DIGITAL TECHNOLOGY FOR ASEAN ENERGY:

HOW DIGITALIZATION CAN ADDRESS ASEAN'S POWER SECTOR CHALLENGES

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CONTENTS

FIGURES AND ACRONYMS

4IR	Fourth Industrial Revolution
ACE	ASEAN Centre for Energy
AEC	ASEAN Economic Community
AEO	ASEAN Energy Outlook
AI	Artificial Intelligence
AMS	ASEAN Member States
APAEC	ASEAN Plan of Action for Energy Cooperation
APG	ASEAN Power Grid
APS	ASEAN Progression Scenarios
ASEAN	Association of Southeast Asian Nations
ASEC	ASEAN Secretariat
ATS	ASEAN Target Scenarios
BAU	Business as Usual
BNEF	Bloomberg New Energy Finance
CHP	Combined Heat and Power
DIFAP	Digital Integration Framework Action Plan
DSM	Demand Side Management
EE	Energy Efficiency
EI	Energy Intensity
EMIS	Energy Management and Information Systems
EV	Electric Vehicle
EVN	Vietnam Electricity
FDD	Fault Detection and Diagnostic
GDP	Gross Domestic Product
GE	General Electric
GWh	Gigawatt Hours
HAPUA	Heads of ASEAN Power Utilities/Authorities
HER	Home Energy Report
HPE	Hewlett Packard Enterprise
IEA	International Energy Agency
IGNITE	ASEAN-USAID Inclusive Growth in ASEAN through Innovation, Trade and E-Commerce
IoT	Internet of Things
IT	Information Technology
KM	Kilometers
kWh	Kilowatt Hours
LNG	Liquefied Natural Gas
MDMS	Meter Data Management System
MPAC	Master Plan on ASEAN Connectivity
MSME	Micro, Small, and Medium Enterprises
MW	Megawatts
OGB	Off-Grid Bazaar
PV	Photovoltaics
RE	Renewable Energy
REPP-SSN	Regional Energy Policy and Planning Sub-Sector Network
SPC	Southern Power Corporation
TAGP	Trans-ASEAN Gas Pipeline
TFEC	Total Final Energy Consumption
TNB	Tenaga Nasional Berhad
TPES	Total Primary Energy Supply
UN	United Nations
US-ABC	US-ASEAN Business Council
USAID	United States Agency for International Development

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In May 2019, the ASEAN-USAID IGNITE project delivered a presentation on the early plans for this report to ASEAN energy officials during an ASEAN Regional Energy Policy and Planning Sub-Sector Network (REPP-SSN) Meeting in Singapore. The authors would like to express their appreciation for verbal and written feedback received during and after this event, which was beneficial to the development of the study.

FOREWORD
U.S. AGENCY FOR INTERNATIONAL DEVELOPMENT

The Association of South-East Asian Nations (ASEAN) stands at a crossroads in terms of its collective energy future. With a combined GDP of US$2.9 trillion in 2018, ASEAN ranks as the third largest economy in the Indo-Pacific, the fifth largest globally and is one of the fastest-growing regions in the world. Due to rapid economic growth, ASEAN expects a 50 percent rise in the demand of energy over the next decade. To meet this increased demand and maintain economic growth, ASEAN countries must integrate leading-edge digital technologies to address energy sector challenges to supplying affordable and sustainable energy.

Recent innovative digital technologies in the energy sector include smart buildings, and improved electricity storage technologies. As a reliable and active partner to ASEAN, the United States Government through the United States Agency for International Development (USAID) is proud to invest in ASEAN's economic success through energy cooperation. Through the U.S. Asia Enhancing Development and Growth through Energy (EDGE) initiative, the U.S. seeks to strengthen energy security, increase energy diversification and trade, and expand energy access across the region.

As part of this greater U.S. effort, USAID is pleased to jointly present this report on digitalization in the energy sector to the Regional Energy Policy and Planning Sub-sector Network. The goal of this study is to assist ASEAN in considering policy options to meet its regional energy target of 23 percent renewables of the region's primary energy mix by 2025 compared to 9.4 percent in 2014. This study provides examples and recommendations on how ASEAN can take advantage of digitization of energy. Digitalization is the defining feature of twenty-first century energy systems. We believe this study flips the switch in catalyzing opportunities for ASEAN policymakers to integrate leading-edge digital technologies and expand access to electricity. ASEAN is well-positioned to harness affordable, sustainable, and reliable power systems while advancing a free, open, and secure Indo-Pacific.

ERIN E. MCKEE
PRINCIPAL OFFICER | USAID/ASEAN

FOREWORD
US-ASEAN BUSINESS COUNCIL

As a region, ASEAN is just beginning to show its full economic strength. In terms of sheer size, it is currently the third largest economy in the Indo-Pacific and the fifth largest in the world. Its growth, which averaged 5.3 percent between 2000 and 2017 and is projected to average 5.5 percent per year over the next three decades, will propel the region to become the fourth largest economy in the world by 2050.

Critical to achieving this level of growth is the energy sector. ASEAN recognizes the importance of the energy sector to continue to drive growth and prosperity. In its own foundational plan for developing the region's energy sector, the ASEAN Plan of Action for Energy Cooperation (APAEC) 2016-2025, energy is recognized as the "key to the realization of the ASEAN Economic Community (AEC)". It is also a crucial element of what will constitute a "well-connected ASEAN to drive an integrated, competitive and resilient region." If current conditions remain the same, energy consumption will have to increase nearly 2.5 times, to almost 1,050 Mtoe, to reach the projected level of economic growth.

However, in light of technological advances, it appears that conditions are unlikely to remain the same, at least in the options available to ASEAN. How these new options could help ASEAN overcome some of its most serious challenges – meeting power demand in a sustainable manner, rapidly closing the energy access gap, and maintaining or improving the resilience of the overall energy system – is the crux of this report.

As with other sectors in the traditional economy, the energy sector is being transformed by digitalization, the trend at the heart of the Fourth Industrial Revolution. U.S. companies are among the global leaders in the development and application of technologies underlying this transformation, with technologies that enable better connectivity and information sharing between energy producers and consumers, more efficient industrial energy use, and better integration of renewable energy sources. The case studies from U.S. companies presented in this report bring to bear how these innovative technologies can help ASEAN address its most critical energy challenges. We hope that this report will serve as a resource for ASEAN countries as they look to grasp the transformational potential of digital technologies in their energy sectors fully. We also believe that it stands as a testament to the ingenuity, innovation, and expertise of U.S. companies operating at this inflection point where the traditional economy and the digital economy meet.

ALEXANDER FELDMAN
PRESIDENT & CEO | US-ASEAN BUSINESS COUNCIL

FOREWORD
ASEAN CENTRE FOR ENERGY

As one of the fastest growing regions in the world, ASEAN is predicted to be an important driver for global economic growth, becoming the fourth largest economy in the world by 2050. In order to maintain its current growth rate, ASEAN must overcome challenges to meet its increasing demand for energy while at the same time moving towards a more sustainable energy system, given the global pressure to reduce rising greenhouse gas emissions.

As we are fast approaching the 4th industrial revolution, the ASEAN energy systems may greatly benefit from adoption of digital technology which would make them more efficient, intelligent, and sustainable. Furthermore, to enhance energy connectivity and market integration, ASEAN Member States shall start to consider the significance of including utilization of digital technology in the ASEAN Plan of Action for Energy Cooperation (APAEC) 2016-2025.

As the centre of ASEAN energy cooperation, ACE appreciates this effort by US Agency for International Development (USAID) and the US-ASEAN Business Council (US-ABC) to assist the Regional Energy Policy and Planning Sub-sector Network (REPP-SSN) in considering policy options to better achieve the APAEC targets.
We believe that this report will greatly assist ASEAN in adopting and optimizing the use of digital technology and in continuing to invest in the development of digitalized energy systems.

DR. NUKI AGYA UTAMA
EXECUTIVE DIRECTOR | ASEAN CENTRE FOR ENERGY

BACKGROUND AND SUMMARY

Digital technologies are transforming industries around the world, including the energy sector. Many experts and organizations including the International Energy Agency (IEA) believe that digitalization could mark a new era for energy, revolutionizing how energy systems are designed and operated and providing the tools for addressing critical challenges. The Association of Southeast Asian Nations (ASEAN) faces its own specific set of energy challenges, and digitalization can play a critical role in addressing these challenges and achieving ASEAN's energy goals.

The Regional Energy Policy and Planning Sub-sector Network worked with the ASEAN-USAID IGNITE project, US-ABC, and the ASEAN Centre for Energy to develop this report to connect ASEAN's energy challenges and digital solutions. This report is intended to help ASEAN and ASEAN Member States address high-priority power sector challenges through increased digitalization by providing useful digital technology and energy sector context, educational and inspirational success stories, and relevant recommendations.

The first section provides an overview of the wave of digital technology and digitalization introduced with the Fourth Industrial Revolution (4IR) from both a global and ASEAN perspective.

The second section discusses digitalization specifically within the energy sector, again from both a global and ASEAN perspective.

The third section gives a brief overview of ASEAN's energy sector and identifies high-priority power sector challenges that could be addressed by digitalization:

THIRD SECTION OF REPORT

1. Meeting power demand sustainably
2. Closing the electricity access gap
3. Maintaining energy system resilience

The fourth section identifies five digital-relevant potential solutions to these challenges:

FOURTH SECTION OF REPORT

1. **Meeting power demand through improved end-use efficiency**
2. **Meeting power demand through improved thermal efficiency**
3. **Meeting power demand through improved renewables grid integration**
4. **Closing the energy access gap with microgrid development**
5. **Maintaining energy system resilence with better weather preparation and recovery**

It then shares 13 success stories where digital technology played an important role in each of these solutions. These success stories came from a diverse set of ASEAN and non-ASEAN jurisdictions, and span the entire power sector value chain from resources to prosumption.

The fifth and final section offers six recommendations that ASEAN and ASEAN member states can carry out for next steps:

FIFTH SECTION OF REPORT

1. Conduct a formal, well-designed **digitalization program**
2. Develop the **enabling infrastructure**
3. Develop the **enabling capability**
4. Introduce **technology-forcing standards**
5. Introduce **technology-encouraging targets**
6. Foster a **creative, innovative, and entrepreneurial culture**

By adopting the recommendations above, ASEAN can better take advantage of the immense promise of digital technology to meet its growing power demand, close its electricity access gap, and maintain its resilience. It can also move one step closer to the goal of a fully affordable, sustainable and reliable power system.

Digitalization

GLOBAL OVERVIEW

Digital technology is broadly defined as any technology involving the use of binary or digital code. This technology is everywhere and has been characterized as the most revolutionary innovation of our modern era. In broad terms, digital technology includes computers and data management systems, software and algorithms, mobile phones, multimedia, online interfacing and games, and much more.

Digital technologies are typically organized into three categories: data, analytics, and connectivity. The first- data, includes technologies that collect, store, and retrieve information. Examples of these types of technologies include Amazon Web Services, Cloud Computing, Big Data and Blockchain. The second- analytics, includes technologies that process and interpret information, such as calculating, controlling, or forecasting with data. Examples include visualization software, Artificial Intelligence (AI), and Quantum Computing. And the third- connectivity, refers to technologies that communicate information, such as sensing and transmitting. Examples of this include the Internet of Things and 5G coverage.[1] Most real-life applications of digital technology include two or more of these categories. For example, something as routine as shopping online or navigating traffic can involve all three elements: data, analytics, and connectivity.

Digitalization refers to the application of digital technologies to improve organizational operations by connecting devices, collecting and sharing data, and analyzing that data.[2] Digitalization is often understood to be improving four organizational functions: monitoring (tracking and collecting data), analyzing (drawing conclusions from the data), predicting (forecasting future conditions or events based on the analysis), and operating (controlling based on the forecast).[3]

FUNDAMENTAL ELEMENTS OF DIGITAL TECHNOLOGY

1. **Data**
   Collects and stores information
2. **Analytics**
   Processes and interprets information
3. **Connectivity**
   Communicates information

DIGITALIZATION FUNCTIONS

1. **Monitor** – track
2. **Analyze** – interpret
3. **Predict** – forecast
4. **Operate** – control

The trend toward greater digitalization is enhanced by advances in all three categories: data, analytics, and connectivity. Ever increasing amounts of data are becoming available thanks to better data collection tools and the declining costs of sensors and storage. The speed and capability of analytics are exponentially increasing as machine learning and more intelligent analyzing systems are developed. And there is better connectivity between people and electronic devices as data and information transmission becomes cheaper and easier.[4]

These advances are synergistic. As data becomes more plentiful and computing power grows, digital connectivity expands dramatically to make use of this information. At the same time, as connectivity expands, more and more data is available for examination and processing. Already, the number of internet users has increased from 500 million people in 2001 to four billion people in 2018. This means over half of the global population now has access to and can contribute to this data revolution.[5]

The cascading effects of digitalization include new entrepreneurial opportunities in the nexus of technology and innovation, such as ride-sharing via GoJek and Grab; adding value to existing businesses, such as the symbiotic

1. Digitalization & Energy 2017. International Energy Agency (IEA), November 5, 2017. https://www.iea.org/digital/
2. Digitalization of Energy Systems. Bloomberg New Energy Finance, November 9, 2017. https://about.bnef.com/blog/digitalization-energy-systems/
3. Renewables Management System. CGI, Accessed July 28, 2019. https://www.cgi.com/en/media/brochure/RMS-efficiently-monitor-and-control-your-full-renewable-portfolio-real-time.
4. Digitalization & Energy 2017. International Energy Agency (IEA), November 5, 2017. https://www.iea.org/digital/
5. New ITU statistics show more than half the world is now using the Internet. ITU News, December 6, 2018. https://news.itu.int/itu-statistics-leaving-no-one-offline/

value that GoFood brings to urban restaurants; and the broad and deep revolution in the underlying capabilities of world-leading firms. Amazon, Google and Microsoft are all excellent examples of large companies seizing competitive advantage by using digitalization as both a "back-office" tool for business analytics and as a "front-office" product in itself.

The wave of digitalization in the economy is sometimes referred to as the Fourth Industrial Revolution (4IR), a revolution of cyber-physical systems that is redefining and recalibrating how we act and interact. The first industrial revolution brought mechanized production, including water and steam power. The second brought mass production built on labor, and the third brought electronics, information technology and automatic production. The Fourth Industrial Revolution is now delivering an intelligent environment of interconnectivity between people and machines. This environment is already enabling previously unimagined innovation, speed, and convenience, and is characterized by the deep and encompassing integration of digital technologies into our everyday lives. Technologies that are most often associated with 4IR include the Internet of Things (IoT), Artificial Intelligence (AI), advanced robotics, 3D printing, and wearable technology such as augmented and virtual reality devices and software.[6]

DIGITALIZATION IN ASEAN

The Association of Southeast Asian Nations (ASEAN) is a regional body consisting of the ten member states of Brunei Darussalam, Cambodia, Indonesia, Lao PDR, Malaysia, Myanmar, the Philippines, Singapore, Thailand, and Vietnam. It promotes economic and sociocultural integration and shared prosperity through cooperation. The ASEAN region is diverse and populous, with the ability to adopt innovations quickly at the individual and corporate levels.

ASEAN Member States (AMS) are experiencing digitalization first-hand as digital technology shifts the region's economy in numerous ways. In many cases, AMS have been adept at adopting new digital technologies. There are numerous examples of ASEAN entrepreneurs, business, and non-profits harnessing the power of digital technologies for innovation. At the same time, some observers within ASEAN have reported that some AMS governments lag behind other economies in the overall use of digital technologies. There is a need for improved policies to pave the way for digital advancements.[7]

The Master Plan on ASEAN Connectivity 2025 (MPAC 2025) focuses on digital innovation and adoption of digital technology by micro, small and medium enterprises via a work plan to enhance their participation in the digital economy.[8] MPAC 2025 estimates that the value of digital technologies in ASEAN could be as much as US $625 billion by 2030. Google and Temasek project that the internet economy in Southeast Asia will grow to US $200 billion annually by 2025, and AT Kearney suggests the digital economy may add up to US $1 trillion annually to ASEAN's total GDP in the same period.[9]

With great potential comes great opportunity. MPAC 2025 notes that capturing the opportunity for increased prosperity from digitalization requires "the establishment of regulatory frameworks for the delivery of new digital services (including data management and digital financial services); support for the sharing of best practices on open data; and equipping micro, small and medium enterprises (MSMEs) with the capabilities to access these new technologies."[10] Some ASEAN economies are pushing strongly for a concrete agenda for ASEAN to advance digital integration, known as the ASEAN Digital Integration Framework Action Plan (DIFAP).[11] ASEAN's mission in part is to better enable the growth of digitalization, while simultaneously developing frameworks that steer this growth in positive directions.

6. *Accelerating 4IR in ASEAN: An Action Plan for Manufacturers. AT Kearney.* *https://www.atkearney.es/documents/20152/1849225/Accelerating+4IR+in+ASEAN.pdf/c1fd001b-a5cb-4a96-c73b-e666c0b88692?t=1547576027637*
7. *Accelerating 4IR in ASEAN: An Action Plan for Manufacturers. AT Kearney.* *https://www.atkearney.es/documents/20152/1849225/Accelerating+4IR+in+ASEAN.pdf/c1fd001b-a5cb-4a96-c73b-e666c0b88692?t=1547576027637*
8. *The Master Plan on ASEAN Connectivity 2025. ASEAN Secretariat, August 2016. https://asean.org/wp-content/uploads/2016/09/Master-Plan-on-ASEAN-Connectivity-20251.pdf*
9. *Promoting the Digital Economy in the ASEAN and APEC Regions, USAID US-ACTI and US-ATAARI projects, April 2018.*
10. *The Master Plan on ASEAN Connectivity 2025. ASEAN Secretariat, August 2016. https://asean.org/wp-content/uploads/2016/09/Master-Plan-on-ASEAN-Connectivity-20251.pdf*
11. *Sagar, Mohit. Thailand pushes for ASEAN Digital Integration Framework Action Plan. OPEN GOV, January 17, 2019.* *https://www.opengovasia.com/thailand-pushes-for-asean-digital-integration-framework-action-plan/*

Digitalization in Energy

GLOBAL OVERVIEW

Like much of the economy, the global energy sector is being inundated with digital technology. In the short term, digital technologies are set to make energy systems around the world more connected, intelligent, efficient, reliable and sustainable.[12] Digitalization is allowing for smarter and more connected transportation, better connectivity of residential and commercial buildings for greater efficiency, the introduction of technologies for safer and more productive industrial energy use, a more interconnected electricity system to match supply and demand, and better integration of renewable energy sources. Digitalization can play a particularly important role where there are opportunities for the integration of newer grid technologies such as solar, wind, and batteries. In the long term, energy experts predict that rapid advances in data, analytics, and connectivity will enable a whole range of new possibilities in energy systems. Digitalization has the potential to transform fundamentally the way energy is produced, transported, and consumed.[13]

Consistent with this increasing role, investment in digital technologies by energy companies has risen sharply in the last decade, particularly in the power sector. Global investment in digital electricity infrastructure and software has grown by over 20 percent annually since 2014, reaching a total of US $47 billion in 2016.[14] This investment includes smart meters, smart grid infrastructure, electric vehicle (EV) chargers, building energy controls, industrial energy management software, and electricity systems software. Bloomberg New Energy Finance estimates the 2017 investment at US $54 billion and projects its growth to US $64 billion by 2025. Grid automation and home system investments are each estimated to be $10 billion or more.[15]

Companies working in the energy sector see the business potential in digitalization. General Electric (GE) suggests that digitalization will be the defining feature of 21st-century energy systems, and envisions a future where the energy system "largely operates autonomously, providing economic and environmental benefits to homes, business, and factories."[16] For this reason, GE is accelerating the digitalization of its offerings through the development of digital platforms and is bolstering its industrial software and analytics capabilities. GE, like other companies in the energy sector, is working on getting "ahead of the curve" in the adoption of these technologies.

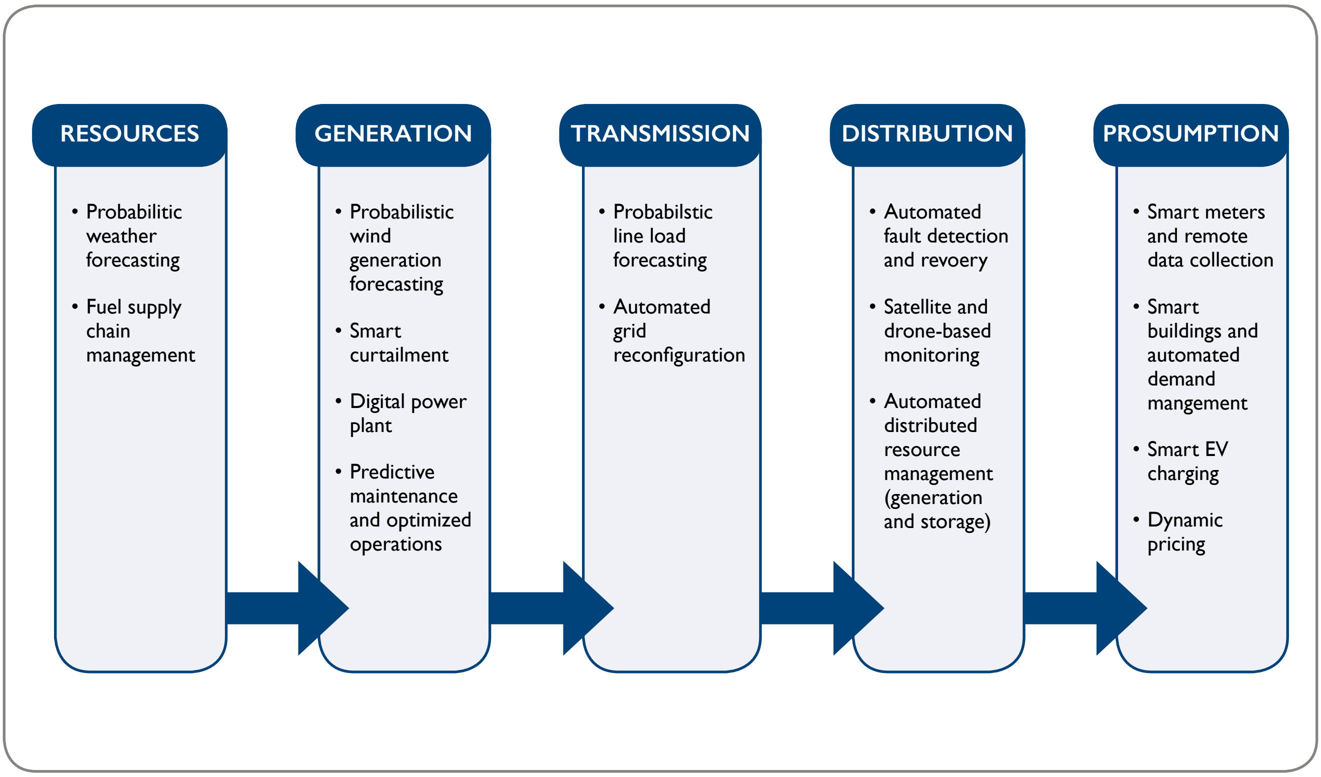
One of the defining qualities of digitalization is that technologies are ever-evolving, which makes the task of forecasting digital innovations particularly challenging. Although this makes it harder to anticipate change, it opens a vast array of opportunities for transformations yet to be realized. Increased digitalization of the power sector is already improving the safety, productivity, accessibility and sustainability of systems. It is changing markets, businesses and employment, and sees an emergence of innovative business models.

