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Moving Toward Net-Zero Carbon Society

Challenges and Opportunities

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Foreword by Dr. Fuh-Sheng Shieu

Extreme weather caused by climate change has seriously threatened the ecosystem and human society, forcing people to rethink eco-friendly production and sustainable development. Major carbon-emitting countries have proposed timetables for achieving net-zero carbon emissions. Policy-makers also work closely to achieve net-zero emissions at both local and global scales. As sustainability policies are being made, it is critical to move toward energy transition and ecological conservation. To address these critical issues, this book explores the net-zero emission studies from various perspectives, ranging from carbon pricing, renewable energy, sustainable development, international legal framework, as well carbon sinks in the Asia-Pacific region.

The book presents the timely issues captured in empirical research, legal framework, case study with the coverage in the topics of "Potential Impacts of Expansion of Afforestation under Carbon Prices and Timber Prices Fluctuation," "Solar PV Mini Grid System for Lighting in Myanmar," "Sustainable Fisheries Under Net-zero Emissions," "Opportunities and Challenges of Sustainable Development and Governance in South Asia," "The Development and Local Content Requirements of the Offshore Wind Power Industry in Taiwan," "The Role of Renewable Energy for Ensuring Net-zero Carbon Emission and Energy Sustainability from Bangladesh Perspective," "Moving Toward Net-zero Emission Society in the Asia Pacific with Special Reference to the Recent Law and Policy Development in Japan, Korea, and Taiwan," "Ensuring a Global Food Supply Chain with Eco-friendly Cooling and Ventilation System on Bulk Carriers for Net-zero Society Pathway," "The Kelp Industry in Japan and its Effectiveness in Blue Carbon," and "The Climate Impacts of Black Carbon and Methane Emissions in the Arctic and Current Frameworks for Prevention."

I believe that this book is a valuable reference that highlights the aforementioned opportune and important themes. I therefore highly recommend it to the researchers in this field.

Dr. Fuh-Sheng Shieu
President of National Chung Hsing University
Taichung, Taiwan

Foreword by Dr. Yueh-Tuan Chen

Climate change has resulted in extreme weather events that threaten lives and property globally. The Sixth UN Intergovernmental Panel on Climate Change (IPCC) report issued in August 2021 indicates that man-made greenhouse gases' emission will result in a global temperature rise exceeding 1.5 °C by 2041. In keeping the global temperature rise under the 1.5 °C threshold, IPCC urges world leaders to take more active climate change mitigation measures to stabilize global temperature rise by the mid-century. EU, USA, Japan, and Korea have officially announced the net-zero GHGs emission target. In Taiwan, President Tsai Ing-Wen is also committed to achieving a net-zero emission target by 2050.

As the President of the National University of Kaohsiung, I fully support and cherish the core value of our university in incorporating SDGs into our teaching, research, and university governance. NUK is the youngest national university in Taiwan, established in 2000. Our university was awarded the Model University of Green Campus, the golden award for sustainable university, and ranked in THE Global University Impact Ranking. I also would like to salute Prof. Hsing-Hao Wu for his outstanding achievement in connecting several prestigious academic institutions in Taiwan and aboard conducting collaborated research activities in the context of climate change studies in the last decade.

This book is the second publication initiative of the proceedings series of the Joint International Conference on Moving Toward Net-zero Society: Opportunities and Challenges, co-organized by the NUK, National Chung Hsing University, and the Ocean Policy Research Institute of the Sasakawa Peace Foundation of Japan in November 2021. This book explores the timely trend of climate change responsive policy and law ranging from basic policy framework and roadmap for achieving net-zero emission goals in energy transition, forest management, sustainable agriculture and fishery, ocean economy, black carbon, and so on. Finally, I am proud to recommend this book because it effectively inspires and educates readers about using interdisciplinary approaches to tackle various climate change law and policy issues in accordance with the insights of specialists at the frontier of climate solutions and research.

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Acknowledgments

The net-zero carbon society is under scientific consensus globally as an essential pathway for climate mitigation and adaptation measures to reduce carbon dioxide (CO_2) emissions by 45% from 2010 levels by 2030, reaching net zero around 2050. The task would require holistic cooperation through the public, private, and other stakeholders from the perspective of renewable energy project implementation, regulation amendment, and the reform of the international legal framework.

To tackle these issues in this emerging field, the editors wish to thank the authors for sharing their research outcomes and making a timely contributions from different angles. We want to express our gratitude to the reviewers for their endeavor in providing valuable comments on the robustness of the manuscripts.

We again convey our gratefulness to President Yueh-Tuan Chen of the National University of Kaohsiung and President Fuh-Sheng Shieu of the National Chung Hsing University for their initiative and support of the joint international conference. Our heartfelt appreciation also goes to President Hide Sakaguchi, Research Director Tomonari Akamatsu, Senior Research Fellow Miko Makewaka, Senior Research Fellow Atsushi Watanabe of the Ocean Policy Research Institute, and President Atsushi Sunami of the Sasakawa Peace Foundation for their encouragement and the supervision.

We thank Mr. Andrew J. Barnes for serving as the managerial editor for this publication and Ms. Minako Akiyama for ensuring administrative procedure. Last but not least, we show appreciation to Springer Climate Series for coordinating this open access book with us. We hope this publication can shed light on understanding the challenges and opportunities for shaping the roadmap toward a net-zero carbon society.

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Chapter 1
Introduction: Connecting Global Issues of Net-Zero Carbon Society in the 21st Century

Michael C. Huang

Abstract Climate change has caused severe flooding and droughts, crop yield problems, and habitat changes, which pose a serious threat to the ecosystem and humanity. As a result, stakeholders are reconsidering environmental management policies and economic development limitations. This chapter introduces the overview of the book that explores achieving net-zero emissions through carbon pricing, carbon trade schemes, renewable energy transition, ecological conservation, and carbon sinks. It also examines the economic and social impacts of introducing carbon-neutral policies in the Asia-Pacific region. The urgency of addressing climate change and finding solutions to mitigate its effects on the environment and society is emphasized.

Keywords Net-zero carbon society · IPCC · Asia–Pacific region

1.1 Introduction

2021, the leaders of major industrial countries declared a shared goal of achieving a carbon-neutral international community by mid-century, during the G7 meeting. This objective is in alignment with the Paris Agreement, which aims to limit global warming to well below 2°C, and preferably to 1.5°C, compared to pre-industrial levels. In addition, major carbon-emitting countries such as the European Union, the USA, Japan, Korea, China, and India proposed specific timetables to achieve net-zero carbon emissions during the COP26 held in Glasgow in 2021. The objective of achieving net-zero carbon emissions involves reducing green house gas (GHG) emissions and balancing the remaining emissions through activities that remove GHGs from the atmosphere. These efforts reflect the urgency to address climate change and the need for coordinated action to achieve sustainable development goals.

After then, an Expert Group was designated by the UN Secretary-General to address a "surplus of confusion and deficit of credibility" over net-zero targets of non-State entities among public and private sectors. In 2022, The COP27 held in

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Sharm el-Sheikh, Egypt, kicked off with the release of the report—"Integrity Matters: Net Zero Commitments by Businesses, Financial Institutions, Cities and Regions" (United Nations 2022) by the Expert Group with ten practical recommendations in four key areas of environmental integrity; credibility; accountability; and the role of governments. Policymakers should strengthen global partnerships more closely with scientists, experts, and enterprises to seek appropriate policy instruments. Measures could refer to the carbon tax, carbon pricing (Arimura and Matsumoto 2021), carbon sinks, global or regional carbon emission trade schemes, energy transitions, and other carbon–neutral policies toward a net-zero emission society by mid-century. In the post-COVID-19 era, adopting a more proactive climate change-responsive policy and establishing international cooperation to save the Earth is indispensable.

At a time when carbon pricing policies are being formulated, climate change-related laws and policies will reshape global governance and the industrial layout between 2021 and 2030, and it is critical to move toward energy and industrial transformation, ecological conservation, and sustainable agricultural development. According to the Global Climate Action in the United Nations Framework Convention on Climate Change (UNFCCC), as of November 2022, 30,765 actors are engaging in climate action globally (UNFCCC Global Climate Actions 2022), of which actors consist of 13,909 companies, 1,562 Investors, 3,451 organizations, 286 regions, 11,361 cities, and 196 countries. In the report, the experts convey the importance of putting the net-zero pledge into practice by setting an evidence-based target. Moreover, utilizing voluntary credits could also help create transparent transition plans with accountability. Finally, these measures may improve the advocacy for accelerating the regulation roadmap.

The book focuses on the emerging issues of net-zero from the perspectives of assessment, legal framework, regulation, and policy simulations among the cases grounded in Japan, South Korea, Myanmar, Bhutan, Bangladesh, Taiwan, and the Arctic. With aims to provide an evidence-based approach for policymaking, the content is divided into three sections: net-zero measures from the land through East Asia, Southeast Asia and South Asia (Chaps. 2–5); net-zero measures from the ocean through Taiwan and Japan (Chaps. 6–9), and net-zero measures under international framework (Chaps. 10 and 11).

1.1.1 Part I: Net-Zero Measures from the Land

Carbon pricing is a policy tool designed to account for the externalities of GHG emissions. The externalities refer to the negative effects on the environment and public health that are typically borne by society as a whole. Such impacts include crop damage, medical expenses associated with heat waves and droughts, and property losses due to flooding and sea level rise. Carbon pricing addresses these externalities by connecting them to the price of carbon dioxide emissions, reflecting the social cost of carbon. This approach incentivizes emitters to reduce their GHG emissions and transition towards cleaner alternatives.(World Bank Carbon Pricing Dashboard

2022). The price could refer to the price of greenhouse gases and allows both the emitter and the emitted to shift the burden for the damage caused by greenhouse gas emissions. The price of carbon helps shift the burden for the damage caused by greenhouse gas emissions onto stakeholders responsible for that damage and can avoid it. Rather than dictating who, where, and how emissions should be reduced, a carbon price gives emitters an economic indicator to decide whether to change their activities and reduce emissions or to continue emitting and pay the price.

