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Harnessing Fourth Industrial Revolution (4IR) Technologies for Climate Change Mitigation in the Asia-Pacific Region

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Abstract

As climate change impacts are getting more intense, all nations around the world are eagerly ramping up joint efforts to ensure the planet's sustainability. Many initiatives are being undertaken with the hope to accomplish the target of net-zero emissions as soon as possible. However, over the past two years the ongoing COVID-19 pandemic has heavily impacted global socio-economic conditions and aggravated the challenges being faced by countries. To address these social, economic and environmental issues and "build back better", the development of advanced tools such as the fourth industrial revolution (4IR) technologies would be crucial, especially in the Asia-Pacific region. This paper discusses the opportunities, challenges, innovations and strategies to enhance climate change mitigation with 4IR technologies from sectoral perspectives and provides policy recommendations based on the analysis.

Keywords: Fourth Industrial Revolution, 4IR Technologies, Climate Change Mitigation, Asia-Pacific Region

1. Introduction

The impacts of climate change have become more profuse in the past few years. In June 2021, the western part of Canada and the north-western United States were hit by a "heat dome" for five days, with temperatures within the area reaching more than 40°C. A heat dome is a mountain of warm air pressing down across a huge area caused by high-pressure fronts to trap the hot air, resulting in scorching temperatures (Agence France-Presse, 2021). As climate change impacts occur in many parts of the world, the Asia-Pacific countries are no exception. In the first month of 2021, Fiji was hit by Cyclone Ana: one person was killed and five were missing. China also experienced the worst sandstorm in ten years, leading to the cancellation of several flights and schools. In April 2021, Indonesia and its neighbouring country, East Timor, were struck by Cyclone Seroja, which triggered flash floods and landslides that killed approximately 150 people (Al Jazeera, 2021).

According to the IPCC Sixth Assessment Reports' Regional Factsheet for Asia, ASEAN's compound impacts of climate change, land subsidence and local human activities will lead to higher flood levels and prolonged inundation in the Mekong Delta region. Heavy rainfall will also increase in frequency and intensity, resulting in more frequent landslides in some mountain areas within East Asia (IPCC, 2021). Such extreme weather events around the globe are projected to be more frequent in the near future; holistically planned response measures are therefore urgently needed. World leaders are committed to the 2016 Paris Agreement to keep global temperature rise well below 2°C above pre-industrial levels and to pursue efforts to limit the temperature increase even further to 1.5°C. To reach these ambitious targets and to help tackle climate change issues, the December 2021 Glasgow Climate Pact emphasises the urgency of scaling up action and support, including finance, capacity-building and technology transfer to enhance adaptive capacity, strengthen resilience and reduce vulnerability to climate change events (UNFCCC, 2021).

Fostering the use of innovative climate technologies is proven to be one of the keys to deal with the impacts of climate change. In a meeting of the Technology Executive Committee held in May 2021, Patricia Espinosa, Executive Secretary of the United Nations Framework Convention for Climate Change (UNFCCC) emphasised the crucial role of technology in tackling the climate change crisis. She stressed that since innovative climate technologies are critical for global response, they need to be an integral part of each national climate plan (UNFCCC, 2021). However, developing such advanced green technologies requires substantial financial resources and world leaders are working towards mobilizing such resources. For instance, at the recent COP26 in Glasgow, Australia's Prime Minister, Scott Morrison, announced that the Australian Government would increase the country's climate funding pledge by A$500 million to a total of A$2 billion, to help fellow neighbouring countries in the Pacific, especially ASEAN, in tackling the issue of climate change (Doran and Dziedzic, 2021).

Among the advanced technologies, 4IR technologies have become a pivotal tool to ensure future sustainability. Building on the Third, the digital revolution, 4IR is defined by a convergence of technology that blurs the distinctions between the physical, digital, and biological realms (Schwab, 2016). Artificial Intelligence (AI), the Internet of Things (IoT), big data, augmented and virtual reality, as well as 3D and 4D printing are becoming more important elements in today's human activities.

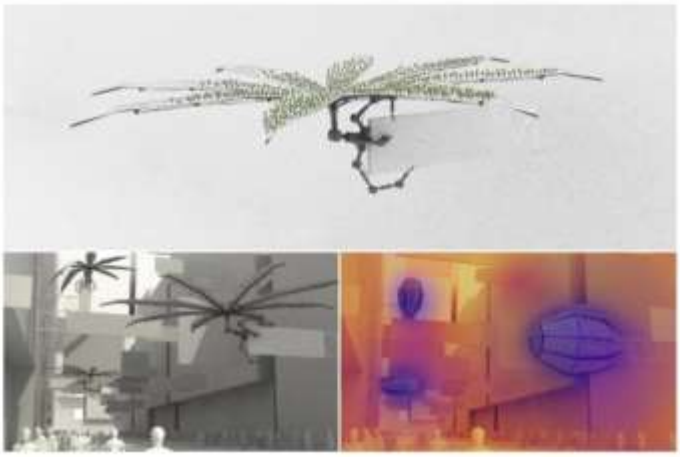
Climate change mitigation efforts are now utilising new and emerging technologies. The aforementioned 4IR technologies can accelerate efforts toward achieving the net-zero target by 2050 worldwide (IEA, 2021). For instance, AI technologies can improve energy efficiency by incorporating data from smart meters so that energy demand can be estimated. Such technology can also help utilities to optimise energy production. 5G-based smart grids can connect to numerous data points across long distances, ranging from wind turbines to rooftop solar panels and electric vehicle batteries. These technologies have promising potential to be the main tools for the region's sustainability and resilience since they provide opportunities to analyse further, mitigate and adapt to climate change impacts (ACCEPT, 2021).

