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APEC Workshop on University Collaboration to Support Data Gathering and Analysis in Energy Efficiency and Renewable Energy

APEC Energy Working Group

April 2022

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Virtual Event | 8-9 June 2021

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APEC Project: EWG 06 2019A

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ABBREVIATIONS

APIs	Application Programming Interfaces
BEVs	Battery Electric Vehicles
EUI	Energy Use Intensity
DES	Distributed Energy Systems
FIT	Feed-in Tariff
GGE	Gasoline-Gallon Equivalent
GUI	Graphical User Interface
ISIC	International Standard Industrial Classification
SDGs	Sustainable Development Goals
SHS	Solar Home Systems

INTRODUCTION

The US-led APEC-funded workshop on **University Collaboration to Support Data Gathering and Analysis in Energy Efficiency and Renewable Energy (EWG 06 2019A),** organized by Claremont McKenna College, California, United States, and King Mongkut's University of Technology Thonburi, Thailand. Co-sponsoring APEC economies are Thailand; the Philippines; Chinese Taipei, and Australia. The project received funding from the APEC Support Fund (ASF) under the Energy Efficiency and Low-Carbon Measures funds. The original plan was to host the workshop in Bangkok, Thailand in 2019. However, due to the Covid-19 pandemic, the workshop was an on- line event from 8-9 June 2021.

GOALS

APEC's Energy Working Group (EWG) and its subfora have identified a broad range of strategic goals to works towards between 2019-2023. They are in line with the APEC aspirational goals endorsed by APEC Ministers and Leaders to 1) double the share of renewables in the APEC energy mix by 2030 and 2) reduce APEC's energy intensity by 45% from 2005 levels by 2035. These ambitious goals and projects require extensive data gathering and synthesis, in addition to the work the policymakers are already doing. Each APEC economy has excellent Universities that could provide additional capacity for this work by offering project-based courses based on the information and analysis that policymakers identify as necessary to meet these goals.

The two half-day workshop brought together APEC members, faculty from APEC universities, and members of APERC and APSEC to talk about potential EWG/University collaboration. The policymakers and faculty actively participated and discussed possible projects that would benefit both the EWG and the university partner.

PROJECT OBJECTIVES

The project aims to:

1. Build the capacity of workshop participants by developing a network be- tween the EWG, APERC, APSEC, and University faculty in APEC economies
2. Share examples of collaborative projects by Universities in APEC economies that address the APEC energy efficiency and renewable energy goals
3. Develop project ideas, between the policymakers and University faculty inAPEC economies, as project-based courses that will help inform energy efficiency and renewable energy goals

This publication is a final report of the virtual workshop and comprises four chapters. Following an overview of the workshop's project goals and methods, Chapter 1 presents critical issues observed from the presentations and discussions divided into six sessions. Chapter 2 compares the key outcomes with the project's objectives for three aspects: 1) Develop a network between the policymakers (EWG, APERC, and APSEC) and University faculty; 2) Share collaborative projects by Universities in the APEC economies that address the APEC energy efficiency and renewable energy goals; and 3) Develop project ideas, between the policymakers and University faculty in APEC economies.

Chapter 3 summarizes all presentations at the workshop, organised according to the workshop agenda. The first part comprised of the policymakers' presentations, the examples of collaborative projects, and the experiences shared by the students. The second part is divided into three groups - Community development; City, buildings, and transportation; and Renewable Energy. Finally, Chapter 4 concludes with key findings, follow-up activities, and future collaborations.

CHAPTER 1
THE VIRTUAL WORKSHOP

This chapter describes two key outputs of the project: the virtual two half-day workshop and the project website. The workshop went well and was a fruitful and interactive event, despite being a virtual meeting. It attracted the University faculty and researchers from 22 institutions with expertise in energy-related fields and other disciplines that would benefit from future collaboration on the APEC energy goals, such as economics and urban planning. Details are as follows.

1.1 OVERVIEW OF THE WORKSHOP

1.1.1 Workshop Objectives

The workshop was a two half-day event to bring together energy policymakers from APEC economies, faculty from APEC universities, and members of APERC and APSEC to talk about potential EWG/University collaboration. The workshop included presentations from experts, energy policymakers, and university faculty, small group discussions, and discussion of collaborative projects to be developed during the next academic year. The policymakers and faculty worked closely together to choose potential future projects that will benefit both the EWG and the university partner.

1.1.2 The Participants

Using the Zoom platform, the online workshop took place in the GMT+7 time zone, from 8:00-12:00 on June 8 and 9 of June 2021. Sixteen speakers and 46 participants attended the two half-day online workshop. Speakers and participants included policymakers, researchers, and University faculty, and students from 18 APEC economies. These included Australia; Brunei Darussalam; Canada; Hong Kong, China; Indonesia; Japan; Republic of Korea; Malaysia; Mexico; New Zealand; Papua New Guinea; The Philippines; Singapore; Chinese Taipei; Thailand; United States of America; and Viet Nam.

1.1.3 Methodology

In addition to the workshop, a website (APEC-collab.kmutt.ac.th) aims to increase the workshop's efficiency and encourage participant engagement before and after the online meeting. The website is used to deposit workshop materials and provide information about the speakers. In order to use the time during the workshop more efficiently, speakers submitted a pre-recorded presentation (~20-30 minutes) for others to watch before the event.

The first day (8 June 2021) started with an introduction and objectives of the workshop, followed by a series of presentations by faculty showcasing examples of collaborative projects. At the end of day one, there was a half hour wrap-up discussion.

The second day (9 June 20121) started with a short overview of collaborative project examples and policymaker’s sharing their need for data, followed by students' experiences of the previously discussed collaborative projects in their classes, andsmaller group discussions. The 3 group discussions included: 1) Community Development, 2) City, Buildings, and Transportation, and 3) Renewable Energy.

Each speaker summarized their longer, pre-recorded presentation and the discussion focused on exchanging ideas and experiences and developing collaborative projects. Subsequently, the moderators reported lessons learned from each group discussion and a brainstorming session was held that included all participants.

1.2 THE VIRTUAL WORKSHOP

1.2.1 Workshop Day 1

On the first day, the organizer welcomed the speakers and participants and introduced the workshop's objectives and how they could contribute to the presentations and discussions using the tools in the Zoom platform. Subsequently, the President of Claremont McKenna College and the Senior Advisor to the President of KMUTT also welcomed the workshop participants. They supported establishing collaborations between universities and policymakers in the APEC region to tackle the pressing problems of energy security and climate change more efficiently. The welcome remarks were then followed by three sessions presented by the university faculty and representatives of policymakers. This part describes key points from the presentations and discussions at the end of day one.

Session 1: Dr Cary Bloyd. (United States) Pacific Northwest National Laboratory: APEC clean energy activities

Dr Bloyd summarized the work that APEC is doing regarding clean energy and also talked about the structure of APEC and how work is accomplished in the organization. He explained that formal meetings of economic leaders of APEC occur once a year. In addition, he shared that fifteen working groups operated under the SOM Steering Committee on Economic and Technical Cooperation (ECOTECH) and cover various topics, such as the Energy Working Group (EWG). The EWG is supported by eight subfora groups such as the Asia Pacific Energy Research Center (APERC/ Japan) and the APEC Sustainable Energy Center (APSEC, China). In 2015, APEC leaders and energy ministers reaffirmed the clean energy goals to reduce aggregate energy intensity by 45% by 2035 and double renewable energy by 2030. Dr Bloyd reminded people about opportunities in working with APEC by writing proposals to the APEC Secretariat in Singapore for funding, as APEC funds 100-150 projects each year with up to $20 million USD. Finally, the universities can help define the future APEC energy options.

Session 2: Examples of Project by University Collaborations
Moderated by Dr Chanyaporn Bstieler

This session was comprised of four university faculty presentations sharing examples of university collaborative projects that address the APEC energy efficiency and renewable energy goals. They provided examples in three main areas. Details are as follows.

The first area was a wide range of topics from the impact of energy policies to environmental quality data collections and analysis. The collaborative projects in Viet Nam and Malaysia involved the assessment of energy efficiency and renewable energy policies. The last project investigated the water and air quality data along the canals in Bangkok and proposed creative initiatives to improve the environmental quality along the canals, aiming to increase non-motorized transportation such as biking and walking in urban areas. The environmental quality data in urban areas may not directly contribute to the energy goals. However, we learned from the success factors of renewable energy policies in Viet Nam that people's awareness and demand for good air quality have supported the government's plan to increase wind and solar power installations. Thus, this water and air quality data may provide a basis for improving urban infrastructure, encouraging people to use more non-motorized and public transport. It can contribute to the reduction in energy use and air pollution from road congestion and, at the same time, improve the health and well-being of people in urban areas.

The second aspect covered during this session was funding opportunities,which are essential to facilitate new collaborations and sustain activities among the universities and policymakers in the APEC region. Dr Keng Tung Wu shared his experience with APEC on how university faculty can apply for APEC support. He addressed the nature of APEC-funded projects and activities, different from academic research projects to create new knowledge. APEC-funded projects are goal-oriented; therefore, they focus on technologies and innovation ready for implementation and scaling up. A few examples of successful collaborative projects include the initiation of adiCET at Chiangmai Rajchabhat University in Thailand. Projects and activities included workshops, pilot studies, demonstration projects, and capacity building in each target sector, suitable for seeking APEC's support. Thus, the university faculty should align their academic interests and expertise with the APEC's energy goals.

The third aspect of this session was funding mechanisms, types of student engagement, and benefits of the past collaborative projects. Dr Norasikin A. Ludin (Malaysia), Prof. Katie Purvis-Roberts (the US), and Dr Kanjanee Budhimethee (Thailand) presented two projects conducted during 2018-2020. The first project was a collaboration between Universiti Kebangsaan Malaysia (UKM) and Claremont McKenna College (CMC), and the second was between King Mongkut's University of Technology Thonburi (KMUTT) and CMC. Past collaborative projects received financial support from CMC and the host universities. The activities and learning objectives varied according to the nature of study programs at UKM and KMUTT. The first project focused on comparative studies of Malaysia and the US energy efficiency and renewable energy policies. Students from both universities engaged in literature reviews and data analysis, academic writing workshops, and visiting Malaysia's green buildings and demonstration sites.

The Canal Revitalisation Project between KMUTT and CMC, on the other hand, had different approaches and activities. This work was a cross-disciplinary project between the design and planning department from KMUTT and the environmental chemistry and science students from CMC. The objectives were to encourage the students to look at the ecological and sustainability issues from different perspectives. At the same time, these issues in real-world situations are complex and require collaborative efforts from other fields. Together with local volunteers who live near the waterways, the design students conducted data monitoring and site surveys from the canals while the science students analyzed the data and shared the results with the design team.This scientific data provided an objective and critical view to the design students, and the collaboration offered a creative outlook to the science students. It is a combination that both teams valued and could perhaps lend more innovative solutions to our energy and environmental problems.

Session 3: Policymakers needs for data analysis/APERC/APSEC Support
Moderator: Dr Katie Purvis-Roberts

Representatives from APERC, APSEC, and policymakers from Thailand and Canada gave presentations on the purpose of their energy policy-related work, data collection methods, and analysis. They also identified data collection and analysis gaps, suggested the types of data needed, and identified how universities in the APEC region might fulfill this need. There were also suggestions on obtaining data from different sources and optimizing the data visualization for the policymaker's decision process.

Types of data needed

- ***Energy data for scenarios and models***

Ms Elvira Torres Gelindon, a representative from APERC, gave an overview of the center's energy data collection and analysis to provide the policymakers in APEC economies with insights into the energy demand and supply outlook. The energy data and models are essential for decision-making in creating and implementing new policies to achieve APEC's aspirational goals. However, the first part of the presentation highlighted the energy consumption data gap, particularly in some energy-intensive sectors and sub-sectors as defined by *The International Standard Industrial Classification of AllEconomic Activities (ISIC)*. Collaborative projects among the universities in the APEC region could help to provide more detailed energy data and relevant information, suchas the adoption of new cooling technology in the building sector. Thus, this data could help to improve the policymaker's energy scenarios and prediction models.

The representative from Canada, Dr Madeleine McPherson (University of Victoria), also focused on developing an energy data modeling and visualization suite, although the approach was different from APERC. The vision is to provide a holistic perspective to energy system's decarbonization through an open platform. The objectives are to explore and support deep decarbonization pathways and actions by delivering relevant and impactful insights to decision-makers. This tool comprised three pillars (smaller models) and the pillar integration (SPINE) to pull the results from the models together. The presentation highlighted three challenges - timeliness, transparency, and inclusiveness - to integrating data to provide evidence for the decision-making process. Collaborative efforts between universities and policymakers may help to overcome these challenges. For example, universities could help with updating data and models continuously, creating an open-access database, and engaging a diverse range of disciplines and perspectives in the modeling process.

More specifically, for Canada, where hydropower accounts for 60% of the economy's electricity generation, this energy modeling also included the water availability data. Water availability refers to the precipitation and environmental restrictions that impact the water level in the dam for electricity production in the power model. Currently, there is great attention to the impact of climate change on precipitation.

- ***Primary energy data and relevant information for the urban Sustainable Development Goal (SDG) tracker for energy and climate change.***

  According to Mr Steivan Defilla from APSEC, there are needs for data collection and analysis for developing the UN's SDG tracker, focusing on disaster risk reduction for cities. Regarding APEC's EWG's goals, it is particularly relevant to energyresilience for urban areas. In developing the SDG tracker, the structure of data required has three levels of commitment. At the first level, the cities collect primarydata such as energy efficiency and renewable energy and they usually keep the records. APSEC has just started a new project and requires more collaborations with universities and cities in other APEC economies to collect fundamental energy data for cities.

- ***Data to support co-benefitting of energy-efficiency and renewable energy implementation.***

  Dr Nuwong Chollacoop, representing DEDE (The Ministry of Energy, Thailand), addressed the economy's efforts to achieve the doubling renewable energy goal and adapt to rapid changes due to disruptive technologies. ENTEC collected and analyzed different approaches and policies that aim to promote co-benefits of energy efficiency and renewable energy implementation in main sectors such as buildings and transportation. The results suggested the critical success factors; some have already been in the APEC quality criteria. For disruptive technologies, policies need to be adapted to rapid changes in power generation, distribution, consumption in key sectors, and financial transactions. Suggestions included cost-effectiveness, considering both direct and indirect costs and benefits to different stakeholders and the government.

Discussion of Data collection, analysis, and visualization

The speakers and participants exchanged views on the period, data collection sources, and data visualization during the discussion. For Thailand, ENTEC obtained the data for these two projects from open sources, such as the energy policies, databases, relevant reports, and case studies in other APEC economies. The data collection in

Canada for the modeling pillars, for example, took around two years to monitor and collect from energy systems. Subsequently, the models could provide results in 2 to 3 hoursto a few days, depending on the required detail of the results.

In Canada, accessibility also depends on the types of data, for example (historical) load data at the provincial level can be founded on the database. But some data from the municipality level, such as for transportation, might be propriety, so the partners need to supply the data. If there was a lack of data, the researcher should show the initial benefits of modeling and how it would be better to obtain the data from relevant partners. The organization may have collected the data, but it would require some time and effort to integrate into the database. Thus, demonstrating the mutual benefits may help to obtain the necessary data.

Ms Elvira Torres Gelindon also mentioned that APERC regularly provides capacity building workshops and training on energy data collection and analysis. Universities interested in participating could get in touch with the APEC's representative oftheir economy. For developing the urban SDG tracker for energy and climate change, Mr Steivan Defilla (APSEC) recommended that the data collection should follow an international framework, particularly *the Sendai Framework - The Disaster Resilience Scorecard for Cities* (published in 2017). It is a good tool and very practical to provide profound changes, such as nature-based, social aspects, and financial aspects relevant to the cities.

Dr Henry Lo (Chinese Taipei) also discussed the sensitivity study for the integrated energy model. They agreed that the sensitivity of each simulation could affect the results of an integrated model. This sensitivity issue is a challenging problem that may need a new research area. Dr McPherson also shared that her team has developed a surrogate model on top of a fundamental model to run faster. The team also experimented with changing the sensitivity of one model and how that will impact the others.

Another challenging aspect of energy modeling is the visualization of the results, as it is essential for communication with non-experts. Questions often arise about which parameters should be selected and how to display them to communicate effectively. Dr McPherson suggested that her system included eight models, and there are two visualization suites. For example, the most generic platforms depend on the temporal resolutions of the models. There are two visualization types: the time series on the operational side and then the other could display the results, such as specific years and time. The users should be able to toggle on and off the type of results required. In general, there should be no more than 4-5 graphs to display at one time.

The final point on the integrated energy modeling platform was on the economic impacts. The expert on economics from Thailand observed that the energy models mainly use quantitative data and suggested that the value of money and investment may affect the decision-making process. Dr McPherson agreed but added that each of the models has a different formulation. Cost optimization does not apply to every sector and each model. For example, the decision on policies for the building sector may be different from the power generation and transportation sectors.

1.2.2 Workshop Day 2

The second day of the workshop comprised three main sessions. During the first session, the student representatives who participated in the past collaborative projects shared their learning experiences and benefits from participating in the projects. Session 5 was the break-out group discussions, which ran concurrently in three separate virtual meeting rooms (5A, 5B, and 5C). The moderators for each small group invited the speakers to give a summary of their longer, pre-recorded talk before inviting other participants to ask questions and discuss common interests. The small group sessions took one hour and then representatives from each group shared lessons learned to the workshop participants. Finally, session 6 was a brain-storming session where all participants discussed on possible collaborative projects and next steps.

Session 4: **Student Experiences**
Moderated by Dr Cary Bloyd (United States)

The students from four universities in Australia, Malaysia, Thailand, and the United States, shared their experiences participating in the previous collaborative projects. This learning approach has impacted their understanding and interests in energy and sustainability issues and, in some cases, future study and careers.

- *Direct academic benefits*

The students shared that the collaborative projects on energy policies and environmental issues help develop their particular topic for academic purposes, such as a thesis. For example, Mr Aaron Midson (Australian National University, Australia) investigated the renewable policy mixed in New Zealand and the Republic of Korea as an honors thesis for his graduation. The academic paper (see APPENDIX B) will add to his portfolio. He also developed a more profound interest in this topic and pursued scholarships for further study. Academic writing was also a part of the UKM (Malaysia) and CMC (United States) student's activities that they valued. Selected papers will be submitted to a peer-review journal (APPENDIX C).

- *Indirect benefits on self-development*

Indirect benefits included building an international network and exposure to other fields of knowledge and cultures. Student activities carried out during the projects also help cultivate essential skills they will need for future work. According to the Future of Jobs Report (2016) from the World Economic Forum, some of these skills are creativity, critical thinking, team-work, interpersonal skills and communication, and leadership. All three projects that the students engaged in did demonstrate these skills to some extent.

The students also expressed their interests in energy and environmental problems and shared that they would continue to explore these issues in the future. Today, the younger generation faces the negative effects of climate change, and their pro-environmental behavior is crucial to mitigate these adverse outcomes (Balunde et al. 2020). Thus, the students' experiences suggested that engaging in collaborative projects between universities to help APEC achieving the energy goals could also contribute to long-term sustainability.

Session 5: Group Discussion (5A-5C)
Session 5A: Community Development.
Moderated by Dr Worajit Setthapun (Thailand)

There were four speakers from the universities in Chile, Thailand, Papua New Guinea, and New Zealand and some 9-12 participants in this session. The first three presentations focused on how the universities could play significant roles as a linkage between the policymakers and communities to create sustainable growth. They also shared success factors in working with the local communities to develop sustainable energy projects in a rural context. The last presentation focused on developing pico-hydro sys- tems with energy storage for rural areas in developing economies. Subsequently, the discussion centered around appropriate microgrid systems and supporting strategies for maintaining renewable energy initiatives in rural areas. They also exchanged views on the decentralization of grid systems, particularly for economies with natural disaster risks.

Roles of the university in community development

Dr Worajit Setthapun (Thailand) highlighted the essential roles of universities in APEC economies that could serve as a linkage between the policymakers and communities to create sustainable growth and promote better health and well-being. The other speakers supported this view and presented how they engaged with the policy-makers and local communities as case studies from their respective economies. The universities provided research, development, and demonstration facilities for appropriate technologies and capacity-building activities. In addition to renewable energy technologies, such as biogas and pico-hydro systems, some of these projects also involved water, food, and waste management. Students are also directly involved with these activities, supporting the local community projects.

Success factors in community development project

Dr Patricio Mendoza-Araya (University of Chile, Chile) shared his experiences developing micro-grid projects for rural communities in Chile and Latin Amerca. He suggested that some success factors and co-construction methodology ensure community acceptance and sustainability of the project. The other speakers also agreed on the following aspects:

- In addition to engineers providing main technological support, a *multi-disciplinary team of experts* should get involved, particularly social scientists and an- thropologists, to works with the communities from the beginning of the project. For example, the non-technical experts could help gather local knowledge from the communities to be incorporated into the new technologies provided to sus- tain the projects over time.
- *Community engagement* is essential to create a sense of ownership and responsibility. The expert team should involve the local communities in every step of the project development and decision-making process. It could start from surveys to identify problems and needs for technology to improve the quality of life. The locals may have priorities other than energy concerns when deciding about the new development projects.

Dr Worajit Setthapun also shared that her students helped the nearby community collect energy demand, water, and waste data, then discussed it with the villagers. Since the community's primary income is from tourism, they have decided to focus on reducing waste.

- *Communication with the local community* should employ various tools to clearly explain the technical issues and facilitate interaction with the residents. For example, Dr Patricio Mendoza-Araya used scaled models of the local landscape and solar PV units to engage the community in planning a new microgrid systems on the island community. In Chiangmai, Thailand, where air pollution is a major concern, the university installed 'adiDUST', an affordable air quality monitoring system in local schools. The air quality data is collected using an intuitiveweb-based system and sent to a mobile application to report.

5A Discussions

Subsequent dialogue focused mainly on the appropriate sizes of micro-grid systems and the sustainability of energy projects in rural communities. The final point was on the decentralization and resiliency of the energy system.

Appropriate micro-grid systems

The participants widely discussed the sizes of micro-grid systems for rural communities with different scales, raised by Dr Keng-Tung Wu (Chinese Taipei). Dr Patricio Mendoza-Araya (Chile) shared his experiences in Chile that ranged from a few kilowatts to tens of KW, but the ones they helped with design only (not installation) were in hundreds of KW. For another village with around 100 villagers, they designed it for a 23KW peak solar Energy, 40 KVA for converted battery, 130 hours of the battery storage, and a 3KW wind turbine as a pilot study. Other projects were about the 10KW scale, which is more suitable for small and isolated communities with 10-100 inhabitants. However, he added that the micro-grid systems should consider a rapid growth in electricity demand as the villager’s lifestyle has changed to be more city-like.

In PNG, the size of micro-grid systems is between 500KW-2MGWatt. The government operates and subsidizes these systems, although they are not financially feasible. Another project is a micro-grid 250KW hydropower system and a 100KW solar power mini-grid run by a local hospital. In the north of Thailand, a micro-grid sys- tem of 100KW provides electricity for a village of 500 residents, while a 25KW system is for a smaller village. Nevertheless, the larger system is still not financially feasible. Dr Setthapun expressed an interest in the pico-hydro systems for Thailand, but there is concern that the water availability is unstable.

In addition to the size of the micro-grids, Dr Ian Mason (NZ) suggested an approach to connect a micro-grid at a village level, mini-grids between many villages within 100 square kilometers, and then reconsider the economy level grid. There should be a discussion about the best thing to do at the economy level, as the conventional approach or the grid should start at the micro-level and then step up. The latter approach is an idea for future research as many economies are facing energy resilience.

New Zealand, for example, is very prone to earthquakes and more than 90% of renewable energy is connected to the economy level grid. This risk also applies to other APEC economies on the Pacific rim or the ring of fire. The penetration of Renewable Energyin micro-grid systems has increased, but they seem to rely on the storage of the economy level grid. Thus, it may make more sense to have many grids as they have aggregated demand and resources around the economy.

Sustainability and affordability

The speakers and participants also exchanged views on financial and technical support to sustain renewable energy projects. For the rural areas, the participants agreed that training the local community to operate and maintain the pico-hydro systems, for example, could be challenging. According to a study in Nepal, small co-op training is possible but requires sponsors and support from the government to invite experts to provide training. In China, large-scale support for clean cookstove design, installation, and maintenance are possible. Dr Ian Mason also shared that *'Energy Poverty: Global Challenges and Local Solutions'* (Halff et al., 2014) introduced many financial instrument models, making these renewable energies, such as the pico-hydro systems, affordable.

Finally, Mr Nobuhiro Sawamura (APERC) expressed his interest in biogas and biomass promotion towards the bio-circular economy by adiCET (Thailand) (BCG committee by Dr Nuwong in Thailand).

Session 5B: City, Buildings, and Transport
Moderated by Dr Chanyaporn B. and Dr Kanjanee B. (Thailand)

This session comprised five presentations; three were about building systems research, and the other two were about transportation in the urban context. Common issues in the building system performance were energy efficiency in HVAC and lighting systems, particularly in tropical climates. These two systems contribute to some 70%-80% of the energy use in commercial buildings. The speakers also focused on the occupant's thermal and visual comfort in certified green buildings. Highlights are the roles of universities in the research and demonstration of these systems, involvement in the design process, and energy monitoring in actual buildings. In addition, many case studies demonstrated the benefits of student engagement.

Building performance in the tropic*s*

By 2060, some 60% of the world’s population will live in tropical climates, and more than 66% will live in urban areas. Tropical climate zones, located between 23.5N and 23.5S latitudes, include many rapidly developing economies. A study on urban growth and heat in tropical climates (Marcotullio et al. 2021) found that urban populations in tropical zones experienced more significant temperature rise than those outside of the city. It seems that dense urban forms are associated with higher temperatures. Therefore, Dr Szu-Cheng Chien (Singapore Institute of Technology, Singapore) and Dr Masayuki Ichinose (Tokyo Metropolitan University, Japan) focused on improving building performance in tropical cities in Asia.

Dr Szu-Cheng Chien (Singapore) highlighted opportunities for Singapore to take advantage of natural ventilation and abundant daylight while minimizing the negative impact of heat gain and discomfort glare. To achieve these energy efficiency and renewable energy goals, universities and the government (including the BCA) have focused on two stages:

1) Research and development using state-of-the-art facilities as testbeds for innovative solutions and materials for building systems and facades

2) Implementing new knowledge and technologies in actual buildings, both the newly built and existing buildings

- ***Design processes for new buildings***

For new buildings, experiences from Singapore highlighted an unconventional design approach, *a design charette*, where stakeholders and all building consultants participated in several workshops to discuss the users' requirements and optimal solutions to achieve a very ambitious energy goal. This participation process of stakeholders, including the anchor tenants of the space (from the aerospace industry), seems to be one of thesuccess factors for designing a green building. During the design development stages, the university faculties and students were involved in advanced simulations to verify various building system’s performance, such as natural ventilation and daylight assessment.

- ***Energy audit and occupant’s survey for existing buildings***

As green buildings have gained popularity, Dr Masayuki Ichinose (Japan) stressed that it is essential to understand how they perform when occupied. He has collaborated with Southeast Asian universities to conduct surveys on energy performance, particularly in the cooling and lighting systems and occupants' thermal and visual comfort perception. The results suggested that the building’s actual energy performance when occupied may be lower than the value used for the green building certification.

For typical commercial buildings, the standard lifespan is between 50-60 years, so they may need significant renovations, including energy performance upgrades,every 10-15 years. Dr Szu-Cheng Chien (Singapore) shared that the university conducted electricity use and workflow surveys before proposing solutions to improve energy efficiency and indoor environmental quality. Comparing the electricity use and occupant's satisfaction surveys before and after the improvement helped validate the project’s success.

Smart lighting and a renew interest in daylighting

Dr Michael Siminovitch (California Lighting Technology Center, the University of California Davis, The United States) presented the center's focus on intelligent lighting and daylight harvesting for broader climatic conditions. These areas align with California's commitment to zero-net-energy buildings. He also highlighted a renewed interest in daylighting design for improving the health and well-being of the building occupants through circadian systems This relatively new knowledge in neuro- science and the physiological impact of light could be an opportunity to promote the useof daylight, a neglected renewable energy source in modern tropical buildings.

Models for student engagement

Students were involved in most of the cases presented in this session. In particular at the California Lighting Technology Center, they were actively engaged in lighting design research through hands-on experiments and real projects. Many of the results contributed to building codes and policy development. Through a new collaborationwith a university in Mexico, Dr Michael Siminovitch introduced this model for student engagement to develop a new daylighting and energy-efficient lighting standard for Mexico. Similarly, Dr Szu-Cheng Chien (Singapore) and Dr Masayuki Ichinose (Japan) engaged students in energy data collection and analysis, occupant's surveys, and building simulations. Dr Ichinose also provided workshops and training for students in partner universities to help collect and analyze data.

Efficient and climate-friendly transport in developing economies

The Philippines and Thailand have faced urban sprawl around the metropolitan areas of their capital cities. The use of private vehicles has increased dramatically and caused traffic congestion, wasting energy and time, and causing air pollution. In the Philippines, road transport accounts for some 30% of energy-related GHG emissions and is the largest source of air pollution. Public transport in the Philippines has relied heavily on the inefficient *Jeepneys*, cultural icons of repurposed army Jeeps left after World War II. In 2015, the Jeepney sector accounted for 15.5% of the road transport GHG emissions. (Source: https://changing-transport.org/modernizing-public-transport- in-the-philippines/)

Dr Crispin Diaz (University of The Philippines) suggested that future research investigate the modernization of public transportation, such as modern jeepneys. He also proposed studying the environmental and economic impacts of new lifestyles due to the COVID-19 pandemic, such as reducing trips to work and increasing food deliveries. Dr Kanjanee Buddhimethee (KMUTT, Thailand) agreed and supported a further study on urban design and planning to instigate behavioral change towards non-motorized transport, such as walking and cycling. A new study could investigate the impact ofthis shift on energy use in commercial and residential buildings and the transportation sector.

Although facing similar road congestion issues in the capital of Thailand, more comprehensive Skytrain and Underground networks in recent years have improved the quality of public transport and slightly eased the traffic. Dr Yossapong Laoonual (KMUTT, Thailand), representing the Electric Vehicle Association of Thailand, shared the Thai government's target and policy to promote electric vehicles (EV). Key drivers are to reduce air pollution and GHG emissions and to create a new industry for the economy. At KMUTT, the university has supported this initiative, collaborating with industry to provide EV charging stations for cars and motorcycles.

5B Discussions

The participants were interested to learn more about the use of natural ventilation in buildings, considering a larger context of air quality and temperature in Singapore. Dr Szu-Cheng Chien explained that the air quality in Singapore varies according to the wind and haze from the west, making it challenging at times to use natural ventilation. Other speakers also agreed and suggested that natural ventilation could be optional, similar to vernacular buildings in the tropics. Alternatively, the architects couldintroduce some mechanical methods to clean the air before entering the buildings at certain times of the year.

Another issue raised by Mr Steivan Defilla (APSEC) was the possible shift of transportation modes in the Philippines, for example, from four-wheelers to two-wheelers and more electric vehicles. However, Dr Crispin Diaz explained that the change to EV might be difficult as it needs stable power, while the shift from private cars to public transport could be possible.

This group has common interests in enhancing cooling and lighting systems performance and indoor environmental quality for major building types in the tropics. Dr Masayuki Ichinose proposed expanding this collaborative project from his partnership in Southeast Asia to investigate more buildings in other APEC economies. Ms Elvira Torres Gelindon (APERC) supported that obtaining the energy data from buildings in use would be valuable for achieving the APEC's energy goals. The participants agreed that there should be a culture of disclosing energy information to improve the performance of our buildings.

Finally, Dr Siminovitch suggested that funding is significant for collaborations, and it is of high importance for the government to fund these activities.

Session 5C: Renewable Energy
Moderated by Dr Katie Purvis-Roberts (United States)

The third group discussion comprised five presentations, focusing on two aspects of renewable energy. One was on the technical aspect of affordable renewable energy, and the other was on the deployment and assessment of energy policies.

Three presentations focus on renewable energy technologies development and demonstrations. In Indonesia, where many rural areas face water shortages, earthquakes, and tsunamis, Dr Ahmad Agus Setiawan presented the development and deployment of solar water pumping systeMs He was highlighting the roles of the university on community empowerment to achieve a sustainable result. Furthermore, the university employs a unique, sustainable education model where students spend some time within the rural communities before providing technical supports and training.

In Brunei Darussalam, due to limited land and strong wind speeds for conventional solar PV and wind turbines, Dr Reddy Prasad (Brunei Darussalam) focused on improving the performance of the solar flat plate collector for harvesting solar energy. These two presentations reflected the need for different renewable energy technologies to suit each economy's natural conditions and limitations.

Dr Luong-Hoang Pham (Viet Nam) suggested that, for developing economies, universities could play a significant role in supporting the energy transition. For Viet Nam, there needs to be a change of using electric fire equipment, such as electric vehi cles and solar boilers for hot water. The university's demonstration projects on energy efficiency and renewable energy and capacity building activities are available to ensure affordable energy.

The other two presentations emphasized different aspects of energy policies. Dr Semee Yoon (Republic of Korea) provided a better understanding of factors affecting the decision-making process and the adoption of modern renewable energies such as solar power among the rural poor in India. As necessary as the technical side of renewable energy, the behavioral and economic study could provide insights into the policy development and reveal barriers to the policy implementation.

Finally, Dr Norasikin Ahmad Ludin (Malaysia) proposed a collaborative project among universities in the APEC region, investigating the policy impact, techno-economic of renewable energies, and recommendations on the policy due to the decentralized distribution energy system (DES).

Discussion 5C

The subsequent discussion on this RE session started with how the researcher made a solar thermal tower suitable for the cloudy climate of Brunei Darussalam. The solar tower technology is usually ideal for the desert regions where direct sunlight provides a more uniform heat distribution. Dr Prasad explained that the team was aware of the limitations, but the solar PV has a lifetime of around 20 years and is not bio-degradable. Thus, they aim to improve the uniform heat distribution in the fluid for a smoother thermal profile by experimenting with different parameters.

Another discussion was about suitable energy technologies for Brunei Darussalam, an exporter of natural gas, oil, and hydrogen. Dr Prasad shared that his team plans for a hybrid system, integrating the solar rooftop PV and the solar thermal tower. Finally, Dr Norasikin Ahmad Ludin (Malaysia) invited other participants to collaborate on the new project by contributing energy consumption statistical data and the status of DES (micro-grids) in each economy.

Lessons Learned from the group discussions

After the group discussions, representatives from each group shared what they had learned from the projects and dialogues. Some essential points across the three groups are characteristics of the team and the process to ensure the success and sustainability ofthe energy-related projects. Student participation and experiences are highly valued.

1. **A multidisciplinary team** of experts, such as technologists, social scientists, and economists, is essential to implementing the projects. In addition to the technical team, other experts collect and analyze various types of data and communicate with the stakeholders.
2. **The participatory process** seems to be another critical success factor in community development projects in rural areas and green buildings design in an urban context. Appropriate media and tools for the participation of each group of the audience are also important.
3. **The sustainability of the project**, particularly the micro-grid systems design and implementation, received much attention. Dr Bundit Fungthamasarn (Thailand) shared that universities should ensure the long-term success of micro-grid installations in rural areas by providing support after implementation. The Joint Graduate School of Energy and Environment (JGSEE) at KMUTT has set up RESCO to help lessen the maintenance burden for rural communities. However, this needs collaboration with local institutions to develop teaching and training materials.
4. **Student engagement** has been raised throughout the presentations, emphasizing the roles of universities in student development, both short-term and long-term. Thus, collaborative projects on the APEC's energy goals could provide valuable learning experiences for the younger generation.

Session 6: Discussions and Brainstorming for Next Steps
Moderated by Dr Chanyaporn Bstieler (Thailand)

During the last session, all speakers and participants exchanged their views on moving forward, focusing on establishing cooperation and finalizing collaborative project plans between faculty and policymakers. The three following steps were dis- cussed:

1) Form a partnership across disciplines

University experts with common interests in energy efficiency and renewable energy for sustainable development of the APEC region should get together and continueexploring a collaborative project. As shared in the previous sessions, *multi-disciplinary* teams successfully implemented energy-related projects, especially community development and green building design. An interdisciplinary teamof experts could provide a holistic view of the technologies, tools, policy development,and implementation.

Dr Reddy Prasad (Brunei Darussalam) suggested two parts of the effort: 1) developing technologies and 2) developing energy policies and, finally, implementing the policies to make a real impact. Thus, both technical and non-technical disciplines are required to support these goals. He also recommended that future workshops and projects emphasize the assessment of implementation, discussing the advantages and disadvantages of the policies.

Dr Puree Sirasoontorn (Thailand), as an expert in economics, also supported this view. She joined all 3 group discussions and suggested that all energy projects consider economic evaluation to assess the cost-benefits to justify the new technologies and policies. For example, green building innovation usually costs more than conventional technologies, and economic assessment could provide evidence for cost-effectiveness.

For the transportation sector, the financial analysis should also include external costs such as pollution, air quality, and network benefits from connecting transportation modes. For instance, Dr Sirasoontorn recommended that the economic evaluation of the EV and electric mass transit in Thailand consider all costs, such as time and convenience costs to people. The researcher should demonstrate that the new technology's net benefits (for the private sectors/individuals) provide a net gain to the economy for the policymaker's buy-in because they can push it forward.

2) Develop collaborative projects to support the policymakers

There are two ways to develop collaborative projects with the policymakers to support the APEC's energy goals. Following step one described above, the team of university faculty will need to align their expertise and interests with the APEC's energy goals. Dr Keng-Tung Wu (Chinese Taipei) suggested that collaborative projects could result from identifying the APEC goals gap, such as the RE's doubling goals and others that need high technological analysis.

Dr Worrajit Setthapun (Thailand) shared how the university should communicate with policymakers, break barriers, and present what it can offer. Subsequently, both parties could develop projects together. Particularly for community acceptance, universities can be a linkage between the policymakers and the rural community to drive the policy implementation at the grass-root level.

In developing collaborative projects to support the policymakers, Mr Steivan Defilla (APSEC) shared that Tianjin University (China) participates in a network of universities from many cities, and the proposed projects should look at district and city levels as opposed to an individual level. He is trying to develop an integrated network between the energy sector to other sectors, such as transportation, waste, and water. In addition to data collection, there should be more effort to determine how these data could help the energy transition and improve the city resident's quality of life. To support much-needed data collection, Mr Edito Barcelona (APREC) suggested that universities train students to collect data.

Mr Harry Lai (Hong Kong, China) shared another approach from his economy to draw experts from universities and develop collaborative projects between policymakers and universities. His department launched a web-based online platform called E&M InnoPortal. They gathered the needs for services improvement from government departments (i.e. operational requirements), then invited universities and startups to provide innovative ideas and solutions for meeting these improvement needs. So far, they had implemented more than 100 pilot projects in this respect.

Another point was to enhance collaborations with universities. For example, the education partnership in Oregon (United States) pulled together universities to work on projects with common interests matching the 17 UN's SDG goals and this network had been expanded to other parts of the world. In Hong Kong, China, government departments would enter into partnership with universities to conduct specific projects, such as the feasibility of installing PV on building rooftops and developing *hydrogen economy* in a compact city, etc.

