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Sustainable Energy and Digitalisation: Practices and Perspectives in Asia-Pacific

Regional Project Energy Security and
Climate Change Asia-Pacific (RECAP) of
the Konrad-Adenauer-Stiftung (KAS)

Foreword

Climate change is a challenge that needs political attention, practical solutions and a sound understanding of our environment.

In this light the decarbonisation and digitalisation of the energy sector is long overdue. Many countries around the world have already begun to change their energy systems according to their respective political, economic and social conditions. Global political frameworks such as the Paris Agreement or the adoption of Sustainable Development Goals have been important drivers for this process.

In recent years, investments in renewable energies have even temporarily exceeded investments in fossil energy plants. Nonetheless, fossil fuels will remain the dominant global energy source for the foreseeable future.
A central component of global decarbonisation is the simultaneous digitalisation. Together they promote the electrification of the energy sector. It also makes the coordination between energy supply and demand much more complex. Hardly any industry is as highly regulated and centralized as the energy sector. The expansion of renewable energies, however, requires decentralized approaches, for which digitalisation offers new solutions. Artificial Intelligence, Distributed Ledger Technologies and the Internet of Things are just the beginning of new decentralized energy networks. This makes regulation more difficult. But perhaps it is also a good opportunity to expose complex energy supply structures to market forces.

The Asia-Pacific region, with its major energy producers and consumers China and India, is of central importance for global decarbonisation. If it succeeds here to make the energy supply structures climate-friendly, then global warming will be slowed down.

Current advancements in the development of renewable energy in the region are encouraging. However, they are superimposed by the even greater expansion of fossil power plants. Therefore, it is now necessary to fully exploit the possibilities of digitalisation and decarbonisation so that new, worthwhile business models can be developed. The goal must be - even in a decarbonising energy world - to enable secure, affordable and sustainable energy supply. The present study is intended to provide an overview of the current state of decarbonisation of the energy sector and the possibilities of digitalisation by using the Asia-Pacific example. I wish you a stimulating read.

Dr. Christian Hübner

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Executive Summary

The study provides an overview of the energy sector and digitalisation in Asia – Pacific. The research highlights the megatrends affecting energy industry and energy transition policy with a focus on disrupting technologies.

Digital technologies like the Internet of Things (IoT), Data Analytics, Artificial Intelligence (AI), Blockchain and Digital Platforms have become imperatives to succeed in combatting climate emergency and allow at the same time for greater empowerment of the customer. New energy storage technologies and flexibility options are necessary contributions to this development.

In this context climate emergency, energy transition (in terms of decarbonisation and decentralisation), and digitalisation have become interlinked trends challenging the energy industry.

Better data quality, greater connectivity, and automation are already making energy systems cheaper and more efficient. Although those aspects of digitalisation will deepen, it is AI and Machine Learning that will open up new business and value-creation models for a greater number of players, including aggregators and prosumers.

The broad effects of digitalisation are starting to gather pace in power systems, industrial production, transport, buildings as well as oil and gas. The industry transitions to an energy system with a substantially larger mix of electrical generation from variable Renewable Energy Sources (vRES), electricity markets, policies, regulation and standards will shift and adapt to facilitate the transition.

Many countries in Asia-Pacific like Singapore, China, Japan, South Korea, Australia, New Zealand, Indonesia, Malaysia and the Pacific Islands already use digital technologies to achieve their decarbonisation targets.

Possible accelerators for sustainable energy: using more domestic renewable energy due to energy security concerns, investors draw to clean energy, climate crisis, regulations on clean energy, governments push for EVs in the transport sector, cost reductions in using renewable energy, the ‘Internet of Energy’ integrates energy sources in more-efficient market-scale systems;

Possible brakes for sustainable energy: populism protecting inefficient subsidies, political polarisation leading to national stagnation, trade conflicts depressing investment in cleaner development and hampering the exchange of new technologies, social media promoting a narrative on energy safety and supporting NIMBY-ism, variable renewable energy cannibalization discourages investors, energy density of batteries struggles to improve further;

Enabling successful digital transformation goes beyond technology. For an organisation to truly benefit from any new approach, every layer of the organisation needs to be involved, and every employee needs to be on board. For many organisations, proving the value of digital transformation will come from real-life use cases that demonstrate digitalisation’s role as the enabler of decarbonisation.

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Megatrends Affecting the Energy Industry

Megatrends Affecting the Energy Industry

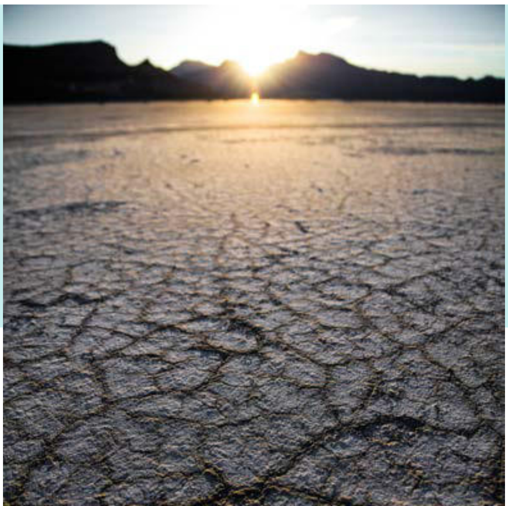
Climate Emergency, Energy Transition and Digitalisation are the megatrends that have an impact on the energy industry – with significant potential for disruption of the individual stakeholders. These trends cannot be looked at in isolation since they are strongly interlinked. Climate Emergency requires a radical move of the power generation towards non-fossil fuels, sustainable use of energy and optimisation of the industry on system-level, which requires large investments. The shift required is possible only through the help of new technologies empowered by Digitalisation. Hence - the Digitalisation of the energy system has become imperative to succeed in combatting Climate Emergency while it will allow for greater empowerment of the customer at the same time.

1.1 Climate Emergency

In recent news, António Guterres, the UN Secretary-General declared that the world is facing a grave Climate Emergency, while cities such as New York and Sydney have called for an immediate response to the climate crisis, urging residents to make necessary adjustments to help slow the pace of change. This marks a seismic shift in the way governments, businesses and communities are talking about climate. We are now facing a very real and immediate risk to our planet.

Climate Emergency caused by anthropogenic carbon emissions is already visibly interfering with the world's climate system, and any further increases in temperature will worsen the effects.

Image 1: 'climate reality' (Source: Patrick Hendry @worldsbetweenlines on Unsplash)



The 2018 Special Report on Global Warming of 1.5 ºC [3] highlights the urgent need to take action, emphasises the challenges associated even with 1.5°C global warming, and points out the huge difference between 1.5°C and 2°C warming, in terms of Climate Emergency impacts and irreversible changes. Every tenth of a degree of warming matters, and risks and economic damage can be substantially lessened by limiting global warming to 1.5°C. Those pathways that overshoot the 1.5°C barrier run a greater risk of triggering 'tipping points' and potentially irreversible and unmanageable, earth-system reactions may occur, even if temperatures should subsequently be reduced.

As the Intergovernmental Panel on Climate Change (IPCC) states [3], the world will need to reach net-zero emissions within 25 years to have a likely chance of keeping warming to 1.5 ºC over the long term. To achieve this will require substantial activities and investments in the transport, building and manufacturing sector, underpinned by an extraordinary transformation of the energy sector.

While many countries are already taking decisive steps to try and reduce their carbon footprint, the global cost of inaction on Climate Emergency is estimated to reach US$ 23 trillion a year by 2020 [4].

For many years the Climate Emergency was discussed in expert circles, but rather ignored or denied by large parts of the public, including politicians and lobbyists, (including but not limited to the fossil fuel industry). The Climate Emergency is now increasingly in focus for politicians, social- and mainstream media and the society at large. Individuals like the Swedish environmental activist Greta Thunberg can activate tenth of thousands of supporters for the “Fridays for Future” movement and have a voice at the UN Climate Action Summit 2019, where she held an emotional and fierce speech to the world leaders [5].

Indeed, the picture looks bleak. The IPCC forecasts that without extraordinary measures, the 1.5°C carbon budget will be overshot in 2028, and in 2049 the 2°C carbon budget will also be exhausted [1]. By mid-century, the overshoot of the 1.5°C budget is 770 Gt of CO2, and the overshoot of the 2°C budget is 21 Gt of CO2. Also, the overshoot continues beyond mid-century: In 2050 alone, emissions are still at around 25 Gt CO2/yr. Thus, the Energy Transition we already see is, unequivocally, not fast enough.

Human-induced global warming has already caused multiple observed changes in the climate system [3]. Changes include increases in both land and ocean temperatures, as well as more frequent heatwaves in most land regions. There is also high confidence that global warming has resulted in an increase in the frequency and duration of marine heatwaves. Further, there is substantial evidence that human-induced global warming has led to an increase in the frequency, intensity and amount of heavy precipitation events at the global scale, as well as an increased risk of drought in the Mediterranean region.

1.2 Energy Transition

The Energy Transition is poised at a critical and complex juncture of opposing forces – political, economic, and technological. Unlike historical transitions driven by scarcity, the present Energy Transition is evolving in an age of abundant availability of energy resources, and in a period where energy consumption is beginning to level off due to rapid efficiency gains. Therefore, in a constrained market, displacement and substitution among technology alternatives are unavoidable [1].

The transition is mission-oriented in the sense that governments are targeting structural energy-system changes as a component towards achieving the UN 2030 Development Agenda and the Paris Agreement. Technologies that advance Decarbonisation hold primacy, but employment and welfare remain important considerations.

The transition is mainly cost-driven. Renewable Energy technologies are crossing performance and cost thresholds, triggering widespread global uptake. Expanding electrification allows for sector coupling between energy-consuming sectors (transport, building, and industry) and the power-producing sector, liberating new synergies and cost deflation. Cost, however, is not the sole arbiter of change.

The transition is technology-driven. It draws on advances in materials and technology that may have arisen outside the energy industry. Digital Technologies are disrupting industries and affecting not only all energy sectors but also the interactions between them, in ways not possible in previous transitions. The Digital Revolution is a critical accelerant of the Energy Transition.

The Energy Transition gives rise to many paradoxes, of which three are critical:

(i) governments are declaring climate emergencies, but continuing with fossil-fuel expansion plans;

(ii) countries on a path towards technology renewal and emissions reduction, pushing their outmoded technology and carbon-intensive production into developing countries – effectively, carbon colonialism;

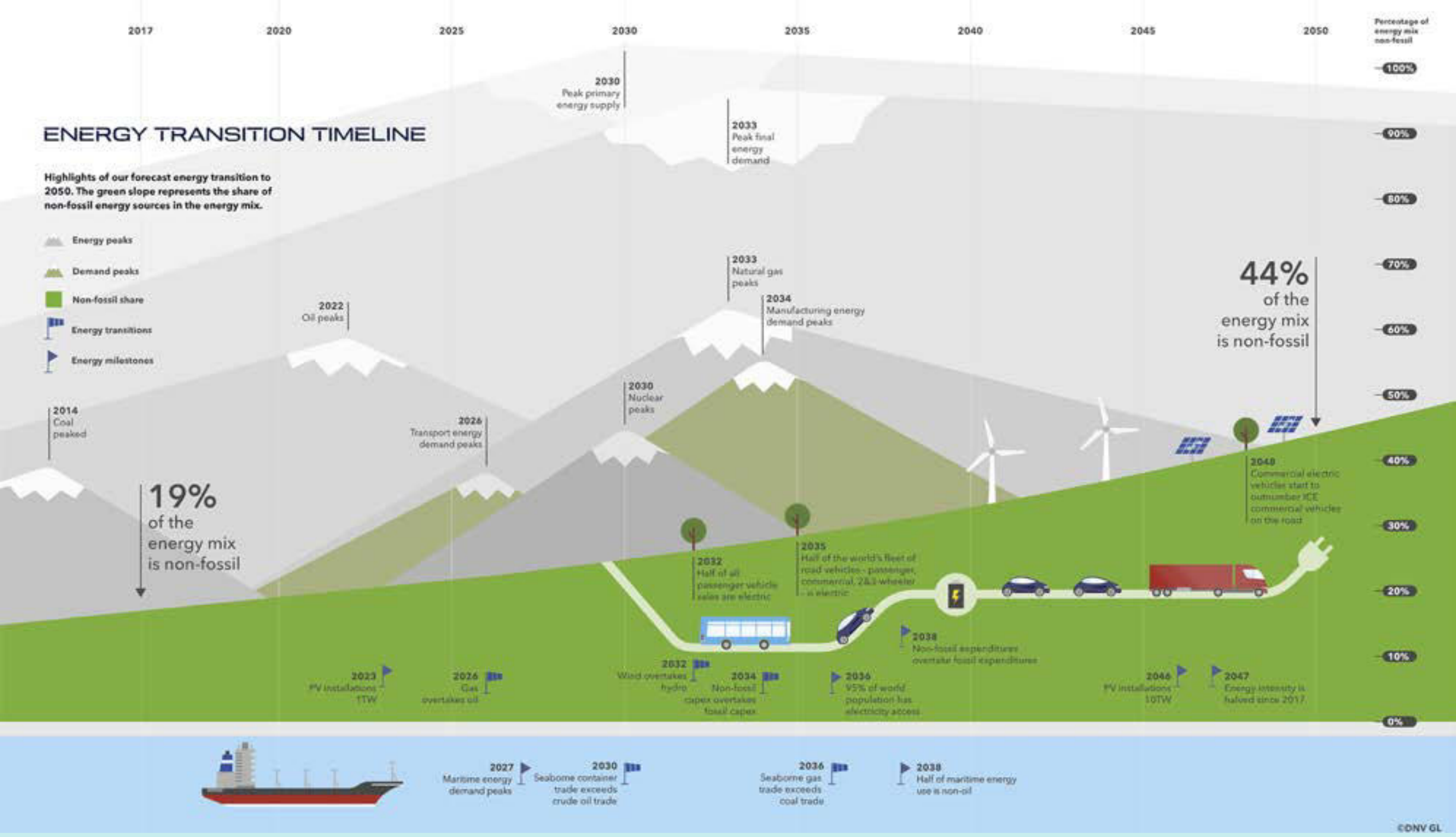
(iii) governments are yielding to the political inertia of stakeholders in legacy systems and hence misdirecting abundant capital and innovation investment to maintain the status quo.

According to technology historian Thomas P. Hughes (Hughes, 1983), this last paradox is key [1]. Legacy systems have built-in resilience, in the form of increasing returns to scale and through mutually reinforcing assemblages of actors, institutions, and finance working to maintain incumbency.

However, from past transitions, we know that government and industry players can nudge fundamental changes by leveraging technology and stimulating pathbreaking entrepreneurship.

The sheer number of drivers of, and barriers to, the Energy Transition creates uncertainty. That said, the mission-orientated nature of the transition, along with fast-paced technological and cost developments, suggests that change will hold sway over continuity. However, in the absence of extraordinary action by humanity, the transition will not unfold rapidly enough to reach the climate goals established under the Paris Agreement.

Image 2: Energy Transition Timeline



1.2.1 Energy Transition in Asia Pacific

The speed at which the Energy Transition will occur will vary and is dependent on geographic position, the circumstances and the socioeconomic realities in each region. The drivers (Climate Emergency and its impact on humanity and economy, Paris agreement, energy security, urbanisation and quality of life, levelized cost of energy, technological progress, new markets and business models) are competing with strong barriers (policy uncertainty, conflicting priorities, energy market rules, subsidies and lack of externality pricing, status quo lobbying and social opposition, lock-in inertia and innovation gaps) which are balanced differently in different parts of the world. In the following, we share an extract of DNV GL's regional assessment of the Energy Transition, which illustrates the significant differences per region. For more information, refer to [1].

GREATER CHINA

Greater China's energy demand is expected to continue to grow strongly for the coming decade, before peaking in around 2030. The peak and decline will be the result of stabilisation of the population, reduction of the share of the secondary sector in the economy, and energy-efficiency gains in all sectors. These three forces are stronger than the effect of economic growth, which is also set to continue.

The share of electricity in the final energy demand will continue to increase, from 21% in 2017 to 52% in 2050 – the highest of all regions. The manufacturing sector will see particularly strong electrification, and both the transport sector – where China is the frontrunner in EVs – and the building sector, will see a rapid shift to electricity. The 2050 electricity mix will be dominated by solar PV, with a 41% share. Wind and hydropower will also be main contributors, taking the renewable electricity share to above 90%.

SOUTH EAST ASIA

South East Asia's final energy demand will continue to grow over the coming decades, starting to level off towards 2050. The largest increase in energy demand will come from buildings, associated with population growth and an increase in income per capita, leading to greater demand for space cooling and appliances. There will also be growth in the energy demand from transport and manufacturing.

The share of electricity in final energy demand will continue to rise, from 15% in 2017 to 41% in 2050. All three main sectors will see strong electrification in the period. The 2050 electricity mix will be dominated by solar PV, with more than one-third of the electricity supply, followed by natural gas and wind. Due to the region's geography and topography, offshore wind is expected to be large, with 15% of overall electricity supply.

OECD PACIFIC

The OECD Pacific's final energy demand has already started to decline and will continue to do so more rapidly than the fall in the region's population. The manufacturing sector will see the largest reduction, a result of production sites moving to lower-wage regions and efficiency gains. The efficiency of the transport sector is also increasing strongly, partly due to the fast uptake of EVs.

The share of electricity in the final energy demand will continue to increase, from 24% in 2017 to 50% in 2050, the second-highest in the world after Greater China. Both the manufacturing and transport sectors will see high electrification. The 2050 electricity mix will be dominated by wind, with more than half of all electricity production in 2050 expected to come from wind, one-third of which being offshore wind. With the solar PV share also significant, the share of fossil fuels in power generation in 2050 will be minor.

1.3 Disruption of the Energy Sector

The electricity sector is going through a transition towards a more dynamic and automated electricity system – with the imperative to remain reliable and affordable. This process of the Energy Transition and the balancing act between sustainable, reliable and affordable is referred to as ‘the energy trilemma’. This transition is also often described by the trends 'Decarbonisation', 'Decentralisation' and 'Digitalisation'.

For the power sector, this shift towards distributed renewable generation translates into an increasing amount of variable, i.e. ‘non-controllable’ power sources like wind and solar, and into a corresponding shift to smaller and more dispersed power generation (often called DER: Distributed Energy Resources).

Advances in Digital Technology are enabling these dramatic changes to our energy system. As the 4th Industrial Revolution blurs the lines between the physical and digital world, it is driving a fundamental shift in the energy industry and disrupting traditional market players. We have seen other industries fall at the mercy of technological and digital innovation, and we have seen new players emerge from these ashes. While the energy industry cannot allow itself to become the next Blockbusters or Kodak, there are already victims of the rapid changes being experienced in the sector. Moreover, power system assets are critical infrastructure and operators need to act based on facts — there is no room for being misled by hype when the reliability of our energy infrastructure has major consequences and can mean the difference between life and death.

The power sector, including utilities as well as system and network operators, are used to making huge decisions with investment horizons that span over decades. However, in many regions in the world, the stable environment in which such decisions are possible is disappearing because of the Energy Transition.

Governmental policies are driving the large-scale implementation of renewables with mixed success. Developments such as electric mobility might speed up, or stall; the use of residential solar and the use of solar panels on residential rooftops is expanding exponentially; market models around flexibility are designed to cope with (local) variable Renewable Energy sources. Moreover, because of the increase of power generation by wind and solar, the electricity system itself is becoming more volatile, which needs to be considered during the design of the network.