When considering global digitalization in energy, the highest adoption potential is within the power sector, given its role in the economy and our daily lives, and the natural fit of the electric sector with digital technology. Figure 1 shows the key elements of the power sector value chain along with examples of relevant digital technology applications at each stage.[17, 18]

Bloomberg New Energy Finance (BNEF) has assessed how digitalization is already affecting various stages of the power value chain globally and predicted the next steps. According to BNEF, digitalization is already significantly established in the transmission stage, though advanced data analytics and machine learning can be applied further. Generation is at an earlier stage of digitalization, and projections for further development are for new power stations fitted with sensors and more advanced communications equipment. Digitalization in the distribution and prosumption stages

12. Digitalization & Energy 2017. International Energy Agency (IEA), November 5, 2017. https://www.iea.org/digital/
13. Sivaram, Varun. 2018. Digital Decarbonization: Promoting Digital Innovations to Advance Clean Energy Systems, Page 1. 1st ed. Council on Foreign Relations.
14. Digitalization & Energy 2017. International Energy Agency (IEA), November 5, 2017. https://www.iea.org/digital/
15. Digitalization of Energy Systems. Bloomberg New Energy Finance, November 2017, Page 1. https://about.bnef.com/blog/digitalization-energy-systems/
16. The Digital Energy Transformation. General Electric, September 2018. https://www.ge.com/content/dam/gepower-pw/global/en_US/documents/hybrid/des/GE_Digital_Transformation.PDF
17. Vingerhoets, Pieter & Chebbo, Maher & Hatziargyriou, Nikos & Kariniotakis, George & Donnelly, Rory & Boeck, Steven & Schneider, Anna-Carin & Johansson, Anderskim & Dotto, Stephane & Hickey, Paul & Monti, A. & Zalaznik, Nina & Bermann, Sasha & Volkerts, Marcel. 2016. The Digital Energy System 4.0. Powering the Future.
18. Greenwald, Judy & Smith, Erin. Digitizing the Grid: Next Steps on Policy. Bipartisan Policy Centre. https://bipartisanpolicy.org/wp-content/uploads/2019/03/BPC-Energy-Digitizing-The-Grid-Next-Steps-on-Policy.pdf

Figure 1: The Energy Value Chain and its Digital Applications



has been widely discussed, but these stages are the least developed and the adoption of new digital systems is only just beginning.[19, 20] In a model adoption of digitalization, the entire value chain would incorporate digital technologies, enabling real-time communication and tracking throughout. The Council on Foreign Relations paints a compelling picture of the digital future where the electric system will be able to identify needs in real time and deliver power at exactly the right time, in the right place, and at the lowest cost.[21]

Digitalization can reduce power system costs in at least four ways: decreasing operations and maintenance costs; improving power plant and network efficiency; reducing unplanned outages and downtime; and extending the operational lifetime of assets. One commonly-cited example is savings through predictive maintenance, involving a mix of data, analytics and connectivity. Another example is efficiency gains achieved by lowering the rate of losses in the delivery of power to consumers through remote monitoring that allows equipment to be efficiently operated and eliminates bottlenecks. The IEA estimates that the overall savings from digitally-enabled measures deployed across the system could be in the order of US $80 billion per year, or about five percent of total annual power generation costs.[22]

In the long term, one of the essential benefits of digitalization will likely be extending the operational lifetime of power plants and network components, through improved maintenance and reduced physical stresses on the equipment. If the lifetime of all global power assets were to be extended by five years, close to US $1.3 trillion cumulative investment could be deferred from 2016 through 2040. On average, investment in power plants would be reduced by US $34 billion per year.[23]

19. Digitalization of Energy Systems. Bloomberg New Energy Finance, November 9, 2017, Page 1.
20. The term "prosumption" refers to consumers who also can produce energy and send that energy back to the grid or to their neighbors
21. Sivaram, Varun. 2018. Digital Decarbonization: Promoting Digital Innovations to Advance Clean Energy Systems, Page 1. 1st ed. Council on Foreign Relations.
22. Digitalization & Energy 2017. International Energy Agency (IEA), November 5, 2017. https://www.iea.org/digital/
23. Digitalization & Energy 2017. International Energy Agency (IEA), November 5, 2017. https://www.iea.org/digital/

DIGITALIZATION IN ASEAN'S ENERGY SECTOR

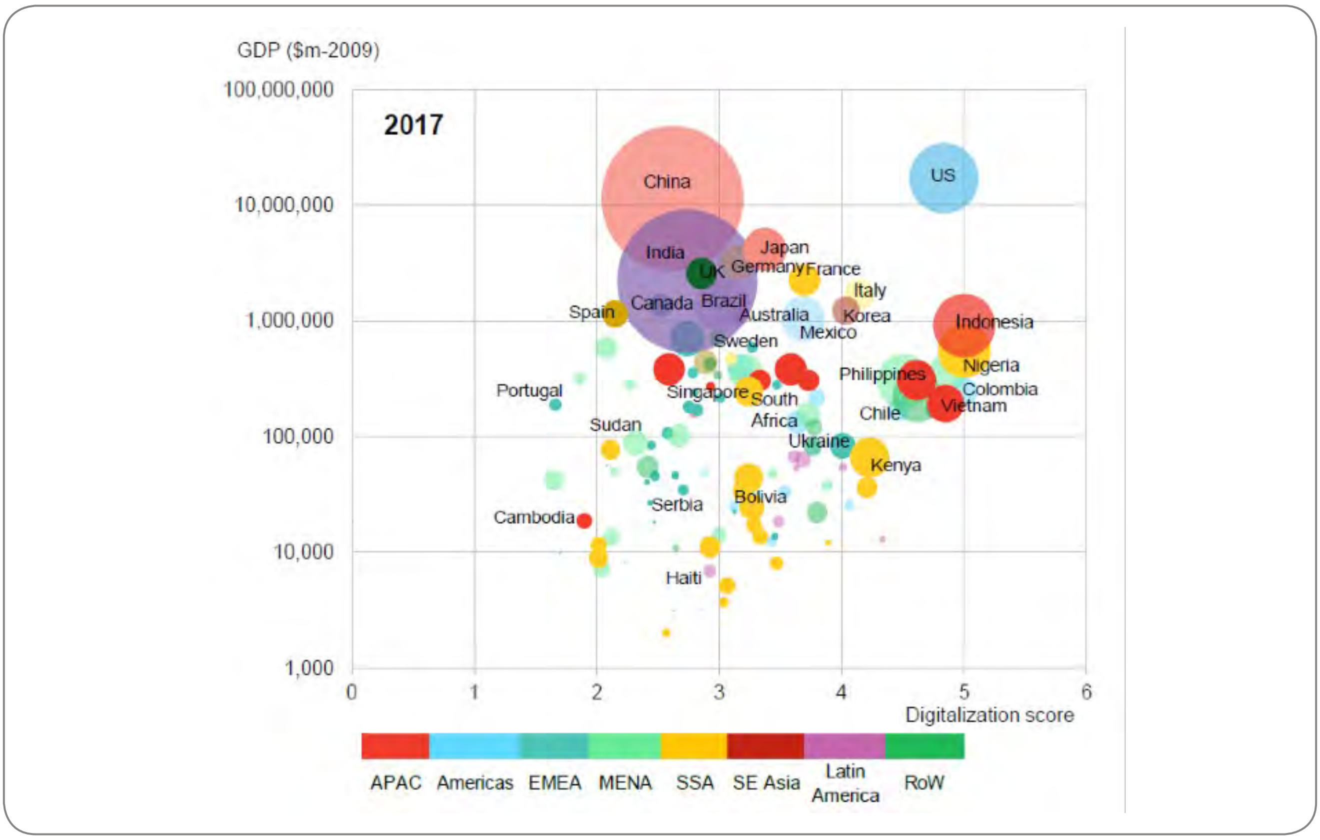
In a comprehensive study of digitalization in the energy sector, Bloomberg New Energy Finance quantified the digitalization potential on a country-by-country basis. Figure 2 compares various countries as of 2017, including those in ASEAN. The figure indicates considerable diversity among ASEAN members.

ASEAN's largest economy, Indonesia, ranks high in digital potential. It provides a conducive environment for digitalization given its high levels of literacy, network coverage, and a domestic digital supply chain that can be leveraged. It is an excellent example of a large emerging economy that has rapidly embraced technology and is likely to digitize quickly.[24] The Philippines and Vietnam also have high digitalization-ready scores, Singapore perhaps surprisingly is somewhere in the middle, while Cambodia scores relatively poorly. Overall, this study and others indicate that ASEAN's energy sector ranks among the highest in terms of digital potential but in some ways lags the rest of the world in digital achievement.[25]

ASEAN is actively seeking to match reality to potential in digital energy. One way is through establishing the ASEAN Power Grid (APG) to enhance both interconnectivity and associated digitalization. The APG is managed by the Heads of ASEAN Power Utilities/Authorities (HAPUA), the primary electricity organization in Southeast Asia. It will first be based on bilateral cross-border arrangements, followed by the sub-regional integration and then a fully integrated regional system. By August 2018, eight of the planned 16 power interconnection projects had been implemented, connecting Singapore, Malaysia, Thailand, Cambodia, Lao PDR, and Vietnam in a power exchange of over 5,200MW.[26]

There are numerous examples where new digital technologies are already changing the way power is

Figure 2: The Digital Potential for Energy – Digitalization of Energy in 2017



Source: Bloomberg New Energy Finance (2017)

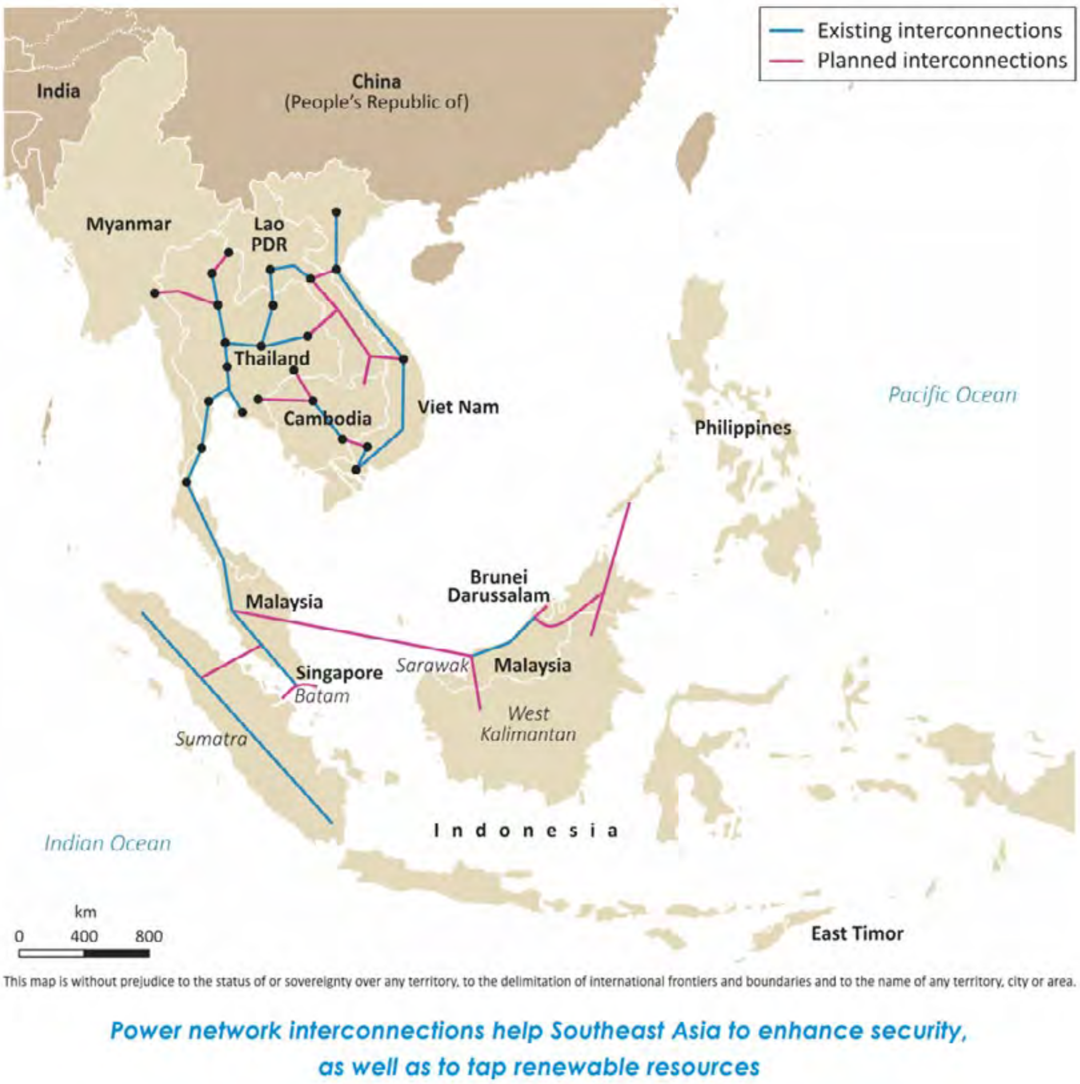
24. *Digitalization of Energy Systems.* Bloomberg New Energy Finance, November 6, 2017. https://about.bnef.com/blog/digitalization-energy-systems/
25. *The Future of Electricity: New Technologies Transforming the Grid Edge.* World Economic Forum, March 2017. http://www3.weforum.org/docs/WEF_Future_of_Electricity_2017.pdf
26. Gnanasagaran, Angaindrankumar. Building ASEAN's Power Grid. The ASEAN Post, May 30 2018. https://theaseanpost.com/article/building-aseans-power-grid

produced and delivered in ASEAN. These range from power plants enhanced by IoT technologies and solar energy mobile pay systems to blockchain technology. Some examples include:

- **Digitally-enabled battery storage** to control grid operations and meet peak demand. Singapore's Energy Market Authority is leading the way with storage investments through public-private partnerships.[27]
- **Mobile power management**, which is built on a digital infrastructure of machine learning, advanced analytics and IoT communication.[28] This infrastructure will be critical as Southeast Asia becomes a data center hotspot.
- **Blockchain-enabled distributed energy resources** being developed by a mix of emerging and established businesses.[29]

The IEA estimates that it will cost ASEAN nearly US $1 trillion through 2035 to develop its power sector. Digitalization can help ensure that this massive investment generates the most significant benefit by reducing operations and maintenance costs, extending lifetimes, improving efficiencies, and enhancing performance.[30]

Figure 3: The ASEAN Power Grid Plan



Source: International Energy Agency WEO Special Report, 2017

27. Yam, Jimmy. Energizing ASEAN's Power Sector with Technology. Business Times, February 22, 2019. https://www.businesstimes.com.sg/opinion/energising-aseans-power-sector-with-technology
28. Yam, Jimmy. Energizing ASEAN's Power Sector with Technology. Business Times, February 22, 2019. https://www.businesstimes.com.sg/opinion/energising-aseans-power-sector-with-technology
29. Tan, Julius, CEO and Co-Founder, Electrify. June 2018 US-ASEAN Workshop.
30. Munuera, Luis, Energy Technology Analyst, International Energy Agency. June 2018 US-ASEAN Workshop.

ASEAN's Key Energy Challenges and Digital Solutions

ASEAN'S ENERGY SECTOR OVERVIEW

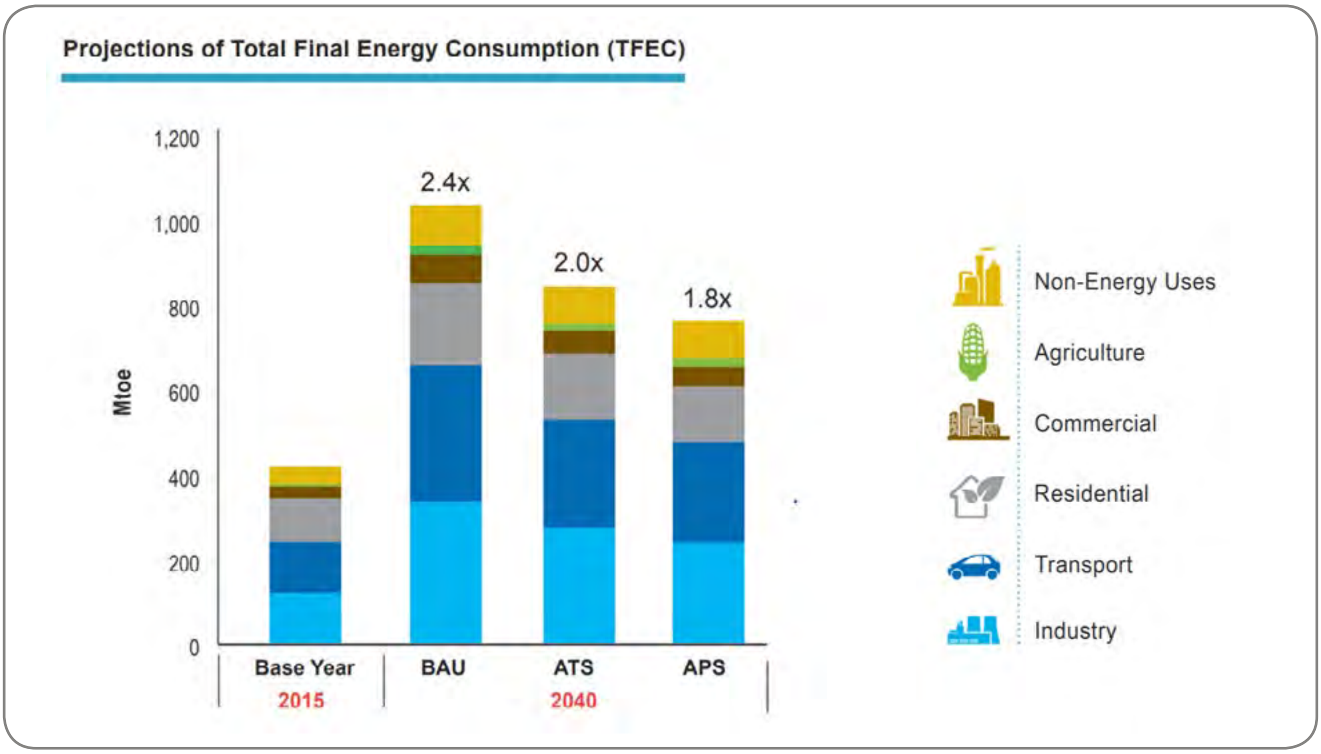
As a primary driver of growth and prosperity in ASEAN, the further development of the energy sector has proven to be vital for the region. The ASEAN Plan of Action for Energy Cooperation (APAEC) 2016-2025 declares that "energy is key to the realization of the ASEAN Economic Community (AEC) which calls for a well-connected ASEAN to drive an integrated, competitive and resilient region."[31]

The ASEAN Centre for Energy (ACE) established energy production and consumption scenarios in the 5th ASEAN Energy Outlook (AEO) covering the period from 2015 through 2040. These scenarios include the Business-as-usual (BAU) scenario, ASEAN Member State target scenarios (ATS) in which most energy efficiency (EE) and renewable energy (RE) targets are reached, and ASEAN progression scenarios (APS) in which the regional targets defined in the ASEAN Plan of Action for Energy Cooperation (APAEC) 2016-2025 are fully reached. The APAEC 2016-2025, widely known as the regional blueprint on energy, laid out key strategies to achieve energy security, accessibility, affordability and sustainability for the region. Two main priorities of the ASEAN energy sector under the APAEC include shifting towards more renewable forms of energy and improving overall energy efficiency.[32] The APS scenario is considered ambitious, given the higher targets for EE and RE.

ASEAN's population has grown swiftly, almost doubling in the past four decades to reach over 642 million in 2017.[33] Economic growth in ASEAN has also been relatively high, averaging 5.3 percent between 2000 and 2017.[34] With this rapid economic and population growth comes a swift increase in energy consumption. ASEAN member states that vary significantly in its stage of development and quality of infrastructure are all working to keep up with demand.

Figure 4 below shows projected ASEAN energy demand through 2040. As the graph indicates, total consumption is

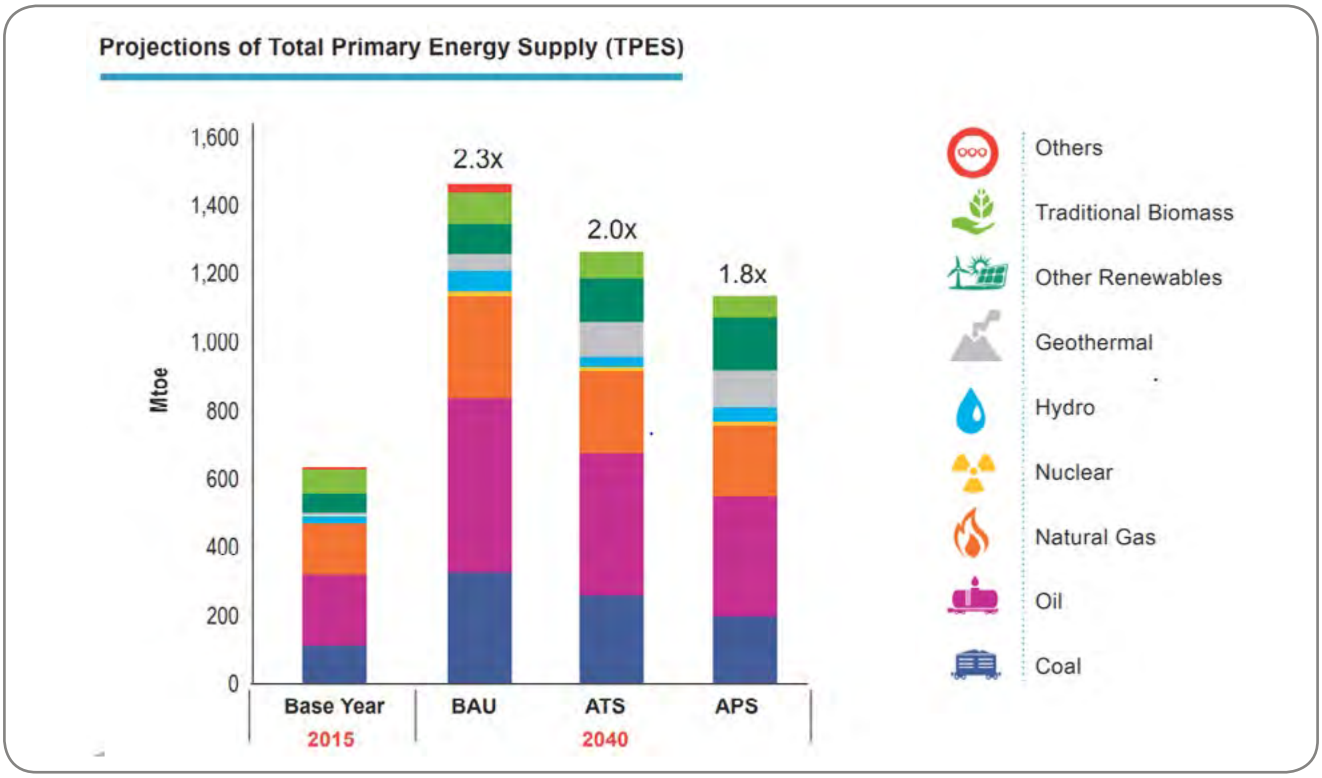
Figure 4: 2015 and 2040 Total Final Energy Consumption (TFEC) in ASEAN



Source: The 5th ASEAN Energy Outlook 2015 – 2040, ASEAN Centre for Energy, 2017

31. ASEAN Plan of Action for Energy Cooperation (APAEC) 2016-2025. ASEAN Center for Energy. https://cil.nus.edu.sg/wp-content/uploads/2019/02/2016-2025-ASEAN-Plan-of-Action-for-Energy-Cooperation-3.pdf
32. ASEAN Plan of Action for Energy Cooperation (APAEC) 2016-2025. ASEAN Center for Energy. https://cil.nus.edu.sg/wp-content/uploads/2019/02/2016-2025-ASEAN-Plan-of-Action-for-Energy-Cooperation-3.pdf
33. ASEAN Key Figures 2018. ASEAN Secretariat, 2018. https://asean.org/storage/2018/12/ASEAN-Key-Figures-2018.pdf
34. ASEAN Key Figures 2018. ASEAN Secretariat, 2018. https://asean.org/storage/2018/12/ASEAN-Key-Figures-2018.pdf

Figure 5: 2015 and 2040 Total Primary Energy Supply (TPES) in ASEAN



Source: The 5th ASEAN Energy Outlook 2015 – 2040, ASEAN Centre for Energy, 2017

expected to increase very substantially. Total Final Energy Consumption (TFEC) in ASEAN was estimated in 2015 at 427 Mtoe, consisting mainly of industrial, transport and residential demand. Under business as usual, TFEC is projected to increase by a factor of 2.4 to 1,046 Mtoe. In the ATS and APS scenarios, the increase is reduced to a factor of 2.0 and 1.8, respectively.[35]

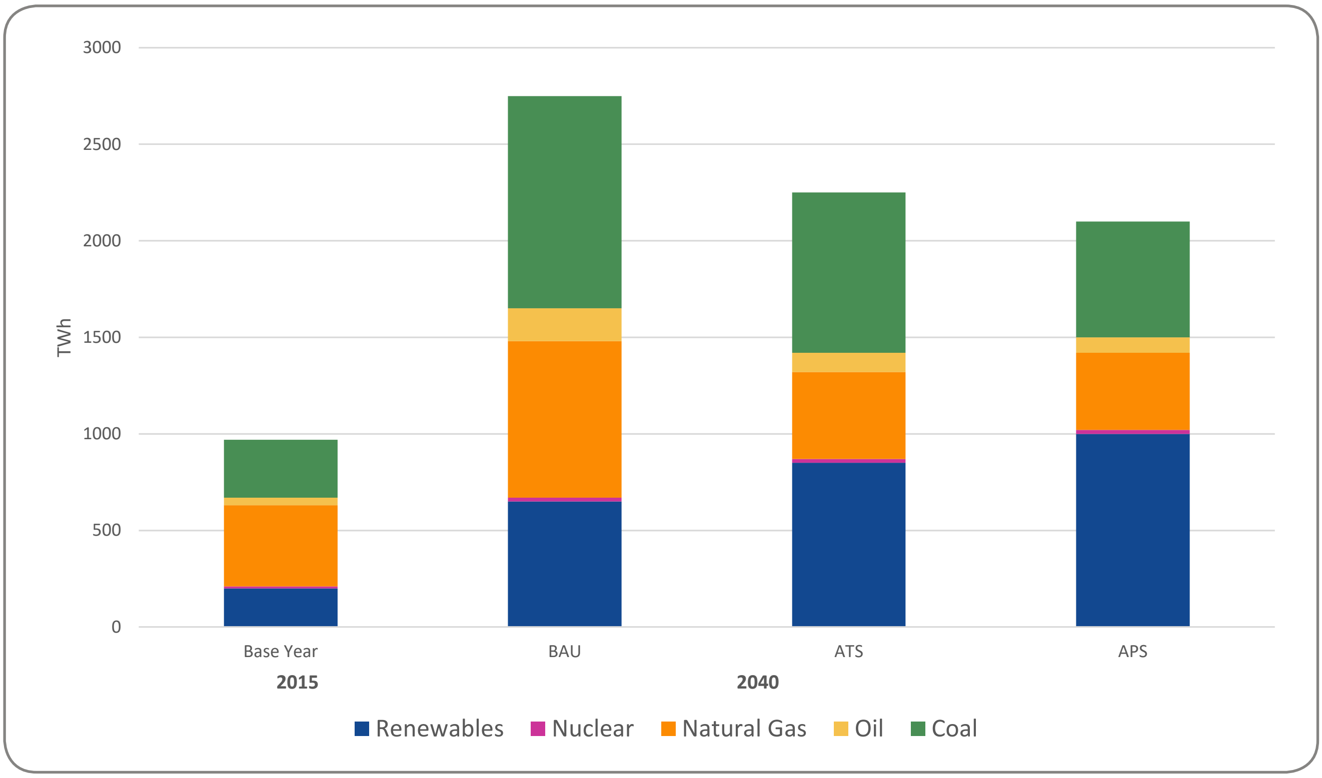
Figure 5 above shows ASEAN energy supply through 2040, indicating how the ASEAN Centre for Energy expects the region will produce energy to meet the rising regional and export demand. In 2015, Total Primary Energy Supply (TPES) in ASEAN was estimated at 627 Mtoe, supplied mainly by oil, coal, and natural gas.[36] Under business as usual (BAU), TPES is projected to increase by a factor of 2.3 to 1,450 Mtoe by 2040. Coal and oil use is projected to nearly triple, and natural gas use to almost double. In the ATS and APS scenarios, growth is reduced to a factor of 2.0 and 1.8 respectively, with coal and oil use still doubling. These projections underscore the immense challenge recognized broadly within ASEAN's energy sector - shifting the heavy dependence on oil and coal into more sustainable alternatives.