In Chap. 2: Potential Impacts of Afforestation Expansion under Price Fluctuations of Carbon and Timber, Wan-Yu Liu and Hong-Wen Yu introduce Taiwan's implementation of carbon trade schemes; forest landowners can acquire carbon credit revenue in addition to timber revenue. The land expectation value (LEV) calculated from the price of timber sale is used to assess the impacts on the afforestation area in Taiwan for carbon trading to analyze the correlation with the area of afforestation. Their results showed that timber prices significantly affected the area of afforestation of Taiwania cryptomerioides. It suggests that to increase the afforestation by 1%, $\text{LEV}^{t}_{\text{log}}$ must increase by an average of 100,261 NTD/ha. After conversion, the price of Taiwania increased by 240 NTD/m^3 or 1.23%. The average carbon credit revenue accounts for less than 3% of the total LEV. It suggests that the total LEV obtained from Taiwania is primarily determined by timber price, with minimal impacts from carbon price fluctuation.

In addition to implementing the large-scale renewable energy project, the Myanmar Department of Rural Development, the leading government agency in implementing the off-grid component of the National Electrification Plan, targets 100% electrification by 2030 through both grid extension and off-grid electrification. Whereas all the policies and plans of the government, a significant population living in remote rural areas will remain far from the national grid and unable to afford connection fees in the distant future. **In Chap. 3: Turning on the Lights with Renewable Energy—Grid System for Lighting in Myanmar**, Li-Chun Chen specifies a tailored pilot project from the International Cooperation Development Fund for rural Myanmar in Magway and Sagaing region. The project achieved the development goals of inclusive growth and environmental protection through access to affordable and clean energy and climate action stated in SDG7 and SDG13. The endeavor from rural areas demonstrates that even the poor or vulnerable groups in developing countries can contribute to a net-zero society.

The current global energy crisis and the climate impacts of non-green energy sources have necessitated the shift toward renewable and sustainable energy in South Asia. However, the limited fossil fuel reserves and Bangladesh's climate change vulnerability index necessitate the country's need to achieve sustainable renewable energy governance and policy development to guarantee net-zero carbon emissions and energy sustainability. **In Chap. 4: Role of Renewable Energy Policy in Ensuring Net-zero Carbon Emissions and Energy Sustainability—A Bangladesh Perspective**, Emadul Islam, Asher Shah, and Tariq A. Karim illustrate the implementation of national and regional policies in addressing the challenges of Bangladesh's transition to green energy from fossil fuels. In addition, the study contributes to national and intergovernmental green energy policy by developing recommendations along the Bay of Bengal region to increase the scalability of technologies and innovations, highlighting the opportunities and strengths of Bangladesh as the founding member of BIMSTEC integration.

Under the transition of the post-COVID era, the climate "red code" world hugely depends on good governance and a transition to low carbon. While world leaders have repeatedly stated a unified goal of establishing a carbon–neutral society by mid-century, the new index proposed by Bhutan could lead the net-zero initiative with motivation. **In Chap. 5: Opportunities and Challenges in Sustainable Development and Governance in South Asia—Case Study of Bhutan**, Shanawez Hossain and Ahmad Tousif Jami show that South Asia's strong economic expansion has paved the way toward sustainable development, yet the region still has many unsustainable practices, except for Bhutan. As the first-only carbon-negative country globally, it is vital to extensively study, learn, and optimize Bhutan's best practices to improve global climate practices. Bhutan's Three *G* model (Gross Domestic Product—GDP, Greenhouse gasses—GHG, Gross National Happiness—GNH) expands development metrics beyond GDP to people's happiness and environmental well-being. This study demonstrates how adapting practices from Bhutan, which have been molded by local experiences, problems, and opportunities, would effectively bolster green climate practices in the South Asian region.

1.1.2 Part II: Net-zero Measures from the Ocean

The oceans cover about 70% of the Earth's surface and are affected by anthropogenic climate change by absorbing 25% of our carbon dioxide emissions while producing 50% of the oxygen we need, as well as helping capture 90% of the excess heat generated by these emissions. The oceans are not only the "lungs of the planet" but also the largest "carbon sink" and an essential buffer against the effects of climate change (United Nations The ocean—the world's greatest ally against climate change 2022). The ocean-related industry "comprises a range of economic sectors and related policies that together determine whether the use of ocean resources is sustainable," or the so-called Blue Economy defined by the UN. The practice of Blue Economy could actualize the sustainable management of ocean resources, which will require collaboration across borders and sectors through a variety of partnerships among stakeholders, including public–private sectors, development banks, and investment funds (Morgan et al. 2022).

In Chap. 6: Sustainable Fisheries under Net-zero Emissions—A Case Study of the Taiwan Fishery Administration, Ching-Hsien Ho and Kuanting Lee analyze the fishery policies in Taiwan and other developed countries to identify green policy strategies and opportunities for a low-carbon economy in the context of net-zero emissions. By collecting and compiling international policy documents and incorporating Taiwan's implemented or planned policies and measures, they evaluate the gap between the current situation and future policy goals and discuss possible implementation directions to address the identified gaps. The study also determines policy issues within short-, medium-, and long-term plans and possible opportunities through the use of Global Reporting Initiative (GRI) standards materiality analysis and the priority research direction determination method, with priority stakeholders identified using the boundary identification method. Overall, the study provides a comprehensive analysis of fishery policies, highlighting the need for a collaborative approach to address climate change and promote sustainability in the marine fishing industry.

Blue carbon is another emerging opportunity for an island country like Japan for its potential to capture CO_2. The kelp industry could bring not only economic impacts in the food processing sector but also environmental impact as blue carbon present the carbon credit contributing to achieving the goal of a net-zero society. **In Chap. 7: The Environmental and Economic Potential of Kelp as Blue Carbon—Case of Hakodate, Japan**, Hajime Tanaka, Michael C. Huang, and Atsushi Watanabe provide an overview of the kelp forests in Hakodate City, Hokkaido Prefecture, Japan. These kelp forests are considered to be a noteworthy blue carbon resource that has garnered worldwide attention. Moreover, the kelp forests have had a significant economic impact in Japan throughout history, while its environmental and economic ramifications of these forests have yet to be fully understood. It is recommended that the cultivation of kelp be promoted from both an ecological and economic standpoint, and that financial schemes be implemented to aid in the conservation and restoration of natural kelp.

In response to the sustainable development goals released by the United Nations, the governments have been actively using policy tools to attract foreign investment to help establish the wind power industry. Like many other countries, the Taiwanese government attempts to distribute the economic benefits of the new energy industry to the local companies and people through the policy of local content requirements.

In Chap. 8: The Legitimacy and Effectiveness of Local Content Requirements: A Case of the Offshore Wind Power Industry in Taiwan, Yachi Chiang discusses the development of the offshore wind power industry and the local content requirement (LCR) policies in Taiwan. The study highlights the potential conflicts and exceptions between LCR policies and the regulations established by the World Trade Organization (WTO). Moreover, the advantages and disadvantages of LCR policies are introduced in the literature with a focus on the energy sector. As the effectiveness of LCR policies varies across countries, it is suggested that the Taiwanese government should adopt a trial-and-error approach to determine their unique strategy with caution in LCR policies to align them with the WTO framework to avoid potential conflicts.

Climate change and global warming have significantly threatened food security and the global supply chain. As the trade volume of bulk commodity grains has been growing steadily, ensuring quality while minimizing losses during long-distance shipping between warm and cold seawater has become a critical issue. An evidence-based approach to provide quantified implications is needed to illustrate a roadmap toward a net-zero-carbon society.

In Chap. 9: Impact Assessment of Eco-friendly Cooling System Implementation on Sea Transportation: A GTAP-E-Power Model Application, Michael C. Huang, Yoko Iwaki, and Ming-Huan Liou apply GTAP-E-Power model to assess the potential economic and welfare impacts of introducing eco-friendly cooling systems in sea transportation in Japan, Australia, and New Zealand. The study employs scenarios based on technology changes in Japan derived from SPIAS-e, along with subsidies for capital-use in the electronics, solar power, and sea transportation sectors for the implementation of cooling systems. The simulation results indicate a modest GDP growth of 0.09% in Japan and 0.11% in Australia and New Zealand. Furthermore, the implementation of eco-friendly cooling systems could lead to an improvement in Japan's welfare of USD 4,219 million and a reduction of GHG emissions by 8.4 million tons, representing approximately 0.9% of Japan's total emissions from the shipping sector.

1.1.3 Part III Net-zero Measures under International Framework

Based on the Sixth IPCC assessment report issued in August 2021, man-made greenhouse gases' emission is responsible for approximately 1.1 °C of warming from 1850 to 1900, and the global temperature is expected to reach or exceed 1.5 °C by 2041(Intergovernmental Panel on Climate Change (IPCC) 2022). The IPCC thus urges world leaders to adopt substantial and sustained reductions to reduce carbon dioxide (CO_2) and other greenhouse gas emissions to stabilize global temperature by the next 20–30 years. In East Asia, the Former Prime Minister of Japan, Yoshihide Suga, declared that Japan will become carbon neutral by 2050. The commitment has been further endorsed by his successor Prime Minister Kishida Fumio. Korea enacted the Carbon Neutrality Act, which requires the government to cut greenhouse gas emissions in 2030 by 35% or more from the 2018 levels in August 2021. In China, President Xi Jinping committed to achieving carbon neutrality by 2060 at the UN General Assembly in September 2020. In Taiwan, President Tsai Ing-wen announced on April 22, 2021, that Taiwan will achieve carbon neutrality by 2050.

In Chap. 10: Moving Toward Net-Zero Emission Society—With Special Reference to the Recent Law and Policy Development in Some Selected Countries, Hsing-Hao Wu specifies the road to achieving net-zero emissions is an ambitious but challenging goal for each significant GHGs emitter in the Asia–Pacific region. Each country has its own economic, social, and technological foundation and capabilities and thus requires different approaches to achieve the same goal by exploring the recent global trends with particular references to EU, USA, and Japan's law and policy development aiming to achieve carbon neutrality goals by 2050.

While rapid environmental changes in the Arctic have brought increasing attention from the international community toward the region, considering these circumstances, the Arctic Council (AC) provides an important vehicle for addressing Arctic issues. **In Chap. 11: Climate Impacts of Black Carbon and Methane Emissions in the Arctic and Current Frameworks for Prevention**, Sakiko Hataya demonstrates a basic overview of the Arctic Council and discusses recent organizational reforms. The content also addresses how Japan is involved in the Arctic, followed by the discussion of what the Arctic Council and other concerned countries are doing to control black carbon emissions, a current problem in the Arctic region.