2. Opportunities and Challenges

OPPORTUNITIES

The 4IR offers economic, environmental, social benefits and opportunities, therefore, it complies with the triple bottom line sustainability concept (Kiel et al., 2017; Gibson, 2006, cited in Müller et al., 2018). The 2017 IEA report, Digitalization & Energy considers digital technologies as a facilitator of sustainable practices. The report points out digital technology's potential to enhance energy and resource efficiency and support renewable energy integration into electricity generation. Furthermore, Kiel et al. (2017) summarise aspects of the Industrial Internet of Things (IIoT) which pertain to the ecological dimension of sustainability. These include transparency of greenhouse gas emissions, increased resource and energy efficiency, reduction of waste and logistics processes, and reduction of wrong delivery and damaged goods.

Figure 1(left): Robotic trees in Mexico
Figure 2(right): Parasitic Drones in Hong Kong



Source: Figure 1 (left) Goodson, 2019; Figure 2 (right) MacDonald, 2014

Technological innovations of the 4IR aiming to reduce carbon emissions include robotic trees, parasitic drones, air-cleaning buses and air separation plants. The robotic trees, as seen in Figure 1, have been placed in Mexico. Each tree contains microalgae that absorb carbon dioxide and produce oxygen. Meanwhile, the use of carbon-sucking polymer in parasitic drones has been explored in Hong Kong, as seen in Figure 2. Air-cleaning buses, as seen in Figure 3, were invented in the UK. They clear away particulate air pollution through a filter system on the roof. Another technological innovation, the air separation plant, is a more refined and efficient advancement of air separation units that adopt advanced robotic, internet-of-things technologies, and artificial intelligence (Corfe, 2020). In addition, 4IR allows data-centered and traceable carbon footprint analyses (Müller et al., 2018).

Figure 3. Air-cleaning Bus in the UK (Taylor, 2018)

In comparison with other regions in the world, the Asia-Pacific is more vulnerable to climate change risks due to its dependence on agriculture and natural resources, heavy populated coastal areas, frail institutions and relatively high poverty levels (ADB, 2012). A 2020 Deloitte global report reveals that 81 per cent of Australia's business leaders believe that their business operations will be negatively impacted by climate change. The number is much higher than the global average of 48 per cent. Australia's business leaders assume that the 4IR technology with the greatest impact for investment is Artificial Intelligence (AI) followed by nanotech (Deloitte, 2020). In China, the Government introduced the country's version of Industry 4.0, "Made in China 2025", in 2015 as one of its efforts to lower carbon dioxide emission intensity per unit of GDP by 60 per cent to 65 per cent of the 2005 levels by 2030. It aims to ensure innovation-driven and green manufacturing in China (UNIDO, 2016).

Challenges

There are promising opportunities for 4IR technologies in climate change mitigation efforts; however, there is a number of challenges. The key challenges of digital transformation in 4IR are the creation of labour-market relevant competencies, an organisational culture that needs to be systematic and process-focused, internal and external support from institutional leaders and through policies, and the acceptance and adoption of the 4IR technologies. External support is needed in terms of policies which would help to supply resources and to enhance informative systems and technologies and learning programmes (Checchinato et al., 2021). For instance, digital infrastructure networks such as sufficiently fast broadband and mobile coverage are crucially needed to support the adoption of 4IR technologies (Corfe, 2020).

Adoption of 4IR technologies requires additional expenses, such as the high initial price of installation (Corfe, 2020). In addition, another barrier in using 4IR technologies for climate change mitigation is technological unemployment, job loss directly caused by new technologies and innovations. Experts suggest that automation and advanced digital technologies are removing the need for people in an increasing number of jobs, resulting in stagnation of median income and the growth of inequality (Rotman, 2013).

Box 1: 4IR Technologies Opportunities in the Asia Pacific - Examples

Technologies that have been successfully applied in the Asia-Pacific region include digital transformations as enablers of dataset connectivity, environmental sensors and databases communication, monitoring and tracking for shifts in ecosystems, analysis of disaster risk management sets of datasets, sustainable supply chain optimisation, and high accuracy traffic and weather forecast (ADB, 2021).