3) Submit a proposal for financial supports

The participants agreed that funding is essential for collaborative projects and activities between universities in the APEC region. For APEC funding opportunities, Dr Cary Bloyd (United States) shared that the EWG's goals have changed to include energy resiliency. He was optimistic that universities in each economy could help APEC achieve these aggressive new plans. Each economy could co-sponsor each other's projects. The universities interested in applying should observe the next round of concept notes, a three-page document, submission dates. Although the participants may not have time to develop a project proposal at this workshop, most agreed to a smaller group meeting to discuss further collaboration.

Final Remarks
by Mr Harry Lai (Hong Kong, China)

In supporting APEC's energy goals, Mr Harry Lai affirmed that his economy had actively participated in the EWG and its sub-groups as well as sponsored and co-sponsored many related projects. While each economy might have unique challenges and experiences, Hong Kong, China had set ambitious goals and initiated various studies/projects to achieve carbon neutrality objectives. Taking the advantage of Hong Kong, China's extensive experience and expertise in enhancing energy efficiency for high-rise buildings, one of the ongoing projects was on the promotion of retro-commissioning in existing buildings.

In his view, this workshop was timely in establishing closer collaborations between universities and policymakers, which would be essential in enhancing their communication through developing a common language amongst them and also improving their understanding to formulate a cooperative network with researchers.

Finally, Dr.Katie Purvis-Roberts thanked all the participants and invited them to continue the conversation later. The workshop website provides contact details of each participant for further collaboration. At the end of the workshop, 42 participants attended the group photo session.

1.3 THE PROJECT WEBSITE

In addition to the online workshop, the project website (accessed at apec-collab.kmutt.ac.th) has provided a virtual platform for compiling and disseminating the project's information to the participants and the general public. It also helped increase the workshop's efficiency and encourage participants' engagement before and after the online meeting. The website displays workshop materials, such as the agenda and examples of collaborative projects and speakers' short biography.

There are five categories of information on the website:

1) The information about the project's goals and objectives, and the workshop's activities, including the agenda and brief description of the three focusing themes. These include Community Development; City, Buildings, and Transportation, and Renewable Energy.

2) The speakers and active participants information with short biography, their affiliations, and expertise, along with their contact and pictures. The organization of this information follows the focus areas of our discussions. This section facilitates potential new networks and collaborations between the policymakers, research centers, and university partners.

3) Examples of collaborative projects by Universities in the APEC economies that address the APEC energy efficiency and renewable energy goals. There are currently four projects. We will add the new one, which has just started in October 2021, between Claremont McKenna and KMUTT.

4) The materials used for the workshop, including video presentations and Power-Point files (only the ones that received permission from the speakers).

5) News section provides an update on the workshop participants' activities, new projects.

CHAPTER 2

KEY OUTCOMES

2.1 PROJECT OBJECTIVES

This chapter describes key outcomes of this workshop, in comparison to the project objectives as follows:

1. Build the capacity of workshop participants by developing a network between the EWG, APERC, APSEC, and University faculty in APEC economies.

2. Share examples of collaborative projects by Universities in APEC economies that address the APEC energy efficiency and renewable energy goals.

3. Develop project ideas, between the policymakers and University faculty in APEC economies, as project-based courses that will help inform energy efficiency and renewable energy goals.

2.2 KEY OUTCOMES

2.2.1 Developing a Network between the Workshop Participants

There were 16 speakers, and 46 participants from 18 APEC economies who attended the two half-day online workshop. Figure 2.1 shows the geographical locations of the 18 APEC economies and a breakdown of the participant's affiliation and expertise. Sites of the economies that participated are well distributed across the APEC region, covering tropical, sub-tropical, and temperate climates. This aspect might be beneficial for developing a network to investigate the development of energy technologies under different climates. As many economies are in the tropical region, which is expected to have 50% of the world population by 2050, this can also be an advantage for comparative studies about common climate-specific topics in multiple locations.

The breakdown of participant's affiliation shows that nearly 30% were government officials, 60% were from universities (faculty and graduate students), and 10% were researchers from APERC and APSEC. The participant's areas of expertise and application can be categorized as follows: 1) Energy policy 2) Energy Research and Development 3) Community Development 4) Cities and Buildings 5) Transportation 6) Others (Economics and Law). One of the workshop findings suggests that a multi-disciplinary approach is needed to develop and implement energy technologies and policies successfully. Thus, this wide range of expertise could help build a university faculty and policymakers network, addressing the APEC's more challenging goals. During the workshop discussions, each topic and technology involved many stakeholders and can be viewed from different angles.

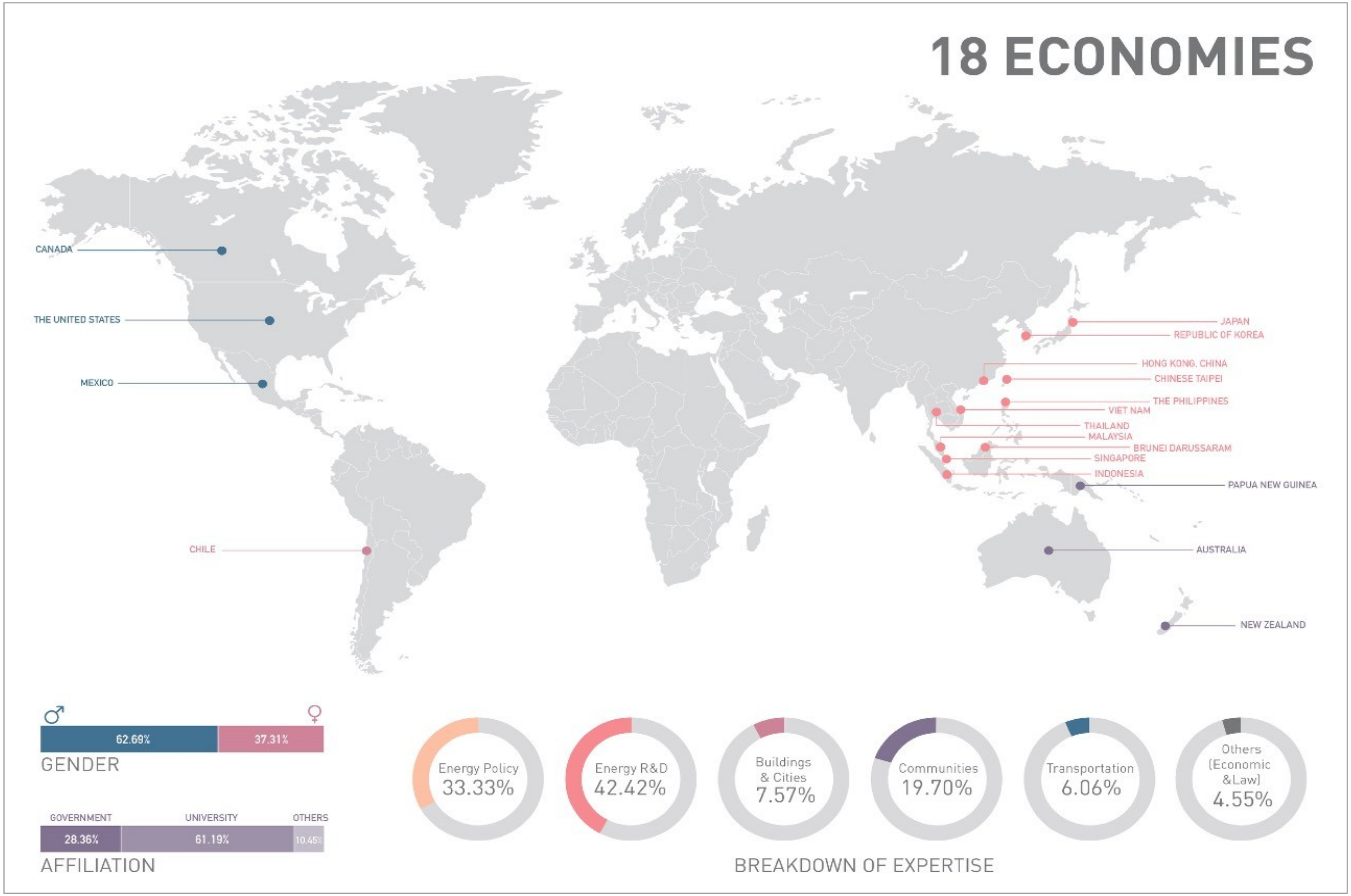

Figure 2.1 Locations and break down of the participants' affiliation and expertise.

Some existing collaborations exist between university faculty and policymakers, for example, in Hong Kong, China, Chinese Taipei, Thailand, Canada, and the United States. Others have co-operations between universities in the APEC region, working on energy and sustainability research and project-based learning courses. These include the United States, Malaysia, Thailand, and Viet Nam. Thus, the workshop could help the existing cooperative projects expand their network and include other areas of expertise or consider different aspects of their projects.

The presentations of the expertise and focus areas of each university and research center have attracted others who have common interests. For example, APERC expressed its interest in biomass and biogas projects in rural areas by adiCET (Thailand). The workshop could also help foster a new network between university faculty, policymakers, and APEC's research centers to obtain much-needed data. For example, APERC urged the universities to collect and analyze energy consumption data in each sub-sector and create a database with open access. They also see an opportunity that the university students can be trained and help to collect the data.

Following the APEC gender inclusion guidelines, the organizer made efforts to invite equal numbers of male and female participants. The percentage of male and female participants was 37.3% and 62.7%, respectively. Nevertheless, during the two half-day virtual workshop, many female participants took active roles as speakers and contributed to the dynamic discussions. Some female participants from Malaysia, Thailand, and the United States also have a leading role in proposing a new network for further collaborations between universities and policymakers in the APEC region.

2.2.2 Sharing Examples of Collaborative Projects by Universities

As described in the previous chapter (Workshop Day 1, Session 2), university faculty shared three examples of collaborative projects that address the APEC energy efficiency and renewable energy goals in Viet Nam, Malaysia, Thailand, and the United States. These covered the assessment of renewable energy policies in Viet Nam and a comparison of various energy policies between Malaysia and the United States. The last presentation was a cross-disciplinary project-based class between environmental scientists and design students. While the first two projects took a top-down approach, this canal revitalization project presented a bottom-up view and investigated the relationship between environmental quality data along the canals and people's behaviors. Although it did not look at energy use directly, the results indicated that improving water and air quality along the waterways in urban areas could encourage people to use more non-motorized public transport such as bicycles and boats. Similar to the policy assessment project in Viet Nam, this study also shared that people tend to value better environmental quality such as clean water and fresh air that could directly impact their health and well-being.

In addition to the presentations in Session 2, the other two projects shared during the workshop on Day 2, in Session 5A and 5B, also addressed collaborations between universities and policymakers in Thailand and the United States. The first example was from the adiCET (Chiangmai, Thailand), showing the excellent role of the university in providing environmental education and building capacity to support the sustainable development of rural communities. It also showed a solid commitment to engage both the students and communities in every development process. The director of adiCET added that more effective communication between universities and policymakers is needed in developing a collaboration. At the same time, universities in the APEC region could facilitate policy implementation, especially in rural areas.

Further discussion after the workshop with Dr Siminovitch, the Director of California Lighting Technology Center, the University of California Davis shared that one of the missions of his lighting center was to develop and assess innovative lighting technologies. Student engagement has significantly contributed to the projects; many results have been incorporated into lighting design codes and standards. In recent years, there has been a collaboration at the state and university level to establish a similar lighting center in a university in Mexico. Adopting a similar model of student engagement, they are involved in developing daylighting strategies and energy-efficient lighting standards for Mexico. In Thailand, the Lighting Research and Innovation Center (LRIC, KMUTT) has collaborated with the California Lighting Technology Centersince 2014 and we are expanding our collaboration to involve the new lighting center in Mexico. This could be an opportunity to investigate common interests in daylighting in the tropics and lighting education.

The last example presented collaborations among universities in Japan and Southeast Asian economies, including Singapore, Viet Nam, Thailand, Indonesia, and the Philippines. Due to the lack of energy consumption data in green buildings in the tropics, their efforts focused on collecting real electricity used for the HVAC and lighting systems. In addition to the collection of quantitative data, it highlighted the importance of occupant's comfort and satisfaction in energy efficiency for commercial buildings in tropical climates. This collaborative project also provided capacity-building activities such as workshops and training for local students.

Overall, the examples of collaborative projects shared by universities showed that they have a wealth of expertise, research-class facilities, demonstration projects, and existing activities that could support the APEC to achieve its ambitious energy efficiency and renewable energy goals.

2.2.3 Developing project ideas between the policymakers and University faculty

The last objective was to develop project ideas, between the policymakers and University faculty in APEC economies, as project-based courses that will help inform energy efficiency and renewable energy goals. The following project ideas were proposed, however, the projects have not been finalized and need further discussions and consultation with the policymakers in relevant economies.

Energy Policy: Distributed Energy System (DES)

Dr Norasikin (Malaysia) proposed a collaborative project about policy implications and techno-economics analysis in the APEC region. The use of renewable energy(RE) has disrupted the conventional distributed energy system (DES). The distributed RE has more potential, including in the rural areas. The decentralization of the DES hasgained interest and become more affordable as they are small and flexible. Thus, the new research will focus on the policy impact, techno-economic of RE, and recommendations on policy. Collaborations will look at the overall potential of DES in the APEC region. Universities in Indonesia and Brunei Darussalam are interested in participating.

Energy Performance and Occupants' Comfort in Green Buildings

Dr Ichinose (Japan) suggested expanding from his existing collaboration with Southeast Asia to include partners from other APEC economies in tropical climates. The proposed project will collect and analyze green buildings' HVAC and lighting systems and correlate them with the occupant's thermal and visual comfort levels. During the discussion, there was a suggestion to investigate a return of the investment in these green building technologies, taking into account the direct benefits of reducing energy savings and environmental impact, and the indirect benefits of increasing occupant's work performance and improved health and well-being. This data might help to accelerate the decision to adopt green building strategies, leading to greater energy efficiency than complying with building codes.

Daylighting in the Tropics, a Renewable Energy Source

The green building project idea described above can be combined with another common interest in daylighting in the tropics. Daylight is renewable energy and can be used directly in buildings operated during the daytime to supplement artificial lighting, thus reducing electricity use and increasing the share of renewable energy. However, daylighting design in the tropics has faced challenging heat gain and glare from the bright sky. For the past 3-5 years, there has been a renewed interest in daylighting, mainly for the health and well-being benefits. It can be seen in the adoption of WELL Standard by many private developers of large commercial buildings. Thus, the lighting research centers in the United States, Mexico, Thailand, and other university partners from Japan and Singapore will explore this opportunity further.

Promotion of Biogas and Biomass: Towards Bio-Circular Economy

APERC expressed its interest in biogas and biomass promotion towards the bio-circular economy by adiCET (Thailand). The director of adiCET suggested that this idea should be developed in cooperation with ENTEC-National Science and Technology Development Agency (NSTDA) and the BCG committee in Thailand. The Bio-Circular-Green (BCG) economy is an economic model for inclusiveness and sustainable growth, aligning with the UN Sustainable Development Goals (SDGs).

The Impact of New Work Patterns and Lifestyles on Overall Energy Use: An Integrated Approach

Dr Diaz (the Philippines) and Dr Budhimethee (Thailand) suggested that due to the COVID-19 Pandemic, there have been changes in work patterns and lifestyles that might impact overall energy use. These include increasing time working from home while reducing travel time and frequency and working in the office. There are also changes in the mode of transport; for example, some people opt for walking or non-motorized transportation. Thus, there should be an integrative approach to investigate human activities at buildings and city scales. The data could provide insights for city planners and policymakers and help to reduce the overall energy use.

CHAPTER 3

SUMMARY OF PRESENTATIONS

This chapter provides a summary of materials presented at the online workshop on 8-9 June 2021. The summary of 26 presentations is divided into 6 sessions and organised according to the schedule of presentations on Day 1 and Day 2 of the virtual workshop. Links to prerecorded videos for each presentation are included, where the speakers give permission to share their work.

3.1 WORKSHOP DAY 1

3.1.1 Session 1: Overview of APEC Clean Energy Activities and Goals
Dr Cary Bloyd. (United States) Pacific Northwest National Laboratory:

Dr Bloyd gave an overview of APEC economic leader's activities and goals. Fifteen working groups operated under SOM – the Steering Committee on Economic and Technical Cooperation (ECOTECH), covering various topics, including the Energy Working Group (EWG). The Energy Working Group is supported by eight sub-fora groups such as the Asia Pacific Energy Research Center (APERC, Japan) and the APEC Sustainable Energy Center (APSEC, China). In 2015, APEC leaders and energy ministers reaffirmed the clean energy goals to reduce aggregate energy intensity by 45% by 2035 and double renewable energy by 2030. He also introduced opportunities to work with APEC by writing proposals to the APEC Secretariat in Singapore for funding, as APEC funds 100-150 projects each year with up to **$20 Million**. Finally, he urged that universities should collaborate and help define the future APEC energy options.

3.1.2 Session 2: Examples of Collaborative Projects
Moderator: Dr Chanyaporn Bstieler (Thailand)

1. **Dr Norasikin Ahmad Ludin (Malaysia)** ***University Kebangsaan Malaysia*** **- Collaboration on comparison between renewable energy policy in Malaysia and the United States** (https://youtu.be/u9VpcfWRDLM)

Dr Norasikin Ahmad Ludin shared details about the collaborative project between UKM, Energy Policies, MSc. Energy Science and Technology and Environmental Chemistry (CMC). The presentation provided objectives, methods, and topics for the students on both sides. It was a hybrid project, conducted through both online activities and site visits in Malaysia. There were three groups of activities looking into five topics related to energy policies. Activities included group discussion, academic writing, and site visits. The faculty evaluated the students and peer-to-peer evaluation by the students (for presentations and participation) was also done. There was a three-day academic writing workshop to practice critical thinking and writing skills. Subsequently, the students presented their work moderated by the faculty from both universities. Finally, the students visited several demonstration sites such as solar power and telecommunication during the day.

The joint projects included: 1. Green buildings and 2. electric vehicles in terms of policy implementation in both Malaysia and the US. They compared the impacts of implementing these policies on the costs, benefits, and energy resources saved (economic values/increased costs of construction and payback period). 3. Energy, Environment, and Economics Forecast towards Industry 4.0 focusing on three leading technologies.
4. Environmental benefits for blending ethanol into gasoline for Kuala Lumpur and Los Angeles (see appendix for example project paper). For example, Malaysia depends more on palm oil and not ethanol which needs higher technology for processing and conversion. However, the transition to ethanol in Malaysia is not practical for the economy. 5. Industrial revolution versus climate change. The site visit was in May 2019, with the representative from the US embassy joining the seminar. Apart from the demonstration sites on campus, there was also a visit to the green buildings in Putrajaya.There were also cultural exchanges. The students all appreciate the academic and cultural experiences.

2. Dr Keng-tung Wu (Chinese Taipei) *Chung Hsing University* - Conducting the APEC Projects by Universities to Provide the Needs of Energy Policy-makers: Barriers and Opportunities (https://youtu.be/XWFWPTzoqsQ)

Dr Keng-Tung Wu has served as the secretariat for *the Expert Group* on *New* and *Renewable Energy Technologies* (EGNRET) since 2011. He shared experiences in APEC energy policy and outlined opportunities and barriers for conducting APEC Projects by Universities. The nature of APEC projects is different from fundamental research for academic purposes. APEC projects aim to foster sustainable growth and usually involve capacity building and transferring knowledge and skills. He also identified barriers to applying for APEC projects. These include fundamental research, non-commercial technologies, and future technology (longer than 20 years). Technology Readiness Levels (TRL) 4-5-6 are still developing and need to be scaled up from small to large-scale prototypes. APEC projects usually are in TRL level 7-8-9 or deployment by the industry.

At the same time, opportunities for universities lie in enhancing industry and academic collaboration to deploy reliable energy technology to suit the requirements of energy policymakers. Energy technology should have widespread use; the universities could help to improve and adapt the service for new technology. They could also help apply and expand existing or new technology, demonstration, and model for ap-plications, demonstration sites - using all 21 economies to promote sustainable growth. A new invention is not necessary for APEC projects. One of the successful projects is by adiCET at CMRU, where the research center acquired APEC funding to establish demonstration sites on their campus in Chiangmai, Thailand. In order to develop a successful APEC energy project he introduced four ideas- RETI: regulations (law), economy, technologies, and integration (source: Best Practices for Developing the Green Energy Smart Farm in the APEC Region, 2017).

3. Dr Thang Nam Do (Australia) *Australian National University*- Viet Nam's solar and wind power success: Policy implications for other economies

Dr Thang Nam Do conducted a collaborative study between universities in Viet Nam, Australia, and Norway. Viet Nam has the largest PV (solar) and wind power installation in ASEAN. The region has 5TW potential for solar and wind energy, but the uptakes are different in each economy. The results showed that four drivers contributed to this success: the government's commitment to energy security, public demand for clean air, solar and wind industry lobbying efforts, and commitment to international climate change goals. Domestic motivations are key underlying drivers to this success of the adoption.

Viet Nam applied incentive instruments, for example first feed-in tariff (FIT) in September 2017, which was a generous FIT. There was a dramatic increase in solar rooftop installations before the end of this tariff. Supporting policies to provide incentives and enabling regulations to encourage investment and included guidelines were discussed. A comparative policy study in ASEAN appeared to show that there was a lack of encouragement for renewable energy. The study identified room for improvement in Viet Nam, such as the short FIT windows. The study also recommended policy implications for ASEAN and added that political will is needed. The global awareness and need for clean air showed that related health benefits can be a strong driver.

4. Dr Kanjanee Budthimedhee (Thailand) *King Mongkut's University of Technology Thonburi* (https://youtu.be/IT2D01ZvUQM); **and Dr Katie Purvis-Roberts (United States) *Claremont McKenna College*- Collaboration on canal revitalization in Bangkok to increase connections to mass transit** (https://youtu.be/_sdzFjpmHT8)

Dr Kanjanee Budthimethee shared a project that she has been working on to revitalize canals in Bangkok, working with communities who live along the canal to under- stand their needs and requests for redevelopment. The goal of the project is to encourage increased, non-motorized transport along the canal, such as walking, biking, and boating. Linking canals to mass transit hubs, such as bus and rail stations, can decrease traffic on roadways and increase energy efficiency through use of public transit.

Dr Purvis-Roberts talked about her student's contribution to the project, analyzing air and water quality samples along the canals. Residents who live near the canals would use the pathways more, if the air and water quality was better in these areas. This connects to the presentation by Dr Do in that people are concerned about the environment they live in, and are willing to make changes, such as use renewable energy or walk/bike along the canals, if the air and water are cleaner.

3.1.3 Session 3: Policymaker Needs for Data Analysis and Support

Moderator: Dr Katie Purvis-Roberts

1. Ms Elvira Torres Gelindon (Asia-Pacific Energy Research Center) APERC Work and the Need for More Data

Ms Elvira gave an overview of APERC's mission, data collection, and analysis to support the APEC energy goals. The presentation highlighted an example of sample data gaps collected from all 21 economies due to the lack of access to energy data from some sectors, such as agriculture and fisheries. This lack of data affected the energy analysis where the Energy Outlook was displaying decomposition and sectoral energy per capita. The International Standard Industrial Classification (ISIC) defines more than 20 sub-sectors, but data from some energy-intensive sub-sectors are missing.

As a result, the lack of energy consumption by some sub-sectors impacted the energy scenarios. As a final thought, she suggested that collaborations with universities could help collect the energy data, not relying only on the energy-related organizations. For example, the university could contribute to energy information by creating a database to share this data (e.g., energy mixed and energy flows). She also added that APERC usually conducts training through the EWG in each economy, as capacity-building activities.

2. Mr Steivan Defilla APSEC- An APEC Urban SDG Tracker for Energy and Climate (https://youtu.be/ChPZE0-ohDo)

The presentation highlighted the need for comprehensive data statistics for cities to cope with the effects of climate change. New types of risks are systematic riskswhere all types and events linked together necessary integrated responses. Data collection should be according to these principles: 1. Statistics database collection of information should base on existing Global Frameworks such as Sendai Framework for disasters and their operation instruments like the scorecards for cities. 2. Statistics should beguided by the APEC energy goals (i.e., to achieve energy intensity 45% by 2025 and doubling renewable energy share by 2030).

He introduced a conceptual framework where the SDG goals are located in the center, illustrating the priorities. The platform for data collection required three commitment levels. For example, at the basic level, the cities are already collecting fundamental data such as energy efficiency and renewable energy. APSEC has just started a new project and contacted universities and cities interested in collecting data for levels 1and 2. Data from all three levels should work well to attain the SDG goals and disaster response if combined. An instrument such as disaster resilience scorecards, used by 4,600 cities, is a good tool and very practical to provide profound changes such as nature-based, social indicators, and financial aspects to complement the SDG and are relevant to the city context.

3. Dr Nuwong Chollacoop (Thailand)- Data Analysis on Renewable Energy and Energy Efficiency through Co-Benefitting and Disruptive Technologies (https://youtu.be/O5Tyk26BOaw)

Two projects reflected the economy's efforts to achieve the doubling renewable energy goal and responded to disruptive technology's impact on energy policies and implementation. The first project looked at different approaches and policies to promote co-benefits of energy efficiency and renewable energy implementations in key sectors such as buildings and transportation. Thailand has been on target in reducing energy consumption, but still finds doubling its renewable energy goal challenging. The project focused on critical success factors, which have already been included in the APEC quality criteria.

For disruptive technologies, policies need to be adapted to rapid changes in power generation, distribution, consumption in key sectors, and financial transactions. ENTEC obtained the data for these two projects from open sources such as energy policy papers, databases, relevant reports, and case studies in other APEC economies. Conclusion: there was a suggestion on cost-effectiveness that it should include both direct and indirect costs and benefits from donors and the government.

4. Dr Madeleine McPherson (Canada) ***University of Victoria*****- Open- source tools for Energy Systems Integration**

This presentation focused on data collection, models, and visualizations, streamlining electrification research and policy workflow. Objectives are 1) To model the electrification and integration to explore deep decarbonization pathways, and 2) To support the deep decarbonization actions by delivering relevant and impactful insights to decision-makers. The open-source tools comprised three pillars that serve as a modeling suite. A key barrier is that energy system integration needs holistic energy data fromeach scale and across systems (e.g., spatial, time scale, type of energy sectors).

As a result of needing all of these types of data, the model is very complex. For example, Pillar A - the X-axis and the Y-axis - are developing many smaller models. Then they need a considerable amount of data input with the Pillar integration (SPINE) to pull the three pillars (ABC) together. Three critical but challenging components to the integration of evidence into the decision-making process include:

1. Timeliness: assemble the data & models in a 'standing' repository - (continuously updated)
2. Transparency (trust): open-access and accessible to people with GUI, to models via APIs).
3. Inclusiveness - convene a diverse range of disciplines, perspectives, and stakeholders within the modeling process.

The team's vision is to provide a holistic perspective to energy systems decarbonization through an open platform.

3.2 WORKSHOP DAY 2

3.2.1 Session 4: The Student Experience
Moderator: Dr Cary Bloyd (United States) PNNL

1. Mr Aaron Midson (Australia) *Australian National University*- Comparison of New Zealand and Republic of Korea renewable energy policy (https:// youtu.be/i75clR_Wp10)

This research investigated the renewable energy policy of individual APEC economies, analyzing combinations of renewable policy for various APEC economies and the generalizable policy lessons that might be useful to the other APEC economies. The research employed an adapted policy framework to analyze each instrument: elements, processes, and characteristics. New Zealand and Republic of Korea have been selected as case studies because they have different energy demands, shared renewable electricity, and other approaches to renewable energy policy. The example findings are that energy and climate change policy could reinforce renewable energy development. Partnerships across levels of government help facilitate fair and effective energy transition. Thedoubling goal is increased to be compatible with the Paris Agreement commitment ofthe economies. (Please see the APPENDIX B for a full paper)

2. Ms Lai Won (Thailand) *King Mongkut's University of Technology Thonburi*, Ms Lelia El Masri (United States) *Claremont McKenna College* Bangmod Pattana study on the effect of CO_2 and PM2.5 on the canals

A collaboration between students from the two universities on the Bangmod Pattana project turns scientific data into a lighting installation. Science students from Claremont concentrated on analysis of observations on numbers of people, motorcycles, boats, and other factors happening during the day and air and water quality data, all along the canal. They aim to observe the impact of motorcycles and boats on air quality by using community data and air quality data (CO_2 and PM-2.5). The result reveals boats have a more significant impact on CO_2 emissions.

On the other hand, architecture students went on site-visits and helped with data collection. They visualize the scientific data into lighting installations under the theme 'the urban forest' on six stops along Bangmod Canal. The installations display positive and negative numbers through color-changing lights to encourage more emission-friendly practices and raise awareness about air pollution among visitors and community members. One difficult part of working on this project is the time difference of KMUTT and Claremont students, as they need to share information and brainstorm.

3. **Ms Nur Farhana Alyssa Ahmad Affandi & Ms Fairuz Mohd Chaculi (Malaysia)** ***Universiti Kebangsaan Malaysia*** **and Mr William Cullen (United States)** ***Claremont McKenna College*** **- Experiences of Collaborative Projects.**

There have been five collaborative projects between students from Claremont and UKM. They think that working on the project is an excellent platform to share ideas from different cultures. After a semester of working together virtually on data analysis and manuscript writing, some Claremont students traveled to Malaysia to meet in person. The activities in Malaysia include site visits, workshops and symposiums, academic writing and discussion, cultural experience sharing, and international networking, allowing them to compare the similarities and challenges that both economies face. It is also an eye-opening experience on cross-culture collaboration. Apart from collaborative projects, there is also collaboration on writing academic papers, which allows them to exchange knowledge and improve critical thinking skills. (Please see the APPENDIX C for a full paper example for this collaboration)

3.2.2 Group Discussion - Session 5A: Community Development
Moderator: Dr Worrajit Setthapun (Thailand)

1. **Dr Patricio Mendoza-Araya (Chile)** ***University of Chile*** **- Microgrids in Chile: working with rural and urban communities for sustainable energy development (**https://youtu.be/MWXzOkco_Xo**)**

Dr Patricio Mendoza-Araya shared his experiences in developing micro-grid projects for rural communities in Chile and Latin America. His research center has helped the government with energy planning. One of the communities is Easter Island, which is connected to the grid but would like to be independent. His team had helped them with energy planning and micro-grid implementation. They employed many tools to engage and communicate with the residents throughout the process. He shared some success factors and co-construction methodology to ensure community acceptance and sustainability of the project. He recommended that there should be a multi-disciplinary team of experts, particularly social scientists and anthropologists, to work with the communities on aspects other than the technologies. This includes gathering local knowledge from the communities to be incorporated into the new technologies and is provided to sustain the projects over time.

2. **Dr Worrajit Setthapun (Thailand)** ***Chiang Mai Rajabhat University*** **- Toward Smart Community: Energy monitoring and planning for the local community**

Dr Setthapun presented the work of the Asian Development College for Community Economic and Technology (adiCET), Chiang Mai Rajabhat University (CMRU), Thailand. The goal of the college is sustainable development by addressing energy efficiency and renewable energy, water, and food (including waste). It also embraces the sufficiency economy approach introducing a cycle of bioenergy to green (i.e. energy to food system). Its demonstration projects and capacity-building activities have played an essential role in sustainable development for rural areas in the northern prov- inces of Thailand. Key initiatives include the adiCET smart community model, renew- able energy generation and distribution implementation, and intelligent information technology systems for the community. Student engagement contributed significantly tothe on-campus and community development activities.

The university established *Chiangmai World Green City, Living Laboratory and Learning Park* with three key flagship projects.

1) *Smart Community Microgrid.* The university has installed a 702 kW PV grid and two small microgrids for ten houses. These facilities provided hands-on experiences for the students; many are from mountainous areas with no grid connections.
2) *Zero Waste - Bioenergy Cycle.* This project developed a Smart Farm and explored generating electricity and bioenergy from different types of waste, particularly agricultural waste. For example, a biomass stove produced hot water for daycare. Another project is the Green campus environmental monitoring called adiDUST; it is the program for haze monitoring in schools, municipalities, and government buildings.
3) *Smart Community Development.* The project focused on the balance of input and output of energy, food, economics, buildings, and the environment. The goalis to develop a balanced community by analyzing real-time data (building energy load profiles, vehicles' fuel, water usage, and waste generation) and changing be- haviour to reduce the use.

3. Mr Manu Rawli (Papua New Guinea) *University of Papua New Guinea*- Connecting the top-down and bottom-up approach for energy access plan- ning for rural communities

Rural communities in Papua New Guinea (PNG) have faced limited energy access. Thus, this research center aims to facilitate energy access planning, employing both top-down and bottom-up approaches. The presentation gave an overview of the current power generation and systems in PNG. The Centre of Renewable Energy (CoRE) at the University of New South Wales, Australia assisted in capacity building for this new energy research center. Motivations to set up the center included: 1. Low energy access, especially with the rural majority (85%) (15% grid access and 45% access to pico lighting and SHS systems). 2. Ambitious targets and increased reliance on thermal generators (70% grid access and 78% contribution to electricity sector) 3. Less emphasis on EE, clean transportation, and clean cooling. 4. Underdeveloped energy sector with missing and weak policies. In addition, there is a long list of development challenges including clean water access, food security, health, education, and infrastructure.

The center's focus areas are local capacity building and data gathering. They also set up a Master’s degree program to produce graduate students who can help accelerate the efforts. Renewable energy and electricity access challenges included political, economic, and social problems, highlighting areas for data gathering. Large populations live in rural areas and cannot afford solar lighting. Technical, environmental, and legal challenges may require connecting top-down and bottom-up planning approaches to achieve sustainability. The presentation also highlighted the need for local communities' engagement in the development process.

4. Dr Ian Mason (New Zealand) ***University of Canterbury Christchurch-*** **Pico-hydro systems with energy storage for developing communities (**https://youtu.be/ykGVzT6C-MM**)**

The presentation focused on the development of Pico-Hydro systems with energy storage for developing communities. The intention is to reduce the use of diesel generators in rural areas. The definition of Pico-hydro is a well-established field and of wide- spread use in Southeast Asia and other parts of the world.

He focused on optimizing the system using renewable energy (solar PV in the New Zealand context). He also investigated how to utilize spill and choose secondary loads such as community heating, ice-making, or hydrogen (more high technology). A possible research agenda may include data collection on Pico-hydro systems, because data are lacking on load profiles of communities in developing economies. New research should also explore other forms of energy storage (as opposed to the chemical battery). Finally, modeling and validating the result in the real world is needed. His team has prepared a plot study, but the study has been delayed.

3.2.3 Group Discussion - Session 5B: City, Buildings, and Transportation Moderator: Dr Chanyaporn B. and Dr Kanjanee B. (Thailand)

1. Dr Szu-Cheng Chien (Singapore) ***Singapore Institute of Technology-*** **Exploring the building sustainability in Singapore: A case study approach**

By 2060, some 60% of the world population will live in the tropics. Thus, there are opportunities for Singapore to take advantage of abundant daylight and natural ventilation while minimizing the negative impact of heat gain and discomfort glare. To achieve the UN's SDG goals, universities and the government (the BCA) have focused on two stages: 1) Research and development using state-of-the-art facilities as testbeds for new technologies. These include the SkyLab for studies under natural sky conditions and the indoor facilities at SinberBEST to test innovative solutions and materials for building systems and facades. 2) Implementing new knowledge and technologies in actual buildings, both the newly built and existing buildings.

For new buildings, during the design process, university faculty and students were involved in advanced simulations to verify various building systems performance, such as natural ventilation and visual comfort according to the architectural design. They were also involved in an unconventional design approach where stakeholders and all building consultants participated in several workshops to exchange and discuss the users' requirements and optimal solutions to achieve a very ambitious energy goal. For existing buildings, the universities also conducted surveys on electricity use and workflow before proposing suitable solutions to improve energy use and indoor environmental quality. A comparison of electricity use and occupant's satisfaction surveys before and after the improvement helped validate the projects' success.

2. Dr Crispin Diaz (the Philippines) *University of the Philippines*- Time Series Trends in Travel Mode Choice in Metro Manila (https://youtu.be/tj_SVTNr-MQw)

Dr Diaz brought attention to the growth of population and travel demand in the greater Manila area, comprising the metropolitan area of Manila and four adjacent provinces. The greater Manila area is home to 50% of the economy's population, covering only 8% of the total land area. As a result, they are the most populated area in the Philippines.

In recent years, the overall trend in travel mode share showed public transport trips have dropped, private mode was relatively stable, and walking has increased. Walking appeared to replace public transport for a significant portion. Local public transport modes include tricycles (motorcycles), jeepneys, and vans or UV-HOV (utility vehicle, high occupancy vehicle). However, due to traffic congestion, the travel time continued to increase for all motorized modes. This problem not only results in an economic loss but also contributes to environmental issues. Transport is the most energy-intensive sector, using 37.2% of the overall energy consumption - primarily fossil fuels. The share of electric vehicles is still minimal, and renewable energies are not the main source for electricity generation.

A comparison of the gasoline-gallon equivalent (GGE) per passenger trip for all modes of transport revealed that each private trip spent 5.5 times more GGE than a public trip. Thus the use of personal vehicles should be reduced while improving public transportation efficiency to decrease time loss and environmental impacts. Before the COVID-19 pandemic, the government planned to modernize public transportation, such as modern Jeepneys and expansion of rail networks.

Since the pandemic, overall travel, particularly with public transport, has decreased while active transportation has gained more popularity, such as cycling and walking. As a result, the authority has allocated more road surfaces for pedestrians and cyclists. Although these changes in the short term seem to head in the right direction, more research would provide evidence to guide policy recalibration. Dr Diaz proposed three research themes:

1) *Avoid/Reduce*: The necessity to work from home during the current pandemic suggested that most organizations could avoid some trips to and from the work-place. Future research should investigate which work and activities do not require employees to be on-site while maintaining work performance.

2) *Shift:* The changing modes of transportation of car users to active transport and home delivery services needs further investigation on the impact of these new logistics on future land use and overall energy consumption.

3) *Improve:* Decreasing passenger trips suggested that future research wouldguide the recalibration of the public transportation policy.

3. Dr Masayuki Ichinose (Japan) *Tokyo Metropolitan University*- Local factors of urban building performance in tropic Asia (https://youtu.be/Um1qxw8B3wE)

Dr Ichinose's research focuses on the actual performance of green buildings in tropical climates. He has collaborations with universities in many economies such as Singapore, Thailand, Viet Nam, and Indonesia, where his team and local partners conducted surveys in actual buildings. As the move towards green buildings has increased, it is essential to understand how these buildings perform. He focused on high-rise buildings with fully-glazed facades and floor areas of more than 10,000 square meters. In addition to indoor environmental quality and energy use monitoring, they also surveyed the occupants' thermal and visual comfort perception. The results suggested differences between the energy performance (actual EUI versus baseline) and the green buildings certifications. As part of his research collaborations, he also provides workshops and training for students in partner universities to help with data collections and analysis.

4. Dr Michael Siminovitch (United States) *University of California Davis*- Student Involvement in Energy Efficient Lighting Research

California is committed to zero-net-energy buildings, and the California Lighting Technology Center at the University of California Davis has contributed significantly to this goal. This presentation highlighted student engagement in lighting design research through hands-on experiments and real projects. The activities include testing and demonstrations on human factors, colour standards, and lighting controls, many of which have been developed into building codes and policies.

Currently, the center has strong collaborations with two university-based lighting centers in Thailand (LRIC at KMUTT) and the new one in Mexico. The model for student engagement has also been introduced to involve architectural graduates to developa new daylighting and energy-efficient lighting standard for Mexico. In addition to energy efficiency, the center also focuses on a new paradigm for daylighting design to promote health and well-being through innovative circadian systems.