The focus of these emerging issues is to highlight and explore the various policy instruments that can be leveraged to achieve an inclusive and effective transition towards a net-zero carbon society. In this context, it is important to acknowledge the interconnectedness of land, ocean, and international frameworks, which have significant implications for stakeholders. This interconnectedness is exemplified by the experience of building platforms among public, private, and non-governmental organizations, which are working towards a common goal of addressing climate change. This book aims to promote evidence-based policy-making (EBPM) and encourage the adoption of climate-friendly practices by identifying effective policy instruments to foster a greater understanding of the complexities of climate change and encourage the development and implementation of effective climate policies. Ultimately, the book seeks to provide policymakers, researchers, and other stakeholders with the tools and knowledge necessary to work collaboratively towards a sustainable future.

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Part I
Net-Zero Measures from the Land

Chapter 2
Potential Impacts of Afforestation Expansion Under Price Fluctuations of Carbon and Timber

Wan-Yu Liu, Hong-Wen Yu, and Ming-Yun Chu

Abstract Taiwan, a non-contracting party to the UN Framework Convention to Climate Change, committed to Net-zero Emission goal by 2050. In implementing carbon trade schemes, forest landowners can acquire carbon credit revenue in addition to timber revenue. To assess the impacts on afforestation area in Taiwan, this study uses land expectation value (LEV) calculated from price of timber sale and carbon trading and analyzes the correlation with area of afforestation. Results indicate that timber price significantly affected the area of afforestation of *Taiwania cryptomerioides* (Taiwania). It suggests that to increase the afforestation by 1%, LEV_{log}^{t} must increase by an average of 100,261 NTD/ha. After conversion, the price of Taiwania increased by 240 NTD/m^3 or 1.23%. The average carbon credit revenue accounts for less than 3% of the total LEV. It suggests that total LEV obtained from Taiwania is primarily determined by timber price, with minimal impacts from carbon price fluctuation.

Keywords Carbon price · Carbon offset market · Land expectation value · *Taiwania cryptomerioides* · Timber price

2.1 Introduction

Since the Industrial Revolution, global anthropogenic greenhouse gas (GHG) content has increased rapidly, especially carbon dioxide (CO_2). From 1995 to 2005, the average annual rate of increase for CO_2 was 1.9 ppm, which was greater than the average annual rate of increase of 1.4 ppm during 1960–2005. The Fourth Assessment Report by the United Nations Intergovernmental Panel on Climate Change (IPCC) stated that to control global warming, CO_2 emissions must be reduced by 50–85% by 2050. In 1997, legal binding of the Kyoto Protocol (KP) signed at the Third Session of the Conference of the Parties (COP3) in Kyoto, Japan formalized the plan to cut back GHG, which was later launched in 2005.

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The New Zealand Parliament passed the Climate Change Response Act in 2008 and the Climate Change Response (Moderated Emissions Trading) Amendment Act in 2009, both standardized the country's mandatory and national carbon trading system. In addition, an international carbon market was opened in New Zealand during 2009. In a transaction where Denmark's government agency and Norway purchased carbon units, the starting price of carbon units was set at 20 USD. Following a decline in market carbon prices, emission reduction units (ERUs), certified emission reduction units (CERs), and removal units (RMUs) were used as incentives to reduce carbon emissions in New Zealand. In December 2013, the government confirmed that after May 31, 2015, Kyoto units (i.e., CERs, ERUs, and RMUs) could no longer be applied to the New Zealand Emissions Trading Scheme (ETS). This was a result the country's failure to sign the KP for the second commitment period (CP2) (The 18th Conference of the Parties voted to exclude countries that had not committed to CP2 and Kyoto units). The recovery of carbon prices in the country after 2013 (Fig. 2.1) reflects the emitters' current demand for New Zealand units (NZUs). One NZU represents the release of 1 ton of CO_2 into the air. In 2016, carbon prices in New Zealand were affected by the Paris COP21, promotion of the ETS by the government, cancellation of the introduction of affordable foreign carbon credit, and carbon emission credits for heavy industry. These policies led to an increase in domestic demand for carbon credit in New Zealand; thereby causing carbon prices to surge. According to the European Climate Exchange, carbon prices have recently recovered (Fig. 2.2). The EU carbon prices declined in 2008 owing to the global financial crisis. In 2012, the price was approximately 7.79 euros and continued to decrease until the beginning of 2013. This is primarily because the demand for the emissions trading system was inhibited by difficulties such as the European Union's energy and climate policies, complex and lengthy administrative procedures, and concerns regarding environmental integrity. The EU carbon trading market's supply far exceeded its demand, causing prices to fall. From 2018 to 2019, owing to an increase in natural gas prices and the UK's postponement of Brexit, the EU carbon price increased rapidly. As of July 2019, EU carbon prices climbed to 29.03 euros.

A comparative study is proposed herein with cases from two island countries: New Zealand and Taiwan. In 2015, New Zealand joined the Paris Agreement, which stipulated a commitment to reduce GHG emissions after 2020. Its total emissions in 1990 were 64.6 million tons of CO_2 equivalent, and in 2015 these were 80.1 million tons, and net emissions were 56.4 million tons of CO_2 equivalent (New Zealand Government 2017). After 2020, New Zealand aims to reduce its GHG emissions to 95% that of 1990; while its 2030 target is 89% of the 1990 emissions. It is committed to various reduction methods to achieve these targets, such as reducing emissions or increasing carbon sequestration by means of forests and participation in international carbon trading. According to Article 3.3 of the KP, "The amount of carbon sequestration provided by afforestation and reforestation implemented after 1990 can serve as deductions for carbon emissions." Using this calculation method, New Zealand received emission reduction credits and carbon credits, and carbon price and timber price affected the amount of afforestation.

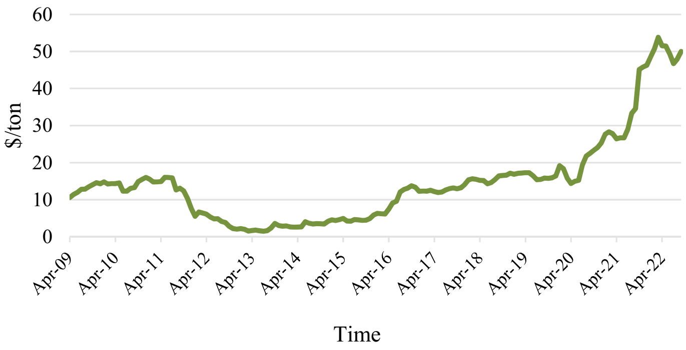

Fig. 2.1 New Zealand carbon price. *Source* Compiled by the authors based on International Carbon Action Partnership (ICAP)

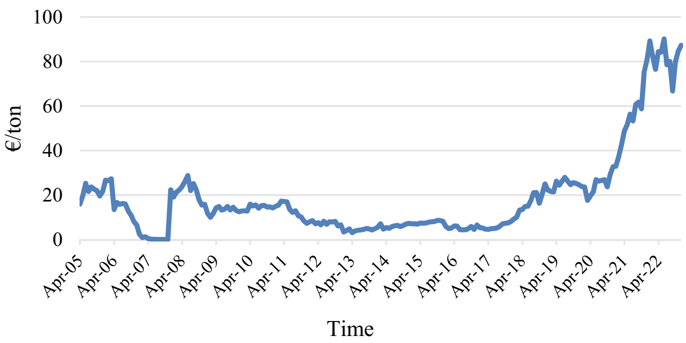

Fig. 2.2 EU carbon price. *Source* Compiled by the authors International Carbon Action Partnership (ICAP)

Taiwan participated in the UNFCCC and as a result, Taiwan passed the Greenhouse Gas Reduction and Management Act (hereafter referred to as "GHG Management Act") in 2015 to manage and reduce GHG emissions, jointly protect the environment, and ensure sustainable development of the country. Its long-term target is set to reduce GHG emissions to less than 50% of 2005 levels by 2050. Currently, Taiwan does not have a carbon trading policy. Afforestation revenue is primarily derived from lumber production and subsidies made available through government afforestation incentive policies. Making matters worse, Taiwan is not a member of the United Nations and cannot directly engage in carbon trading in the international market using the Clean Development Mechanism (CDM). It can only employ the Verified Carbon Standard (VCS) model, using intermediaries to sell to purchasers (Leu 2019). As such, forest carbon sequestration as a policy tool for reducing CO_2 emissions and converting agricultural land into afforested land to increase carbon sequestration are becoming increasingly important in countries.

Meanwhile, forest carbon sequestration has become a trend throughout the world in countries seeking to control GHG emissions (Liu et al. 2009). In response to international GHG reduction targets, mechanisms such as the introduction of a carbon tax and the establishment of carbon emissions trading or carbon payment will become incentives for the premature deforestation of existing young forests. If governments provide carbon payments for the carbon sequestration of newly planted and mature forests, premature deforestation of mature forests can be reduced. The degree of alleviation is determined by the payment levels of mature forests (Lin and Liu 2007).

Several international studies have investigated the factors affecting afforestation areas. For example, Kline et al. (2002) developed a prediction model for afforestation areas in the southern USA. The areas of reforestation and afforestation zones were estimated according to variables such as the price of standing trees or pulp, afforestation cost, land expectation value, interest rate, and the previous year's yield. Forbes and SriRamaratnam (1995) developed a model for estimating the total forestry area in New Zealand by estimating the total area of planted forest based on time and the average export prices of logs, sawn timber, and paper pulp. Wang et al. (2008) analyzed changes in the period from 1981 to 2006 in afforestation areas in Liaoning Province and determined that afforestation areas were extensively affected by policy and that a long-term equilibrium relationship exists between afforestation area and afforestation cost, lumber price, lumber output, and interest rate. Other studies (e.g., Alig 1986; Ahn et al. 2000; Haim et al. 2011) found that changes in land use correlate with future forest areas. Horgan (2007) revealed that afforestation areas from 1991 to 2004 were highly correlated with the internal rate of return (IRR) of forestry investments. Manley and Maclaren (2009) used Horgan's data to establish a linear relationship between afforestation area and IRR, as well as to evaluate the impact of carbon price on IRR.

Although the effect of carbon trading on afforestation has been investigated (Haim et al. 2014), few studies have analyzed the actual impact of a real carbon trading market on afforestation areas. These analyses suggest that carbon trading increases the profitability of forests and encourages afforestation. Thus, attaining an optimal afforestation method that can increase biomass production and the rotation length of afforestation. Therefore, key issues requiring discussion and motivation for this study are as follows: the additional afforestation area required to achieve the GHG Management Act target, provided that Taiwan has a carbon trading market, the relationship between afforestation revenue increase and afforestation area increases, and the severity of carbon credit revenue's impact on afforestation areas.