All these unknowns make long term investment decisions hazardous. So, in many regions in the world – including Asia Pacific, stakeholders in the electricity sector - utilities as well as network and system operators - are forced to make fundamental choices.

Traditionally, utilities used to make their largest profits with their power generation portfolio. Since 2008 that has changed drastically, and they are forced to rethink their complete business models, acknowledging the fact that the liberalisation of generation, combined with the increase of renewable generation results in a lasting shift of profitability from the beginning of the electricity value chain towards the end. The split between the traditional power generation and the retail and grid activities of E.ON into respectively Uniper and E.ON; and of RWE into respectively RWE and Innogy are examples of this on an organisational level.

However, at the end of the value chain, competition for consumers is fierce and might eventually result in a shakeout, if the utilities fail to diversify and create new value. Digital Technologies and concepts - including IoT, Data Analytics, Artificial Intelligence (AI), Blockchain and Digital Platforms - will be a part of forming this new value and differentiators. Chapter 2 of this report describes the most important Digital Technologies and their impact on the energy industry.

Despite all these changes, network and system operators often are required to operate in a strict regulatory framework and have an assigned task to fulfil. However, the dimensions and metrics they use in designing and operating their grid will also need to change. This is due to the emergence of distributed generation, less predictable and more correlated loads, and load situations that can change much faster than before, which may be caused by substantial installations of solar panels or charging stations of electric vehicles in a neighbourhood.

In summary, both energy utilities and grid operators face challenging times as their environment is changing and they are forced to cope with growing uncertainty and complexity, changing policies, regulations, market models and fast technological developments. Because of variable renewable power generation, the system is becoming more volatile, and these developments will accelerate the adoption of Digital Technologies and concepts in both, network operations and emerging energy parties, such as the aggregators and energy service companies.

2

Overview of Digital Technologies

Overview of Digital Technologies

Advances in Digital Technology are enabling the required dramatic changes to our energy system. Digitalisation is an important instrument for the Energy Transition and an enabler of two key industry trends: Decarbonisation and Decentralisation, both critical to enabling the Energy Transition.

The next chapters describe the most important Digital Technologies and their impact on the energy industry – namely IoT, Data Analytics, Artificial Intelligence (AI), Blockchain and Digital Platforms.

2.1 Internet of Everything and related concepts

2.1.1 Technology Introduction

The actual idea of 'connected devices talking to each other' has been around at least since the 1970th, then known under the name of 'embedded internet' or 'pervasive computing'. Kevin Ashton coined the buzz-term 'Internet of Things' (IoT) in 1999 during his work at Procter & Gamble [6], where he tried to get senior management's attention for a then-new technology called Radio Frequency Identification (RFID) – a form of wireless communication that incorporates the use of electromagnetic or electrostatic coupling in the radio frequency portion of the electromagnetic spectrum to uniquely identify an object, animal or person [7].

Internet of Things (IoT): IoT has yet a wider reach as it also includes connections beyond the industrial context such as wearable devices on people.

The term 'Internet of Things' reached mass-market awareness when in January 2014 Google announced to buy Nest for US$ 3.2bn [8], which today has developed to Google's smart home brand [9]. When talking about the 'Internet of Things' though, often this serves as an umbrella term for related concepts which together lay the foundation for the connectivity required to enable the Industrial Revolution 4.0 – also addressed as 'Internet of Everything' (IoE, a term used by Cisco) or 'embedded internet' (Intel) [7].

Internet of Everything (IoE): Still a rather vague concept, IoE aims to include all sorts of connections that one can envision. The concept has thus the highest reach.

M2M: The term Machine to Machine (M2M) has been in use for more than a decade and is well-known in the telecoms sector. M2M communication had initially been a one-to-one connection, linking one machine to another. However, today's explosion of mobile connectivity means that data can now be more easily transmitted, via a system of IP networks, to a much wider range of devices.

Web of Things: The Web of Things is much narrower in scope as the other concepts as it solely focuses on software architecture.

Industrial Internet of Things (IIoT): GE strongly pushes the term 'Industrial Internet'. It goes beyond M2M since it not only focuses on connections between machines but also includes human interfaces.

2.1.2 Current State and Use Cases

A current definition of the 'Internet of Things' is offered by McKinsey: Internet of Things = "sensors and actuators embedded in physical objects are linked through wired and wireless networks, often using the same Internet Protocol (IP) that connects the Internet."

Some well-known examples for 'Internet of Things' applications today are:

(i) Wearable devices/fitness trackers (for example, Jawbone Up, Fitbit, Pebble)

(ii) Home Automation (Examples: Nest, 4Control, Lifx)

(iii) Industrial asset monitoring (GE, AGT Intl.)

(iv) Smart energy meters

Current developments in the industry in Asia Pacific include:

SINGTEL

Singtel, in collaboration with Microsoft, announced plans early 2019 to launch an AI-powered IoT network over Microsoft Azure – a unified and programmable platform that combines intelligent connectivity with the cloud for IoT. Through integrating Singtel's IoT network functions into Microsoft Azure's core cloud capabilities, the aim is for IoT applications to flexibly migrate from devices to networks and clouds seamlessly [10].

With computing powered by Microsoft Azure, the platform will also tap into Azure's set of cloud services including IoT Hub, IoT Edge and other Machine Learning and cognitive services to extend cloud intelligence and analytics to devices. With insights-driven AI layered into the network, the platform delivers timely intelligence on the performance of applications and devices to facilitate better business decisions. This simplifies and facilitates the management, development and deployment of IoT devices and solutions in the cloud at scale.

ENVISION

Envision Energy is headquartered in Shanghai with a branch in Singapore and provides wind turbines, energy management software and energy technology services. Envision owns the intelligent IoT platform, EnOS, currently managing 100GW of energy assets globally. In Singapore, Envision Digital has been awarded the tender for the Hosting and Development of GovTech Device Management Control and Data Acquisition System (DECADA). The project aims to provide a ready-to-use IoT services platform to government agencies using Envision Digital EnOS IoT Operating System. EnOS provides an open platform to accelerate the development of next-generation IoT based solutions by government agencies in their Digitalisation goals [11].

TENAGA NASIONAL BERHAD

A total of 9.1 million households across Peninsular Malaysia are expected to be equipped with a Tenaga Nasional Berhad (TNB, large Malaysian utility) smart electric meter by 2026. Smart Meter or Advanced Metering Infrastructure (AMI) is an electronic device that records consumption of electricity and communicates the information to TNB for monitoring and billing. This data can be valuable for a utility to enhance their customer engagement and influence the consumers' consumption pattern by e.g. displaying back to them how energy is utilised and how it could be utilised more efficiently.

TELENOR CONNEXION

Telenor is one of the largest mobile network operators, with its APAC headquarter in Singapore. Telenor has a team of dedicated IoT experts organised as 'Telenor Connexion' with a regional office in Japan. Telenor offers the design, implementation, operation, monitoring and further development of IoT systems - together with partner companies – to provide their clients with custom made solutions.

ENGIE

Engie Group is a global firm transforming to offer low-carbon energy and services. In response to the urgency of climate change, Engie's ambition is to become the world leader in the zero-carbon transition with their customers - in particular businesses and local authorities. Engie relies on its key businesses (Renewable Energy, gas, services) to offer competitive turnkey solutions "as a service". The company is supporting the energy and technology revolution in various companies and regions. The Group has introduced two networks for the Internet of Things (IoT) in Belgium and Singapore to let smart objects communicate reliably, at low cost and without excessive energy use. Known as Engie M2M (Machine to Machine), the network enables a high-speed, low-energy data connection between connected objects [13].

2.1.3 Outlook

Digital Transformation relies on the availability of data. In 2015, there were about 15.4 billion connected devices. According to analysts IHS, this figure will grow to 30.7 billion in 2020, and 75.4 billion by 2025. Intel's projection is even bigger. The company forecasts 200 billion connected devices by 2020. However, much of the data generated by these connections is today untapped [2].

While the numbers differ slightly in the assessment of the current state and the projection towards the future, it is undisputed that connectivity will substantially increase going forward. The development of successful business cases will largely define the pace of growth of IoT. While it is clear that the Digitalisation of the energy ecosystem needs connectivity and data, it is equally clear that only useful data and connectivity will sustain, and a significant consolidation should be expected in the future.

2.1.4 Risks and Potential

In the energy sector, IoT holds great potential to gain better insights into consumer and prosumer (private and industrial) behaviours, to get a better picture of the current state of the energy ecosystem (generation, transmission, distribution, load) and to lay the foundation for automation of this ecosystem by fuelling other technologies such as AI with the required information for and feedback on automated decisions. This increased connectivity though also comes with potential risks that need to be addressed and can broadly be listed as [14]:

(i) Business risk:
  a. Health and safety
  b. Regulatory compliance
  c. User privacy
  d. Unexpected costs

(ii) Operational risk:
  a. Inappropriate access to functionality & Cybersecurity
  b. Shadow usage
  c. Performance & Quality of Data

(iii) Technical risk:
  a. Device vulnerabilities & Cybersecurity
  b. Device updates
  c. Device management

While IoT helps to gain better insights into an asset to managing it more efficiently, it is clear that IoT also adds a new layer of infrastructure that needs to be managed and maintained. This is one possible example of how Digitalisation may destroy jobs (e.g. machine operator) but replace it with (fewer) higher value jobs that require higher capabilities (e.g. analyst).

2.2 Data Analytics / Data Science

2.2.1 Technology Introduction

As discussed in the previous chapter, technologies such as IoT provide access to a large amount of data. This data in isolation is of limited value and needs to undergo a thorough process of Data Cleaning, Data Management, Exploration, Interpretation and Visualisation. The required skillsets for these activities are broad, including math, statistics, advanced computing, visualisation, domain expertise and data engineering. For many companies who plan to internalise Data Analytics and Data Science, this requires hiring individuals "who enjoy exploring, thinking creatively, and discovering new knowledge; who are constantly looking for patterns and anomalies in whatever space they are placed in", as Dr Kirk Borne, Principal Data Scientist and executive advisor at Booz Allen Hamilton, emphasizes [15].

Hilary Mason, CEO of Fast Forward Labs, and Chris Wiggins, Chief Data Scientist at the New York Times, have proposed a possible Data Science taxonomy that chronologically orders the functions of a Data Scientist [15]:

Obtain: Obtain a sufficient amount of usable data and derive information from multiple sources.

Scrub: Data scrubbing is the process through which any inconsistent labelling or formatting in a data set is rectified for consistency and accuracy. This is a tedious activity that may present the most labour-intensive part of a Data Science project.

Explore: This activity comprises the visual representation of data, for example, in the form of single-feature histograms, scatterplots or clustering, a process through which data is grouped based on similarities.

Model: Selecting a machine-learning algorithm or statistical methodology that fits the data being used in the project. That usually entails testing multiple models to find the best fit for the particular case.

Interpret: As Mason and Wiggins state, "the purpose of computing is insight, not numbers.". Hence the most important skill that a Data Scientist should possess is the ability to simultaneously produce models that output useful products to provide suggestions for which direction to explore next.

It is important to note that many organisations fail with the approach to maintain a Data Analytics / Data Science team in isolation. Best outcomes can be expected if these teams are working closely together with operational teams with subject matter expertise.

2.2.2 Current State and Use Cases

Data Analytics can provide the backbone for multiple use cases in the energy industry, such as [16]:

- Failure probability modelling
- Outage detection and prediction (predicting the influence of weather conditions on the power grid; predicting the impact of the near-term asset values on the power grid; detecting possible outrages by smart meter events; detecting outages in the specific areas, etc.)
- Dynamic energy management
- Smart Grid security and theft detection
- Preventive equipment maintenance
- Demand response management
- Real-time customer billing
- Improvement of operational efficiency
- Optimising asset performance
- Enhanced customer experience

[17] provides insights into how utilities can benefit from analytics with regards to cost reduction, reliability improvement and customer engagement:

Cost reduction: Analytics help large utilities increase capital productivity and save millions in operations and maintenance expenditures by helping them improve operations (which also reduces adjacent cost such as call centre volumes), optimize capital deployment (by identifying the most efficient ways to reduce risk) or understand their procurement better (weighing spending against value).

Reliability: Advanced analytics also help boost reliability dramatically by preventing outages through more accurate predictions about when to replace failing equipment or improving outage response through situational awareness (for example, automated dispatch through real-time identification of an issue) and better management of performance.

Customer engagement: Data analytics help utilities understand customers and their energy use better. This knowledge utilities can use to design new products and services, such as demand-side management programs that reduce electricity use at peak times. Analytics also allow utilities to provide more accurate information to customers about power outages, grid updates and repair work by field crews, all of which can raise customer satisfaction.

While Data Analytics is often undertaken in house or invisible to the public, some firms are offering respective services:

BAZEFIELD

BazeField is a Norwegian smart windfarm technology company which has been acquired by the Chinese wind-turbine manufacturer Envision. BazeField system includes turnkey interfaces for SCADA, grid, meteorological forecasts and trading systems. It includes a suite of monitoring, analysis and operations management applications, key performance indicator measurements and reports needed for supporting the operations and maintenance of wind farms, helping to improve data management for analysis. Integrating all of the data with condition monitoring sensors on the individual asset aims to reduce downtime, improve availability and increase the efficiency of assets [18].

GREENBIRD

Greenbird, headquartered in Norway with a branch in Singapore, has the vision of accelerating the energy revolution towards smarter energy solutions. The firm offers out-of-the-box system integration for utilities. Greendbird's solution Utilihive is a domain-specific integration hub, enabling the digital utility to create sustainable value from its data to ensure it can adapt quickly to the changing environments and opportunities in the ongoing energy transformation. By leveraging on data analytics, the grid operations can be optimised by using technology for predictive maintenance and self-healing grids. Nowadays, utilities are entering the data economy where the ability to fully utilise data from the digital grid infrastructure will determine future profitability. Greenbird strives to enable disruptive and data-driven business models [19].

SPARK BEYOND

Spark Beyond – with an office in Singapore – offer a platform that harnesses the world's collective intelligence by collecting open-source analytics solutions and integrating them into an analytics platform. For the energy industry Spark Beyond has developed analytics solutions towards (1) reduction of customer churn, (2) optimisation of EV charging, (3) outage and fault location, (4) retail product mix optimisation, (5) inventory management, (6) maximisation of asset production and (7) asset risk assessment.

2.2.3 Outlook

Data Analytics will become a common discipline across all industries, and talent will be scarce. According to the forecasts of the World Economic Forum [20], by 2020 data analysts will be in high demand in companies around the world. The LinkedIn Workforce Report maintains that, in the USA, demand for these professional figures has grown six-fold compared to five years ago, and data analysts will continue to be the most sought-after profiles over the next five years. This is further confirmed by IBM, which claims that the annual demand for data scientists, data developers and data engineers will lead to 700,000 new recruitments by 2020 [21].

This scarcity may be a temporary phenomenon only though, since (1) platforms like Microsoft Azure or IBM's Watson constantly get better equipped to offer out of the box analytics, (2) there is a large open-source and sharing community available to everyone – usually for free, which provides (3) a chance for everyone with a computer and an internet connection to join the Data Analytics scene (a great opportunity for countries like India, China and many South East Asian countries where access to education for different reasons is still difficult for many), and (4) there are an increasing amount of commercial companies and platforms that offer Data Analytics as a service to defined industries – as e.g. https://www.arundo.com/ or https://www.veracity.com/.

2.2.4 Risks and Potential

The single biggest risk of Data Analytics and Data Science is described with the jargon term “Crap in, crap out”. This refers both to the data as well as the models with whom the analytics are undertaken. Prof. Michael Jordan, University of California, Berkeley in an interview [22] warns that “The overeager adoption of big data is likely to result in catastrophes of analysis comparable to a national epidemic of collapsing bridges”. The essence is that any results gained through Data Analytics need to be critically looked at and tested before they inform any decision making.

The potential though is big if applied correctly and a necessity for the imperative Digitalisation of the energy industry. Already today, but even more so going forward, deep insight into data will define the competitive advantage of companies. The organisation of future grids will need to be AI-supported since humans will not be efficient enough to handle the complexity anymore.

DNV GL is working with leading utilities in South East Asia today to build the basis for a data-driven future. The major challenge is to transition the organisation towards a culture where data is collected and organised towards a common information model with clearly defined ‘single sources of truth’. This is a tremendous undertaking that can take years. However, it is an essential step for a utility to transition from an organisation that sells kWh to become a fully customer-oriented organisation with the ability to manage complex transmission and distribution grids.

2.3 Artificial Intelligence

2.3.1 Technology Introduction

The term “Artificial Intelligence” (AI) was officially introduced by John McCarthy in 1956. Google CEO Sundar Pichai believes that AI is the most important thing humanity is currently working on, while other prominent voices like Elon Musk have warned that AI may pose a threat to the human race. A key enabler of AI is Machine Learning (i.e. supervised, unsupervised and reinforcement learning) which - as a field of study - is an interface between statistics and computer science and enables machines to process and learn from data autonomously [23]. The concept is not new and went through a few winters over the decades, repeatedly falling short to satisfy expectations. However, with the recent advancements in computational power, AI is on the rise and already in many ways part of our everyday life (for example speech and image recognition, natural language processing, autonomous vehicles, fraud and intrusion detection).

The term “Artificial Intelligence” is often connected to the science-fiction vision of ‘robots taking over the universe’. And while there is indeed already a discussion about the so-called ‘possibility of singularity’ (the moment when AI becomes so intelligent that its intelligence will exceed that of its creators accompanied with a point of no return) and the need to contain AI to prevent this [24], this is far from reality today. As the former NASA scientist and principal Data Scientist at Booz Allen Hamilton, Dr Kirk Borne puts it, AI in its application today is more accurately expanded as ‘accelerated’, ‘actionable’, ‘adaptable’, ‘amplified’, ‘assisted’ or even ‘augmented’ intelligence [25] providing decision support or help to automate and to action decision process much faster than a human would be capable off.

A way of AI to develop its intelligence is to utilise so-called neural networks – a network of artificial neurons – to generate an output, based on weights associated with the inputs. This concept is inspired by the human brain and tries to replicate how neurons (i.e. nerve cells) in the brain receive inputs, process the inputs and then produce an output (i.e. the activation of a synapse) [23].

Two main challenges of this approach are that (1) dependent on the input the output can be biased [26] and (2) even if AI produces the correct outputs it is currently not fully understood how AI arrives at this output, which makes ‘explainable AI’ a current research field [27].

2.3.2 Current State and Use Cases

Artificial Intelligence is increasingly moving into the energy space and use-cases today span from Energy Forecasting, Energy Efficiency, Energy Accessibility [28] over Energy Management [29] to Cybersecurity, Fraud and Intrusion Detection [30]. Shawn Chandler, a senior member of the Institute of Electrical and Electronics Engineers (IEEE), pinpoints five main areas where AI in energy is beneficial [30]:

Reliability: Self-healing grids, operations improvement and efficient use of renewable resources and energy storage;

Safety: Outage prediction and outage response;

Cybersecurity of systems: Threat detection and response;

Optimisation: Asset, maintenance, workflow and portfolio management;

Enhancements for the customer experience: Faster and more intuitive interactive voice response, personalisation, product and service matching.

Below we have summarised some actual use cases:

AUTOGRID

AutoGrid is a US firm with a branch in Japan that provides a flexibility management solution for the global energy industry. It has been in collaboration with Amazon Web Services (AWS) to bring AI-powered distributed energy management to its energy-industry customers and to deliver new insights into operations across energy facilities that will optimise production and improve process efficiencies of distributed energy resources and demand response.

