account for about 75% of companies' emissions (C. Tan, 2023b). Despite attempts to address these emissions, companies continue to face difficulties in accurately quantifying them due to the complexity of tracking every component in a supply chain, the lack of comprehensive data, and the absence of an internationally recognised measurement system (A. Tan, 2021). Even with standardised measurement methods, the consensus is lacking on viable green transition pathways and how companies can achieve their decarbonisation goals.

Aside from emissions, most supply chains continue to rely on physical paperwork for receiving, tracking, and fulfilling orders, resulting in operational inefficiencies. It is estimated that trade documentation for a single shipment can require up to 50 sheets of paper (Casanova et al., 2022), markedly compounding waste at landfills (UKISUG, 2023). Encouraging paperless trade and digitising the entire supply chain will streamline current processes, reduce paper-related costs, and minimise the ecological footprint.

Current Measures

- The government has launched initiatives to support small and medium-sized enterprises (SMEs) in digitising their operations and participating in the digital economy. In addition to collaborating with larger companies to provide technical assistance through initiatives like IMDA's Chief Technology Officer (CTO)-as-a-service with Accenture and Stone Forest Group, the government also offers grants to encourage firms to digitise their supply chains. Examples include the Productivity Solutions Grant by Enterprise Singapore, which funds projects that improve operational productivity and efficiency (ESG, n.d.-c), and the Enterprise Development Grant, which funds new projects, with sustainability-related projects receiving up to 70% funding (ESG, n.d.-a). Other key government initiatives include the National Sustainable Procurement Roundtable (NSPR), which promotes sustainable procurement within supply chains (NSPR, n.d.), and the Enterprise Sustainability Programme, which supports SMEs in driving sustainability across value chains (ESG, n.d.-b).

- The government has expanded its efforts to track its own emissions. Building on its momentum to disclose its Scope 1 and 2 emissions, recent commitments include adopting sustainability-related considerations into tender evaluation points for construction and information and communication projects, which make up more than 60% of the government's procurement contracts (C. Tan, 2023b). These measures could assist the government in disclosing its Scope 3 emissions. The government has announced the implementation of mandatory climate-related reporting for large companies according to International Sustainability Standards Board standards. Some of these requirements may come into effect in early 2025, with others being gradually phased in (Segal, 2024).

7. Policy Recommendations

This section highlights our recommendations to encourage digital-green growth in Singapore. Broadly, we recommend that the government invest in technologies to upgrade grid capacity, push for regional mechanisms like the APG, invest in waste management education and technologies, and reassess the digital talent pipeline.

7.1. Upgrading Grid Infrastructure and Capacity

Electricity grid infrastructure will need to be imported as Singapore looks to import 30% of energy from low-carbon sources by 2035 (C. Tan, 2023a). The government has commissioned studies to explore the potential of higher transmission voltage levels from power generation plants for long-distance electricity transmission and to increase low-voltage electricity networks for households and smaller businesses (C. Tan, 2023a). Supporting this transition will require increased investment in smart grids.[3] Digitalising the grid will be crucial to balancing energy loads and detecting leakages. This comprises upgrading various grid components such as power transformers, substation automation, flexible alternating-current transmission systems, and advanced sensors.

Singapore should focus on efforts to facilitate cross-border energy trade. Whilst Singapore maintains bilateral agreements with neighbours such as Malaysia and Indonesia, it should continue building on ASEAN mechanisms such as the APG to facilitate sustained long-term energy cooperation. The APG represents an ambitious plan to connect ASEAN's grids to distribute loads and maximise where energy is generated and subsequently used. Cross-border electricity trade will require significant investment to connect grid infrastructure and develop large-scale renewable energy storage to cope with intermittent supply and consumption needs (Tham, 2023).

[3] According to the International Energy Agency, smart grids are electricity networks that use digital technologies, sensors, and software to better match the supply and demand of electricity in real time whilst minimising costs and maintaining the stability and reliability of the grid.

Ongoing efforts to explore the use of low-carbon alternatives should be expanded. Hydrogen has been identified as a major decarbonisation pathway under the National Hydrogen Strategy, and Singapore has since signed various memorandums of understanding (MOUs) for low-carbon hydrogen technologies (MTI, 2021; MTI, 2023) and hydrogen supply chains (Keppel Infrastructure and ExxonMobil Asia Pacific Pte. Ltd., 2023) with other governments and companies. The government is researching less conventional technologies, such as small modular reactors and floating nuclear power plants (Yeoh, 2022), and exploring the feasibility of harnessing geothermal energy (Begum, 2022).

7.2. Investing in Technology to Reduce the Carbon Footprint

Investments should be made in green computing, and its adoption should be encouraged across industries. Green computing refers to hardware–software co-optimisation to maximise energy efficiency and minimise environmental impact (IMDA, 2024a). Green coding, a subset of green computing that strives to minimise the amount of energy used to process code, should be leveraged by organisations to support their sustainability initiatives. In addition to reducing overall energy consumption, green coding is fundamental to green software, where functions are designed by default to limit energy consumption and emit less carbon. Even as both the public and private sectors continue embracing code-intensive technologies such as AI, green coding can increase efficiencies in various business operations and reduce energy consumption, thereby reducing an organisation's carbon footprint.

Green coding will be an especially useful tool for DC providers, given the industry's substantial carbon footprint (Knowles, 2021). It can complement other tech-enabled solutions to lower energy consumption in DC facilities. The government should continue investing in expanding green coding capabilities to further digital sustainability, in line with its goal to chart a more sustainable pathway for DC growth in Singapore under IMDA's Green Data Centre Roadmap launched in mid-2024 (IMDA, 2024b).