Considering its dependence on agriculture by much of the population, its heavily populated coastlines and poverty, Southeast Asia is particularly vulnerable to the impacts of climate change. However, the region can significantly contribute to climate change mitigation. For instance, the adoption of blockchain technologies allows cost-effective and transparent carbon emissions tracking as well as the establishment of carbon markets. In addition, the region has opportunities for leapfrogging intermediate technological steps to localise renewable energy production, which would lower the need for expensive power distribution networks investment. Such opportunities also appear to enhance the monitoring of forestry activities by the use of artificial intelligence, drones and remote sensing to prevent human-induced degradation (WEF and ADB, 2017).

During the 2021 Dialogue on Sustainable Digital Transformation in Asia and the Pacific by the UN International Telecommunication Union (ITU), it was explained that China has developed the transformation of digitalisation for sustainability in industry, power, buildings and traffic. The industrial transformations are the use of AI, big data, deep learning, modulation, 5G networks and machine vision. Some companies have successfully applied such digitalisation in the power sector. For instance, Chinese electrical equipment manufacturer TBEA has a photovoltaic power station e-cloud intelligent operation and maintenance platform, which improves efficiency by 10%, increases power generation by 2%, and reduces kWh costs by 4%. Datang Taizhou Thermal Power Co., Ltd has also built a smart power plant that lowers gas consumption by 9.3% annually and auxiliary power consumption by 0.96% (CAICT, 2021). Meanwhile, The Nippon Telegraph and Telephone Corporation (NTT) has developed an Innovative Optical and Wireless Network using nanotech that aims to reduce power consumption, enlarge capacity with high quality and lower latency (NTT, 2021). These efforts in energy efficiency play a critical role in reducing carbon emissions and mitigating the effects of climate change.

3. Sectoral Perspective

No single sector or technology can overcome all climate change mitigation challenges. This indicates that a diversified portfolio is required. Since the opportunities arising from the evolution of 4IR technology are vast, it can be put to a variety of uses, including disaster prevention, waste management, and early warning systems. Here are some sectoral perspectives on the application of 4IR technology.

3.1 Transportation

4IR technologies create opportunities for developers in the transportation infrastructure sector and have the potential to bring various environmental benefits. 4IR can change the way individuals travel, with the rise of the automotive club, telematics and electric and autonomous vehicles. Estimates suggest that Automated vehicles (AV) could lead to a 2-4% reduction in oil consumption and associated greenhouse gas (GHG) emissions annually over the next ten years. These AVs could play a key role in reducing air pollution, as they enable more efficient driving patterns, with fewer stop-start cycles (Corfe, 2020).

For years humans have been obsessed with creating transportation networks free from traffic jams. One way to overcome congestion on land is to shift to autonomous vehicles. The commonly used AV is the Unmanned Aerial Vehicle (UAV) which is run manually or with an embedded programming algorithm (Mirza et al., 2020). Drones are one type of UAV and play an important role in optimising processes in various industries such as providing efficiency and effectiveness while prioritising safety and savings. Virtually limitless aerial perspectives offer the ability to collect and analyse data, and to use in security monitoring and logistics; these tasks can be combined with AI interfaces. In logistics, drones can help deal with poor infrastructure in remote areas in the delivery of light and high-value goods such as medical supplies. One example of the combination of drones with AI's powerful analytics is Malaysia-based Aerodyne. An aerodyne is a heavier-than-air vehicle or aircraft which utilises the upward thrust due to air movement or self-generated aerodynamics on the wings. Apart from asset inspection, management and project monitoring in various sectors, it also actively provides services in geospatial intelligence, emergency response, 2D and 3D mapping, and precision agriculture (Thomas, 2021).

Drones are getting more affordable, thus encouraging an increase in their use by various groups. It is predicted that drone units will continue to increase due to rising market demand and are expected to support market growth. The Drone Analytics Market is expected to register a Compound Annual Growth Rate (CAGR) of over 15% during the forecast 2020 to 2025 period. (Research and Market, 2021). For example, China, which has become a global hub for drone manufacturing in the last six years, supports around 70% of the global civilian drone market. The Chinese market had around 1,200 drone manufacturers at the start of 2019 (up from 130 in 2013). The Chinese Government provides various subsidy schemes and other favourable domestic policies in purchasing drones to promote adoption in various industrial sectors. The growing drone application area is simultaneously driving the demand for these UAVs in the country. Meanwhile, Australia has emerged as a major industrial hub in the Asia-Pacific, which is witnessing the growing importance of Beyond Visual Line of Sight (BVLOS) testing. As of July 2019, there are more than 1,200 operators of drones for such purposes in the country (Research and Market, 2021).

3.2 Smart Cities

To accelerate sustainable urban development, the following 4IR innovations are 'game-changers' that combine technologies and provide opportunities for emerging cities to address current and future environmental challenges. Many cities are targeting the delivery of smart mobility solutions as part of their smart city blueprints. Here are some of the key innovations in 4IR technologies that we are now looking at:

- **Adaptive Cities:** Making the Most of Multifunctional Space

  Maximising the existing potential of features such as urban land, space and buildings can be a game-changer for fast-growing cities looking to promote better densities and reduce inefficient expansion costs. Using 4IR technology, existing buildings and spaces can be upgraded to become multi-use. Examples of technologies that can be used include blockchain and AI technologies that can help automate property planning and development processes. In addition, drones, 3D printing, and robots can also be used to leverage existing resources and construct new multifunctional buildings in a more timely and efficient manner (PwC, 2017).