AutoGrid builds software applications that enable a smarter, distributed energy world. The company's suite of flexibility management applications allows energy companies to deliver clean, affordable and reliable energy by managing networked distributed energy resources (DERs) in real-time and at scale [31].

GRID EDGE

Grid Edge is a UK firm pioneering the application of AI for building energy systems. The company uses AI technology to create a unique foresight-driven approach to building energy management to dynamically optimise the building's day-ahead energy, carbon and comfort profile. The company introduces the concept of smart energy management from the perspective of not how much energy is being used, but when and how it is being used. Grid Edge develops cloud-based Artificial Intelligence software services to empower building operators to predict, optimise and control their energy profile, enabling them to become active and intelligent participants in the energy system [32].

NNERGIX

NNergix technology is a Spanish firm that uses satellite weather data and energy production values through customised solutions and specific monitoring designed for energy integration purposes. The company uses Machine Learning technology to forecast atmospheric conditions and weather, including the amount of hourly photovoltaic energy produced at power plants. The objectives include the development of specific predictive models for solar photovoltaic and wind power plants, including demand loads to generate a better control on assets based on the upcoming weather events [33].

SUNPOWER

SunPower is a US firm with branches in Australia and Japan that empowers homeowners to understand the amount of energy they can generate with solar energy by using aerial imagery and Machine Learning. SunPower produces solar panels with distribution to both residential and commercial customers. However, potential solar buyers find it challenging to fully understand the potential savings as well as individual factors which are unique to each home. By partnering with Google Could, SunPower has developed 'Instant Design', a technology that allows homeowners and businesses to create their own solar setup planning. With the help of an AI platform, the project allows for a calculation of the amounts saved by Solar Energy, including weather data, utility electricity rates, 3D modelling and shade calculations [34].

2.3.3 Outlook

Artificial Intelligence already today can support and action decisions much faster than human beings – though still within relatively narrow boundaries. The next couple of decades will show if AI can indeed hold the promise to be capable of as complex decision making as a human (with all the risk discussed previously and in the following to be addressed!). However, even on the way to that point (which may mark a point of no return and the end of human inventions as some belief [24]), it will have most likely a substantial impact on tasks undertaken by humans today. While this topic is discussed controversially [35], experience from earlier Industrial Revolutions suggest that “the end of humans in jobs” is a groundless fear, inconsistent with the evidence.

In the energy industry, indeed AI may much rather well be seen as an enabler for services and operations that may not be possible without AI and hence rather boost the industry than anything else – i.e.:

The expected substantial increase of Renewable Energy generation [1] for example is only possible if electric grids can be operated highly responsively. Generation and consumption forecasting based on weather forecasts, deep understanding of consumption patterns and predictive analytics regarding asset availability/downtimes, for example, will allow an improved and more reliable operation of the grid. With regards to grid failures, Artificial Intelligence can be instrumental in predicting these outages and automate the grid restoration.

Going one step further – looking at it purely from a technical perspective, assuming regulations are put in place to enable this and simplifying drastically for the benefit of clarity – Artificial Intelligence could optimise an electricity grid on entire system level. If every appliance (electricity consumer) and every generator (electricity-generating asset) are controlled by AI, that can predict at any point in time

- the consumption preferences/flexibility of each customer
- the availability and capacity of the grid and
- the availability and capacity of every generator

AI could maximise the overall value to the consumer and operator of the electricity system. Furthermore, AI could easily recognise deviations from the predicted consumption, availability and generation patterns and therefore detect potential failures off or intrusions/attacks on the system, flag those and work around those to keep their impact to a minimum.

What may read as (and today still is) a science-fiction scenario, is happening in parts and limited scale already today as the examples mentioned in [28] and [29] show. A small-scale demonstration project is, for example, the Power Matching City project in the city of Groningen [36].

2.3.4 Risks and Potential

While AI holds the potential to optimise the reliability, safety, cybersecurity, availability and value of the energy industry, AI also comes with mainly three pitfalls [23], namely Privacy, Replication and Bias.

Privacy can be defined as the state of not being disturbed by others or to be free from public attention. Although this may seem fairly simple, living in the information age means that the right to privacy is continuously threatened by various technologies that store, modify, and exchange personal data [23]. There are various risks associated with AI technologies that threaten individuals’ right to privacy. This list shows some of the ways AI applications can affect privacy:

Data exploitation: AI applications can generate, collect and share data of individuals/companies without their knowledge or consent, which may allow concluding personal behaviours or business practices.

Prediction: By analysing non-sensitive data that is readily available, AI applications can infer and generate sensitive information about individuals/ companies. For example, they can infer the (emotional) state of an individual or the success of a company based on changes of patterns.

Profiling: AI applications can be used to sort, score, classify, evaluate, and rank individuals and companies, often without their consent.

Replication is the inability of humans to replicate a decision made by a machine, and thus the inability to identify the reasons why a machine made a specific decision. In short, the problem is that humans cannot replicate how the neural network has reached its prediction without understanding how it is composed (structure), and what data has been used to train it – a task that can be incredibly difficult [23]. Applying this pitfall, for example to the optimisation of the energy system, will make it hard for humans to understand why a grid was operated in a specific way.

Bias is an important consideration when designing AI. When bias manifests within algorithms, it is commonly referred to as algorithmic bias. The concept of algorithmic bias refers to the instances where the data, which is fed into algorithms, contain biases (including political, racial, and gender bias), which result in the machine providing an output that aligns with the skewed and biased data that was used to train it. The prediction that the algorithm is designed to make is wholly dependent on the training data, so if the bias is not consciously eliminated from the training data, the predictions made by this algorithm could negatively impact how certain groups of individuals or companies are subjected to the algorithm [23]. Applying this pitfall to the optimisation of the energy system this could, for example, entail that specific groups of individuals or companies are provided with less energy than others.

2.4 Blockchain

2.4.1 Technology Introduction

Blockchain is a term widely used to represent an entirely new suite of technologies. At a high level, Blockchain Technology - also called distributed ledger technology (DLT) - allows a network of computers to agree at regular intervals on the true state of a distributed ledger. Such ledgers can contain different types of shared data, such as transaction records, attributes of transactions, credentials, or other information. The ledger is often secured through a mix of cryptography and game theory and does not require trusted nodes like transactional networks. This is what allows bitcoin - perhaps the most prominent use case of Blockchain to date - to transfer value across the globe without resorting to traditional intermediaries such as banks [99].

On a Blockchain, transactions are recorded chronologically, forming an immutable chain, and can be more or less private or anonymous depending on how the technology is implemented. The ledger is distributed across many participants in the network that does not exist in one place. Instead, copies of the ledger exist and are simultaneously updated with every fully participating node in the network. A block could represent transactions and data of many types - currency, digital rights, intellectual property, identity, property titles or others. Every node that participates in the network can verify the true state of the ledger and transact it at very low cost.

The technology is what economists call a general-purpose technology (GPT) with the potential to disrupt industries such as the Finance Sector, the energy industry or any sort of transactional business and offer substantial advancements in the handling of identity and privacy, smart contracts, provenance and ownership, Internet of Things, Robotics and Artificial Intelligence.

2.4.2 Current State and Use Cases

Blockchain is still at an early stage and can be implemented in many ways depending on the objective. This still causes a lot of confusion and hesitation in adoption. While the technology as such is relatively simple, its implementation often goes together with a radical change of workflows and shift of powers between the stakeholders in the respective ecosystem. In banking, for example, Blockchain could make the role of banks to settle and record the transfer of money obsolete.

There are already quite some Blockchain applications in the energy sector today, with most of them focusing on peer to peer (P2P) electricity trading and creative financing of Renewable Energy projects. The following introduces some of the use-cases:

ELECTRIFY ASIA

Launched in 2017, Electrify Asia is Singapore's first retail electricity marketplace that helps businesses and households to source and compare energy plans from a multitude of retailers. Electrify Asia describes itself as an energy technology company that is building sustainable energy ecosystems through the development of transactive energy platforms that will democratise access to clean energy across Asia Pacific. The company's marketplace acts as a web and mobile platform, allowing consumers to purchase energy from electricity retailers or directly from their peers (P2P) with smart contracts and Blockchain [37].

ENERGY WEB FOUNDATION

Energy Web Foundation (EWF) is a German/US firm that has pioneered an enterprise-grade Blockchain platform tailored to the sector's regulatory, operational, and market needs. EWF claims to be the world's largest energy Blockchain ecosystem - with a growing community of over 100 energy market participants. The Energy Web has become one of the industry's largest energy Blockchain ecosystem for decentralised technology powering the world's energy future [38]. In September 2019 EWF launched the 'PTT Renewables Marketplace Platform' in Thailand in cooperation with PTT (a Thailand-based multinational energy conglomerate) that is expected to be a fully commercial application by May 2020 [39]. The platform was inspired by strong corporate demand for Renewable Energy Certificate (REC) options in Thailand and ASEAN. The platform will help corporations buy regionally-sourced RECs to match energy demand from local facilities and give them a better way to track emissions through the supply chain. It also aims to give regional Renewable Energy developers a new revenue stream and ignite further investment in clean energy.

LO3 ENERGY

Lo3 Energy is a US firm with a branch in Australia that combines expertise in renewables with proprietary technology, creating solutions that will revolutionise the way to produce, consume, and think about energy. Lo3 Energy is partnering with utility companies, energy wholesalers, distribution and transmission system operators, and communities to develop customised innovations for energy secure future. Transactive energy is a concept that uses Blockchain Technology to conduct thousands of very small energy transactions between enabled systems automatically, creating a secure energy marketplace and effectively managing energy supply and demand at a local level. For the vast, sprawling region of South Australia, LO3 Energy has teamed up with Yates Energy Service's to enable transactive energy. The project is focused on the Riverland region of South Australia, offering commercial customers options in Renewable Energy sources and pricing, as well as incentives for generating and conserving energy.

The Goal of the project is to expand in scope to ultimately include a larger region and offer service to residential customers. [40].

POWER LEDGER

Power Ledger is an Australian headquartered firm that has developed a Blockchain-enabled energy trading platform to make energy markets more efficient. Power Ledger's technology can be used to make trading of environmental commodities and Renewable Energy Credits more transparent, secure and efficient. The market for trading environmental commodities is evolving rapidly, and there is a mounting pressure to ensure that credits are not double-counted or misappropriated. The proprietary Blockchain Technology of Power Ledger is designed to track energy from renewable sources to offset emissions as well as tracking the multitude of transactions relating to environmental commodities and Renewable Energy Credits. [41].

SINDICATUM BLOCKCHAIN TECHNOLOGIES

Singapore-headquartered Sindicatum Blockchain

Technologies has launched its Reneum platform in 2018 which aims to mobilise additional investments in Renewable Energy of $100bn by 2030 to support the Energy Transition. Reneum was the only project from Singapore, and one of only a handful of projects from the Association of Southeast Asian Nations (ASEAN) selected to be showcased at the Paris Peace Forum. The platform welcomes solar, wind or geothermal Renewable Energy projects of all sizes around the world, as well as selected other Renewable Energy projects. Once projects are accepted on Reneum's platform, they will be issued one Reneum token for each megawatt-hour of Renewable Energy that they produce. Renewable Energy generators can sell Reneum tokens to buyers of Renewable Energy including corporations, governments, institutions and individuals and via selected crypto-currency exchanges [42].

SINGAPORE'S REC MARKETPLACE

Recently Singapore has made it possible to buy and sell "green credits" for the companies looking to offset their carbon footprint. The SP Group (Singapore Power) – a government-owned electricity and gas distributor - has introduced the 'Renewable Energy Certificate Marketplace' powered by Blockchain Technology to connect the buyers and sellers of the Renewable Energy Certificates (RECs). The Blockchain Technology allows for quick, seamless and secure operation and validation for offsetting the use of non-clean energy in big companies.

SUN EXCHANGE

Sun Exchange claims to be the world's first peer-to-peer solar leasing platform. Through Sun Exchange, anyone, anywhere in the world, can own Solar Energy-producing cells and generate revenue by leasing those cells to power businesses and organisations in emerging markets, with installations and maintenance taken care of by Sun Exchange's partner network. Sun Exchange leverages on financial innovation and the power of the crowd to drive sustainable energy development and make the environmental, social and economic benefits of solar accessible and affordable for all [43].

IMPACTPPA

ImpactPPA is a Blockchain-based technology platform that strives to transform the global energy marketplace allowing consumers of energy to "Pre-Pay" for electricity from a mobile device. ImpactPPA uses Blockchain to provide a payment rail for investors, project developers, service providers, governments utilities and others, driven from a trusted and transparent platform. The ImpactPPA solution also allows for the unbanked population of the world to gain identity and reputation through transacting on the platform for the most basic of needs – electricity [44]. ImpactPPA was selected in 2018 as the Blockchain technology provider for the Indian government initiative, Bhartiya Harit Khadi Gramodaya Sansthan (BHKGS), which loosely translates to the "Indian Green Cotton Textile Village Development Organization". This initiative aims to employ up to 50 million women from various states in India.

ELECTRON

Electron is a UK-based energy technology company, combining Blockchain and energy expertise to design and build a digital infrastructure for the energy industry. Electron develops the identity and trading platforms that will underpin the transition to cheaper, cleaner, more resilient power systems. Electron's vision is to capitalise on the opportunities presented by the rapid changes in the energy market, driven by Decarbonisation, Decentralisation, Digitisation and Democratisation. The company aims to create innovative, collaborative solutions, based on the Blockchain's guarantees of a secure, robust and transparent platform [45]. Recently, Electron awarded funding to run a flexibility trading platform in South Korea in collaboration with the local partner GridWiz [80]. The collaborative work will research, design, and test an energy flexibility product for the South Korean electricity market. The platform will be built on Electron's existing flexibility trading platforms, creating energy flexibility with a cheaper and greener electricity system [80].

2.4.3 Outlook

Blockchain is likely to play a significant role in the energy industry in the future, unlocking use cases and business models which are hardly viable today. This is mostly because of an immense cost reduction potential in the recording and actioning of transactions as well as the potential speed (lacking currently, see below) and immutability of Blockchains.

2.4.4 Risks and Potential

While Blockchain is often described as an immutable ledger, it is not completely free from potential risks. The inbuilt security – often through a mix of cryptography and game theory – and consensus process are designed to make it incredibly expensive to retrospectively change the ledger (and hence limiting the motivation), but a collusion of nodes (more than 50% of the nodes intentionally confirming a modified entry retrospectively) or the advent of quantum computing could potentially jeopardize the integrity of public-key cryptography, which is the backbone of Blockchain security [46].

Another drawback is that today the consensus mechanism is still comparably time intensive and the technology is not ready today to record a large number of transactions happening in the energy ecosystem. There are though less time- and energy-intensive consensus mechanisms in development and that problem is likely to be solved.

Assuming these hurdles can be overcome, Blockchain has the potential to become the next general-purpose technology (GPT), driven mostly by large cost savings, taking out intermediaries and middle-men. New business cases – such as an induction charge of an EV at a red traffic light [47] – will be unlocked, opening new ways of using energy, which today are not viable since the administration of the transaction may cost more than the value transferred in the transaction.

Another potential of Blockchain is the financing of new Renewable Energy projects (also refer to Use Cases above) by either enabling crowdfunding (for example giving the public access to small ticket investments vs institutional investors) of projects or the tokenisation of (subsidised) kWh (to be produced in future).

2.5 Digital Platforms

2.5.1 Technology Introduction

Digital Platforms in the enterprise world empower technologically-enabled and data-driven business models that create value by digitally facilitating exchanges between two or more interdependent groups, i.e. matching providers with consumers. They typically manage an end-to-end business process, necessary to achieve the goals of their customers and partners. For example, making transactions and interactions more efficient or improving customer experience [48].

Platform business models are powerful because of the positive network effects that can arise from their eco-systems of connected providers and consumers, compared to others building single services only. They have therefore become one of the most important and successful business models of the 21st century, where five of the six most valuable firms in the world are built around these types of platforms. Platform businesses have been around for quite some time already, and going back 20 years, 43 publicly-listed platform companies were identified in the Forbes Global 2000. These platforms generated the same level of annual revenues (about $4.5 billion) as their non-platform counterparts but used half the number of employees. They also had twice the operating profits and much higher market values and growth rates.

Digital Platforms have technologically been enabled by the dot.com, IT revolution and the “fourth industrial revolution”, where internet, cloud, computing power and personal computers and phones have made it possible to efficiently connect the whole world in “one place”, namely a Digital Platform. Platforms today are mainly cloud-based and can for easier definition and analysis be split into two categories; innovation platforms, and transaction platforms. It is also possible to create a hybrid between the two.

- Innovation platforms enable third-party firms to add complementary products and services to a core product or technology. Prominent examples include Google Android and Apple iPhone operating systems as well as Amazon Web Services.

- Transaction platforms enable the exchange of information, goods, or services. Prominent examples include Amazon Marketplace, Airbnb, or Uber.

However, creating a successful platform business is not easy. The most common mistakes platforms make when trying to establish a successful business can be described as (1) mispricing on one side of the market, (2) failure to develop trust with users and partners, (3) prematurely dismissing the competition, and (4) entering at the wrong time.

2.5.2 Current State and Use Cases

As mentioned, platform business has been around for quite some years; however, it differs how far and mature it is, depending on industry vertical and if it is business to consumer (B2C) versus business to business (B2B) oriented. B2B platforms are far less mature than B2C platforms, and progress is only slowly made on how to take advantage of the platform business models in B2B.

In the energy industry, potential B2B platforms are provided by the OEM's such as Virtual Power Plant (Bosch), Decentralized Energy Management System (SIEMENS), Symphony Plus (ABB), Digital Power Plant (GE), with the limitation though that their ecosystems are usually very much restricted by the OEM's ecosystem, and that data sharing between these platforms is not encouraged. There is no off the shelf solution that allows, for example, a utility to gather the data of their critical assets on one platform (let alone the fact that some operating power assets are so old that already the data extraction is a problem) to feed applications (developed in-house or bought in) with this data to unlock greater potential.

An even never space for the energy industry are B2C platforms. Some utilities have established digital interfaces with their clients, but those are mainly used to provide consumption insights or some basic benchmarking. Executives have recognised that B2C platforms can help them create new ways of engaging with customers and reimagine customer experiences, launch products as a service and not least develop entirely new business models that can open significant new revenue streams besides selling kWhs. However, they also realise that this will be a years-long journey, that starts with basic tasks like Data Quality, Data Management and the establishment of a Common Information Model accompanied by large investments into the upgrade of their assets. According to Accenture, 50% of executives think platforms are core to their business strategy, while around 40% of executives believe platforms enable their core strategies. In the following some use cases:

SP GROUP POISED TO TRANSFORM INTO 'POWER SECTOR'S UBER'

SP Group - formerly known as Singapore Power Ltd - owns and operates electricity and gas transmission networks in Singapore and Australia. The group, fully-owned by Temasek Holdings, made S$923.5 million in net profit in 2016, on revenue of S$3.9 billion. As wave after wave of disruption buffets the power sector, grid operator SP Group is taking steps to turn itself into the industry's "Uber": In time to come, it sees itself providing a platform that matches the supply and demand of power, especially as power generation becomes a fragmented and distributed business.

At the heart of this transformation is the desire to stay relevant to the Singapore consumer, particularly as the progressive liberalisation of Singapore's electricity market has led to a fully open market by mid-2018 [49].