2.2 Methods

The present study employed the land expectation value (LEV) model employed in Manley's (2017) study to analyze the correlation and impact of timber price and afforestation amount in Taiwan. First, a relationship between LEV and afforestation amount was identified in the absence of a carbon price market. Carbon price was then included in consideration of LEV to analyze the effect of the price on LEV. Finally, we conducted a sensitivity analysis on the effects of changes in variables such as carbon price, timber price, and discount rate on LEV and afforestation areas. Next, a correlation was established between afforestation area and LEV when only timber price ($\mathrm{LEV}_{\log}^{t}$) was considered. Then, considering the carbon price, we studied the benefits of carbon trading in the LEV model, and conducted a correlation analysis on the afforestation area and LEV. We further calculated regression formulas, and compared differences and analyses for two formulas; one prior to and the other after the inclusion of carbon price.

2.2.1 LEV Model

LEV is a benchmark for the economic income of afforestation landowners. LEV implies that both the total return after land has been managed for a period of time, and the highest amount a landowner is willing to pay for the land. According to Faustmann (1849), LEV is the net present value (NPV) of future revenue and costs related to forestry on permanent land. In the existing carbon trading market, LEV comprises two major parts: LEV ($\mathrm{LEV}_{\log}^{t}$) for lumber revenue and LEV ($\mathrm{LEV}_{\mathrm{carbon}}^{t}$) for carbon credit revenue.

$\mathrm{LEV}_{\log}^{t}$ is the discount on lumber revenue and costs during infinite rotation periods. The revenue is derived from log sales at harvest, and the cost is derived from afforestation, tending, maintenance, harvest, and management of tree crops. Given the established assumptions, a linear relationship exists between $\mathrm{LEV}_{\log}^{t}$ and timber price, as shown in Formula (2.1):

$$\mathrm{LEV}_{\log}^{t} = \sum_{k=0}^{\infty} (V * L - C) * \mathrm{e}^{-rtk} - C_0 \tag{2.1}$$

where V_t is the timber volume (m^3/ha) of a stand in year t, L_t is the timber price in year t (NTD/m^3), C_t is the management cost during the afforestation period in year t and includes maintenance and harvesting (NTD/ha), r is the discount rate, t is the rotation length (years), C_0 is the initial afforestation cost (NTD/ha), and k is the number of rotation periods.

$LEV^{t}{}_{\mathrm{carbon}}$ is the discount of carbon credit revenue and carbon trading costs during infinite rotation periods, where revenue is derived from annual carbon credit, cost derived from participation in carbon trading, and from payment for review and certification fees. All property and forestry management and maintenance fees are included in *the* $\mathrm{LEV}_{\log}^{t}$. Given the established assumptions, a linear relationship exists between $\mathrm{LEV}_{\mathrm{carbon}}^{t}$ and the carbon price, as shown in Formula (2.2):

$$\mathrm{LEV}^{t}_{\mathrm{carbon}} = \sum_{k=0}^{\infty} (A * P - c) * \mathrm{e}^{-rtk} \quad (2.2)$$

where A_t is the carbon stock per metric ton of CO_2 in the forest in year t (t/ha); P_t is the carbon price per metric ton of CO_2 in year t (NTD/t CO_2), c is the unit cost of carbon trading (NTD/ha), r is the discount rate, t is the rotation length (years), and k is the number of rotation periods.

When calculating LEV, all factors except timber price (L) and carbon price (P) remained unchanged. According to a sensitivity analysis by Hsu and Liu (2017), LEV is substantially affected by carbon price, carbon release rate, and discount rate. The length of the optimal rotation decreased with increasing carbon price. Nölte et al. (2018) indicated that extending rotation length and management without thinning could increase the amount of carbon sequestration by forests. However, the economic loss caused by the rotation period elongation is exceedingly high. In the present study, for example, at a discount rate of 5%, extension of the rotation period by 50% reduced LEV by 25.1%. LEV also increases as thinning increases; however, the absence of thinning management reduces the LEV.

2.2.2 Relationship Between Afforestation Amount and LEV

The LEV model was employed to explore the correlation between LEV and the amount of afforestation. First, LEV considers only lumber revenue to evaluate the impact of lumber income on afforestation areas. The relationship between afforestation area and the $\mathrm{LEV}^{t}_{\mathrm{log}}$ of the landowner's LEV is shown in Formula (2.3):

$$F_t = f\left(\mathrm{LEV}^{t}_{\mathrm{log}}\right) \quad (2.3)$$

where F_t represents the total afforestation of the area in year t, and $\mathrm{LEV}^{t}_{\mathrm{log}}$ is the LEV of lumber revenue in year t (NTD/ha).

The following data were collected for each tree species and each year: timber price per cubic meter, timber volume equation, rotation period, management cost, initial afforestation cost, and discount rate of the current year. These data were used to calculate the $\mathrm{LEV}^{t}_{\mathrm{log}}$ of each tree species in each year. Further, a correlation analysis was conducted using $\mathrm{LEV}^{t}_{\mathrm{log}}$ and the afforestation amount of tree species in each year to identify the relationship between afforestation amount and $\mathrm{LEV}^{t}_{\mathrm{log}}$.

When carbon price exists, LEV includes lumber and carbon revenue, as shown in Formulas (2.4) and (2.5):

$$\mathrm{LEV}_{\mathrm{Total}} = \mathrm{LEV}^{t}_{\mathrm{log}} + \mathrm{LEV}^{t}_{\mathrm{carbon}} \quad (2.4)$$

$$F_t = f(\mathrm{LEV_{Total}}) \tag{2.5}$$

where F_t represents the total afforestation amount (ha) of the area; LEV_{Total} is the LEV (NTD/ha) per unit area when considering lumber and carbon revenue, ${LEV^t}_{log}$ is the LEV (NTD/ha) per unit area considering only lumber revenue, and ${LEV^t}_{\mathrm{carbon}}$ is the NPV of carbon credit revenue per unit area.

According to the model, LEV is the sum of $\mathrm{LEV}^t_{\mathrm{log}}$ when revenue is derived from log sales at harvest and $\mathrm{LEV}^t_{\mathrm{carbon}}$, which is derived from future carbon costs and the NPV from carbon revenue. During the calculation, all factors remain unchanged except for the price of timber and carbon. Therefore, we can understand this as LEV $= \mathrm{LEV}^t_{\mathrm{log}} + \mathrm{LEV}^t_{\mathrm{carbon}}$. Because $\mathrm{LEV}^t_{\mathrm{log}}$ has only one variable (timber price), it can be viewed as a function of timber price and expressed as $\mathrm{LEV}^t_{\mathrm{log}} = \mathrm{LEV}^t_{\mathrm{log}}$ (L), where L represents the timber price. Similarly, because $\mathrm{LEV}^t_{\mathrm{carbon}}$ has only one variable (carbon price), it can be regarded as a function of carbon price and can be expressed as $\mathrm{LEV}^t_{\mathrm{carbon}} = \mathrm{LEV}^t_{\mathrm{carbon}}$ (P), where P represents the carbon price.

2.2.3 *Variable Setting*

2.2.3.1 Tree Species Selection

Taiwania cryptomerioides, also known as Taiwania (Fig. 2.3), belongs to the Taxodiaceae family and is endemic to Taiwan. The lumber processing properties of Taiwania are exceptional and are characterized by resistance to rotting and termite. Therefore, its lumber applications are extensive, such that it is an important economic tree species in Taiwan. This, and *Calocedrus formosana*, *Chamaecyparis taiwanensis*, *Chamaecyparis formosensis*, and *Cunninghamia konishii* are collectively referred to as the "Top 5 Conifers of Taiwan" (Liu et al. 1984). The trunk of Taiwania is straight and solid, and the tree can reach heights of 60 m in natural forests. It is a crucial afforestation tree species in Taiwan because of its exceptional wood substance and wide applications (Kao 2013). Moreover, comprehensive information on Taiwania timber prices (for 20 years, from 1999 to 2018, can be found in the Wood Price Information System) facilitates the research and analysis of this study. Therefore, we selected this species for the LEV for subsequent simulations and analyses. According to the regulations, the rotation period of Taiwania is 80. Therefore, the LEV was calculated using a rotation period of 80 years.

2.2.3.2 Timber Volume

The Taiwania growth model by Lee et al. (2000) was employed for the timber volume equation. Equation (2.6) is as follows: $V(T)$ is the timber volume of Taiwania at time T (m^3/ha), and T is the stand age (years):

Fig. 2.3 Taiwania. *Source* Compiled by the authors

$$V(T) = 578.6851 * \left(1 - T^{-1.5402}\right)^{54.3344} \quad (2.6)$$

The LEV model of the study was set prior to thinning, with felling accomplished only when the rotation period had expired. According to the growth model by Lee et al. (2000), the timber volume of 80-year-old Taiwania was estimated to be 543 m^3/ha (Fig. 2.4). Cheng et al. (2014) compiled various stand characteristics of Taiwania plantations in Xitou, Taiwan, among which the timber volumes of 74-year-old plantations reached 918 m^3/ha with a standard error of 146 m^3/ha. Therefore, the timber volume estimation employed in this study can be regarded as "conservative."

2.2.3.3 Afforestation Cost

Liu et al. (2009) divided afforestation costs into planting, nurturing, and weeding costs. Because the Taiwanese government rewards afforestation, if seedlings are provided by the forestry authority and planting costs are estimated using the contractor's contract price, the stand owner must pay 30,000 NTD (~1000 USD) per ha for planting in the first year. Mowing costs were calculated based on the stipulation by the Forestry Bureau, Council of Agriculture, Executive Yuan (2011)

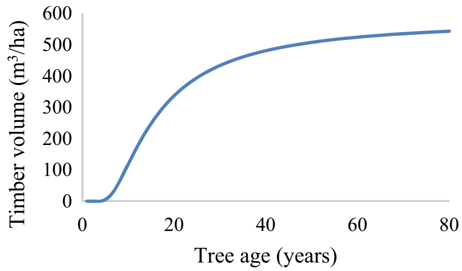

Fig. 2.4 Taiwania timber volume. *Source* Compiled by the authors

for plantations where it is performed twice annually for a 1-year-old plantation, with eight workers per ha each time, three times annually for 2- and 3-year-old plantations, with eight workers per ha each time, and twice annually for a 4-year-old plantation, with nine workers per ha each time. For 5- to 9-year-old plantations, 5-year-old plantations are mowed twice, with nine workers per ha each time, and 6-year-old and older plantations are mowed once, with 10 workers per ha each time. The wage for mowing workers was 1500 NTD (~$30 USD) according to the 2002 Agriculture and Forestry document No. 0910000477 issued by the Forestry Bureau, Council of Agriculture, Executive Yuan (2022a). By extension, 15,000 NTD, the wages of 10 workers per ha for one mowing of 6- to 9-year-old plantations, was used as the annual management cost of 10-year-old and older plantations.