- **Regenerative Cities:** Intelligently Responding to Catastrophic Risk

  Response simulation and regenerative materials are effective means of protecting urban life and the environment in developing cities that are at risk of or vulnerable to climate shocks and natural disasters. These means can help cities and communities plan, prepare and collaborate with businesses and Government. IoT technology, blockchain and advanced sensor platforms, together with predictive AI analytics, can help cities monitor natural hazards in real-time. For example, in Indonesia, PetaBencana.id combines several open-source sensors, AI and social media reports on floods in the capital city of Jakarta (PwC, 2017). Latest update, it covers also already other provinces in Indonesia.

- **Government Involvement**

  Due to environmental pressures and rapid growth, Asia-Pacific (APAC) governments are very focused on smart urban planning. Several smart country initiative programs in the APAC region have been launched. China, in its national smart city program, t invested CNY 500 billion (approximately USD 74.3 billion), and in 2017, 500 smart cities were leveraging IoT, big data and other smart systems. In addition, South Korea is also starting to develop IoT domestically by investing USD 350 million in 300 companies. A pilot is being launched in the southeastern city of Seoul to set up IoT-based infrastructure for renewable energy and smart cars (Equinix, 2019).

- **Building Energy Management Systems (BEMS)**

  According to Global Industry Analysts, Inc., the Asia-Pacific region ranks as the fastest-growing market for BEMS during the analysis 2020 period, and companies such as NTELS, a Korean technology company, are focused on capturing this growth in ASEAN. Smart buildings integrated with smart grids will provide infrastructure to help ASEAN countries achieve their goal of being more energy efficient. In addition, smart buildings will manage energy supply and demand to help eliminate energy wastage and reduce greenhouse gas (GHG) emissions using building software, sensors, and data analysis software (Asia IoT Business Platform, 2020).

3.3 Manufacturing

The COVID-19 pandemic has been a catalyst for immense change in manufacturing, unexpectedly accelerating companies into 4IR. In ASEAN, manufacturing is a key driver of economic growth, accounting for about USD 670 billion, or 21 percent, to the region's GDP in 2018 and is expected to double to USD 1.4 trillion by 2028 by embracing 4IR technologies (A.T. Kearney, 2018).

Dependence on manufacturing industry in developing Indo-Pacific countries is very significant as a proportion of economic output. Specifically, in 2018, in Thailand, 26.9% of GDP came from manufacturing, and 24% in Myanmar (by comparison, in Australia, manufacturing contributed to 6% of annual GDP) (Innovation Change, 2020).

In China, car manufacturers and energy solution providers BYD, in collaboration with VeChain and DNV GL, are developing Carbon Credit Applications to empower digital technologies. This technology can estimate the mileage, fuel and electricity consumption. With the collection and processing of data, users can monitor, analyse and calculate the level of carbon emissions and generate the distribution of carbon credits recorded in the Blockchain (Hübner, 2020).

4. Policy Framework

In 2018, the World Economic Forum (WEF) launched a report on the countries' "readiness for the global future of production." This report aims to assess the level of preparedness of the countries in the world and also identify the leading 4IR countries. After considering several categories such as technology and innovation, human capital, global trade and investment, institutional framework, sustainable production and the demand environment, Japan and South Korea are found to be the leading countries in 4IR that have a high production base level, implying a high level of preparation in the near future. Japan itself has also high scores in all those evaluated fields and has the highest invested capital (WEF & A.T. Kearney, 2018).

Box 2: Case Study: Japan's Fourth Industrial Revolution

In 2016, the Government of Japan enacted the initiative called "Society 5.0". This initiative emphasises the ways in which emerging technologies are transforming not only the current country's production but also the whole society. "Society 5.0" is a super smart society where the new technologies integrate cyberspace and physical space to bring prosperity of the Japanese people (Government of Japan, 2016). All the economic and social activities combined with 4IR technologies enhance the country's economic development and provide solutions, not only for social issues but also for environmental problems (Government of Japan, 2017). The government is also working with the industrial sector in a project called "Connected Industries", which is a new concept framework for the industries to create greater added value and solutions to many issues, including climate and energy. Therefore, to facilitate these initiatives, the Japanese Government has been advancing a wide variety of policy regulations in order to form a harmonious nexus between the economic and environmental (METI, 2017).

The fight against climate change is no longer a cost factor for the Japanese people, especially its government. Proactive measures are now seen as a great opportunity for strong economic growth in the future. To achieve such a harmonious nexus of economics and environment, the Government of Japan launched the "Green Growth Strategy through Achieving Carbon Neutrality in 2050" at the beginning of 2021. The key principles in Japan's approach to tackling the challenges of climate change revolve around advanced technologies, including the promotion of innovation and technology as the agents of change, to promote green finance as support for this development and also for greater international cooperation in the business-led adoption of innovative green technologies. From budgeting to taxation and to regulatory reform, all available policies are required to stimulate innovation in different areas. Notable among the efforts is the establishment of the 2 trillion Japanese Yen (USD 18.2 billion) Green Innovation Fund. The fund will continue to support a range of initiatives, from ambitious Research Development (R&D) to social implementation over the next decade (Government of Japan, 2021).