Figure 6 on the following page displays similar information regarding power generation. Power generation is currently dominated by coal, gas and hydro – the dominant renewable technology. With BAU, projections show that coal and hydro will triple in use, gas will nearly double, and other technologies will continue to contribute relatively little.[37] In absolute numbers, coal increases the most – creating a dilemma for ASEAN's sustainable energy future. Even in ATS and APS scenarios, coal use for power is projected to more than double.

ASEAN has set ambitious goals for its energy sector. The 5th ASEAN Energy Outlook (AEO) 2015-2040 presents energy intensity targets, with a 2030 framework

35. The 5th ASEAN Energy Outlook 2015 – 2040. ASEAN Centre for Energy, 2017. http://www.aseanenergy.org/resources/the-5th-asean-energy-outlook/
36. The 5th ASEAN Energy Outlook 2015 – 2040. ASEAN Centre for Energy, 2017. http://www.aseanenergy.org/resources/the-5th-asean-energy-outlook/
37. The 5th ASEAN Energy Outlook 2015 – 2040. ASEAN Centre for Energy, 2017. http://www.aseanenergy.org/resources/the-5th-asean-energy-outlook/

Figure 6: 2015 and 2040 ASEAN Power Generation Estimates by Type



Source: The 5th ASEAN Energy Outlook 2015 – 2040, ASEAN Centre for Energy, 2017 data

offering opportunities for more coordinated energy efficiency and renewable energy policies among the ASEAN Member States. This 2030 plan also incorporates efforts on the integration of electricity grids and markets specifically to support the Paris Agreement.[38] ASEAN as a region does not define specific carbon-dioxide emissions reduction goals, but the APAEC 2016-2025 does identify opportunities for cleaner energy such as reducing energy intensity by 20 percent in 2020 and increasing renewable generation to 23 percent by 2025.[39] As noted earlier, the ASEAN Power Grid (APG) effort is underway to interconnect the region further, improving operations and increasing efficiency. APG faces legal, technical and financial challenges,[40] and if these challenges can be overcome, APG can enable successful multilateral electricity trading to better meet regional supply and demand.

ASEAN'S TOP PRIORITY ENERGY CHALLENGES

A December 2018 United Nations (UN) report, in partnership with ACE, identified three main challenges for ASEAN's energy sector: access challenges, particularly for those considered in energy poverty (around 107 million); resource challenges, with heavy reliance on fossil fuels which are limited; and environmental challenges, resulting from environmental damage and climate change.[41]

Based on these challenges, energy experts from ASEAN's Member States were surveyed to determine which of the four broad challenges – access, power, transport, and resilience - was of the highest priority.[42] As discussed in the next section, they were also asked which digital-relevant solutions would be most useful in addressing these energy

38. The 5th ASEAN Energy Outlook 2015 – 2040. ASEAN Centre for Energy, 2017, Page 21. http://www.aseanenergy.org/resources/the-5th-asean-energy-outlook/
39. The 5th ASEAN Energy Outlook 2015 – 2040. ASEAN Centre for Energy, 2017, Page 106. http://www.aseanenergy.org/resources/the-5th-asean-energy-outlook/
40. Gnanasagaran, Angaindrankumar. Building ASEAN's Power Grid. The ASEAN Post, May 30, 2018. https://theaseanpost.com/article/building-aseans-power-grid
41. Energy Interconnection in ASEAN for Sustainable and Resilient Societies: Accelerating Energy Transition. ASEAN Centre for Energy (ACE), Global Energy Interconnection Development and Cooperation Organization (GEIDCO), and the United Nations, December 2018. https://www.unescap.org/sites/default/files/Final_publication_PEI_ASEAN_WEB%20%282%29.pdf
42. See Appendix 1

PRIORITY POWER CHALLENGES IDENTIFIED

1. Meeting **power** demand sustainably
2. Closing the energy **access** gap speedily
3. Maintaining energy system **resilience**

challenges. There were 31 respondents from seven of the ten ASEAN economy governments as well as other non-government representatives.

Figure 7 shows the survey results. As indicated, Meeting Power Demand Sustainably was viewed as the most critical challenge. More than ¾ of the 31 respondents identified it as a top priority, and the rest believed it to be a least a second-tier priority (see Appendix 1). Around half the respondents identify the challenges of Closing the Energy Access Gap Speedily and Maintaining Energy System Reliance as a top priority. Meeting Transport Demand Efficiently was less crucial with only about ¼ identifying it as a top priority.

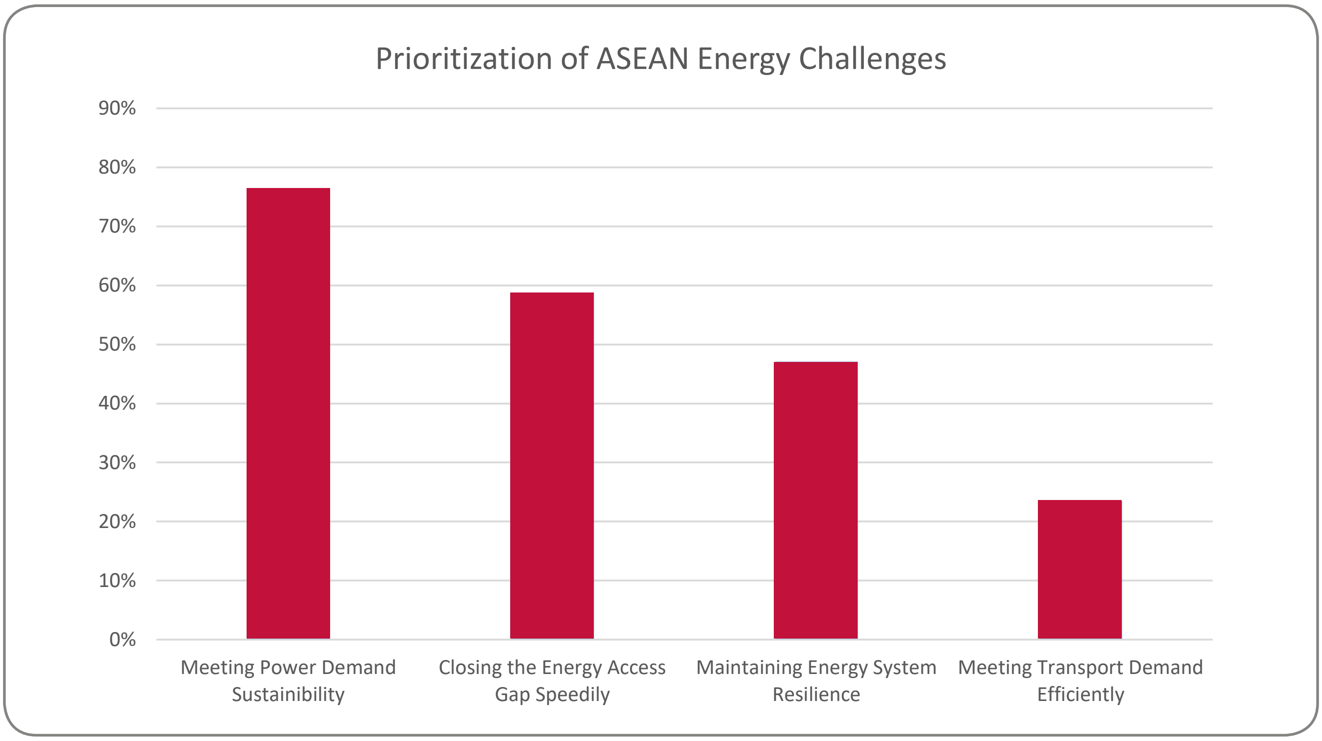
Based on the survey, this report focuses on three high-priority challenges facing ASEAN's power sector in order of importance: 1) meeting power demand sustainably, 2) closing the electricity access gap, and 3) maintaining power system resilience. These challenges will have to be addressed if ASEAN is to continue to grow and prosper. Figure 8 on the following page shows how these challenges fall across the major stages of the power value chain.

MEETING POWER DEMAND

Perhaps the greatest challenge facing ASEAN is meeting the projected dramatic increase in electricity demand affordably, reliably, and sustainably. As shown in Figure 9, ASEAN expects to meet this demand increase by tripling the power generation from less than 1000 TWh in 2015 to more than 2500 TWh in 2040 if under the BAU scenario. The bulk of this increase will be from fossil fuel generation, particularly coal.

The ASEAN Plan of Action for Energy Cooperation (APAEC) 2016-2025 includes several initiatives

Figure 7: Prioritization of ASEAN Energy Challenges

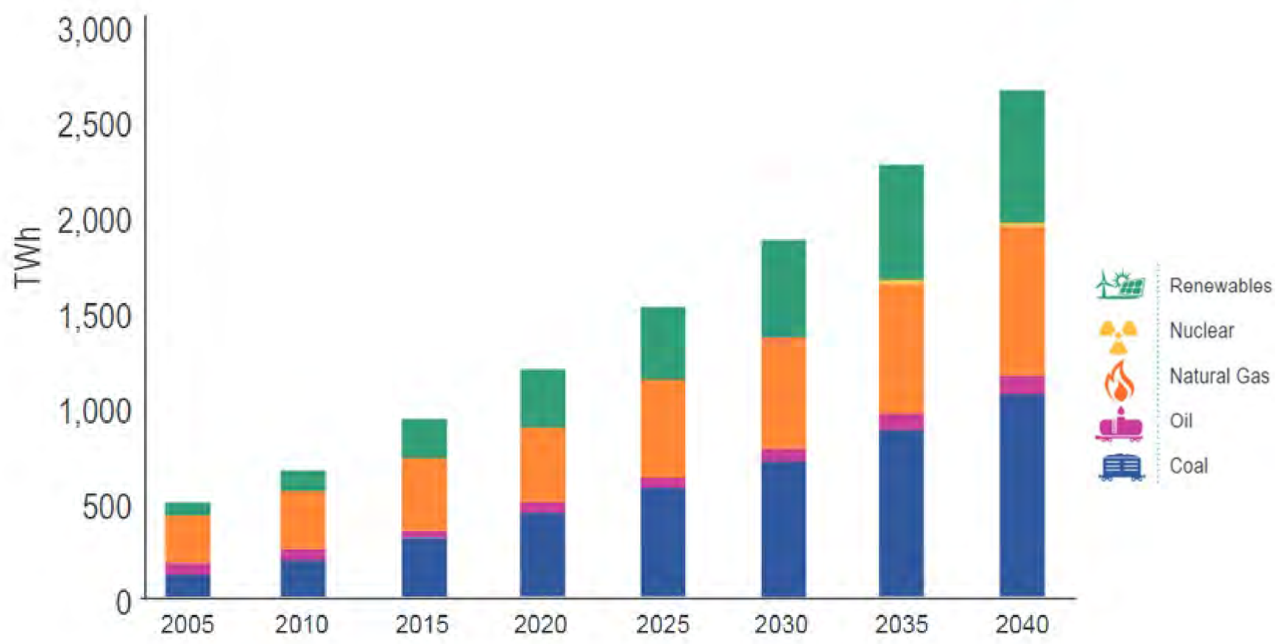


Source: ASEAN-USAID IGNITE Survey Data

Figure 8: The Energy Value Chain and Challenge Mapping

RESOURCES	GENERATION	TRANSMISSION	DISTRIBUTION	PROSUMPTION
Power Demand				
		Access		
Resilience				

Figure 9: Power Generation BAU Projections, 2005-2040



Source: The 5th ASEAN Energy Outlook 2015 – 2040, ASEAN Centre for Energy, 2017 aimed at meeting this surging demand. These involve expanding multilateral electricity trading supported by APG, enhancing gas connectivity by incorporating LNG into the Trans-ASEAN Gas Pipeline (TAGP) effort, promoting clean coal, promoting EE and RE, and building capabilities for nuclear energy.[43] Figure 10 below showcases some of Indonesia's planned LNG-to-power facilities, and provides a glimpse into the scale of the envisioned physical infrastructure investment to meet this growing demand.

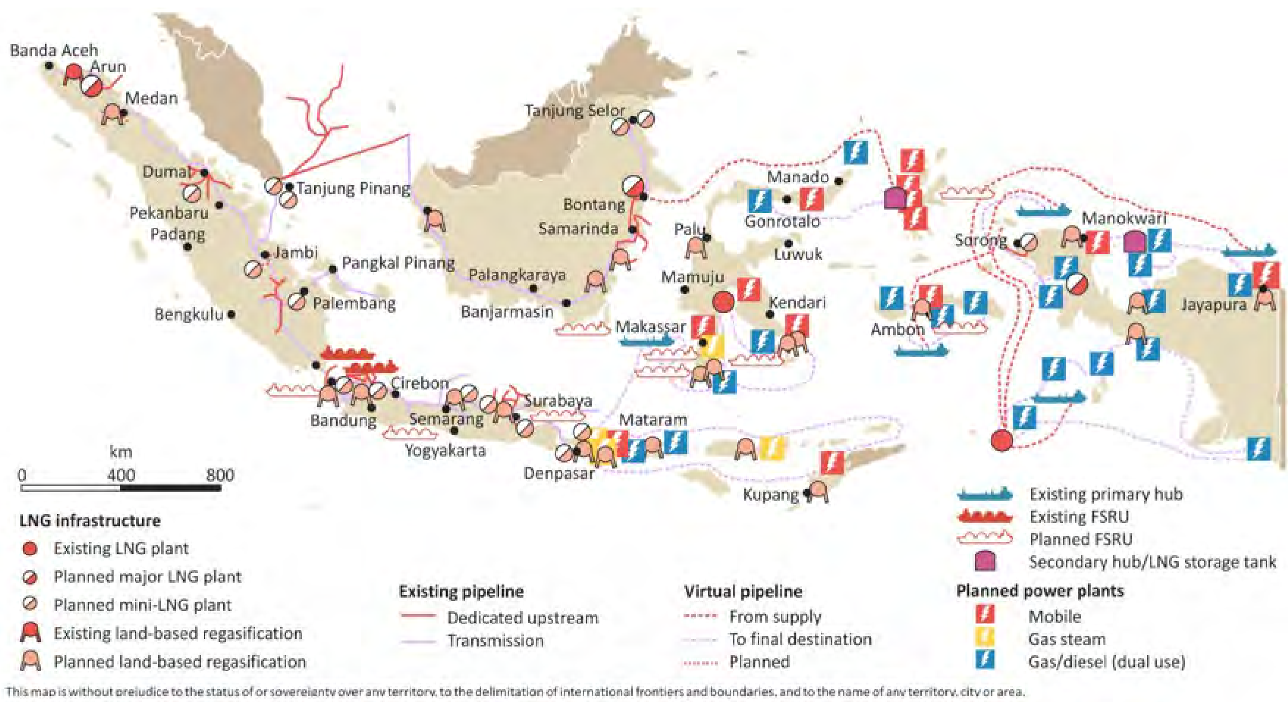
CLOSING THE ACCESS GAP

Closing the electricity access gap speedily is another high regional priority. According to the IEA, in 2000, Lao PDR, Cambodia, and Myanmar were under 20 percent electrification rates, Indonesia was near 50 percent, and several other AMS were at around 80 percent. Over the past several decades, AMS have devoted enormous efforts to providing more access to populations in need. By 2016, Cambodia and Myanmar had increased to 60 percent access, and the remaining AMS had risen to 90 percent or above. By 2030, the IEA projects that all ASEAN economies will be at or above 95 percent access.[44] Figure 11 on the following page shows these great strides in energy access.

Despite this past and projected future success, energy access remains a concern in several ASEAN member states. Cambodia and Myanmar in particular still have a relatively low level of access, and full electrification is still a decade or more away in the Philippines, Vietnam and Indonesia. This lack of full access can drastically limit people's ability to learn, work, and prosper.

Figure 12 shows the plans underway to reach remote populations in the Philippines and Myanmar, using established grids and microgrids. These plans indicate the geographic scale of the efforts needed to meet the remaining access challenge.

Figure 10: Indonesia's Natural Gas-Based Electrification Plans

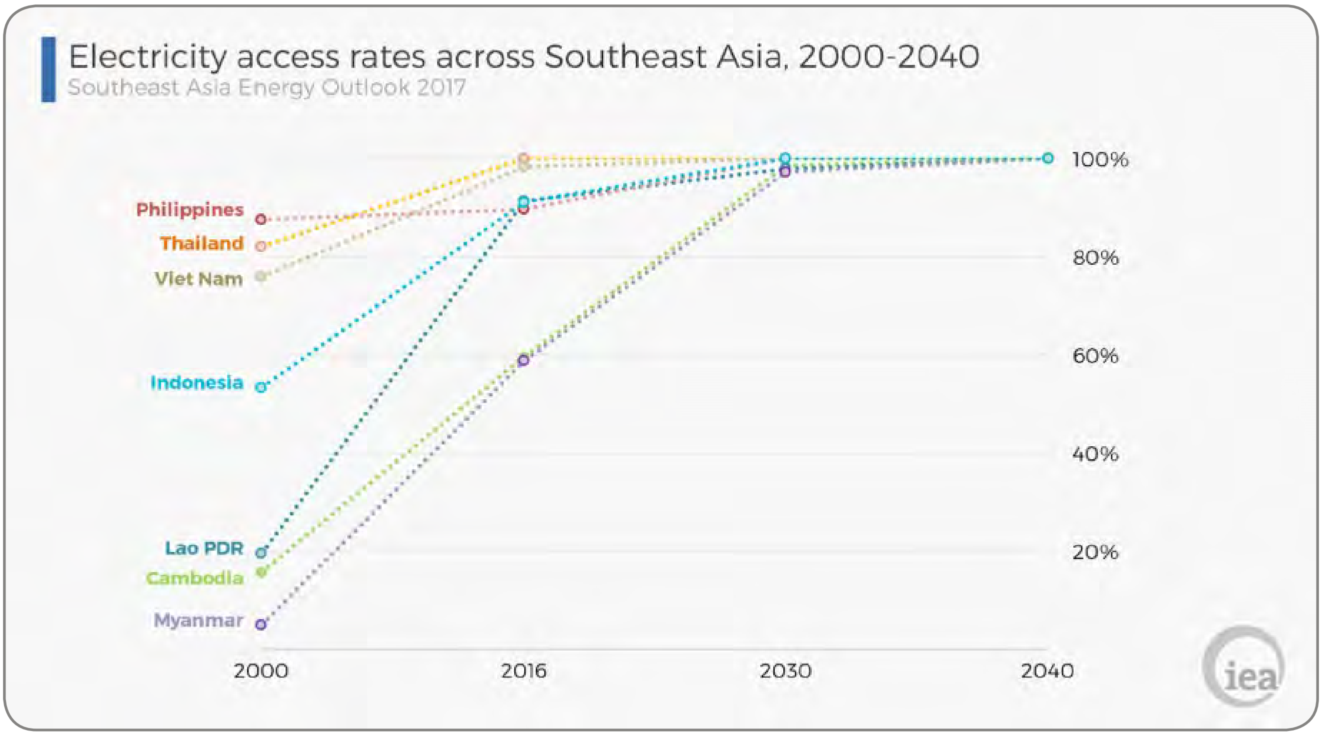


Natural gas infrastructure has been identified as a central component in Indonesia's energy access strategy

Source: International Energy Agency WEO Special Report, 2017

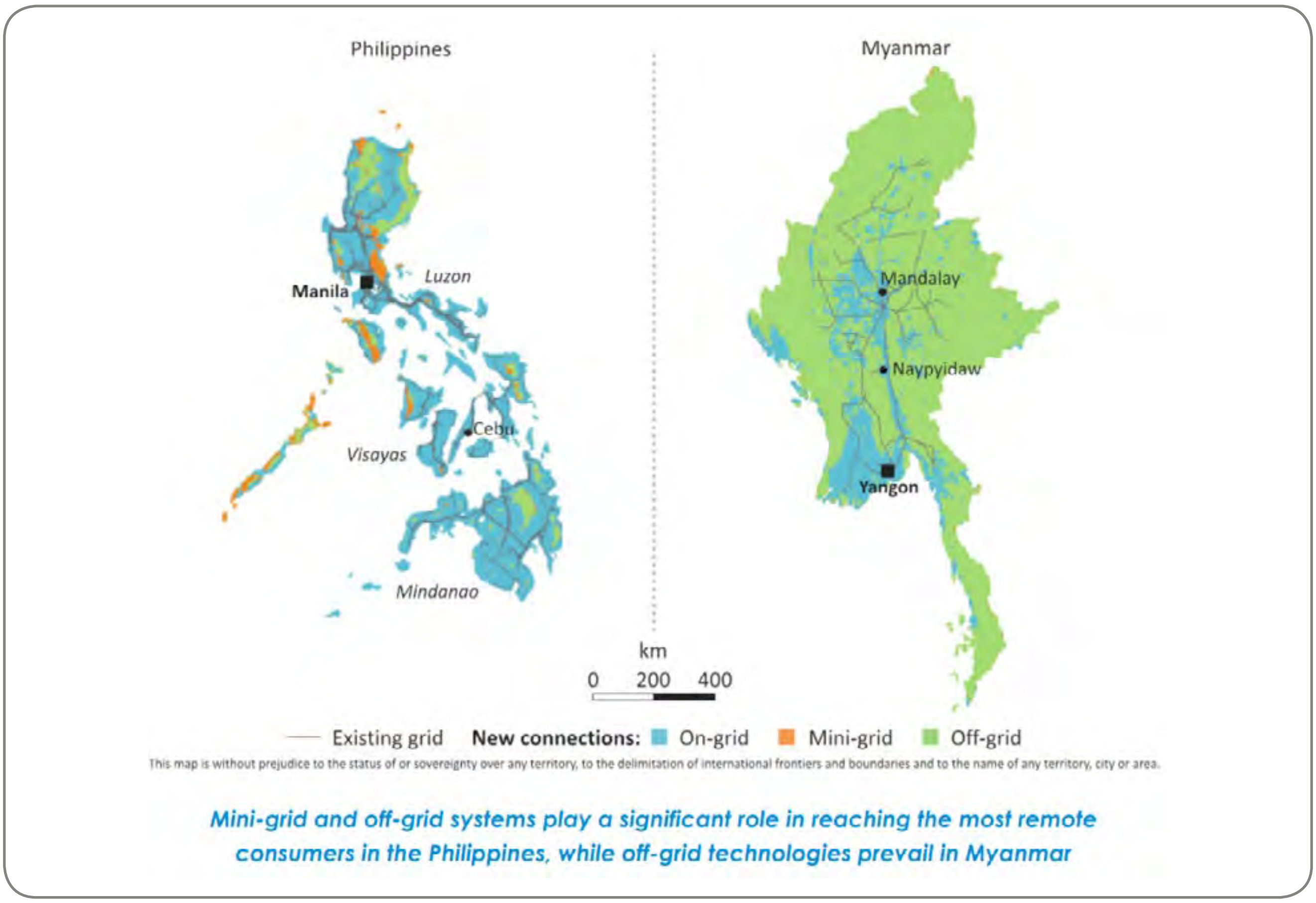
43. ASEAN Plan of Action for Energy Cooperation (APAEC) 2016-2025. ASEAN Center for Energy, Page 2. https://cil.nus.edu.sg/wp-content/uploads/2019/02/2016-2025-ASEAN-Plan-of-Action-for-Energy-Cooperation-3.pdf
44. Southeast Asia Energy Outlook 2017. International Energy Agency (IEA), October 24, 2017. https://www.iea.org/southeastasia/