The Green Computing Funding Initiative and Green Software Trials launched in early 2024 underscore the government's commitment to digital sustainability. These initiatives fund research and trials of green computing solutions with industry leaders (Puthucheary, 2024). Building on this, the government can work towards developing regulatory frameworks for green computing and consider providing financial incentives to help smaller businesses overcome the initial costs of adopting the technology.

To address the issue of supply chain sustainability, Singapore will eventually need to confront the large carbon footprint from Scope 3 emissions. Whilst Scope 3 emissions comprise a huge percentage of overall emissions, most firms lack the tools and impetus to track or measure them. These challenges

are exacerbated by the persistent reliance on physical documentation for trade transactions (Suominen, 2023), making it difficult for firms to effectively collect and consolidate data for reporting purposes.

End-to-end supply chain digitisation is thus crucial to track and monitor Scope 3 emissions. In addition to reducing friction in trade, it will enable firms to measure their Scope 3 emissions through data consolidation. This will allow larger firms to identify and select suppliers aligned with their long-term decarbonisation targets, incentivising them to reduce their emissions. A corollary effect is a reduction of paper waste from trade; the United Nations Economic and Social Commission for Asia and the Pacific estimates that digitalising supply chains could save up to 13 million metric tonnes of paper (ESCAP, 2021).

To further support companies in quantifying and subsequently reporting Scope 3 emissions, the government could develop standardised reporting frameworks to ensure that emissions data is comparable and ubiquitously understood amongst stakeholders. The main hurdle larger firms experience when voluntarily reporting their Scope 3 emissions is the reliability of data (Kong and Wau, 2023). Hence, most firms default to using proxies or estimates from third-party providers, which may not accurately reflect the emissions produced in their value chain.

7.3. Waste Management

Waste management infrastructure must be enhanced, and a paradigm shift in businesses and consumers towards adopting greener habits is encouraged. The government's Zero Waste Masterplan includes initiatives to convert waste into energy, implement a circular economy, and promote resource efficiency in the consumption and production of goods.

The government can improve waste management using a two-pronged approach. First, it can collaborate with stakeholders to upgrade waste management infrastructure by investing in innovation and technology. As Singapore adopts advanced technologies that can treat food waste and convert it to other useful products and energy (MEWR, 2019), the government can expand collaboration with industry leaders to conduct pilot programmes evaluating technology that converts waste to energy. Second, to facilitate a paradigm shift in businesses and consumer preferences towards greener practices, the government can launch public awareness campaigns and school curriculum programmes to emphasise the negative environmental impacts of overconsumption and the long-term implications for business operations and consumers' lifestyles. Collaboration with businesses can further support these initiatives by providing consumers with the ability to choose more sustainable options.

7.4. Prioritising Green and Digital Skills Development

Finally, the development of a sustainable digital economy will need to be accompanied by the upskilling of workers at all levels. Whilst advanced digital skills in AI and ML, cloud computing, and the Internet of Things have generally been acknowledged and valued by employers in Singapore, green skills continue to lack recognition despite their increasing significance in the job market (Economist Impact, 2023). Globally, it is expected that the demand for green skills will outpace the increase in supply of workers equipped with these skills, according to LinkedIn's 2023 Global Green Skills Report (LinkedIn Economic Graph, n.d.).

A long-term plan should be developed to facilitate a talent pipeline for the digital and green economies. Most government initiatives have focused on upskilling the workforce through programmes such as Skills Future SG and SG: Digital. More focus can be given to students who form the prospective workforce, familiarising them with in-demand technology and green skills at an early age.

At the primary and secondary levels, the Ministry of Education (MOE) can build on the EdTech Masterplan 2030, which includes developing students' digital literacy and use of technological skills as one of its aims (MOE, 2023). MOE can provide schools with resources and course material to ensure the consistency of content whilst incorporating the use of emerging technologies. For example, teachers can educate students on the ethical use of AI, such as ChatGPT, and discuss its promises and pitfalls, thereby starting a conversation on the safe use of AI. Familiarising students with these new technologies early on will hone their interest in the digital economy, which will likely increase the ease of picking up in-demand skills. An annual review of digital competencies and technological skills taught should be implemented to ensure that the curriculum remains relevant, considering the rapid pace of development. Considering the overlap of skills needed in the digital and green economy, MOE could consider including content that highlights the importance of digital tools in helping Singapore achieve its sustainability goals.

The emphasis on skills promoting digital sustainability should be considered more broadly. The green transition has driven an increase in demand for skills traversing the digital-green nexus, particularly in carbon-intensive industries such as energy production, utilities, and transport. As a result, digital-green skills such as sustainability reporting, carbon emissions accounting, impact assessment, and energy management are increasingly in demand. This trend is likely to continue as more companies will need to comply with new sustainability reporting standards.

8. Conclusion

Singapore's well-developed infrastructure, strong connectivity, and embrace of technology position it to capture opportunities in the digital economy. However, the country's steadfast commitment to achieving net-zero emissions by 2050 amid extant natural constraints reveals the difficulties it continues to face in its green transition. With the burgeoning digital economy contributing significantly to carbon emissions, a multi-pronged approach that leverages technology to ensure sustainable growth is necessary. The government has already committed funding and support for these new priority areas. Greater investments in innovation and human capital development must be complemented by continued collaboration between the public and private sectors to ensure that policies remain fit for purpose. Successful pathfinding in these areas will augment Singapore's current efforts in fostering a digital-first economy, ultimately enabling the country to overcome its resource limitations and achieve its net-zero targets.

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