5. Dr Yossapong Laoonual (Thailand) *King Mongkut's University of Technology Thonburi*- Zero Emission Vehicle Policy in Thailand (https://youtu.be/2VwWaV8Qjg0)

Dr Laoonual gave an overview of the current status of the electric vehicle market and introduced the government's zero-emission vehicle (ZEV) policy in Thailand. Currently, Hybrid Electric Vehicles (HEVs) still dominate the local market, while the government's new goals focus on increasing Battery Electric Vehicles (BEVs) due to their zero emissions promise. By 2030, Thailand aims to increase the production of ZEVs to 30% and the sales to 50%. These include popular types of vehicles: passenger cars, pick-up trucks, and motorcycles. The main drivers are 1) Air pollution reduction, 2) Green House Gas emissions reduction, and 3) New industry creation.

Thailand's automotive industry has contributed to 12% of the GDP and the economy is ranked as the largest automotive producer in Southeast Asia and 12th in the world. Compared with the global electric vehicles market share led by European countries and China, the local market share is minimal and, therefore, to achieve this new goal is very challenging. At the same time, this new zero-emission vehicle policy has brought the public sector, academics, and industries to work together to support the transition of Thailand's significant industry towards a more environmentally responsive path.

3.2.3 Group Discussion - Session 5C: Renewable Energy
Moderator: Dr Katie Purvis-Roberts (United States)

1. Dr Ahmad Agus Setiawan (Indonesia) *Universitas Gadjah Mada*- Renewable Energy Applications for Community Empowerment

The first presentation was about renewable energy deployment in Indonesia and the roles of the university on community empowerment to achieve a sustainable result. The university aims to ensure universal access to modern energy services. Due to water resources development, earthquakes, and tsunamis in Indonesia, the university focused on solar water pumping systeMs With their unique educational model, students directly engaged with the community, conducting surveys on local needs and services and acting as change agents. Subsequently, the university provided technical and organizational support to the community, including training to ensure sustainability. This model demonstrated the roles of universities to offer education for sustainable development and encourage community involvement and collaboration with both local and economy level governments.

2. Dr Semee Yoon (the Republic of Korea) *Yonsei University*- Let There Be Light: Innovative Solutions for Energy Access in India

Dr Yoon investigated the adoption of modern renewable energy technologiesfrom the users' point of view, offering different but significant aspects to policy development and implementation. Her research aims to understand better the processes and factors affecting the decision of the rural poor population in developing economies. Thecase studies focused on how the communities in rural India decided to adopt solar power lighting systems. The results highlighted some key barriers and suggested alternative solutions supporting the rural communities to access modern renewable technologies. She is planning a similar study in Indonesia and investigating the perception of the priceof rooftop solar PV in Cambodia.

3. Dr Luong-Hoang Pham (Viet Nam) *Hanoi University of Science & Technology*- Current status and development perspectives of Renewable Energy and Energy Efficiency Technologies in Viet Nam

The third presentation was about the current status of the energy transition in Viet Nam. Although renewable energy has increased dramatically, the supply is still lower than the demand. Government efforts focus on reducing the use of coal while expanding energy production using biomass and waste. There needs to be a change to using electric equipment, such as electric vehicles and solar boilers for hot water for the demand side. Currently, the university has many demonstration projects on energy efficiency and renewable energy to ensure affordable energy. In collaboration with the government, the university can provide capacity building to support this energy transition in Viet Nam.

4. Dr Reddy Prasad (Brunei Darussalam) *Universiti Teknologi Brunei*- Experimental investigation on the performance characteristics of flat plate collector for harvesting radiation energy (https://youtu.be/xEwP2WcMA4Q)

Dr Reddy Prasad (Brunei Darussalam) brought attention to the research and development of the solar flat plate collectors for harvesting radiation energy. As Brunei Darussalam is a small economy with little wind energy, the use of wind turbines and solar PV systems are not suitable. This collaborative research between Brunei Darussalam and Indian universities aims to optimize solar thermal flat plate technology parametersin this partially cloudy and hot-humid climates. He also has a plan to experiment with optimisation of the integrated solar PV and this flat plate collector system.

5. Dr Norasikin Ahmad Ludin (Malaysia) *Universiti Kebangsaan Malaysia*- Policy Implication and Technoeconomic Analysis of Distributed Renewable Energy Systems in APEC Region Towards Energy Transition (https://youtu.be/7OhXHZjFl_4)

As the costs of renewable energies, such as solar PV, reduce and the systems are smaller, Dr Norasikin Ahmad Ludin proposed a collaborative project among universities in the APEC region to collect and share data on distributed energy systems. It will investigate the policy impact, techno-economic of renewable energies, and recommendations on the policy due to the decentralized distribution energy system (DES).

CHAPTER 4
CONCLUSIONS AND NEXT STEPS

4.1 MAIN FINDINGS

The following summarizes the result of the group discussions and brainstorming:

1. ***Direct and indirect benefits***. Drawn from the experiences of University faculty and students who participated in the previous projects, in addition to the immediate academic achievement, the students seemed to develop a more profound and long-term interest in promoting clean energy and a sustainable environment. Therefore, supporting project-based learning is a valuable strategy for capacity building among the younger generation in the APEC region. Working with colleagues from other cultures and disciplines also widens their perspectives.

2. ***Multi-disciplinary approach.*** Joint projects on data gathering and analysis for the APEC energy goals could benefit more from a multi-disciplinary approach that could help to address social and economic impacts of the energy efficiency and renewable energy projects. These aspects are also essential to the broader adoption of energy efficiency and renewable energy implementation. For example, innovative energy-efficient technologies for commercial buildings may cost more than standard practice, while a healthier and more comfortable working environment contributes to building occupant’s better work performance. In this case, the financial analysis may provide quantitative evidence for building owners to opt for cleaner building technologies.

3. ***Public health concerns***. Lessons learned from Viet Nam's solar and wind power success, in addition to a strong will from the policymakers, one of the key factors was immense public support. Like other developing economies such as Thailand and Indonesia, Viet Nam has faced severe air pollution, which people can experience in their every-day life. Thus, the expansion of renewable energy production provides a tangible solution to cleaner air and better quality of life.

4. ***Communication and community engagement.*** Users' participation and engagement are essential to the success and sustainability of energy efficiency and renewable energy projects for community development. Local universities are also well-positioned to facilitate the communication between the policymakers and the communities, particularly in the rural areas.

4.2 POST-WORKSHOP ACTIVITIES AND NEXT STEPS

4.2.1 A Seminar on Funding Opportunities

Project ideas described in s section 2.2.3 are not finalized and still need to be developed. In the meantime, funding is an essential element to enable these collaborative projects and activities to happen. Dr Cary Bloyd from the Pacific Northwest National Laboratory (United states) has years of experience with APEC and implementing projects within the Energy Working Group. He offered to give a one-hour seminar to workshop participants and speakers about the kinds of projects APEC is interested in and pursue funding for those projects. The project overseer organized this talk on Wednesday, August 11, 2021, at 8 am Bangkok Time (GMT+7) via Zoom platform and attended by 26 participants. New information on funding opportunities and any progress on collaborative projects will be updated on the workshop project website.

4.2.2 A Submission of New Project Proposal to APEC

To provide a common platform for exchanging ideas among the university networks and collaborations developed from this workshop, Dr Katie Purvis-Roberts has submitted an APEC Concept Note (CN EWG 6: APEC Workshop Furthering University Collaboration to Support Data Gathering and Analysis in Energy Efficiency, Renewable Energy, and Energy Resiliency). The concept note has been approved in-principle by APEC's Budget and Management Committee (BMC), and she submitted the Project Proposal in September 2021. In the meantime, the organizer encourages the workshop's participants to continue their dialogues and develop new collaborations further.

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APPENDIX A

SUMMARY OF THE EVALUATION

There are 26 respondents (9 females, 17 males) in total from 14 APEC economies. The responses are summarised as follow.

1. The objectives of the workshop were clearly defined

76.9% of the respondents strongly agree, and 23.1% agree that the objectives of the workshop were clearly defined.

The participants were informed clearly about the objective, program, agenda, and presentation material prior to the workshop.

2. The project achieved its intended objectives

53.8% of the respondents strongly agree, and 46.2% agree that the project achieved its intended objectives.

Comment:

Participants report they have broadened ideas for future research collaboration and possible opportunities. However, a few participants think the time difference was a burden that limited them to fully participate in the workshop.

3. The agenda items and topics covered were relevant

73.1% of the respondents strongly agree, and 26.9% agree that items and topic covered were relevant.

4. The content was well organized and easy to follow

76.9% of the respondents strongly agree, and 23.1% agree that the content was well organized and easy to follow

Comment:

The content was organised following the agenda and groupings in the breakout sessions were sensible and logical. However, participants wish to have access to the presentation that they did not attend during the breakout sessions and access to shared files because some presentations were not easy to read when uploaded as video clips.

5. Gender issues were sufficiently addressed during implementation

61.5% of the respondents strongly agree, and 38.5% think that gender issues were sufficiently addressed during implementation.

Comment:

The participants respect gender equality and think that there were a good number of female participants for this workshop.

6. The materials distributed were useful

57.7% of the respondents strongly agree, and 42.3% think that the materials distributed were useful.

Comment:
The prior uploading of video is a time-saver for online workshops due to time-zone differences that limit the workshop to a few hours per day. The copies of the presentation shouldbe made available for download as they would help the better absorption of such a wide range of topics.

7. The time allotted for each session was sufficient
Half of the respondents strongly agree, and another half agree that the time allotted for each session was sufficient.

Comment:
A two and a half days workshop is sufficient and the organizer managed timing quite well. However, the group discussion may need more time but with the virtual modality, it is hard to organize sessions that last too long.

8. How relevant was this project to you and your economy?

61.5% of the respondents think that the workshop was very relevant to them and their economies, followed by 30.8% mostly relevant and 7.7% somewhat relevant.

10. Please explain the relevance of the project to your economy.

Policy:

- Government Policy has more impact on each economy, society and environment .
- It is important to know and learn about other economies´ policies, implications and experiences, specifically in term of social awareness and development
- Evidence based decision making is highly relevant to policy making and the direction of university institutions in my economy.
- Green New Deal and carbon neutrality are key themes of the Korean economy and politics.
- In Chile, the Energy Efficiency law was passed recently, and it relates to several aspects of our economy, with Energy an obvious one. Also, several projects in Chile, particularly microgrids, are generating operational data. I believe sharing data from projects like microgrids will be very useful for the APEC economies to learn from each other
- Providing university's professors with an understanding of APEC's operation and current APEC energy policy direction for proposing the APEC projects in the future.
- Henry Lo’s energy efficiency management project has a sub-contract with the university to study the policies' impacts.

Update trend on energy:

- The workshop provides useful information on trends in energy demand and supply in the region
- Energy use is a very relevant issue. Power shortages are occurring which may need to be addressed through shifting usage patterns in transport and buildings.
- Renewable energy, energy efficiency, electric vehicles, sustainability
- Decarbonisation targets are well aligned with the project goals.
- Viet Nam government attend to develop economy trend to sustainable way so energy efficiency and renewable energy development are prioritized
- Focus on energy efficiency and renewable energy are important to address global warming.

Data collection:

- Not only in our economy, but worldwide, the insufficiency of data is a problem. It is a good idea to involve students in data collection.
- I am from the National Center for Transportation Studies. We are doing research on transportation and are basically collecting data from different agencies.
- Data is needed for drawing energy policy and very important to the decision making for the economy.
- My expectation on data collection was too high. In the workshop, data requirements were on micro level except for the energy modeling in Canada which covers the whole economy.
- Data gathering is still necessary and important to both RE and EE policies. In addition, university or academic institutions have potential in personnel to carry out the necessary related data.
- Building energy database project at APERC

Networking and collaboration:

- Improving international networking on renewable energy.
- The university project collaboration among economies is needed to expand the network and also to translate the research outputs as one of the economy's solution
- It good to know how progress on university collaboration and which data are needed
- It was interesting to hear more about the collaborative projects across APEC economies.
- The Philippines is faced with challenges of providing enough energy while moving to a more carbon neutral and sustainable arrangement. However, local knowledge on managing the transition is lacking. I think that APEC partners may be able to help.

11. In your view, what were the project's results/achievements?

Collaboration and networking:

- The understanding about the status of energy project in the APEC economies andmake a cooperation of the researchers
- Opportunities between economies and ideas to further develop relevant research for students
- Forming cooperative arrangements by people that would be mutually beneficial.
- Network building for further in-depth collaborative projects. Also, cross-disciplinary learning and awareness.
- The possibility to have contact with other participants from the workshop is preferred.
- The researchers related to the energy efficiency and renewable energy are gathered and future collaboration can be furthered identified
- Collaboration between different economies to address emerging issues and to prepare the future workforce.

Good starting platform

- Exchange information and knowledge sharing to develop ideas and guidelines in each economy.
- This project can provide a good example for university collaboration and show the awareness that universities can play roles in data collection.
- The project achieved greater collaboration among APEC members on renewable energy research.
- The project was able to show that universities can help energy/environmental policymakers.
- Highlight the importance of data, for example, how to analyze energy data that we need to use to support energy efficiency development.

12. What new knowledge or perspective did you gain from this event?

Energy issue

- Gain a new understanding and appreciation for renewable energy work in economies across Asia, including other economies' recent energy issues
- Modelling knowledge of energy systems and EV development
- The importance of public support for clean air and how it relates to gaining support for needed energy/climate policy.

Policy

- Similarity of issues, but variances in nuances of context may help the formulation of effective new energy policies.

Research methodology

- Universities can be an excellent source of innovative ideas.
- Open source tools for energy systems integration.
- Research methodology for energy analysis.

Collaborative model

- International collaboration has shown positive improvement in projects, builds up research opportunities into new areas bridging industry and academician
- The presentation from University of Victoria, Canada provides a visualization of modeling that is a really good concept for us.
- Collaboration between technical experts and social scientists.
- The potentials of applied research plans across APEC
- Power of collaboration on data gathering and analysis across disciplines

Important of data

- The database is crucial in analysing the energy scenario in the APEC region. New knowledge corresponding to the policymaker is needed.
- The various aspects of the energy technology application with data analysis.
- It is important to collect and analyze results accurately or it might give different interpretations.
- QA and QC of Data
- Data usage for policymakers
- The shared perspective about the need for more data and the barriers to obtain it.
- There is great potential for students to use real-world data for the benefit of both creating useful outputs and generating knowledge and networks for the students.

13.- 14. Level of knowledge of the topic before and after participating in the event

	% of respondents who rate the level of knowledge prior to participating in the event	% of respondents who rate the level of knowledge after participating in the event
Very high	15.4	30.8
High	30.8	65.4
Medium	38.5	3.8
Low	15.4	-
Very low	-	-

In general, the respondents report they have higher knowledge after participating in the event. The percentage of respondents who have a very high level of knowledge rises from 15.4% to 30.8% after participating in the event. The respondents who rate medium level of knowledge before the event are 38.5% have decreased to 3.8% after the event, which makes the high level of knowledge respondent rises up to 65.4%. There is no low level of knowledge respondent after the event, compared to 15.4% before the event.

15. On the scale 0-5, how much did this workshop impact your interest in collaborating with other universities and organizations? (0 = Not at all to 5= Strongly impact) Around 75% and 35% of the respondents indicated that the workshop strongly impact theirinterest in collaborating with other universities and organisations respectively.

16. On the scale 0-5, how likely are you to explore the possibility of collaborating with other universities and organizations after this workshop? (0=Not at all likely to 5=Extremely likely)

Around 70% and 35% of the respondents indicated that it is extremely likely and very likely that they will explore the possibility of collaborating with other universities and organisations.

18. How will you apply the project content and knowledge gained at your workplace? Please provide examples (e.g. develop new policy initiatives, organize training, develop work plans/strategies. draft regulations, develop new procedures/tools etc.)

Develop work plans

- Develop a much comprehensive work plan and strategies to tackle the issues faced in Malaysia energy development
- Integrate into teaching curriculum and research
- Engage student's projects with data gathering.
- Review a framing research on energy, transportation and urban planning and hopefully develop collaborations from that.

Develop new policy initiatives

- Develop new policies at the institutional level and own strategies, including work plan for new collaborative projects
- Develop new policy initiatives, draft regulations and apply energy economics with the data
- Develop new procedure on energy data gathering and Internal knowledge management (KM)
- Develop partnership initiatives with local universities in APEC economies

Transfer knowledge

- Organize new trainings and webinars
- Transfer knowledge to students and colleagues like organizing a short course

- Inform energy data of focal points of member economies of universities that implement NRE projects that might be captured by the economy's energy statistics like the solar energy systems installed by Gadja Mada University of Indonesia.
- Encourage more university professors to participate in the APEC project.
- Create networks to generate new renewable energy research projects.

Develop new tools

- Formulate a research to tackle individual energy use in transport and activities in buildings.
- Use data analysis in research project
- Visualization of simulation model
- Develop building energy baseline / design guideline for ZEB, nZEB and Green-Building based on actual status in Asia
- Develop data gathering skill to be more accurate and complete

19. What needs to be done next by APEC? Are there plans to link the project's outcomes to subsequent collective actions by fora or individual actions by economies?

Direction

- I think APEC should plan to link the project's outcome to subsequent collective action by fora.
- Modelling suggests that APEC could double renewables by 2025, which highlights the need to increase the target to be compatible with Paris Agreement commitments of the economies.
- APEC objective abide the SDG, thus includes industrial and economies policy maker to make and action driven research would ramp up opportunities for studentsand academicians
- APEC should establish a clear direction, in order to deploy the project's results for future concrete implementation regarding RE and EE.

Funding

- Some researchers would also need funding. Maybe APEC can also allot funding for research apart from bringing together these pools of experts.
- More funding for collaborative research among APEC economies' universities would be great
- Economic assessment
- Invite ODA experts in DAC member economies of APEC to give feedback on the potential to use development aid funding to nurture academic partnership

Data sharing

- Develop energy data sharing platform for academic and research purposes for the APEC Economies

Conferences/ workshops

- More such conferences, workshops and hackathons to bring young talent to work together.
- Regular meetings or seminars will help for the collaboration
- If possible, follow up meetings might be organized to further develop collaborations among the participants.
- Expert meeting with specific collaborative project such as for building energy

Platform / community for collaborative projects

- An expert community to share and cooperate in coming projects
- Continue to collaborate with universities and expand areas of collaboration.
- Develop platforms for data sharing among APEC economies

Expand the community

- Continue to promote the existing projects and foster future collaboration.
- Let universities learn more information and activities of APEC.
- More number of participants should be invited

Interest on particular topics

- green hydrogen technology and development.
- The APEC EWG can initiate a project with the universities from 21 economies to work together to study the harmonization of air conditioner, refrigerator and LED lighting energy efficiency test methods and management policies.

20. How could this project have been improved? Please provide comments on how to improve the project, if relevant.

Future conference

- An in-person workshop would be more preferable in the future as it helps building relationship
- The conference went well, considering the circumstances. No suggestion for improvement

Topics

- Initiate a collaborative research project that fits with the theme of the workshop. Those can be the focal point to run cross-economies and cross-cutting research projects.
- This project can be more focused on the topic, such as the harmonization of energy efficiency test methods.
- Incorporate the research area of economics, social science and humanity in energy workshops.
- A session regarding collaboration on course for energy data gathering and analysis
- Expand to research projects

Timing

- The period of conferences should be when most APEC member economy's universities are on break. Korean universities are still in the academic year in early June.
- Workshop time allotted should be increased.

Database

- Building energy databases as they are disclosed in other economies (US, Japan, etc.) but most of the economies are not disclosed due to information protection or non-existent. Through this collaboration, stakeholders and the government's disclose building data will accelerate SDGs/ESG in APEC.
- Databases of potential collaborators and their expertise can be placed on the web site. This will allow individuals initiating a project to search for relevant partners.
- One likely suggestion for future workshops on data collection is not to forget the cities who are indispensable partners for data collection.

Keep community active

- Stay motivated by awarding contests for interesting and actionable projects.
- More organizations/ universities will invite and involve
- Get more participants to join the workshop.
- More interaction between participants would be much appreciated.

APPENDIX B

STUDENT PAPER 1

Policy for Renewable Energy in the Asia-Pacific Economic Cooperation

Australian National University 'Special Topics' Report

Aaron Midson

First submitted 17 June 2020, changes made 16 September 2021.

Please consider printing double-sided, or multiple pages per sheet to save paper.

Abstract

Renewable energy deployment is pivotal to sustainable development, as are the policies which drive penetration of this technology into the market. The twenty-one economies of the Asia-Pacific Economic Cooperation (APEC) account for roughly 60% of global energy demand (APERC, 2019) and are striving for “doubling the share of renewables in the APEC energy mix, including in power generation, from 2010 levels by 2030” (APEC, 2014: 2). This transition is not on track if business-as-usual prevails (APERC, 2019). However, modelling by the Asia Pacific Energy Research Centre provides a pathway to achieving the goal at a net cost saving (APERC, 2019), requiring member economies to work on “improving economics for renewables, adopting more supportive policies and reducing energy demand” (APERC 2019: 81). This report adapts Rogge and Reichardt’s (2016) framework for policy-mix analysis to energy policy in APEC economies, focusing on New Zealand and the Republic of Korea. It explores the interaction between policy strategy, the instrument-mix, and policy processes and characteristics, to suggest seven generalisable actions for the economies, towards APEC’s pressing 2030 target. These address coherence, stringency and comprehensiveness of a policy-mix, consistency of governance, just transition, circular economy, and grid integration.

Contents

Acronyms

APEC: Asia-Pacific Economic Cooperation
APERC: Asia-Pacific Energy Research Centre
BAU: Business-as-usual (scenario)
CCC = Climate Change Council (New Zealand)
CO2: Carbon dioxide
CO2e: Carbon dioxide equivalent
ETS = Emissions trading scheme
FED = Final energy demand
GDP = Gross domestic product
GW: Gigawatts
Mtoe: Million tonnes of oil equivalent
NRE = New and renewable Energy
RD&D = Research, development and demonstration
RPS = Renewable portfolio standard
TFED: Total final energy demand
TGT: (APEC) Target (scenario)
V2G = Vehicle to grid (integration)
2DC: Two-degrees celsius (scenario)

Introduction

An emerging economic rationale is driving energy change towards renewable sources (IRENA, 2018), fostered by recognition of technological developments and climate change impacts. Shifting energy production towards renewables plays a well-recognised role in sustainable development (UN, 2019), as limiting warming to less than 2°C above pre-industrial levels (UN, 2015) becomes an ever more immediate task (IPCC, 2018), and energy demand increases (IEA, 2019).

Globally, the role of renewables is described by the 7th United Nations Sustainable Development Goal for *Affordable and Clean Energy* which looks to, “by 2030, increase substantially the share of renewable energy in the global energy mix” (UN, 2019: 1). As such, various regional, sub-economy, economy, and industrial renewable-energy-policy initiatives have emerged.

By scale, actions of the Asia-Pacific Economic Cooperation (APEC) and its 21 member economies are central to progress towards global energy goals. The APEC region has a population of 2.9 billion people (2017) (APEC, 2019c) and makes up roughly 60% of world energy demand (APERC, 2019). These 21 economies are: Australia; Brunei Darussalam; Canada; Chile; China; Chinese Taipei; Hong Kong, China; Indonesia; Japan; Malaysia; Mexico; New Zealand; Papua New Guinea; Peru; The Philippines; Republic of Korea; Russia; Singapore; Thailand; the United States; and Viet Nam.

Therefore, success for APEC's aspirational goal of "doubling the share of renewables in the APEC energy mix, including in power generation, from 2010 levels by 2030" (APEC, 2014: 2) as per the *Beijing Declaration*, is important to the global discourse. The 'doubling goal' would increase 'modern renewable energy' from 6.1% to 12.2% of total final energy demand (TFED) (APERC unpublished, 2020). In 2017, the share of modern renewables in TFED was 8.4%; about 37% of the way to the goal (APERC unpublished, 2020). However, modelling shows that in a business-as-usual scenario, modern renewables are set to fall short by around 0.85% of TFED in 2030 (APERC, unpublished, 2020) – a roughly 14% reduction of the target.

Renewables counted in the APEC doubling goal are referred to as 'modern renewables' which include hydropower and do not include biomass in residential or service sectors, referred to as 'traditional biomass' (APERC, 2019; APERC, 2016: 15). Figure 1 is a guide to relevant terminology.

To test the potential for accelerated progress of the doubling goal, modelling by the Asia Pacific Energy Research Centre (APERC) (APERC, 2019) provides a path to fill the projected gap as early as 2025 (APERC, 2019). The model, known as the *APEC-target-scenario* (TGT) (APERC, 2019), simultaneously achieves APEC's complimentary energy goal of "reducing regional energy intensity by 45% between 2005 and 2035" (APERC, 2019: 1). Notably, the TGT scenario is less than required of the economies for a 50% chance of holding climate change to 2^{o}C (APERC, 2019).

For the TGT scenario to be realised, APEC will need "an extra 851 GW of renewables power capacity, 38 [million tonnes of oil equivalent] Mtoe of additional biofuels for transport and 24 Mtoe for industry [by 2030]" (APERC, 2019: 81). This is to be achieved by "improving economics for renewables, adopting more supportive policies and reducing energy demand" (APERC, 2019: 81).

As such, the APEC Energy Working Group suggests that "collecting data on the current status of renewable energy capacity, generation, and policies in each economy… are crucial steps" (2017: 16). Thus, success for economy-specific renewable energy policy in APEC is a key element in the realisation of APEC's energy goals in the global push for renewable energy deployment.

Reference to an APEC 'economy' or 'economies' (common procedure in APEC work), describes a single APEC-member, not the combined APEC region. Hence, in this paper, "economy-specific" refers to the scale of a single APEC-member economy.

While APERC reports cover economy-specific overviews, trends and projections (see APERC, 2019a), analysis of successes in the empirical renewable energy policy-mixes of APEC economies, from their development to implementation and evaluation, is lacking and could be useful for knowledge sharing and capacity building across the APEC forum.

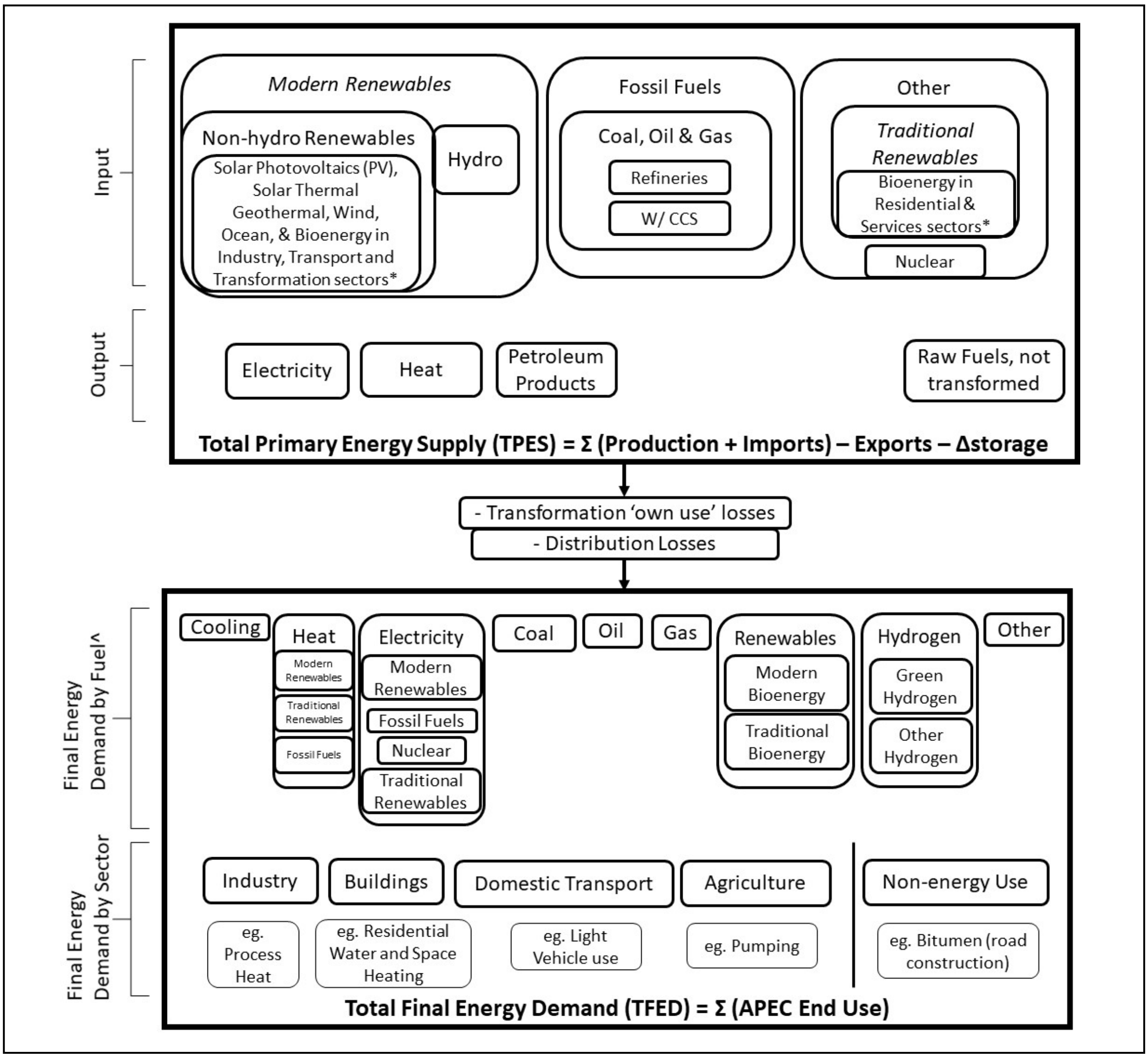

*Figure 1. Terminology Guide to Energy Flows for the APEC Doubling Goal. If a box is inside another box, it makes up part or all of the category written in the outer box. Note that total final energy demand is less than total primary energy supply due to losses. ^ Final Energy Demand by Fuel can be thought of as what is consumed. Also, * renewables are split into 'Modern' and 'Traditional' and Traditional isn't counted towards the doubling goal. Bioenergy in Modern Renewables are 'Modern Bioenergy', and all other Bioenergy is 'Traditional'. Non-energy use is not included in TFED. CCS= carbon capture and storage. Adapted from: APERC datasheet (2019).*

A 'policy-mix' is defined as encompassing policy instruments as well as "the processes by which such instruments emerge and interact" (Rogge and Reichardt, 2016: 1621).

Therefore, the main research questions are: "what are examples of current renewable-energy-policy-mixes in individual APEC economies and what generalisable policy lessons do they establish to progress the doubling goal?"

To answer these questions, a framework for analysing policy is selected from a short literature review, and evidence is provided by an overview of intergovernmental statistics and analysis of government policy and grey literature. Using this approach, the paper is structured as follows: 1) a high-level overview of the state of renewable energy uptake and policy regionally within APEC, 2) application of Rogge and Reichardt's (2016) framework to analyse the renewable-energy-policy-mixes of New Zealand and the Republic of Korea, representing economies with different natural resources and approaches to renewable energy uptake, and finally 3) discussion of the results, including comparison between case-studies and the key take-aways which transcend a variety of contexts.

Methodology

A framework for analysing policy is selected from a short literature review and applied using evidence from intergovernmental statistics, government policy and grey literature. This triangulation (Moran-Ellis et al., 2006) of scholarly policy literature with these data sources, allows for comparison and contrasting of case studies to strengthen the validity of findings.

First, a review of frameworks entails searching *Web of Science* for key terms (policy, analysis, framework, sustainability) and reviewing policy-related articles written in the past five years. Frameworks were considered for their practicality and relevance to the bounds of the research. From this, an adaptation of Rogge and Reichardt's policy mix framework (figure 2) is taken to analyse two case studies, one for each of two APEC economy-specific policy-mixes. The 'Policy Mix' framework allows boundaries for analysis to be set in line with current renewable energy policy at the economy-specific scale within APEC. Instruments considered in the case-study analyses are confined to those described in appendices 2 and 3 for New Zealand and 7 and 8 for the Republic of Korea based on a review of government and related agencies websites and documents.

Secondly, sources for synthesising key issues in renewable energy regionally within APEC are reports primarily by the Asia-Pacific Economic Cooperation (APEC) and Asia Pacific Energy Research Centre (APERC) to the most recent year of publication, because they feature the renewable energy doubling goal and the 21 economies. Also, work from the International Renewable Energy Agency, International Energy Agency, and Asian Development Bank are used. Hence, this section provides a context for analysis of economy-specific case studies.

Thirdly, for more in-depth study, two APEC-member economies are selected by applying the first of ten components of the Policy Mix framework – *policy strategy* – by tabling renewable energy targets (RET) from the twenty-one economies. Then, based on highest aspiration of RET within regions, the framework's second component – *policy instruments* – is applied to the nine economies which illustrate aspects of Rogge and Reichardt's matrix for the intersection of *type* and *purpose* of instruments. Of these, two case-study economies are selected who have different natural resources and reasonable availability of information to fulfil other components of the Policy Mix framework. Government documents and grey literature provide evidence for analysis of each case study. Notably, components of the Policy Mix framework (appendices 4 and 9) which cannot be located are labelled 'not reported'. Updated information to this draft is welcomed. Finally, case-study findings inform discussion as to commonalities and differences between cases, and the lessons which emerge.

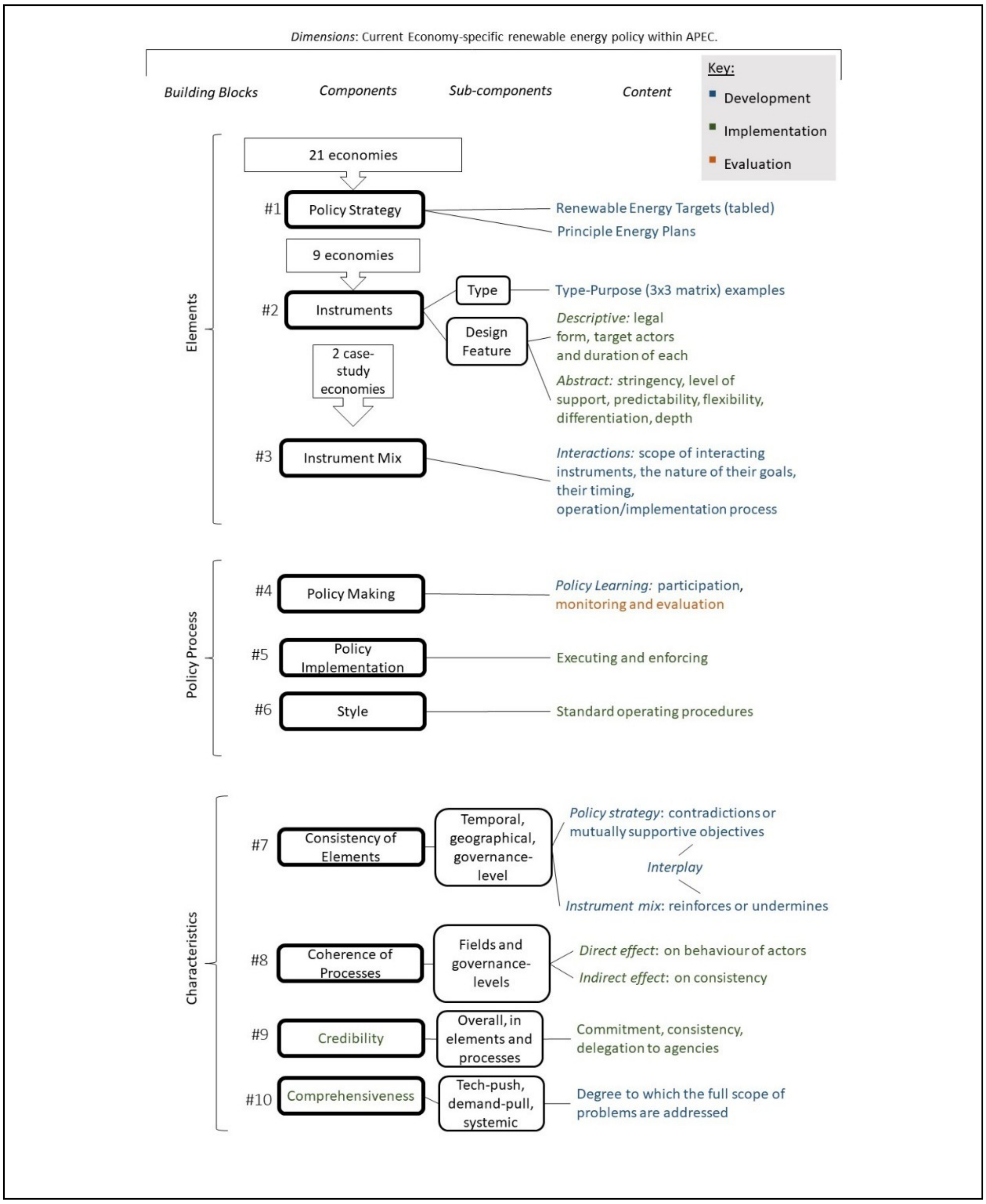

Figure 2. 'Policy Mix' Framework applied to each case study. Adapted from Rogge and Reichardt (2016).

Literature Review of Frameworks

This analysis requires structure to guide and provide bounds to the qualitative research. There are few examples in the literature over recent years of frameworks, which cover a comprehensive range of qualitative information on existing policy, yet only require a review of documents available online, which are requirements of this research.

Tuokuu et al. (2019) use Q-methodology to assess policy. This is an evolution of survey-based research (R Methodology). Q-methodology "is a scientific method for collecting statements on a particular research question or issue, and to assess the perceptions, beliefs, attitudes, concerns, and standpoints of selected individuals" (Tuokuu et al., 2019: 108). This intends to reveal patterns in the viewpoints of stakeholders to inform policymakers (Tuokuu et al., 2019). However, Q-methodology is not suited to this study because opportunity to find and communicate with participants internationally is limited.

Another example is given by Pan et al. (2019) who analyse scenarios for urban system interactions using an integrated modelling framework. This framework is unrealistic for use in this project because it doesn't directly address policy and the spatially explicit approach is infeasible to pursue at the scale of an APEC economy. Also, a multivariate approach used in defining the role of renewable energy in sustainability targets by Alola et al. (2019) is not conducive to the scale and timeline for research.

Further, the literature includes frameworks intended as tools for government authorities themselves. For example, Rai et al. (2017) create a framework for local authorities regarding sustainability of urban freight transport. This includes "cost-effectiveness analysis (CEA), social cost-benefit analysis (SCBA), multi-criteria analysis (MCA) and multi-actor multi-criteria analysis (MAMCA)… [and] a set of 45 indicators for the collection of [urban freight transport] UFT data" (Rai et al., 2017: 27). Also, Indra al Irsyad et al. (2017) discuss alternative analytical approaches involving "system thinking, life cycle thinking, and decision support analysis" (Indra al Irsyad et al., 2017: 1). While these could be adapted for this project, they again are not conducive to the scale and timeline for research.

However, Rogge and Reichardt's (2016) 'Policy Mix' framework provides a holistic range of considerations as to what policy *processes*, *elements* and *characteristics* make a policy-mix successful from its development to implementation and evaluation. This involves 10 integrated components. This approach is manageable with only a review of online documents, which makes it practical. Also, it has scope for a comprehensive range of qualitative information on existing policy, which makes it relevant. Further, this framework could be adapted to narrow-down throughout the report. Broad and inclusive impressions from across APEC are included in the first component. Then a selection of nine economies are considered by the second component. Finally, a richer analysis is made of the preceding components which are applied to two case studies individually. The structure of the final analysis is shown in figure 2.