Figure 11: Electricity Access Rates Across Southeast Asia, 2000-2040



Source: Southeast Asia Energy Outlook 2017, International Energy Agency

Figure 12: Access Solutions by Grid Type in the Philippines and Myanmar



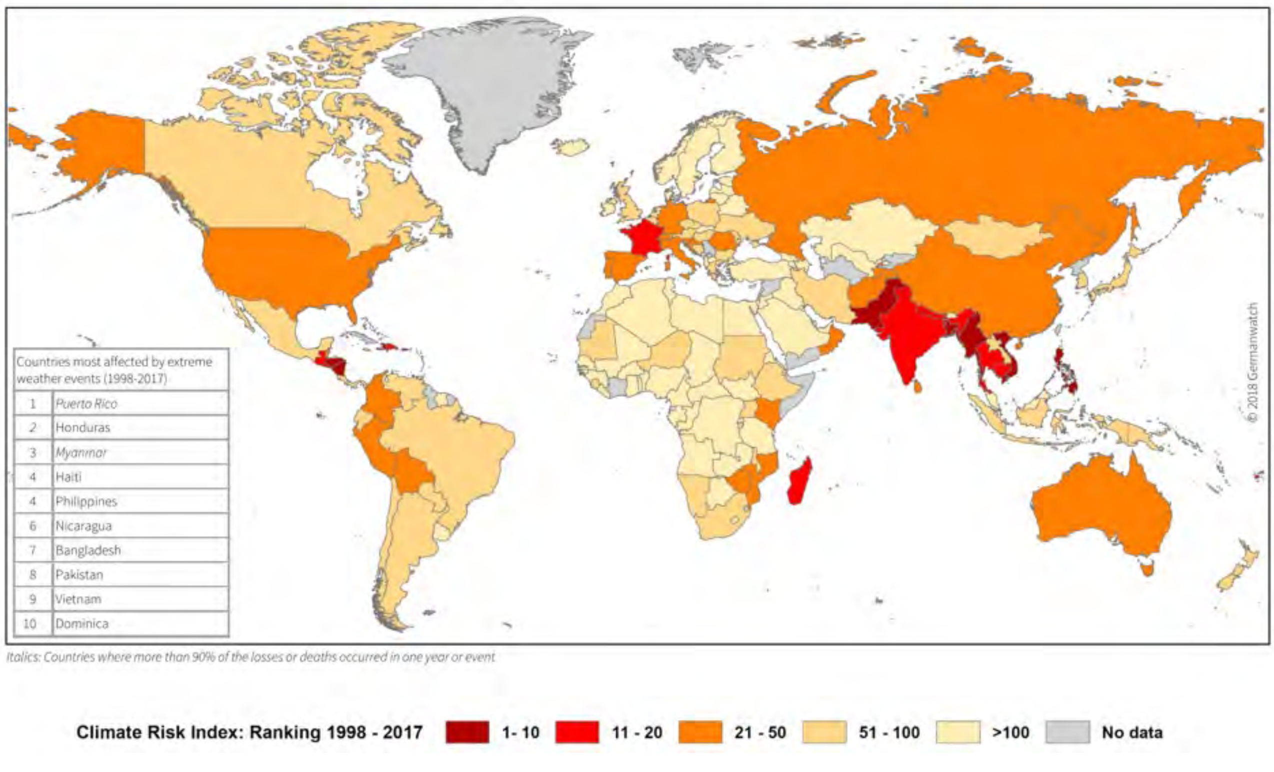
Source: International Energy Agency WEO Special Report, 2017

MAINTAINING ENERGY SYSTEM RESILIENCE

Maintaining energy system resilience is another high regional priority. As Figure 13 below indicates, Southeast Asia is particularly vulnerable to climate change. The Global Climate Risk Index reports that Vietnam, Myanmar, the Philippines, and Thailand are among the 12 countries most affected by climate change the world.[45] This vulnerability includes both chronic (sea level rise) and acute (more frequent and more severe storms) effects. Typhoons and floods are becoming more intense and more frequent, and large low-lying areas could be permanently inundated. Maintaining resilience to climate-related risks is essential for the region's health and prosperity.

ASEAN has been working on this issue, and one of its most significant contributions has been increasing the interconnectedness of the transmission grid.[47] This is a key step to improving resilience to weather and other disruptions.

Figure 13: Countries Most Affected by Extreme Weather Events, 1999-2017



Source: Global Climate Risk Index 2019, GermanWatch[46]

45. *Prakash, Amit. Boiling Point. Finance & Development, September 2018, 55 (3)* *https://www.imf.org/external/pubs/ft/fandd/2018/09/southeast-asia-climate-change-and-greenhouse-gas-emissions-prakash.htm*
46. *David Eckstein, Marie-Lena Hutfils, and Maik Winges. Global Climate Risk Index 2019. GermanWatch, 2019.* *https://germanwatch.org/sites/germanwatch.org/files/Global%20Climate%20Risk%20Index%202019_2.pdf*
47. *Energy Interconnection in ASEAN for Sustainable and Resilient Societies: Accelerating Energy Transition. ASEAN Centre for Energy (ACE). Global Energy Interconnection Development and Cooperation Organization (GEIDCO), and the United Nations, December 2018. https://www.unescap.org/sites/default/files/Final_publication_PEI_ASEAN_WEB%20%282%29.pdf*

Power Sector Digitalization Success Stories

As noted above, the survey of ASEAN energy officials for this project identified three high-priority power sector challenges:

1. **Meeting power demand**
2. **Closing the energy access gap, and**
3. **Maintaining energy system resilience.**

At the same time, it also identified five high-priority digital-related solutions to these challenges:

1. **Meeting power demand through improved end-use efficiency**
2. **Meeting power demand through improved thermal efficiency**
3. **Meeting power demand through improved renewables grid integration**
4. **Closing the energy access gap with microgrid development**
5. **Maintaining energy system resilience with better weather preparation and recovery**

This section includes examples where success is being achieved with each of these solutions using digital technology. As Figure 14 illustrates, these examples come from a variety of jurisdictions both inside and outside of ASEAN and span the entire power value chain from resources to prosumption. Each case is intended to be directly relevant to ASEAN member states, and to provide information and motivation for action.

Figure 14: Value Chain and Digital Solution Mapping

<table>
<tr><th>RESOURCES</th><th>GENERATION</th><th>TRANSMISSION</th><th>DISTRIBUTION</th><th>PROSUMPTION</th></tr>
<tr><td></td><td></td><td></td><td></td><td>End-Use Efficiency - Malaysia</td></tr>
<tr><td></td><td></td><td></td><td></td><td>End-Use Efficiency - Califonia</td></tr>
<tr><td></td><td></td><td></td><td></td><td>End-Use Efficiency - Taiwan</td></tr>
<tr><td></td><td></td><td></td><td></td><td>End-Use Efficiency - Singapore</td></tr>
<tr><td></td><td>Thermal Efficiency - Japan</td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td colspan="2">Renewables Grid Integration - Thailand</td></tr>
<tr><td colspan="3">Renewables Grid Integration – Denmark</td><td></td><td></td></tr>
<tr><td colspan="3">Renewables Grid Integration – Hawaii</td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td colspan="2">Microgrids – Myanmar</td></tr>
<tr><td></td><td></td><td></td><td colspan="2">Microgrids – Nepal</td></tr>
<tr><td></td><td></td><td></td><td colspan="2">Preparation and Recovery - Vietnam</td></tr>
<tr><td></td><td></td><td></td><td colspan="2">Preparation and Recovery - Texas</td></tr>
<tr><td colspan="3">Preparation and Recovery – Ireland</td><td></td><td></td></tr>
</table>

MEETING POWER DEMAND THROUGH IMPROVED END-USE EFFICIENCY

End-use energy efficiency is typically measured via energy intensity (EI) – the ratio of energy consumed to economic value created. The former is usually measured via primary Btu's or oil equivalent and the latter by GDP, although there are a variety of ways to measure both numerator and denominator. A lower ratio means that less energy is required to produce a given amount of economic value.

Figure 15 below shows past and projected ASEAN EI. Since 2005, EI has improved (declined) moderately – at perhaps one percent per year. It is expected to continue to grow modestly over the next few decades. The nominal case is that it will only improve by perhaps 25 percent by 2040 (from 80 percent of 2005 levels to 60 percent of 2005 levels) or one percent per year.

Digital technology can help ASEAN meet the challenge of power demand through improved energy efficiency. The examples below illustrate how.

MALAYSIA

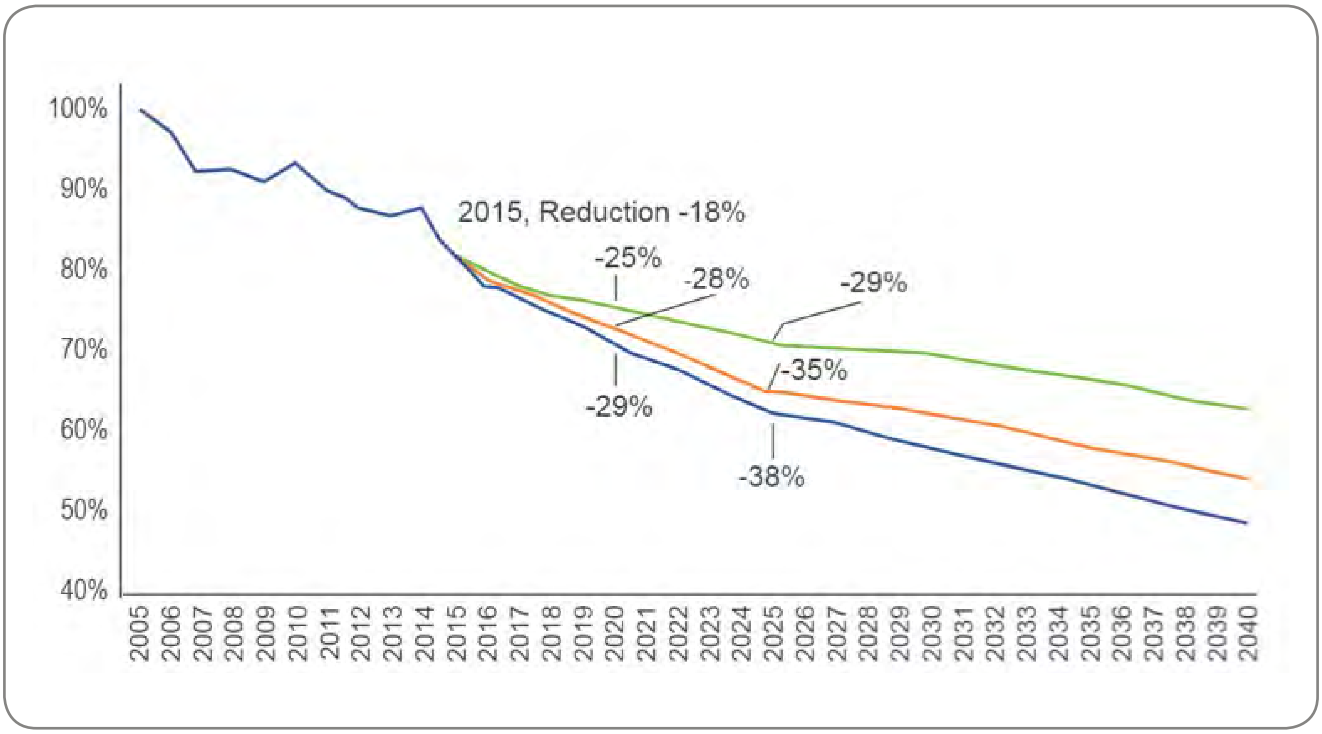
If there is one word describing energy consumption in Malaysia, it is growth. Malaysia's economy and electricity consumption have been growing dramatically over the past decades, and this trend is projected to continue well into the future. Figure 16 on the following page shows the growth in per capita consumption since the 1970s. Growth has been constant, although it shows some signs of slowing.

In recent years, the government of Malaysia has become increasingly focused not just on economic and energy growth, but on energy efficiency as well. Although these are still early days, significant positive steps are being taken to meet these efficiency goals.

How is this being accomplished?

Government support plays a critical role in energy efficiency through guidelines, standards, incentives and even research. Malaysia has a well-established "green energy" plan, and recently approved a new Energy Efficiency and Conservation Act focused on reducing energy use and lowering electricity bills.[48]

Figure 15: Projections on APAEC Energy Intensity Target, 2005-2040

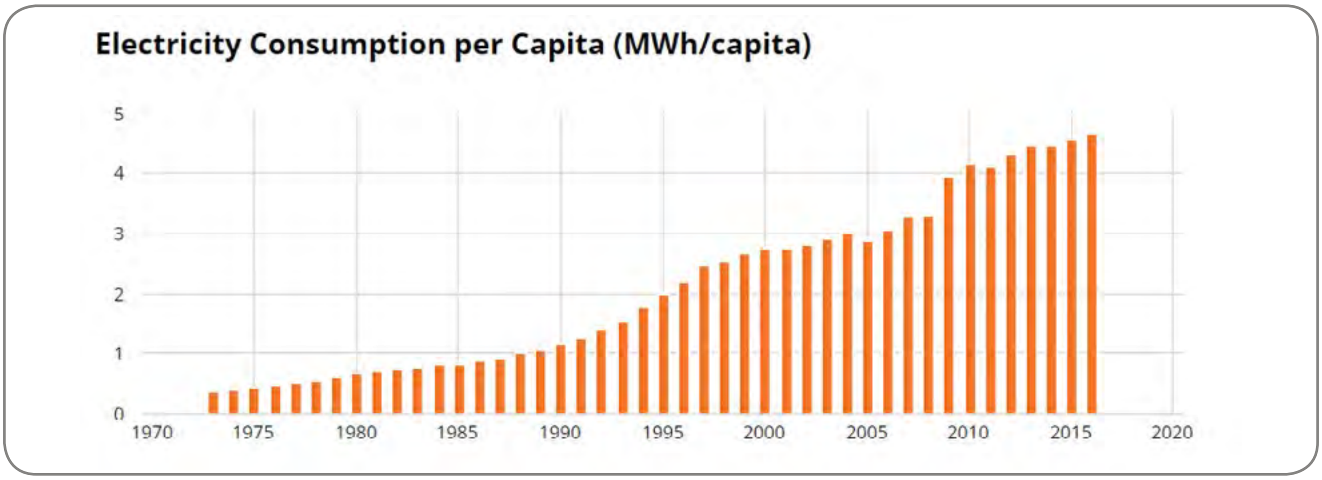


Source: The 5th ASEAN Energy Outlook 2015 – 2040, ASEAN Centre for Energy, 2017

48. Energy Efficiency and Conservation Bill to be tabled end of this year, says minister. MalayMail, July 4, 2019. https://www.malaymail.com/news/malaysia/2019/07/04/energy-efficiency-and-conservation-bill-to-be-tabled-end-of-this-year-minis/1768303

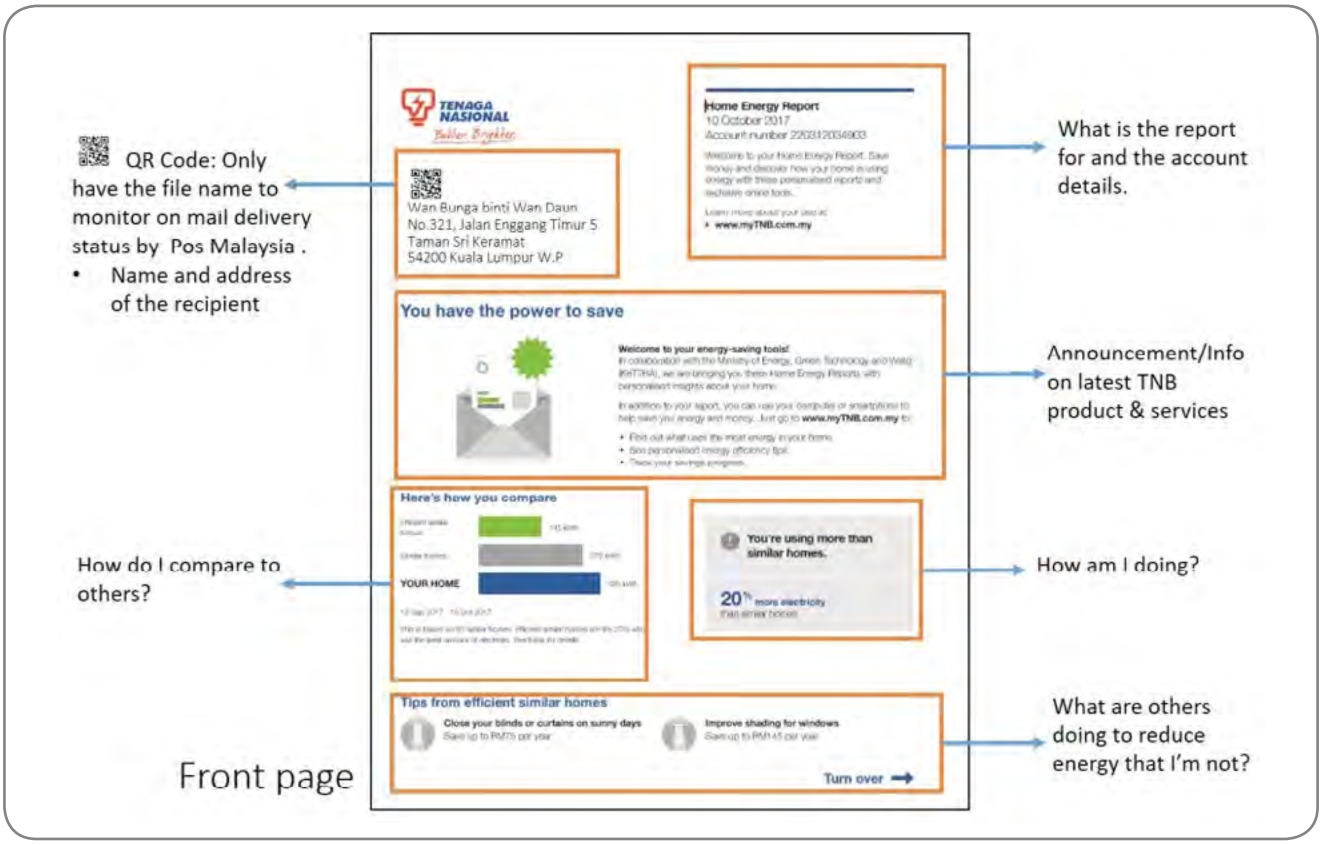
At the same time, enabling digital technology also plays a central role, particularly when energy efficiency is paired with a vibrant economy, as is the case in Malaysia. An excellent example is the Home Energy Report (HER) launched in 2015 by Malaysia's largest electric utility, Tenaga Nasional Berhad (TNB). Through an online portal, HER provides customers useful insights into their energy usage and customized recommendations on energy savings. HER is based on Oracle Utilities Opower customer engagement solutions that combine a cloud-based SaaS platform with big data analytics and behavioral science.[49] Figure 17 below shows a HER screenshot from TNB.

Figure 16: Electricity Consumption per Capita in Malaysia



Source: International Energy Agency, http://energyatlas.iea.org/

Figure 17: TNB Home Energy Report Screenshot



Source: https://www.tnb.com.my/residential/her

49. Sachar, S., Das, S., Emhoff, K., Goenka, A., Haig, K., Pattanaik, S., Uchin, M.. Behavioral Energy Efficiency Program for India. Alliance for an Energy Efficient Economy and Oracle Utilities, 2019. https://www.oracle.com/a/ocom/docs/industries/utilities/behavioural-energy-efficiency-wp.pdf

As the colorful graph (Figure 18) below illustrates, HER programs have been shown to reduce energy consumption by as much as three percent.[50]

While this may seem like a fairly small amount, it represents a demand reduction in Malaysia of more than 50,000 MWh and is a unique accomplishment outside of OECD. As the American Council for an Energy Efficient Economy says:

> *"[T]hese results show how TNB's HER programme — the first in ASEAN and the first such programme in a non-OECD country — performs favourably compared to similar programmes around the world, even compared to regions with more mature utility-led DSM initiatives.[51]"*

CALIFORNIA

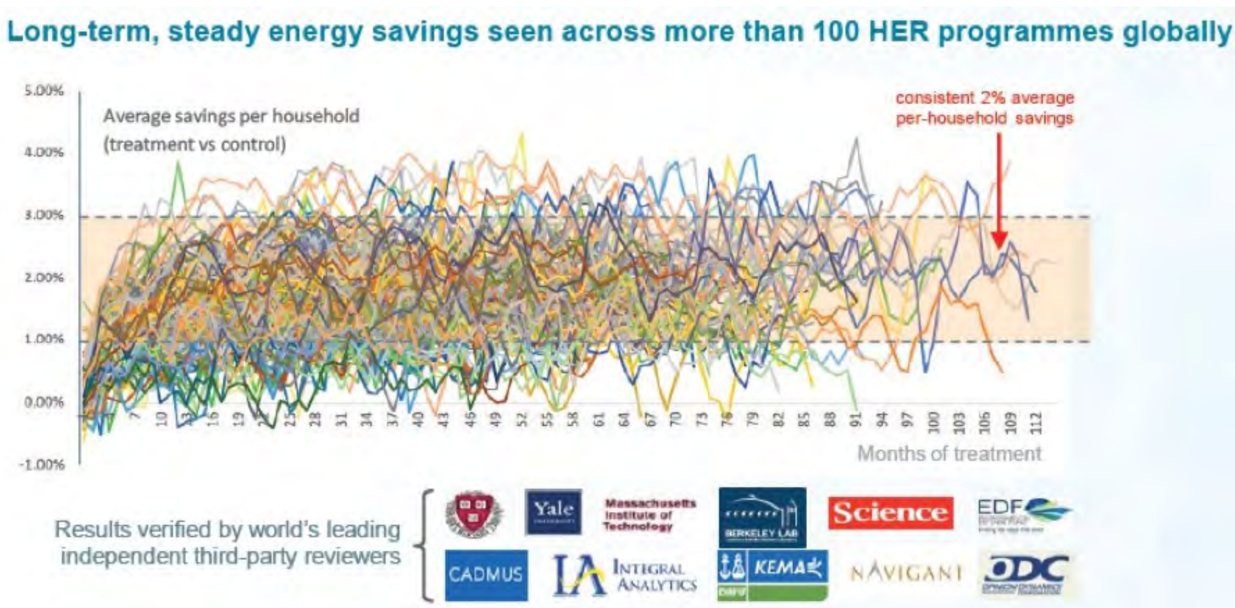
By many measures, California is a role model for energy efficiency. As Figure 19 shows, California has displayed a nearly 40 percent improvement in overall energy intensity between 2000 and 2017, more than two percent per year.

How is this being accomplished?