One of the R&D initiatives is solar cells which are Japan's leading technology driven by 4IR by level of research and development. For example, Japan has made possible an ultra-lightweight solar module by using an innovative process involving a thin layer of perovskite, a calcium titanium oxide mineral. The Global Zero Emission Research Center (GZR) was established by the National Institute of Advanced Industrial Science and Technology and has been developing a multi-junction (tandem) solar cell made from layered materials that have significantly better conversion efficiency than the conventional cells, and which enable higher power generation in a smaller area. If their application is proven, these technologies will facilitate installation in areas where traditional solar cells have been difficult, such as on building walls, and factory and warehouse roofs, where heavy loads usually cannot be carried. In addition, these technologies are expected to have a wider range of applications, such as mounting on vehicles and use as a power source for IoT devices like stand-alone sensors (Government of Japan, 2020).

In addition to the R&D Initiatives, the 4IR technology partnership in the energy sector has also been strengthened. Japanese utility, Kansai Electric Power Company (KEPCO), in cooperation with the University of Tokyo, Mitsubishi UFJ Bank and Unisys are testing Blockchain technologies for surplus electricity trading. The aim is to use Blockchain technology to acquire knowledge and experience of transactions between power consumers and prosumers. KEPCO operates Japan’s second-largest industrial region, and can thus incorporate cities like Kyoto, Kobe and Osaka during the testing phase (KAS, 2020).

The Republic of Korea's key driver for 4IR technologies in tackling climate change focuses on pollution control. This country's coal-fired plants are one of the main contributors to air pollution. These plants accounted for 52.5% of the country's total power generation in 2018 (U.S. Department of Commerce, n.d.). The Government of the Republic of Korea monitors and regulates emissions of air pollutants and hazardous air substances under the Clean Air Conservation Act. As this country has the highest share of super and ultra-super critical power plants in operation in the world, the Government is taking steps to fit out the plants with Carbon Capture and Storage (CCS), Selective Catalytic Reduction (SCR), and Flue Gas Desulfurization (FGD) systems. In addition, Korea Electrical Power Corp. (KEPCO), the largest electric utility in the Republic, has been promoting the use of 4IR through a digital power plant construction project since May 2019. A digital power plant involves the application of IoT and big data platform technology to the entire cycle of a power plant, including the design, operation and preventive maintenance of boilers, turbines, generators and auxiliary equipment. KEPCO projected that digital power plants will be able to identify optimal operating conditions and maintenance points in order to improve power generation efficiency and minimize impacts of climate change by reducing fine dust and CO emissions (Herh, 2019). Even though, the Republic of Korea's coal-fired power plants are relatively modern and large, with newer steam parameters, in July 2016, the country's Trade Minister announced further air pollution control measures by targeting the retirement of 10 thirty-year-old coal-fired power plants by 2025. The Government will also replace turbines at several plants to boost power efficiency and expand the capacity of circulation pumps to further reduce the country’s emissions (U.S. Department of Commerce, n.d.).

Thus, a 4IR regulatory framework on climate change, especially in the energy sector, is needed in several ASEAN Member States (AMS) to accelerate the fast growth of digital and technological advancement and equip the ASEAN region's industries and societies for navigating the opportunities and challenges of this advancement. Government as the body which formulates the activities, plans and initiatives for a country's interests is pivotal to determine the future of their nation through strict policies. The Association of Southeast Asian Nations (ASEAN) as the main intergovernmental organisation in the Southeast Asia region, needs to facilitate innovation, transfer and the uptake of 4IR technologies, particularly for tackling the issues of climate change.

According to the aforementioned WEF report, Malaysia is the leading 4IR country in Southeast Asia after Singapore. Recently, Malaysia has implemented a National 4IR policy. "The policy is aimed to leverage on the synergy of the physical, biological, and digital worlds to elevate the country's over-all value based on four policy thrusts; to equip the rakyat (citizen) with 4IR knowledge and skill sets, to forge a connected nation through digital infrastructure development, to future proof regulations to be agile with technological changes, and to accelerate 4IR technology innovation and adoption (Chin, 2021).

With this National 4IR Policy, action plans and initiatives of various Malaysian ministries and entities will be aligned in steering the country to achieve balanced, responsible and sustainable growth by leveraging technological adoption and innovation. This National 4IR Policy advocates the use of technology for social, economic, and environmental sustainability. Harnessing technologies to enhance ecological integrity is one of the key missions of Malaysia's 4IR policy in order to reduce greenhouse gas emissions intensity by 45% by 2030. This includes both ecosystem and sectoral approaches, where the Government promotes private sector innovation and the application of technology for 4IR by mobilising co-investment funds for industrial adoption. 4IR technologies that Malaysia has developed to mitigate climate change are battery and energy storage as well as advanced materials which provide opportunities to reduce reliance on foreign input and to produce higher value-added products for export. These in turn provide potential spill over effects in energy consumption, such as the power grid support market and energy efficiency (Economic Planning Unit, Prime Minister's Department, Malaysia, 2021).