MERALCO TO REINFORCE CUSTOMER SERVICE ON 'DIGITAL PLATFORM'

The Manila Electric Company (Meralco) announced in 2017 its ambition to get into the "app-y preferences" of electricity consumers, with it reinforcing customer service on a digital platform [50]. Meralco President Oscar S. Reyes said the utility firm will be enhancing its "customer-centric" approaches by "making sure that service to the customer will be at its highest on reliability and efficiency as well as on ease of doing business." He stressed that the company will be "investing handsomely on putting out customer service on Digital Platforms because that’s how new customers have been relating. Everybody is now into the digital space.”

Since 2016, Meralco has been working on its suite of “digital transformation marketing tools and solutions,” including its: “I Join” that shall enable customers to start and track their applications online; “I Pay” which digitizes the utility firm’s billing system and enhances capacity of online payments; “I Ask” that unlocks self-service knowledge database for customers and will also allow them to chat directly with a live agent; and “I Need Repair” that sets competence for Meralco to inform its customers on power outages and restoration via short messaging system, e-mails or push messages.

With these new offers, the company noted that it would be able to meet its changing customer needs by opening new digital channels, “providing more information and insights and offering more innovative products and services.”

2.5.3 Outlook

While the potential and benefit of Digital Platforms are clearly understood and it is widely accepted that business and clients are demanding for their implementation, the transition towards this future will see iterations and consolidation – potentially the entry of disruptors from other industries.

The big challenge is that moving towards a meaningful platform model requires an integrated approach that will need to cut across the entire value chain from generation to use, with the target to optimise the system performance rather than the individual asset. This comes with a shift from a ‘provide services to an end-user’ to a ‘user in the centre’ approach. In the extreme case, no human interaction will be required anymore on the generation, transmission and distribution side in future. Most of the utilities would therefore, if they remain in their current setup, degenerate to commodity providers providing maintenance to the assets they own (or are contracted to look after). Their value share in the Internet of Energy could be marginal, and data powerhouses like Alphabet (Google), Microsoft and Apple or alike may gain significant power in the electricity industry, providing the platform, including communication, data storage, data analysis, process control, reporting, billing, user interfaces, etc. All of them do already have connections into our households and businesses and have collected many user data over the years.

2.5.4 Risks and Potential

Applications on Digital Platforms usually outperform even better designed stand-alone applications – at least if the platform application is well integrated into the platform's ecosystem, as this opens the possibility for many additional services to compliment and increase the value generated. Because of this, it is expected that more and more firms will build or join a platform to deliver their services, and the firms outside the network will struggle to create enough value alone to be able to compete.

The rapid expansion of platforms across industries represents a tremendous opportunity for companies to grow. However, it also can seriously threaten a company’s business - and in some cases, its very existence - if a company fails to define its platform strategy effectively. Things to consider include but are not limited to:

Exclusion and Competition: If the strategy is to not engage in a digital platform model now, other platforms (e.g. Telecommunication) may try to incorporate competing solutions into their ecosystem, which then presents a much higher value to clients and wins them over.

Marginalisation: Digitalisation is changing what it takes to generate value. This may imply that a company cannot grow in the traditional way anymore, and new business models need to be defined that allow charging e.g. a percentage of the created value.

Reach: Digital Platforms and ecosystems work best if they have a global reach. How should the regulatory apparatus, which still focuses on the dynamics of one country at a time, be adapted? We see recent pushback from politicians in several countries and talks about splitting up platform firms, but this will be hard to do in practice due to the network effects that tend to drive users towards the largest network.

Moreover, there are security risks as well. Platforms are a highly lucrative target for threat actors since they hold a great amount of data (that may be stolen or compromised) and a breakdown of the platform could potentially harm a large number of businesses/users. In the worst case, a large scale, long-duration power outage induced by a threat actor could have a massive impact on the society and economy of an area or even a country.

2.6 Interdependencies

With the Energy Transition progressing as an imperative to combat Climate Emergency by integrating large amounts of, for example, Renewable Energy and Electric Vehicles towards a more sustainable future, the Digitalisation of the energy system equally becomes imperative. Large amounts of variable generation (wind and solar) and dynamic loads (EV fleet, deferred consumption, etc.), as well as increasing request for customised services, steer the energy ecosystem towards a highly complex system that cannot be operated efficiently by humans anymore.

The challenge though is that the time to substantially combat Climate Emergency is shorter than it will take to transform the energy system probably. In addition, the growing threat of cyber-attacks on an increasingly connected energy ecosystem is not helping this dilemma either. All major technology providers, numerous start-ups and most of the stakeholders in the ecosystem though understand this challenge also as a chance to step up and jointly move towards secure, data-driven operations. The Digital Technologies described in isolation above will unfold their biggest potential if they are combined, which would allow achieving four main targets of the energy industry:

Asset life cycle management: Real-time, remote-controlled or predictive maintenance extends the life cycle or operating efficiency of generation, transmission or distribution assets and infrastructure. Key initiatives are Asset Performance Management, Digital Field Worker and Smart Asset Planning;

Grid Optimisation and Aggregation: Grid optimisation is possible through Energy Aggregation Platforms, Real-time Supply and Demand Platforms, Real-time Network Controls, and Connected and Interoperable Devices – enabled by connected assets, machines and devices, and advanced monitoring capabilities;

Integrated Customer Service: Digitally enabled products and services relating to energy generation and energy management can be bundled into integrated customer services. Key initiatives are Energy Storage Integration, Digital Customer Model, Energy Solution Integration and Energy Management;

Beyond the Electron: Hyper-personalized connected services go beyond the electricity value chain and adapt to the consumer. In this way, electricity stops being a commodity and becomes an experience. The three initiatives are Living Services, Industrial Services and Municipal Services.

3

Other Technologies

Other Technologies

Apart from great advancements in the Digital Technologies described, there are several other technologies which – partly empowered by Digitalisation – have a great impact on the future of the energy industry – namely storage and other flexibility options which will play key roles [51]. A range of flexibility options are summarised below:

Energy Storage

Technologies include pumped-hydro, batteries, flywheels and compressed-air storage in caverns. Pumped-hydro and batteries are the only technologies considered to have any significant impact.

Greater Interconnection

Improving connections between neighbouring grids enables balancing of supply and demand over larger geographies, ‘smoothing’ variability and improving robustness to failures. Such as the approved 1.4 GW NorthConnect interconnector between the UK and Norway, which will be 665 km of high-voltage direct current cable, due to be operational in 2023/24.

Flexible Generation

Electricity systems already make substantial use of generators with the ability to start quickly and vary their output rapidly. Examples are hydro and diesel generators, and open-cycle gas turbines.

It should be noted that output from solar PV and wind generation can also be adjusted rapidly; but while power can be easily reduced, any increase is limited by weather conditions at the time. This limitation is removed where storage is integrated into hybrid systems so that output can correspond more closely to demand.

Flexible Demand

Integrating Demand Side Response (DSR) measures to encourage reduced power consumption at peak times reduces strain on the grid and lowers costs for the consumer. We predict the DSR market to grow both in industry, where it is more established, and in commercial and residential buildings. The lower cost of sensors, greater data processing capacity and advancements in Artificial Intelligence will enable DSR to be applied in a more automated and specific manner, providing a more granular level of control. EV charging is also a major new source of DSR both for fleets and domestic use.

Flexible Markets and Regulation

With more distributed generation and DSR, greater flexibility in markets will evolve to enable power systems to operate efficiently. The increased number of sites to manage will lead to greater devolution of responsibility; this may result in Transmission System Operators (TSOs) being responsible for frequency management and black start, with Distribution System Operators (DSOs) and other market participants taking a larger responsibility for voltage and reactive power flow. Flexible and interconnected markets and regulation will be important in facilitating closer cooperation and coordination between market participants, such as cooperation within each synchronous area (an area where the frequencies of the electrical grids are synchronised) for efficient frequency control.

3.1 Storage

Of the options summarised above, energy storage is the area where we predict the most significant growth. Pumped-hydro is a mature storage technology predicted to grow noticeably over the coming decades but limited by the number of places where it can be used.

With recent advances in battery storage technology and, importantly, lower costs due to greater production volumes, its use is predicted to grow significantly in the coming decades.

Lithium-ion (Li-ion) is currently the most cost-effective battery chemistry for most battery storage uses, including large-scale applications for the grid and in EVs. We predict it to dominate the battery storage market over the coming five years. Further refinement in Li-ion batteries will improve their performance, increase energy density, and reduce the use of key raw materials such as cobalt. Newer battery technologies such as solid-state also offer better energy density, reduced fire risk, longer life and faster charging/discharging capability; these are likely to be mass-produced in the next five to 10 years. Redox flow batteries are currently very limited in use but do offer a potential solution for longer storage periods, and as such may see increased use beyond 2030 as variable renewables penetration increases.

Battery storage also offers flexibility through modular construction easily adapted for residential use, typically sub-15 kWh; smaller behind-the-meter projects, typically sub-1 MWh; or for combining multiple battery containers to provide hundreds of MWh of storage. The first GWh-scale projects will be built in 2020 with more to come over the next five years. We anticipate that although large scale in-front-of-the-meter battery storage projects will offer the lowest cost option for power system batteries, there will be a large market for residential and behind-the-meter storage where they can maximise the value of local generation and minimise peak power costs for consumers.

Demand Side Response (DSR), interconnections and storage, particularly batteries, are good for the short timescales. For example, we are beginning to see significant growth in batteries being used along with solar PV to smoothen the mid-day peak in solar production into the evenings.

The greatest challenge to flexibility providers is seasonal variability in demand, and in the wind and solar production. Storing surplus solar production in summer for use in winter/monsoon is unfeasible with conventional batteries. Long- duration technologies that decouple power and energy to take advantage of low-cost storage materials are required. Such technologies could use pressure, gravimetric or electrochemical conversion processes, but many are not in widespread commercial use today. In addition to hydro reservoirs which are in use, credible options presently include power-to-gas or liquid fuels and long-term heat storage for use as heat, such as in district heating systems. These options are examples of 'sector coupling', connecting electricity markets to gas, fuel, and heat markets.

3.2 Demand Side Response (DSR)

Demand Side Response (DSR) has been available to industrial companies for decades. However, increasing penetration from onsite renewables will create the opportunity to provide further flexibility through DSR, supporting and benefitting from the broader Energy Transition.

DSR can be implemented through time-based electricity tariffs encouraging consumers to reduce consumption during high tariff periods; it can also be implemented in reserve markets through tendered contracts between utilities, Transmission System Operators (TSOs) or Distribution System Operators (DSOs) and end consumers, mostly industry. For example, companies that have daily pumping requirements have a certain electricity demand, but the exact time in the day (or week) of this demand could be changed according to flexibility requirements in the market without disturbing the company's primary processes.

DSR can be used to control demand profiles in various ways, such as peak shaving (to reduce peak load on the system) or by increasing demand (for example to help with frequency control or to absorb local surplus Renewable Energy). In manufacturing, decreasing or switching off non-time-critical processes could provide demand-based flexibility. Examples include short-time batch processes, municipal water pumping and wastewater treatment.

Additionally, local microgrids or smart grids could provide larger, aggregated demand-side flexibility from clusters of end consumers (homes, small industries and businesses). Within these future systems, sophisticated communication and controls could be integrated to coordinate flexible resources across consumer-based supply and demand, both for local purposes and as a service to the central level.

3.3 Electric Vehicles

Electric Vehicles (EVs) are more than three times more efficient than the internal combustion engine and have zero emissions at the point of use. With that, they have the great potential of carbon dioxide emission reduction of road transport.

EVs providing flexibility in the grid is also an important trend. They can be viewed as smart, connected batteries on wheels. As range increases, charging infrastructure improves, and the uptake of EVs accelerates, the option of using spare capacity in EV batteries for vehicle-to-grid (V2G) services becomes increasingly valuable. In future decades, as EVs dominate new vehicle sales, we predict they will play a major role in frequency response and help to shift renewable generation to when there is greater need.

By 2032 we predict that 50 per cent of sales of light vehicles worldwide will be electric. That is a massive increase from today and recent reports show that, in Europe, sales of battery electric vehicles and plug-in hybrids totalled over a quarter of a million in the first six months of 2019, which is over a 30 per cent increase compared with the same period in 2018.

Globally, industry experts expect that by the end of 2019 there will be over four million electric vehicles on the road, which is a significant increase over 50 per cent year on year. And although Norway remains the leader in this sector, a much bigger impact will be made in the world's largest countries:

India has announced the faster adoption and manufacturing of hybrid and electric vehicles scheme called the FAME India policy. This policy aims to foster greater demand for electric vehicles, as well as promote a greater supply of them – to drive the local industry and combat air pollution in India's megacities.

China has invested over 60 billion US dollars in the electric vehicle industry over the last decade and is leading the way in the electric vehicles industry. There are more electric vehicles on the roads in China than in the rest of the world combined. Again – a big driver is combatting air pollution – but also the rapid development of world-leading technology. There are over one hundred electric vehicle manufacturers in China and some, for example the Chinese SEIC motor corporation, is planning a 350 million USD investment in India through MG Motor, which is its British subsidiary.

Also, the established and traditional car manufacturers globally – including but not limited to Ford, Volvo, VW, BMW, Mercedes – are investing heavily in electric vehicles.

The two obstacles for large scale adoption currently are still the high upfront cost to the consumer as well as the charging station infrastructure. While cost will come down and the network will increase over time, we see creative solutions to this problem, such as the Singapore based EV sharing business https://www.bluesg.com.sg/ who operates a network of 1,000 shared cars and self-service stations located in the city centre, public housing and commercial estates around the island nation.

4

Impact of Digitalisation and Digital Technologies on the Energy Industry

Impact of Digitalisation and Digital Technologies on the Energy Industry

More and better data, advanced Data Analytics, greater connectivity, and automation are already making energy systems cheaper and more efficient. Although those aspects of Digitalisation will deepen, it is Artificial Intelligence and Machine Learning that will open up new business and value-creation models for a greater number of players, including aggregators and prosumers.

The broad effects of Digitalisation are starting to gather pace in power systems, industrial production, transport, buildings, and oil & gas.

4.1 Cross-connectivity of the Energy System

Smart technologies are changing how power is transmitted, distributed, and managed. The complete automation of energy billing and accounting processes is already well advanced in certain regions, but in future will be standard practice across most parts of the world. IT platforms will open the door to new distributed providers of energy and flexibility, helping to balance grids connected to ever-more sources of power. These sources will include individual households, communities, or investor groups selling electricity from wind, rooftop solar, and EVs back to the grid.

Connectivity is an important enabler of variable renewables, which, even at utility-scale, typically have a smaller generation capacity than traditional power plants. For solar PV, assuming, on a global basis, that the average size of a utility-scale power plant is 200 MW, then 40,000 solar-PV power plants will need to be connected to achieve the predicted total installed utility-scale capacity of 8 TW by 2050. Smaller PV installations, i.e., hundreds of millions of rooftop installations, will increase demand for connectivity. Applying the same principles for wind, and using a 300 MW average power plant size, then 12,000 onshore, and 5,000 offshore, wind farms will be connected to the nearby grid [1].

Variable renewables require storage, and much of this will be provided by the EV fleet, comprising almost 3 billion vehicles in 2050. Achieving this will require smart connections to the grid. It will also need business models that incentivise vehicle owners to make their batteries available as temporary components for balancing the grid.

With ever-greater and ever-more distributed electrification, the electricity grid will triple in size from today to 2050. Not only will this future grid be vastly bigger, but it will also be more efficient – controlled by AI, using data platforms – and will effectively become the hub of an ‘Internet of Energy’.

In all sectors, Digitalisation will increase asset utilisation, optimisation, and integration. For example, digital information and communication technologies will allow tighter integration of gas use in power plants and electricity networks.

Consumers who use both gas and electricity for heat, depending on the local energy mix, will be contingent on automated, digital control systems in order to manage this complexity in real-time and for utilities to deliver the best price for the consumers’ needs. Supporting Digital Platforms will also provide regulators and other stakeholders with greater insights into markets. This will lead to more competition and lower prices, including across national boundaries.

4.2 Increased Asset Utilisation through Digitalisation

Digitalisation and connectivity will enable increasing asset utilisation across all demand sectors, reducing energy use per unit of service delivered. As the assets themselves become more efficient (for example, EVs), this will have profound implications for the global energy system.

In addition, energy asset data, when combined with external weather and market data, provide opportunities for further improving forecasting and utilisation across the energy value chain.

Organisations that are able to utilise all connected information will be able to drive the Digital Transformation, creating new business models that would further reduce costs for the consumer, and, at the same time, allow the companies to increase their profitability. Examples are where asset-heavy industries use Digital Transformation to re-emerge as organisations that provide services to their customers – the so-called 'servitisation' of an industry. This leads to increased efficiency, including maximising asset use - but decreasing energy use - per unit of service delivered, and thus providing the opportunity for more players to become producers, as well as consumers, of energy services [1].

Especially for the network operators though there are some hurdles for asset management to become more data-driven [52]. One major hurdle is that existing grid assets have a very long (technical) lifetime, some ranging over 60 years – and many of them are not monitored (this was not on the agenda when they were installed decades back).

There is extensive knowledge and information about failure mechanisms and core failure causes available, gained by power failure investigations. However, there is surprisingly little 'raw' data about asset failures – and if, they are difficult to compare. Grid assets may operate under very different circumstances and in very different environments. In combination with the limited amount of failures, it is a challenge to gain enough statistically relevant data to use common 'Big Data' techniques to correlate data of asset failures with data about their historical use and environment. So, while there is no doubt that asset management - especially asset maintenance - will benefit from Data Analytics, there are two main challenges to overcome:

1. How to gain more relevant data about asset failures and especially near 'misses'—to optimise maintenance models (obviously without creating more failures), and

2. How to maximise the learning from the data that is available by 'generalising' it somehow so that it can be linked to data from assets operating in different situations and circumstances, as well as generally be applied to all assets considering all different uses and circumstances.

The first challenge can be greatly reduced if grid operators would share data about failures — as well as their healthy asset population — to some extent. There is much value in sharing data if that gives a competitive advantage. For grid operators (who do not directly compete against each other on the reliability of their grids), there would be great value in sharing information about asset failures. Sharing data with (energy-intensive) industry may help increase both the (healthy) population data and the failure data. Standardisation, recommended practices and independent IT-platforms may support such developments. The oil industry recognised decades ago that they were not competing on the reliability of their assets and are now sharing reliability data in the OREDA organisation (Offshore and onshore Reliability Data).

The second challenge can only be addressed by recognising that the availability of (failure) data will remain an issue and thus a different approach is required than with normal big data applications, that presume an 'abundance' of data. The required methodologies need to make optimal use of the relatively small amount of data that is available. For example, as assets will be more and more monitored, new tools, such as 'rare event' statistics, can be applied, giving better predictions of the asset lifetime.

Increased monitoring also means that failure data and data about the circumstances and environment before and during the failure will become available. However, for this to become truly valuable, this needs to be generalised to apply to the whole asset population.

Although Data Analytics promises to find predictive patterns in the data in isolation, combining it with fundamental knowledge about the system has huge benefits. This “knowledge analytics” can be represented by a Bayesian network, which is essentially a complete representation of the interconnections between different features of a system that lead to performance failures.

The interconnections in a Bayesian network are represented by conditional probabilities (for example, the probability of an interconnect failure given the probabilities of encapsulation), which are derived from data, experience, and models. Using Bayesian networks in this way offers several advantages: they can be used to perform sensitivity analyses, thus providing leading indicators of failures; they can be used to conduct dynamic risk management using sensor inputs.