As illustrated in Figure 20, California achieved improved energy efficiency through a mix of appliance standards, building standards and energy efficiency programs.[52]

Beginning in the 1970's, there was a strong commitment in California across both the executive and legislative branches of government to dramatically improve energy efficiency, and that commitment was widely shared among private individuals and non-government institutions. Interestingly, the standards that resulted from this commitment did not dictate the use of digital technology, but many such standards strongly encouraged or effectively forced digitalization as the best, or perhaps

Figure 18: Long-term Energy Savings Across HER Programs Globally



Source: White Paper on Behavioural Energy Efficiency Potential for India

50. Sachar, S., Das, S., Emhoff, K., Goenka, A., Haig, K., Pattanaik, S., Uchin, M.. Behavioural Energy Efficiency Program for India. Alliance for an Energy Efficient Economy and Oracle Utilities, 2019. https://www.oracle.com/a/ocom/docs/industries/utilities/behavioural-energy-efficiency-wp.pdf
51. Sachar, S., Das, S., Emhoff, K., Goenka, A., Haig, K., Pattanaik, S., Uchin, M.. Behavioral Energy Efficiency Program for India. Alliance for an Energy Efficient Economy and Oracle Utilities, 2019. https://www.oracle.com/a/ocom/docs/industries/utilities/behavioural-energy-efficiency-wp.pdf
52. California Energy Commission. Tracking Progress, September 2018. https://www.energy.ca.gov/data-reports/tracking-progress

Figure 19: California Energy Intensity, 2000-2017

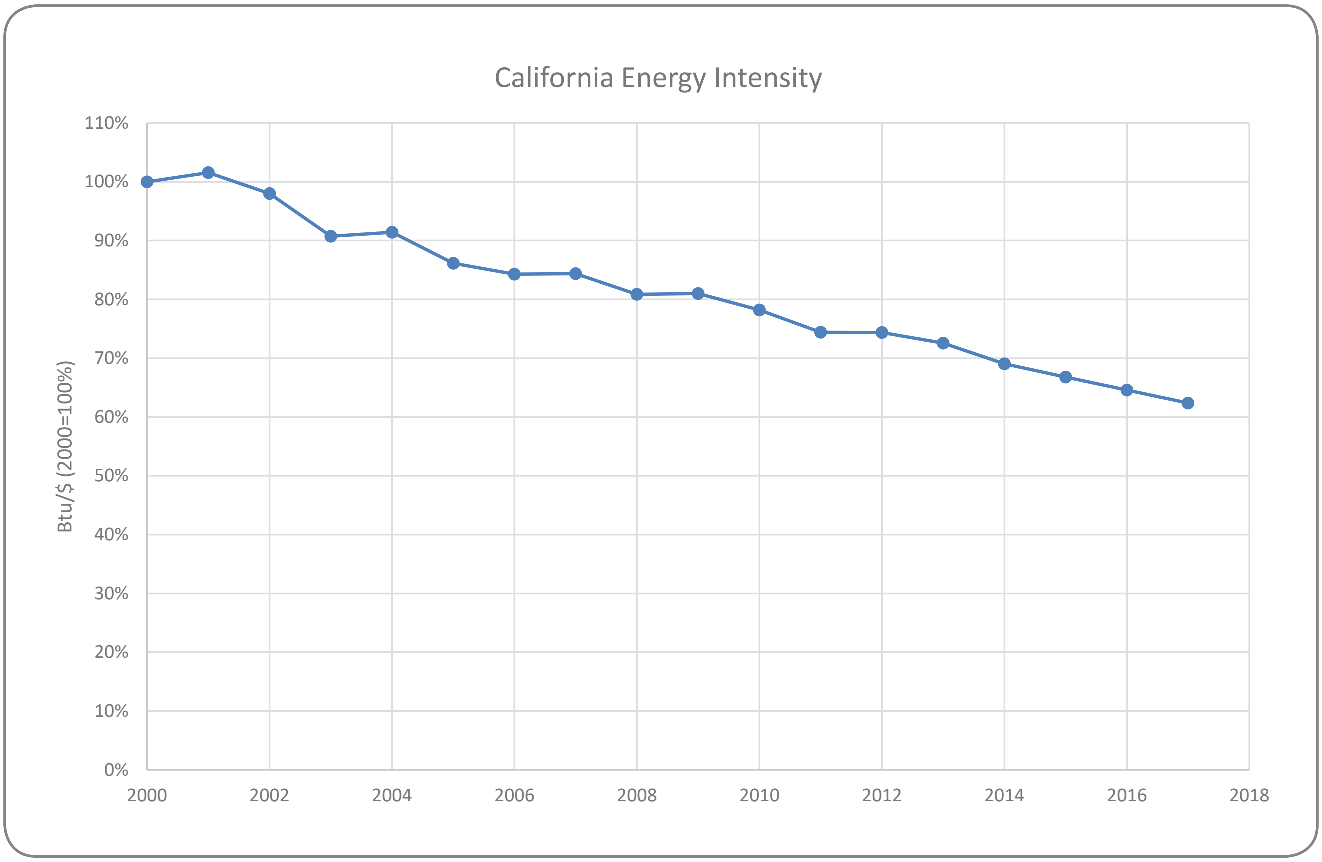
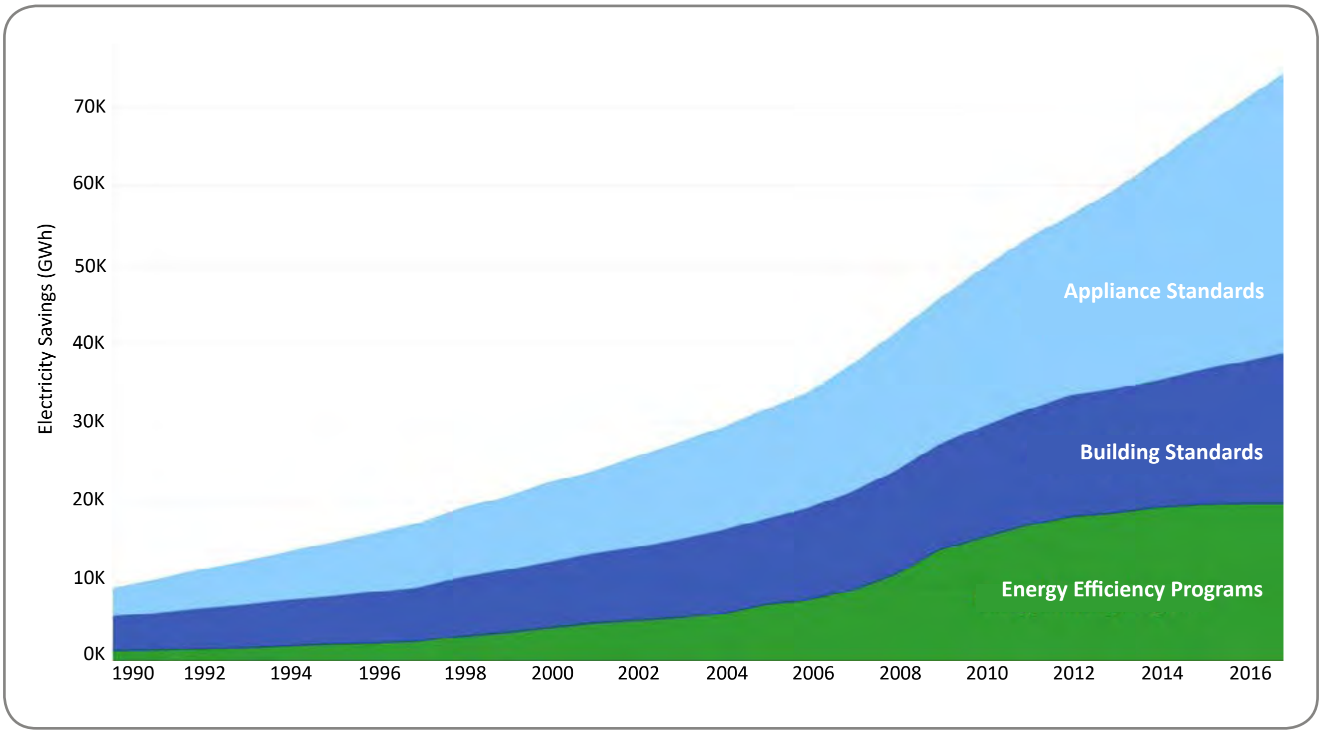


Figure 20: California Energy Efficiency Standards, 1990-2017



Source: California Energy Commission

the only, path to compliance. Of course, California also has the institutional, physical and cyber infrastructure to support digitalization.

Digital technology is essential across the range of energy efficiency standards and programs, as emphasized by the Environmental and Energy Study Institute. Under the heading "smart appliances, smart buildings, smart grid," they noted:[53]

> *"More manufacturers are including internet-connected ("smart") features in thermostats and other products, enabling consumers to view real-time energy use, receive energy-related alerts, and manage appliance settings remotely. Smart technologies enable two-way communication between energy utilities and end-users, providing the capability to respond to utility signals and limit energy use during more expensive peak demand times. Demand-side, grid-connected energy storage technologies, even low-tech ones like water heaters, will also play an important role in energy management."*

Building energy use is one of the most promising energy efficiency applications of digital technology. Increasingly, the focus is on "whole building" systems called Energy Management and Information Systems (EMIS) as well as specific end-use components. Digital technology is at the core of EMIS, particularly the Fault Detection and Diagnostic (FDD) software that tracks performance by analyzing building automation system data. There are numerous EMIS success stories in office buildings, hotels, hospitals and college campuses. For example, the California State University at Dominguez Hills installed an EMIS covering 1.2 million square feet over 22 buildings using SkySpark FDD software from SkyFoundry.[54] Figure 21 on the following page shows the projected energy savings both for individual end-uses and whole building systems.[55]

The California Energy Commission estimates that its energy efficiency measures reduce annual electricity demand by an astounding 70 billion kWh a year, equivalent to the energy production of roughly 15 1000MW coal plants.[56]

TAIWAN

Taiwan has limited energy resources and, as a result, has had a strong emphasis on energy efficiency for years. It has also made dramatic strides in energy efficiency in recent years. In rankings by the American Council for an Energy Efficient-Economy, Taiwan improved from 13th out of 23 countries in 2016 to 9th among 25 countries in 2018. The chart (Figure 24) shows energy intensity in Taiwan since 2000. While the trend has slowed, Taiwan achieved a nearly 25 percent improvement between 2000 and 2016.

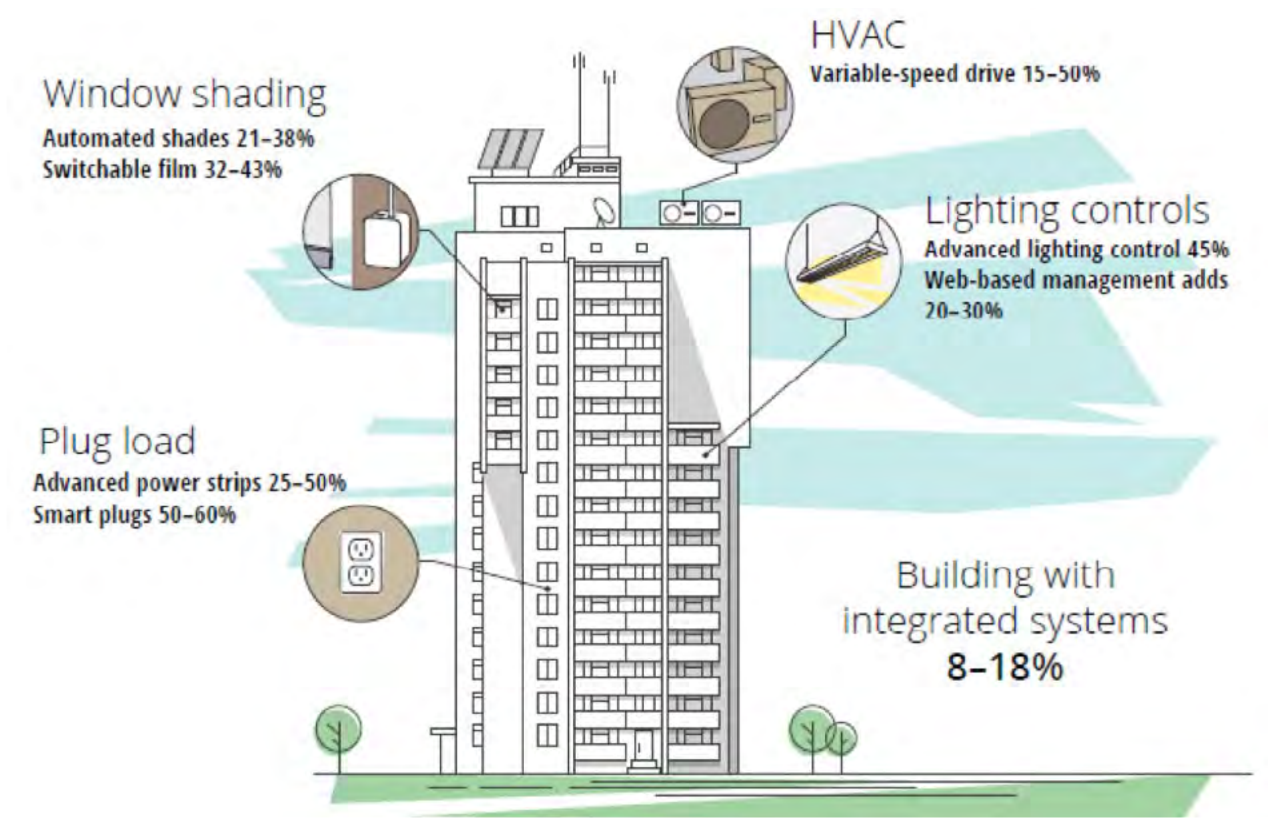
How is this being accomplished?

This improvement in energy intensity is driven by a broad commitment to energy efficiency by the government, business and society, as well as a wide range of mandatory and voluntary energy efficiency standards. Digital technology plays a pivotal role because it is the driving force behind meeting many standards.

Street lighting is a significant component of electricity demand and is becoming increasingly critical as societies urbanize. In Taiwan, cities are deploying digital technology to reduce energy consumption and cost.

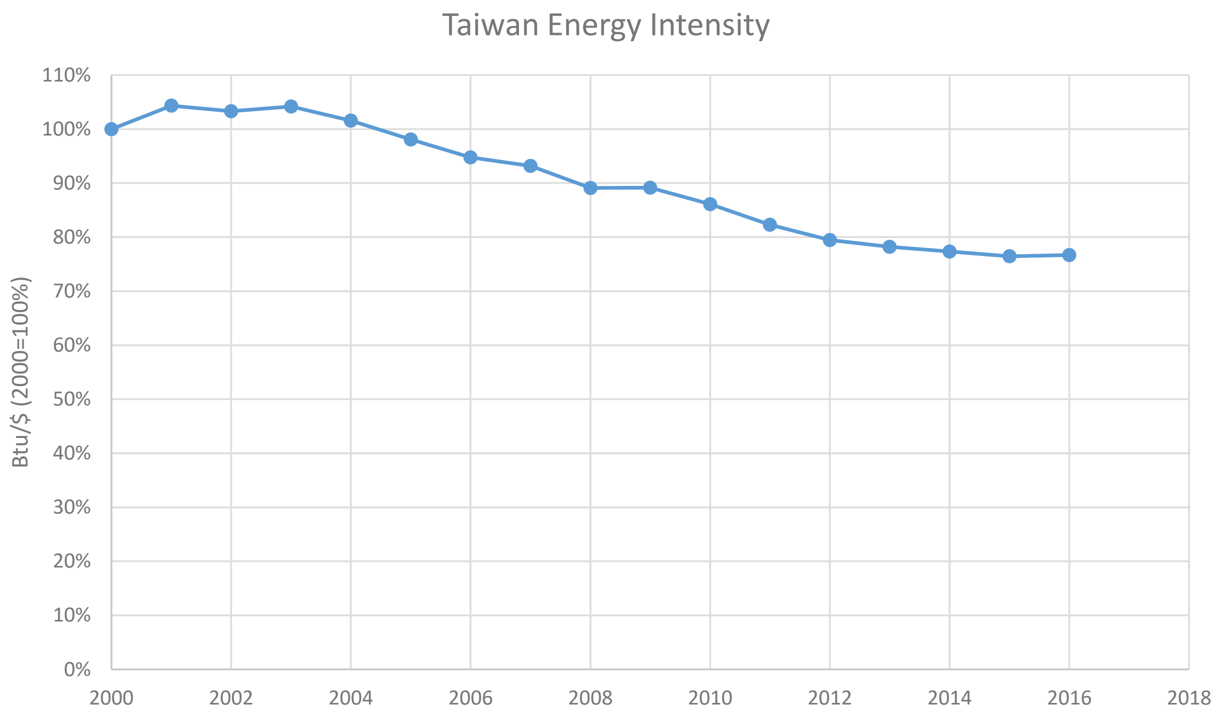
53. Fact Sheet - Energy Efficiency Standards for Appliances, Lighting and Equipment (2017). Environmental and Energy Study Institute, August 11, 2017. https://www.eesi.org/papers/view/fact-sheet-energy-efficiency-standards-for-appliances-lighting-and-equipmen
54. Building Analytics Success Story: CSU Dominguez Hills. https://skyfoundry.com/library, accessed July 27, 2019. https://skyfoundry.com/file/301/Case-Study-California-State-University-Dominguez-Hills.pdf
55. Bastian, Hannah. Achieving Deeper Energy Savings through Integrated Building Systems. American Council for an Energy-Efficient Economy, February 7, 2019. https://aceee.org/sites/default/files/eo-smart-buildings.pdf
56. California Energy Commission, Demand Analysis Office, 2018.

Figure 21: Savings from Individual and Integration Building Systems



Source: King and Perry, 2017 via Hannah Bastian, American Council for an Energy-Efficent Economy

Figure 22: Taiwan Energy Intensity, 2000-2016



Taoyuan City is an excellent example.[57] As Mayor Cheng Wen-Tsan said:

> *[we] needed a streetlight solution that could respond in real-time to changing environmental conditions to ensure optimal street lighting conditions for our citizens and road users. We also see future opportunities to create a city-wide central nervous system that aggregates data on weather, pollution, parking, traffic and environmental conditions to enable us to fully realize our vision of being a smart city.*

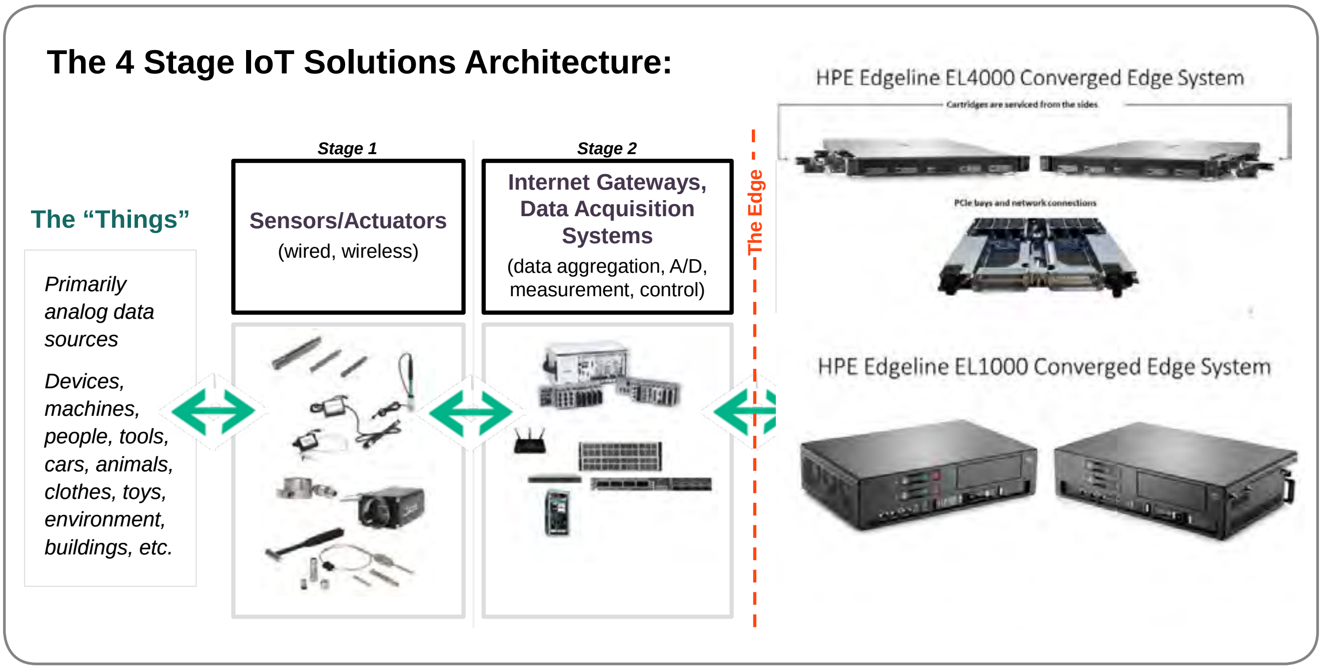
To achieve this vision, the Hewlett Packard Enterprise (HPE) Innovation Center in Singapore and the HPE Pointnext team partnered with gridComm, a Singapore-based smart city solutions company, to design and implement a digital solution that integrates gridComm's SmartLight technology of hybrid power line communications - radio frequency devices and systems with HPEs data management platform in Taiwan. Figure 23 below provides a schematic of the HPE platform architecture.[58] The system will reduce costs by as much as 40 percent.

Lighting, including outdoor lighting, represents as much as 20 percent of total electricity demand. This digital approach to outdoor lighting can lower consumption by as much as 80 percent.[59]

MEETING POWER DEMAND THROUGH IMPROVED THERMAL EFFICIENCY

Efficiency improvement at the end-use level, as described above, is often viewed as the best path for reducing the consumption of fossil fuels to meet power demand.

Figure 23: The Internet of Things Solutions Architecture



Source: Hewlett Packard Enterprise

57. HPE improves energy efficiency of Taoyuan City through real-time monitoring of streetlights. Hewlett Packard Enterprise, September 13, 2018. https://www.hpe.com/us/en/newsroom/news-advisory/2018/09/hpe-improves-energy-efficiency-of-taoyuan-city-through-real-time-monitoring-of-streetlights.html
58. Patterson, Jr., Robert C.. Powering the Intelligent Edge: HPE – IoT Strategy and Direction, June 21, 2017.
59. Perandones, Jorge et. al.. Energy-saving Smart Street Lighting System based on 6LoWPAN, Proceedings of the First International Conference on IoT in Urban Space, October 2014.

However, thermal efficiency – the efficiency with which fossil fuel resources are converted to electricity, is also important. Thermal efficiency varies widely from less than 40 percent for older, less advanced coal-fired plants to more than 60 percent for newer, more advanced gas-fired plants. Higher thermal efficiency means fewer resources are wasted, with more resources devoted to meeting consumer's ultimate needs. An increase in thermal efficiency from 40 to 50 percent represents a 25 percent reduction in fuel use.

There is relatively little information on the thermal efficiency of power plants within ASEAN. Figure 24 below shows historical and projected thermal efficiency from the Third Annual Energy Outlook.[60]

The figure shows that thermal efficiency has improved in the past but is projected to grow only modestly going forward to remain well below 40 percent efficiency. Although it is understandable, given the fuel and technology mix within ASEAN, this is still low by international standards. Fundamental changes may be needed in fuel and technology, but digitalization can also play a role in meeting ASEAN's power demand with improved thermal efficiency.

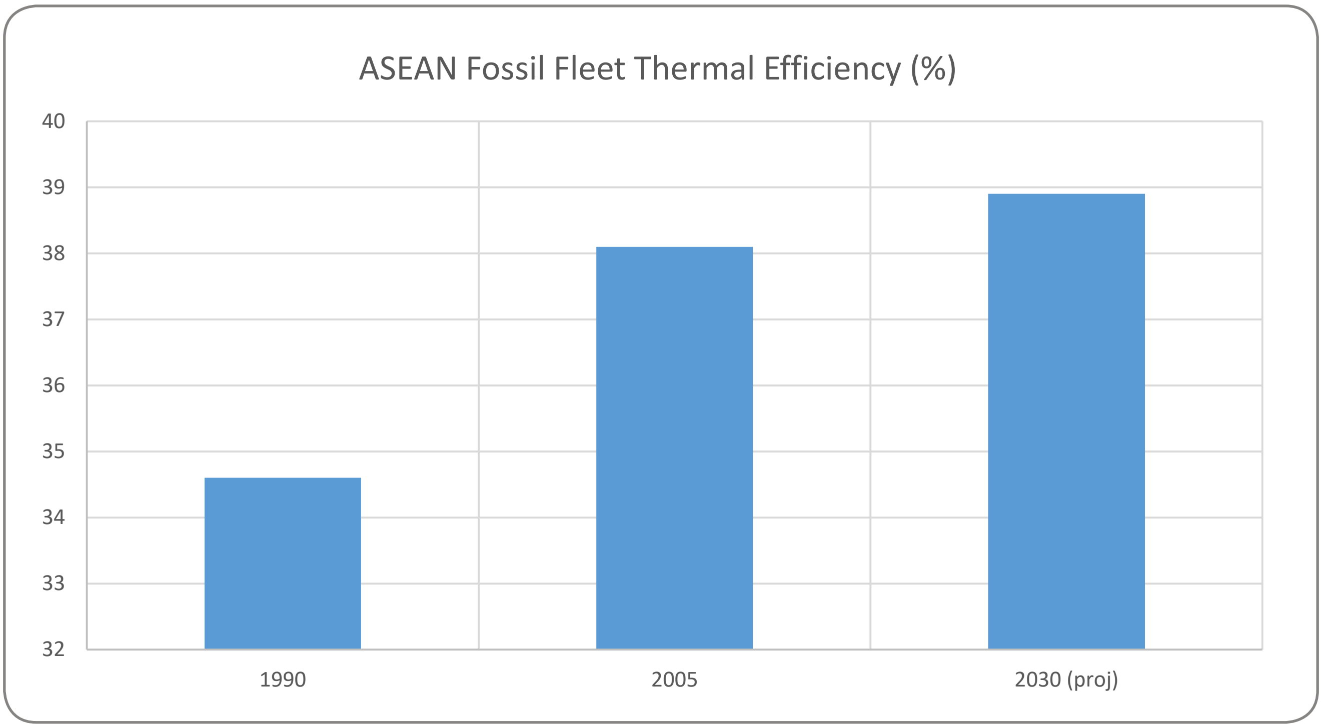
SINGAPORE

While thermal efficiency improvement often focuses on large central-station power plants, one of the most attractive approaches to enhanced thermal efficiency is through the adoption of cogeneration on the prosumer side. With cogeneration, multiple energy-related products are produced from the same plant. In the past, the two products were typically power and heat or steam, hence the term Combined Heat and Power (CHP). More recently, cooling has been introduced as another element and the term CHP now sometimes refers to Cooling, Heating and Power.

The modern definition of cogeneration then becomes the centralized, high-efficiency production of cooling, heating and/or power. With cogeneration, the energy that is usually wasted and vented is instead used productively at a customer site in residential, commercial or industrial applications. This dramatically increases the overall thermal efficiency to as high as 80 or 90 percent.

Cogeneration is often associated with large industrial facilities that consume both electricity and heat

Figure 24: ASEAN Fossil Fleet Thermal Efficiency, 1990, 2005, and 2030



Source: ASEAN Centre for Energy data

60. Institute of Energy Economics – Japan and the ASEAN Centre for Energy. The 3rd ASEAN Energy Outlook. ASEAN Center for Energy, February 2011.

(sometimes in the form of steam). In Singapore, a great deal of cogeneration producing power and heat/steam is associated with refineries on Jurong Island. At the same time, Singapore is a world leader in district cooling. As shown in the figure below, Singapore is home to the world's largest underground district cooling system at Marina Bay.[61] In March 2019, Engie was awarded the contract to design an even larger "integrated" district cooling facility for the Punggol Digital District.[62] District cooling specifically, and cogeneration generally, contributes significantly to improved thermal efficiency and meeting power demand.