Two of the Malaysia's 4IR policy strategies highlight the nation's initiatives to embrace the planet's sustainability. Strategy 14. "Enhance financial support to facilitate 4IR technology adoption and development", has two initiatives. Initiative 27 is to incentivise 4IR technology applications for business improvement (performance-linked incentives) and Initiative 28 is to mobilise co-investment funds for 4IR technology adoption by industry. In addition, Strategy 15, "Support 4IR technology innovation focusing on social and environmental issues" has two initiatives: Initiative 29 is to provide support to innovative businesses and social enterprises to leverage 4IR technology to solve socio-environmental issues and Initiative 30 is to prioritise public sector R&D and Creativity and Innovation (C&I) funding for technology innovations (Economic Planning Unit, Prime Minister's Department, Malaysia, 2021).

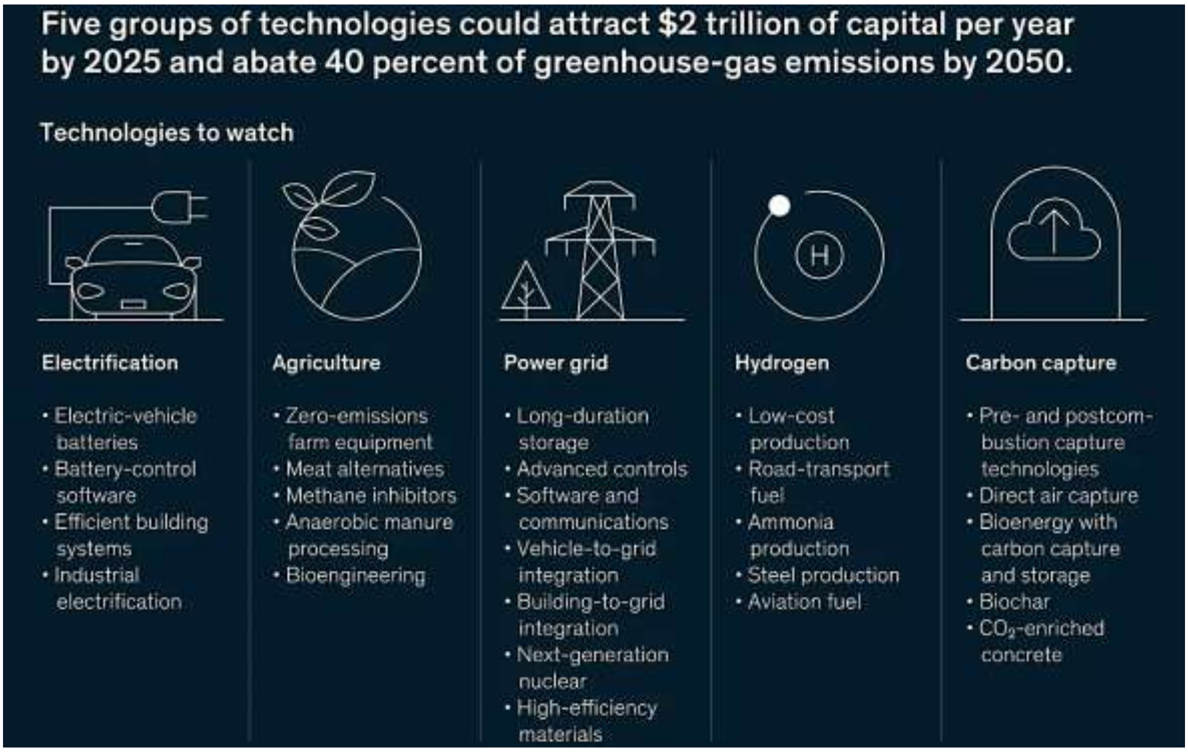
70% of the targets in the UN Sustainable Development Goals (SDGs) are achievable by utilising 4IR technology applications (World Economic Forum and PwC, 2020). One of the key steps towards the adoption of 4IR technologies in ASEAN or other Asia-Pacific regions is incentivising 4IR technologies' developers to improve the region's competitiveness. Just like Malaysia's latest 4IR policy, these incentives should include additional 4IR-related tax incentives and support for research and development in the implementation of such technologies. This would support the acquisition and application of advanced green technologies in the manufacturing of goods and delivery of services. Part of this will include additional support to develop new enterprises and grow existing ones in the 4IR sector to create solutions that address the Asia-Pacific's challenges in fighting climate change (Marwala, 2020).