Key Issues in Renewable Energy within APEC

This section provides a high-level overview of the state of renewable energy uptake and policy regionally within APEC framed by the doubling goal as context for analysis of economy-specific case studies. This section draws extensively on APERC publications. APERC is a relevant authority on APEC energy matters (APEC, 2019a) and reports are recent. However, future research could utilise statistics from a wider range of authors on intergovernmental and economy-specific scales, to increase validity and joint understanding.

Firstly, final energy demand (FED) under BAU shows growth to 2030 in all economies except for Japan (figure 3), where a decrease of 18 Mtoe (million tonnes of oil equivalent) between 2016 and 2030 (calculated from: APERC, 2019a) is due to population change. FED per capita in Japan remains constant between 2016 and 2030 at 2.3 toe - the APEC mean being 1.9 toe per capita (calculated from: APERC, 2019a). China and the United States (US) make up most of total final energy demand (TFED) within APEC (figure 3). China and the US also have the largest growth in FED to 2030 (figure 3), followed by Indonesia, Russia, Thailand, the Republic of Korea and Viet Nam. Overall, APEC's TFED was 5404.8 Mtoe in 2016 (calculated from: APERC, 2019a) growing to 5971.2 Mtoe in 2030 under BAU (calculated from: APERC, 2019a). However, in the case of the TGT scenario where the doubling goal is achieved, TFED is 419 Mtoe lower in 2030 (APERC, 2019).

Secondly, renewable energy capacity in APEC is greatest in China and the United States (figure 4), as is recent growth in capacity since the inception of the doubling goal in 2014. The next largest growth in renewable energy capacity occurred in Japan, Canada, the Republic of Korea, Australia and Mexico (figure 4). Overall, the total installed capacity increased by 437.13 GW (IRENA, 2019) from 892 GW in 2014 to 1330 GW in 2018 (IRENA, 2019).

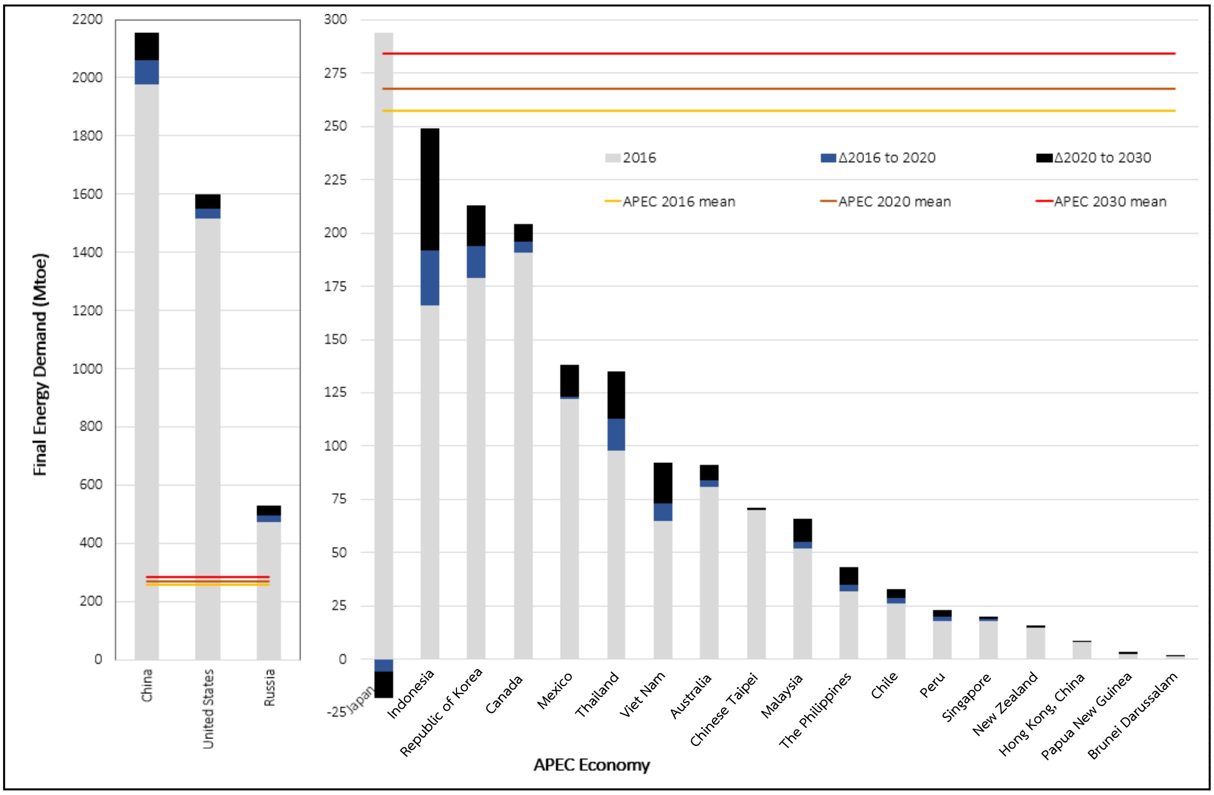

Figure 3. Final energy demand in APEC economies in 2016, with BAU projections for change to 2020 and 2030. Mtoe = million tonnes of oil equivalent. Two scales are used to include all economies. Data Source: APERC (2019a).

The capacity from renewables reached in 2018 was more than double the 2010 level of 612 GW (APEC EWG, 2017), the reference year for doubling renewables in TFED. Thus, the role of electricity generation in achieving the doubling goal goes far beyond doubling the installed generation capacity of renewables. This is because the share of renewables in TFED is diminished by concurrent demand for new non-renewable additions, prominently natural gas, to meet the increase in TFED expected in 2030 under BAU (APERC, 2019).

Therefore, accelerating the deployment of renewables is key to meeting the doubling goal. The TGT scenario suggests that a 25% increase (APERC, 2019) of the average rate of BAU capacity additions would be enough to gain the additional 851 GW needed to reach the target in 2030 (APERC, 2019). This equates to averaging 119 GW of additions (excluding pumped hydro) per year from 2016 to 2030 (APERC, 2019). The actual rate required may have marginally increased, seeing as 2016 for example had 108 GW (APERC, 2019) of additions.

Furthermore, slowing the rate at which TFED increases can promote the share of renewables in TFED by minimising the need for additions of non-renewables into the market. As such, APEC's energy intensity goal compliments the doubling goal by indirectly improving energy efficiency, which can work to reduce TFED. Hence, these factors explain why APERC finds that "improving economics for renewables, adopting more supportive policies and reducing energy demand" (APERC, 2019: 81) are critical to achieving the doubling goal.

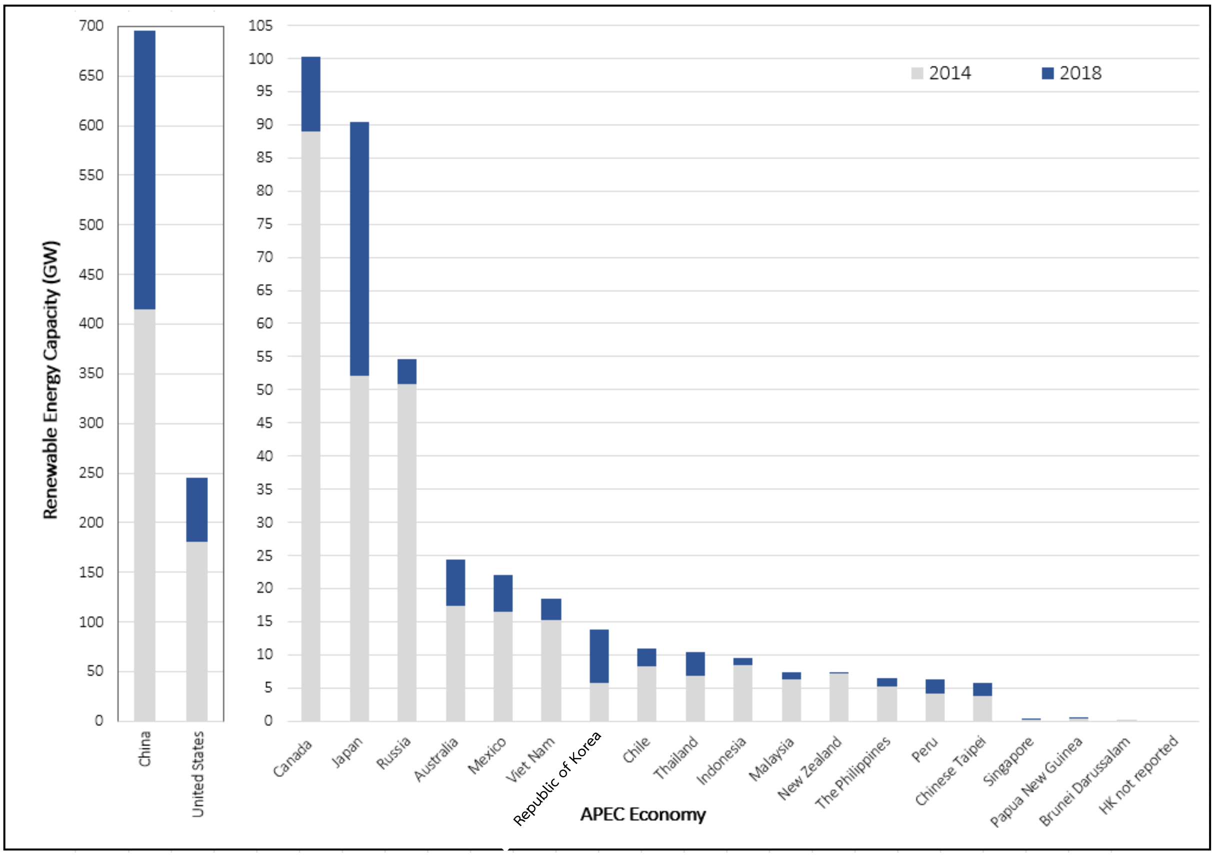

Figure 4. Renewable energy capacity in APEC economies in 2014 and 2018. Values for Hong Kong, China (HKC) are not reported in source data. GW= gigawatts. Two scales are used to include all economies. Data Source: IRENA (2019).

Additional to electricity generation, transformation of the fuel-mix used in transport and industry is central to the doubling goal. The TGT suggests that the role of the transport and industry sectors is equivalent to "38 Mtoe of additional biofuels for transport and 24 Mtoe for industry" (APERC, 2019: 81) to meet the target. Electric and hydrogen fuel-cell vehicles are expected to play a key role in future transport, focused in China and the US (APERC, 2019), where electrification shifts demand towards electricity. Industry is the largest demand sector

(APERC, 2019). Specifically, this includes use of process heat (APERC, 2019) – the "energy used as heat mainly by the industrial and commercial sectors for industrial processes, manufacturing, and warming spaces" (NZ Gov., n.d.:1). New avenues to meet process heat requirements are emerging, such as ways of refining metallic ores to make 'green steel' (OECD, 2019).

Overall, the APEC fuel-mix consists of predominantly fossil-fuels (APERC, 2019) which remain dominant in both the BAU and TGT scenarios (figure 5), however, fuel-switching occurs from coal to natural gas (APERC, 2019) and renewables emerge in the market (APERC, 2019). Further, the share of hydropower in the installed capacity of renewables has decreased from 88.9% in 2006 to 60.1% in 2015 (APEC EWG, 2017) with the growth of wind and solar capacity. Note that in figure 5, modern renewable energy makes up part of *renewables* (the rest being traditional bioenergy) and part of *electricity* (the rest being from fossil fuels and nuclear).

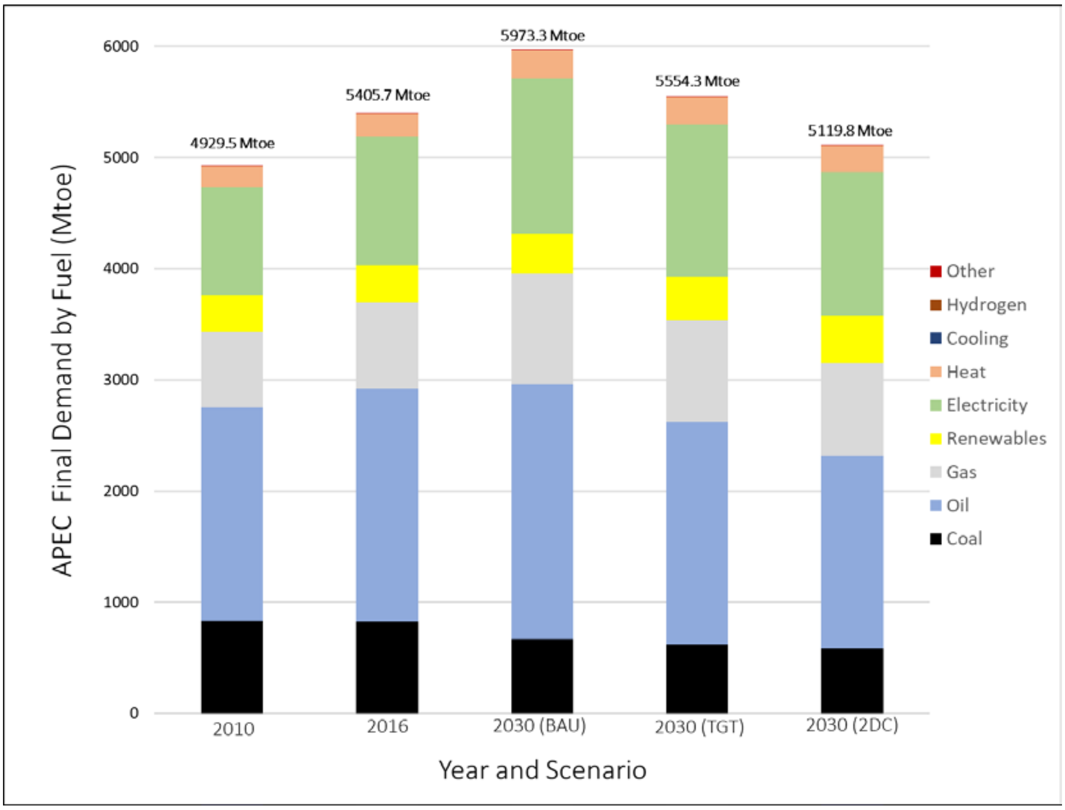

Figure 5. Change in APEC Final Demand and fuel-mix over the duration of the doubling goal. Final Demand includes non-energy use in 'other'. Data Source: APERC datasheet (2019).

Thirdly, among APEC economies it is commonplace to have renewable energy policies (figure 6), however measures (such as technological development) or specific instruments (such as feed-in-tariffs) vary among the economies (figure 6). While development of renewable technologies for example is predominant (figure 6), renewable energy certificates are utilised in around a third of policy-mixes based on economy-specific circumstances. In general, recently identified challenges for policy makers, and barriers to renewable energy development are the "effect of intermittency on grid stability… [the] cost of electricity storage… [and] policies continuing to favour fossil and nuclear energy" (Willcock, 2019: 7).

With a longer-term outlook than the doubling goal, the TGT scenario creates a net cost saving of ~USD $3.2 trillion by 2050 (APERC, 2019), while simultaneously achieving an 11% reduction of cumulative carbon dioxide emissions compared to BAU (APERC, 2019). However, as the IEA states "[i]t is Governments that set the conditions that determine energy innovation and investment… [and] to whom the world looks for clear signals and unambiguous direction about the road ahead" (2019: 6).

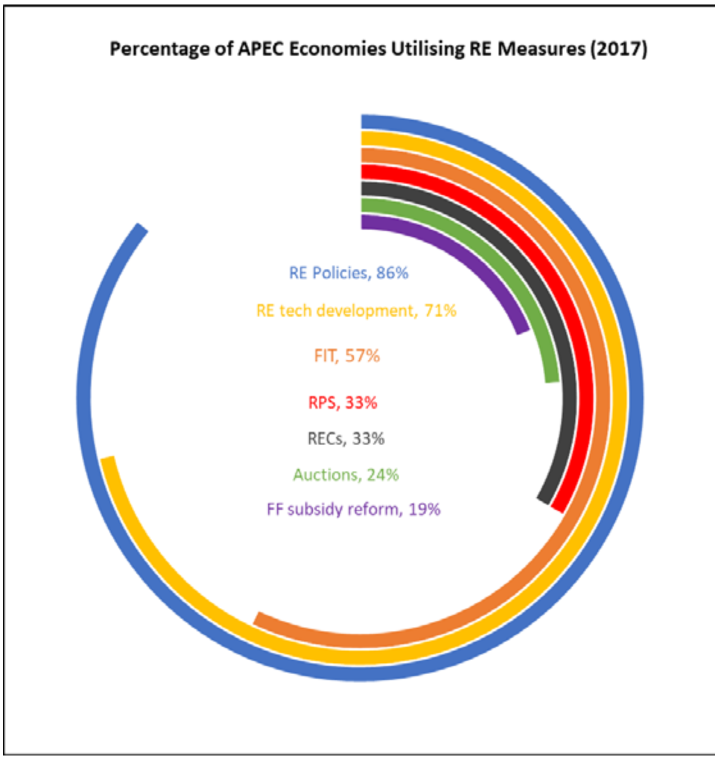

Figure 6. Utilisation rate of a selection of renewable energy measures among the 21 APEC economies in 2017. For example, 86% of APEC economies in 2017 had renewable energy policies (ie. 18 of the 21 economies). Each economy applies to more than one category. RE = renewable energy, tech = technology, FIT = feed-in-tariff, RPS = renewable portfolio standard, RECs = renewable energy certificates, FF = fossil fuels. Data source: APEC EWG (2017).

Thus, this achievement will depend on the policy decisions made by the economies, particularly during the period of the doubling goal. For example, "USD 15 trillion in power plant investment decisions [are] made through 2030 in the BAU [scenario]… [and these] projects typically have long lifespans and payback periods (i.e. more than 30 years)" (APERC, 2019:8-9) meaning that any short-term energy deployment will directly affect outcomes in 2050. Additionally, near-term decisions will define first movers who "open themselves to global markets for low-carbon goods and services… [and] secure a strategic advantage in the growing low-carbon marketplace" (APERC, 2019: 9).

Stronger economy-specific policy for renewables is clearly needed to achieve the doubling goal, and the APEC forum provides a platform for such policy learning between economies. Thus, the next section explores economy-specific energy policy using the policy mix framework. This narrows the analysis from highlighting the targets of each economy, to providing examples of policy instrument types from nine economies, and eventually focusing on case studies of two economies.

Analysis

Component 1: Policy Strategy

Renewable energy targets (RET) represent the long-term renewable energy goals of each APEC economy. All APEC economies have economy-level renewable energy targets except for the US and Canada, however sub-economy RETs exist (table 1). Furthermore, all targets extend beyond 2020 except for those of Australia and Singapore (table 1). The magnitude, timing and type of indicator(s) used in the framing of each RET orients the policy-mix.

Also key to policy strategy are the principal energy plans underpinned by these renewable energy targets. However, principal energy plans are explored per case study (appendices 1 and 6). Nine economies highlighted in table 1 are further investigated who have relatively large renewable energy targets, but also represent a diverse range of economies geographically, as well as in terms of economic development. Economic development refers to the UN classifications (UN, 2019a).

*Table 1. Renewable energy targets of the APEC economies. Orange boxes indicate economies to be applied to the 3x3 matrix (table 2). * = Sub-economy RET(s) exist in the absence of an economy target. TPES = total primary energy supply. Adapted from APERC (2019).*

Economy	Economy RET
Australia	33,000 gigawatt-hours (~23.5%) of electricity generation by 2020, nil beyond 2020 *
Brunei Darussalam	10% of generation by 2035
Canada	*
Chile	60% by 2035, 70% by 2050
China	15% by 2020 and 20% by 2030
Chinese Taipei	20% of generation by 2025
Hong Kong, China	7.5% - 10% by 2035; Increase to 15% subsequently (Hong Kong's Climate Action Plan 2050, 2021)
Indonesia	Renewables electricity as a share of TPES: 11% in 2025 and 17% in 2050
Japan	22%–24% of generation by 2030
Republic of Korea	20% generation and 34% capacity by 2030
Malaysia	7.8% of generation and 11% of capacity by 2020, 17% of generation by 2030, and 21 GW of capacity by 2050

Economy	Economy RET
Mexico	At least 35% of generation by 2024 and 50% by 2050
New Zealand	90% of electricity generation by 2025, 100% by 2035 (NZ Gov., 2019a)
Papua New Guinea	100% of generation by 2050
Peru	Reach 5% share (excluding large hydro) by 2023
Russia	4%-6% (excluding large hydro) of generation by 2030
Singapore	PV reaches ~4.5% of peak electricity demand (350 MWp) by 2020
Thailand	30% of generation by 2036
The Philippines	20 GW of capacity by 2040
United States	*
Viet Nam	38% of generation by 2020, and 43% by 2050

Component 2: Instrument Type

Instruments represent the visible actions of economies to achieve their renewable energy targets. Breaking instruments into categories based on their *type* and *purpose* (table 2) can be used as a simple guide to consider the comprehensiveness of a set of policy options. Such options are illustrated in table 2.

Examples of *systematic* instruments show the creation of markets and educational institutions (table 2), while examples for *demand pull* are more direct in auctioning, scheduling and demonstrating renewables (table 2). *Technology push* is even more direct, addressing specific audiences via price setting, competition and training (table 2).

Table 2. Example policy instruments by type and purpose (acknowledging that overlap exists in this simplification). These examples are selected to show variety and are not necessarily the main instrument applied by the given economy. Economies are selected from table 1. Typology Matrix as per Rogge and Reichardt (2016).

		Purpose		
Type		*Technology Push*	*Demand Pull*	*Systemic*
	Economic Instruments	The Philippines – Feed in Tariff and Net Metering for renewable energy (APERC, 2018).	Mexico – Auctions of power, capacity and clean energy certificates for contracts of 3 to 20 years, including buyers and sellers, facilitated by a government regulatory agency (German-Mexican Energy Partnership, 2018).	New Zealand – Emissions trading scheme, incentivising emissions reduction and promoting the competitiveness of renewables among other measures (NZ Gov, 2019).
	Regulation	Republic of Korea – Mandating new building >1000 m^2 to install New and Renewable Energy facilities equal to 12% of their energy use (KEA, n.d.d).	Chile – "…schedule for the withdrawal or reconversion of coal-fired power plants, and introducing specific measures for electro-mobility" (APERC, 2019a: 70).	Viet Nam – Renewable Portfolio Standard for largescale power generation to guide deployment (IEA, 2016).
	Information	Thailand – Specific renewable energy courses available to build capacity in business and education (Thai Gov, 2015).	China – Demonstration zones for renewable energy including specific projects such as solar thermal (PRC, 2016).	Papua New Guinea – "energy-related subjects in all higher education curricula… [and] establish[ing] an energy research institute" (APERC, 2019a: 258).

Selecting Case Studies

The remainder of the Policy Mix analysis focuses on New Zealand and the Republic of Korea. These economies differ in terms of the size of their energy demand (figure 7), the share of modern renewables (figure 7), and as later discussed in the context sections for each economy, vary in availability of natural resources as well as in their policy approach to renewable energy. These circumstances affect the achievement of doubling renewables on an economy-specific basis and thus for APEC as a collective. Hence, these case studies have been chosen to be most relevant to a wide range of APEC economies.

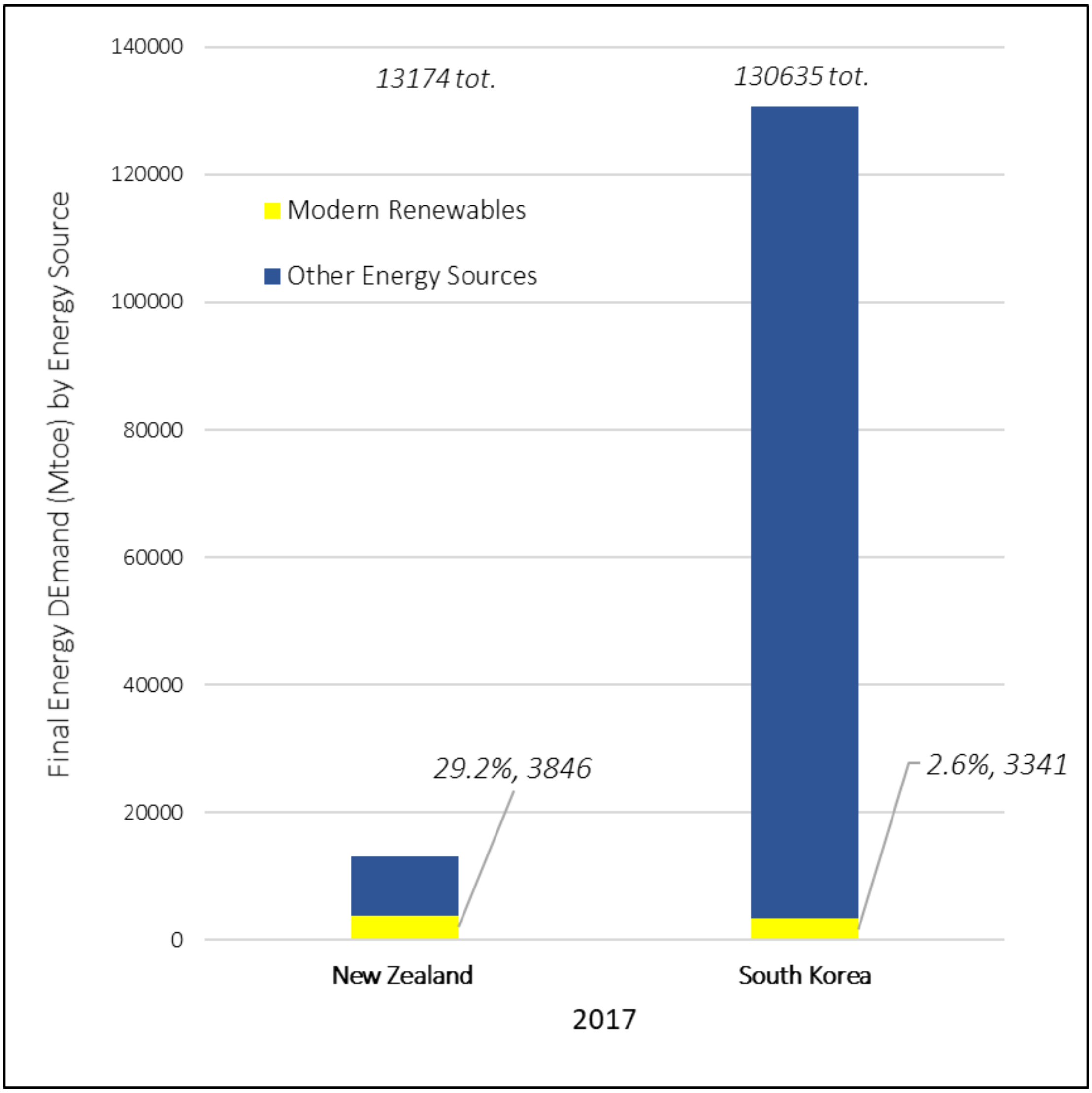

Figure 7. Final Energy Demand for the Republic of Korea and New Zealand in 2017 showing the share of renewable energy in each economy and the difference in FED. Note that FED does not include non-energy use which is significant in the Republic of Korea (see: 'context' for the Republic of Korea). Mtoe = million tonnes of oil equivalent. Data Source: APERC (2019b).

Overview of Stepwise Results

To communicate the general outcomes for each component of the framework, figure 8 uses a traffic-light summary, ranking each policy-mix as having low, moderate or high achievement. Holistically, New Zealand and the Republic of Korea show evidence of aptitude in most components (figure 8). Not surprisingly, neither policy-mix did so in every component. The plans and goals which make up *policy strategy* are shown to have room for greater aspiration for both economies. Additionally, *comprehensiveness* is reduced for the Republic of Korea because of disjointed partnership with sub-economy Governments. Components are examined for the economies individually in the following sections.

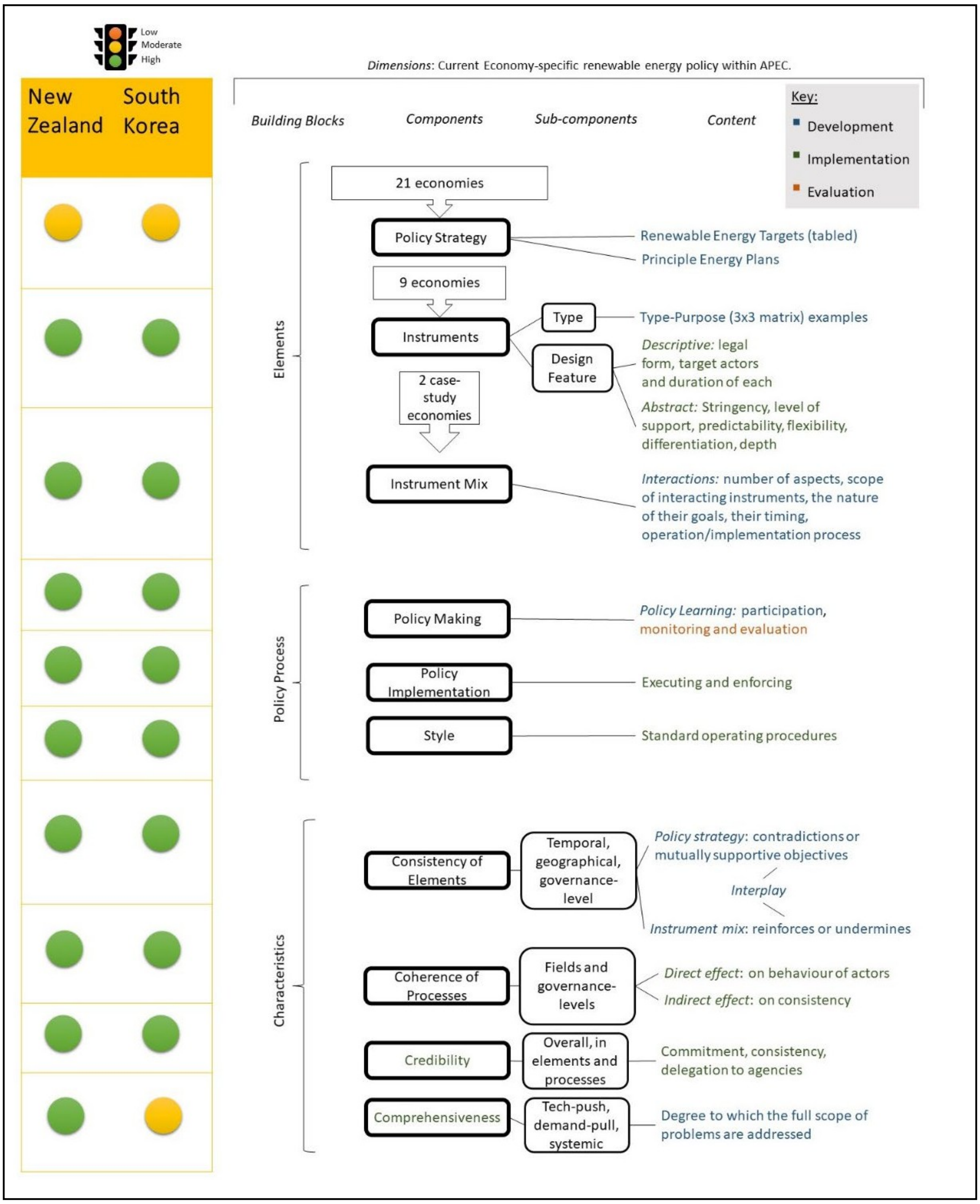

Figure 8. Overall indication of results from policy mix framework analysis in this report.

New Zealand

Context

New Zealand has a large share of renewables in their primary energy mix, 40% of supply in 2018 (NZ Gov., 2019b). This is especially the case for electricity with 84% of generation from renewables in 2018 (NZ Gov., 2019b). New Zealand also has the highest target of all APEC economies for the share of renewables in electricity, 100% by 2030 (Ardern, 2020). This target does go beyond the share of renewables in electricity under business-as-usual, which would be up to 93% by 2035 (NZ Gov., 2019a).

Electricity generation has historically been dominated by hydro – based on resource availability (ADBI, 2018) – which allowed renewables to make up 80% of generation when the wholesale market was set up in 1996 (ADBI, 2018). However, gaps in energy security filled by thermal coal reduced the share of renewables to 65.4% in 2008 (ADBI, 2018). Since then, geothermal (on the North Island) and wind resources have helped bring the share back to 84% (ADBI, 2018). Today, "energy markets are open to private-sector investment and competition, with the exception of transmission and distribution networks for both gas and electricity, which are regulated natural monopolies" (APERC, 2019a: 238). Five main generators/retails exist and "transmission costs make up a large proportion of electricity cost" (ADBI, 2018: 14).

Renewable energy targets to 2035 would see renewables in electricity increase in share by around 1% per year. While this change is above the APEC average in projections (APERC datasheet, 2019), it resembles the rate for New Zealand in an APEC Target Scenario (TGT) but falls short of the rate for APERC's 2ºC Scenario (2DC) (APERC datasheet, 2019) which reaches 100% by 2030. However, the final steps towards a 100% renewable electricity grid present specific challenges, such as grid and demand management (Stephenson et al., 2018) and transition of workforce and communities to day zero for non-renewables in the electric sector. New Zealand's experience with these challenges will provide insights for others who follow.

Progress (in the way that the doubling goal is measured, but not specifically the way that New Zealand energy targets are framed) of *modern renewables share in final energy demand* is the lowest among APEC economies – decreasing by 1.1% between the start of the doubling goal in 2010 and data to 2017 (APERC unpublished, 2020). This is because the supply of non-renewables increased faster than modern renewables which went up 2.3% (APERC unpublished, 2020).

The challenge of halting non-renewable deployment as well as accelerating renewable deployment, or the "zero-sum-game", is common among APEC economies (APERC unpublished, 2020). In New Zealand's case, this will remain a challenge as electricity demand is set to increase with the uptake of electric vehicles and electrification in buildings – the transport and buildings sectors being two of the largest energy consumers (APERC datasheet, 2019) alongside industry. Thus, improvement is also required in industry, specifically regarding process heat (NZ Gov., 2017).

While buildings, industry and transport all make up large shares of demand (figure 9), figure 9 provides an example of how fuel sources can be more diverse in some sectors than others, with implications for policy aimed at transition to modern renewables.

Energy and therefore renewable energy policy is related to emissions reduction policy via an emissions trading scheme (ETS), currently in review to be made compatible with New Zealand's emissions reduction target of 30% (from 2005 levels) by 2030 (NZ Gov., 2020) then net zero carbon dioxide (CO2) emissions by 2050 (NZ Gov., 2019d). This revision takes the ETS from having "a very limited role in encouraging emissions reductions" (NZ Gov., 2019j: 57) to leading internationally as the first emissions price to include agriculture (NZ Gov., 2019k). The following section applies the policy mix framework to analyse New Zealand's energy policy plans and actions, later compared to the Republic of Korea.

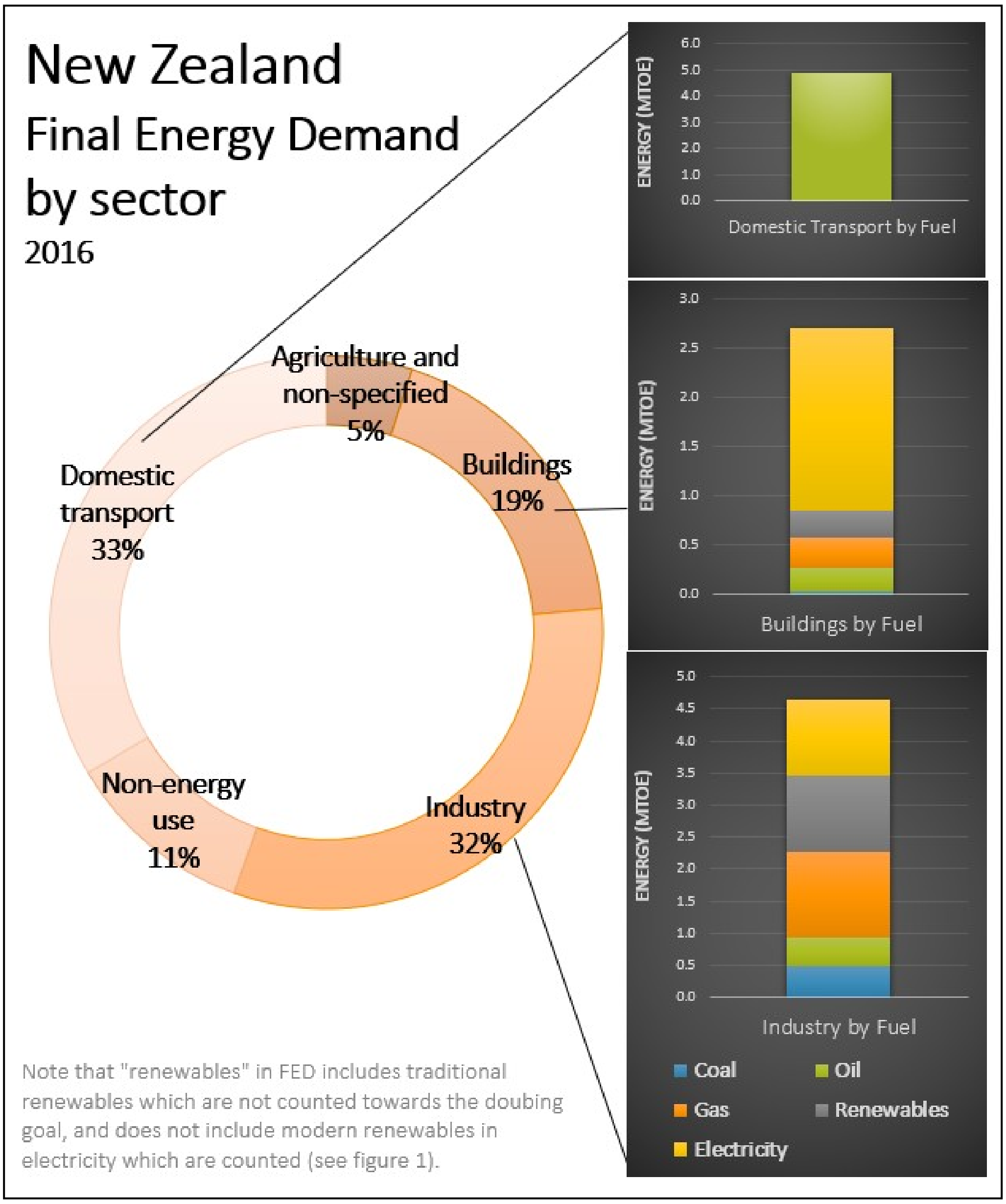

Figure 9. New Zealand Final Energy Demand in 2016. Transport, Industry and Buildings make up the majority of demand. Industry has the most diverse fuel sources. Data Source: APERC datasheet (2019).

Synthesis of Components 3 to 10

New Zealand's energy policy has in recent history been guided by two documents: *Developing Our Energy Potential: New Zealand Energy Strategy 2011-2021* (NZ Gov., 2011a) and *Energy Efficiency and Conservation Strategy 2017-2022* (NZ Gov., 2017). Now, the Zero Carbon Act (NZ Gov., 2019d) has also become central to energy plans. The overarching goal of the two former energy plans (appendix 1) is "an energy productive and low emissions economy" (NZ Gov., 2017: 8) which has a focus on improvements in process heat, transport, and efficient use of electricity (NZ Gov., 2017). These improvements are measured against three key indicators (NZ Gov., 2017: 22):

1. Decrease in industrial emissions intensity (kg CO2-e/$ Real GDP) of at least one percent per annum on average between 2017 and 2022.
2. Electric vehicles make up two percent of the vehicle fleet by the end of 2021.
3. Ninety percent of electricity will be generated from renewable sources by 2025 (in an average hydrological year), providing security of supply is maintained.