Felling costs were calculated according to the approach proposed by Zheng and Shih (2006). Multiple regression analysis was conducted using stand felling operation cost and operation status data from the Nantou Forest District Office of 46 leased plantations of national forests. The felling costs of each leased plantation served as the response variable. The timber volume of a stand, as well as the transportation distance to the nearest lumber market and logging wages, served as explanatory variable items. After substituting the average timber volume, average transportation distance, and average logging wage of the 46 data items, the felling cost of leased plantations in national forests was estimated to be 1493 NTD/m^3.

2.2.3.4 Amount of Carbon Sequestered

The increase in GHG emissions is considered to be the primary factor affecting climate change. Forests can store carbon by absorbing CO_2, and forestation represents a critical approach for countries reducing GHG emissions. This study included carbon trading prices and incorporated this form of revenue in addition to that from forest landowners' wood products. Following Zheng (2009), the CO_2 storage conversion formula proposed by the IPCC was adopted for the estimation. The formula is as follows:

$$B = V \times V_T \times W_T \times (1 + R) \tag{2.7}$$

Table 2.1 CO_2 storage conversion formula coefficients

Tree species	V_T	W_T	R	C_T
Taiwania	1.65	0.32	0.220	48.32%

Source Lin et al. (2002)

$$C_{CO_2} = B \times C_T \times (CO_2/C) \tag{2.8}$$

where B is the unit biomass (t/ha), V is the stand timber volume per hectare (m^3/ha), V_T is the conversion coefficient between the timber volume of the tree and log timber volume, W_T is the conversion coefficient between weight and timber volume, R is the root–shoot ratio, C_{CO_2} is the amount of CO_2 stored per ha of stand (ton CO_2/ha); C_T is the conversion coefficient of carbon content; and CO_2/C is the conversion coefficient of CO_2 and carbon.

The required coefficients for Taiwania are listed in Table 2.1. This formula converted stand timber volume to tree timber volume and multiplied it by the wood-specific gravity and root–shoot ratio to obtain the stand biomass. The stand biomass was then multiplied by the carbon content conversion coefficient and CO_2 and carbon conversion coefficients to obtain the stored CO_2. Subsequently, the 30-year carbon storage per ha of was obtained; it was multiplied by the carbon price at the time to obtain the carbon credit revenue from carbon trading during one rotation period.

2.2.3.5 Carbon Price

Because Taiwan lacks a carbon trading market, this study referred to the research by Chiang et al. (2020) for the derivation of carbon price; they observed that the break-even carbon price of Taiwania was between 367.13 NTD and 803.58 NTD/ton CO_2. The penalty for exceeding the stipulated carbon emissions was 1500 NTD/ton CO_2. Therefore, calculations were performed for carbon prices of 400, 600, 800, and 1500 NTD.

2.2.3.6 Discount Rate

The LEV model was employ yed to analyze the impact of carbon and timber prices on afforestation. To enable a comparison at the same point in time, future revenues and costs (post-felling lumber revenue and carbon payment revenue as well as afforestation, management, cultivation, and felling costs) must be discounted. Thus, we used the current afforestation loan interest rate of 1.04% (Agriculture Department of Yunlin County Government 2019) as the discount rate.

2.2.3.7 Afforestation Amount

The afforestation amount represents the ratio of the afforestation area of a tree species to the total afforestation area in that year. The tree species selected were Taiwania. Considering that the growth environment of Taiwania is fairly similar to that of other cypresses, its amount of afforestation was calculated as the proportion of total cypress afforestation area in that year. According to the forestry statistics of the Forestry Bureau, Council of Agriculture, Executive Yuan (2018), the afforestation area of Taiwania from 1999 to 2018 was the sum of the areas of general afforestation and related afforestation plans. The total afforestation area of the cypress species was based on statistics published by the Forestry Bureau, which illustrate the afforestation areas during 1999–2018 for *C. lanceolata*, *C. konishii*, Cryptomeria, and Taiwania. The total afforestation area of the cypresses was calculated as the sum of the afforestation areas of these four species. This afforestation area is the sum of the areas of general afforestation and related afforestation plans.

2.3 Results and Discussion

2.3.1 Correlation Between Timber Price and Afforestation Amount

This study first examined the correlation between timber prices and afforestation amounts. A bivariate correlation analysis was performed concerning Taiwania's timber price with its afforestation area, the ratio of this area to total afforestation area, its ratio to coniferous afforestation area, and its ratio to cypress species afforestation area over the period from 1999 to 2018. The historical data are presented in Table 2.2.

The results (Table 2.3) indicated that timber price exhibited a significant positive correlation only with the ratio to the cypress afforestation area. Therefore, for investigation and analysis "afforestation amount" was limited to the ratio of the afforestation area of Taiwania to total cypress afforestation area. Although the results of the bivariate analysis were nonsignificant for Taiwania timber price and afforestation area, ratio to total afforestation area, and ratio to coniferous afforestation area, the Pearson correlation coefficient was positive, and a positive relationship may exist between them.

As can be observed in Table 2.3, the significance between Taiwania timber price and the ratio to total afforestation area, ratio to coniferous afforestation area, and ratio to cypress afforestation area all revealed that as the denominator of Taiwania's afforestation area ratio increased, the timber price and afforestation area became increasingly significant. Arranged in descending order by denominator, the significance of the ratio to total afforestation area, ratio to coniferous afforestation area, and ratio to cypress species afforestation area were 0.287, 0.052, and 0.011, respectively.

Table 2.2 Historical timber prices of Taiwania and afforestation data

Year	Taiwania timber price (NTD)	Taiwania afforestation area (ha)	Total afforestation amount (%)	Coniferous afforestation amount (%)	Cypress species afforestation amount (%)
1999	16,456	15.75	1.21	7.95	57.69
2000	19,907	3.80	0.44	4.09	18.81
2001	19,907	3.04	0.49	9.51	38.34
2002	19,907	5.61	0.52	18.30	86.18
2003	19,907	17.14	2.67	29.38	81.43
2004	19,567	40.91	3.56	14.72	40.55
2005	19,632	16.94	2.43	33.19	80.44
2006	17,271	7.73	2.67	18.65	55.89
2007	14,474	17.42	3.27	11.90	45.35
2008	13,953	13.10	4.23	25.25	63.29
2009	14,522	0.67	0.19	0.95	6.82
2010	14,548	14.52	1.68	12.62	52.72
2011	17,912	6.24	0.35	8.56	89.14
2012	21,660	16.51	1.01	21.54	86.85
2013	23,074	31.03	3.63	22.53	97.33
2014	22,718	32.27	3.98	32.25	90.44
2015	24,485	30.68	4.43	36.07	92.10
2016	24,817	11.86	2.09	17.53	63.87
2017	24,316	5.02	1.58	13.18	76.88
2018	22,605	21.13	7.78	62.46	100.00

Sources compiled by the author Forestry Bureau (Taiwan) (2022b)

Table 2.3 Bivariate correlation analysis

		Taiwania afforestation area	Ratio to total afforestation	Ratio to coniferous afforestation	Ratio to cypress species afforestation
Taiwania timber price	Pearson correlation	0.32	0.251	0.44	0.557*
	Significance (*P*-value)	0.169	0.287	0.052	0.011

Source Compiled by the authors
Note P-value < 0.05 is significant; afforestation area is the area of newly planted afforestation
* $p<0.05$

Thus, the impact on Taiwania timber price is most significant when forest landowners select cypress species for afforestation.

When using the Taiwania afforestation area and the proportion of cypress afforestation areas to calculate historical afforestation amounts of Taiwania, the results are shown in Table 2.4. A correlation analysis was then conducted for Taiwania timber price and afforestation amount for the period from 1999 to 2018. The results were significant ($P = 0.011$); the Taiwania afforestation amount exhibited an increasing trend as the timber price increased (Fig. 2.5).

We performed a simple linear regression between the timber price and afforestation amount and then analyzed the lag order. The R^2 value was used to examine the impact of timber prices on future afforestation areas in each year (Table 2.5). The results indicated that timber price exhibited the greatest explanatory power for the afforestation amount in the current year ($R^2 = 0.272$), which suggests that the timber price of the current year most substantially affected the afforestation amount in the current year, followed by the afforestation amount for the following year ($R^2 = 0.225$). The explanatory power of timber prices declined for the afforestation

Table 2.4 Historical afforestation amount of Taiwania

Year	Taiwania afforestation area (ha)	Cypress species afforestation area (ha)	Afforestation amount
1999	15.75	27.3	0.58
2000	3.80	20.2	0.19
2001	3.04	7.93	0.38
2002	5.61	6.51	0.86
2003	17.14	21.05	0.81
2004	40.91	100.88	0.41
2005	16.94	21.06	0.80
2006	7.73	13.83	0.56
2007	17.42	38.41	0.45
2008	13.10	20.7	0.63
2009	0.67	9.82	0.07
2010	14.52	27.54	0.53
2011	6.24	7	0.89
2012	16.51	19.01	0.87
2013	31.03	31.88	0.97
2014	32.27	35.68	0.90
2015	30.68	33.31	0.92
2016	11.86	18.57	0.64
2017	5.02	6.53	0.77
2018	21.13	21.13	1.00

Source Forestry Bureau (Taiwan) (2022b); compiled by the authors

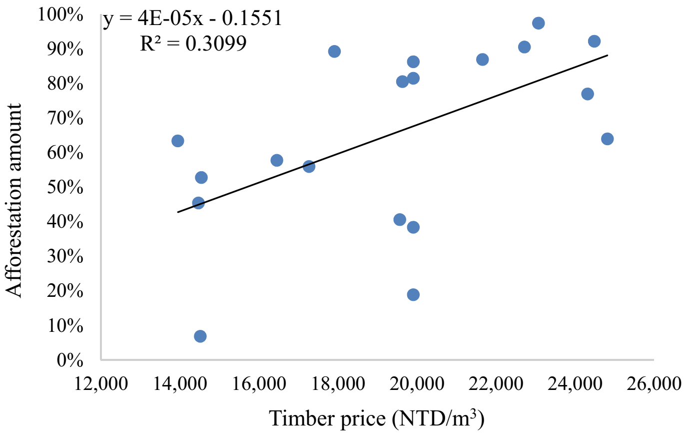

Fig. 2.5 Correlation between Taiwania timber price and afforestation amount. *Source* Compiled by the authors

amount in the second year ($R^2 = 0.111$), and the correlation between timber price and afforestation amount became nonsignificant afterward, which indicates that timber price minimally impacted afforestation a year later.