5. Business Models

There are four business models with different types of assets and technologies as well as economic outcomes: asset builders, service providers, technology creators, and the best performing of all, network orchestrators which create a platform that members use to connect or transact with the many other parties of the network. In general, companies with the network orchestrators business model grow revenues faster, generate high profit margins and use assets more efficiently. These benefits come by leveraging technology and the network effect (WEF, 2016). Digital Platforms use data-driven business models that build value by digitally facilitating exchanges between participants. For instance, Norwegian company Greenbird strives to activate data-driven business models and aims to accelerate the energy revolution towards smarter energy solutions. Greenbird's integration hub generates sustainable value from its data to ensure it can adapt immediately to the dynamic environments and opportunities in the current energy transformation (KAS, 2020).

Re-evaluation of cleantech stocks and investment growth for sustainability and for environmental, social and corporate governance (ESG) objectives involves a bountiful increase in capital. Hence, climate-change responsive technology is a basic requirement. It presents huge potential markets and investment opportunities. Capital investment could reach USD 1.5 trillion to USD 2 trillion per year by 2025, invited by the next-generation technologies (Hellstren et al., 2021), which can be seen in Figure 4. Therefore, an evaluation is suggested of the most prominent business model in 4IR, the use of network orchestrators to promote not only the inclusive and sustainable application but also the commercialisation of 4IR technologies.

Figure 4. Climate Technologies



Source: Hellstren et al., 2021., originally produced by McKinsey & Company

Burmeister *et al* have: “a technology-enabled trend promising to fundamentally change the way in which we organize production and value creation” (p. 125, Burmeister et al., 2016). It also promotes digital enhancement and re-engineering of products and services (Porter and Heppelmann, 2014 and Rudtsch *et al.*, 2014, both cited in Burmeister et al., 2016). Burmeister (p. 125) say “A core idea of I40 is the implementation of cyber-physical systems (CPS) for industrial production i.e., networks of microcomputers, sensors and actuators embedded in materials, machines or products that have been connected along the value chain (Porter/Heppelmann, 2014; Rudtsch *et al.*, 2014). More specifically, I40 yields new value propositions for highly customized or differentiated products, well-synchronized product-service combinations, and value-added services (Iansiti/Lakhani, 2014; Rudtsch *et al.*, 2014).

The 4IR business models (BM) should consider customer-centricity, value creation, and data. Furthermore, a systematic process for Business Model Innovation (BMI) is needed to produce the appropriate BM of a company in the 4IR (Burmeister *et al.,* 2016). Burmeister et al. use Schröder's (2008) general definition of innovation and define BMI as "the (dynamic) generation process and initial implementation of a (static) BM, which is new from the perspective of the company or target market" (p. 128). Industry 4.0 is becoming an essential driver for the implementation of industrial dedicated BMI activities (Burmeister *et al.*, 2016).

In terms of the partnership, "some companies rely on ad-hoc partnership management, while others introduce dedicated functions for partnering and offer guidelines and support for easier initiation, collaboration, and control" (Burmeister et al, 2016, p. 140). Therefore, the essential characteristics of BMI processes are flexibility, openness, and market-relatedness. In addition, corporate culture is an important aspect for BMI, as the major foundation is an entrepreneurial mindset with an increase in employee freedom and responsibility as well as development in failure management. As for managers, they should adopt the initiative and systematically form an understanding of the industry 4.0 technology and the resulting BM opportunities (Burmeister *et al.*, 2016).

Company boundaries may be impacted by the ability to control digital structure, information availability and information access, or even establish new forms of these boundaries (Leih et al., 2015, cited in Burmeister *et al.*, 2016). Therefore, new concepts of firm boundaries may be necessary, for example the "open business model" (Chesbrough, 2006; Frankenberger *et al.*, 2014, both cited in Burmeister *et al.,* 2016). In addition, focus on identifying and evaluating customer value drivers is needed since the industry 4.0 value propositions have high customer-centricity. Hence, a better approach to customer-centric value proposition design (Kagermann *et al.,* 2013; Westerlund *et al.,* 2014, both cited in Burmeister *et al.,* 2016) could serve more benefits (Burmeister *et al.*, 2016).

Existing distribution channels and customer relations are expected to be shifted by 4IR through digital communication links and integration. “I40 is expected to change existing distribution channels and customer relations through digital communication links and integration. Enabling former B2B businesses to broaden their footprint and directly reach the end-customer (“B2B2C”) who owns/uses their products will disrupt existing industry structures and likely strengthen the position of dominant players such as OEMs and key technology leaders (Porter/Heppelmann, 2014), who then become platform owners”.

Box 3: Business Model Changes by the Industrial Internet of Things (IIoT)

The potential of BMI based on digital, technology- and data-centered business logic is highlighted in recent research. BM changes have been triggered by the Industrial Internet of Things (IIoT), which are: the "transition from product to system offerings" data as a springboard for value creation; IT and software know-how as essential workforce resources, intensified customisation and customer relationships; increasing interconnection with partners; increasing employee requirements for flexibility, and changing cost structure (Arnold et al., 2017, as cited in Müller et al., 2018, p. 5). One of the applications of the Internet of Things is smart energy meters. Malaysian electrical utility Tenaga Nasional Berhad (TNB) is expected to equip smart electric meters for a total of 9.1 million households in 2026. Another firm that utilises IIoT is the French multinational Engie Group, with its low-carbon energy and services. Its key businesses are renewable energy, gas, and services. Engie aims to become "the world leader in the zero-carbon transition with their customers" (KAS, 2020, p. 20).