With the help of Bayesian networks, raw data from among others power failure investigations, as well as other sources, like sensors, can be unravelled or factorised into root causes and root mechanisms that impact the probability of failures. These factors can then be compared with factors of other failures and recombined and used to predict the probability of failures of other assets, even assets in different circumstances. The advantage of this methodology is that these ‘root’ factors (i.e. core aspects affecting failure) can be updated with new specific data as it becomes available (using, for example, Bayesian statistics) and thus an ever-increasing ‘knowledge base’ is created.

In addition, the opportunity to combine data from multiple sources (for example multiple cooperating grid operators from all over the world or in a specific region), stakeholders multiplying knowledge on their existing assets might prove invaluable to speed up the learning experience of new, relatively unfamiliar asset types, like DC equipment and batteries, making their application in the future much more likely to be successful.

4.3 Impact of Digitalisation on Grid Operations

For both utilities and grid operators, the ability to optimise and fine-tune their operations is ever increasing. However, as they control increasingly detailed aspects of the power system, they increasingly require more and different kinds of data and more advanced models and Data Analytics to do so. So, to fully benefit from Digitalisation and Data Analytics, it is inevitable that the analytical processes, as well as their eventual results — i.e. the decisions and actions — are automated. A typical example is the ELVIS information system of FinGrid, applying among others, IBM’s Watson, to enhance many grid related applications, in operations as well as in asset management [52].

Distribution System Operators (DSOs) need to automate Data Analytics for optimising operations to a much larger degree than utilities or Transmission System Operators (TSOs). This is due to the size and numbers of the issues they might face. Instead of facing a few ‘global’ problems, DSOs face multiple relatively small local problems.

For example, capacity problems due to the intermittency of solar power generation or the sudden charging of electric vehicles will likely appear in many parts of the grid simultaneously. Each of these individual problems will be too small to justify manual decision making.

Grid automation includes tap changers and smart transformers, managing voltage levels in the grid so power can flow ‘two ways’. It includes automated grid-reconfiguration of loops to reduce both grid losses as well as reduce the effects of potential outages and the effects of outages themselves, in the context/case of self-healing grids. It might also include activating automated demand response and local storage, that will help

DSOs to reduce peak loads to avoid grid losses and capacity problems. Also, the management of the maintenance workforce will be optimised using more data and smart analytics/Artificial Intelligence.

The operations department within the DSO will get a more strategic role as grid automation, and the use of the flexibility of customers' assets will gain importance and prove to be a viable alternative to investments in excess capacity to accommodate the increasing amount of variable renewable generation and demand.

This will be achieved by incorporating more automated analytics and decision support, both on a local and a global level, to utilize the potential of flexible demand of electric vehicles, heat pumps, building climate installations and some industrial processes to balance against the variations in the power generation of renewables, reduce resistive losses and implement concepts like self-healing grids.

Through 'faster-than-real-time' simulations for example based on load flow simulations and state estimation, it will be possible to incorporate scenarios and risk in operations, gaining large operational benefits both in cost reductions as in quality or risk reduction (for example fewer customer minutes lost). Operations can be optimised using several forecast scenarios and potential risks, including risks associated with using Information and Communication Technologies (ICT) itself.

The simulation models itself can draw from previously compiled, more detailed simulations and learn over time, developing an increasing ability to prevent grid instabilities that otherwise might emerge because of unexpected interference of behaviour of smart devices [52].

This behaviour is simulated by 'digital twins', digital models that are compiled beforehand and then tested (and certified) so they can be trusted to react the same as their real counterparts and thus can be used to study and examine their behaviour on the grid and other digital twins. They can be published for use by other grid operators, for example using Blockchain Technology to ensure their integrity.

For other stakeholders in the power system, Data Analytics and automated decision making can play a similar role in operations. Automation already plays a major part in power trading (similar as in stock market trading) and in control of power plants and is likely to expand further.

4.4 Improved RE resource planning and dispatch

Probably the most forecasted system is the weather. Weather prediction has a history as old as humanity itself. In the electricity sector, extensive use is being made of weather forecasts, historically mostly for load forecasting, but forecasting the generation of weather-dependent Renewable Energy is becoming more and more crucial. Generally, weather forecasts from meteorological institutes are used as the basis for the forecasting of Renewable Energy as well as demands [52].

It is not difficult to notice how many ways of forecasting the weather there are; from detailed physical modelling to empirical methods and looking at trends. Nowadays, practically all of them use a lot of different sources of digitalised data, such as pressure, wind speeds, temperatures, data from satellites, etc.

Numerical Weather Prediction (NWP) is a container for many computer-aided predictions based on physical modelling, parameterisation, statistics, etc. An interesting observation concerning NWP is that the best results are achieved when using models with many slightly different initial states, known as 'ensemble forecasting', and even using different models, such as 'super ensemble forecasting'.

Power generation from wind and solar is highly dependent on the weather. Data from specialized weather forecasts, (for example for a wind farm these could be wind speeds, wind speed variations, wind direction, pressures, temperatures, etc.) is combined with characteristics of the specific wind farm, like historical performance, reactiveness to wind variations (ramping), probability of icing dependent on wind and temperatures. All these data and models are combined to form a generation profile for the next period (which could be 15 minutes ahead to a week).

Weather forecasts will continue to become more accurate as the amount of input data computing power is increasing. More detailed data is becoming available. Examples of this are the Sentinel Satellites from the EU's Copernicus program; more local sensors and weather stations, allowing much higher detail of the forecasting models (from 5 km to 2 km resolution); high quality imagery of cloud coverage and waves between offshore wind turbines, giving information about wakes behind the turbines, etc.

However, being a chaotic system, each slight improvement of forecasting will require an exponentially increasing amount of data and computing power and large jumps in the increase of accuracy of weather predictions are not expected, not even through the application of new methodologies or forecasting techniques like deep learning. Though especially for predicting 'rare' events, like storms or floods that might put the electricity system at risks, these 'slight' improvements still might prove to be quite significant.

The use of weather predictions to calculate the power output profile of a wind turbine or solar panel, and especially a whole wind or solar farm is a much younger science, which is increasingly becoming more critical for wind farm operations in recent years. Wind (and solar) energy is affecting the power system and power markets, and operations are shifting from maximising energy yield to integrating the farm into the electricity system and market.

The need to translate weather forecasts to power output is fast developing and is gaining importance. Some examples are the re-evaluation and adjustments of assumptions made in the first generations of models; the development of advanced models, able to accurately model turbulence and wakes and thus the influence of wind turbines on each other; and models and methodologies to estimate the effect of clouds and cloud movement on the power output of solar farms.

4.5 Improved Demand Forecasting

As with renewable generation, electricity demand is highly influenced by the weather, especially heating and cooling. Variations in demand used to be the main source of uncertainty in the electricity system, thus forecasting load always has been an important topic in electricity systems. Both short term forecasting, necessary for contracting and planning of dispatch of generation; as well as long term demand, influencing investment decisions in power generation and transmission and distribution networks [52].

Long term forecasting, in general, relies on scenario planning, based on general and local economic developments, correlated with data from industry, commercial and residential demand and possible technological developments like for example energy savings, the use of electric vehicles and solar energy.

Short term load forecasting depends on statistical learning algorithms, regression models, neural networks and other pattern recognition methods.

Because aggregated demand has a very periodical (i.e. day/week/season) and stable behaviour, even relatively simple methods that exploit this behaviour, like the 'similar day approach' based on historical data, prove to be surprisingly accurate for a large number of consumers.

These methods take a 'top-down' approach, using (well-known) patterns in overall loads as a basis for the forecast. The demand of even a few hundreds of households follows a regular pattern, and on a scale of millions of households, industry and commercial buildings, the demand is regular and shows a well-known pattern that is easy to forecast using the prementioned methods.

However, demand is becoming more correlated due to the ongoing electrification of heat (heat pumps, air-conditioning) and transport (electric vehicles).

Local (solar) generation is also increasingly occurring in distribution grids, so the statistical averaging out will become less in the future. More relevant, because expanding the network capacity to cope with this synchronisation of demand and generation in the capillaries of the network is very expensive, these capacity limitations will lead to the necessity for local 'balancing' (i.e. congestion management), and thus for local demand forecasts consisting of much smaller numbers of end-users.

An alternative approach to top-down forecasting considers the use and demand of individual appliances, correlated with other demand, events and local weather forecasts, before being aggregated into a forecast of (part of) the demand. The main advantage of this so-called 'end-use method' is that patterns and correlations can be found on the appliance level. Therefore, forecasts can be made much more local and flexible, for example, considering local weather variations, events and scenarios. As more demand data becomes available for analysis, due to the presence of smart meters and the metering of individual devices among others, this approach is becoming more accurate and therefore feasible.

The 'top-down' methodologies in load forecasting will remain dominant for a long time. However, because the aforementioned increase in correlation in electric demand and importance of local forecasting of smaller numbers of end-users, it is likely that they will be gradually being complemented by bottom-up approaches, like the end-use method and 'big data' approaches; where correlations in the use of appliances and external factors are identified by combining data from individual users, building up to a picture of the total system.

The combination of a top-down and bottom-up approach is much more flexible than the traditional top-down approach alone because it can handle forecasting a smaller number of end-users and can consider changing local circumstances like the local weather, events and local trends, while still retaining the accuracy in forecasting a large number of end-users.

4.6 Storage Empowered by Digitalisation

Storage technologies are inherently digital. This is because storage is dispatchable and can act as both a load and a generation source at different times. The intelligent timing of this cycling is dependent on the instantaneous needs of the electricity market and relies heavily on digital decision-making. For many new players in the energy storage market, the challenge is not about Digitalisation to improve process efficiencies as we see in other industries. It is about bringing innovation to a traditional market and co-creating the future of the energy landscape alongside the conventional energy value-chain and legacy technologies. DNV GL surveyed the energy storage industry to reveal the current progress of Digitalisation; to uncover which Digital Technologies are making an impact; which barriers the industry is facing and how organisations can take advantage of the many opportunities that Digitalisation presents.

The research [53] reveals that 43% of the 2000 respondents working with energy storage have Digitalisation as a core part of their publicly stated strategy.

When it comes to the perceived benefits of Digitalisation, those working in energy storage place improving operational efficiency (54%), improving decision making (42%) and helping innovation (39%) as top priorities. The energy storage industry's prioritisation of innovation is not surprising. This young industry shares many qualities with the global tech giants, many of which grew from an idea to global domination in less than a decade.

The energy storage market looks set to follow a similar path, with analyst Globaldata forecasting that the battery storage market will be worth $13 billion by 2023. The storage industry's attitude to investing in Digitalisation also reflects a willingness to try new initiatives with 75% of respondents saying their organisation proactively invests in Digitalisation to meet its goals.

The ability to create new technologies and solutions in a young but rapidly growing industry is an attractive prospect. [53] shows that the energy storage industry is offering employees the chance to influence and directly shape the digital strategies of their companies; with 70% of respondents saying that they are involved in shaping digital strategy or have influence over investment and spending on Digital Transformation.

Some of today's storage and energy solutions are focused on a single task, but many are leveraging software to increase their functionality to meet higher economic returns by value-stacking. Value-stacking, the process of being able to perform multiple tasks at the same time, unlocks huge potential value and new business avenues for the storage industry. For instance, using the same battery for different applications, an example of this is seen in the electric vehicle (EV) sector. EVs will play an important role in the integration of variable renewable generation due to the flexibility that will be available from smart charging and vehicle-to-grid (V2G) services. V2G technology expands upon the potential of smart charging by enhancing the utilisation of the battery storage of EVs by allowing power to flow in both directions, between the electric network and EVs. In addition to powering EVs for typical usage, the batteries are used as electrical storage for the electricity network. Using batteries in this way has numerous applications: from managing demand to ensuring that an increased share of Renewable Energy can be used.

4.7 Security of the Energy System

Automation and increased connectivity between IT and OT offer great advances, but also bring additional risk. Digitisation of all data and many processes increases the complexity and exposure of the energy system, making it more vulnerable to cyber-attacks. IT product manufacturers and device manufacturers will need to assure and validate that their products and processes are cyber secure, and governments will need to ensure that regulations are in place to be certain that operations and infrastructure can be trusted as being safe and secure [1].

Research by Osborne Clarke has found that 74% of energy companies today are reluctant to adopt new technologies because of privacy concerns and the increasing threats around data security. The recent cyberattack on Norsk Hydro, for example, highlighted the huge economic impact incidents like this can have, with the overall cost expected to have reached almost US $75 million. While the financial consequences have proven severe, the bigger issue is the impact that cybersecurity breaches could have on progression. Businesses are in very real danger of falling behind the curve if they do not move with the times and embrace breaking technologies.

On the other hand, Digitalisation allows for example for the detection of "non-technical losses" (NTL), in particular electricity theft, by tampering with or bypassing the electricity meters (for example use of electricity for illegal drugs cultivation). Typical indirect methods use periodic behaviour of currents (aligned with growing patterns), using data mining techniques. Newly proposed methods use a 'load low analysis' technique to estimate "normal conditions" in terms of active and reactive power and voltage and expected (technical) losses. Next-generation fraud detection may also draw on Power-Quality data and Total Harmonic Distortion (THD) since illegal growing, for example, tends to use LED lightning that requires less power and therefore causes smaller power deficits and voltage drops but on the other hand, adds harmonics through the use of electronics.

Ideally, these methods allow for zooming down to the exact location of the perpetrators. This can be done by using Data Analytics to narrow down the NTLs to a single distribution substation or feeder, based on smart meter data [52].

4.8 Impact of Digitalisation on commercial wholesale operations

Like network operation, commercial operations will be highly affected by Digitalisation and Data Analytics.

Commercial operations include (renewable) power generation, trading, electricity supply and aggregation. The commercial domain in the electricity sector can roughly be divided into a wholesale part, where energy parties interact with each other, and a retail part, where energy is sold to (or bought from) essentially non-energy companies and citizens. While this division is blurring as companies and citizens are getting more involved in 'traditional' wholesale activities, such as power generation and changing business models of retailers and aggregators are integrating wholesale and retail processes more and more, this division is still quite insightful [52].

As discussed, Data Analytics play a major part in forecasting renewable generation and demand, as well as in market price forecasting. As forecasting is being developed to become increasingly sophisticated, it results in temporary advantages to the companies who forecast best. However, markets and especially market prices, are dependent on the actions of other stakeholders and their forecasts. So, while market forecasting is tremendously important to the relative competitive advantage of the participants, it is an arms race that does not change the system overall.

More data, and especially more real-time data together with advanced analytics will give traders, retailers and aggregators a better insight into their current and future market positions and risks. To optimise their market positions, they will need to adjust their portfolio of generation, demand and contracts, by trading among each other. This will lead to new tradable products and more differentiated markets.

Just like the increase in Solar Energy will likely lead to a further differentiation of tradable futures beyond the current 'base', 'peak' and '16h-peak' products, more (real-time) data will lead to a differentiation of short-term tradable products (and possibly new market places) to utilize the results of these analytics.

Traders trade energy in time blocks called 'Imbalance Settlement Period' (ISP, in most countries, this is 15 minutes). If the physical demand and generation in an ISP do not match, they must compensate the TSO for solving the created problem. To solve these imbalances the TSO has contracted power generation, and in some countries, the TSO has organised an 'automatic semi-real-time auction' (the imbalance market) where market parties can offer power to the TSO to restore the balance. The cost the TSO incurs (and forwards to the responsible party that caused the imbalance) is only known after the ISP is closed. For many smaller parties, there are benefits to lock this price in a trade with another party (which can more easily bear or hedge this risk, for example, because of aggregation or available flexibility) for a price before or even during an ISP.

Numerous other possible new products and markets will emerge as a response to the Digitalisation of these markets in combination with Data Analytics and Data Exchange. For example, around Power Purchase Agreements (PPAs) between renewable generators, storage and industry (6), especially industry able to response to fluctuations in renewable output: Industry would secure Renewable Energy, while the renewable generator would benefit from being shielded from the fluctuations of the power market by synchronous generation of Renewable Energy. Other examples might be around differentiation of energy by source, location and even application; or around products where risks of intermittency of renewables are shared and mitigated through 'private' capacity products.

4.9 Impact of Digitalisation on retail operations

In the electricity sector retail is generally reserved to indicate electricity sales to commercial and residential end-users, and often also includes energy services and energy data services to end-users. Although through developments such as local generation by prosumers and demand response (end-users offering flexibility to the electricity sector), the distinction between retail and wholesale is becoming blurred [52].

The impact of Digitalisation and Data Analytics on retail operations will be much more visible to the public than the impact of Digitalisation and Data Analytics on wholesale and grid operations. Like in all other consumer sectors, Data Analytics and big data allow retailers and aggregators to much better tweak their propositions to individual consumers, creating higher marketing efficiencies and sales, eventually leading to smart energy contracts, that respect the individual wishes and requirements of consumers instead of the 'one size fits all' energy contracts that are dominant today.

On the appliance level, smart thermostats exist already for some years, monitoring the behaviour of residents in a building and optimise heating accordingly. Devices (physical or virtual cloud-based) that analyse smart meter data go way beyond merely showing energy use and can disaggregate smart meter data into the load of individual appliances using self-learning (non-intrusive) load monitoring algorithms.

The change in retail operations that will likely have the biggest impact on the other parts of the electricity value chain will likely come from retailers and aggregators aggregating flexibility from end-users, using demand response. They might use this flexibility to optimise trading on electricity markets; sell it to grid operators as emergency power, or to solve congestions - adopting the concept of flexibility as a new commodity. Alternatively, they might use it to tune their client's individual energy use to their specific wishes, thus using flexibility as diversification opportunity in the retail market.

4.10 Automation enabled by Digitalisation

Digitalisation will enable further automation of industrial and manufacturing production. Energy demand in the manufacturing sector is mainly for heat. The sectors with the greatest heat demand, such as steel or cement, have already achieved optimised systems regarding energy use in their operations. However, growth in connectivity will spur on further improvements in efficiency, such as electrification of low heat demand, and greater automation of manufacturing through, for example, advances in additive manufacturing.

An increasing share of operational-technology (OT) systems will be connected to the internet for updating and optimising over time. For example, the latest EVs can add new functionality through wireless updating of onboard software, without switching hardware. Not only can this enable automation or remotely-controlled operation, but it can also improve operating/energy efficiency, reduce downtime for maintenance, and allow Machine Learning for further optimisation of performance.

4.11 Digital transformation of the building sector

Digital Transformation of the buildings sector includes a vast and growing array of control technologies, as well as connectivity effects. For example, the uptake of smart thermostats is growing and could receive a boost from the spread of smart speakers, bringing with them the increasing convenience of using voice commands. The technological progress in sensors, communication, and data processing is expected to continue to drive the adoption of more-advanced building controls and thus contribute to the projected improvement in energy efficiency in buildings [1].

Growing connectivity will allow the owners/ managers of buildings to collaborate with energy suppliers to use electricity when it is needed, most abundant, or cheapest. Buildings will also increasingly generate and store energy, with connectivity enabling 'prosumption'; i.e., supplying energy back to the grid.

5

Impact of Markets, Policies and Standards

Impact of Markets, Policies and Standards

As the industry transitions to an energy system with a substantially larger mix of electrical generation from variable Renewable Energy Sources (vRES), electricity markets, policies, regulation and standards will shift and adapt to facilitate the transition.

5.1 Energy Markets

Markets are in principle designed and regulated to provide mechanisms for efficiently meeting the needs of society but are impacted by political concerns.