Next, we conducted a linear regression analysis by using the averaged past timber prices and the average prices and afforestation amounts. The R^2 value shown in Table 2.6 suggests that the afforestation amount and mean timber prices in the current year exhibited the greatest explanatory power ($R^2 = 0.272$). Afforestation amount was also significantly correlated with the means of timber prices in the previous two and three years; however, significance and explanatory power both declined as the number of accumulated years increased.

These two analyses indicate that lumber price significantly affected the afforestation amount in the current and the following year; exhibiting the greatest explanatory power for the afforestation amount in the current year ($R^2 = 0.272$). The relationship between afforestation and timber price in the earlier three years was significant. However, the afforestation amount and mean timber prices in the current year exhibited the greatest explanatory power ($R^2 = 0.272$). The authors believe that the R^2 value of the two analyses was only 0.272 because several other factors interfere with

Table 2.5 Regression analysis of timber price and afforestation amount in lag years

Lag (years)	R^2	*P*-value
0	0.272	0.011*
1	0.225	0.023*
2	0.111	0.096
3	−0.066	0.951

Source Compiled by the authors
* p<0.05

Table 2.6 Regression analysis of past timber price mean and afforestation amount

Mean of timber prices in cumulative years	R^2	P-value
Current year	0.272	0.011*
Previous 2 years	0.265	0.014*
Previous 3 years	0.248	0.021*
Previous 4 years	0.151	0.069
Previous 5 years	0.054	0.195

Source Compiled by the authors
* p<0.05

afforestation amount and area. Therefore, the explanatory power is limited when only considering the correlation between timber price and the amount of afforestation.

2.3.2 Correlation Between Afforestation Amount and LEV Considering Only Lumber Price

The analysis reveals that in Taiwan, the afforestation amount and the mean timber prices in the current year demonstrated the greatest explanatory power. Therefore, we further calculated $\mathrm{LEV}^t_{\log}$ based on the yearly timber price and performed a regression analysis with the afforestation amount of the current year. The distributions of the calculated $\mathrm{LEV}^t_{\log}$ and afforestation amounts are shown in Fig. 2.6. The regression analysis comprised a linear model, a second-order curve model, a logit model, and an exponential model. Due to the substantial gap between the $\mathrm{LEV}^t_{\log}$ and values concerning afforestation amount, the natural logarithm of $\mathrm{LEV}^t_{\log}$ was obtained prior to analysis. The results are listed in Table 2.7 and Fig. 2.7.

The R^2 values of the linear, second-order curve, and logit models were equal to the P-value and exhibited the same explanatory power. Therefore, to distinguish whether the logarithm affected the regression model, a regression analysis was performed directly using $\mathrm{LEV}^t_{\log}$ and the amount of afforestation (Table 2.8 and Fig. 2.8). We observed that the R^2 value of the second-order curve model decreased, and the explanatory power of the linear model ($R^2 = 0.272$) was slightly greater than that of the logit model ($R^2 = 0.271$). However, the afforestation amount of the linear model continued to increase with the $\mathrm{LEV}^t_{\log}$. The afforestation amount of the logit model approached a definite value as $\mathrm{LEV}^t_{\log}$ increased, which conformed more to the actual situation. Thus, we consider the logit model to be the optimal explanatory model.

Although the logit model was more in line with the actual situation, its explanatory power was similar to that of the linear model ($R^2 = 0.271$). Therefore, to facilitate the analysis, a linear model was further developed to analyze the marginal rate of increase in $\mathrm{LEV}^t_{\log}$ to the afforestation amount. The results indicated that for each increase of 1,000,000 NTD/ha in $\mathrm{LEV}^t_{\log}$, the afforestation amount of Taiwania increased

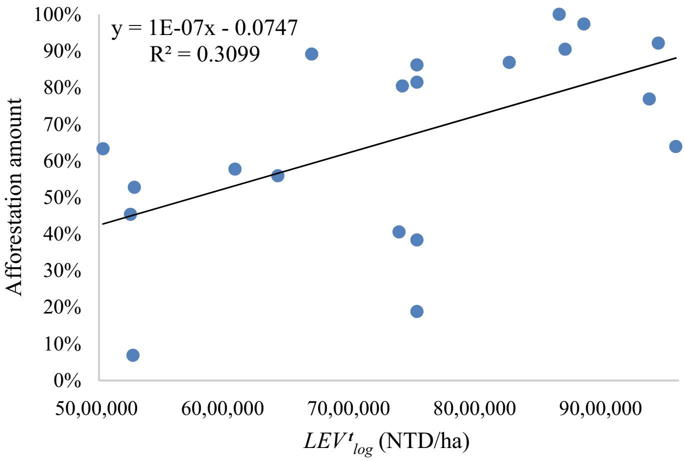

Fig. 2.6 Distribution of LEV and afforestation amount

Table 2.7 Regression model of afforestation amount ($\text{LEV}^t_{\text{log}}$ takes natural logarithm)

Model	Estimation equation	R^2	P-value
Linear	F_t = -10.435 + 0.703 ($\ln \text{LEV}^t_{\text{log}}$)	0.271	0.011*
Second-order curve	F_t = -4.905 + 0.022 $(\ln \text{LEV}^t_{\text{log}})^2$	0.271	0.011*
Exponential	$F_t = 2.523 * 10^{-11} * 1.510^{(\ln \text{LEV}^t_{\text{log}})}$ $F_t = 2.523 * 10^{-11} * 1.510^{(\ln LEVtlog)}$	0.194	0.029*
Logit	$F_t = -29.861 + 11.061 * \ln(\ln \text{LEV}^t_{\text{log}})$	0.271	0.011*

Source Compiled by the authors
Note F_t represents the afforestation amount of newly planted Taiwania; the independent variable is $\ln(\text{LEV}^t_{\text{log}})$ after taking the natural logarithm.
* $p<0.05$

by 9.97%. Therefore, to increase its afforestation by 1%, $\text{LEV}^t_{\text{log}}$ must increase by approximately 100,261 NTD/ha on average. After conversion, its timber price must increase by 240 NTD/m^3, which is an average increase of 1.23% of its original price.

Although the result of the logit model was significant ($P = 0.011$), its explanatory power was low ($R^2 = 0.271$). To accurately predict afforestation amounts, other variables must be added to strengthen the explanatory power of the regression model. A study by Wang et al. (2008) determined that afforestation areas were severely affected by policy. Thus, we can consider the policy variable, which may increase the explanatory power of the model. Possible differences in afforestation in Taiwan caused by the government's promotion of different afforestation policies can be a direction for subsequent research.

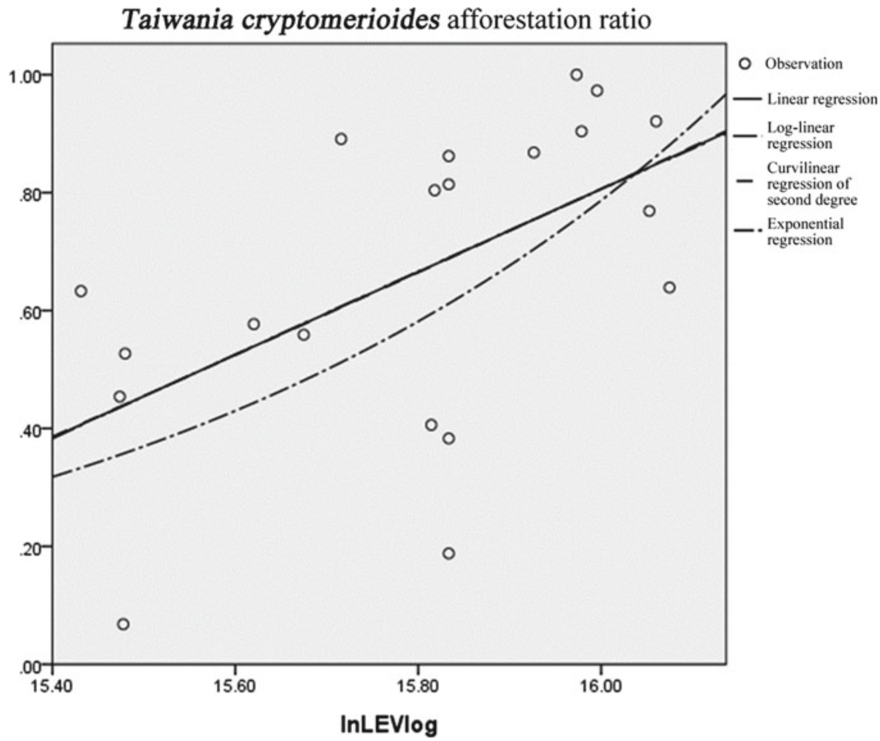

Fig. 2.7 Regression model of Taiwania afforestation amount and LEV (logarithm). *Source* Compiled by the authors

Table 2.8 Regression model of afforestation amount (LEV^t_{log})

	Model	R^2	*P*-value
Linear	$F_t = -0.075 + 9.974 * 10^{-8}\ LEV^t_{log}$	0.272	0.011*
Second-order curve	$F_t = -0.294 + 1.625 * 10^{-7} LEV_{t\text{-}log}$-4.319 * $10^{-15}(LEV^t_{log})^2$	0.230	0.042*
Exponential	$F_t = 0.120 * (2.126 * 10^{-7})^{LEVtlog}$	0.190	0.031*
Logit	$F_t = -10.435 + 0.703 * \ln(LEV^t_{log})$	0.271	0.011*

Source Compiled by the authors

Note F_t represents the afforestation amount of newly planted Taiwania; LEV^t_{log} is the LEV brought by lumber revenue (NTD/ha).