As a large source of emissions (NZ Gov., 2017), transport is a priority relevant to New Zealand's emissions reduction target, and renewable electricity supply is increasingly important for electrification of vehicles, buildings, and industrial processes, as well as for displacing fossil fuels in the existing electricity mix. These priority areas are supported by several government actions in practise (NZ Gov., 2017). Although, action towards the first indicator, as it relates to process heat, have been slower to emerge (EECA, 2021a). Also, stringency of the first indicator is undermined by exemption to exclude "chemicals, metals and electricity generation" (NZ Gov., 2017: 22) on the grounds that large firms are not the target area (NZ Gov., 2017), despite the indicator being for industrial emissions.

Flexibility of the policy mix is highlighted by the phrasing of the indicator for renewable electricity, which regards evaluation based on 'an average hydrological year' and 'providing security of supply is maintained'. This epitomises the importance of storage and demand management to facilitate high penetration of variable renewables into any grid. Further, maintaining security of supply is clearly related to resources on an economy basis, which for New Zealand means planning for drought conditions due to reliance on hydro power (ADBI, 2018).

Meanwhile, the indicator for transport is inclined towards electric vehicles. However, the low emission transport fund (EECA, 2021), investment in hydrogen refuelling infrastructure (Hiringa, 2020), and the hydrogen roadmap (Venture Taranaki, n.d) suggests progress for hydrogen. Also, the indicator of emissions intensity is bound solely by the use of gross domestic product (GDP) which is increasingly questioned as a measure (Costanza et al., 2016; Kubiszewski et al., 2013) of the 'worth' to society in this case, of emissions produced in some industries. To what extent the lack of an indicator for hydrogen will be a limitation is unclear.

The New Zealand *renewable energy instrument-mix* (below) considered in the scope of this analysis has four primary and four secondary instruments (noting that some programmes or sets of actions are described here as one *instrument* for simplicity, e.g. 'cease to offshore oil and gas exploration permits, plus transition support'). These instruments operate in the form that the government passes laws which prohibit practises (NZ Gov., 2018), set standards

(NZ Gov., 2019f) and establish agencies (NZ Gov., 2019d), create taxes (NZ Gov., 2019i) and funds (APEC, 2017), encourage and disincentivise practises and promote research and education, as well as applying influence within international platforms (NZ Gov., n.d.a):

Primary Instruments (of greatest relevance to renewables):

- Emissions trading scheme (ETS).
- Cease to offshore oil and gas exploration permits, plus transition support.
- Research funding.
- Climate Change Commission (CCC).

Secondary Instruments:

- Fossil fuel subsidy reform advocacy.
- Low emissions and electric vehicles (EV) programmes.
- Electricity switching fund and complaints commission.
- Healthy homes standard.

These instruments (described in detail in appendices 2 and 3) are differentiated to target a range of actors and several key sectors, with the ETS now in its latest iteration (first established in 2008) (ICAP, 2020) applied the most widely to include emissions intensive and emissions sink industries as well as public-sector and individual consumer choices.

Recent reforms of the ETS (ICAP, 2020) showcase the level of support for the energy agenda across the political spectrum. The National Party supports emissions reduction via means other than an ETS, advertising a fear of disadvantaged farmers and trade exposed industry (National, 2019). Alternatively, the Green Party has long been in favour of ETS reforms (Green, 2016). Despite this divide, New Zealand has greater longevity and stability of policy compared to Australia for example (ADBI, 2018), with predictability of the energy agenda being maintained by the Zero Carbon Act (NZ Gov., 2019d) which has bipartisan support to achieve net zero CO2 emissions by 2050 and requires any government of the day to work within the given framework. Additionally, standard operating procedures for the release of energy plans has been consistent since the *Energy Efficiency and Conservation Act* in 2000 (figure 9).

The nature of each instrument's goals is guided by emissions reduction and energy security as central themes, with various instruments having particular overlap. Both the *ETS* and *Electricity switching fund/complaints commission* increase competition, while the *CCC* and *research funding* both drive new knowledge. Also, *cease to offshore oil and gas exploration permits plus transition support* work to adapt workforce and community (NZ Gov., 2018c) in concert with energy systems, while the *healthy homes standard* increases energy efficiency and equity. Additionally, the *low emissions/ EV programmes* work to reduce emissions and thus require renewable electricity. Finally, the *fossil fuel subsidy reform advocacy* seeks trade arrangements and international commitments to foster cooperation in these areas.

Further, operation of instruments is also complementary. The *ETS* is influenced by advice from the *CCC*, and the *cease to offshore permits and transition support* are tightly related. Further, *cease to offshore permits plus transition support* is reinforced by *research funding* because the New Energy Development Centre (NZ Gov., 2019h) was developed in the Taranaki region – most effected by the cease to permits (NZ Gov., 2018c). Finally, *research* *funding* also shapes the success of *low emissions and EV programmes* (eg. the GREEN grid project) (Stephenson et al., 2018).

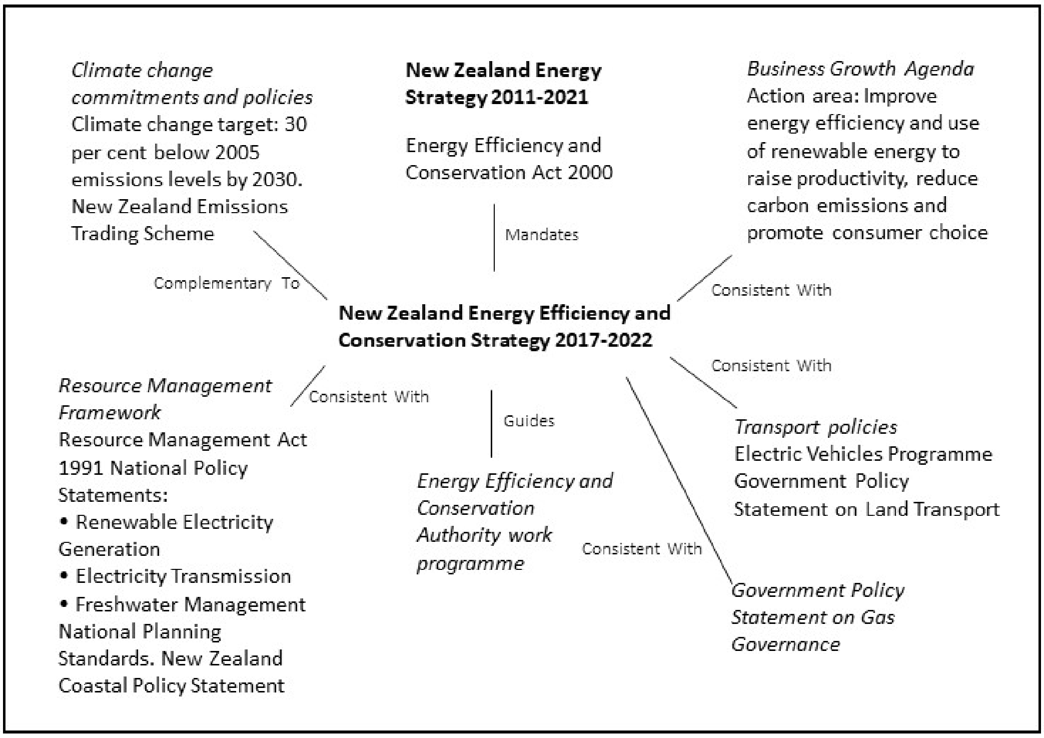

Figure 9. New Zealand Energy Plans in context. Adapted from: NZ Gov. (2017).

The participation of community, business and Governments in the Taranaki region is a leading example of how the phase-out of fossil fuels can be complementary with uptake of renewables. A hotspot of oil and gas exploration, the region is affected by the cease to offshore oil and gas exploration permits (appendix 2, box 3) and weight is placed by Governments on fairness in the resulting transition for fossil-fuel reliant communities (NZ Gov., 2018b).

From early in this transition, the Government of New Zealand has acted as an ally to sub-economy Governments (regional council and local councils) (NZ Gov., 2018c) to support the creation of a community roadmap for the region to 2050 (see: Venture Taranaki, 2020) which now guides the short and longer-term transition. The roadmap included business and community input, extended to school children and was aided by academic advice, all facilitated by the cooperation of levels of Government.

The New Zealand Government facilitated the process with the creation of a 'Just Transitions Unit' who hosts discussion "between government, Māori, business, the workforce, and communities" (NZ Gov., 2018c: 3) such as a summit in 2019 and other roundtables (see: NZ Gov., 2018d) to identify impacts and opportunities. At the 24th Council of the Parties, New Zealand showed their appreciation for transition support by signing the UNFCCC *Silesian Declaration on Just Transitions* (COP, 2018), and delivered on this position, providing investment from the Provincial Growth and Green Investment Funds for NZ $20 million towards projects diversifying the economy of Taranaki (NZ Gov., 2018b).

Central to the transition; the decision to stop these fossil fuel permits was not in isolation from the decision to create new green industries. Instead, the hub for energy innovation of the future, the *New Energy Development Centre*, was set up in Taranaki (NZ Gov. 2019h) allowing local business to continue playing a key role in providing energy for New Zealand.

More generally, participation is evident in the policy cycle – it is mandatory in approval procedures for large-scale renewable energy projects (Schumacher, 2019), industry groups commonly respond to draft policy documents like the Energy Efficiency and Conservation Strategy (NZ Gov., 2017a), and an independent climate change commission was established to provide insights from experts in the field (CCC, 2019). However, participation appears to be limited by the window of time open for input (twenty days for large-scale renewable projects), as part of streamlining the approvals process, which for large-scale renewables takes around ninety days (Schumacher, 2019).

Central to participation and the developments in Taranaki is the coherences of processes between government actors which effects the success of implementation directly via behaviour and indirectly via consistency. Integration and coordination between federal and local administrators of policy are established by the *National Policy Statement for Renewable Electricity Generation* and its implementation guidelines (see: NZ Gov., 2011) which acts as a framework for the relationship between and responsibilities of central and local authorities for managing renewable electricity in policy. For example, under the statement, monitoring and evaluation is a requirement of the Minister for the Environment (NZ Gov., 2011). This proactive approach has benefited New Zealand's policy-mix.

The importance of monitoring and evaluation to the New Zealand policy mix is clear by investment towards data collection (NZ Gov., 2017), publishing of statistics about the state of energy (NZ Gov., 2019b) and progress of policy instruments (NZ Gov., 2016b) for the participation of stakeholders, and the creation of the CCC to monitor and evaluate relevant policy.

The operation of instruments would be flawed without a democratically established legal basis for enforcement – for the ETS "failure to surrender emission units results in a requirement to make good those units alongside a financial penalty of NZ$30 per unit. Interest accrues until the penalty is paid. Failure to comply with data collection, record-keeping, reporting, registration, or notification requirements carries a fine. Knowingly providing false information carries a larger fine and/or a prison term" (Leining and Kerr, 2018: 11).

Overall, the policy strategy, instruments and instrument mix are reinforcing. Firstly, the renewable energy target matches principal energy plans, integrated with wider political strategy for emissions reduction (figure 9). Also, the target for renewables in electricity compliments targets in transport and process heat. Further, instruments are complementary – especially between *research funding* and *cease to offshore oil and gas exploration permits plus transition support,* and *research funding* with *Low emissions and EV programmes*. The same applies for the *ETS* and the *CCC*. Finally, the *healthy homes standard* complements (via efficiency) but does not interact with other instruments, while the *fossil fuel subsidy reform advocacy* operates with its own international outlook.

The credibility of the policy mix is supported by bipartisan commitment to the long-term net-zero CO2 emissions target by 2050 (NZ Gov., 2019d), with medium-term reviews (5 yearly)

(NZ Gov., 2019d), plus the standard operating procedures for release of guiding energy documents and the proactive cooperation framework between governance levels - providing basic certainty. Further, the independence of the CCC's advice, delegation to agencies like the Electricity Authority to act as a market watchdog (APERC, 2019a), and the legal basis to enforce regulations, provide further believability and reliability to the policy mix.

However, the share of modern renewables in final energy demand has decreasing by 1.1% between the start of the doubling goal in 2010 and data to 2017 (APERC unpublished, 2020). This observation undermines the international credibility of the policy mix, and hence greater aspiration of the policy strategy to amend this decline is needed. This is reflected in figure 8 results.

Key sectors (process heat, electrification in transport, and renewables in electricity) are largely addressed by policy instruments and processes. The electricity target is addressed most directly via the *ETS*, *cease to offshore oil and gas exploration permits*, *research funding* including as part of Taranaki's transition, and to a lesser extent the *electricity switching fund and complaints commission*. Further, the *fossil fuel subsidy reform advocacy* extends the scope to the international agenda. The transport goal is served by a programme of instruments (appendix 3, box 7), some of which extend until the target it met (NZ Gov., 2019i). Finally, the target for industry is provided for by the Government Investment in Decarbonising Industry Fund (EECA, 2021a).

Therefore, while little is done to directly deploy more renewables, a market-based approach is taken which incentivises renewable energy especially through the ETS. However, direct action towards the phase out of fossil fuels is taken by ceasing new offshore oil and gas exploration permits. The target for renewables is in electricity which plays to the strength of New Zealand's already high share of renewable generation. This is a leading example of the push towards a 100% renewable grid (NZ Gov., 2019a) and is key to 'piggybacking' of the transport and industrial sectors towards being powered by renewable electricity.

Republic of Korea

Context

The history of energy in the Republic of Korea has been shaped by many of the same *factors* as it has in New Zealand. These factors include from resource availability, to privatisation, increasing demand, social and political ties to the status-quo being replaced by demand for emissions reduction, the desire to protect industry competitiveness in trade and security of supply, and an increasing awareness of low-carbon market opportunities. However, the circumstances of many of these factors has been different in the Republic of Korea.

Low resource availability (APERC, 2019a) led to high reliance on energy imports (APERC, 2019), sparking the desire for independence via domestic nuclear energy (MOTIE, 2014). The Republic of Korea now has the highest density of nuclear reactors globally (Sun-Jin, 2019), and coal imports remain high (APERC, 2019a).

The rush towards energy independence left safety gaps in regulation and practise (MOTIE, 2014), and public pressure exacerbated by the Fukushima disaster in Japan (MOTIE, 2014) in 2011 has led to nuclear being phased out, which may take 60 years (APERC, 2019a), to be replaced by renewables (APERC, 2019a). Additionally, there is a move away from coal imports: to reduce particulate matter problems (Jensterle et al., 2019), in response to climate change (MOTIE, 2014), and to reduce reliance on imports (APERC, 2019a). The Republic of Korea's Paris Agreement contribution is to reduce emissions by 37% from an 851 Mt baseline (Cornot-Gandolphe, 2018).

The dual transition – out of nuclear domestically and out of coal imports – is a challenge for maintaining energy security (APERC, 2019a). As a result, gas imports are to be used (APERC, 2019) in conjunction with increased domestic solar and offshore wind (APERC, 2019a). New floating storage regassification units may be used to foster imports of gas (APERC, 2019). The potential for international trade in electricity is highlighted by the signing of a memorandum of understanding to promote grid interconnection between transmission companies in the Republic of Korea, China and Russia (APERC, 2019). While no formal intergovernmental agreements have yet been made (APERC, 2019), the Republic of Korea encourages the concept of a 'Northeast Asia Super Grid' (see: MOTIE, 2019: 14).

Imports provided around 86% (crude oil, coal, gas) of energy supply in 2016 (APERC datasheet, 2019). Domestic production was dominated by nuclear, at 83% (APERC datasheet, 2019). While oil is the largest fuel source (APERC, 2019a), just over half is used as non-energy use (APERC datasheet, 2019) - "energy products used as raw materials that are not consumed as fuel or transformed" (APERC, 2019a: 176) such as in petrochemical industry to make plastics (APRERC, 2019). Also, the Republic of Korea has a large oil refinery capacity (APERC, 2019).

Four sectors shared most of consumption in 2016 (APERC datasheet, 2019) – buildings (24%), industry (27%), non-energy use (28%), and domestic transport (19%). It has been suggested that transport and buildings are areas to focus on for decarbonisation (APERC, 2019a), due to contribution of industry (specifically manufacturing exports (APERC, 2019a)) and non-energy use to GDP (APERC, 2019a). Also in manufacturing, the Republic of Korea plans to be an early mover in the hydrogen economy (APERC, 2019).

The Republic of Korea is one of five APEC economies on track in a BAU scenario to achieve the doubling goal (APERC unpublished, 2020). In 2017, modern renewables accounted for 2.6% of FED (APERC, 2019b). Despite this share being far less than that in NZ (figure 7), the Republic of Korea's renewable energy capacity has outgrown that of NZ since 2014 (figure 4). FED is around ten times larger in the Republic of Korea (figure 7). Between 2010 and 2017, modern renewables increased in share of FED by 1.3% (APERC unpublished, 2020). Solar was the primary renewable in electricity (calculated from APERC data, 2019) and waste-to-energy in bioenergy use (Lee, 2017). The renewable energy target is for 20% of generation and 34% of capacity by 2030 (APERC, 2019), then 30 to 35% of generation by 2040, up from 7.6% in 2017 (MOTIE, 2019).

tis one of the fastest growing APEC economies (APERC, 2019a). Demand for energy was below the APEC 2016 average (figure 3) but final energy demand per capita was above average (APERC datasheet, 2019). FED under BAU could increase by 32% by 2050 (APERC, 2019a), however this rise is considerably less if achieving the TGT scenario (APERC, 2019a). It is suggested that significant efficiency gains are possible in industry

(APERC, 2019a), which may be central to increasing the share of modern renewables as it can decrease reliance on imported gas.

Distributed generation (APERC, 2019a) and smart grids are of high interest and the Republic of Korea is an emerging leader in this approach and related technologies. Smart grids reduce the need for large generation and transmission land-use, which is important because space has become a limiting factor in energy developments due to not-in-my-backyard opposition (Jensterle et al., 2019; MOTIE, 2019). Additionally, social pressure has called for a more participatory and democratic energy system (Sun-Jin, 2019), with community and co-op models and public-deliberation (MOTIE, 2014). Further, with few hydro-resources, battery and fuel-cell storage used in smart grids is needed to accompany renewables. Further, the smart grid platform can facilitate demand management.

Of note, power generation has been liberalised, but there remains low competition, while transmission, distribution and retail are state operated by Korea Electric Power Corporation (Jensterle et al., 2019). Also, the energy paradigm in the Republic of Korea often considers a version of *renewable energy* ("solar, wind, hydro (including hydropower >10 MW), ocean(tide), geothermal, bioenergy, and waste" (Jensterle et al., 2019: 10)), together with *new energy* ("hydrogen, fuel cells, coal to liquid, and coal to gas" (Jensterle et al., 2019: 10)) as one concept – *New and Renewable Energy* (NRE). The following section analyses the plans and actions of the Republic of Korea using the policy-mix framework.

Synthesis of Components 3 to 10

The Republic of Korea's principal energy plans (appendix 6) are described by the *Third Energy Master Plan 2019* (MOTIE, 2019), which provides the direction for various other energy planning documents. The vision of the master plan is to "achieve sustainable growth and enhance the quality of life through energy transition" (MOTIE, 2019: 3). The plan sets out 8 goals, with about 11 objectives and 22 indicators (MOTIE, 2019):

1. Innovation in the energy consumption structure.
2. Transition towards a safe and green energy mix.
3. Improvement of energy security.
4. Enhanced energy safety management.
5. Expansion of distributed and participatory energy systems.
6. Global competitiveness of the energy industry.
7. Better infrastructure and market systems for energy transition.
8. More infrastructure for energy transition.

This addresses the challenge of growing energy use per capita (APERC, 2019a) and the desire for energy supply without nuclear, large reliance on imports (Jensterle et al., 2019), or hazardous pollution (Sun-Jin and Yeon-Mi, 2017). It reflects calls for a more inclusive energy system (Sun-Jin, 2019), and a vision for the future of the significant manufacturing industry (Jensterle et al., 2019). Overall, it shows that a district transition of energy infrastructure, operation and use is to take place with the aim of improving well-being.

Indicators (appendix 6) for the objectives underlying these goals are stringent; specifying specific, measurable outcomes, except for indicators for creation of new businesses and market systems which are unspecific or missing, although other indicators show progress towards facilitating such systems. Further, the role of gas and the phase out of coal is vague in the masterplan, however is described in the *Eighth Basic Plan for Long-term Electricity Supply and Demand 2017 to 2031* (MOTIE, 2017) which suggests that the share of gas in power generation will be 18% in 2030 up from 16.9% in 2017 and coal 36.1% down from 45.3% (Cornot-Gandolphe, 2018).

Although, reduction to coal fired power depends on energy stability: “coal fired power generation will be drastically reduced to within the range necessary to secure a stable supply and demand” (MOTIE, 2019: 12). Like New Zealand, energy security remains the top priority.

t’s short and long-term targets (appendix 6) and considerable stringency and breadth of support provide a level of predictability. Support is high for the policy mix, especially a discourse away from nuclear with four of five candidates for the 2017 presidential election “promised to shut down the aged nuclear and coal power plants and replace them with gas and renewables” (Jensterle et al., 2019: 23). Further, various acts of parliament mandate the creation of action plans from any government of the day, delivering a level of consistency.

The Republic of Korea’s *renewable energy instrument-mix* (below) considered in the scope of this analysis has five primary and one secondary instrument (noting again that some programmes or sets of actions are described here as one *instrument* for simplicity, eg. ‘smart grid and distributed energy developments’ which involves more than a dozen individual actions). Instruments operate (appendices 7 and 8) in the form that the government of the Republic of Korea creates legislation (box 11) and standards (box 14), provides funding (box 15) and subsidies (box 13), sets tariffs (boxes 12 to 13), creates agencies (box 16) and companies (box 12), supplies infrastructure (box 13), and facilitates public deliberation (Sun-jin, 2019):

Primary Instruments (of greatest relevance to renewables):

- Smart grid and distributed energy developments.
- Demand management instruments.
- Low emissions vehicles instruments.
- Renewable portfolio standard (RPS).
- Research, development and demonstration (RD&D) investment.

Secondary Instruments:

- Energy Efficiency and Climate Change Bureau.

These instruments (described in detail in appendices 7 and 8) like those of New Zealand are differentiated to target a range of actors and several key sectors, with the RPS (KEA, n.d.) providing the basis for many other instruments in the market between renewable energy generators extending supply, and retailers extending demand for renewable energy.

Most instruments existed prior to but were upgraded or reinforced by the 2019 master plan. The focus on smart grids and demand management came about from the 2014 master plan, alongside changes to the role of public participation in creating the 2014 masterplan. This changed public opinion from being an uninfluential last-minute addition in the first masterplan in 2008, to being formally acknowledged from start to end (MOTIE, 2014).

Learning from the past, the policy mix includes emphasis on safety, for instance "76 billion won worth of investments into safety facilities within five years" (MOTIE, 2019: 12) of the 2019 master plan.

Public Participation was key in the decision to phase out nuclear power facilitated by a public engagement commission (Sun-Jin and Yeon-Mi, 2017). With about 60% public support, this also resulted in the decision to continue building multiple reactors that were under construction to avoid lost investment (Sun-Jin and Yeon-Mi, 2017), which will now draw the desired phase out of nuclear over sixty years (APERC, 2019a). Additionally, participation is engrained in the direction of the master plan, which encourages consumers to also be producers of energy in the smart grid network ('prosumers') (MOTIE, 2019) which includes household, business and community batteries, and to have a better understanding of their energy consumption.

However, while focus on implementing a new energy system is strong, there is no plan for the transition of workers, businesses, and communities who have high reliance on nuclear and coal industries (Climate Analytics, 2020), despite being a signatory of the Silesian Declaration on Just Transitions (COP, 2018), alongside New Zealand. For example, Sun-Jin and Yeon-Mi (2017) highlight the need to include workers (eg. the Korea Hydro and Nuclear Power labour union) in planning a transition from nuclear-based work. Despite this, provincial governments in the Republic of Korea have stepped up as leaders in North-east Asia, joining coalitions to advocate for the swift phase-out of nuclear and fossil fuels and smooth transition to renewables.

For instance, *South Chungcheong Province,* which hosts around half of the Republic of Korea's coal power generation capacity, joined the *Powering Past Coal Alliance* in 2018 (Climate Analytics, 2020). This government has introduced its own energy centre (The Korea Times, 2019) to take a leading role in the energy transition and has created a *2050 Energy Vision Plan* (PPCA, 2020). The plan would close 14 coal fired power plants by 2026 (18 GW) (PPCA, 2020a) and increase the local share of renewables in generation from 8 to 48% (PPCA, 2020a). However, success depends on the central government who retain some regulatory powers (PPCA, 2020). Advocacy by provincial governments has led the central government decision to close two coal fired power plants in South Chungcheong Province in 2020 before the end of their scheduled lifetime (PPCA, 2020), with accompanying measures to foster employment to be devised also in 2020 with few details evident (PPCA, 2020).

Thus, the government of the Republic of Korea has not taken the approach of New Zealand to partner with provincial Governments to facilitate coherent planning and maximise opportunities for win-wins in the phase-out of old and phase-in of new energy systems. The financial and organisational support in this regard could be expected to be more crucial in the case of South Chungcheong Province, which has a population of two-million people (PPCA, 2020), than in Taranaki with 110,000 people (NZ Gov., 2020a). The lack of multi-level government co-operation is a barrier to the success of the policy mix and a missed opportunity for translation of skills and a fair transition. This is reflected in figure 8 results.

The instrument-mix operates well. *RD&D* informs the development of all instruments, as can the *Energy Efficiency and Climate Change Bureau*. The *RPS* increases the supply of renewable energy, which is needed for electric vehicles to be low-emissions, and for hydrogen vehicles to be fuelled by green-hydrogen (although this may be imported) (Jensterle et al., 2019). Further, low emissions vehicles are becoming integrated into the smart grid network (eg. ‘Vehicle to Grid’ connection as a second use for electric vehicle batteries) (appendix 7, box 12). Also, the smart grid network complimented by the *RPS,* increases supply of renewable energy and facilitates demand management (box 12).

Further, the nature of each instrument’s goals overlaps. Foremost, the *RPS* increases the share of renewables in the energy mix, especially where combined with storage. This works towards reducing particulate matter and greenhouse gas emissions, placing the Republic of Korea as a leader in the low carbon market, and delivering a safe energy system (MOTIE, 2019). The *low emissions vehicles instruments* work towards the same outcomes and aim to integrate into the operation of smart grids. *Smart grid distributed energy developments* work towards a green energy mix based on renewables that has many small-scale points of renewable generation and energy storage (appendix 7, box 11). This also works to make the energy system participatory, allowing prosumers, facilitating demand management, and associated new business models. The *demand management instruments* work to reduce energy consumption, especially at peak times, which aids the integration of renewables into the grid and reduces reliance on fossil fuels. Finally, *RD&D* aims to improve outcomes in all these areas, with the same end goals, as does the *Energy Efficiency and Climate Change Bureau* by providing advice to Government.

For example, this looks like the RPS providing an incentive for a solar PV rental business (see: KEA, n.d.e), where the customer purchases the service of PV installation, operation and maintenance. The consumer makes a net saving; paying for the service with savings from reduced electricity bills, which provides income for the business who can also sell the renewable energy certificates associated with their PV panels to energy suppliers who have obligations to surrender certificates to the regulator as a percentage of their total generation. Thus, renewables are deployed in a distributed system and can be included in a smart grid; facilitating prosumers as part of a new business model where safety is upheld by qualified maintenance.

This kind of service economy business is conducive with circularity of the economic system (a ‘circular economy’) (WEF, 2014) because the service provider retains ownership of the hardware, and thus is rationally incentivised to provide a) PV panels that last, b) are repairable and upgradeable, and c) to re-use and recycle the materials from the panels to maintain their economic value.

This kind of circularity is recognised by the government of the Republic of Korea as important to the lifecycle net-benefit and long-term prospects of renewable energy, with related consumption of finite resources and production of waste set to increase as the share of renewables in the energy mix increases (Kim and Park, 2018). As such, the government of the Republic of Korea is taking leadership in (KEA, n.d.e; MOTIE, 2018):

- Encouraging circular business models like the PV example, via the Korea Energy Agency.
- Setting standards and common components for consumer confidence and reparability, including for energy storage systems. As well as promoting international standardisation.
- Providing a triaging repair service centre.
- Establishing a centre for recycling of PV modules.
- Setting wind turbine blade waste management guidelines.

The execution of policy involves the Ministry of Trade, Infrastructure and Energy who establish plans and projects, the Korea Energy Agency who set standards, and the New and Renewable Energy Centre who oversee the whole process including administering instruments and partnering with companies – each with some overlap (KEA, n.d.a).

The success of policy instruments requires enforcement which similar to New Zealand applies under an *Act on the Promotion of the Development, Use and Diffusion of New and Renewable Energy* (IEA, 2013), as a legal basis for the RPS for example.

A system of legislated acts and the energy plans which they mandate (figure 10) provide consistency and a depth of short and long-term, narrow and broad plans for the energy system. This promotes the ongoing evolution of the Republic of Korea's energy discourse (Jensterle et al., 2019). From observations during this analysis the current plans in figure 10 are consistent are re-enforcing, and this also appears to be the case for each plan between years.

Policy learning is crucial for the evolution of policy with social and technological uncertainty such as Korea's energy transition. Monitoring and evaluation done by the Korea Energy Agency applies the *Energy Management System* standard (KEA, 2015).

The large number of official plans, goals, instruments, indicators, investment and other expenditure suggest that commitment is high. Further, the use of legislated acts which mandate creation of plans regardless of the government of the day, provide a level of continuity. Also, delegation such as the creation of a *Public Engagement Commission* (Sun-Jin and Yeon-Mi, 2017) and the *Safety Management Committee* (MOTIE, 2019) promote credibility.

While commitment, continuity, and delegation enhance credibility, there are undermining inconsistencies. Internationally, while the Republic of Korea's energy plans establish that fossil fuels are unfit for the life that their citizens wish to lead, the government continues to invest in coal plants in South-East Asia (Climate Analytics, 2020).

The Republic of Korea's energy transition is supported by a comprehensive policy-mix. Renewable energy generation at large and small scales is addressed, especially via the *RPS* with weighted certificates (KEA, n.d.), and this underpins the energy transition alongside progress towards efficiency. However, gas is still considered as necessary to the future fuel-mix (MOTIE, 2019). Storage, as a key part of renewables integration into the grid, is considered in a way that makes energy more participatory, stimulates new business and allows for efficiency gains, using a smart grid set-up, supported by various investments and developments.

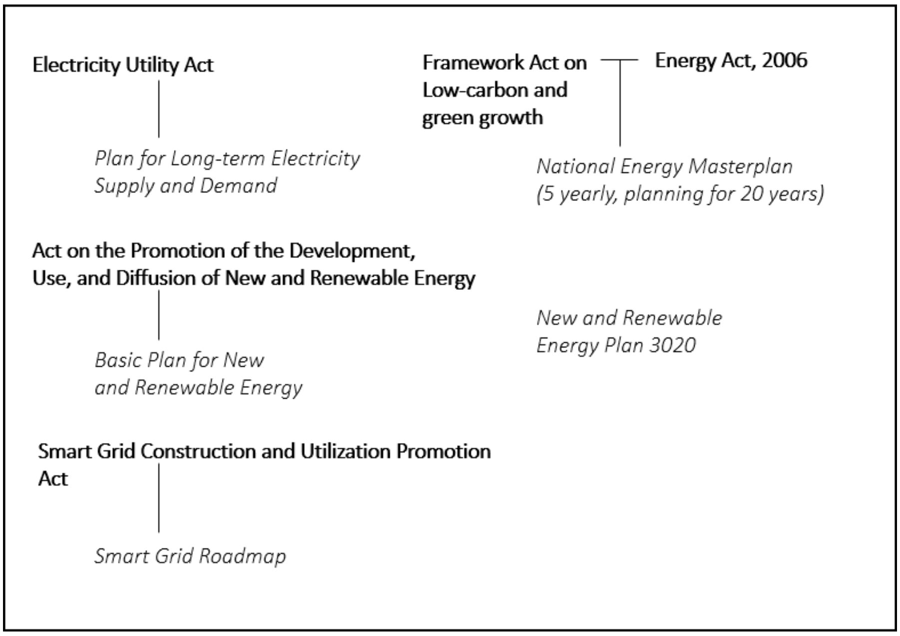

Figure 10. Structure of Energy documents in the Republic of Korea. ***Bold*** *= legislation, Italics = name of document produced based on the associated act. New and Renewable Energy Plan 3020 has no specific associated Act. Adapted from: Jensterle et al. (2019).*

Transport, industry, buildings and non-energy use made up 98% of consumption in 2016 (APERC datasheet, 2019). Transport is addressed via fuel efficiency standards (including for heavy-duty vehicles) and charging infrastructure to advance the low-carbon fleet (appendix 7, box 13). Industry is at the forefront of demand management with incentives and monitoring (box 12). Buildings are also key, with new standards for low-carbon living and working in the future, as prosumers (box 11). Finally, non-energy use is addressed by the advancement of industry towards being leaders in hydrogen vehicles and smart grids (box 15).

Although, concrete plan-making, skill-translation and re-training of the workforce in transition from nuclear and coal related industries appears to be lacking (Climate Analytics, 2020), despite the Republic of Korea being a signatory of the Silesian declaration on Just Transitions (COP, 2018). Focus on bringing in the new age of energy without enough consideration for phasing out the old could undermine the energy transition.

Finally, while the *Eighth Basic Plan for Long-term Electricity Supply and Demand 2017 to 2031* would cut emissions from electricity generation by more than the emissions reduction target for electricity in 2030 (Cornot-Gandolphe, 2018), generation at this time will remain around 60% nuclear and coal powered (Cornot-Gandolphe, 2018). In this vein, there are calls to suggest that aspiration for the rate of energy transition in the Republic of Korea could be increased (Climate Transparency, 2019). This is reflected in figure 8 results. Furthermore, investment in gas infrastructure (APERC, 2019a) could leave a legacy of stranded assets, which, like is the case for the recently constructed nuclear plants, will draw the transition out over many years, at the detriment of the master plan's vision for energy change.

Overall, renewable energy goals and the instruments which promote deployment of renewables are integrated into wider energy policy. Further, all energy goals are conducive to and underpinned by renewable energy (appendix 6). Additionally, instruments are complimentary and support the objectives. Finally, the increasing number of variable renewables in the grid is supported by demand management, which is facilitated by rollout of smart grids and electric vehicles, all supported by RD&D.

Discussion

The Policy Mix Framework

The analysis framework used in this report adapted from Rogge and Reichardt (2016) has proven effective at guiding research towards a holistic appreciation of renewable energy policy beyond a focus on isolated instruments. Without the framework, instruments would have been more dominant in the analysis because information is more accessible.

Difficulty in finding evidence increases from instruments to the interaction of the instrument mix. More-so, the details of policy making such as monitoring and evaluation procedures are often inaccessible online. This difficulty limits the scope of the third building block – *characteristics* – which considers consistency, coherence, credibility, and comprehensiveness of only what has been uncovered earlier in the research.

As such, research should take into account that policies are inherently organised and showcased to be complementary. Conceivably, information on fossil fuel subsidies which may counteract renewable energy policy, is not likely to be located within principal energy plans about green growth. Therefore, scoping of information on such energy matters – if they are not addressed by relevant principal energy plans – is advisable to avoid bias results.

Finally, some evidence for every aspect of the framework was able to be located for this report in a reasonable amount of time, and the time taken was reduced for the second case study, with knowledge of the types and sources of information which proved useful for the first case study. Thus, the concept of the policy mix and the path it provides for policy analysis may be informed by the report's original analysis structured for each component, provided in appendices 4 (New Zealand) and 9 (the Republic of Korea).

Analysis Findings

Both New Zealand and the Republic of Korea have set principal energy plans (MOTIE, 2019; NZ Gov., 2017) with a similar vision of green growth via a transition to renewable energy in combination with efficient energy use. For both economies, integrating renewables securely into the grid is a key challenge at odds with the zero-sum game (APERC unpublished, 2020) required to achieve the doubling goal – swapping coal with renewables without adding new fossil fuels like natural gas.

In both cases the transport fleet is set to be replaced with low-emissions vehicles (relying on a swift increase of renewables) (MOTIE, 2019; NZ Gov., 2017). Additionally, efficient energy use in industry and buildings is financially encouraged (Jensterle et al., 2019; NZ Gov., 2017; NZ Gov., 2019f), and research, development and demonstration are pivotal at all stages of the energy transition (MOTIE, 2019; NZ Gov., 2019h).

New Zealand is directly halting new offshore oil and gas exploration permits (NZ Gov., 2018b), and the Republic of Korea will have no new nuclear plants (MOTIE, 2019), although reductions for coal are inexplicit, instead focusing on encouraging deployment of renewables. As such, New Zealand has partnered with their sub-economy Governments to support a fair transition (NZ Gov., 2018c), which remains disjointed in the Republic of Korea.

Where New Zealand has an emissions trading scheme (NZ Gov., 2019) central to its instrument-mix and fewer instruments overall, the Republic of Korea has a renewable portfolio standard (KEA, n.d.) and many instruments – both approaches fostering systemic change. New Zealand's approach integrates well with climate policy, but the Republic of Korea's approach covers many key aspects of a successful energy transition like circular economy practises (KEA, n.d.d) and safety measures (MOTIE, 2019).

Policy learning between case studies of New Zealand and the Republic of Korea, and other APEC economies, has limited use for replication of *instruments* which are highly dependent on local resources, and existing political and social circumstances. For example, a renewable-friendly grid does not necessarily require demand management, nor batteries or fuel cells; as other alternatives exist – for instance, where it is valuable to apply pumped hydro storage by repurposing coalmines as reservoirs (Fan et al., 2020). However, there are take-aways which can be applied from these two different policy-mixes, about policy processes and characteristics.

These two policy-mixes have shown that energy plans and instruments which are stringent and reinforcing in their (long and short-term) goals, operation and timing provide a consistent policy mix, when also integrated with climate and other relevant policy. Further, policy making with extensive participation, embedded and transparent monitoring and evaluation, and a legal and financial basis, make the policy-mix credible. Moreover, coherence of processes between levels of government enhances comprehensiveness and successful implementation.

Therefore, this report suggests, based on the renewable energy policy-mix of New Zealand and of the Republic of Korea, the following vision for policy in APEC economies, towards achieving the doubling goal:

1. Energy and climate change policy reinforce renewable energy development.

2. Policy supports a renewable-friendly grid via locally compatible energy storage and/or demand management, to enable energy security without the investment lock-in-lifetime of gas infrastructure.

3. Proactive frameworks and/or acts of legislation support consistency of multilevel governance, the publishing of energy plans and reporting, and safety measures across election cycles.

4. Central Governments partner with and build capacity of sub-economy Governments to support fossil fuel industry reliant workers and communities in planning and achieving a fair and effective transition. Such regions may remain key energy providers for the wider economy as hubs for renewable energy innovation.

5. Government leadership on circular economy practises in the energy transition supports win-win solutions. Addressing energy-related finite resources and waste supports job creation, community participation, and achievement of energy goals.