How is this being accomplished?

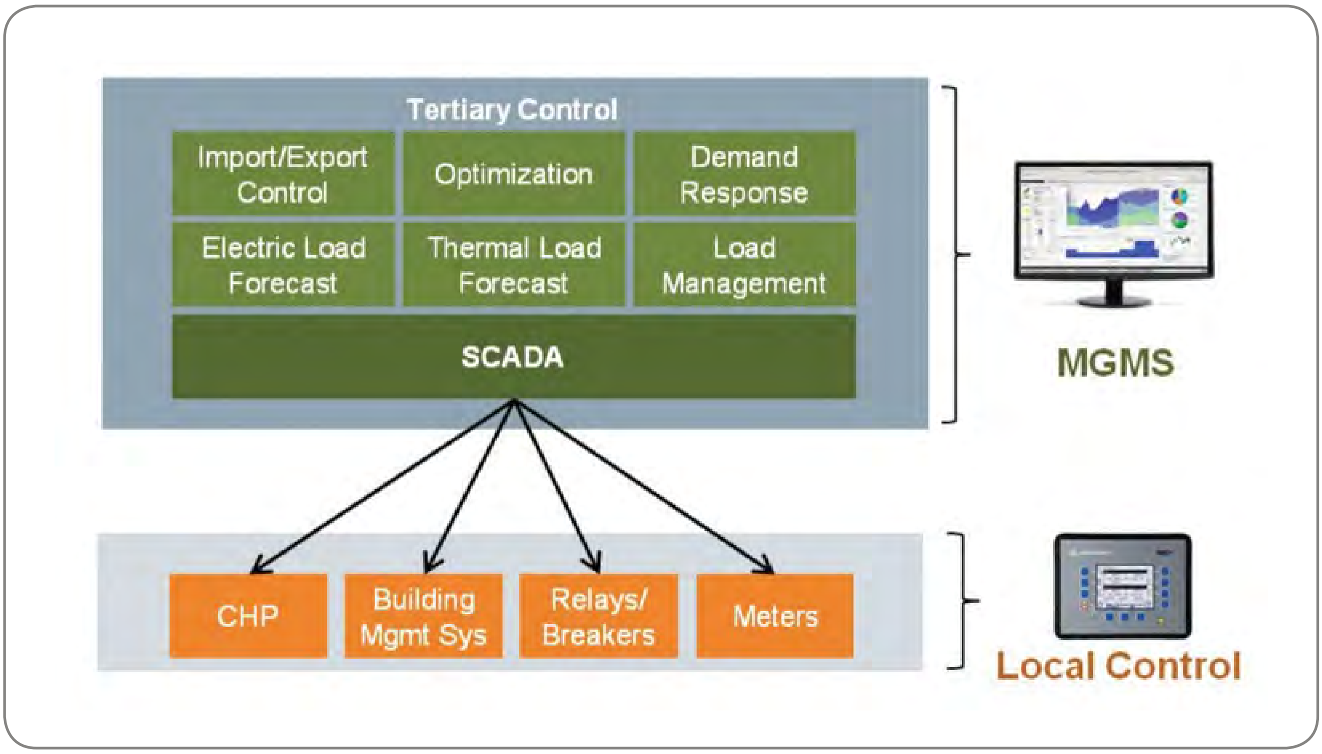
Singapore's commitment to thermal efficiency is driven in large part by necessity. Singapore has a vibrant economy without conventional energy resources, as well as a history of economic dynamism and technology innovation.

Digital technology also plays a vital role in cogeneration because it requires simultaneous real-time management of multiple inputs and outputs. This means intensive monitoring, predicting, analyzing and controlling.

Not surprisingly then, digital systems are available specifically for managing cogeneration systems. Figure 25 below shows the high-level architecture of SiemensUSA's cogeneration optimization software called SpectrumPower MGMS.[63]

Cooling accounts for more than 30 percent of Singapore's electricity demand.[64] Cogeneration, including district cooling, can increase overall thermal efficiency by as much as 40 percent.[65, 66] District cooling may not be technically or economically feasible across all of Singapore but if fully adopted, it could reduce overall electricity demand by as much as 10 percent.

Figure 25: Spectrum Power Functions and Communication to Local Resource Controllers



Source: SiemensUSA, Optimization Software for Combined Heat and Power (CHP)

61. Othman, Liyana. World's Biggest District Cooling Network Now at Marina Bay. Today, March 2, 2016.
https://www.todayonline.com/singapore/plant-underground-district-cooling-network-marina-bay-commissioned
62. ENGIE to build Singapore's first integrated district cooling network. Smart Energy International, March 12, 2019.
https://www.smart-energy.com/industry-sectors/smart-energy/engie-build-singapores-first-integrated-district-cooling-network/
63. Optimization Software for Combined Heat and Power (CHP). SiemensUSA.
64. Oh, Seung et al.. Forecasting long-term electricity demand for cooling of Singapore's buildings incorporating an innovative air-conditioning technology, Energy and Buildings, 127, September 1, 2016, pages 183-193.
65. Combined Heat and Power (CHP) Partnership. Environmental Protection Agency (EPA), accessed July 30, 2019. https://www.epa.gov/chp/chp-benefits
66. District Cooling. Stellar Energy, accessed July 30, 2019. http://www.stellar-energy.net/what-we-do/solutions/district-cooling.aspx,

JAPAN

Globally, the average efficiency of fossil-fired power plants continues to improve. Power plant technology has advanced, with new gas-fired power plants replacing old coal-fired power plants. Japan, a country with few domestic resources, has been very active on the thermal efficiency front. Figure 26 below compares coal fleet thermal efficiency in Japan with other parts of the world.[67] Japan is clearly the best performing country, and a similar situation is emerging with gas-fired plants as well. Overall, Japan is a leader in generating as many kWh as possible from each unit of fossil fuel.

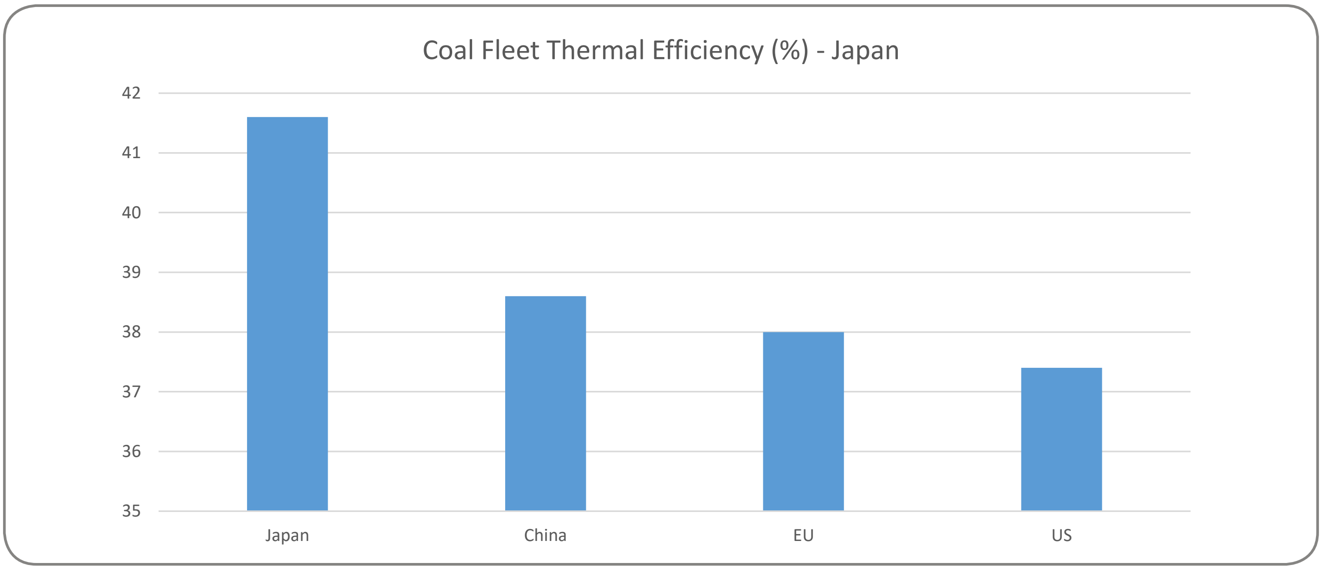
How is this being accomplished?

Japan's emphasis on thermal efficiency is in large part driven by necessity, like Singapore. Japan has few energy resources. In addition, after the Fukushima nuclear accident, Japan's foray into nuclear power is over. As a result, the Japanese government has committed to maintaining and increasing its leadership in thermal efficiency. The well-known Japanese societal attention to detail and quality will help. Digital technology has played, and will play, an important role.

The Chubu Electric (Japan) Nishi-Nagoya power plant was recently announced by Guinness World Records as the world's most efficient combined-cycle gas-turbine facility, achieving 63.08 percent gross efficiency.[68] This plant takes advantage of numerous advances in design and materials, but such records also rely heavily on the latest plant monitoring, prediction and management software that GE calls "the digital power plant."[69] To quote GE:[70]

> *"[H]ow does a record-setting power plant efficiency percentage happen? With the help of GE's Digital Power Plant capabilities, which helped to unlock power… that had previously been inaccessible. Capabilities, including the digital control system, use real-time data to deliver better plant outcomes with stable and efficient operations, while providing valuable predictive insights for higher reliability and optimization."*

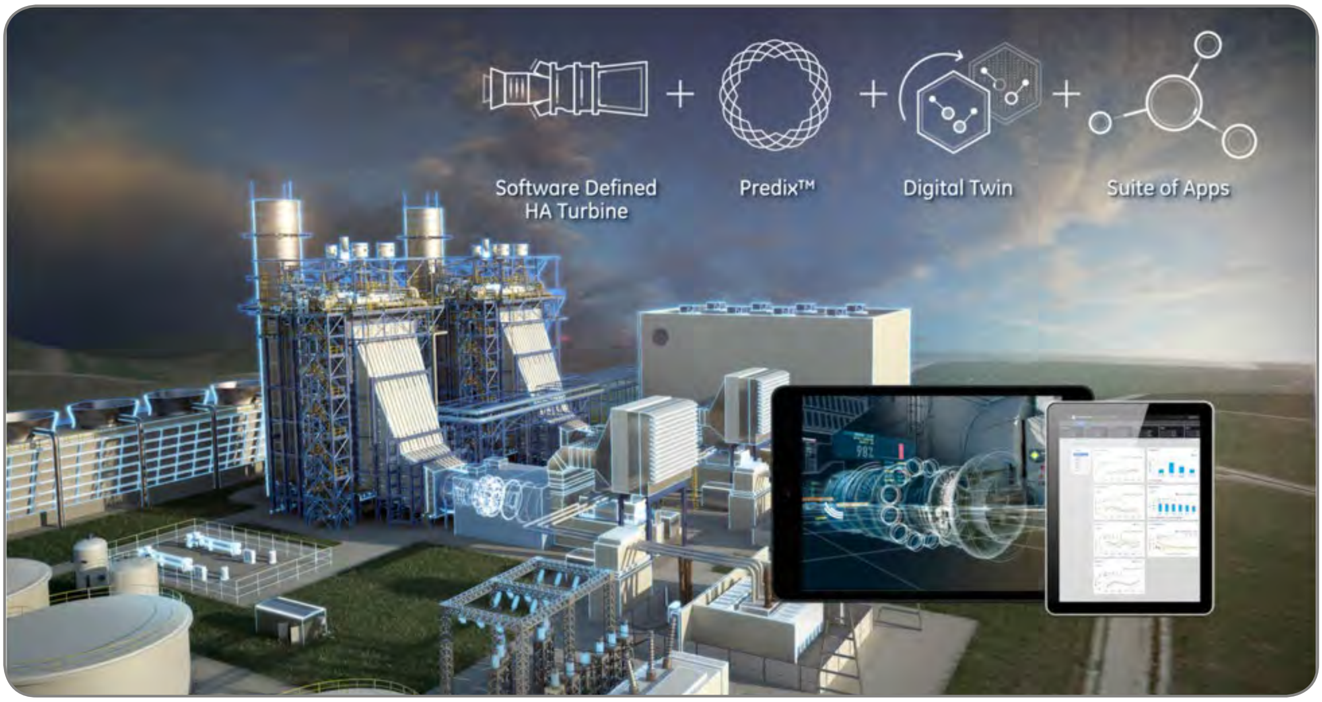
Figure 26: Coal Fleet Thermal Efficiency in Japan, China, the EU, and the US



Source: IEA Clean Coal Centre

67. Malgorzata Wiatros-Motyka, IEA Clean Coal Centre. An overview of HELE technology deployment in the coal power plant fleets of China, EU, Japan and USA. IEA Clean Coal Center, December 2016. https://www.usea.org/publication/overview-hele-technology-deployment-coal-power-plant-fleets-china-eu-japan-and-usa-ccc
68. Patel, Sonal. GE HA Turbine Snags Another World Record for CCGT Efficiency. POWER, March 28, 2018. https://www.powermag.com/ge-ha-turbine-snags-another-world-record-for-ccgt-efficiency/
69. The Digital Power Plant. General Electric. https://www.ge.com/digital/sites/default/files/download_assets/GE-Digital-Power-Plant-Brochure.pdf
70. Breaking the Power Plant Efficiency Record. General Electric, April 2016. https://www.ge.com/power/about/insights/articles/2016/04/power-plant-efficiency-record

Figure 27: Example of Digital Power Plant Infrastructure



Source: General Electric, https://www.ge.com/reports/every-electron-gets-byte-digital-power-plant-makes-electricity-smart/

Japan produces more than 700 billion kWh of electricity from fossil fuels each year. Relying on a coal fleet with 50 percent thermal efficiency rather than 40 percent thermal efficiency can eliminate the need for perhaps 25 1000MW coal-fired power plants.

MEETING POWER DEMAND THROUGH IMPROVED RENEWABLE GRID INTEGRATION

One of digital technology's most significant contribution to meeting power demand is the increased penetration of renewable energy on the grid. The past and projected role of renewables in ASEAN electricity generation is seen on the following page.

As Figure 28 indicates, renewable energy – including biomass, geothermal, hydro, wind and solar – currently represents roughly 20 percent of generation in ASEAN. Most of this contribution comes from hydro, and very little from the two world-leading technologies – wind and solar. With BAU, this share is projected to increase only to around 25 percent by 2040, driven primarily by hydro. In this BAU scenario, under five percent of generation will come from wind and solar in 2040, which is disappointing.

While ASEAN has laudable renewable energy targets, the penetration of wind and solar lags well behind both what is achieved elsewhere and what is feasible in the region. Therefore, digital technology is critical for improving this situation and in reducing the dominant role of fossil generation. The examples below show how.

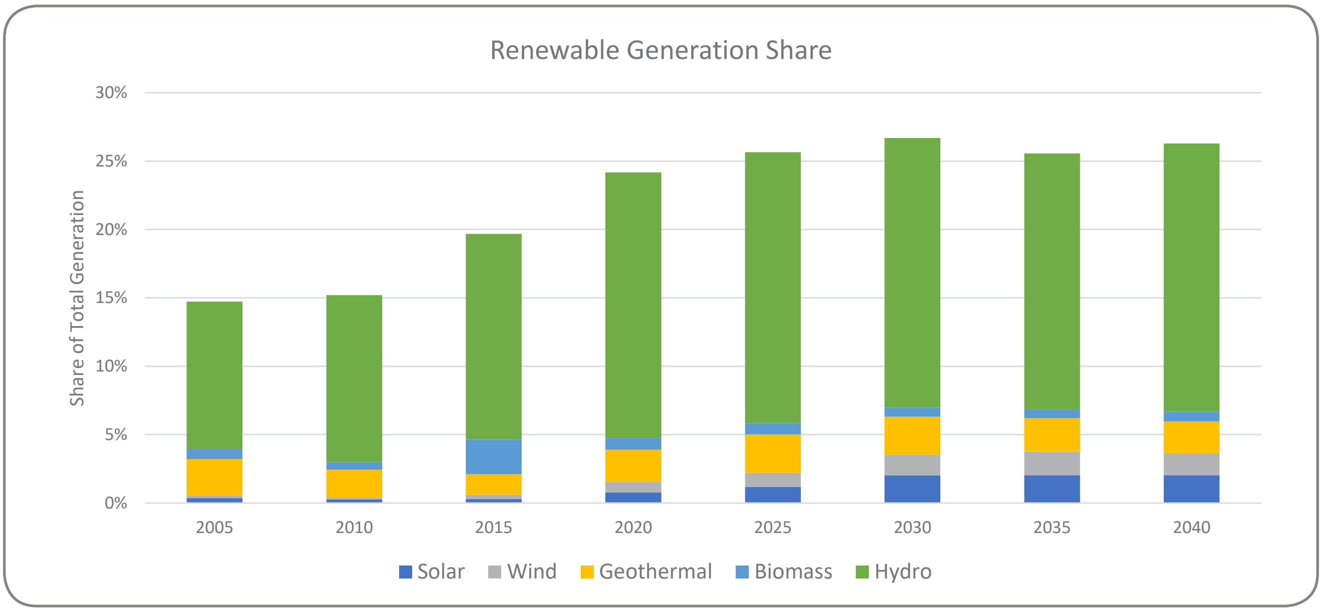
THAILAND

As noted above, ASEAN has surprisingly little solar and wind generation. Thailand is the clear ASEAN leader in solar power, with more than 2500MW of installed capacity and more than 3000GWh of solar generation each year. It has a 6000MW target in 2036. Figure 29 shows the growth in installed solar photovoltaics (PV) capacity. While growth has slowed since 2017 and the total is still a relatively small part of the overall energy mix, the increase is still impressive.

How is this being accomplished?

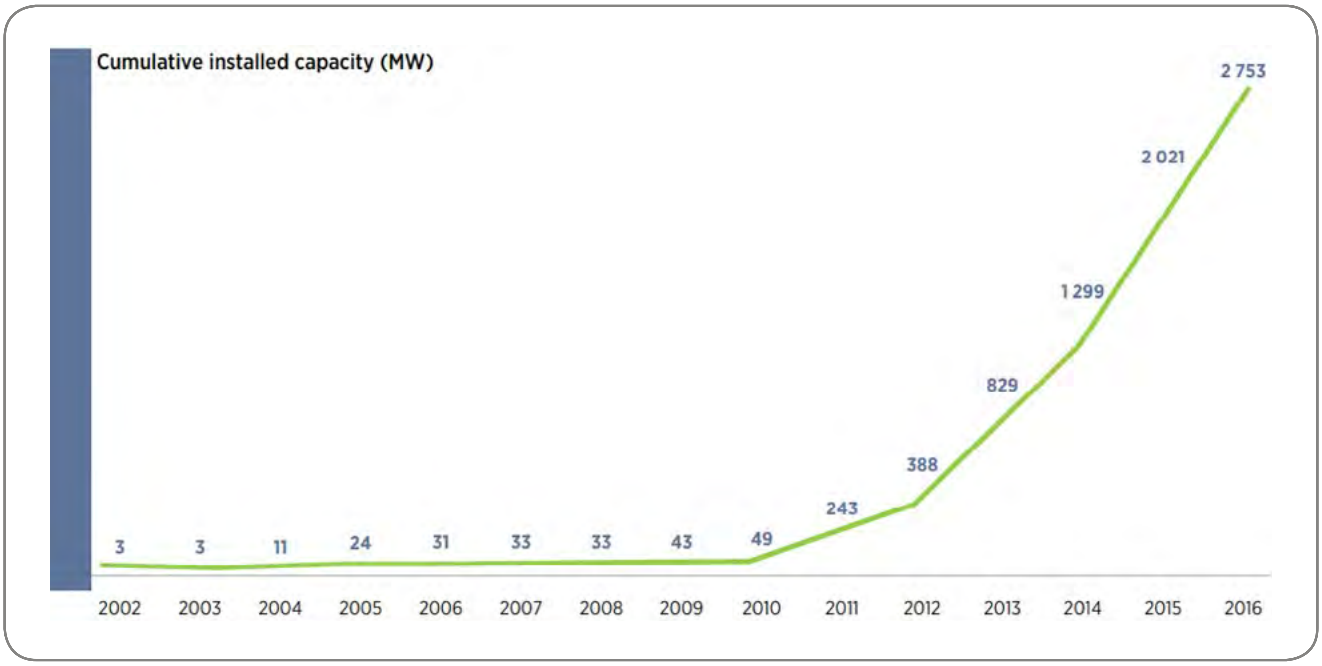
Like other jurisdictions, the increase in solar capacity is due to a mix of government/societal support (a form of demand pull) and enabling technology development (a form of supply push). One exciting development in Thailand is the increasing role of distributed or rooftop solar. Although still at modest levels, it is expanding rapidly and, much like other jurisdictions around the globe, the government is working on updating policies and regulations to match. Starting in 2013, around 200MW of rooftop solar was installed under the original regulations. More recently, Thailand has just passed a new net metering law, and a pilot 100MW program is underway.[71]

Figure 28: BAU Generation Projections Share by Renewable Energy Technology



Source: The 5th ASEAN Energy Outlook 2015 – 2040, ASEAN Centre for Energy, 2017

Figure 29: Thailand's Cumulative Solar PV Installed Generating Capacity, 2002-2016



Source: IRENA (2017), Renewable Energy Outlook: Thailand, International Renewable Energy Agency, Abu Dhabi

71. Bellini, Emiliano. Thailand launches a net metering scheme for residential PV. pv magazine, May 24, 2019. https://www.pv-magazine.com/2019/05/24/thailand-launches-net-metering-scheme-for-residential-pv/

Digital technology, blockchain, in particular, is playing a key role by enabling a peer-to-peer solar energy market. This new market involves an interesting mix of old and new businesses:[72]

> *"BCPG, a subsidiary of state-owned oil refiner Bangchak, recently joined forces with real estate developer Sansiri to offer blockchain-linked solar power system in Bangkok. Their rooftop panels can produce 635 kW of power to be used by a local shopping mall and nearby community. "This is the first solar power system with blockchain technology ever in ASEAN, and it is our pilot project," said Uthai Uthaisangsuk, a senior executive at Sansiri, one of the country's biggest property groups. The executive added that with BCPG's cooperation, Sansiri expects to expand the service to 20 projects over the next few years. Banpu Infinergy, a subsidiary of coal miner Banpu that installs rooftop solar panels, is also developing its own blockchain platform to tap into rising demand."*

Figure 30 illustrates the financial and power flows associated with blockchain rooftop solar.[73] Blockchain technology facilitates the business transaction between two parties (peer-to-peer) while the traditional electricity grid enables the actual power flows.

Thailand's electricity generation is still dominated by fossil fuels. Each MW of solar PV replaces roughly 1500 MWh of fossil-based electricity a year.

DENMARK

Figure 31 shows the evolving generation mix in Denmark between 1990 and 2015.

In 1990, more than 90 percent of electricity in Denmark was generated from fossil fuel, primarily coal. By 2015, that fraction had been reduced to 30 percent. Wind accounted for more than 50 percent, while another 20 percent came from non-variable renewable sources – biomass and hydro. Since 2015, this trend has continued with more wind and less fossil. By 2022, the share of wind is expected to increase to more than 70 percent, with fossil fuel playing a diminishing role. In just 25 years, Denmark is well on its way to replacing its fossil generation with renewables. As such, Denmark is a "role model" for integrating variable renewable generation on the electricity grid.

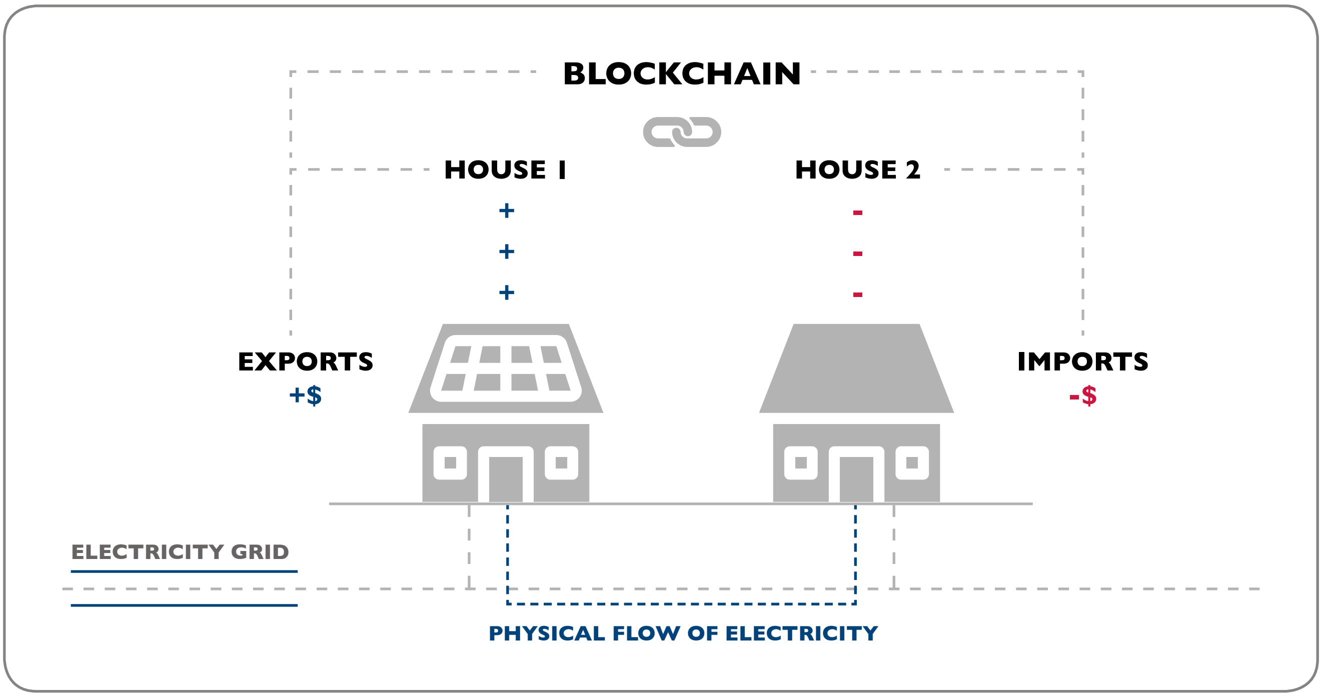
How is this being accomplished?