The 'new' complexity of the electricity sector calls for increased use of market mechanisms and less use of traditional planning-based decision making. There are three essential reasons to rely on market mechanisms and distributed decision making on both investment and dispatch decisions, where prices serve as the key coordination mechanism among stakeholders:

1. The need to forecast 'physical' factors will grow with deep Decarbonisation. In electricity systems based solely on coal and gas, it is enough to forecast demand to come up with a reasonably efficient production plan for the following day. With a huge variety of energy resources, there is a lot more forecasting to be done, so that there is time to ensure plans are compatible with available network capacity. This is achieved efficiently via markets.

2. To ensure efficient utilisation of scarce network capacity, market mechanisms play a fundamental role in simultaneously informing network operators about the immediate (short-term, up to day-ahead) demands from producers and end-users. These mechanisms also signal to market participants how they can optimise their short-term operations.

3. Markets also play a vital role in ensuring an efficient allocation of financial risks. Long-term markets allow for a separation of who takes the financial risks and who takes more operational risks in maintaining and operating power plants. Long-term markets tend to be more efficient if they can work in parallel with short-term markets.

To facilitate the Energy Transition, most modern and developed markets will have a greater focus on shorter horizons and settlement periods to facilitate flexibility, including further development of balancing markets. In many regions, markets were structured to work efficiently with large centralised thermal generation. Wind and solar PV generation behaves, and is controlled, very differently; so, as the Energy Transition progresses, market rules and regulations will continue to change to ensure that the value of distributed generation and flexibility options can be truly recognised. For example, it might be better to produce ammonia locally, based on available generation profiles, rather than producing it centrally and transporting it to where it is needed. The value chain will also be more granular. With locally distributed energy resources, larger consumers will have greater options for influencing local generation.

New renewable generation will also have a big impact in less-developed regions by bringing electrification to new areas and improving power supply in others. As new microgrids and mesogrids are developed, markets will be structured differently for the distributed generation on these, to recognise the value that power is providing to people's lives.

Effective markets are technology agnostic, but certain technologies can visibly perform well under particular market conditions. For example, markets for ancillary services can be open for anyone able to comply with the requirements of the system operation rather than focusing on a limited group of suppliers like large thermal generators. Trends such as this result in the substantial projected growth in battery storage discussed in Chapter 3.1 and 4.6.

The increasing Digitalisation of power systems is enabling change from more rigid mechanisms to direct markets, such as flexibility markets and the growing role of aggregators. This also drives market focus towards shorter horizons and provides closer to real-time flexibility. The ability to efficiently process increasing volumes of data from distribution systems will also help markets to operate effectively, through aspects such as optimisation of markets based on the specific location of smaller generation and load and enabling improved short-term forecasting of renewable generation and power prices.

5.2 Energy Policies

Over the next decade, Climate Emergency and pollution control policies will continue to drive the Energy Transition. They will vary between regions but will have common themes. The Government of India's policy goal is to reach 175 GW of renewable generating capacity by 2022 and 275 GW by 2027, compared with the current installed capacity of 75 GW. In Greater China, the 2018– 2020 Three-Year Action Plan for clean air indicates the coming together of the nation's management of air pollution and Climate Emergency. The plan calls explicitly for large reductions in total emissions of major pollutants in coordination with the reduction in emissions of greenhouse gases. It mandates reductions of at least 18% in levels (compared with a baseline in 2015) of particulate matter with a diameter of 2.5 micrometres or less in more than 300 cities.

Policies will also continue to consider energy security and opportunities for local job creation, all of which will have an impact on the Energy Transition. In many regions, the technologies often advance faster than policy development, which must adapt to keep up. Historically, policies would drive technology development, but many of today's policies would not be possible without technologies being demonstrated as viable options. The bans on new petrol and diesel cars in several locations around the world would be unlikely without industry having first proved the capability of EVs and the infrastructure to support them.

Rapid technological advances and ramping up of production in the solar PV industry led to solar generation growing faster than many policymakers had anticipated. This resulted in support mechanisms such as feed-in tariffs being reduced or withdrawn more abruptly than planned. The anticipated technological and financial trends will lead to the point where, in many regions, subsidy-free renewable generation will be the optimal choice. At that stage, policies will have a decreasing impact on the Energy Transition; market economics will be the driving force.

The region Asia-Pacific is continuing to be the dominating leader in the economic growth and technological advancement with China dominating the region for renewables. The digitally empowered technological innovations such as IoT, AI, DLT and Digital Platforms will continue to fundamentally change the approaches to sustainability in the region with policies needing to keep pace in order to provide the right environment for acceleration [54].

In order to achieve the Paris Agreement, the pace of the Energy Transition will have to increase quite significantly, whereby the policies will have to meet the demand [55]. Also, the universal access to energy - Sustainable Development Goal (SDG) 7 - requires a careful and considerate approach to decentralised energy solutions, especially for the region of Southeast Asia with expected population growth and a comparatively high ratio of not connected households.

The deployment of decentralised renewables will accelerate the pace of energy access in developing countries. With relation to the SDG 7, the provision of flexible approaches which consider both on- and off-grid solutions and provide regulatory measures to the generation and trade of electricity – including for example Blockchain backed P2P solutions. At the same time, greater attention needs to be given to the reduction of the traditional fuels (also for cooling and cooking) which is ever so important to the developing region of Asia and the Pacific [55].

The issue though is that despite promises made during COP21, energy in Asia and Pacific remains highly political. Countries show varying support for renewables, and in most of them, clean energy still faces persistent policy and financial challenges [56]. Examples of regulatory and policy barriers include bad policy design, discontinuity of policies, perverse or split incentives, unfavourable or inconsistent policies, unclear agreements (such as power purchase agreements, feed-in tariffs or self-consumption) and a lack of transparency. Uncertainty and inconsistency about targets and policies, including retroactive changes, further hamper Renewable Energy expansion and are hence counterproductive [55].

It is also worth to note that many countries in the Region Asia Pacific do not have comprehensive policies and regulations towards Digitalisation – let alone policies and regulations that address the Digitalisation of the energy industry.

5.2.1 Political drivers and support

The significant growth and maturity of the Renewable Energy lead to a new set of challenges for policymakers, including the need for more flexible energy systems, cost-effective system integration and a move towards Digitalisation with an overall approach reflecting the changes within the energy sector and the society [55]. The key players in the renewable sector are the US, Europe, China and India, however also smaller countries in the region of Asia Pacific, such as Thailand, Vietnam, Taiwan, Philippines, South Korea and Japan are on the rise with respect to Renewable Energy – because or despite current policies in place and often driven by private developers and investors. It is worth noting that today Renewable Energy in most countries is not only a necessity to combat Climate Emergency but increasingly a lucrative business case as well.

Nevertheless, Renewable Energy investment is traditionally supported by a number of policy frameworks which are predominantly based on the country's economic factors, geographical location, previous investment involvements and political support of the renewable sector. For investors, renewable policies should not only showcase opportunities but also disclose uncertainties and risks – for example with regards to political support, grid constraints but also emerging technologies.

Overall countries show varying support for renewables, and in most of them, clean energy still faces persistent policy and financial challenges. In the following, an excerpt of the findings in [56] for various countries in the region:

- Thailand has incentivised investment in solar projects for more than a decade and now reaps the benefits of this consistent support, being ASEAN's front-runner in installed solar, wind and biomass capacity;

- Vietnam differentiated its tariffs for solar by regions, offering higher support in the cloudy north to deploy renewables more evenly across the country in order to facilitate infrastructure development and prevent grid instability;

- The oil and gas kingdom of Brunei Darussalam, which is just as sun-drenched, has installed a mere 1 MW of solar power only though;

- Indonesia - the biggest consumer of energy in ASEAN —is expected to become the world's fourth most powerful economy by 2050, and while ranking third for total Renewable Energy capacity in the ASEAN, it remains the region's top-user of coal. One problem reportedly is, that the country's state-owned utility company Perusahaan Listrik Negara (PLN) may not be fully incentivised to commit itself to renewables;

- In Malaysia, the government is introducing a net energy metering programme to catalyse Renewable Energy growth in the country, which ranks fourth among the ASEAN member states for total renewables capacity;

- Singapore – long-time rather standing still with regards to Renewable Energy - is now building one of the world's largest offshore floating solar systems that is expected to start operating late 2019;

- In Cambodia and Laos hydropower accounts to more than half of the generated electricity and hence there has not been a vibrant wind or Solar Energy market yet. But, a solar auction policy implemented in Cambodia has made the Renewable Energy sector increasingly attractive in the country recently – potentially also to slightly combat the country's dependence on electricity imports to power its growing economy;

- In Myanmar, hydropower has an equally high share in the power mix (65%). On the other hand, the country also ranks at the bottom for energy access in ASEAN, with more than 40 per cent of its people still living in the dark.

5.2.2 Sector-Specific Policies

RENEWABLE ENERGY POLICIES FOR HEATING AND COOLING

Significant attention is brought to heating and cooling systems with a specific set of policies for Renewable Energy use in the heating and cooling sectors; with a certain set of ways of how to achieve the targets in the most efficient way.

In 2015, the largest end-use in energy which accounted for more than 50% of global final energy consumption, was heat. The breakdown of which equals to about 50% for the production of steam for industrial processes and the remainder compromising of heating buildings and water for cooking and agricultural uses [55]. According to the International Energy Agency (IEA) [59], heat consumption remains heavily fossil-fuel based, with about 39% of total annual energy-related emissions related to heat production. In Asia Pacific, large amounts of energy consumption are related to heating, cooling and cooking. The progress in introducing clean cooking fuel has been disappointingly slow, increasing to only 51% in 2014, producing most of the household air pollution especially in the regions of South East Asia and the Western Pacific [100]. This results in a call for policy implementation with emphasis on the Decarbonisation of heating, cooling and cooking. According to the IEA studies, the absence of new policies for the traditional cooking methods will result in an increasing number of people in developing countries relying on biomass for cooking which will increase to over 2.6 billion by 2015 and 2.7 billion by 2030 due to the population growth. Alternative solutions would include modern bioenergy, solar, thermal, geothermal and renewable electricity.

In the built environment, the use of energy for heating and cooling purposes is largely dependent on the geographical location, the insulation, the construction and the age of the building, its occupancy, its use and many other factors making policymaking a rather complex and challenging task. Despite the relatively high contribution of heat consumption to the overall energy demand and emissions (especially regarding developing countries), policymakers tend to concentrate on the electricity supply, with heating and cooling being largely neglected.

RENEWABLE ENERGY POLICIES FOR TRANSPORTATION

There are two major advancements concerning sustainable energy use in the transportation sector. These are associated with the use of biofuels and the electric-power transportation, which has been on the rise, however with implications needed in the production, deployment and the fuel distribution sectors. Policies and planning in this sector should aim at overcoming key barriers, such as the immaturity and the high cost of certain technologies, inadequate energy/ charging infrastructure, sustainability considerations and slow acceptance among users due to new technologies and systems being introduced in rapid cycles [55]. Setting a carbon price and low carbon-fuel standards are some of the suggested measures for the practices for the Decarbonisation of transport. Overall, Decarbonisation of the transportation sector requires fundamental changes in public transportation demand vs availability as well as improvements in sustainability practices for certain types of vehicles [55].

RENEWABLE ENERGY POLICIES FOR POWER SECTOR

According to IRENA, in the year 2015 renewables provided about 23.5% of all electricity generated, the bulk of which came from hydropower, followed by wind, bioenergy and PV. This was achieved by falling technology costs and supporting policies.

The pricing policies for the feed-in tariffs will need a continuous adaptation for the changing market, reflecting the falling cost of technology. While at the same time, distributed generation requires the attention of the net metering and net billing in the context of self-consumption and self-production. Here, the policies should reflect the specific country conditions, state of the energy market, the advancement of the technology, and the overall objectives and milestones set for that particular achievement [55].

5.2.3 Policies for energy access

Although there has been a great process towards universal energy access - alongside the population growth and hence greater energy demand – the region of Asia Pacific still has around 455 million people lacking access to electricity with 1.9 billion people dependent on traditional solid fuels for cooking and heating [60]. In accordance with ESCAP [61] many countries of the region are working towards bringing the electricity to the growing populations especially in rural areas with specific policies backed by supportive programmes and economic measures with China achieving universal electricity access in 2014. However, the region remains rather diverse and complex with economies of less than 50% electrification including Democratic People’s Republic of Korea, Papua New Guinea, Solomon Islands, Timor-Leste, Vanuatu and American Samoa [61].

The universal access to energy - a target with respect to the SDG 7 - requires a careful and a considerate approach to decentralised energy solutions, especially in the region of Asia and the Pacific. The deployment of decentralised renewables will especially accelerate the pace of much-needed energy access in developing countries. With relation to the SDG 7, the provision of flexible approaches which consider both on- and off-grid solutions and provide regulatory measures to the generation and trade of electricity. At the same time and as mentioned previously, greater attention needs to be given to the reduction of the traditional fuels for heating and cooking in developing parts of the region [55].

The achievement of the universal access to electricity has been the policy focus for the region, also addressing multiple contributing factors related to energy access such as reliability and affordability. This extends to the provision of adequate power supply, regulations and standards directed at cost reduction, increased capacity and stabilising the reliability of the power supply.

5.3 Digitalisation Policies

As discussed, Digitalisation plays a significant role in the future energy supply and demand sector. In the majority of the region of Asia and the Pacific, the success of Digital Transformation in the private sector has not yet been reflected in the policy design, development, implementation and evaluation. The development and the application of Digital Technologies in policy design though holds a number of opportunities including citizen engagement. This will, however, depend on the government's willingness to scale and use Digital Technology, the full understanding of privacy concerns, cybersecurity and other vulnerabilities. As such, certain aspects require attention for the successful Digital Transformation, including but not limited to:

- Data access and interoperability of data systems
- Framework of information

- Sufficient public infrastructure
- The ownership of digital data

Currently, the technology innovation, with particular emphasis on Digitalisation, is allowing for new solutions and changes to existing policies, whereby changing the behaviour and the consumption with regard to energy combining energy efficiency, smart meters and solar powers resulting in a new perception of energy systems [55].

5.4 Technical Standards for Digitalisation Policies

The immense growth of Digital Technologies including IoT, Blockchain, Data Analytics, AI and others, requires technical standards and specifications to be set in place - especially in order to provide internationally agreed ways for connectivity, interoperability, security and privacy. With the increasing adoption of new technologies across different sectors, the need for standardised technical implementations and architecture becomes ever more relevant. An organisation such as ISO step on this plan.

The ISO Technical Committee 307: ‘Blockchain and distributed ledger technologies’ for example, was established in 2016. Currently, it consists of six working groups and a study group in order to facilitate the standardisation processes and meet the growing demand for internationally agreed standards. In accordance with the strategic business plan of the ISO/TC 307, the standards will be related to terminology, reference architecture, security and privacy, identity, smart contracts, governance and interoperability for Blockchain and DLT. It will also list the specific standards for industry sectors and generic government requirements [62]. The benefits of developing the standards and unifying the specifications can thus be characterised as beneficial under the following criteria [63]:

Practical essentials

- Unified terminology
- Interoperability between different ledger technologies and other technologies
- Improved security and privacy
- Enabling compatibility between tech and legal frameworks
- Reduced implementation cost

Risk reduction

- Removing the barriers to entry
- Reducing the risk of locking-in to non-standard approaches
- Aid the assessment of Blockchain quality
- Increase trust and reputation

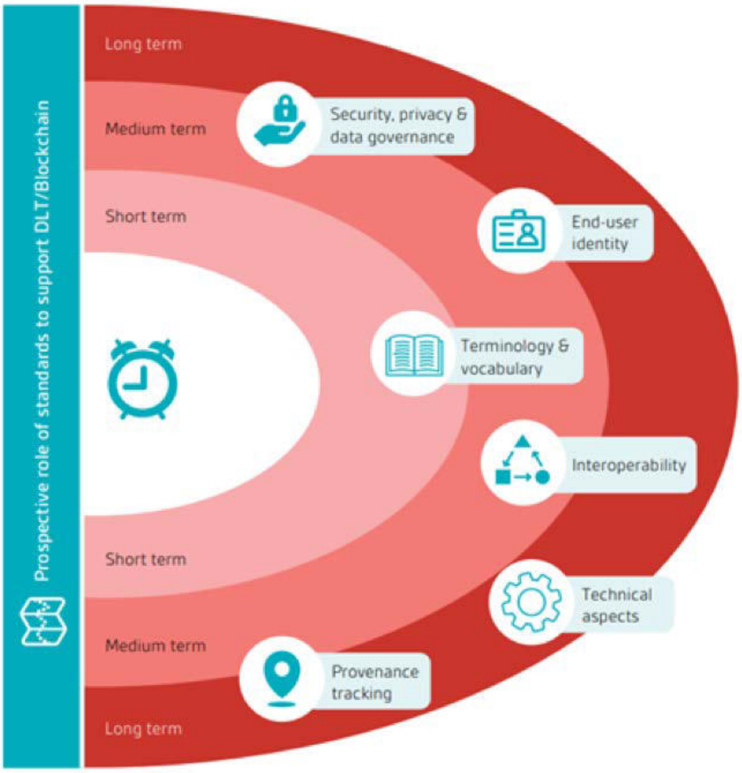
By-product benefits

- Support of innovation, competition, governance, development and growth, especially cross-organisation and cross-border
- Increased understanding
- Potential use case references or repository
- Increased adoption
- Increased investment

Overall, the prospective role of standards also includes reducing the risk of fragmented ecosystems, creating trust in the technology via addressing the security and the resilience concerns as well as digital identity management. According to the BSI Group [64] standardisation, specifically interoperability, is indeed important for the wider development and adoption of DLT/Blockchain. The below figure demonstrates the areas where standards could play a role in supporting DLT/Blockchain with an indication of a prospective timeline [64].

See Image 3 on next page.

Image 3: Areas where standards could potentially play a role in supporting DLT/Blockchain, and an indication of the prospective timelines. (Source: RAND Europe)



In accordance with the International Organization for Standardisation, the strategic business plan for the current set of standards and regulations for DLT and Blockchain regulation will be finalised no later than 2021, highlighting the topics of cross-organisation and cross-border usage scenarios. In addition, a specific terminology of international standard that will provide a unified vocabulary for Blockchain and DLT standardisation will also have to be specified.

6

A Closer Look on Asia Pacific

A Closer Look on Asia Pacific

The following chapter introduces policies and regulations with regard to sustainability and Digitalisation of Singapore, China, Japan, South Korea, Australia, New Zealand, Indonesia, Malaysia and the Pacific Islands. The above-listed countries have been chosen due to being the most representative of the region with a diverse level of economic, social and sustainable development.

6.1 Singapore

Singapore is heavily dependent on fossil fuels for energy generation. At present, gas is the key energy resource, which is currently generating about 95% of electricity for the whole island of Singapore. However, the advancements of renewables have been on the rise as well, with PV (rooftop and floating) being the most viable Renewable Energy resource for Singapore.

Currently, offshore pipelines fed by Malaysia and Indonesia satisfy Singapore's natural gas demand and satisfy the domestic energy need. In accordance with DLA Piper [65] the five principles of Singapore's energy sector are to 1) promote competition to keep energy affordable; 2) diversify energy supplies to guard against supply disruptions, price increases and other threats; 3) improve energy efficiency (in accordance with the "Efficient Singapore Plan"); 4) invest in the energy industry and in research and development; and 5) improve on international cooperative measures.