6. Policy addresses energy efficiency in transport, industry, and buildings.

7. APEC and economies recognise that stronger policy for renewables is needed to achieve the doubling goal. Modelling suggests that this could support APEC to achieve the goal five years early. This goal should be revised to a more substantial target compatible with Paris Agreement commitments of the economies.

Conclusion

Since APEC took an important first step towards sustainable development in 2014 – creating a joint goal for double the share of renewable energy, within sixty percent of the world's energy demand – progress has been too slow to see its achievement by 2030. Only five of the twenty-one economies are on track, one of them being the Republic of Korea. Stronger renewable energy policy is needed to accelerate renewable deployment, while upholding energy security. This report has explored examples of renewable-energy-policy-mixes in APEC economies, specifically New Zealand and the Republic of Korea. Both aim for a transition to renewables and green growth, but from different starting points, and with different approaches. Applying a policy-mix analysis framework, lessons have emerged which are relevant across the APEC forum. These recommendations envisage renewables plus storage, supported by demand management and efficiency measures, embedded in both energy and climate change policy. Together with frameworks that provide continuity across election cycles, and partnerships that support coherence between levels of government, this can drive the swift and fair transition needed. Further, government leadership on circular economy practises in this transition can create win-wins for business, community, and Government. Finally, modelling suggests that APEC could double renewables by 2025, which highlights the need to revise the target to be compatible with Paris Agreement commitments of the economies. Thus, this report intends to act as a contribution towards an ongoing APEC conversation about renewable energy matters on an economy-specific scale, towards achieving the doubling goal by 2030, or before.

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Appendices

1. New Zealand Principal Energy Plans:

GUIDING PRINCIPLES:

- "Diverse resource development (including the development of renewable energy).
- Environmental responsibility.
- Efficient use of energy.
- Secure and affordable energy" (NZ Gov., 2017: 5).

GOALS:

- "New Zealand has an energy productive and low emissions economy" (NZ Gov., 2017: 8).

OBJECTIVES:

- "Businesses make energy efficient and renewable energy investments and adopt best practice energy management.
- Individuals, households and community institutions choose energy efficient technologies, adopt energy efficient behaviours and make greater use of renewable energy.
- The public sector demonstrates leadership by adopting greater energy efficiency and renewable energy" (NZ Gov., 2017: 8).

PRIORITIES:

- "Renewable and efficient use of process heat.
- Efficient and low-emissions transport.
- Innovative and efficient use of electricity" (NZ Gov., 2017: 8).

INDICATORS:

- "Decrease in industrial emissions intensity (kg CO2-e/$ Real GDP) of at least one per cent per annum on average between 2017 and 2022.
- Electric vehicles make up two per cent of the vehicle fleet by the end of 2021.
- Ninety per cent of electricity will be generated from renewable sources by 2025 (in an average hydrological year), providing security of supply is maintained" (NZ Gov., 2017: 22).

Defined by:

- *Developing Our Energy Potential: New Zealand Energy Strategy* 2011-2021 (NZ Gov., 2011a).
- *Energy Efficiency and Conservation Strategy* 2017-2022 (NZ Gov., 2017).

BOX 1

2. New Zealand Primary Instruments (Relevant to Renewables):

Emissions Trading Scheme (ETS)

Operation: 'New Zealand Emissions Units' equal to one tonne of carbon dioxide or equivalent (CO2e) are given to or purchased by emitters and earned by removals, with no cap on units (Leining and Kerr, 2018). One unit has a price ceiling of NZ$25 (Leining and Kerr, 2018). All sectors are required to report on emissions and, excluding individuals and agriculture, to surrender units equal to their emissions (Leining and Kerr, 2018). However, reform may soon include capping units to match an emissions budget (NZ Gov., 2019), adjusting the price ceiling, and including agriculture in obligations to surrender units (NZ Gov., 2019). This would increase the fraction of New Zealand's emissions which have surrender obligations from just over half in 2017 (Stats NZ, 2019).

New Zealand's Paris Agreement Contribution is 30% emissions reduction (from 2005 levels) by 2030 (NZ Gov., 2020), using a budget of 601 Mt CO2e (between 2021 and 2030) (NZ Gov., 2020). Also, net-zero CO2 emissions by 2050 is legislated (NZ Gov., 2019d), as is 24 to 47% reduction of biogenic methane (below 2017 levels) by 2050 (NZ Gov., 2019d).

BOX 2

Cease to offshore oil and gas exploration permits, plus transition support

Operation: No exploration permits are granted for offshore oil or gas (NZ Gov., 2018b). Existing exploration permits covering 100,000km^2 (NZ Gov., 2018b) are not affected but will expire by 2030. However, existing and 'new-and-successful' mining fields in this area during these permits could last beyond 2050 (NZ Gov., 2018b). Alternatively, onshore exploration permits may be offered in the *Taranaki* region until at least 2021 (NZ Gov., 2018b).

Additionally, weight is placed on fairness in the resulting transition for fossil-fuel reliant communities (NZ Gov., 2018b) including signing of the COP24 Silesian Declaration on Just Transitions (COP, 2018). Investment from the Provincial Growth and Green Investment Funds includes $20M towards projects diversifying the economy of Taranaki (NZ Gov., 2018b). Further, the creation of a *Just Transitions Unit* facilitates discussion "between Government, Māori, business, the workforce, and communities" (NZ Gov., 2018c: 3) such as hosting a summit in 2019 and other roundtables (see: Gov., 2018d) to identify impacts and opportunities. A community roadmap to 2050 now guides the short and longer-term transition for the region (see: Venture Taranaki, 2020).

BOX 3

Research Funding

Operation: Investment in clean energy research focuses around a National New Energy Development Centre created in Taranaki (NZ Gov., 2019h). Projects include "offshore wind, solar batteries, hydrogen and new forms of energy storage" (NZ Gov., 2019h: 1), such as the centre's development of the H2 Taranaki roadmap for hydrogen (see: Venture Taranaki, n.d.) (NZ Gov., 2019g). Additionally, university partnerships include funding the GREEN grid project, investigating how to manage grid security with high penetration of renewables, bi-directional power flows, and new technologies and practises (Stephenson, et al., 2018).

BOX 4

Creation of Climate Change Commission

Operation: The *Climate Change Commission* (CCC) (formerly the *Interim Climate Change Committee (ICCC)*) was established to monitor and review progress and "provide independent, evidence-based advice to government to help Aotearoa New Zealand transition to a low-emissions and climate-resilient economy" (CCC, 2019: 1). For example, the ICCC report *Action on Agricultural Emissions* (ICCC 2019a) and the CCC's submission on proposed settings (CCC, 2020) inform ETS reforms underway at the time of writing. In energy, the ICCC report *Accelerated Electrification* (ICCC, 2019) advised in 2019 that the government "prioritises the accelerated electrification of transport and process heat over pursuing 100% renewable electricity by 2035 in a normal hydrological year because this could result in greater greenhouse gas emissions savings while keeping electricity prices affordable" (ICCC, 2019: 98). The report also recommended "the potential for pumped hydro storage to eliminate the use of fossil fuels in the electricity system" (ICCC, 2019: 98).

BOX 5

3. New Zealand Secondary Instruments:

Fossil Fuel Subsidy Reform Advocacy

Operation: New Zealand is a founding member of *Friends of Fossil Fuel Subsidy Reform* – "an informal group of non-G20 economies aiming to build political consensus on the importance of fossil fuel subsidy reform" (FFFsR, 2020) with a focus on trade measures (NZ Gov., n.d.a). New Zealand participated in the APEC peer review of fossil fuel subsidy reforms (see: APEC, 2015), which concluded that none of New Zealand's eight policy instruments reviewed "were 'inefficient subsidies that resulted in wasteful consumption'" (APEC, 2015: 71) and made a number of recommendations. Domestically "in 2017, the estimated amount of support to fossil fuels in New Zealand was $56 million, down from $59 million in 2016" (Stats NZ, 2019b:60), not including all instruments examined in the peer review.

BOX 6

Low Emissions and Electric Vehicles Programmes

Operation: This programme contains multiple instruments. 1) A contestable fund "offers up to $7 million a year to co-fund projects with private and public sector partners in areas where commercial returns aren't yet strong enough to justify full private investment… paid for via a levy on petrol and engine fuels (EECA, 2020: 1)." 2) Light and heavy electric vehicles (EVs) are excepted from road user charge until EVs make up 2% of their respective fleets (NZ Gov., 2019i). 3) A $5M EV promotion campaign (NZ Gov., 2019i). 4) "An initiative to enable road controlling authorities to make bylaws to allow electric vehicles access to special vehicle lanes" (NZ Gov., 2019i:1). Also, coordination of EV charging infrastructure (NZ Gov., 2019i), among others (see: NZ Gov., 2019i).

BOX 7

Electricity Switching Fund and Complaints Commission

Operation: The legacy of the 2010 electricity market reforms (see analysis: APEC, 2017) includes the fastest rates of retailer switching by consumers (APEC, 2017). The electricity switching fund of $15M followed by $7.5M in 2014 (APEC, 2017) promoted completeness of information for consumers and removed barriers to switching retailers (APEC, 2017). While this program has expired, the education campaign and services are still active (see: Consumer NZ and NZ Electricity Authority, 2020).

Promotion of competitive pricing is furthered by an electricity and gas complaints "Commissioner [who] has legislated functions to independently resolve disputes between electricity providers and consumers" (APEC, 2017: v) funded by electricity retailers.

The 2010 reforms also required "major electricity generators to put in place an accessible electricity hedge market…, [and] generators or retailers to compensate consumers in the event of conservation campaigns or a dry-year power cut" (NZ Gov., 2015: 36)."

BOX 8

Healthy Homes Standard

Operation: Sets standards for rental properties (NZ Gov., 2019f) covering heating, insulation, ventilation, moisture ingress and drainage, and draught stopping. Specifically, energy efficiency is affected by the requirement for *NZS 4246:2016* compatible insulation (NZ Gov., 2019f). This follows previous policy known as 'Warm Up New Zealand' (NZ Gov., 2016). Contributes to the doubling goal via energy efficiency.

BOX 9

4. New Zealand Policy Mix Framework Analysis

Policy Mix Framework, Component 2.2: Instrument Design Feature

Instrument design is investigated first in terms of descriptive features followed by abstract features as per the Policy Mix framework (figure 2).

Descriptive Features

Component	Evidence
2.2.1 Legal Form	The New Zealand Government passes laws which prohibit practises (NZ Gov., 2018), set standards (NZ Gov., 2019f), and establish agencies (NZ Gov., 2019d). As well, government taxes (NZ Gov., 2019i) and funds (APEC, 2017) encourage and disincentivise practises and promote research and education. Further, New Zealand has influence within international platforms (NZ Gov., n.d.a). A sample of Acts is provided in table 3, appendix 5.

Instrument	Component	
	2.2.2 Target Actors	*2.2.3 Duration*
Emission Trading Scheme	Emission intensive industries specifically process heat (NZ Gov., 2017), and investors. Emissions sink industries (Leining and Kerr, 2018). Consumer choices (passed on by price).	Since 2008 (12 years, ongoing, soon to be associated with emissions targets for 2050) (NZ Gov., 2019).

Cease to offshore oil and gas exploration permits, plus transition support	Communities reliant on fossil fuel transformation, specifically the Taranaki region (NZ Gov., 2018b).	Since 2018 (ongoing) (NZ Gov., 2018b).
Research Funding	Taranaki workforce (NZ Gov., 2019h). Also, university researches and associated developers.	[Used in this analysis:] Since 2012 (ongoing) (Stephenson, et al., 2018).
Climate Change Commission	Independent experts in the field (CCC, 2019).	Since November 2019 (ongoing - providing recommendations to 2050 targets) (NZ Gov., 2019d).
Fossil Fuel Subsidy reform advocacy	Economies and groups such as APEC and G20 (NZ Gov., n.d.a).	Since June 2010 (ongoing) (FFFsR, 2020).
Low Emissions and Electric Vehicles Programmes	Private and public sector developers (EECA, 2020) and consumers.	Since May 2016 (indicator to 2021) (NZ Gov., 2019i).
Electricity Switching Fund and Complaints Commission	Electricity consumers (including businesses) and retailers (APEC, 2017).	2010 to 2017 (APEC, 2017) (legacy ongoing) (Consumer NZ, 2020).
Healthy Homes Standard	Landlords (energy efficiency) (NZ Gov., 2019f).	Since July 2019, (ongoing) (NZ Gov., 2017b; 2019f).

Abstract Features

Component	**Evidence**
2.2.4 Stringency	Measurable indicators behind policy instruments provide rigour. Indicators under the Energy Efficiency and Conservation Strategy (box 1) target three priority areas: 1) process heat, 2) transport, and 3) electricity. The first is to be achieved via creation of a Process heat action plan (however, so far only a preliminary document discussing barriers has been located: NZ Gov., 2019e). Further, exemption is made: “chemicals, metals and electricity generation are excluded as these include very large firms which would make the measure less useful or are not relevant to what is being targeted by the Strategy (NZ Gov., 2017: 22).” More recently however, the Government Investment in Decarbonising Industry Fund (EECA, 2021a) has addressed process heat. The second is achieved through several measures (box 7) without clear caveats. The third is a broader result which plays into the first and second targets via electrification. Further, targeting electricity addresses consumption in buildings which is another key area for improvement (APERC, 2019a). This indicator does make exception for fluctuation in water availability due to reliance on hydro as well as prefacing achievement with maintenance of energy security as the priority.

2.2.5 Level of Support	Debate around the process of reforming New Zealand's Emissions trading scheme (ICAP, 2020) provides an indication of division across the political spectrum. The National Party supports emissions reduction via means other than an ETS, for fear of hurting farmers and disadvantage in trade (National, 2019). Alternatively, the Green Party has long been in favour of ETS reforms (Green, 2016). However, the Zero Carbon Bill (NZ Gov., 2019d) (net zero CO2 emissions by 2050) has bipartisan support.
2.2.6 Predictability	New Zealand has short- and long-term targets and has greater longevity and stability of policy compared to Australia (ADBI, 2018).
2.2.7 Flexibility	The target which best relates to renewables policy (90% in electricity by 2025) includes the caveat "providing security of supply is maintained (NZ Gov., 2017: 22)" allowing flexibility. Similarly, including the basis of an average hydrological year signals reliance on hydro and flexibility around its fluctuations. However, in transport, a target of based on electric vehicles may miss developments in green hydrogen.
2.2.8 Differentiation	Policy Instruments are differentiated to target a range of actors and several key sectors.
2.2.9 Depth	Depth is criticised by some: "Epitomizing a lack of ambition in energy policy and commitment, neither the NPS-REG nor the 90% renewable energy generation target by 2025 came with any substantive policy measures (over and above the ETS) that might have increased investment (ADBI, 2018)." However, a counterargument to criticising a one-instrument-heavy approach can be made.

Policy Mix Framework, Component 3: Instrument Mix

Combining instruments, with their various types and purposes (table 2) to achieve an objective raises the issue of the interaction of instruments which is discussed here as per the Policy Mix framework (figure 2). A policy mix strives to maintain complementary instruments (Rogge and Reichardt, 2016).

Component	Evidence
3.2 Scope of interacting instruments	The ETS has the widest scope, along with the CCC and research funding, while the other instruments are narrow. The fossil fuel subsidy reform advocacy operates with a different scope to the rest, in the international arena.
3.3 The Nature of their Goals	Emissions reduction is a central theme, while energy security is often highlighted. Both the ETS and Electricity switching fund/ complaints commission increase competition. The CCC and research funding both drive new knowledge. The cease to permits and transition support work to transition workforce and community. The healthy homes standard increases energy efficiency and equity. The low emissions/ EV programmes work to reduce emissions and thus involve electrification requiring renewable energy. Alternatively, the fossil fuel subsidy reform advocacy seeks trade arrangements and international commitments.
3.4 Their Timing	All in operation. The CCC, cease to permits/ transition support and healthy homes standards are relatively new. However, reforms of the ETS are ongoing at the time of writing.

3.5 Operation/ Implementation Process	The ETS is influenced by advice from the CCC. The cease to offshore permits and transition support are two tightly related instruments and are supported by research funding because the New Energy Development Centre was developed in Taranaki. Research funding also shapes the success of low emissions and EV programmes (eg. smartgrid project). Alternatively, the fossil fuel subsidy reform advocacy operates within international forums.

Policy Mix Framework, Component 4: Policy Making

Adaptive management, or the ability to make iterative policy based on evaluation of previous policy results, is recognised as benefiting a policy mix which faces uncertainties such as technological change (Rogge and Reichardt, 2016). Therefore, policy learning is a central component to policy making, which is considered here (as per figure 2) by investigating how and to what extent, if any, a policy mix gains participation of actors with information to contribute and achieves monitoring of indicators and evaluation of the results.

Component: *4.1 Participation*	
Synthesis: Participation is clear, however appears to be limited by the window of time open for input.	
Strong Points	**Weak Points**
Public participation is mandatory in approval procedures for large-scale renewable energy projects (Schumacher, 2019).	…however, this lasts for twenty days - seen by Schumacher (2019) as limited.
It is common for industry groups to respond to draft policy documents like the Energy Efficiency and Conservation Strategy (see: NZ Gov., 2017a).	…however, recent reports by news outlets about changes to the ETS suggest discontent with the ability to participate: “Federated Farmers and BusinessNZ have also hit out at the short, two-month, window for submissions to the proposals (NZ Herald, 2019:1).”
Business and community input to the community roadmap to 2050 for Taranaki, which for example, extended to “Taranaki children to share what they think the region could look like as a low emissions economy in the year 2050 (TODD Energy, 2019:1).”	
Creation of the independent CCC of experts in the field (CCC, 2019).	…however, some news outlets suggest that the CCC is not consolidated enough (NZ Herald, 2019).

Component	**Evidence**
4.2 Monitoring and 4.3 Evaluation	It is a requirement of the Minister for the Environment to monitor and review (NZ Gov., 2011) the *National Policy Statement for Renewable Electricity Generation* – a framework for the relationship between and responsibilities of the economy and local policymakers for managing renewable electricity in policy. Also, investment is given towards “quality end-use data” (NZ Gov., 2017: 23). As such, statistics are published about the state of energy (NZ Gov., 2019b)

	and progress of policy instruments (NZ Gov., 2016b). Further, the CCC was established to monitor and evaluate relevant policy (CCC, 2019).

Policy Mix Framework, Component 5: Policy Implementation

The actions of policy instruments may have to overcome challenges such as high transaction costs and political or social resistance (Rogge and Reichardt, 2016). Thus, the structures and mechanisms which are applied to implement policy instruments are examined here (as per figure 2).

Component	Evidence
5.1 Executing	Central and local government agencies are the most relevant administrators of energy policy (NZ Gov., 2017). The *National Policy Statement for Renewable Electricity* guides implementation of renewable electricity in policy between the economy and local levels (See: NZ Gov., 2011). Notably, the CCC operates independently (CCC, 2019). Also, new roles have been created such as the electricity complaints commission (APEC, 2017). The transition support in Taranaki was developed with local businesses, community and local government (NZ Gov., 2018c).
5.2 Enforcing	In terms of the ETS enforcement: “Failure to surrender emission units results in a requirement to make good those units alongside a financial penalty of NZ$30 per unit. Interest accrues until the penalty is paid. Failure to comply with data collection, record-keeping, reporting, registration or notification requirements carries a fine. Knowingly providing false information carries a larger fine and/or a prison term (Leining and Kerr, 2018).”

Policy Mix Framework, Component 6: Style

The style of policy process is regarded as the historically “typical kind of goal setting or flexibility in instrument application” (Rogge and Reichardt, 2016: 1626).

Component	Evidence
6.1 Standard Operating Procedures	The guiding document; *Energy Efficiency and Conservation Strategy 2017-2022* proceeds the 2007 version and the 2001 version (NZ Gov., 2007) which was initiated by the framework *Energy Efficiency and Conservation Act 2000* (figure 9). Approval process for large-scale renewable energy projects involves an average of 11 steps (Schumacher, 2019) and an average duration of 90 days (Schumacher, 2019) and this is seen as a short timeframe (Schumacher, 2019).

Policy Mix Framework, Component 7: Consistency of Elements

Elements include policy strategy, instruments and instrument mix (figure 2). Consistency of elements can be considered temporally, geographically and across governance levels, in terms of the supportiveness of objectives within the policy strategy, the reinforcement of instruments in the instrument mix, and the interplay of policy strategy and instrument mix.

Component	Contradicts/ undermines	Mutually supportive objectives/ reinforces
7.1 Policy Strategy		Renewable energy target matches principal energy plans integrated with wider political strategy for emissions reduction. Target for renewables in electricity compliments targets in transport and process heat.
7.2 Instrument Mix		Instruments are complementary – especially research funding with cease to offshore permits and transition support and Low emissions and EV programmes, and ETS with CCC. The healthy homes standard complements (via efficiency) but does not interact with other instruments, while the fossil fuel subsidy reform advocacy operates with its own international outlook.

Policy Mix Framework, Component 8: Coherence of processes

Synergy of actions between fields or ministerial portfolios as well as between governance levels has direct effects on the behaviour of actors and indirect effects on outcomes via consistency (Rogge and Reichardt, 2016). For example, conflicting policies between governance levels reduces the ability for successful policy implementation, or consistent presentation of a policy stance between ministers can promote confidence and ease implementation.

<table>
<tr><th>Component</th><th>Evidence</th></tr>
<tr><td>8.1
Direct Effect on Behaviour of Actors</td><td>Integration and coordination occur via the National Policy Statement for Renewable Electricity Generation and its implementation guidelines (NZ Gov., 2011) between federal and local levels.</td></tr>
<tr><td>8.2
Indirect effect on consistency</td><td>Consistency is shown by figure 9 via the integration of processes.

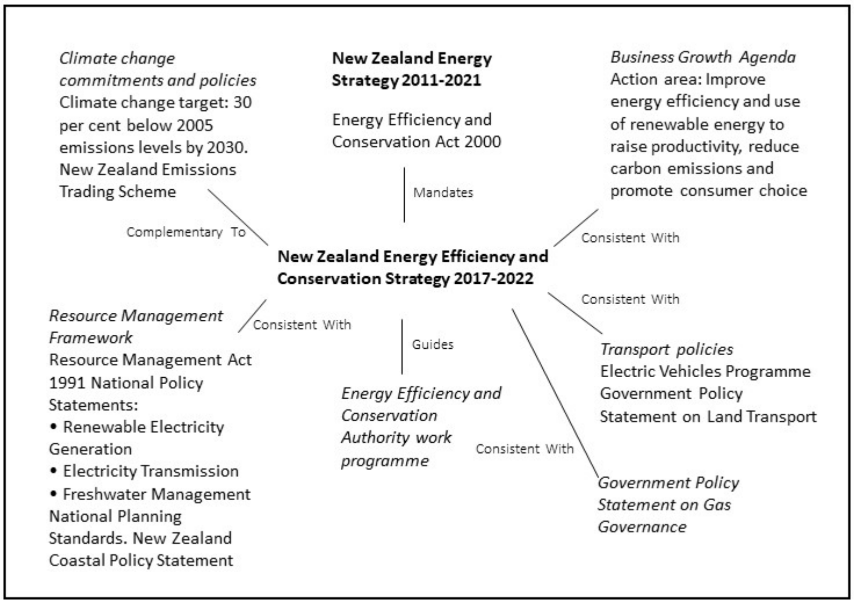

Figure 9. New Zealand Energy Strategy in context. Adapted from: NZ Gov. (2017).</td></tr>
</table>

Policy Mix Framework, Component 9: Credibility

Rogge and Reichardt define credibility as "the extent to which the policy mix is believable and reliable" (2016: 1627).

Component	Evidence
9.1 Commitment and 9.2 Consistency	Bipartisan support for the long-term net-0 CO2 emissions target by 2050 (NZ Gov., 2019d), with medium-term reviews (5 yearly) (NZ Gov., 2019d), providing industry certainty. As for instruments, changes to the ETS fluctuate between election cycles (Leining, 2016).
9.3 Delegation to Agencies	Various agencies operate in the energy space such as the CCC (2019) and the Electricity Authority – a "market watchdog tasked with ensuring fair competition and supply security" (APERC, 2019a).

Policy Mix Framework, Component 10: Comprehensiveness

This component reviews all other components together considering the original policy problem (Rogge and Reichardt, 2016).

Component	Evidence
10.1 Degree to which the full scope of problems is addressed	Key sectors (process heat, electrification in transport, and renewables in electricity) are addressed by policy instruments and processes. The electricity target is addressed most indirectly via the ETS, cease to permits, developing research including as part of Taranaki's transition, and to a lesser extent the electricity switching fund and complaints commission. Further, the fossil fuel subsidy reform extends the scope to the international agenda. The transport goal is served by a programme of instruments, some of which extend until the target it met. Although action towards the first indicator, as it relates to process heat, has been slower to emerge, it is now supported by the Government Investment in Decarbonising Industry Fund (EECA, 2021a).

5. New Zealand Acts of Parliament

Table 3. Legal Form New Zealand Renewable Energy Policy Mix. Function description refer to Dovers and Hussey (2013). ETS = emissions trading scheme (NZ).

Legislation	Function	Source
Electricity Industry Act 2010	Provides a framework for the regulation of the electricity industry.	(NZ Gov., 2018: 10-12)
Energy Efficiency and Conservation Act 2000	Promotes, in New Zealand, energy efficiency, energy conservation, and the use of renewable sources of energy.	
Climate Change Response (Zero Carbon) Amendment Act 2019 [amending the Climate Change Response Act 2002]	Provides a framework by which New Zealand can develop and implement clear and stable climate change policies. • Defining of Agency Responsibilities (Climate Change Commission) • Punitive Measures (ETS enforcement)	(NZ Gov., 2019d: 4)
Crown Minerals (Petroleum) Amendment Bill 2018 [amending the Crown Minerals Act 1991]	• Prohibition of practises (offshore exploration permits)	(NZ Gov., 2018)
Healthy Homes Guarantee Act 2015 Amending the Residential Tenancies Act 1986	• Establishes standards for rental houses including insulation.	(NZ Gov., 2019f)

6. The Republic of Korea's Principal Energy Plans:

GUIDING PRINCIPLE:

- "Achieve sustainable growth and enhance the quality of life through energy transition" (MOTIE, 2019: 3).

GOALS:

- "Innovation in the energy consumption structure" (MOTIE, 2019:2).
- "Transition towards a safe and green energy mix" (MOTIE, 2019: 12).
- "Improvement of Energy Security" (MOTIE, 2019: 15)
- "Enhanced energy safety management" (MOTIE, 2019: 16).
- "Expansion of distributed and participatory energy systems" (MOTIE, 2019: 18).
- "Global competitiveness of the energy industry" (MOTIE, 2019: 20).
- "Better infrastructure and market systems for energy transition" (MOTIE, 2019: 22).
- "More infrastructure for energy transition" (MOTIE, 2019: 24).

OBJECTIVES:

- "Improve demand management by sector, including industry, buildings and transportation, and facilitate the demand management market" (MOTIE, 2019: 4).
- "Innovate buildings and industries with better energy efficiency at the system and community levels" (MOTIE, 2019: 6).
- "Improve energy efficiency in the transport sector by promoting eco-friendly transportation and intelligent traffic systems" (MOTIE, 2019: 8).
- Create new business and markets (MOTIE, 2019).
- Increase renewable energy, reduce coal-fired power, phase out nuclear power, and increase the role of natural gas (MOTIE, 2019).
- "Strengthen energy security through global cooperation" (MOTIE, 2019: 15).
- "…Government will therefore develop a pre-emptive safety management system for its citizens to consume energy in a safer manner" (MOTIE, 2019: 16).
- "Enhance regional energy independence through distributed generation and smart grids" (MOTIE, 2019: 18).
- "Develop the energy industry as a new growth engine and excellent source of quality jobs" (MOTIE, 2019: 20).
- "Advance the electricity, gas and heat market systems" (MOTIE, 2019: 22).
- "Develop the technologies and manpower for energy transition" (MOTIE, 2019: 24).

INDICATORS:

- "…reduce energy consumption by 18.6% below the [2017] BAU level by 2040" (MOTIE, 2019:), equivalent of 39.2 Mtoe (MOTIE, 2019).
- "Buildings constructed after the year 2030 will maximize their energy consumption efficiency and become zero energy buildings that self-sufficiently generate their energy needs" (MOTIE, 2019: 6).
- "By 2030, FEMS [factory energy management systems] will be introduced to more than 1,500 SMEs that lack investment capabilities" (MOTIE, 2019: 6).
- Decrease "energy intensity of the industrial sector" (MOTIE, 2019: 7) by 21% between 2017 and 2040.
- Decrease "energy intensity of the building sector" (MOTIE, 2019: 7) by 38% between 2017 and 2040.
- "Develop and operate [20] microgrid industrial complexes [by 2030]" (MOTIE, 2019: 7).
- "Establish and operate [40] regional energy efficiency communities [by 2030]" (MOTIE, 2019: 7).
- "Launch village-based energy rebuilding demonstrations with 3 apartment complexes in 2020 (MOTIE, 2019: 7).
- Number of eco-friendly vehicles reaches 11.2M by 2040, around a quarter are hydrogen vehicles and the rest electric (MOTIE, 2019).
- "Average fuel efficiency of passenger vehicles [doubles between 2017 and 2040]" (MOTIE, 2019: 9).
- "Average fuel efficiency of heavy-duty vehicles [increases by 1.5 times between 2017 and 2040]" (MOTIE, 2019: 9).
- 30 to 35% of power generation from renewables by 2040 (MOTIE, 2019).
- No new nuclear reactors and no extensions to lifespan of aged reactors (MOTIE, 2019), 14 units are predicted to remain in 2038 of 24 units in 2017 (MOTIE, 2019).
- "Coal-fired power generation will be drastically reduced to within the range necessary to secure a stable supply and demand" (MOTIE, 2019: 12).
- "Investments in overseas resource development" (MOTIE, 2019: 15).
- Diversified import routes and progress on the Northeast Asia Super Grid project (MOTIE, 2019).
- "76 billion won worth of investments into safety facilities within five years" (MOTIE, 2019: 12).
- "Formulation of the Second Master Plan for Gas Safety Control (2020-2024)… the Safety Management Plan for Oil and Gas Storage Facilities (2019)… Legislation of the Electrical Safety Control Act… [and] Establishment of ESS [energy storage systems] standard and certificate systems" (MOTIE, 2019: 17).
- Increase the share of distributed generation (in all generation) from 12% in 2017 to 18% by 2030 then 30% by 2040 (MOTIE, 2019).
- Increase the number of renewable energy facilities from 220 thousand in 2018 to between 1.9 and 2.7 million by 2040 (MOTIE, 2019).
- Produce 6.2 million hydrogen vehicles by 2040 (MOTIE, 2019).
- 15GW of fuel-cells applied for industrial use and 1.2GW in household use by 2050 (MOTIE, 2019).
- 5.26 million tons hydrogen supplied by 2040 (MOTIE, 2019).
- "Real-time markets and supplementary service operation systems will be introduced and aligned to further deploy renewable energy" (MOTIE, 2019: 22).
- "Improving the rate system for power generation of the Korea Gas Corporation" (MOTIE, 2019: 22).
- "Heat supply markets, which are divided by region, will be connected to promote heat trading between different regions" (MOTIE, 2019: 22).
- "Clean energy R&D investment [of 1.12 trillion won by 2021]" (MOTIE, 2019: 25).
- "An energy big data platform to provide energy information on supply, demand and technologies in an integrated manner [by 2022]" (MOTIE, 2019: 25).

Defined by:

- *Third Energy Master Plan 2019 (MOTIE, 2019).*

BOX 10

7. The Republic of Korea's Primary Instruments (Relevant to Renewables):

Smart Grid & Distributed Energy Developments

Operation: Smart grids (IEA and IRENA, 2015) use wireless communication of metering information between market operators and energy consumers/ producers at any number of sources (IEA and IRENA, 2015). This detailed monitoring allows control of supply and demand, for reliability of supply and creation of new markets (IEA and IRENA, 2015), which equate to less costs and efficient energy use (IEA and IRENA, 2015). Such control can remove the barrier of high demand peaks, which limit integration of variable renewables (IEA and IRENA, 2015). Smart grids are conducive to distributed generation and storage from many small-scale units, adjacent to demand (MOTIE, 2019).

In the Republic of Korea, 34 million smart meters and 151 micro-grid projects have been established since 2011 (Jensterle et al., 2019). Work is underway to enable unlimited grid connection for small scale renewables (Jensterle et al., 2019). The Act on *Compensation and Assistance for Areas Adjacent to Transmission and Transformation Facilities* has relaxed availability of sites for renewable energy infrastructure (Jensterle et al., 2019). Additionally, integrating land uses is encouraged by low interest loans for farmers to install PV (Jensterle et al., 2019). Net metering is available for small scale PV (<100 kW) (MOTIE, 2018), as is a feed-in-tariff (FiT) system which allows farmers, fishers and cooperatives to "obtain stable profits for 20 years" (MOTIE, 2018: 8).

From the Korea Energy Agency (KEA): instruments include standards, certification and in cases verification of technology, equipment, buildings, and instillation companies (KEA, n.d.d). These include mandating new building >1000 m^2 to install New and Renewable Energy (NRE – see *context*) facilities for 12% of their energy use (KEA, n.d.d), as well as renewable heat obligation for new large buildings such as from solar thermal (KEA, n.d.d). Also, facilitation of NRE test-beds (KEA, n.d.d), NRE subsidies for residential buildings (KEA, n.d.d) and NRE facilities and projects diversifying NRE use (KEA, n.d.d), plus grants to local NRE projects working with local Governments (KEA, n.d.d). As well, solar PV rental market are promoted by the renewable portfolio standard (see box 14), and KEA supplies a triage NRE repair service (KEA, n.d.d).

With a focus on stakeholder participation in planning and deploying distributed generation (MOTIE, 2019) such as community/co-op business models (Jensterle et al., 2019), the concept of prosumers (consumers who also sell back into the grid) is emerging (MOTIE, 2019). Such distributed generation will include not only solar PV systems but Energy Storage Systems (ESS) (MOTIE, 2019) and Vehicle to Grid capability which utilises EV batteries (MOTIE, 2019) (see: demand management instruments). Also, virtual power plants (VPPs) will emerge which aggregate groups of small power sources to operate as one larger utility (MOTIE, 2019).

BOX 11

Demand Management Instruments

Operation: Demand management works to transform where and how much energy is used when (IRENA, 2019a) via market design, system operation, enabling technologies and business models (IRENA, 2019a). Demand management can reduce both overall demand and consumption at peak times – promoting grid stability, efficiency, and reduced cost for consumers (IRENA, 2019). In the Republic of Korea, instruments focus on promoting efficiency and timing of energy consumption in industry (APERC, 2019a), design standards for buildings (APERC, 2019a), and fuel efficiency standards (box 10) including for commercial vehicles (APERC, 2019a). A variable power tariff for industry incentivises behind-the-meter batteries to shift consumption to low-cost times (Jensterle et al., 2019) which reduce demand peaks. Also, Building Energy Management System will be widely introduced to reduce energy consumption in buildings (MOTIE, 2019).

Further, the Republic of Korea's facilitation of a demand management market to attract private investment (APERC, 2019; MOTIE, 2019) involves a) promotion of demand management service companies who utilise technologies like artificial intelligence (MOTIE, 2019) and b) distribution and connection of smart energy infrastructure (ie. smart grids using demand response (DR) (figure 11) including V2G (figure 11)) (MOTIE, 2019). This infrastructure includes electric heat-pumps (APERC 2019), "local battery storage, rooftop solar PV, home appliances and smart meters" (IRENA, 2019a: 1).

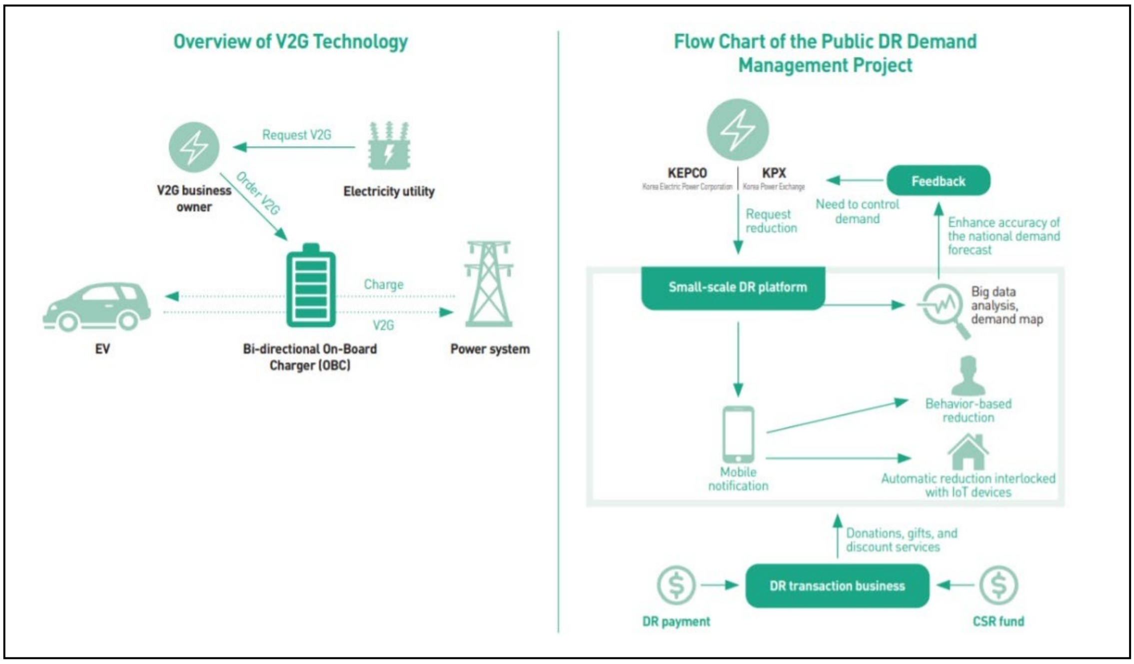

Figure 11. Smart Grid systems create new businesses and markets. V2G = Vehicle to gird interconnection, DR = demand response. Re-printed from MOTIE (2019).

BOX 12

Low Emissions Vehicles Instruments

Operation: New passenger and heavy-duty vehicles come under fuel efficiency standards (MOTIE, 2019), including via the Renewable Fuel Standard for oil refiners, importers and exporters (KEA, n.d.c). Further, both electric and hydrogen fuel-cell vehicles are being promoted (MOTIE, 2019). A barrier to low-emissions vehicle uptake is charging infrastructure which has been provided via charging-tariffs (such as at the Jeju Island testbed) (Jensterle et al., 2019) and subsidies for installation (Jensterle et al., 2019). "The number of publicly available chargers has grown in the Republic of Korea from 62 in 2011 to 9,300 in 2018… [and] the government plans to supply 3,428 high-speed battery chargers by 2021" (Jensterle et al., 2019: 21).

Additionally, electric vehicle integration within smart grids (eg. V2G) makes electric vehicle uptake more cost effective (Jensterle et al., 2019: 11). However, V2G is not yet widespread, but is being tested in Sejong between 2019 to 2021 (Jensterle et al., 2019). Also, energy use and emissions associated with congestion are expected to decrease with advances in automated driving technologies sharing information via the internet (Jensterle et al., 2019).

The Republic of Korea plans to become the "world's leading manufacturer of hydrogen-powered cars and fuel cells" (Jensterle et al., 2019: 28). This involves a preparatory phase in the early 2020s including testing of three 'hydrogen cities', an expansion phase in the mid-2020s, and a leading phase in the mid-2030s (see: MOTIE, 2019: 21). Beyond cars, the Republic of Korea plans on developing "hydrogen vessels, hydrogen trains as well as hydrogen drones" (Jensterle et al., 2019: 28).