* $p<0.05$

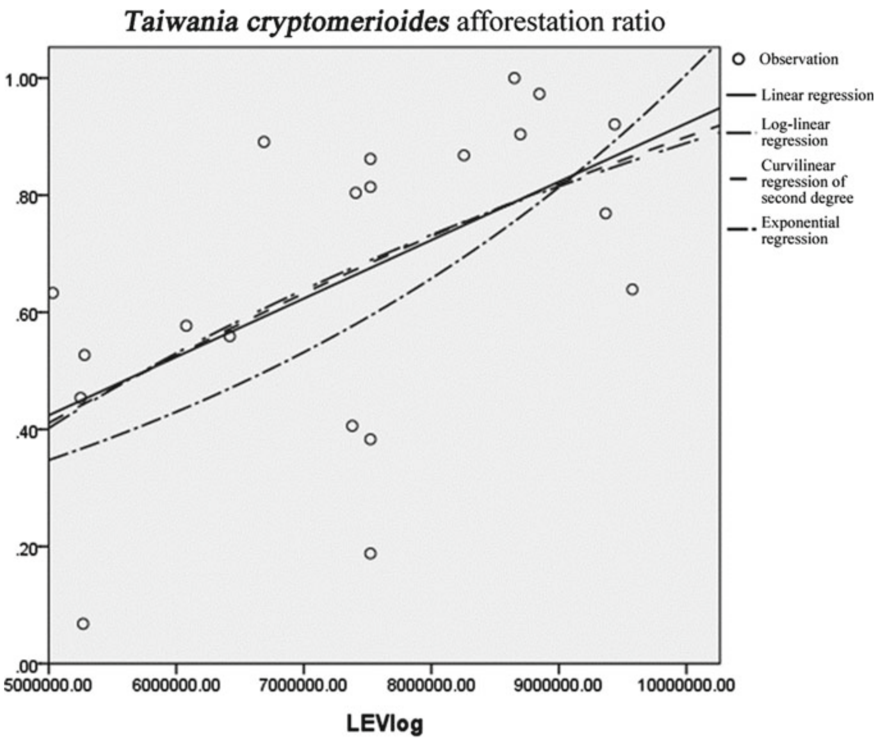

Fig. 2.8 Regression model of Taiwania afforestation amount and LEV. *Source* Compiled by the authors

2.3.3 LEV Considering Both Lumber Price and Carbon Price

For the carbon trading scenario, an ex-post payment model (Liu 2008) was adopted, in which a landowner did not receive any revenue when beginning afforestation and only received revenues at the end of afforestation (rotation period) from lumber and carbon sequestration. The rotation period of Taiwania was set at 80 years. After 80 years, a one-time felling was performed. The carbon sequestration per hectare in Taiwania is shown in Fig. 2.9, which reached 619.68 ton/ha CO_2 in the eighth year.

Based on the aforementioned assumptions, Taiwania afforestation could fix 619.68 tons of CO_2 every 80 years. After multiplying this by carbon price, one can obtain the revenue from carbon credit and use it to calculate LEV^t_{carbon}. The calculation results are presented in Table 2.9, where LEV^t_{carbon} is the LEV derived from carbon credit revenue, LEV^t_{log} is the LEV derived from lumber revenue, and LEV_{Total} is the sum of the two values. Because Taiwan does not yet have a carbon trading market, carbon prices were calculated using 400, 600, 800, and 1500 NTD/ton CO_2 separately.

When the carbon price was 400 NTD/ton CO_2, 600 NTD/ton CO_2, 800 NTD/ton CO_2, and 1500 NTD/ton CO_2, the mean LEV^t_{carbon} was 0.73%, 1.09%, 1.45%, and

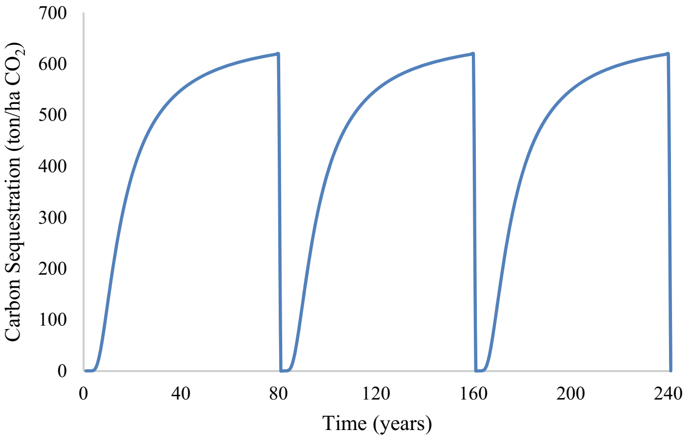

Fig. 2.9 Historical accumulated carbon sequestration of Taiwania. *Source* Compiled by the authors

2.68% of the LEV_{Total}, respectively. The results indicate that when the ex-post payment model was adopted for the carbon trading scenario, the LEV of Taiwania afforestation derived from carbon credit revenue (LEV^{t}_{carbon}) accounted for less than 3% of the total LEV (LEV_{Total}). Therefore, the authors believe that LEV is primarily affected by the LEV derived from lumber revenue (LEV^{t}_{log}). The total LEV is primarily determined by the timber price, and the impact of carbon price is minimal. It is speculated that the low ratio of Taiwania's LEV derived from carbon credit revenue is caused by its higher timber price. Thus, the use of tree species with rapid growth and short rotation periods for afforestation, such as *Acacia confusa*, can result in greater proportions of carbon credit revenue.

The impact of LEV derived from carbon credit revenue (LEV^{t}_{carbon}) was also considered under different rotation periods. The carbon price was calculated at 1500 NTD/ton CO_2, and the results are listed in Table 2.10. The results revealed that when the rotation period was extended, the ratio of LEV derived from carbon credit revenue (LEV^{t}_{carbon}) increased (Fig. 2.10), which means that the portion derived from carbon credit revenue should be of interest to the landowners of the forest. However, an increased rotation period also decreased the discounted revenue. For every 10-year increase in the rotation period, the total LEV decreased by an average of 17.38%. Thus, the maximum income can only be obtained by the timely shortening of the rotation periods.

2.4 Conclusion and Recommendations

This study referenced the LEV model of Manley (Manley 2017) to analyze the correlation between afforestation amount and LEV in Taiwan and to examine Taiwania's afforestation amount. The model was also adopted to estimate lumber and carbon

Table 2.9 LEV at different carbon prices

	Carbon price (NTD/ton CO_2)											
	400			600			800			1500		
Year	$LEV_{t\text{-log}}$	LEV_{carbon}	LEV_{Total}	$LEV_{t\text{-log}}$	LEV_{carbon}	LEV_{Total}	$LEV_{t\text{-log}}$	LEV_{carbon}	LEV_{Total}	$LEV_{t\text{-log}}$	LEV_{carbon}	LEV_{Total}
1999	6,078,329	52,085	6,130,414	6,078,329	78,127	6,156,456	6,078,329	104,170	6,182,499	6,078,329	195,318	6,273,647
	(99.15%)	(0.85%)	(100.00%)	(98.73%)	(1.27%)	(100.00%)	(98.32%)	(1.68%)	(100.00%)	(96.89%)	(3.11%)	(100.00%)
2000	7,522,069	52,085	7,574,154	7,522,069	78,127	7,600,196	7,522,069	104,170	7,626,238	7,522,069	195,318	7,717,387
	(99.31%)	(0.69%)	(100.00%)	(98.97%)	(1.03%)	(100.00%)	(98.63%)	(1.37%)	(100.00%)	(97.47%)	(2.53%)	(100.00%)
2001	7,522,069	52,085	7,574,154	7,522,069	78,127	7,600,196	7,522,069	104,170	7,626,238	7,522,069	195,318	7,717,387
	(99.31%)	(0.69%)	(100.00%)	(98.97%)	(1.03%)	(100.00%)	(98.63%)	(1.37%)	(100.00%)	(97.47%)	(2.53%)	(100.00%)
2002	7,522,069	52,085	7,574,154	7,522,069	78,127	7,600,196	7,522,069	104,170	7,626,238	7,522,069	195,318	7,717,387
	(99.31%)	(0.69%)	(100.00%)	(98.97%)	(1.03%)	(100.00%)	(98.63%)	(1.37%)	(100.00%)	(97.47%)	(2.53%)	(100.00%)
2003	7,522,069	52,085	7,574,154	7,522,069	78,127	7,600,196	7,522,069	104,170	7,626,238	7,522,069	195,318	7,717,387
	(99.31%)	(0.69%)	(100.00%)	(98.97%)	(1.03%)	(100.00%)	(98.63%)	(1.37%)	(100.00%)	(97.47%)	(2.53%)	(100.00%)
2004	7,379,949	52,085	7,432,034	7,379,949	78,127	7,458,076	7,379,949	104,170	7,484,119	7,379,949	195,318	7,575,267
	(99.30%)	(0.70%)	(100.00%)	(98.95%)	(1.05%)	(100.00%)	(98.61%)	(1.39%)	(100.00%)	(97.42%)	(2.58%)	(100.00%)
2005	7,407,107	52,085	7,459,191	7,407,107	78,127	7,485,234	7,407,107	104,170	7,511,276	7,407,107	195,318	7,602,424
	(99.30%)	(0.70%)	(100.00%)	(98.96%)	(1.04%)	(100.00%)	(98.61%)	(1.39%)	(100.00%)	(97.43%)	(2.57%)	(100.00%)
2006	6,419,323	52,085	6,471,408	6,419,323	78,127	6,497,450	6,419,323	104,170	6,523,493	6,419,323	195,318	6,614,641
	(99.20%)	(0.80%)	(100.00%)	(98.80%)	(1.20%)	(100.00%)	(98.40%)	(1.60%)	(100.00%)	(97.05%)	(2.95%)	(100.00%)
2007	5,249,364	52,085	5,301,449	5,249,364	78,127	5,327,491	5,249,364	104,170	5,353,534	5,249,364	195,318	5,444,682
	(99.02%)	(0.98%)	(100.00%)	(98.53%)	(1.47%)	(100.00%)	(98.05%)	(1.95%)	(100.00%)	(96.41%)	(3.59%)	(100.00%)
2008	5,031,200	52,085	5,083,284	5,031,200	78,127	5,109,327	5,031,200	104,170	5,135,369	5,031,200	195,318	5,226,517

(continued)

Table 2.9 (continued)