In Denmark, the role of renewables has been facilitated by a favorable policy and regulatory environment, including financial incentives that began in 1990 with "Energy 2020." But this favorable environment was not sufficient. Beyond politics and economics, the electrical system must be technically capable of absorbing and managing a high level of intermittent power. This is where digital technology comes in to do the following– monitoring the state of the grid, forecasting future weather and system conditions, and optimizing supply and demand.

In order to make effective use of wind and ensure a stable grid, the Danish utility – Energinet.dk – has adopted advanced day-ahead weather forecasting, and integrated this into its management of generation, transmission and distribution. In addition, the utility is incorporating AI to

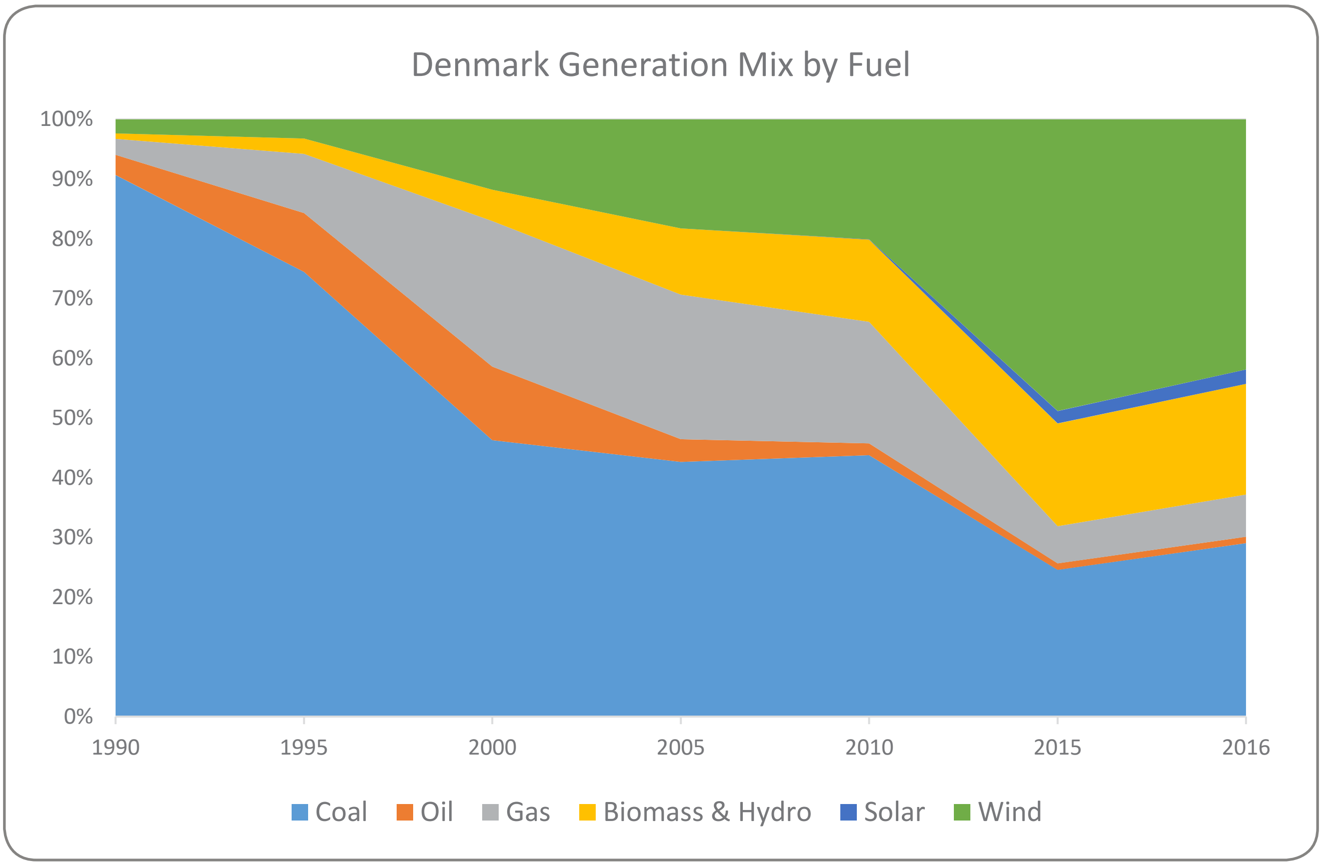
72. Phoonphonghiphat, Apornrath. *Thailand braces for a surge of blockchain-enabled solar power.* Nikkei Asian Review, September 6, 2018. https://asia.nikkei.com/Business/Business-trends/Thailand-braces-for-surge-of-blockchain-enabled-solar-power
73. Maisch, Marija. *Fremantle residents to trade solar energy using blockchain.* pv magazine, December 6, 2018. https://www.pv-magazine-australia.com/2018/12/06/fremantle-residents-to-trade-solar-energy-using-blockchain/

Figure 30: Financial and Power Flows through Blockchain Linked Solar Power



Source: PV Magazine Australia

Figure 31: Denmark Generation Mix by Fuel, 1990-2015



Source: International Energy Agency data continue improvement in its approach. As Eric Martinot of the Institute for Sustainable Energy Policies said:[74]

> “ *During the day, in real time, the Danish power system control center constantly compares actual output of renewables against predictions made the day before. The error of actual vs. predicted is then used to forecast the output of renewables in coming hours ahead of real time. This leads to a situation one senior manager of the Danish power grid said ‘virtually eliminates errors in the predictability of renewable output.’ To implement this approach, Energinet relies on a platform jointly developed with the Canadian IT consulting firm CGI called DataHub. CGI refers to DataHub as “a solution that provided a centralized, secure platform that enabled fair competition, better communication among market parties and easy access to data and information sharing…” DataHub first went live in 2013, but has been upgraded and expanded, and will soon include Norway, Finland and Sweden as well as Denmark.*[75] ”

Denmark is a small country of less than six million people. Annually, it generates almost 15 billion kWh of wind energy, the equivalent of 3 1000MW coal fired plants.[76]

Figure 32: Denmark Wind Turbines

Source: Eco News:
http://econews.com.au/36686/wind-power-blows-denmark-output-above-50/

HAWAII

Several U.S. states are moving towards 100 percent renewable or carbon-free power. But most of these states continue to rely on baseload sources of energy such as nuclear and hydro. Hawaii is a unique state in that it is moving towards 100 percent renewable power based almost entirely on wind and solar, along with battery storage.

Figure 33 on the following page shows the actual and target renewable percentages. Hawaii already gets roughly 25 percent of its electricity from renewables, dominated by wind and solar. Going forward, Hawaii will be increasingly relying on wind, solar and batteries.

How is this being accomplished?

As with other jurisdictions, necessity has been the mother of invention. Hawaii has few conventional resources, but an abundance of wind and solar. Like California, it also has a strong government, business and societal commitment to renewable energy. But as in Denmark, this commitment alone is insufficient. Digital technology is required to integrate renewables work technically, and

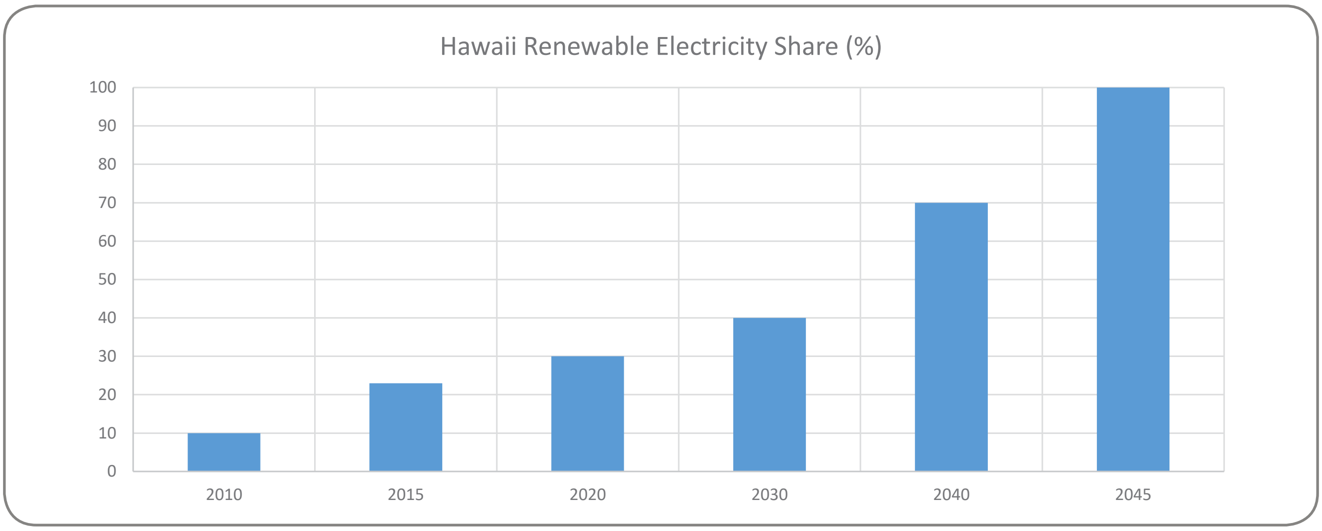
74. Martinot, Eric. How is Denmark integrating and balancing renewable energy today?. January 2015. http://www.martinot.info/Martinot_DK_Integration_Jan2015.pdf
75. Energinet: Successful DataHub solution sets the foundation for the future of the Danish electricity retail market. CGI, 2019. https://www.cgi.com/en/media/video/successful-datahub-solution-sets-foundation-future-danish-electricity-market-0
76. Electricity Information 2018, accessed July 30, 2019. https://webstore.iea.org/electricity-information-2018,

the challenge may be even greater for an isolated grid. This experiment is being watched closely in other states and countries.[77]

In Hawaii, wind and solar resources are not centralized but dispersed over a wide geographic area. Digital technology must be applied to this distributed network. One such technology is the "smart inverter" – a device associated with rooftop solar that performs many of the short-term grid operation functions associated with full-scale utility equipment. A recent National Renewable Energy Laboratory study concluded that "it is possible to deploy significant amounts of PV without impacting grid reliability or customer production if smart inverter functions are properly used."[78]

Currently, Hawaii generates roughly 2.5 billion kWh or 25 percent of its electricity from renewable sources, including a substantial amount of distributed solar. This displaces the equivalent of a 500MW coal plant.[79]

Figure 33: Hawaii Renewable Electricity Share, 2010-2045



Source: Hawaii State Energy Office

Figure 34: Residential Solar PV in Hawaii, United States

Source: https://www.nrel.gov/esif/partnerships-heco-solar-inverter.html

77. Fialka, John, E&E News. As Hawaii Aims for 100% Renewable Energy, Other States Watching Closely. Scientific American, April 27, 2018. https://www.scientificamerican.com/article/as-hawaii-aims-for-100-renewable-energy-other-states-watching-closely/
78. Hoke, Andy et al.. Integrating More Solar with Smart Inverters: Preprint. Golden, CO. National Renewable Emergy Laboratory (NREL), June 2018. . https://www.nrel.gov/docs/fy18osti/71766.pdf
79. Hawaii Energy Facts and Figures. Hawaii State Energy Office June 2018. http://energy.hawaii.gov/wp-content/uploads/2018/06/HSEO_2018_EnergyFactsFigures.pdf

CLOSING THE ENERGY ACCESS GAP THROUGH MICROGRID DEVELOPMENT

Energy access around the globe, including among ASEAN member states, has improved dramatically over the past few decades. Most of that improvement came from extending the main utility grid. This works well for expanding service to relatively high-density urban areas, but less well in relatively low-density rural areas. In ASEAN for example, 50 percent or more of the rural population in Myanmar and Cambodia are still without access, and as much as 15 percent in rural Indonesia, Lao PDR and the Philippines.[80]

Looking ahead, closing the remaining gap in energy access will require success in remote and/or sparsely populated rural areas where grid extension is technically and/or economically difficult. Under these circumstances, one crucial solution to the energy access challenge will be the use of renewable or hybrid (renewable plus fossil) microgrids. Microgrids are small stand-alone grids that are not connected to the main utility grid.

Digital technology, particularly involving communications, can play a significant role in the development and operation of these microgrids, and thereby accelerating the closing of the energy access gap. The examples below show how.

MYANMAR

Myanmar is a challenging environment for energy access and, like similar countries, is using microgrids to increase access in rural areas. Some experts believe that microgrids will leapfrog traditional grid power, just as mobile phones have leapfrogged conventional landlines.

How is this being accomplished?

Two key drivers of microgrid development in Myanmar are the encouragement of entrepreneurship and technology availability. As in other ASEAN member states, Myanmar's strong government commitment is also critically important.

Figure 35: Solar Microgrids in Myanmar

Source: https://govinsider.asia/smart-gov/how-solar-micro-grids-are-powering-myanmars-villages/

81. Energy Access Outlook 2017. International Energy Agency (IEA), 2017. https://webstore.iea.org/download/summary/274?fileName=English-Energy-Access-Outlook-2017-ES.pdf

Myanmar has a target of 100 percent energy access by 2030 and has enlisted multilateral organizations in that effort.[81]

The leading microgrid developer in Myanmar is Yoma Micro. In 2018, Yoma had roughly 50 microgrids in place. By the end of 2019, the figure is projected to be more than 200. And more than 2000 by 2020.[82]

Like many other microgrid developers, Yoma Micro is heavily invested in digital technology. Yoma management has extensive experience in software and telecom, and a strong emphasis on high-tech operations. It is "pioneering the use of responsive demand-side management, implementing smart meters and digital payments like Wave Money, which fosters financial inclusion by bringing previously unbanked customers into banking and financial sectors."[83]

Between private and public efforts, as many as one million people in Myanmar will gain access to electricity via microgrids in the next few years. These are some of the most challenging locations in the country, and will be an important step in closing the energy access gap.

NEPAL

Nepal has among the most challenging conditions for electricity transmission and distribution. Over the past twenty years, Nepal has successfully "electrified" almost all its urban and rural population. In urban areas, much of this was achieved through grid extension. But in rural areas, microgrids played a dominant role. With more than 80 percent of Nepal's population living in rural areas, this is quite an achievement.

How is this being accomplished?

To a great extent, the success of microgrids in Nepal is directly linked to two drivers – one social/political, the other technological. The social/political driver is the encouragement of entrepreneurship. Microgrid development is typically the domain of small entrepreneurs. The technological driver is digitalization. Microgrids in locations like Nepal would simply not be possible without the advances of remote sensing, smart metering and the like.

Gham Power, a leading microgrid developer in Nepal, relies on digital technology throughout the entire microgrid design, implementation and operation process. Its microgrids are "equipped with data sensing devices that track and feed live data usage over a period of time. They are financed by communities that installed them and are provided with 'pay-as-you-go' financing mechanisms."[84]

One particularly interesting element of Gham Power's business model involves the use of digital technology for off-grid crowdfunding. Potential investors can find investment-ready projects on its Off-Grid Bazaar (OGB) – "an interactive online platform to scale the implementation of off-grid solar-based projects that serve small-holder farmers…"[85]

The same platform is used to track operations. Figure 37 shows a screenshot of the platform's operational dashboard for irrigation-focused microgrid development. The dashboard displays operational data on power, water and other variables in real time, and is available remotely.

In Nepal, the majority of the population lives in areas where grid extension is challenging. For this population, microgrids are often the only way to provide access to genuinely productive power. In 2006, there was a major urban-rural access gap- 90 percent of the urban population and only 45 percent of the rural population had access. By 2016, the urban share had increased to 95 percent. Even more positively, the rural population had risen to 85 percent. This narrowing of the gap is primarily due to microgrids.[86]

81. Energy Access Outlook 2017. International Energy Agency (IEA), 2017. page 109. https://webstore.iea.org/download/summary/274?fileName=English-Energy-Access-Outlook-2017-ES.pdf
82. Gan, Jasmine. How solar micro-grids are powering Myanmar's villages. Energy Insider, July 8, 2019. https://govinsider.asia/smart-gov/how-solar-micro-grids-are-powering-myanmars-villages/
83. Yoma Micro Power. https://www.yomamicropower.com/
84. Gham Power, accessed July 23, 2019. http://ghampower.com/product/microgrids/
85. Gham Power, accessed July 23, 2019. http://ghampower.com/product/microgrids/
86. World Resources Institute. https://www.wri.org/

Figure 36: Microgrid in Nepal

Source: *http://ghampower.com/product/microgrids/*

Figure 37: Gham Power Operational Dashboard

Source: *http://ghampower.com/wp-content/uploads/2019/05/Investors-booklet_May2019.pdf*

MAINTAINING ENERGY SYSTEM RESILIENCE WITH BETTER WEATHER PREPARATION AND RECOVERY

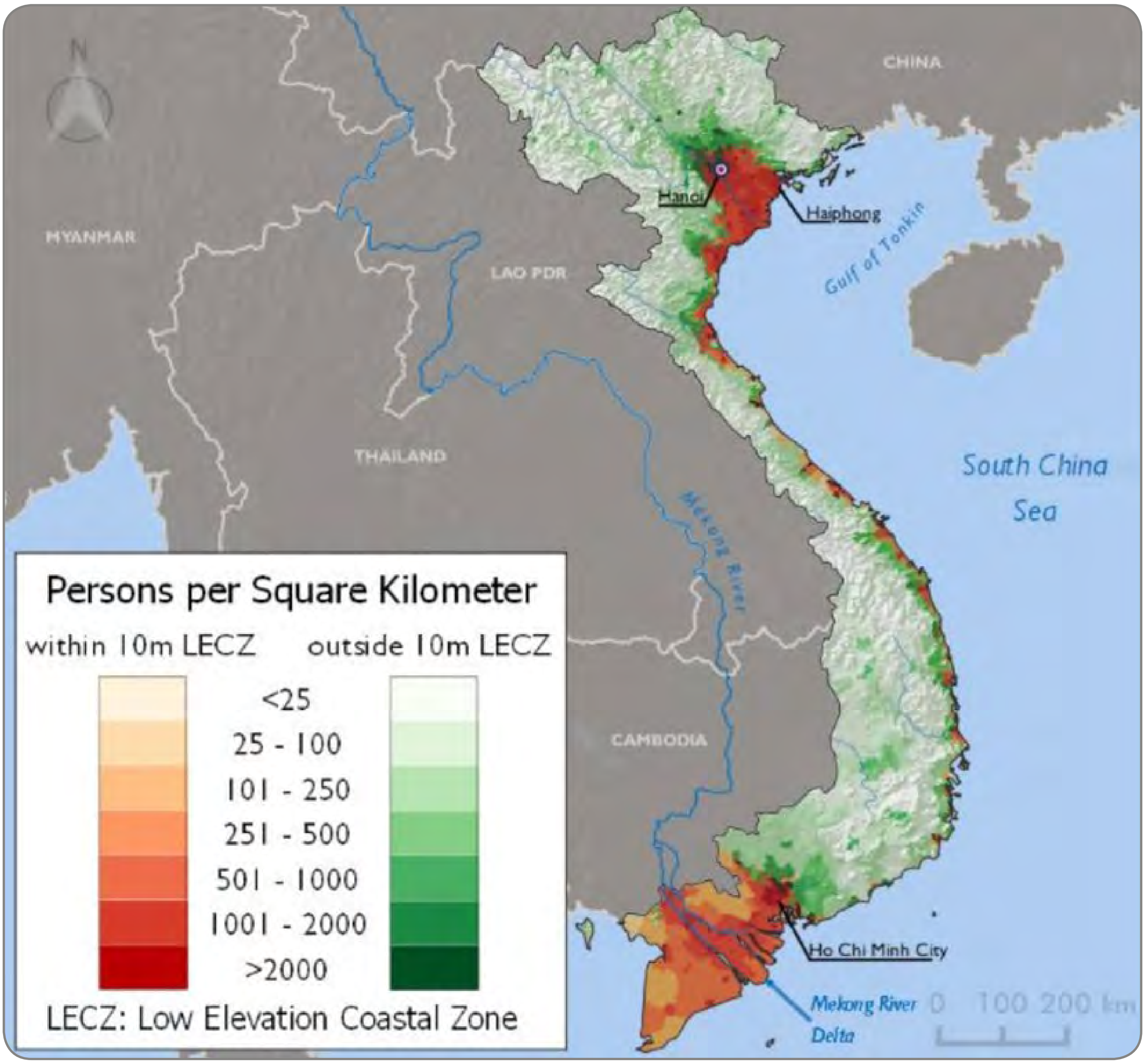
Climate resilience – the ability to deal both with acute climate events such as storms and chronic climate challenges such as sea-level rise – is becoming increasingly important. ASEAN has long recognized the climate change challenge and the importance of climate resilience. Digital technology can help, mainly through improved weather preparation and recovery.

VIETNAM

Like most of ASEAN, Vietnam is highly vulnerable to climate change. As Figure 38 below shows, much of the population and infrastructure are located in low-lying coastal areas, exposed to storms and floods.

By some accounts, Vietnam is among the top five most climate-vulnerable countries. The government recognizes

Figure 38: Vietnam Population Density in Coastal Areas



Source: Hawaii State Energy Office

this situation and has responded with policies to increase resilience in key sectors, including energy.

How is this being accomplished?

The Vietnamese government has instituted policies to prepare for and respond to the effects of climate change, such as floods and storms by keeping accurate and up-to-date weather information and using digital technology.

Vietnam has made no secret of its plans to become a leader in digital technology. In 2018, the two largest utilities in Vietnam – Vietnam Electricity (EVN) and Southern Power Corporation (SPC) – won Asian Utility Week's award for the best digital transformation. EVN and SPC have adopted Landys+Gyr's Meter Data Management System (MDMS) for improved customer service and grid operations. MDMS provides a single integrated platform for data, analysis and communication including load forecasting, fault detection and outage management.[87] All these features are important for weather preparation and recovery. The figure below shows MDMS "in action." In Vietnam, the system makes hundreds of millions of system readings every day.

TEXAS

2017 was a "banner year" for hurricanes across the globe. In terms of the number of named storms, it was one of the worst hurricane seasons. In terms of economic damage, it was widely reported as the costliest. While Texas is no stranger to hurricanes, it was struck a particularly hard blow by Hurricane Harvey (Figure 40). Harvey was not just an intense Category 4 hurricane; it was also one of the most damaging. It made landfall three separate times over six days, delivered a record of 60 inches of rain in a matter of hours, and flooded more than one-third of Houston.[88]

Given Harvey's astounding strength, the damage to Texas was extensive. Lives were lost. Homes were flooded. Businesses were disrupted. However, in all this, the power grid fared relatively well. There were considerably fewer power outages compared to weaker storms, and recovery took substantially less time.[89]

How is this being accomplished?

The main driver that most observers point to in explaining the resilience of the power grid to Hurricane Harvey

Figure 39: Landys+Gyr's Meter Data Management System (MDMS)

Source: Landys+Gyr's Meter Data Management System

Figure 40: Hurricane Power Outage in Houston

Source: *https://www.cnbc.com/2017/08/28/texas-utilities-struggle-to-restore-power-as-harvey-hampers-progress.html*

87. Landis+Gyr, EVN and EVNSPC. Win for Best Digital Transformation of Vietnam with Landis+Gyr at Asian Utility Week 2018. Asia Today, July 11, 2018.
http://asiatoday.com/pressrelease/evn-and-evnspc-win-best-digital-transformation-vietnam-landisgyr-asian-utility-week-201
88. Kennedy, Merritt. Harvey The 'Most Significant Tropical Cyclone Rainfall Event in U.S. History'. NPR, January 25, 2018.
https://www.npr.org/sections/thetwo-way/2018/01/25/580689546/harvey-the-most-significant-tropical-cyclone-rainfall-event-in-u-s-history
89. Greenley, Steve. Texas Strong: Hurricane Harvey Response and Restoration. Centerpoint Energy, February 21, 2018.
https://www.energy.gov/sites/prod/files/2018/02/f49/2_Emergency%20Response%20and%20Resilience%20Panel%20-%20Steve%20Greenley%2C%20CenterPoint%20Energy.pdf

is the investment – in both physical and human capital - that the local utility, Centerpoint Energy, made in its Intelligent Grid. Kenneth Mercado, Centerpoint's Chief Integration Officer, explained the extensive role that digital technology played:

> *"When you digitize your grid, you see things in real time that you never could see before. It allows us to efficiently monitor our system for real problems, prioritize our resources, and efficiently recover from our damages. It also allows us to prepare for communications with customers and other stakeholders…. [We] avoided more than 40 million outage minutes during Hurricane Harvey. Hundreds of power line monitoring devices, remote switches, smart meters, and other automation equipment helped crews locate outages and speed repairs….Digital smart metering was probably the most important advancement. It worked incredibly well. We were able to use the remote capabilities of meters even when the streets were flooded and not passable. The meters enabled us to communicate with customers about outage conditions during and after the storm. We were reading meters, turning them back on, and getting lights back on….We were well-prepared and well-drilled.[90]"*

CenterPoint's Intelligent Grid has been honored as one of the world's best Smart Grid projects. The Figure 41 on the following page shows some of its key metrics.