The National Environment Agency of Singapore outlines the Energy Efficient Singapore strategy which encourages the reduction of greenhouse gas emissions by improving the overall energy efficiency and using less carbon-intensive fuel.

Situated on one degree north of the equator and with very limited hydro, wind and geothermal resources, Singapore, on the other hand, enjoys an average of annual solar irradiance of 1,580kWh/m2/year [66]. Being an island nation though, Singapore has limited area for deployment. Also, wave, tidal and ocean thermal energy are limited because of the vibrant shipping industry around Singapore. The main sustainability focus of the government of Singapore is hence largely on R&D, environmental technology, green and smart transport, water-saving and energy efficiency – spearheading the technology development in the region – also and especially with regards to digitally empowered technologies.

However, Singapore has announced to increase its current solar energy production to 2 GWp from the current 260 MWp by the year 2030, aiming to meet the annual needs of around 350,000 households in Singapore and covering about 4% of Singapore's total electricity demand.

6.1.1 Existing energy policies and regulations

The lack of policies on sustainable use of energy makes it hard to determine the exact outline for the foreseeable future. The analysis is therefore based on the consultation and recommendation papers as proposed by the Energy Market Authority (EMA) and the National Environment Agency (NEA) of Singapore.

Currently, renewables represent only a fraction of Singapore's power mix. The future for solar energy, however, involves the installation of solar panels on rooftops of housing developments as well as installation of floating PV structures on water surfaces of reservoirs.

The government of Singapore has announced plans to raise the adoption of solar power to 1 GWp beyond the year 2020 [67]. To support this, the Energy Market Authority (EMA) has progressively made several regulatory enhancements to facilitate the Renewable Energy deployment by facilitating the renewables into the energy mix. These include:

- Streamlining market participation and settlement rules to make it easier for the Intermittent Generation Sources (IGS) to receive payments for excess electricity exported into the grid, including the launch of the Central Intermediary Scheme ("CIS");

- Streamlining the commissioning procedures for solar photovoltaic (PV) installations to connect to the grid;

- Launching the one-stop solar PV portal which allows consumers to access information easily on the regulatory framework;

- Reviewing metering requirements to allow eligible consumers to use an alternative arrangement (such as an estimated IGS profile that is approved by the EMA) for the settlement of relevant market charges, thereby lowering the metering costs for such consumers. [67].

Another great example of sustainable and affordable energy in the region of Southeast Asia is the Renewable Energy Integration Demonstrator Singapore (REIDS). This demonstrator is a Singapore-based R3D (Research, Development, Demonstration and Deployment) platform which is dedicated to designing, demonstrating and testing solutions for sustainable and affordable electricity distribution. The unique approach of REIDS includes a technology roadmap which was built on a 'technology-systems tripod' consisting of 1) Renewable Energy sources; 2) energy storage systems and 3) integration by way of microgrids under the control of intelligent and adaptive energy management systems and the interconnection of the microgrids on a bi-directional electrical network, empowered by a comprehensive ICT network called Low Voltage Micro Grid Cluster (LVMGC).

Remarkable is also NEA's initiative to develop the Integrated Waste Management Facility (IWMF) equipped with state-of-the-art technologies for handling multiple waste streams and optimising resource and energy recovery. The waste streams include incinerable waste, household recyclables from Singapore's National Recycling Programme, source-segregated food waste and dewatered sludge from the Tuas Water Reclamation Plant (TWRP).

The facility will be able to provide many opportunities for the water-energy-waste nexus, which include:

- Co-digestion of IWMF and TWRP sludge to increase the production of biogas

- To use TWRP biogas at IWMF to increase the overall plant thermal efficiency and power production

- To supply electricity from IWMF to TWRP to lower TWRP's energy cost

- To supply treated effluent water from TWRP to IWMF for its processes

Singapore is a leading example of the greening of the built environment. Providing green coverage of buildings is the most effective way to keep the buildings cool and to reduce the city's overall carbon footprint. The Building and Construction Authority (BCA) has launched the Green Mark rating scheme with an overall target of 80% of Singapore's buildings to achieve the standard by 2030 and become more energy efficient. In the public sector, all new and existing buildings must achieve environmental sustainability standards. This also includes achieving the Green Mark standards as part of the Governmental Land Sales conditions. [67].

The Carbon Pricing Act (CPA) came into operation on January 1, 2019. Currently, it is set at a rate of $5 per tonne of greenhouse gas emissions until the year 2023. Further plans may increase the rate to between $10-$15 per tonne by the year 2030. The first payment of the carbon tax will take place in the year 2020 and will be based on the emissions from the calendar year 2019. It will thus greatly contribute to the overall contribution of renewable deployment in Singapore.

6.1.2 Smart Nation Singapore

About 87% of Singaporean households have access to a computer, and 91% have access to the internet with a 154.1% mobile penetration rate as of May 2019 [68]. With such high connectivity rate, Singapore's Smart Nation initiative aims at equipping all Singaporeans with the know-how on how to use Digital Technologies safely and confidently.

The Smart Nation is an example of an implementation of mostly Digital Technologies for the benefit of the citizens of an advanced nation. Singapore is a one-of-a-kind example in Asia Pacific because unlike the majority of countries in the region, the degree of innovation and technological advancement is set by the government, instead of the private sector. The digital government programme, which is led by the Government Technology Agency (GovTech) aims for collaborations between the citizen and the city by encouraging a digital connectivity approach.

The government of Singapore has started the e-government programme over 30 years ago. The Digital Government Blueprint (2018), The Digital Readiness Blueprint (2018) and The Digital Economy Framework for Action (2019) provide a solid foundation for the overall Smart Nation Framework approach for Singapore [69]. Singapore's Smart Nation Framework addresses growth and prosperity through labour productivity factor, which can be achieved through a mix of heavy investment in technology and business education.

The focus of the Smart Nation Framework concentrates on citizen-centric approach, integrating most of the transactions between the citizens and the Government to be done online. The strategic National Projects which has been launched in support of the Smart Nation and Digital Group of Singapore consists of the National Digital Identity, the E-payments, Moments of Life, Smart Nation Sensor Platform and Smart Urban Mobility.

With a mandate to become the most digitally advanced city of the region, technology and Digitalisation policymakers are increasingly promoting the benefits of technological advancements. From the year 2020, ministries are encouraged to include Digitalisation in the strategic planning cycle [70] as well as to facilitate the implementation of AI, Data Analytics, IoT and smart systems.

The process of integrating policy and operations with technological advancements remains the foundation for successful digitising processes in Singapore. The success is believed to remain in the operational and technological integration, community engagement and the understanding of technological advancements in order to achieve the set goals.

The Smart Nation initiative is proving to be a success as Singapore tops the Asian Digital Transformation Index. According to [71], Singapore tops the rank in comparison to Japan, Hong Kong and South Korea. This is the direct result of policies in the information and communication technology (ICT) which are in sync with its vision of having a robust digital infrastructure in place.

Image 4:
The Asian Digital Transformation Index 2018. (Source: The Economist)

Asian Digital Transformation Index – Overall Rank and Score

Average		43.0	Change in rank
1	Singapore	78.0	--
2	Japan	63.5	+1
3	Hong Kong	62.3	+1
4	South Korea	61.0	-2
5	Taiwan	55.7	--
6	Malaysia	36.9	--
7	Mainland China	36.4	--
8	India	31.0	+1
9	Thailand	23.0	-1
10	Philippines	12.8	--
11	Indonesia	12.2	--

6.1.3 Singapore's Blockchain policy and Open Data Program

The Monetary Authority Singapore (MAS) has demonstrated support for DLT/Blockchain adoption through the launch of related programs and the recent promise to become Asia's Blockchain Hub. With the country welcoming about 400 fin-tech companies, more than 20 global financial institutions set up innovation labs [73]. Singapore is striving to provide a supportive ecosystem for Blockchain start-ups through tax initiatives, grants and other means. By establishing Blockchain strategies and regulations, the government of Singapore may prove to be in a competitive advantage for innovation in the age of Digital Transformation.

To encourage the harnessing of data, Singapore has also launched the Public Data Portal Data.gov.sg which provides data from the sectors economy, education, environment, finance, health, infrastructure, society, technology and transport. This portal also offers real-time APIs and encourages developers to build smart applications to support Singapore's efforts towards a smart nation.

6.1.4 Cybersecurity

Singapore's Operational Technology Cybersecurity Masterplan [72] developed by the Cyber Security Agency of Singapore (CSA) highlights the importance of cybersecurity demonstrating the overall worrying threat to Operational Technology (OT) in connection to the Information Technology (IT) with a focus on Industrial Control System (ICS) which makes up the majority of the OT systems. The past decade has proven that the traditional mindset of OT systems being safe from cyber-attacks is no longer correct. Hence, a broader understanding of the systems, trust and information sharing between all parties is necessary. The document highlights the importance of the process engineers to work with IT engineers in order to understand the extent of cyber threats and come up with stronger and more effective defence mechanisms. In accordance with the Masterplan, in order to cover all aspects of IT and OT cybersecurity, the team of expert defenders should include both the engineers and IT analysts.

In order to bring the procedure mentioned above into action, organisations must have governing processes in the form of policies, standards, regulations and suggestions in place. As implied by the Cyber Security Masterplan [72] – the mandatory codes and standards of compliance need to be in place as well as procedures for detailed steps on the exact actions necessary to implement a specific mechanism, control or solution.

While the masterplan is of primary importance for the owners of the OT Critical Information Infrastructure (CII), by looking at the security requirements, keeping up with innovation, evolving Digitalisation and conducting the business-as-usual activities. With the expansion of digital services, it is only vital for cybersecurity to become an important aspect of governmental policies, businesses and individuals.

6.2 China

China's rapid industrialisation has brought great economic prosperity to the country, however with great environmental consequences. As a result, China has announced action plans to tackle the pollution problems introducing several green initiatives to tackle environmental problems and address long term sustainability measures. The long-term implementation of the SDGs was introduced in 2016 with an approach of translating every SDG into an 'action plan' specifically designed for China. The environmental tax has spearheaded the initiative for an upgrade of production technologies and encourage environmentally responsible behaviour.

The National Energy Administration (NEA) of China is the responsible body for the implementation, formulation and development plans of industrial policies while also promoting institutional reform in the energy sector, administering energy sectors including coal, oil, natural gas and Renewable Energy. In May 2019, China has released its final policy portfolio standard (RPS), which outlines the increase of the share of non-fossil fuels to 20% of primary energy consumption by 2030. Being the largest wind power producer, China continues embarking on the renewable sector.

China' s Renewable Energy law and system has been an essential supportive factor in the process of Renewable Energy exploitation. Since the 12th Five Year Plan, which has called for the expansion of Renewable Energy in all forms throughout the country, wind and solar capacities have maintained an exponential growth.

China is also rapidly moving ahead in the adoption of digital technologies and is among the leading nations in Artificial Intelligence and Quantum Computing. According to [74], China is ambitious to rapidly innovate in the areas AI, quantum information, mobile communications, IoT and Blockchain.

The 13th five-year plan, which was released in 2016, already identified Blockchain as a “strategic frontier technology” and has been endorsed for research and development, specifically for technology and practical applications. The Ministry of Commerce has proposed Blockchain solutions in areas ranging from credit reporting and supply chain management to e-commerce and the financial industry.

A great example of digitally empowered sustainability solutions is the development of a Carbon Credit App by the car manufacturer and energy solution provider BYD in cooperation with VeChain and DNV GL. The solution allows for the calculation of the user’s carbon emission level by collection and management of data. Specifically, the technology gathers the data on mileage, fuel and electricity consumption. This allows the user to monitor and analyse the consumption, resulting in a distribution of carbon credits which are recorded in a Blockchain and can be exchanged for goods and other services [75].

6.3 Japan

Japan currently generates around 90 per cent of its energy from fossil fuels, and current plans call for that figure to drop to just over half, with energy efficiency policies to cut demand. JAPAN'S government has pledged to modestly boost the amount of energy coming from renewable sources to around a quarter while nuclear power remains central to the country's policy. The plan aims to have 22% to 24% of Japan's energy needs met by renewable sources, including wind and solar by 2030 [101].

Much more forward-leaning Japan though is when it comes to Digital. Studies indicate that 99.5% of the population (aged 15-24) are ‘digital natives’ – i.e. people who have interacted with Digital Technology since an early age [76]. At the same time, companies in Japan promote Digital Technology and opportunities to work with constantly evolving Digital Technology. Japan’s mobile carriers have been on the rise for the provision of 5G technologies, fostering the 5G innovation, development and application. The current target is to allow for global connectivity to be widely available by 2020, which will coincide with the 2020 Olympic games hosted in Japan. However, Japan is still recovering from the consequences of the “Lost Decade” of economic expansion, resulting in low growth and deflation. Society 5.0, on the other hand, aims to portray a different picture – by incorporating technical innovations for its ageing society. The effort will be following the mandate for sustainability, addressing the SDGs and creating the “super smart” society to lead as an example [77].

Japanese utility KEPCO in cooperation with the University of Tokyo, Mitsubishi UFJ Bank as well as Unisys is testing Blockchain technologies for surplus electricity trading. Specifically, it aims to use Blockchain tech to acquire knowledge and experience of transactions between the power consumers and prosumers [78]. KEPCO operates Japan’s second-largest industrial region, whereby it incorporates cities like Kyoto, Kobe and Osaka during the testing phase [78].

6.4 South Korea

South Korea began its transformation towards clean energy in 2017, intending to boost the share of renewables from 6% to 20% by the year 2030 with a further increase of a total Renewable

Energy supply to reach 35% by the year 2040 [79]. Currently, South Korea operates around 60 coal power plants owned by state-run utilities, which supply around 42% of the country's electricity [80]. In order to meet the Paris agreement, South Korea would need an overall improvement in introducing renewable alternatives, keeping coal contribution at a minimum.

South Korea demonstrates a diverse range of strengths, especially with reference to high levels of investment in R&D, a highly educated and skilled workforce as well as a high take-up on advanced technologies including ICT. South Korea also provides good conditions for innovation along with a strong government commitment to innovation-led growth.

The largest power provider of South Korea – Korea Electric Power Corporation (KEPCO) is involved in a Blockchain-powered platform for RECs. This involved an agreement between KEPCO and Nambu Electric Power, following an earlier contract to establish the Blockchain-based REC system with Korea Southern Power Co. Under this joint agreement, the three companies will reportedly build a collaborative system to implement the "Blockchain public pilot project" for REC transactions [81].

Another example of environmental sustainability powered by Digital Technology evolution is the partnership between Swytch and Chuncheon – the capital of the Gangwon Province in South Korea. Swytch is a digital asset platform which allows for secure, permissioned and exchangeable digital assets. The platform tracks and verifies the carbon impact of Renewable Energy generation, alongside other sustainable actions. It then utilises smart meter and Blockchain technology to reward the companies and individuals on cutting down the carbon emissions [82].

6.5 Australia

Australia has been the grip of attention with regard to energy sustainability as it is one of the top 10 largest greenhouse gas (GHG) emitters. It is the world's largest coal and liquefied natural gas exporter. The current numbers for Australia coal and gas exports total over 1.1bn tonnes of carbon dioxide which is more than double of its domestic emissions – making Australia the world's third-largest exporter of fossil carbon, behind only Saudi Arabia and Russia [83]. In order to meet the Paris Agreement, Australia would need to implement environmental policies to meet the challenges. The review by the OECD on the Environmental Performance of Australia [84] is highlighting the lack of long-term national vision on sustainable development; the lack in the long-term strategy for lowering the emissions; the lack of wildlife and biodiversity conservation strategies; and the lack of public vs private transport investment [83].

The current Renewable Energy Target is to achieve a minimum of 20% of electricity production from renewable sources by 2020. Currently, the commitment is for Renewable Energy to supply over 23.5% of Australia's electricity by 2020. Overall, the Renewable Energy Target (RET) for Australia is set up of two schemes which are: The Large-scale Renewable Energy Target and the Small-scale Renewable Energy Target. The former is a financial initiative for the creation and the expansion of the Renewable Energy markets (such as solar and wind) while the latter creates a financial incentive for individuals and small businesses to install eligible small-scale Renewable Energy sources such as residential solar panels [85].

The Digital Transformation Strategy has been set up by the Australian Digital Transformation Agency in order to spearhead Digitalisation and spur public engagement in a Digital Development Processes. The strategy formulates the vision to deliver world-leading digital services for the benefit of all Australians by 2025. The three strategic priorities are (1) a government that is easy to reach, (2) a government that is informed by the people and (3) a government that is fit for the digital age.

6.6 New Zealand

New Zealand is generating approximately 80% of its electricity from Renewable Energy intending to increase the share to 90% by the year 2025. While wind energy was the predominant source, in recent years solar is on the rice due to its cost competitiveness.

New Zealand Energy Strategy sets the strategic direction for the energy sector and the role energy will play in the New Zealand economy. The current New Zealand Strategy (NZES) for the year 2011-2021, sets the Government's goal for New Zealand to make the most of its abundant energy potential through the environmentally responsible development and efficient use of the country's diverse energy resources.

The strategy sets out four priority areas:

1. Diverse resource development;
2. Environmental responsibility;
3. Efficient use of energy;
4. Secure and affordable energy [86].

As reported by the IEA [86] the government of New Zealand needs to facilitate technology opportunities for Renewable Energy and energy efficiency in the building, industrial heat, transport and agriculture sectors in order to meet the Paris agreement.

Comparable to Australia, New Zealand's government has formulated a digital strategy (https://www.digital.govt.nz/).

6.7 Indonesia

Indonesia is one of the largest coal producers and exporters as well as the world's tenth-largest gas producer, with nearly 45% supplied to the neighbouring countries. Indonesia is also one of the largest biofuel producers and is looking into the exploitation of its Renewable Energy potential. At the same time, Indonesia has the world's fifth-highest number of internet users, which have increased from 132.7 million to 150 million in 2018 [87].

The geographic location has gifted the country with immense potential for Renewable Energy production such as wind, solar, tidal and geothermal. Indonesia has the potential to generate 788,000 MW of power from Renewable Energy sources, which would be 14 times higher than the country's current electricity consumption. Indonesia has 40% of the world's geothermal energy storage, which would be enough to produce 29,000 MW of energy, yet, in the year 2018 only about 12% of the electricity was produced by Renewable Energy sources, with the remaining sourced from coal (55%), gas (26%) and oil (7%) [88].

Indonesia strives to be the next Digital Hub of the region with companies such as Go-Jek - a company like Uber and Grab which has also extended its services to food delivery, mobile payments, logistics and others. The Indonesian government has launched the "2020 Go Digital Vision" as well as the "Indonesia's e-Commerce Road Map" which aim to support the growth of the e-Commerce ecosystem for agriculture, fishery and SMEs to digitise and expand their networks. Under the new policies, the government will fund e-Commerce start-ups, strengthen cybersecurity and increase online transactions with an overall target of creating 1,000 technology start-ups by 2020 [89].

6.8 Malaysia

The Malaysian government has set an ambitious target to introduce a higher percentage of renewables into its current energy mix. At present, only 2% of the energy produced comes from renewable sources. In 2018 Malaysia announced a target of 20% Renewable Energy by the year 2025. The undergoing transformation of polices showcases this transformation and the commitment for implementation of Renewable Energy in the country. Tenaga Nasional Berhad (TNB) has set up a subsidiary known as TNB Renewables in order to facilitate the shift towards renewables under this transformation program [90].