BOX 13

Renewable Portfolio Standard (RPS)

Operation: A market for new and renewable energy is made between generators and retailers (Jensterle et al., 2019). Renewable energy certificates (CER) are awarded to generators, which are then sold to energy retailers (with capacity > 500 MW (ITA, 2016)) who are obliged to surrender CERs to a government regulatory agency (Jensterle et al., 2019). "In 2018, the RPS was 5%; it will increase to 7% by 2020, and 20.5% by 2029" (Jensterle et al., 2019: 16). Further, the RPS directs the market by differentiating CER weightings (see: KEA, n.d.). For example, cases of renewables plus storage are awarded higher weighted certificates (Jensterle et al., 2019: 17) to promote integration of renewables into the grid.

Additionally, public institutions are obligated to install energy storage capacity for 5% of their contract power (Jensterle et al., 2019).

BOX 14

Research, Development and Demonstration (RD&D) Investment

Operation: Funding included USD$757m in the 2018 budget (Jensterle et al., 2019) – the eighth largest globally. A wide range of projects received funding (figure 12) with weight placed on renewables and efficiency (figure 12). The government intends to increase this to 1.12 trillion won by 2021 (MOTIE, 2019: 25).

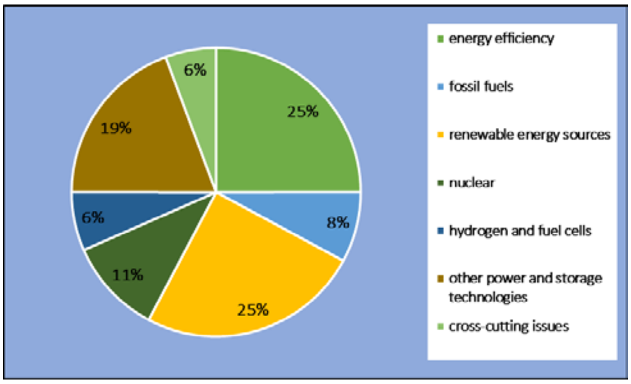

Figure 12. Distribution of RD&D in Republic of Korea's 2018 budget. Adapted from (Jensterle et al., 2019).

BOX 15

8. The Republic of Korea's Secondary Instruments:

Energy efficiency and Climate Change Bureau

Operation: An agency established by the Ministry of Trade, Investment and Energy to support policy (APERC, 2019a).

BOX 16

9. The Republic of Korea Policy Mix Framework Analysis

Policy Mix Framework, Component 2.2: Instrument Design Feature

Instrument design is investigated first in terms of descriptive features followed by abstract features as per the Policy Mix framework (figure 2).

Descriptive Features

Component	Evidence
2.2.1 Legal Form	The government of the Republic of Korea creates legislation (box 11) and standards (box 14), provides funding (box 15) and subsidies (box 13), sets tariffs (boxes 12-13), creates agencies (box 16) and companies (box 12), supplies infrastructure (box 13), and facilitates public deliberation (Sun-jin, 2019).

Instrument	Component	
	2.2.2 Target Actors	*2.2.3 Duration*
Smart grid and distributed energy developments	Communities, households and individuals to contribute to the grid with ownership and awareness. Businesses and entrepreneurs to develop new business models (eg. VPP) and technological supports (eg. vehicles capable of V2G).	Introduced in 2014 (MOTIE, 2014), updated in 2019 (MOTIE, 2019) (ongoing to 2040).
Demand management instruments	Consumers of energy - businesses and industries, as well as households, to use energy wisely. Also, businesses and entrepreneurs to develop new business models and technology (as above).	Introduced in 2014 (MOTIE, 2014), updated in 2019 (MOTIE, 2019) (ongoing to 2040).
Low-emissions vehicles instruments	Consumers – commuters to choose low emissions options. Manufacturing industry to develop the technology.	Since 2015 (MOTIE, 2016), updated in 2019 (MOTIE, 2019).
Renewable Portfolio Standard	Renewable energy generators to extend supply of, and retailers to extend demand for, renewable energy.	Introduced in 2012 (Jensterle et al., 2019), updated in 2019 (MOTIE, 2019) (ongoing to 2040).
Research, development and demonstration	Public and private sector researches and developers, domestically – and in collaboration internationally (MOTIE, 2019). Communities and businesses in demonstration 'test-beds'.	Ongoing with a target for 2021 (MOTIE, 2019).
Energy efficiency and climate change bureau	Public service.	*Not reported.*

Abstract Features

Component	Evidence
2.2.4 Stringency	The direction of Republic of Korea's numerous goals and associated objectives (box10) are solidified by the many indicators provided (box 10). Most of these indicators are rigorous; specifying specific, measurable outcomes (box 10). However, indicators for creation of new businesses and market systems are unspecific or missing (box 10). Note that while not in the Master Plan (box 10), the *Eighth Basic Plan for Long-term Electricity Supply and Demand 2017 to 2031* suggests that the share of gas in power generation will be 18% in 2030 up from 16.9% in 2017 and coal 36.1% down from 45.3% (Cornot-Gandolphe, 2018). Finally, Indicators do reflect the policy instruments in place.
2.2.5 Level of Support	A key feature of the Republic of Korea's energy transition is the discourse away from nuclear energy, and four of five candidates for the 2017 presidential election "promised to shut down the aged nuclear and coal power plants and replace them with gas and renewables (Jensterle et al., 2019: 23)." Thus, support is high for the direction of this policy-mix.
2.2.6 Predictability	The Republic of Korea has short and long-term targets and considerable stringency and breadth of support, to suggest that predictability is reasonable. Having so many Acts!
2.2.7 Flexibility	Caveats in indicators provide flexibility at cost to stringency and predictability. For example, reduction to coal fired power depends on energy stability: "coal-fired

	power generation will be drastically reduced to within the range necessary to secure a stable supply and demand (MOTIE, 2019: 12).” In terms of nuclear, while no extensions to lifespan of *aged* nuclear reactors can be made, construction of multiple partially built reactors continues following public engagement, where “59.5% of the representative citizen participants agreed to resuming construction (Sun-Jin and Yeon-Mi, 2017: 15).” For renewable energy, flexibility is embedded in the target for renewables in power generation by using a range (30-35%) (box 10).
2.2.8 Differentiation	Policy Instruments are differentiated to target a range of actors and several key sectors, working towards both social and technological change, often together.
2.2.9 Depth	In terms of emissions, the *Eighth Basic Plan for Long-term Electricity Supply and Demand 2017 to 2031* (see: MOTIE, 2017) would cut emissions from electricity generation by more than the emissions reduction target for electricity, in 2030 (Cornot-Gandolphe, 2018). However, generation at this time will remain around 60% nuclear and coal powered (Cornot-Gandolphe, 2018). In this vein, there are calls to suggest that aspiration for the rate of energy transition in the Republic of Korea could be raised (see: Climate Transparency, 2019).

Policy Mix Framework, Component 3: Instrument Mix

Combining instruments, with their various types and purposes (table 2) to achieve an objective raises the issue of the interaction of instruments which is discussed here as per the Policy Mix framework (figure 2). A policy mix strives to maintain complementary instruments (Rogge and Reichardt, 2016).

Component	Evidence
3.2 Scope of interacting instruments	The purpose of *smart grid distributed energy development* (box 11) and *demand management instruments* (box 12) is to make systematic change using economic, regulatory and information (table 2) types of instruments, involving many actors. The *renewable portfolio standard* (box 14) also makes systematic change, with a narrower scope in terms of target actors. The *low emissions vehicles instruments* (box 13) have a narrower scope because they target transport and push electric and hydrogen vehicle technologies. *RD&D* (box 15) inherently has a narrower scope of target actors, but developments are in a wide range of areas and can contribute to the operation of all other instruments. The *Energy Efficiency and Climate Change Bureau* (box 16) has a similar scope.
3.3 The Nature of their Goals	The *renewable portfolio standard* (box 14) works to increase the share of renewables in the energy mix, especially where combined with storage; reducing particulate matter and greenhouse gas emissions and become a leader in low carbon market and have a safe energy system. The *low emissions vehicles instruments* (box 13) works towards the same outcomes, as aims to be integrated into the operation of smart grids. *Smart grid distributed energy development* (box 11) works towards a green energy mix based on renewables and has many small-scale points for renewable generation as well as energy storage. This also works to make the Republic of Korea’s energy system participatory, and the sharing of information between generation sources to a central location as well as communication between energy market operators and prosumers facilitates demand management and new business models. *The demand management instruments* (box 12) work to reduce energy consumption, especially at peak times, as well as prompting energy efficiency, as this aids the integration of renewables into the grid and reduced reliance on fossil fuels. *RD&D* (box 15) aims to improve outcomes in all these areas, with

	the same end goals, as does the *Energy Efficiency and Climate Change Bureau* (box 16).
3.4 Their Timing	Many of the instruments were introduced in the second energy masterplan in 2014 (MOTIE, 2014) and updated in the third energy masterplan in 2019 (MOTIE, 2019). Although an RPS has existed since 2012 (table x), the current discourse begun in 2014 and is ongoing, with the end of the most recent energy masterplan being 2040 (MOTIE, 2019).
3.5 Operation/ Implementation Process	The operation of all six (categories of) instruments considered in this analysis are intertwined. RD&D informs the development of all instruments, as can the Energy Efficiency and Climate Change Bureau. The RPS increases the supply of renewable energy which is needed for electric vehicles to be low-emissions, and for hydrogen vehicles to be fuelled by green-hydrogen (although this may be imported (Jensterle et al., 2019)). Low emissions vehicles are becoming integrated into the smart grid network (eg. V2G). The smart grid network also partially relies on the RPS to increase supply of renewable energy. The smart grid network integrated with low emissions vehicles facilitates demand management.

Policy Mix Framework, Component 4: Policy Making

Adaptive management, or the ability to make iterative policy based on evaluation of previous policy results, is recognised as benefiting a policy mix which faces uncertainties such as social and technological change (Rogge and Reichardt, 2016). Therefore, policy learning is a central component to policy making, which is considered here (as per figure 2) by investigating how and to what extent, if any, a policy mix gains participation of actors with information to contribute and achieves monitoring of indicators and evaluation of the results.

Component: *4.1 Participation*	
Synthesis: Public participation is well considered in energy policy. This represents a change between the first energy masterplan in 2008 and the second in 2014: “the collection of public opinion on the First Energy Master Plan took place in the final stages of planning as a matter of formality, the Second Energy Master Plan was designed to reflect the views of the public from the very beginning through the formation of public-private working groups (MOTIE, 2014: 36).”	
Strong Points	**Weak Points**
Public opinion did informed decisions around the decision for the phase out of nuclear power via the *public engagement commission* (Sun-Jin and Yeon-Mi, 2017).	Sun-Jin and Yeon-Mi (2017) highlight the need for participation of workers in transition from nuclear-based work, such as the Korea Hydro and Nuclear Power labour union.
The move towards smart grids is encouraging prosumers of energy.	

Component	Evidence
4.2 Monitoring and 4.3 Evaluation	The Korea Energy Agency applies the *Energy Management System* standard (EnMS) (KEA, 2015) which involves both monitoring and evaluation of energy systems (KEA, 2015). National Energy Masterplans plan for 20 years ahead and are written every five years (Jensterle et al., 2019). While the second energy masterplan provided an evaluation of the previous masterplan (MOTIE, 2014), the recent 2019 masterplan did not (MOTIE, 2019).

Policy Mix Framework, Component 5: Policy Implementation

The actions of policy instruments may have to overcome challenges such as high transaction costs and political or social resistance (Rogge and Reichardt, 2016). Thus, the structures and mechanisms which are applied to implement policy instruments are examined here (as per figure 2).

Component	Evidence
5.1 Executing	Central and local government agencies are the most relevant administrators of energy policy, particularly the Ministry of Trade, Innovation and Energy (MOTIE, 2014). Specific commissions and committees are made such as the *Public Engagement Commission* (Sun-Jin and Yeon-Mi, 2017) and the *Safety Management Committee* (MOTIE, 2019), and roadmaps are developed such as the *National Smart Grid Roadmap 2050* (Jensterle et al., 2019). The New and Renewable Energy Centre processes renewable energy certificates for the RPS (Lexology, 2019). Also, Korea Electric Power Corporation along with prosumers provide function to RPS (GLI, 2020).
5.2 Enforcing	The RPS is enforced by law under *the Act on the Promotion of the Development, Use and Diffusion of New and Renewable Energy* (IEA, 2013).

Policy Mix Framework, Component 6: Style

The style of policy process is regarded as the historically "typical kind of goal setting or flexibility in instrument application" (Rogge and Reichardt, 2016: 1626).

Component	Evidence
6.1 Standard Operating Procedures	The government releases energy master plans every five years, planning for a period of 20 years (Jensterle et al., 2019) and multiple subsequent strategies specifically on renewables for example (MOTIE, 2018). Substantial public participation in energy policymaking is standard since 2014 (MOTIE, 2014).

Policy Mix Framework, Component 7: Consistency of Elements

Elements include policy strategy, instruments and instrument mix (figure 2). Consistency of elements can be considered temporally, geographically and across governance levels, in terms of the supportiveness of objectives within the policy strategy, the reinforcement of instruments in the instrument mix, and the interplay of policy strategy and instrument mix.

Component	Contradicts/ undermines	Mutually supportive objectives/ reinforces
7.1 Policy Strategy		Renewable energy goals and the instruments which promote deployment of renewables are integrated into wider energy policy (box 10) and fit within broader interests for transition to improve sustainability and wellbeing (box 10). All energy goals (box 10) and instruments (box 10) are conducive to and underpinned by renewable energy.
7.2 Instrument Mix		Instruments are complimentary to each other and support the objectives (box 10). Especially, demand management is facilitated by smart grids and electric vehicles, and RD&D is critical for developing smart grids. Distributed renewables do not compete with larger generators in the RPS for demand, instead both continuing to minimise reliance on fossil fuels. The increasing amount of variable renewables on the grid is supported by demand management. Notably, "Currently, energy from waste accounts for more than 60% [of NRE]. This includes waste heat from industries, originating from fossil fuels" (Jensterle et al., 2019). This may provide a contradictory leg-up to profitability of fossil fuels, but is also a means of efficiency by minimising losses prior to the shut down of fossil fuel plants.

Policy Mix Framework, Component 8: Coherence of processes

Synergy of actions between fields or ministerial portfolios as well as between governance levels has direct effects on the behaviour of actors and indirect effects on outcomes via consistency (Rogge and Reichardt, 2016). For example, conflicting policies between governance levels reduces the ability for successful policy implementation, or consistent presentation of a policy stance between ministers can promote confidence and ease implementation.

Component	Evidence
8.1 Direct Effect on Behaviour of Actors	The energy discourse is increasingly involving local leaders, forming bottom-up coalitions, such as 46 local Governments in a "Declaration of Post-Nuclear Energy Transition Cities in 2016" (Sun-Jin, 2019: 28) and the first and second local Governments' council for energy transition in 2016 and 2018 (Sun-Jin, 2019). The *New and Renewable Energy Centre* oversee the policy cycle and beyond (figure 13). The Korea Energy Agency develops technology standards to

<table>
<tr><td></td><td>enhance consumer confidence (KEA, n.d.b), and promotes use of common components to minimise production costs and enable repairability (KEA, n.d.b).

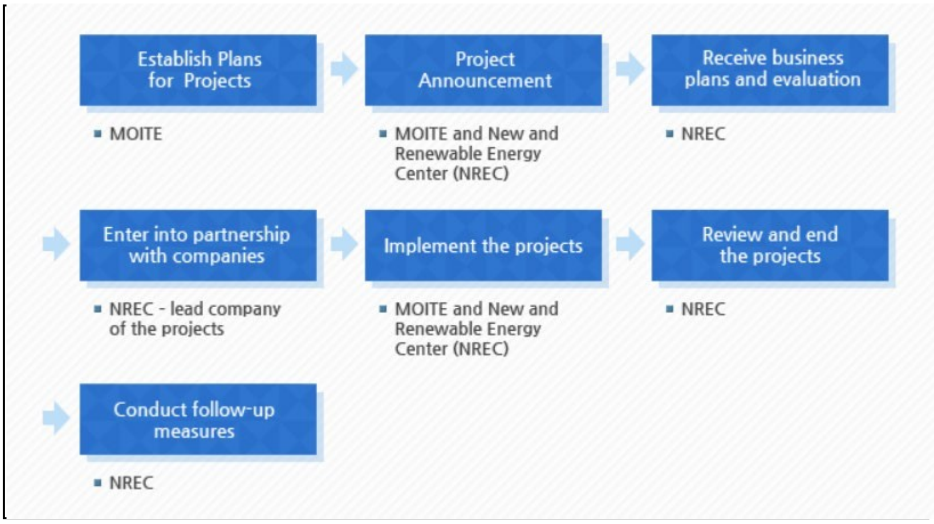

Figure 13. Process between key energy sector actors. MOITE = Ministry of Infrastructure, Trade and Energy, NREC = New and Renewable Energy Centre. Re-printed from: KEA (n.d.a).</td></tr>
<tr><td>8.2
Indirect effect on consistency</td><td>While the Third National Energy Masterplan (2019) is the primary guiding energy document and the focus of this analysis, Republic of Korea characteristicallyhas numerous energy documents for specific purposes (figure 10).

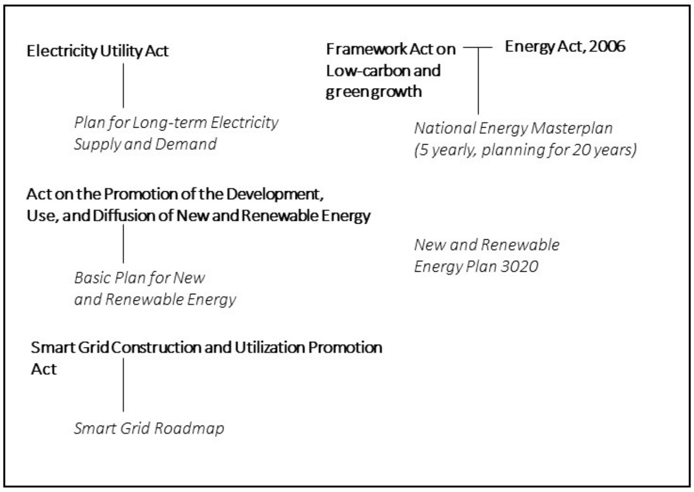

Figure 10. Structure of Energy documents in the Republic of Korea. Bold = legislation, Italics = name of document produced based on the associated Act. New and Renewable Energy Plan 3020 has no specific associated Act. Adapted from: Jensterle and colleagues (2019).</td></tr>
</table>

Policy Mix Framework, Component 9: Credibility

Rogge and Reichardt define credibility as "the extent to which the policy mix is believable and reliable" (2016: 1627).

Component	Evidence
9.1 Commitment and 9.2 Consistency	The large number of official plans (figure 10), goals (box 10), instruments (boxes 11 to 16), indicators (box 10), investment (eg. box 15) and other expenditure (eg. boxes 11 and 12), and participation (table x) suggest that commitment is high. Further, the use of legislated Acts which mandate creation of plans regardless of the government of the day provide a level of continuity (figure 10). From observations during this analysis the different plans in figure 10 are consistent are re-enforcing, and this also appears to be the case for each plan between years.
9.3 Delegation to Agencies	The government receives policy advice from the *Energy efficiency and Climate Change Bureau* (APERC, 2019a). There are also the *Public Engagement Commission* (Sun-Jin and Yeon-Mi, 2017) and the *Safety Management Committee* (MOTIE, 2019). Also, work by the *Korea Energy Agency* (KEA, n.d.), and the *New and Renewable Energy Centre* (KEA, n.d.a).

Policy Mix Framework, Component 10: Comprehensiveness

This component reviews all other components together considering the original policy problem (Rogge and Reichardt, 2016).

Component	Evidence
10.1 Degree to which the full scope of problems is addressed	The Republic of Korea's energy transition is supported by an extensive policy-mix. Renewable energy generation at large and small scales is addressed, especially via the RPS with weighted certificates, and this underpins the energy transition alongside progress towards efficiency. However, gas is still considered as necessary to the future fuel-mix. Storage, as a key part of renewables integration into the grid, is considered in a way that makes energy more participatory, stimulates new business and allows for efficiency gains, using a smart grid set-up, supported by various investments and developments. Transport, industry, buildings and non-energy use made up 98% of consumption in 2016 (APERC datasheet, 2019). Transport is addressed via fuel efficiency standards (including for heavy-duty vehicles) and charging infrastructure to advance the low-carbon fleet. Industry is at the forefront of demand management with incentives and monitoring. Buildings are also key, with new standards for low-carbon living and working in the future, as prosumers. Non-energy use is addressed by the advancement of industry towards being leaders in hydrogen vehicles and smart grids. Although, concrete plan-making, skill-translation and re-training of the workforce in transition from nuclear and coal related industries appears to be lacking, despite the Republic of Korea being a signatory of the UNFCCC Silesian declaration on Just Transitions (COP, 2018). Focus on bringing in the new age of energy without enough consideration for phasing out the old could undermine the energy transition.

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APPENDIX C

STUDENT PAPER 2

Environmental and Policy Implications for Blending Biofuel into Gasoline forKuala Lumpur, Malaysia, and Los Angeles, United States

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Abstract

Ethanol as a renewable fuel has shown great promise in reducing the damaging environmental impacts of fuel use. As a fuel additive, ethanol must be supported by legislation to be a viable source of renewable energy. The current state and future viability of using ethanol for a renewable fuel in Malaysia and the United States was investigated. Ethanol use in fuel is strongly supportedby financial incentives in place by state and economy level governments in the US and is effectively implemented to support agricultural feedstock. The current pricing structures for fuels are also affected by Malaysia's fossil fuel-subsidizing policy, negatively impacting the competitiveness ofbiofuels. The introduction of biofuels to the market is very dependent on governmental policies. Malaysia is heavily invested in biodiesel due to available feedstocks and legislation; a transition to ethanol is not anticipated to be viable. From an economic standpoint, ethanol is challenging in its competitiveness with other fuels, the consumer willingness to embrace green fuels, as well as low oil prices acting as a cap for ethanol prices.

Keywords: Biofuel market, ethanol blending into gasoline, biofuel incentives and policy, Production method technology, Renewable fuel legislation

1. Introduction

The impacts of climate change are some the biggest risks to Earth and human existence. One of the major causes of this is the increase in greenhouse gas emissions since the 1950's (Figure1). The United States Environmental Protection Agency (US EPA) predicts that 14% of global greenhouse gas (GHG) emissions derive from transportation. Automobiles, trains, boats, and aircrafts rely on fossil fuel combustion, resulting the emission of GHGs, primarily carbon dioxide(CO_2) (Earth Science Communications Team, 2016). Due to this, renewable fuels have been explored and implemented in an attempt to reduce emissions and prevent climate change impacts,including the increased incidence, duration, and strength of wildfires, droughts, and tropical storms (Wang et al., 2014). Biofuels could potentially provide 42% of lower GHG emissions fromtransportation related sources, so this will likely be a primary technology used to de-carbonization transportation sources by 2050 (EIA U.S. Energy Information Administration, 2016).

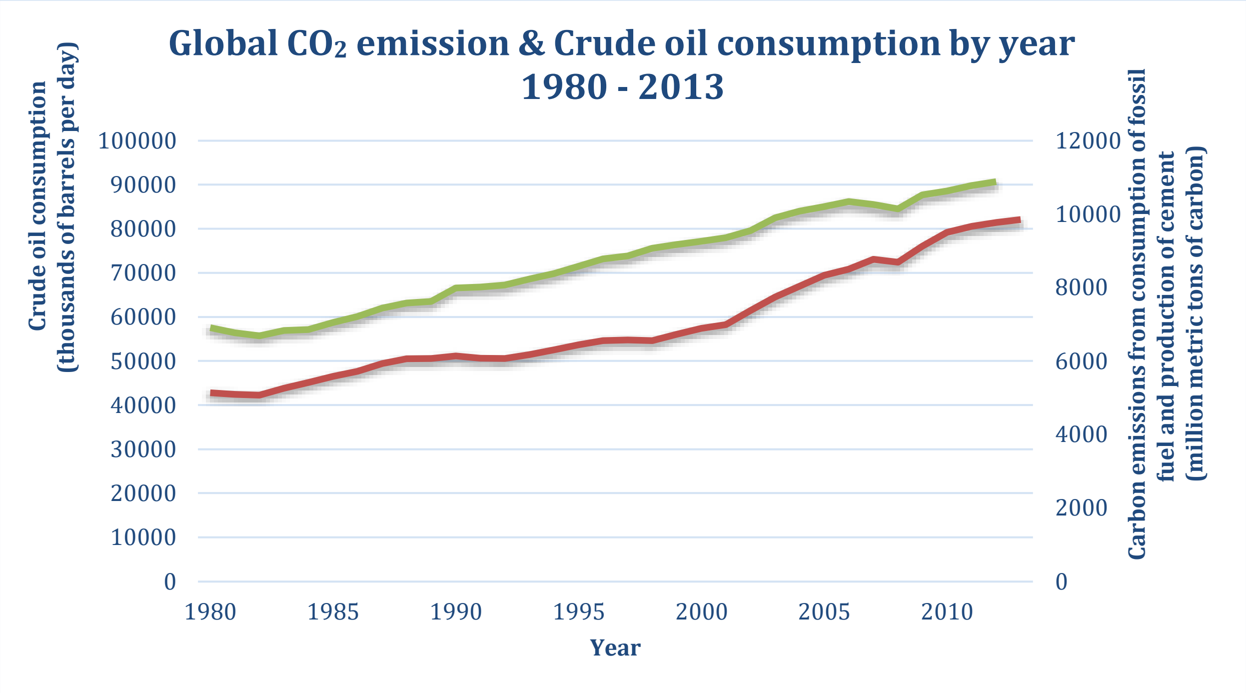

Figure 1: Global CO_2 emissions (solid line) and crude oil consumption (dotted line) by year, 1980 -2013 (EIA U.S.Energy Information Administration, 2016)

Ethanol is the top potential renewable fuel source because it is inexpensive and efficient compared to other fuel additives. Ethanol has long been used in spark-ignition engines as the onlyfuel or in gasoline blends in the US. Ethanol fuel comes in varying blends from E1 to E100 (the blending amount that is commonly used is dependent on the economy or region). This common denotation indicates the amount of ethanol in gasoline; E1 contains 1% ethanol and E100 contains100% ethanol. Since the introduction of ethanol-blended gasoline, the materials used to build modern car engines as well as altered fuel injection systems have been developed to support low-percentage ethanol blends (Yusoff et al., 2018). Manufacturers have developed improvements onmodern cars to satisfy the properties and properly ignite the fuel-air ratio when using ethanol fuel (U.S. Department of Energy, 2016). Flexible-Fuel Vehicles are designed to operate on either pureethanol or a gasoline/ethanol mixture and are also part of the innovation. This practice has becomecommon in many parts of the world, but in some locations, it is not practical yet due to limitationsof supply, technology, and production. This paper will analyze the advantages and disadvantagesof blending ethanol into gasoline in the United States and Malaysia. The feedstock of bioethanol for each region will also be highlighted.

2. Ethanol Production
2.1 Feedstocks and Production Methods

Ethanol is most commonly produced by (Wu et al., 1986) fermenting biomass sugars. Over 70% of the biomass of plants contains the sugar sucrose or the organic polysaccharides hemicellulose and cellulose, so cellulosic ethanol can be produced from these raw plant materials (Figure 2) (Ding et al., 2017; Hosseini and Wahid, 2015). Cellulosic ethanol is also called an “advanced” biofuel of second generation, as this fuel is manufactured from biomass not used for food. Ethanolcan be produced from biomass feed stocks through two methods. A more capital-intensive and expensive method, wet milling is designed to extract the highest yield from each component of thefeedstock (Figure 3).

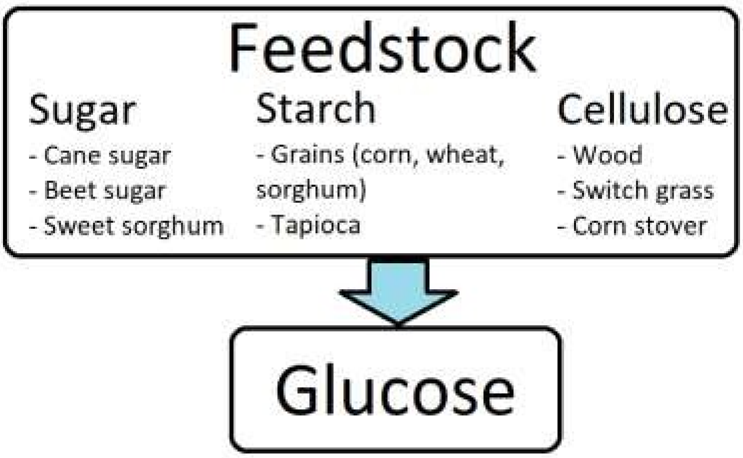

Figure 2: Biomass that is commonly used to produce ethanol

The dry milling processes uses less equipment and is cheaper, focusing on production of grain ethanol from fine grain meal (AMG, 2020). This method is the most common because it is relatively inexpensive compared to pure petroleum gasoline costs (EIA U.S. Energy Information Administration, 2016; Hosseini and Wahid, 2015). Ethanol production is even more efficient due to the use of primary crop feed stocks that are grown on commercial agricultural scales.

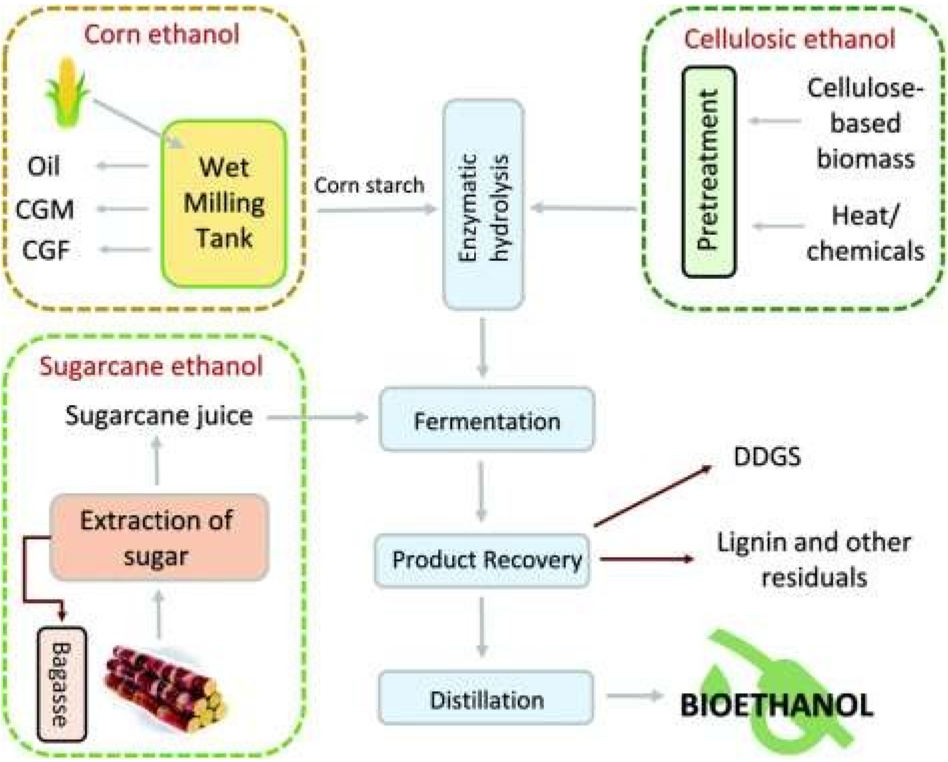

Figure 3: Bioethanol production process (Gavahian et al., 2019)

Another way to produce ethanol is through a synthetic route. This can be done through three methods. The first is direct hydration of ethylene and the second is a less common reaction,Fischer-Tropsch conversion or hydrogenation of acetic acid. The method of direct hydration of ethylene is most commonly used, and is an improvement over the second method, an indirect hydration of ethylene, through a reduction of pollutants and limiting byproducts (Clark, 2015). Finally, ethylene can be synthesized by cracking petroleum, and then hydrating the double bond to yield ethanol. Ethylene and steam are passed over an acidic phosphoric(V) catalyst (H_3PO_4) at high pressures and temperatures. This reaction is reversible, so ethanol must be continuously removed from the reaction, and the unreacted ethylene recycled to achieve high levels of conversion (Figure 4).

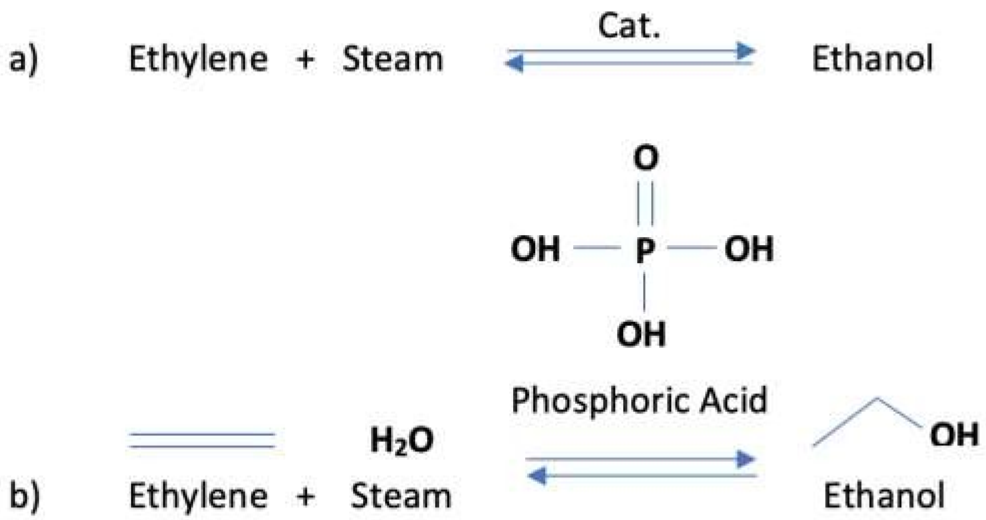

Figure 4: (a) The general reaction scheme for the synthetic production of ethanol; (b) specific reaction of ethylene,steam ($H_2O(g)$), and a phosphoric acid catalyst to produce ethanol ((Harding Bliss and Dodge, 1937).

The significant drawback to synthetic methods is the far less environmentally friendly process compared to production via fermentation. This is due to the high energy costs, extreme conditions of the reactions, and the risk of toxicity of the involved materials. Since petroleum is used as a starting material, this route is not renewable. Also, this technique requires a large input of energy because the reaction needs to be kept at very high temperatures and pressures. Due to this, most of the global fuel ethanol is made by fermentation of sugars derived from biomass, although synthetic ethanol is still produced for industrial or consumer applications that require high purity.

Although many different feedstocks can be used in the production of ethanol, primarily corn, sugarcane, and palm oil waste (also called palm oil mill effluent [POME]) will be discussed because they are the significant feedstocks for the US and Malaysia. Other feedstocks, such as switchgrass, are used in the US because it is native to North America (Mumm et al., 2015). Corn is a plant native to the Americas, is one of the food crops most widely distributed around the world,and it is easily cultivated around the world (Encyclopedia, 2011). Sugarcane, another good sourcefor ethanol production, is a perennial grass grown primarily in the tropics and subtropics (van Zelmet al., 2018). The oil palm is a tree found throughout Africa and Southern Asia and is used for palmoil production as well as the creation of bio-products (Bujang et al., 2016).

Although the feedstock can be varied, the first step in ethanol production is growing and harvesting the crops. Next, the sugars from the feedstock need to be isolated in preparation for thefermentation process. Sugarcane feedstock is cut and milled with water to produce a sucrose containing “juice” that is fermented to manufacture ethanol (Machado et al., 2018). The most commonly used feedstock in the US is corn, because there is already farmland and infrastructure to support the process of corn farming and ethanol production. After the corn is harvested, it is finely ground and treated with water and fermented with *Saccharomyces cerevisiae* or another strain of yeast to break down the complex carbohydrates (Figure 5). Palm oil mill effluent shows great promise as a potential ethanol feedstock and is the waste from palm oil production and its preparation for ethanol production is very similar to corn (Loya-González et al., 2019).

The fermentation process for different feedstock is the same after the sugars are isolated from the other components of the plants. Yeast is added to the sugar solution and stored in an airtight vessel at about 35 °C for 40-60 hours to ferment. It is very important to exclude oxygen during the fermentation process because oxidation of ethanol to acetic acid can occur.

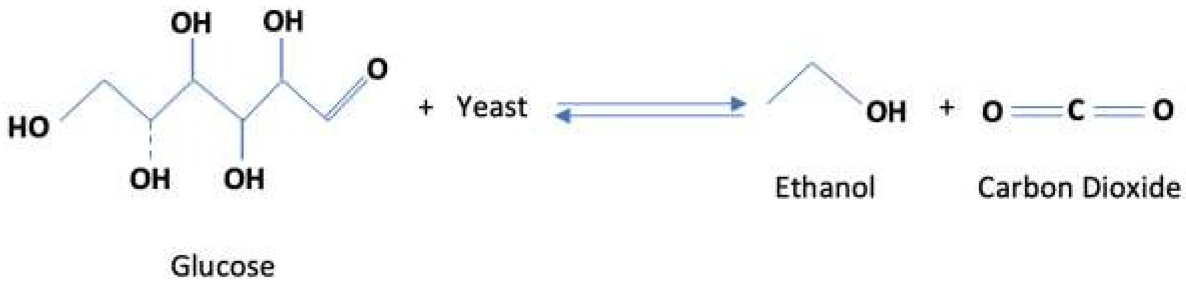

Figure 5: The reaction scheme for fermentation of yeast and glucose to make ethanol and carbon dioxide

After fermentation, the ethanol is separated by distillation. This ethanol contains 6-12% water which can be removed by storing over molecular sieves, corn grits, or tapioca (Greenblatt etal., 2018). This process yields 200 proof ethanol, which requires denaturation with a small amountof gasoline (2-5%) or another denaturing agent in order to ensure that it cannot be consumed and so is not subject to duty on alcohol meant for consumption. It is then stored and eventually mixedwith more petroleum to produce ethanol blended gasoline.

Although the processes might be similar, different feedstock yields varying amounts of ethanol. On average, 420 gallons (1,590 L) of ethanol can be produced from an acre (0.40 hectares)of corn compared to 560 gallons (2,120 L) from one acre (0.40 hectares) of sugarcane (Garritano et al., 2018). Effluent from palm oil mills is the least efficient of these types of feedstock materials,with the creation of 4.6% (volume ethanol/volume POME). POME also produces the most waste,78 tons of waste for every 100 tons of fruit processed (Stichnothe and Schuchardt, 2011). Differentmethods have been developed, but due to the low yield of ethanol produced from POME, which is already a limited feedstock as a waste byproduct, it is not a viable commercial source. Improvedproduction techniques, however, could provide a great value for Malaysia in a sustainable ethanolsupply, as palm oil production provides the highest agricultural revenue in Malaysia (Hosseini andWahid, 2015; Szulczyk and Atiqur Rahman Khan, 2018). Although a non-toxic waste, POME is often discarded into large ponds or other bodies of water, releasing large quantities of methane gas. POME also has the capacity to by oxygen depleting in these environments, due to the organic and nutrient contents, and so improved end-use must be found and applied. POME has shown potential to produce natural biogas through anaerobic digestion and other improvements intreatment for waste disposal have been investigated. These are more viable options than ethanol production for disposal end-use.