Centerpoint Energy has roughly 2.5 million customers, virtually all of which were affected by Hurricane Harvey. Digital technology played a significant role in climate resilience, saving hundreds of thousands of those customers from hours of power outages during a critical time.

IRELAND

2017 was also a year in which the hurricane season extended to areas typically considered safe from such storms, including Ireland. On October 16, 2017, tropical storm Ophelia (Figure 42) hit southwest Ireland with record-breaking winds.

Ophelia caused an estimated US $100 million in damage. But as with Centerpoint and Texas, the power grid proved to be resilient. Given the unprecedented nature of the storm, there were considerable distribution-related outages. However, the core generation and transmission facilities remained intact and operational.

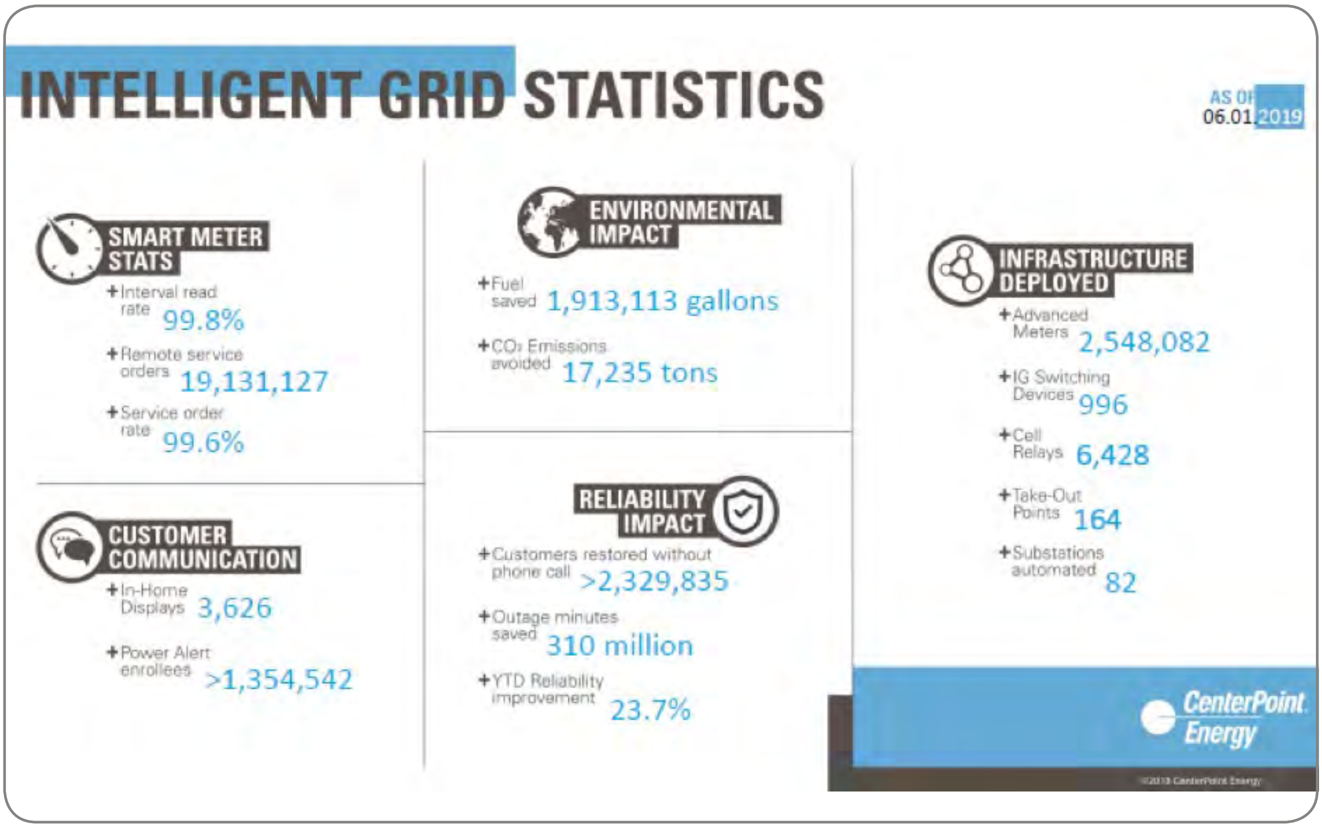
How is this being accomplished?

CenterPoint was mainly concerned with the distribution network and minimizing customer outages in Texas. But in Ireland, the key concern for the transmission grid operator EirGrid was managing generation – particularly Ireland's wind turbines. The record-breaking winds were uncharted territory.

Fortunately, EirGrid's National Control Centres had adopted digital technology, including a Smart Grid Dashboard for remote generation monitoring and management. EirGrid was able to curtail wind production selectively in real time as the storm moved across the country, and to ramp up conventional power plant generation to balance the system's production and demand. Despite the unusual and extreme weather conditions,

90. Mercado, Kenneth. Centerpoint's Chief Integration Officer.

Figure 41: Intelligent Grid Statistics



Source: *https://www.centerpointenergy.com/en-us/Documents/Intelligent-Grid-Stats.pdf*

Figure 42: Ireland Weather Risks

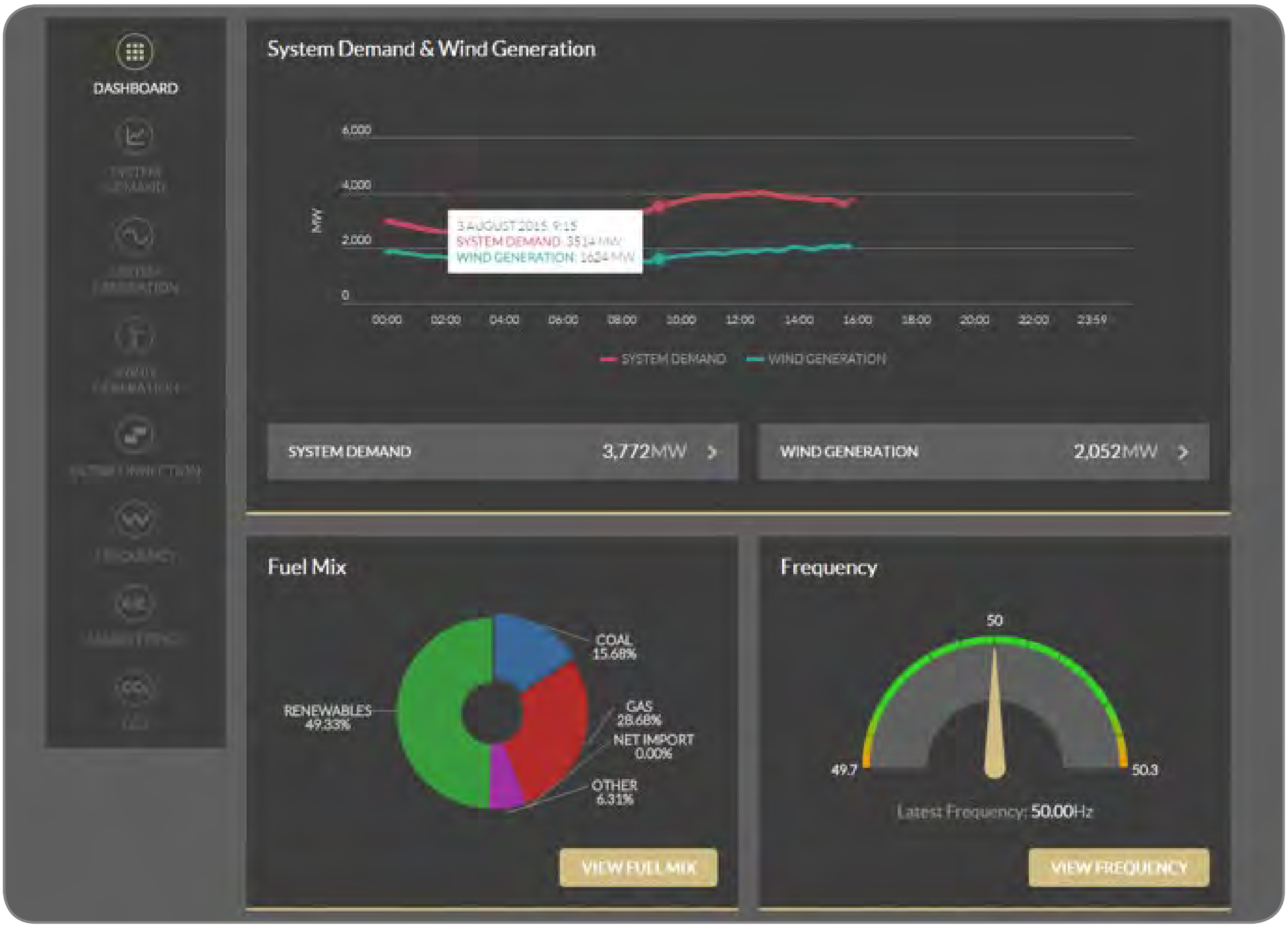
Source: *https://www.vox.com/energy-and-environment/2017/10/16/16482208/wind-rain-wildfire-hurricane-ophelia-europe-ireland-portugal* system operations were unaffected. As EirGrid operations charge engineer Marie Hayden explained:

> “ *The power system was much more robust than I expected… I expected a lot more damage to power lines and a significant loss of transmission and generation facilities to occur. In the end, this did not materialize.*[91] ”

Figure 43 below shows a screen shot of EirGrid’s Smart Grid Dashboard with real-time system information.

Ireland has a 7000MW of conventional generation, 3000MW of wind capacity and more than 7000 km of high-voltage transmission lines.[92] As the experience with Ophelia shows, digital technology played a key role in ensuring that this essential infrastructure remained intact and operational under challenging weather conditions.

Figure 43: EirGrid’s Smart Grid Dashboard



Source: *https://www.highcharts.com/blog/use-cases/smartgrid/*

91. *Weathering the Storm (Part I): A report on the impact of Storm Ophelia on Ireland’s transmission system. Engineers Journal, March 20, 2018. http://www.engineersjournal.ie/2018/03/20/weathering-storm-insights-ophelia-part-1/*
92. *All-Island Transmission System Performance Report. EirGrid, 2015. http://www.eirgridgroup.com/site-files/library/EirGrid/AITSPR2015_FINAL_TO_RAS.pdf*

Recommendations

This report is intended to help ASEAN and ASEAN Member States address high-priority power sector challenges through increased digitalization by providing useful digital technology and energy sector context, educational and inspirational success stories, and relevant recommendations. This section includes two types of recommendations for potential next steps among ASEAN officials and member state governments and institutions.

First, it offers recommendations that are explicitly directed at increased digitalization, and where power sector challenges are addressed as an important but largely indirect result. These are called digitalization-centric recommendations, which are derived from the many available digitalization studies.

Second, it offers recommendations that are directed specifically at addressing power sector challenges, and where increased digitalization is an important but largely indirect result. These are called power-centric recommendations, stemming from the insights and lessons of the success stories. They include detailed suggestions for ASEAN policies that lead to the adoption of digital technologies through standards, targets, and other means.

DIGITALIZATION-CENTRIC RECOMMENDATIONS

There are many reports and articles proposing recommendations on adopting digitalization in general, as well as in the energy sector. The relevance of these recommendations to the current effort must be evaluated carefully before adoption.

Many studies focus on digitalization as an end rather than as a means to an end. They make "digital for digital sake" recommendations without adequately considering the goal of improved human welfare or economic prosperity. These recommendations must be considered with our ultimate goal – addressing high-priority ASEAN power sector challenges – in mind.

In addition, many studies on digitalization focus on private businesses, not governments or public institutions. In the 2016 report Unlocking Indonesia's Digital Opportunity, for example, the word "policy" never appears.[93] Even sources that focus on governments typically address digitalization of the government, not facilitation of digitalization in the overall economy by the government.[94] These recommendations must be thought through with the target audience – ASEAN officials and member state governments and institutions – in mind.

With these caveats, there appears to be a consensus regarding three important actions that ASEAN and AMS can take to facilitate beneficial digitalization.

1. Conduct a formal, well-designed ***digitalization program***

   - This is a process-oriented recommendation. Industry experts argue that successful digitalization requires a concerted well-designed, digital-oriented effort. One must establish clear goals involving digital technology, monitoring and measuring progress, learning from and coordinating with other parties involved in digitalization, and experimenting, adapting and adjusting when necessary. The United Nations Development Program's digitalization report puts most of its emphasis in this process area, particularly on goal setting, measurement, leadership and coordination.[95] The IEA, too, references building flexibility, monitoring impacts, learning from others, and incorporating flexibility.[96] While digitalization programs will typically be at the AMS level, ASEAN can play a critical information-sharing and coordination role with

93. Das, Kaushik et. al.. Unlocking Indonesia's Digital Opportunity. McKinsey & Company, October 2016. https://www.mckinsey.com/~/media/McKinsey/Locations/Asia/Indonesia/Our%20Insights/Unlocking%20Indonesias%20digital%20opportunity/Unlocking_Indonesias_digital_opportunity.ashx
94. See for example, Mourtada, Rami et. al.. How to Supercharge Your National Digital Transformation. BCG, July 25, 2018. https://www.bcg.com/publications/2018/how-supercharge-your-national-digital-transformation.aspx
95. Lovelock, Peter. Framing Policies for the Digital Economy: Towards Policy Frameworks in the Asia-Pacific. United Nations Development Programme (UNDP), February 28, 2018. https://www.undp.org/content/undp/en/home/librarypage/capacity-building/global-centre-for-public-service-excellence/DigitalEconomy.html
96. Digitalization & Energy 2017. International Energy Agency (IEA), November 5, 2017. https://www.iea.org/digital/

regular communication regarding the latest status of digitalization efforts.

2. Develop the ***enabling infrastructure*** – both physical and electronic - necessary for digitalization

    - This is an outcome-oriented recommendation. As noted in the report, digitalization is driven both by "demand pull" and "supply push." Adequate infrastructure – modern internet and Wi-Fi access, open-source GIS, cloud-based data storage and computing – is a key element of supply push. Without the appropriate foundation, digitalization is simply not possible, and it cannot help address high-priority power sector challenges. Virtually all digitalization studies note the importance of infrastructure, and most emphasize specifically that privacy and security must be designed upfront into it. There are local, national and regional elements to this infrastructure so that both AMS and ASEAN can contribute.

3. Develop the ***enabling capability*** – both human and institutional - necessary for digitalization

    - This is also an outcome-oriented recommendation, and is probably the most overlooked insight from digitalization studies. If infrastructure is the "hard" side of digitalization, capability is the "soft" side. It is a second key element of "supply push." Without educated and trained people and institutions, digitalization is difficult, and it cannot help address high-priority power sector challenges. The Bipartisan Policy Center's digitalization report refers to this as the "workforce" issue.[97] Bain's digitalization report refers to this issue as broadening the digital "talent base."[98] Capability will typically be housed at the local and national level, but ASEAN can play a central role by facilitating cost-effective regional education and training.

POWER-CENTRIC RECOMMENDATIONS

As described in section 4, there are many stories of the successful contribution of digitalization to ASEAN's high-priority power sector challenges. Many of these stories have a familiar theme. The government takes action with the power sector in mind, and adopts digitalization as a means to an end.

There are three key recommendations for ASEAN-level policy development based on lessons from these success stories.

1. Introduce ***technology-forcing standards***

    - Digitalization-centric recommendations focus on "supply push" – the enabling infrastructure and capability. Technology-forcing standards are a key element of the other, "demand pull" aspect. In many success stories, current technology is incapable of meeting governments' established standards. This leads to a demand to "force" the development and adoption of new, often digital technology. This story is repeated regularly, as with the energy-efficiency standards in Taiwan and California. Of course, this approach will be ineffective unless twinned with the "supply push" approach that ensures adequate infrastructure and capability. ASEAN can play a central role here in facilitating regional standards across a large market and coordinating the efforts of individual member states.

    - The APAEC 2016-2025 proposes outcome-based strategies for the promotion of EE standards for air-conditioning and lighting.[99] An effective way to achieve the region's desired efficiency levels will be to establish minimum but ambitious standards that require new technology adoption, not just

97. Greenwald, Judi and Smith, Erin. Digitizing the Grid: Next Steps on Policy. Bipartisan Policy Center, December 2017. https://bipartisanpolicy.org/report/digitizing-the-grid-next-steps-on-policy/
98. Hoppe, Florian et al.. Advancing Towards ASEAN Digital Integration. Bain & Company, September 3, 2018. https://www.bain.com/insights/advancing-towards-asean-digital-integration/
99. ASEAN Plan of Action for Energy Cooperation (APAEC) 2016-2025. ASEAN Center for Energy, Page 32. https://cil.nus.edu.sg/wp-content/uploads/2019/02/2016-2025-ASEAN-Plan-of-Action-for-Energy-Cooperation-3.pdf

an incremental improvement using the same "old fashioned" technologies. Along with these "reach" standards, the ASEAN Secretariat and ACE could simultaneously provide information on the enabling digital technologies and relevant best practices, as referenced in the success stories, necessary to meet them.

2. Introduce ***technology-encouraging targets***

- A second "demand pull" recommendation is the establishment of targets, together with penalties and incentives. Like standards, these provide a strong motivation to develop and adopt new, often-digital technology. Denmark's wind-generation accuracy target and Japan's thermal efficiency focus are both particularly good examples. ASEAN can play a central, regional role in defining these targets and motivating governments and institutions to meet them.

- The development of the ASEAN Power Grid offers an opportunity for the region to capitalize on digital technologies for increased renewables integration. In the HAPUA Council Members 2018 joint statement, HAPUA committed to exploring ways to deploy smart grid and digitization technologies to contribute to reaching the ASEAN renewable energy targets.[100] Similar to the establishment of standards, if ambitious but realistic RE integration targets tied to the APG are established, they can catalyze change. Actively encouraging and reporting against these targets is one of the best ways to meet regional goals, and targets linked to the APG can help individual AMS achieve their RE goals. Once interconnected, AMS can increase their use of renewables and capitalize on the diversity of the grid and digital technologies to manage intermittency. As with standards, ACE and other stakeholders can offer information and assistance in how to best meet RE targets, presenting digital technologies as key.

3. Foster a ***creative, innovative, and entrepreneurial culture***

- Government policies and institutional activities play a very vital role in the success stories. They are critical to the development and adoption of useful digital technology. At the

100. The HAPUA Council Members Joint Statement 2018. HAPUA, 2018. http://hapua.org/main/2019/05/01/the-hapua-council-member-joint-statement-2018/

same time, many success stories depend not just on well-established government and business institutions, but on individuals and small organizations that recognized and seized an uncertain technology-based opportunity. Digital technology is, after all, a young, dynamic, emerging force, and the culture must be adequately supportive of this force. Microgrid development in Myanmar and Nepal are examples of efforts that were only possible due to the supportive culture. This is primarily an issue at the level of member states, but ASEAN can play a coordinating and encouraging role.

- As part ASEAN's response to 4IR and alongside the proposed ASEAN Digital Integration Framework Action Plan, an ASEAN Innovation Roadmap has been proposed to promote innovation through 2025. The Innovation Roadmap can include specific steps on how ASEAN can better develop an entrepreneurial culture promoting further technological developments within the region, and in this way advance the digital technologies that impact the power sector as well. One strategy is to leverage the activities of private organizations, including angel networks such as the Keiretsu Forum Singapore chapter and startup accelerators/incubators such as Plug and Play Asia Pacific. Often, these private organizations are the first to identify and support promising entrepreneurs and technologies, as well as to pilot innovative programs. Many of these organizations operate on a tight budget with considerable volunteer labor, and ASEAN can play an important facilitation and coordination role in ensuring a friendly ecosystem for startups.

BENEFITS

The power sector challenges that ASEAN faces are substantial. At the same time, the potential contribution of digitalization to these challenges is also considerable. By adopting the recommendations above, ASEAN and its member states can better take advantage of the immense promise of digital technology to meet its growing power demand, close its electricity access gap, and maintain system resilience. In this way, the region can move one step closer to the goal of an entirely affordable, sustainable, and reliable power system.

Appendix 1:
Survey on ASEAN Energy Challenges

No.	ASEAN Member State	How important are the following energy challenges for ASEAN? Meeting Power Demand Sustainability	Meeting Transport Demand Efficiently	Closing the Energy Access Gap Speedily	Maintaining Energy System Resilience	Other
1	Brunei Darussalem	1: Top Priority	1: Top Priority	1: Top Priority	2: Medium Priority	-
2	Indonesia	1: Top Priority	1: Top Priority	1: Top Priority	2: Medium Priority	Energy distribution across the outer border and small islands: 2: Medium Priority
3	Indonesia	1: Top Priority	2: Medium Priority	2: Medium Priority	1: Top Priority	-
4	Indonesia	1: Top Priority	2: Medium Priority	1: Top Priority	2: Medium Priority	-
5	Indonesia	1: Top Priority	1: Top Priority	1: Top Priority	1: Top Priority	Rural distribution information via LTE: 1: Top Priority
6	Indonesia	1: Top Priority	2: Medium Priority	2: Medium Priority	1: Top Priority	Biomass energy renewable: 1: Top Priority
7	Indonesia	1: Top Priority	3: Low Priority	2: Medium Priority	2: Medium Priority	Lower energy price: 1: Top Priority
8	Indonesia	1: Top Priority	2: Medium Priority	1: Top Priority	1: Top Priority	Establish energy system flexibility: 1: Top Priority
9	Indonesia	1: Top Priority	1: Top Priority	2: Medium Priority	1: Top Priority	Energy elasticity: 1: Top Priority
10	Indonesia	1: Top Priority	2: Medium Priority	2: Medium Priority	1: Top Priority	-
11	Indonesia	1: Top Priority	1: Top Priority	1: Top Priority	2: Medium Priority	-
12	Lao PDR	1: Top Priority	2: Medium Priority	1: Top Priority	2: Medium Priority	Cross border power: 1: Top Priority
13	Malaysia	1: Top Priority	2: Medium Priority	2: Medium Priority	1: Top Priority	-
14	Malaysia	1: Top Priority	2: Medium Priority	1: Top Priority	1: Top Priority	Sustainable energy: 1: Top Priority
15	Malaysia	2: Medium Priority	2: Medium Priority	1: Top Priority	2: Medium Priority	-
16	Malaysia	1: Top Priority	2: Medium Priority	1: Top Priority	1: Top Priority	Oil security: 1: Top Priority
17	Malaysia	1: Top Priority	2: Medium Priority	2: Medium Priority	1: Top Priority	Introducing a full market mechanism to the system: 1: Top Priority
18	Malaysia	1: Top Priority	2: Medium Priority	2: Medium Priority	1: Top Priority	-

No.	ASEAN Member State	How important are the following energy challenges for ASEAN?				
		Meeting Power Demand Sustainability	Meeting Transport Demand Efficiently	Closing the Energy Access Gap Speedily	Maintaining Energy System Resilience	Other
19	Other	1: Top Priority	1: Top Priority	1: Top Priority	2: Medium Priority	-
20	Other	1: Top Priority	1: Top Priority	2: Medium Priority	2: Medium Priority	Energy Efficiency: 2: Medium Priority
21	Other	1: Top Priority	1: Top Priority	2: Medium Priority	1: Top Priority	Activate private sector entry of power sales: 1: Top Priority
22	Other	1: Top Priority	2: Medium Priority	2: Medium Priority	2: Medium Priority	Resource optimization: 1: Top Priority
23	Other	2: Medium Priority	1: Top Priority	1: Top Priority	2: Medium Priority	-
24	Philippines	1: Top Priority	1: Top Priority	1: Top Priority	1: Top Priority	-
25	Philippines	2: Medium Priority	3: Low Priority	1: Top Priority	1: Top Priority	-
26	Singapore	2: Medium Priority	1: Top Priority	1: Top Priority	2: Medium Priority	-
27	Singapore	1: Top Priority	3: Low Priority	2: Medium Priority	2: Medium Priority	Financing: 1: Top Priority
28	Singapore	1: Top Priority	2: Medium Priority	1: Top Priority	2: Medium Priority	-
29	Singapore	1: Top Priority	2: Medium Priority	1: Top Priority	1: Top Priority	Cybersecurity in the power sector under Resilience
30	Thailand	1: Top Priority	2: Medium Priority	1: Top Priority	1: Top Priority	-
31	Vietnam	1: Top Priority	2: Medium Priority	2: Medium Priority	2: Medium Priority	-