6. Strategies and Recommendations

6.1 STRATEGIES

There are several strategies for mitigation of climate change that can be implemented by leveraging advances in 4IR technologies and building on existing initiatives in the asia-pacific region. The strategies can be adopted and adapted based on the strengths and weaknesses of each country (Noor, 2019).

a. **Investment in R&D of Innovative Technologies**

As the impact of the implementation of 4IR continues to expand not only to the manufacturing sector but also to the production, supply chain, and logistics sector, investing in R&D connects various parts of the strategy. Both governments and companies are usually willing to support higher education institutions by investing in interdisciplinary education in economics, engineering, computer science, and mathematics for future software employees (Sima et al., 2020). For example, more and more professions combine skills in robotic technology with AI to reduce carbon footprints. This has been implemented by Korea to achieve the 2030 GHG emission reduction target of 37% compared to the business as usual (BAU) level in the First Basic Plan for Climate Change Response in 2016, and the Med- and Long-Term Plan for Climate Technology Cooperation 2018-2020 which set by the Government (Kim, 2021).

b. Building A Climate Roadmap

A roadmap can be defined as a strategic plan that determines expected goals or results and involves the major steps needed to achieve them. Therefore, in tackling climate change using 4IR technology, a long-term strategy is needed. India's TIFAC 2035 Technology Vision and the ICC Green Economy Roadmap build a desirable long-term vision expressed as a statement and images of desired and plausible futures. Australia has also launched an energy roadmap by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) in the exploration of innovation, technology, or policy pathways to achieve its vision (Noor, 2019).

c. Consolidation Strategy

One regional cooperation strategies that can be used as an example is the Consolidated Strategy on the 4IR for ASEAN which aims to provide policy guidelines in building a Digital Community which will help to tackle climate change through a combination of 4IR technology. It is used in the ASEAN Region to build "a digital ASEAN that is open, secure, transparent, and connected and that leverages technology to build resilience and a globally competitive economy that embraces innovation in transforming societies and contributes to social progress and sustainable development". The focus areas and strategic priorities are the technological governance and cybersecurity, digital economy and digital transformation of society (ASEAN, 2021, p. 7).

6.2 Recommendations

A benefit of regional cooperation is the integration that allows businesses to access larger markets and thus become more efficient. This creates opportunities for cross-fertilisation of ideas, transfer of knowledge, and collaboration of complementary resources. In terms of variables and climate change, it is difficult for the stakeholders in developing countries to keep up with the impacts changing weather patterns and climate shocks. Many developing countries lack the human and institutional capacity to carry out environmental planning activities and rely on assistance from the international development community. Here are some recommendations for regional cooperation in adopting 4IR technology for climate change mitigation:

- **Responsible Technology Policy and Regulation:** To implement secure 4IR technology, Governments need to establish transparent policies to set clear parameters for technology innovators and ensure the use of 4IR technologies to monitor natural resources and combat climate change. In addition, definitions and standards should be developed regarding the misuse of 4IR technology, while "ensuring that environmental considerations are incorporated into the national digital strategy" (PwC, 2018, p. 27).

- **Develop a planning strategy,** to ensure that homes being built today are suitable for a carbon "net zero" world of lower rates of private car ownership. The creation of "smart", internet- and data-driven towns and cities, with the supporting broadband and mobile infrastructure, needs to be central in the planning process (Corfe, 2020).

- **Harness Data-Sharing Initiatives**: Data is the foundation of the Fourth Industrial Revolution on which all new technology is built. In this case, the ability to transfer and access data across borders is needed. Combining different types of data and reusing existing data allow an exponential increase in the creation of economic and social benefits. However, security and privacy are one of the biggest challenges, so countries need to work collaboratively on regulations (WEF and ADB, 2017).

7. Conclusion

The increase in global temperature over the past decades has led to more intense impacts of climate change in many parts of the world. The climate change issue has raised serious concerns for the world's leaders to look out for the best efforts in achieving world sustainability. In the context of the emergence of more advanced digital technology and its social diffusion, harnessing 4IR technologies to mitigate climate change seems to be an important initiative for the future of the Asia-Pacific region, especially ASEAN. Although this region is struggling with the initial high cost of applying the technologies in many sectors like transportation, manufacturing and smart cities, once implemented such technologies would have significant potential to maximise global efforts. Strengthening R&D capability, collaborating cross-border R&D, as well as accelerating technology transfer, commercialisation, and adoption of 4IR technologies for climate change adaptation and mitigation in the region are strongly encouraged. Furthermore, regulation of a national policy framework for the adoption of 4IR technologies is necessary in order to support further initiatives of climate change mitigation. If we are unable to achieve our goals to tackle further impacts of climate change, the existence of human beings will be far more threatened. Therefore, more research and innovations are needed to enhance the efforts in order to preserve future generations.

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