3. Ethanol Incentives and Policy

3.1 Malaysian Legislation

Few sizable ethanol producers exist in Malaysia as of 2018, with an annual production capacity of 9 million liters. Malaysia has primarily imported its ethanol for consumption (Ghani Wahab, 2017). Although sugar plantations exist in Malaysia for the production of raw sugar, the molasses from this sugar cane production is sold domestically as syrup for local edible delicacies. The lack of economies of scale and the high cost to produce ethanol due to technological limitations make it economically untenable to produce ethanol from sugar cane. There are small volumes of ethanol production in Malaysia derived from POME, palm trunk and palm oil mill effluent waste, however, ethanol is not produced commercially from this feedstock because it would be too expensive to transport the feedstock from rural plantations to urban processing plants.Instead, palm plantations produce ethanol from their waste and use it to generate electricity to runthe boilers (Figure 6).

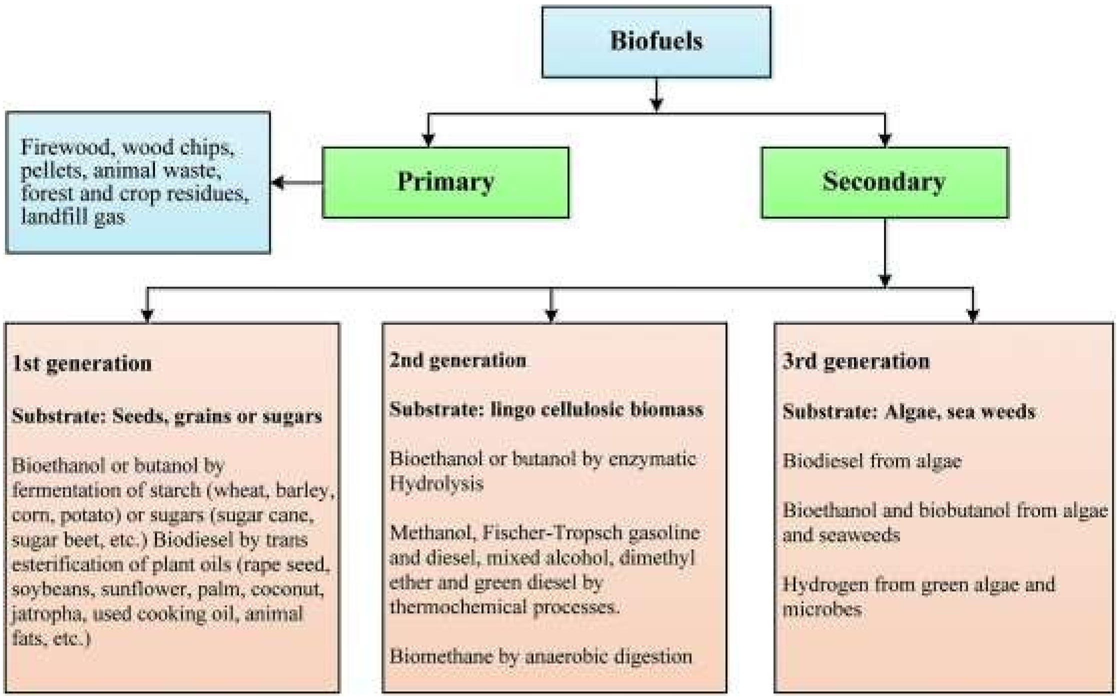

Figure 6: Biofuels in generation (Sebayang et al., 2016)

There was a government-backed initiative in 2008 to produce ethanol from POME commercially by Mitsui Engineering and Shipbuilding partnered with Sime Darby Plantation. Thelack of capable technology and the high capital investment required for a second-generation bioethanol plant project have made it unfeasible and the project was terminated (Abdulrazik et al., 2017). In addition, it is difficult to source a constant supply of feedstock, which is prohibitively expensive. As such, ethanol is not used for fuel or in production of industrial chemicals in Malaysia.

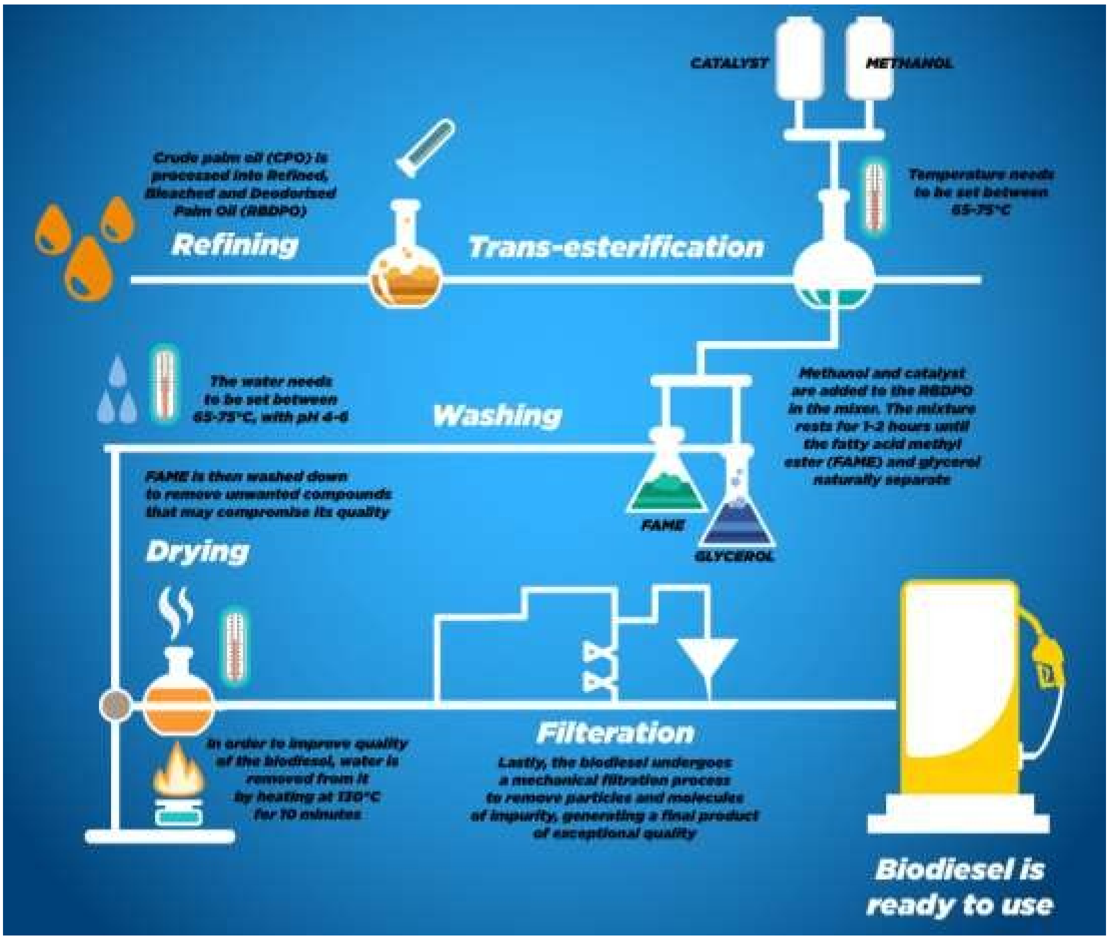

Figure 7: Malaysia biodiesel production process (Chin, 2019)

The focus in Malaysia seems to be the manufacture and use of biodiesel, and not the synthesis of bioethanol. Biodiesel production process in Malaysia is generally shown in Figure 7.For example, in Malaysia the emphasis in on the utilization of crude palm oil by synthesizing B5 biodiesel (palm methyl ester). The policies and laws developed by the Malaysian government to encourage the synthesis of B5 biodiesel are summarized in Figure 8 below:

1982-1985
- Pilot production laboratory study of palm oil methyl-ester, formation of steering committee. (DOE, Department of Energy, 2008)

1995
- Production of eleochemicals, carotenes, and vitamin E by technology transfer of palm methyl-ester (PME) to industry (Kettha, 2011)

2001
- Initiation of crude palm oil (CPO) and fuel oil blend to generate power and research on palm diesel with low-pour-point. (Kettha, National Energy Balance, 2011)

2005
- Five Fuel Diversification Policy 2005 (DOE, 2008)

2006
- National Biofuels Policy allowed the original commercial-scale biodiesel plant to open. (NationalEconomic, 2007)

2007
- Envo-Diesel began and 92 biodiesel licenses approved. (BiofuelsDigest, 2018)

2008
- Malaysia Biofuel Industry Act 2007, the original palm oil biofuel, Envo Diesel, was changed to B5. (Biodiesel, 2007)

2009
- National Renewable Energy and Action Plan (Abdullah, 2009)

2016 - 2020
- Eleventh Malaysia Plan (Sadhukhan, 2018)

2020
- The National Biomass Strategy 2020 (NBS2020, 2018)

Figure 8: Malaysia policies and acts towards biodiesel

In March 2006 in Malaysia, the National Biofuel Policy was created in order to reduce the economy's dependence on fossil fuels, encourage the use of sustainable and environmentally conscious energy sources, and to stabilize and increase palm oil prices (Szulczyk and Atiqur Rahman Khan, 2018). The National Biofuel Policy specified that biofuels were to be produced for use in transport and industry and for export. In addition, the Government of Malaysia (GOM) encouraged the development of innovative biofuel technology within Malaysia, including the creation of second generation (or more advanced) biofuels.

Parliament passed the Biofuel Industry Act in 2007 (Hassan et al., 2011). This policy stipulated that the Ministry of Plantation Industries and Commodities to put into action mandate for a biodiesel blend. However, this policy did not include ethanol as a potential source of alternative fuels under the National Biofuel Policy. The plan was initially to start production of B-5 (5% blended biodiesel) in 2008, it did not begin until 1 June 2011. The B-5 blend was first introduced to the central region (including Selangor and Negeri Sembilan), and then to the southernregion (including Johore and Malacca), in July 2012. The northern region was then added(including Penang, Perlis, Kedah, and Perak) in October 2013, and then finally added to the east coast states (Kelantan and Pahang), in February 2014 (Hassan et al., 2011). At the end of 2014, B-5 was finally introduced to both East and Peninsular Malaysia. The decline of prices along with agrowth in crude palm oil (CPO) stocks pressed the GOM to increase the CPO used for biodiesel production, leading to the B7 mandate in 2017 (Sadhukhan et al., 2018).

The GOM released the Eleventh Malaysia Plan (2016-2020) to promote consumption of biodiesel within the economy (Sadhukhan et al., 2018). The goal was to include a B-15 mandate foron-road transportation by, but with no implementation information. However, manufacturers of automobiles were uncertain use of the new fuel in diesel engines, as they believed the injection system could be damaged with the use of a blending rate higher than 7% of palm methyl ester. Inorder for consumers to have confidence in blended biodiesel products, the GOM must continue towork on issues such as, supply and delivery; quality control; safety; and education of end user.

However, in order to limit GHG emissions by 2020 in Malaysia, the National Biomass Strategy 2020 encourages 10% bioethanol blending in petrol fuel (Onoja et al., 2019).With this mandate, a demand for 1 million tonnes of bioethanol in Malaysia per year would be created. In order to satisfy this demand, the first bioethanol plan derived from lignocellulosic biomass was planned to be online between 2013 and 2015. However, the market price does not encourage players to invest and enhance commercial production of bioethanol. Therefore, the focus has changed to synthesizing bioethanol from both wood waste and biomass from oil palm instead.

4.2 United States Legislation

In the United States, the regulatory framework is centered on the Renewable Fuel Standard(RFS) that was created in the Energy Policy Act of 2005, which required refiners to use mandatedamounts of ethanol (U.S. Congress, 2005). The RFS was expanded as part of the Energy Efficiency Act of 2007, which substantially increased the renewable fuels target (Department of housing andurban development US, 2015). Consumption of ethanol would increase under the mandate that theeconomy's gasoline supply contain 36 billion gallons (136 billion liters) of ethanol by 2022, with 21billion gallons derived from cellulosic or advanced biofuels. By reaching this goal, ethanol or otherrenewable fuels would account for about 22% of the US transportation fuel mix.

For renewable fuels, the RFS sets required levels for blending. The law also established GHG reduction targets and a method for determining life-cycle GHG emissions for ethanol blending. The program established definitions for renewable fuels according to their GHG reduction profiles. The US EPA proposes requirements by fuel volume for renewable fuels by the July (U.S. Environmental Protection Agency, 2020) and announces a final rule by 30 November to set the RFS for each ensuing year (U.S. EPA, 2010). The EPA can waive the RFS requirements,if there is not enough domestic supply of ethanol to achieve the mandate. These RFS standards and projected standards are summarized in Table 1.

Table 1: Summary of the finalized and proposed RFS fuel volumes by year for major renewable sources and total(including other renewable fuel sources), in billions of gallons.

	2014	**2015**	**2016**	**2017**	**2018**	**2019**
Cellulosic Biofuel	0.033	0.123	0.230	0.311	0.238	n/a
Biomass based diesel	1.63	1.73	1.90	2.00	2.10	2.10
Advanced biofuel	2.67	2.88	3.61	4.28	4.24	n/a
Total renewable fuel	16.28	16.93	18.11	19.28	19.24	n/a

In 2010, the revised Renewable Fuels Standard (referred to as RSF2) was enforced using asystem of tradable credits called Renewable Identification Numbers (RINs) (U.S. EPA, 2020). Every US refiner or importer of refined product must generate an assigned quantity of RINs everyyear by purchasing ethanol for blending into gasoline. The RIN credit is calculated by taking intoaccount both the renewable portion of the fuel and energy content. The EPA assigns other biofuels different RIN values. Examples include tax exemption of ethanol blenders (University of Illinois Extension, 2020), Volumetric Ethanol Excise Tax Credit (Siciliano, 2018), and Small Ethanol

Producer Tax Credit (U. S. DOE, 2013). However, most of these policies expired by 2011 as theindustry matured.

States in the US also make regulations about fuel use. For instance, the California Low Carbon Fuel Standard (LCFS) program was approved in April 2010 (California Air Resources Board (CARB), 2019). Beginning 1 January 2011, a regulated party (the producer or importer) must meet the average carbon intensity requirements as well as reduction targets as outline by theLCFS. The aim is to reduce California's average carbon intensity from 95.61 grams of CO_2 equivalent per megajoule of energy (gCO_2e/MJ) in 2011 to 86.27 gCO_2e/MJ by 2020, based on full fuel-cycle carbon emissions (Agostinho and Ortega, 2013; Wang et al., 2014).

In the US in 2017, about 14.5 billion gallons (55 billion liters) of ethanol, in 143.85 billiongallons of gasoline, were used for fuel in automobiles, trucks, small aircraft, and most other typesof gasoline-powered vehicles or small appliances (EIA U.S. Energy Information Administration, 2016). Since the 1980s, all vehicular and small non-vehicular engines have been designed to operate with E-10, and improvement is continued through advances in changing internal engine pressure (Yusoff et al., 2018). The average concentration of ethanol in gasoline increase from 1%in 2000, 9.8% in 2013 towards 10.02% in 2017. The turnaround in US gasoline demand has supported fuel ethanol consumption and has slightly exceeded the 10% RFA target. Ethanol consumption hit the so-called "blend wall," 10% ethanol blending is the marketplace limit for ethanol in US gasoline (U.S. Environmental Protection Agency, 2020). Drivers for future demandgrowth will include higher ethanol blend markets, as an octane improver, and ethanol as a low- carbon fuel in regional markets such as California.

By 2030, California plans to limit petroleum use by half in order to reach both climate change and air quality goals. California is the top ethanol consuming state and accounts for over 10% of total ethanol demand in the US. Thus, CI evaluates GHG emissions calculated with a complete life-cycle analysis including the direct effects of fuel use and production and the indirecteffects associated with crop-based biofuels. This has increased demand in California for advancedbiofuels such as ethanol made from sugarcane originating in Brazil, as well as cellulosic ethanol (de Mattos Fagundes et al., 2016; Ghani Wahab, 2017).

The EPA published the proposed volume requirements in May 2015 for 2014, 2015, and 2016 under the RFS, as well as the 2017 volume requirements for diesel based on biomass. In December 2017, the finalized law for 2018 and 2019 diesel based on biomass was announced, following a proposal made in July 2017. Most recently, on August 2, 2018, the US EPA released a proposal to 1) weaken the federal fuel-efficiency standards and 2) remove the ability for California to set state-level, stricter levels of greenhouse-gas emissions from vehicles. This was driven by the Trump administration's argument that requiring vehicle manufacturers to meet California's current efficiency standards costs too much and will increase the price of vehicles.

This claim is proposed to result in customers retaining older, less-safe vehicles, resulting in a greater occurrence of fatal accidents. This has been pointed to by scientists as baseless, and an incident of “political opportunism” of the Trump administration. The Trump administration proposal includes multiple options for changing Obama-administration rulings, but highlights thecourse of action that freezes all vehicle standards until 2020. Under this plan, an estimated increase of 20% in CO_2 emissions would occur through 2025 from new US vehicles, in comparison to emissions under regulations currently enforced by the US EPA.

5. Benefits of Blending Ethanol

The most important reason ethanol is blended with gasoline is a decrease in net GHG emissions in comparison to the consumption pure petroleum fuel. The presence of ethanol in gasoline was found to increase CO_2 emissions compared to neat gasoline (U.S. Department of Energy, 2016). There is a tradeoff between CO, unburnt hydrocarbons (UHC), and CO_2 emissionsthat needs to be considered. Despite an increase in CO_2 emissions by the ethanol blended gasoline,the caCO_2 is taken from the atmosphere with crops that are used to make the ethanol, so blendingreduces net CO_2 emissions. An analysis on the life-cycle of ethanol done by the Argonne National Laboratory and compared ethanol derived from corn, cellulosic biomass, and sugarcane (Machadoet al., 2018). The study found that ethanol synthesized from corn lowers the life-cycle GHG emissions by 34%, and cellulosic biomass reduces emissions 108% (Table 3) (von Blottnitz and Curran, 2007). Emissions of palm oil production and transportation has been studied and quantified, although the use of POME ethanol has not b.een well studied in order to determine lifecycle GHG emissions (Hosseini and Wahid, 2015) When burned in an internal combustion engine,ethanol releases CO_2, but the released CO_2 is captured and recycled when the crops are grown, resulting in zero or significantly reduced net CO_2 emissions (Hoover and Abraham, 2009).

Table 2: Life-cycle GHG emissions savings for different ethanol sources, including and excluding land use change (LUC) emissions in comparison to GHG emissions of petroleum gasoline, using information adapted from (Wang etal., 2015)

WTW GHG emission savings	**Corn**	**Sugarcane**	**Switchgrass**
Include LUC	34%	51%	88%
Exclude LUC	44%	68%	89%

The amount of tailpipe emissions in a flexible-fuel car with varying ethanol blends (E0-E80) has been studied (Hubbard et al., 2014). New research applies the US EPA Motor Vehicle Emissions Simulator (MOVES) modeling system in order to investigate these more moderate ethanol blends, as used predominantly in strong ethanol-using economies such as Brazil (Benites- Lazaro et al., 2018; Grau et al., 2013). Although emissions increased for some compounds (ethanol, acetaldehyde, formaldehyde, methane, and ammonia), there was a major reduction of both non-methane hydrocarbons (NMHC) and NO_x. A pronounced minimum emission was observed with mid-level blends (E20-E40) for non-methane organic gases (NMOG) and total hydrocarbons (THC). This minimum can be explained by two counteracting trends. First, with anincrease in ethanol content, the amount of unburned ethanol increases, resulting in emissions of partially oxidized products and therefore increasing the emissions of NMOG. Conversely, with higher amounts of ethanol, the number of unburned hydrocarbons (corrected NMHC) decreases. Since THC and NMOG are sums of these different components, the trends counteract each other at the extremes (E0 and E80) resulting in a minimum around E30-60 (Wallington et al., 2016). These results are dependent on the particular study and the emitted compounds analyzed, indicating that moving to the use of these more moderate levels of ethanol blends would have a positive result on overall emissions.

Blending ethanol with petroleum has been found to have major impacts on tailpipe emissions. Nitrogen oxides (NO_x) are released from burning fuels and are a class of highly reactiveand poisonous gases. From 1970 to 2005, NO_x emissions decreased by 71% in the US (Hoekman and Robbins, 2012; Spliethoff et al., 1996). Flexible-fuel vehicles can utilize blends of up to 83%ethanol in fuels, provides a way to continue this decrease of harmful pollutants.

The most significant role of fuel additives is that of oxygenates. Oxygenates are oxygen containing hydrocarbons, and to be effective and practical as a gasoline additive, the oxygenate must be inexpensive and have a slightly cooler burn temperature than petroleum (Ghani Wahab, 2017). The increased oxygen content in the gasoline allows for a more complete burn of petroleum,and the lower burn temperature results in spark plug longevity and fewer combustion deposits. Theresulting cleaner burn results in a major decrease in toxic tailpipe emissions. Most notably, the useof oxygenates can reduce carbon monoxide (CO) and polycyclic aromatic hydrocarbon (PAH) emissions.

After the transition away from leaded gasoline in the 1970's, aromatic additives were usedas octane boosters. An octane booster contributes to the fuel's octane rating, which contributes tostability under pressure and improves performance by ensuring that fuel in a cylinder ignites hen it should, providing resistance to detonation and engine knock. BTEX Complex was a very efficient booster and it was comprised of benzene, toluene, xylene, and ethylbenzene (Szulczyk and Atiqur Rahman Khan, 2018). An additive, methyl tertiary butyl ether (MTBE), was used starting in the 1980's, but production and use as an oxygenate increased rapidly between 1990 and1994. After MTBE, ethanol was used because it is not directly toxic to humans or the environmentand it results in improved air quality by reducing other emissions. However, more recently ethanolhas significantly increased in atmospheric measurements (Chillrud, 2016; U. S. DOE, 2018). While not considered a toxin, the EPA does consider its byproducts acetaldehyde and ozone as hazardous pollutants (Dunmore et al., 2016).

Currently in Malaysia, esters derived from palm oil are used as an oxygenate in fuel. Depending on the particular ester used, esters are competitive with ethanol as an oxygenate blend component, and in the case of some esters such as 3-Hydroxybutyrate methyl ester (HBME), havebeen found to have better oxygenate properties than ethanol (Pelucchi et al., 2016). Esters are notused as oxygenates in the United States as they have not had the requisite body of test data to showthe potential dangers of use with respect to emission control devices or negative health impacts.

Ethanol is also an efficient octane booster, which is necessary to prevent "knocking" duringfuel combustion. This occurs when an air/fuel mixture is detonated out of sync with the normal engine cycles (Yusoff et al., 2018). This can cause damage to engine components and eventually require expensive repairs (Chillrud, 2016). Due to the health dangers of earlier oxygenates, a transition from aromatics to oxygenates took place in the 1990's. Different methods are used to measure the octane rating, 1) motor octane numbers are taken at high speeds and temperatures; 2)research octane numbers are measured under mild conditions; and 3) road-index octane numbers are reported on gasoline pumps and are an average of the motor and research octane numbers. Road-index octane numbers (RION) for different additives are shown in Table 5 (Hertel et al., 2010). Although ethanol is not as efficient as other additives, it is the most environmentally friendly and generally the cheapest option due to US government mandates targeting ethanol, at
$1.22 per gallon by production costs (Lane, 2017).

Table 3: Octane ratings of commonly used octane boosters. Larger value indicate a more effective octane booster(Hubbard et al., 2014)

Additive	Road-Index Octane Number
Heptane	0
Benzene	101
Toluene	112
Ethanol	114
MTBE	117-121

Blending ethanol with gasoline has been found to have many benefits. The most obvious benefits are the major reduction in GHG emissions. Also, ethanol reduces reliance on toxic gasoline additives such as MTBE, which have proven to cause negative health and environmentalimpacts. Transitioning to higher blends of ethanol used in the transportation sector could be a solution for combating climate change and increasing the overall health of billions of people.

6. Disadvantages of Blending Ethanol

Pushback from people and lawmakers over blending ethanol with petroleum has occurred.One of the bigger concerns is the land use change required to sustain high levels of ethanol in gasoline. Since the most efficient way to produce ethanol is from fermentation of corn, sugarcane,and switchgrass crops, more land will be required to produce enough biomass for ethanolproduction. Hertel *et al.* estimate that an additional 50.51 Gigalitres of ethanol will need to be produced per year to meet the growing demand (Hertel et al., 2010). This translates to 3.8 millionhectares worldwide that would be converted to new cropland to meet demand. The deforestation that would be required would have detrimental impacts on not only the environment, but also people and cultures.

Corn-based ethanol has a high carbon footprint, which is the total carbon emissions of carbon dioxide equivalence, or the amount of CO_2 which has the same impact. Mubako and Lant report that corn-based ethanol production has a low energy balance, meaning that it has a high input for little gain, and is a water-intense crop to produce. There are tradeoffs between corn-based ethanol production and environmental resources, specifically water quality and quantity. The waterrequirement to produce ethanol has decreased over time as production has improved in efficiency, currently approximately 3 gallons (11.4 L) of water is utilized to synthesize 1 gallon (3.8 L) of ethanol. This has decreased from 5.8 gallons (22.0 L) of water to produce 1 gallon (3.8 L) of ethanol in 1998 and 4.2 gallons (15.9 L) of water to 1 gallon (3.8 L) of ethanol in 2005. With pesticides and other chemical used in corn production, water released from the agricultural areas can contaminate water resources present in nature. Moreover, corn growth can cause a differencein carbon footprints as there tends to be more land being converted to corn farms. The productionof ethanol from corn can either increase or decrease depending on corn crop yield.

Large scale land conversion is required to meet high demand of ethanol fuel consumption.With increasing ethanol fuel consumption in the Midwestern region of the US, many prairie grasslands have been converted to agricultural areas (i.e. corn farms) for producing biomass used for making ethanol (Mumm et al., 2015). A similar situation of deforestation also happens in Malaysia, except that Malaysia does not commercially rely on ethanol fuel as a resource for renewable energy. Instead, Malaysia uses biodiesel from palm oils as a primary resource of renewable fuel (Hussan et al., 2013). Even though the source of renewable fuels is different for the US and Malaysia, the environmental impacts are similar. Malaysia is a biodiversity hotspot, meaning that it is rich in plants and animals, and is threatened with deconstruction and deforestation. Conversion of tropical forests to agricultural areas such as sugarcane, corn, and palm oil is one of the largest sources of deforestation in tropical economies, including Malaysia. The loss of natural ecosystems directly affects biodiversity and species interactions.

In the US, corn monoculture affects biodiversity and prairie ecosystems. A conversion of natural to agricultural lands decreases biodiversity that can promote ecosystem services. For example, the conversion of natural ecosystems reduces resources and spaces available for wild organisms such as native plants and insect communities. Even though grasslands are thought of asunpopulated and less species-diverse biomes, they can support diverse communities and provide pest controls. This is especially important with regards to plant species, many of which are only found in grasslands. The imbalance of pest controls can potentially decrease crop production. A lack of natural predatory pest control is associated with necessitating an introduction of pesticidesand other chemical usage in order to manage pest populations. Over time, these pest populations can develop an evolutionary resistance to pesticides being used. This resistance can be combattedby farmers; however, it often comes at the cost of greater and more varied chemical use.

Monoculture, cultivation of a single crop in a certain area, can have negative impacts on soil property in ethanol-related crops (Mosher, 2012). Monoculture can degrade soil properties in several ways, including reduction of soil moisture, nutrients, and microbial communities. Microbial communities, for example, require certain environmental conditions to maintain their community structure and functions (Ofori-Boateng and Lee, 2014). A combination of chemical usage and water runoff from agricultural areas can alter soil microbial communities (Marais et al.,2012). Moreover, the monoculture can cause soil erosion in areas with less plants covered in soil surfaces. The monoculture of ethanol-related crops has adverse impacts on water contamination, soil degradation, loss of biodiversity, and increase in chemical usage in agriculture.

7. Potential of Ethanol in Energy Usage

7.1 Economic Impacts (US)

Because biofuels, such as biodiesel and ethanol, are produced from agricultural products, ethanol production has had a substantial, positive effect on the US economy by creating jobs. Thestate of Iowa has benefited from the production of ethanol by an increase in over 43,000 jobs, an increase in purchases of $6,610,000, and a GDP increase of $4,532,000 (Iowa Renewable Fuels Association, 2020).

The US leads in ethanol production and produces the most ethanol in the world. With flat landscapes and plentiful water resources, the Midwest is one of the largest agricultural farmlandsin the world, and produces the most ethanol. As demand for ethanol fuels increases, alternative biomass resources will be used in ethanol production, such as sugarcane and corn-based ethanol made from the sucrose and glucose. The remaining energy stored in these plants is in form of fibers. Current research focuses on how fibers in switchgrass can be converted to ethanol, but thiscould be applied to other feedstocks. Even though primary ethanol production is from corn in theUS, additional crops (i.e. sugarcane, switchgrass, hybrid poplars, and hybrid willows) can be usedfor ethanol production.

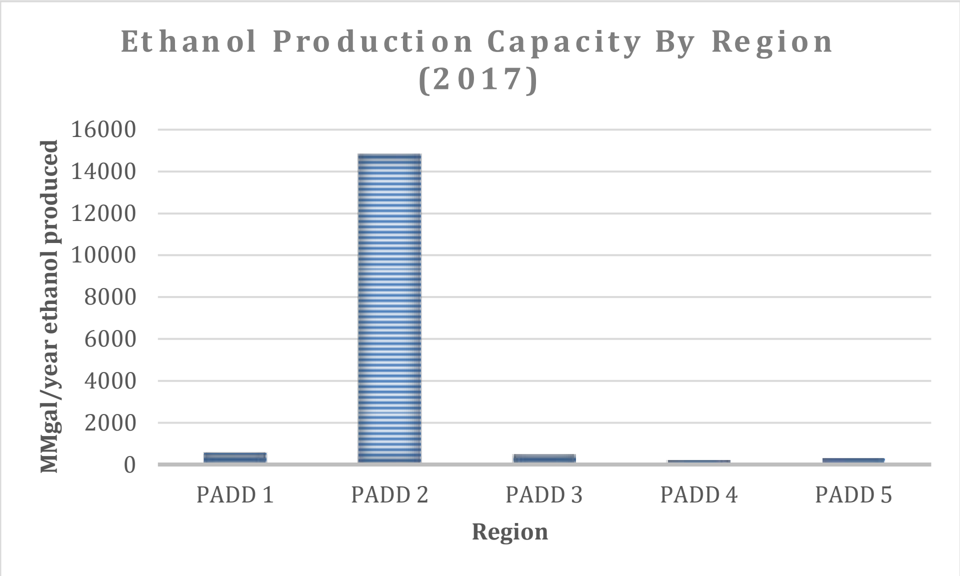

Figure 9: Ethanol production capacity by region (2017). Petroleum Administration for Defense District (PADD) with ethanol producing states: PADD 1: Georgia, North Carolina, New York, Pennsylvania, Virginia. PADD 2: Iowa, Illinois,Indiana, Kansas, Kentucky, Michigan, Minnesota, Missouri, North Dakota, Nebraska, Ohio, South Dakota, Tennessee, Wisconsin. PADD 3: Mississippi, Texas. PADD 4: Colorado, Idaho. PADD 5: Arizona, California, Oregon.(US EIA, 2018)

People living in different US regions benefit from ethanol production. California is the topethanol consuming state and accounts for over 10% of US demand. However, California only produces small amounts of ethanol that can support less than 10% of in-state ethanol demand. Withvery small ethanol production in California, ethanol fuels are imported from other states, mostly from the Midwest, to support energy consumption in California.

Another major concern is the increase in global food prices. Food prices have increased and are project to continue rising, since additional crops are being grown for fuel. As of December2007, food prices in the world had risen by 40% in the past year, according to the UN Food and Agriculture Organization (FAO) (Wallington et al., 2016). Furthermore, this burden primarily fallson developing economies, with over half of the $11.6 billion estimated import increase from 2005-2010 being paid for by developing economies (Wise, 2012). Despite the benefits of blending ethanolwith gasoline, a plan needs to be developed to accommodate the growing demand for affordable food.

An additional economic impact is how closely tied corn, ethanol, and gasoline prices are. As ethanol is a constituent of current gasoline, the price of fuel is dependent on the price of ethanoland its corn feedstock. The price of ethanol blended gasoline is cheaper than pure gasoline and a higher percentage of ethanol mixed into gasoline is associated with lower prices (Table 4). Historically, E85 has the lowest price and E0 (pure gasoline) has the highest. Based on this economy level average fuel price, one can conclude that ethanol blended fuels reduce GHG emissions and fuel costs. Due to this, it is cost-effective for the consumer to use alternative biofuels like ethanol gasoline. However, not all vehicles have been updated to run on high percentages of ethanol blended fuel.

Table 1:Comparative pricing for ethanol, fuels and co-product ((US Grains, 2017)

Comparative Pricing for Fuels and Co-Products					
Product	Current Price	Prior Week Average	Previous Year	Percentage Change (Week over Week)	Percentage Change (year over year)
Ethanol					
Ethanol (FOB Gulf)	$1.621	$1.606	$1.520	0.9%	6.6%
Ethanol (FOB Santos, Brazil)	$2.208	$2.196	$2.237	0.5%	-1.3%
Gulf discount/premium from Santos	-$0.587	-$0.590	-$0.717	-0.5%	-18.1%
Ethanol (FOB PNW)	$1.670	$1.852	N/A	0.9%	N/A
Gasoline/chemical components/additives					
MTBE (FOB Gulf)	$2.03	$2.00	$1.70	1.8%	19.8%
MTBE Premium/Discount to Ethanol (FOB Gulf)	$0.41	$0.39	$0.18	$0.01	$0.13
Aromatic Octane Enhancers (BTX)					
Benzene (FOB US Gulf)	$2.69	$2.74	$2.45	-1.9%	9.6%
Toluene NITN (FOB US Gulf)	$2.51	$2.40	$1.92	4.5%	31.1%
Mixed Xylene (FOB US Gulf)	$2.56	$2.48	$2.10	2.9%	21.4%
Weighted Average Aromatic Price (BTX)	$2.56	$2.49	$2.09	2.7%	22.3%
Gasoline (FOB Gulf)	$1.802	$1.852	$1.319	-2.7%	36.6%

**All price in $/gallon (Source: World Perspectives, Inc)*

Currently ethanol is about 40 cents cheaper than gasoline per gallon, so standard E10 blends are saving consumers about $6 per fill-up for an average 15 gallon gas tank (Lane, 2020). Due to the rapid increase in required supply to meet the needs for blending requirements of ethanol,concerns exist that the price of ethanol may increase, again placing burden on the consumer. However, as demand has increased, the supply of ethanol has risen to meet requirements, resultingin ethanol remaining a cost-effective fuel by volume. It was determined that energy use in ethanolproduction decreased by 46% per bushel of corn from 1991 to 2010 due to greatly improved production methods. Further developments and proposals have indicated that this efficiency will continue to improve. Despite the correlation between ethanol and gas prices, the improved energyefficiency of modern ethanol production plants will result in blended gasoline at reduced cost dueto production savings as compared to other fuel options.

Motorists also have concerns about the effects of ethanol on the automobiles. Ethanol hasa very high-water affinity, and if water contaminates the ethanol-blended gasoline it can cause phase separation. This would result in a water/ethanol solution to separate and form a layer in the bottom of the gas tank (Kookos et al., 2019). If this occurs, significant damage to the engine and even catastrophic failure are probable. For phase separation to occur, a fair amount of water is required, about 4% by volume. Due to this, low percentage blends (E5-E15) are generally not a concern, but with higher concentrations (E80-E95), preventing phase separation can be a major challenge. Throughout the distribution and use, ethanol is not exposed to water to reduce the potential contamination. Another method to prevent separation is that ethanol and gasoline are stored and transported separately and they are not mixed until stored at the filling station, althoughthis generates safety concerns as well as a decreased accuracy in blending proportions. Between these methods, advances in engine technology, and phase separation filters, high level blends willnot harm automobiles and should not be a concern for the consumer. Further education of consumers as well as developments in engines to increase ease of use will continue to reduce theseconcerns and increase the acceptance of ethanol and other biofuels.

Although the merits of blended gasoline are plentiful, increased production of ethanol holdssome major drawbacks. Currently there is work being done to develop efficient ethanol productionmethods for cellulosic feedstocks that have reduced land requirements compared to corn. This could potentially be a solution to these challenges, but in order to be economically viable with corn-sourced ethanol in the US, efficiency and cost will need to be dramatically reduced (Sikarwaret al., 2016).

7.2 Economic Impacts (Malaysia)

Ethanol fuel production in Malaysia is not feasible due to the high cost of large-scale production. Hii *et al.* reports that the cost of existing substrates (feedstock) available for cellulosicfermentation (i.e. an ethanol production) is very high and not viable commercially. Also, limitations of available cropland make expanding into corn and sugarcane farming difficult. Significant areas of land would have to be converted from forest to agricultural farmland. With large scale ethanol production, more land is necessary to create the biomass. Malaysia is geographically approximately 30 times smaller than the United States and has $1/10^{th}$ the population, and so it is less practical to have large-scale land conversion for non-food agriculturalcrops. This means that ethanol would need to be imported, which increases cost and reliance on other economies. Moreover, there are alternative renewable energy and fuels that can are widely used in Malaysia as Malaysia relies on biodiesel from oil palms instead of ethanol fuels. While biodiesel could help reduce Malaysian GHG emissions, it is not yet price competitive with biodiesel and so is used in blended fuels (Szulczyk and Atiqur Rahman Khan, 2018). A large portion of Malaysia’s economy relies on palm oil, so transitioning from palm oil biodiesel to ethanol blended gasoline would be detrimental to their economy. The economic effects of ethanolfuel in Malaysia are somewhat unknown because it is not viable for them to start blending ethanolwith petroleum.

8. Conclusions

The situation with ethanol is quite fluid and dynamic. In Malaysia, the outlook of ethanol use appears bleak, as there are no currently viable methods for commercial production or economicsupport for large-scale importation. With no outlook of a sustainable, large-scale feedstock, Malaysian domestic production of ethanol is expected to remain low. Projections of future US consumption are subject to technical, economic, and legislative forces. The future of ethanol is complicated by the emergence of new competitive fuels, such as BP and DuPont's biobutanol fuel,expected to be soon approved by the EPA to be sold as a 16% gasoline blend (Siciliano, 2018). The development of technology for producing ethanol economically from cellulose has been slow.Although big cellulosic ethanol projects such as DuPont's cellulosic ethanol facility have announced commercial production, the output of cellulosic ethanol was low. There have been ongoing improvements to enzymes and conversion efficiencies. Small-scale cellulosic ethanol projects built close to conventional corn facilities have made more progress. Ethanol is additionallydependent on the success of alternative clean fuel technologies. Electric cars, as well as cars powered by hydrogen cells or natural gas, make up a small market share but are available for purchase. Furthermore, until late 2010, the EPA allowed a maximum concentration of 10% ethanolin gasoline. In early 2011, E-15 was introduced for discretionary use (not mandated), but the market grew slowly owing to infrastructure and warranty concerns. E-85 has been available for two decades and will be relied on to overcome the blend wall, but the successful development of the E-85 market relies on a solid RFS target. From an economic standpoint, ethanol is challenged in its competitiveness with other fuels, the consumer willingness to embrace green fuels, as well as low oil prices acting as a cap for ethanol prices.

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