Malaysia also pursues technological advancements towards the use of AI, IoT, Big Data and Blockchain. The government of Malaysia has drafted several policies and roadmaps to strengthen the business environment. These include the National Industry 4WR Policy aiming to attract stakeholders to industry 4.0 with the establishment of Digital Technology labs and collaborative platforms for knowledge transfer. The National BDA Framework intends to create a national Big Data Analytics (BDA) ecosystem to enhance the economic growth further. In addition, the National AI Framework and the National IoT Framework along with Malaysia's Innovation Policy Council strive to further accelerate the growth of Malaysia's tech industry towards Digital Economy [90].

An Australian Blockchain company "Power Ledger" has begun a partnership with Malaysia's Sustainable Energy Development Authority (SEDA) for a pilot of peer-to-peer energy trading. This shall allow for a more equal energy distribution. Currently, Malaysia has more than four million buildings with rooftop solar in Peninsular Malaysia. The partnership promises an opportunity for energy trading among the prosumers and consumers [91].

6.9 The Pacific Islands

The Pacific Islands composing of the islands of Fiji, Kiribati, Marshall Islands, Micronesia, Nauru, Palau, Samoa, Solomon Islands, Tonga, Tuvalu and Vanuatu with a combined population of about 2.3 million people have declared a switch from fossil fuel imports and announced an ambitious 100% Renewable Energy target by 2020 (in case of Cook Islands, Niue and Tuvalu) and by 2030 (in case of Fiji, Vanuatu and the Solomon Islands) [92].

Most of the Pacific Islands benefit from sunshine all year round and – besides solar - have great capabilities for wind, hydro and geothermal energy. At the same time, the islands suffer drastically from the consequences of the Climate Emergency, while contributing less than 1% to the overall global greenhouse gas emissions [93]. The islands have been faced with more frequent storms, floods and heavier rainfalls during summer as well as winter months.

7

Required Transformation of the Energy Industry

Required Transformation of the Energy Industry

Transformation of a company, let alone industry, is usually a painful process since it comes with a lot of change and uncertainty. And in fact, it has the potential to shake things up significantly with an impact on every individual employee. How can a company prepare for the transformation with regards to organisation and strategy will be briefly discussed in the next two chapters.

7.1 Organisation

Enabling successful Digital Transformation goes beyond technology. For an organisation to truly benefit from any new approach, every layer of the organisation needs to be involved, and every employee needs to be on board.

Organisations can invest millions into new systems, processes and technologies, but all this investment will be worthless if the company structure and culture prevents the new Digital Transformation strategy from becoming established [2].

A recent survey conducted by North Carolina State University's Enterprise Risk Management Initiative and management consulting firm, Protiviti Inc, of directors, CEOs, and senior executives found that Digital Transformation risk is their number one concern in 2019. However, 70% of all Digital Transformation initiatives do not reach their goals. Of the $1.3 trillion that was spent on Digital Transformation last year, it was estimated that $900 billion went to waste [95].

According to the Harvard Business Review [96] the reason why some Digital Transformation initiatives fail is that although most Digital Transformation initiatives enable efficiency gains and customer intimacy, if people lack the right mindset to change and the current organisational practices are flawed, Digital Transformation will magnify those flaws.

According to [2] states that when it comes to challenges preventing successful Digital Transformation, internal barriers related to company culture and employees are much more common than external barriers such as regulation or industry standards. Especially lack of Digital Skills and lack of Digital Mindset are the main barriers to Digitalisation, including for transmission system operators who cite mindset as the biggest challenge.

While the technology to enable Digital Transformation is available and skills training can be implemented, there is another critical element missing that needs to be in place for Digitalisation to be successful. Just as it is required to foster an individual mindset geared towards Digitalisation, there is also need to foster a collective one, one which goes to the core company culture and challenges the strategic and operational ways of working.

For traditional energy companies, this shift is often centred around collaboration, innovation, networking and breaking down departmental silos. Building a new company culture with digital at its core involves every employee buying into the organisation's digital goals and vision.

However, [2] states that in larger organisations, employees are less likely to be actively involved in their organisation's Digital Transformation strategy. They hence view Digitalisation as something that happens to them or happens elsewhere, rather than something that they are shaping and are actively participating in.

Even though large organisations are more likely to have a public-facing strategy, it seems they are not willing to involve their employees in shaping this, which could spell disaster for motivating and retaining staff, as well as attracting new talent to the organisation.

This could be especially detrimental when it comes to attracting younger employees with sought-after Digital Mindsets and the skills needed to shape the future direction of the company. These digital natives are the ones most overlooked when it comes to shaping an organisation's digital strategy, with half of the millennials that were surveyed in [2] saying that they are not actively involved in their organisation's Digital Transformation strategy, despite saying that it impacts their job.

To ensure that Digital Transformation is successful, organisations need to ensure they are involving employees, encouraging collaboration, and replacing hierarchy with cross-functional teams. For large organisations, this is especially important to prevent younger employees from jumping ship to join start-ups where they will be given more involvement in decisions that impact their careers.

7.2 Strategy and Business Cases

The technology is in place to enable Digital Transformation, the data exists, and the tools needed to extract value from this data are available. While this is a great starting point, what is often missing is the vital next step – to create vital business cases fitting to the company’s strategy.

Many companies struggle in the transformation since their focus is on enabling Digital Transformation without fully appreciating why they should digitalise and transform. While Digitalisation is viewed as a major strategic goal for many companies in the energy industry, rather than seeing Innovation and Digitalisation as goals and an end, Digitalisation should be the means to an end. On a journey where meeting long-term business goals are the destination, Digitalisation is simply one of the modes of transport to get there.

When it comes to reasons for implementing a Digital Transformation strategy, the organisations with clearly defined goals are already seeing evidence that these goals are being mirrored by the benefits as the survey undertaken as a basis for [2] reveals:

- Improving efficiency is a unanimous goal of Digitalisation. 88% of the 2000 global energy industry professionals surveyed rank this in the top half of their goals (out of seven), with 49% ranking this as their number one goal. Efficiency was also the most commonly identifiable benefit seen by 55% of participants as a main benefit of Digitalisation;

- Reducing costs is the next most important goal, being identified by 75% of participants, higher than creating new products or services or enhance customer connection.

Despite the emphasis on efficiency and cost reduction, several other perceived benefits rank highly for the energy industry, including creating new products, enhancing customer connections and improving safety.

In accordance with [2] states that today, Digitalisation is having the biggest effect on asset operations and management, with larger companies currently seeing a more significant impact.

For many organisations, proving the value of Digital Transformation will come from real-life use cases that demonstrate Digitalisation’s role as the enabler of Decarbonisation.

8

Possible Future Scenarios

Possible Future Scenarios

Looking ahead and predict how the energy industry will change and look like in the future is an exciting task, but a difficult undertaking. Change has never been faster than today, and the speed of change will only accelerate. While we do have a relatively good view on the next couple of years, looking further ahead can only provide possible scenarios of which we will share one in chapter 9.2.

8.1 The Next Five Years

This chapter focuses on the next five years and highlights political, social, and technological themes that may influence the direction and pace of the Energy Transition. These areas are either in rapid flux or are at a decision crossroads, and they are either accelerators or brakes for the Energy Transition. Observing their development in the short term may provide insights on whether we need to adjust our long-term forecast [1].

8.1.1 Politics

Governments at all levels must solve the trilemma of simultaneously making energy affordable, clean, and reliable, and in a way that is acceptable to citizens. Whereas emerging economies – especially for example in Asia – are likely to continue to prioritise growth and development over Decarbonisation, it is by no means certain that larger industrialised or mixed economies will move fast enough to meet the Paris COP 21 climate-change targets.

While this picture is mixed in Asia-Pacific the undisputed leader in the Energy Transition, topping expansions in renewable power is Greater China. China's share of electricity in final energy demand will grow from 21% in 2017 to 52% in 2050 – the highest of all regions, over 90% from renewable sources China's energy mix, currently dominated by coal, will reduce its coal share from 60% to 16% in 2050. Also, in OECD Pacific, the primary energy use will fall more rapidly than the population decline in this region. By 2050 the electricity mix will be dominated by wind, and at 50% of final energy demand, will be the second-most electrified region in 2050 after China.

China and India are superpowers in terms of population and growing energy demand, and their clean-energy plans have the scale to influence the world. Driven by energy security, concerns over pollution in their mega-cities, and growing indigenous industrial-technology sectors, both countries are driving their Energy Transition at an accelerating rate. Due to the sheer size and growth rates of their energy markets, and the economies of scale that these factors have on the cost of energy-related equipment, they are also pulling the rest of the world with them on the transition. Both China and India have Nationally Determined Contributions (NDCs) with ambition levels lagging behind real developments; stronger pledges in the 2020 NDC updates may further accelerate the transition beyond our present Outlook.

Recent years have globally seen a rise in right-leaning populist movements in several countries that are either major primary energy markets, major primary energy suppliers, or both. Because they generally espouse policies that protect the domestic jobs of their political base, populist politicians are likely to delay the Energy Transition in countries that are significant producers or consumers of hydrocarbons, where such industries have a large employment base. For example, thermal power stations represent significant historical investments by utilities, many of them state-owned, and governments are under pressure by their operators not to turn these into stranded uneconomic assets.

Protecting the electoral base also leads to economic protectionism, often veiled in the cloak of nationalism. If not curtailed in the near term, ever-increasing tariffs between the large independent economies and trading blocs will suppress trade volumes, reducing economic growth and thereby overall welfare, as well as affecting energy consumption. Nationalistic tendencies also encourage the “not-invented-here” syndrome, delaying international acceptance of new ideas and technologies that are potentially cleaner and more efficient. Similar movements often discourage cross-border cooperation on shared infrastructure projects such as interconnectors, transnational gas pipelines, and large hydropower schemes, all of which are necessary to make the transition happen. This may lead to a slower transition and possibly lower energy use [1].

A further political influence could come from large corporations setting internal targets on clean-energy use and other sustainability issues. Besides, the investor community is increasingly funding clean energy projects as good business, and not just for corporate responsibility green-washing. This may decrease over the next five years if governments respond to lower Renewable Energy costs by withdrawing subsidies and refusing to underwrite power-purchase agreements while failing to withdraw fossil fuel subsidies.

For investors in projects where governments operate auction systems for new renewables projects, the margins are already thin and getting thinner, and therefore this sector may also become less attractive in the near term. Against this, at a macro- investment policy scale, many large investment funds, especially sovereign wealth and pension funds, are withdrawing from fossil-fuel related investments owing to their associated long-term risks. This is likely to gather momentum: ahead of the 2019 G20 summit in Japan, 477 investors representing USD 34tn in assets (half the world’s invested capital), signed an open letter “to the governments of the world” demanding more urgent action on Climate Emergency.

Accelerators to watch:

- Energy-security concerns leading to investments in domestic Renewable Energy
- Investors increasingly are drawn to clean energy
- The size and influence of the climate-crisis youth movement

Brakes to watch:

- Populism protecting jobs in hydrocarbon and thermal power industries
- Political polarisation leading to national stagnation on key decisions on energy infrastructure and clean-energy incentives
- Trade wars depressing investment in cleaner development and hampering the exchange of new technologies

8.1.2 Society

The Energy Transition might be accelerated by the co-benefits of addressing two major societal concerns: Climate Emergency and pollution. Addressing Climate Emergency is a major driver of the Energy Transition. Public concern has been re-energised in the last year after a fall-off in the immediate afterglow of the COP 21 agreement in Paris.

In 2019, inspired by Sweden’s Greta Thunberg, student strikes spread to thousands of schools in over 130 countries. Over the next five years, school-going protesters will become eligible voters, but even before then they may exert a strong influence on society, starting with their own families. New sustainability agendas of governments are already having an impact on policy choices around clean energy and sustainability.

Although public awareness of Climate Emergency has increased, its long-term nature makes it less tangible than the effects of air pollution that can be seen, smelt and touched by all – and, importantly, measured. The global market for air quality monitors is expected to grow at a compound annual growth rate (CAGR) of almost 7% to reach USD 25bn by 2024 (MnM, 2019). As a result, over the next five years, Decarbonisation will be driven more strongly by health concerns around air pollution in cities than by fear of Climate Emergency. Many politicians recognise the related costs for healthcare provision to address pollution-induced illnesses.

As the worst air pollution is concentrated in cities, local government entities often lead the way in addressing these issues. Citywide bans on internal combustion engine (ICE) vehicles in general, and types of diesel, in particular, will spread over the next five years, and we will see the use of public transport encouraged through fare subsidies, denser networks, and more frequent services. Much of this transport will be electric, LNG, hydrogen, or hybrid driven. Municipalities will adopt similar alternative fuels for their broader public service vehicle fleets.

This tension between demands for clean energy and more tourism is further complicated by urban myths about the safety of energy sources. This applies particularly to hydrogen and nuclear, as well as fears over electromagnetic radiation from power lines, leading to 'not-in-my-backyard' (NIMBY) attitudes. Public acceptance of new energy developments is often contested, frequently based on false narratives, and concerns over the visual pollution of large wind farms, solar parks, and overhead power lines, along with agitation over hydro or tidal schemes drowning landscapes, also contribute to the confusion. Such public debate, although on a local case-by-case basis, will have a cumulative effect on the Energy Transition over the next five years.

While many of these factors may delay the Energy Transition, there are numerous examples of islands, small towns, industrial and port sites, plus individual domestic energy users, who are already converting to distributed generation, independent of utilities and the delays caused by other members of society or slow-moving local or national governments. Systems at this scale create 'prosumers' who both produce power and sell it to others but consume it when their demand exceeds their own ability to supply. The number of prosumers can be expected to increase over the next five years as they exploit the projected lower costs and flexibility of renewable generation and storage.

However, the growth of this market is highly dependent on better regulatory frameworks for the large-scale market integration of prosumers.

Accelerators to watch:

- Climate and pollution concerns of youth movements of future voters
- Regulations and target setting on clean-energy issues at state and city levels backed by individual large corporations

Brakes to watch:

- Social media promoting a narrative on energy safety and supporting NIMBY-ism

8.1.3 Technology

Rapid cost reductions have resulted in solar PV and wind being the lowest cost options in many new projects. Over the next five years, electric and hybrid vehicles will become mainstream. Several countries and many cities, independent of national requirements, are setting targets for the elimination of ICE (internal combustion engine) vehicles and this trend can be expected to continue. However, the uptake will continue to depend on tax breaks and other incentives in countries where such growth has not yet taken off, as well as restrictions on ICE vehicle use or new licences (as we see it in some countries in Asia Pacific already). At the same time, investment in charging infrastructure must continue to grow rapidly, and manufacturers must overcome public perceptions on range limitations by exploiting new battery and fast-charging technologies. With the indicators that all the major international vehicle manufacturers are now producing EVs along with many start-ups, the competition in this evolving field should see many consumer concerns being met over the next five years, thus supporting the transition.

Gas grids able to cope with multiple sources of hydrocarbon gas (e.g. natural gas, biogas from plants, and biogenic gas from waste) are already being tested. Such grids will, over time, add hydrogen to their mix while selling the gas based on its variable calorific value and not at a fixed specification as is currently the case.

Analyses of data from power-generating sites, hydrocarbon-production sites, distribution grids, all forms of transport, manufacturing and processing plants, and commercial, retail and domestic properties will enable operators and owners across the energy value chain to improve their assets' operability and maintainability and help them to lower costs. Machine-learning and Artificial Intelligence techniques should enhance the systems' efficiency by optimising assets.

Asset data, when combined with external weather and market data, should allow for improved forecasting across the energy value chain. Improved forecasting should facilitate demand response to tailor user demand to the generating supply. In addition, new business models will be developed that should decrease consumer costs while simultaneously allowing energy companies to maintain a fair level of profitability.

Digitalisation will allow many current asset-heavy industries to reconfigure themselves as services to their customers – the so-called 'servitization' of an industry-leading to increased efficiency, including maximising asset use but lowering energy use per unit of service delivered. It will also allow for a reconfiguration of many consumers as prosumers.

Finally, Digitalisation offers the 'Internet of Energy' whereby different power-generation sources combined with storage across the spectrum, from utility-scale to localised distributed hubs, may be integrated via a smart grid. This would be controlled by Artificial Intelligence, using data platforms to maximise the efficiency of an energy system and the market that it supports. Over the next five years, we will see a proliferation of pilots that will ultimately assist in bringing the predicted Energy Transition to fruition. The cumulative effect of Digitalisation will become clearer in the next five years and may prompt us to adjust our forecast accordingly.

Accelerators to watch:

- Government push for EVs in the transport sector through financial incentives
- Cost reductions in storage, wind, and solar PV technology continue to outperform expectations
- The 'Internet of Energy' integrates energy sources in more-efficient market-scale systems

Brakes to watch:

- Charging infrastructure for EVs cannot keep pace with demand, and lack of government support to advanced biofuel infrastructures prevents developments.
- Variable Renewable Energy cannibalisation discourages investors
- Energy density of batteries struggles to improve further

8.2 Further Ahead?

What lies further ahead is relatively hard to predict. The only thing clear is that the energy industry will go through a massive transformation which most probably will entail a reshuffling of the current industry setup. Established players may fade out, new players may come in, disruptors from other industries – for example big platform providers, telecommunication firms or strong players in the Information and Communication Technology (ICT) space – may be able to establish a position that allows them to gain the largest profits out of a "customer in the centre" shift. New technologies as discussed in this report may make intermediaries (Blockchain) and large parts of the workforce (AI and Robotics) obsolete.

Epilogue

The world's energy system is changing profoundly, bringing opportunities and risks.

The transition from fossil-based to zero-carbon is happening fast but not quickly enough to meet the Paris Agreement's objectives to limit global warming to 'well below 2°C', let alone 1.5°C. [1] confirms that available technologies and systems have the potential to close the 'emissions gap', the difference between the current rate of decarbonising energy and the pace needed for global warming of 1.5°C.

For the next decade [1] forecasts growth of 1000% in solar power to 5 terawatts (TW) and 500% in wind power to 3 TW. Fifty million electrical vehicles (EVs) per year will be needed by 2030, requiring a 50-fold increase in batteries, and large-scale charging infrastructure. A lot of these changes will happen in Asia Pacific.

Digital Technologies, as discussed in this report, will play a significant role to enable the energy industry to transition. However, despite the availability of the technologies, time is against us and we are moving in the wrong direction. Higher energy demand in 2018 drove a 1.7% rise in global energy-related carbon dioxide (CO2) to a record 33.1 gigatons (Gt), according to the International Energy Agency. This was the fastest growth since 2013. Emissions from all fossil fuels increased, with the power sector accounting for nearly two-thirds of this growth.

In addition to technology, we need extraordinary policy action: policies that advance renewables, new decarbonization technologies and systems, EVs and energy efficiency. Beyond this, we need to change the prevailing mindset from 'business-as-usual' to 'business-as-unusual'. Only by challenging how businesses and societies operate and behave can we start to close the emissions gap between where we are headed on global warming and where humanity has agreed through the Paris Agreement and the Sustainable Development Goals.

Government and business leaders need to make immediate and concerted efforts to accelerate action. They must determine which energy sources need to be scaled up and down and how fast. IEA et al. (2019) estimate that an average annual investment of about USD 1.4 trillion is required between 2018 and 2030 to achieve all related UN Sustainable Development Goal 7 targets: i.e. ensuring access to affordable, reliable, sustainable and modern energy for all. However, this is nothing compared with the expected price of dealing with the impacts of climate change: the cost of doing nothing. Private sector capital is central to meeting this investment challenge.

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