	Carbon price (NTD/ton CO_2)											
	400			600			800			1500		
Year	$LEV_{t\text{-log}}$	LEV_{carbon}	LEV_{Total}	$LEV_{t\text{-log}}$	LEV_{carbon}	LEV_{Total}	$LEV_{t\text{-log}}$	LEV_{carbon}	LEV_{Total}	$LEV_{t\text{-log}}$	LEV_{carbon}	LEV_{Total}
	(98.98%)	(1.02%)	(100.00%)	(98.47%)	(1.53%)	(100.00%)	(97.97%)	(2.03%)	(100.00%)	(96.26%)	(3.74%)	(100.00%)
2009	5,269,305	52,085	5,321,390	5,269,305	78,127	5,347,432	5,269,305	104,170	5,373,475	5,269,305	195,318	5,464,623
	(99.02%)	(0.98%)	(100.00%)	(98.54%)	(1.46%)	(100.00%)	(98.06%)	(1.94%)	(100.00%)	(96.43%)	(3.57%)	(100.00%)
2010	5,280,316	52,085	5,332,400	5,280,316	78,127	5,358,443	5,280,316	104,170	5,384,485	5,280,316	195,318	5,475,633
	(99.02%)	(0.98%)	(100.00%)	(98.54%)	(1.46%)	(100.00%)	(98.07%)	(1.93%)	(100.00%)	(96.43%)	(3.57%)	(100.00%)
2011	6,687,450	52,085	6,739,535	6,687,450	78,127	6,765,578	6,687,450	104,170	6,791,620	6,687,450	195,318	6,882,768
	(99.23%)	(0.77%)	(100.00%)	(98.85%)	(1.15%)	(100.00%)	(98.47%)	(1.53%)	(100.00%)	(97.16%)	(2.84%)	(100.00%)
2012	8,255,472	52,085	8,307,557	8,255,472	78,127	8,333,599	8,255,472	104,170	8,359,642	8,255,472	195,318	8,450,790
	(99.37%)	(0.63%)	(100.00%)	(99.06%)	(0.94%)	(100.00%)	(98.75%)	(1.25%)	(100.00%)	(97.69%)	(2.31%)	(100.00%)
2013	8,847,075	52,085	8,899,160	8,847,075	78,127	8,925,202	8,847,075	104,170	8,951,245	8,847,075	195,318	9,042,393
	(99.41%)	(0.59%)	(100.00%)	(99.12%)	(0.88%)	(100.00%)	(98.84%)	(1.16%)	(100.00%)	(97.84%)	(2.16%)	(100.00%)
2014	8,698,210	52,085	8,750,295	8,698,210	78,127	8,776,337	8,698,210	104,170	8,802,379	8,698,210	195,318	8,893,528
	(99.40%)	(0.60%)	(100.00%)	(99.11%)	(0.89%)	(100.00%)	(98.82%)	(1.18%)	(100.00%)	(97.80%)	(2.20%)	(100.00%)
2015	9,437,559	52,085	9,489,644	9,437,559	78,127	9,515,687	9,437,559	104,170	9,541,729	9,437,559	195,318	9,632,877
	(99.45%)	(0.55%)	(100.00%)	(99.18%)	(0.82%)	(100.00%)	(98.91%)	(1.09%)	(100.00%)	(97.97%)	(2.03%)	(100.00%)
2016	9,576,295	52,085	9,628,380	9,576,295	78,127	9,654,422	9,576,295	104,170	9,680,465	9,576,295	195,318	9,771,613
	(99.46%)	(0.54%)	(100.00%)	(99.19%)	(0.81%)	(100.00%)	(98.92%)	(1.08%)	(100.00%)	(98.00%)	(2.00%)	(100.00%)

(continued)

Table 2.9 (continued)

	Carbon price (NTD/ton CO_2)											
	400			600			800			1500		
Year	$LEV_{t\text{-log}}$	LEV_{carbon}	LEV_{Total}	$LEV_{t\text{-log}}$	LEV_{carbon}	LEV_{Total}	$LEV_{t\text{-log}}$	LEV_{carbon}	LEV_{Total}	$LEV_{t\text{-log}}$	LEV_{carbon}	LEV_{Total}
2017	9,366,672	52,085	9,418,756	9,366,672	78,127	9,444,799	9,366,672	104,170	9,470,841	9,366,672	195,318	9,561,989
	(99.45%)	(0.55%)	(100.00%)	(99.17%)	(0.83%)	(100.00%)	(98.90%)	(1.10%)	(100.00%)	(97.96%)	(2.04%)	(100.00%)
2018	8,651,077	52,085	8,703,162	8,651,077	78,127	8,729,204	8,651,077	104,170	8,755,246	8,651,077	195,318	8,846,395
	(99.40%)	(0.60%)	(100.00%)	(99.10%)	(0.90%)	(100.00%)	(98.81%)	(1.19%)	(100.00%)	(97.79%)	(2.21%)	(100.00%)

Source Compiled by the authors

Table 2.10 Analysis of LEV under different rotation periods

Rotation period (years)	LEV_{Total} (NTD)	LEV^t_{logs}(NTD)	LEV^t_{carbon}(NTD)	Ratio of LEV^t_{carbon} (%)
40	17,343,502	16,908,448	435,054	2.60
50	13,792,199	13,444,861	347,339	2.61
60	11,145,206	10,862,823	282,384	2.63
70	9,137,703	8,904,410	233,293	2.65
80	7,581,467	7,386,149	195,318	2.68
90	6,350,225	6,184,909	165,316	2.71
100	5,35,737	5,217,557	141,180	2.75
110	4,548,220	4,426,757	121,463	2.79

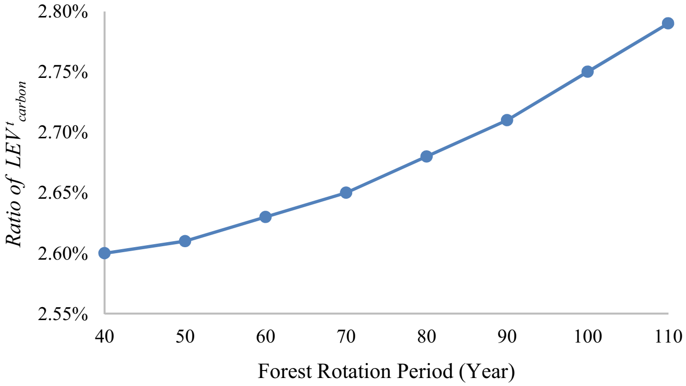

Fig. 2.10 Ratio of LEV^t_{carbon} under different rotation periods. *Source* Compiled by the authors

prices to identify approaches for increasing afforestation areas. This study obtained conclusions with respect to its three goals:

2.4.1 Investigation of the Correlation Between Timber Price and Afforestation Amount

In the past, the relationship between Taiwania's timber prices and new afforestation areas was nonsignificant. The authors believe that new afforestation areas are affected not only by timber price but also by diverse factors such as policy, lumber output, and discount rate (Wang et al. 2008). Therefore, if only timber price is considered, the explanatory power for the new afforestation area of Taiwania is insufficient and renders the relationship between the two nonsignificant. Meanwhile, a significant correlation was identified between timber price of Taiwania and its ratio to the afforestation amount of the cypress species. The afforestation amount can be considered the forest landowner's intention to select Taiwania. A related analysis involving lag order was conducted to further examine whether timber prices affected future afforestation amounts. The timber price of Taiwania significantly affected its afforestation amount in the current and following year, but exhibited a particularly significant impact in the current year.

Accordingly, if governments wish to increase afforestation areas, increasing timber prices and suppliers' afforestation intention would not be effective. This should be pursued through other means, such as policies and interest rates. However, if governments wish to promote a certain tree species, then finding methods to increase the price of timber of that species can effectively increase suppliers' intention to select the species for afforestation.

2.4.2 Correlation Between Afforestation Amount of the LEV Considering Only Timber Price

A regression analysis was performed using the afforestation amount of Taiwania and LEV with the inclusion of only lumber revenue ($\text{LEV}^t_{\text{log}}$). Regression analysis was conducted separately using a linear regression model, a second-order curve model, an exponential model, and a logit model. The results were all significant, and the R^2 values of the linear model, second-order curve model, and exponential model were all 0.271. The authors considered the logit model as the optimal explanatory model, as follows:

$$F = -29.861 + 11.061 * \ln(X) \tag{2.9}$$

where F represents the afforestation amount of Taiwania, and $\text{LEV}^t_{\text{log}}$ is the LEV derived from lumber revenue (NTD/ha). The R^2 value of this logit model was 0.271, and the P-value was 0.011.

The logit model was considered the optimal explanatory model for the following reasons. First, the fit of the linear model continuously increases with LEV, and the afforestation amount also increases continuously; however, the afforestation amount has an upper limit (100%). Thus, the linear model was deemed to be inconsistent with real situations and was excluded from consideration. Although the explanatory power of the second-curve model was identical to that of the logit model, this was the result of a regression analysis using the logarithm of LEV. Because the explanatory powers of the three models were identical, a regression analysis was performed directly on the LEV and afforestation amount. The explanatory power of the second-order curve model declined, possibly owing to changes in the log-transformed data. However, the explanatory power of the logit model did not decline in the second regression analysis. The accuracy of the logit model continued to increase with LEV; although the afforestation amount also increased, it approached a limiting value (not 100%, however). Thus, the logit model was more consistent with real situations and was regarded as the optimal explanatory model. The authors recommend that subsequent studies include other factors in the regression analysis to enhance the explanatory power of the models.

2.4.3 LEV Considering Both Timber Price and Carbon Price

Carbon prices in this study accounted for four scenarios—400 NTD, 600 NTD, 800 NTD, and 1500 NTD per ton; at these prices, the mean carbon credit revenue accounted for 0.73%, 1.09%, 1.45%, and 2.68% of LEV, respectively. With the adoption of an ex-post payment model in a carbon trading scenario, the LEV of Taiwania afforestation derived from carbon credit revenue (LEV^t_{carbon}) accounted for less than 3% of the total LEV (LEV_{Total}). Therefore, the LEV that primarily affects LEV is derived from lumber revenue (LEV^t_{log}), meaning that the total LEV is largely determined by timber price and that the impact of carbon price is minimal. The authors speculate that the low ratio for Taiwania LEV derived from carbon credit revenue results from its higher timber price. Thus, the use of tree species with rapid growth and short rotation periods for afforestation, such as *A. confusa*, can lead to greater carbon credit revenue.

Finally, the impact of LEV derived from carbon credit revenue (LEV^t_{carbon}) was considered under different rotation periods. The results indicated that when the rotation period was extended, the ratio of LEV derived from carbon credit revenue (LEV^t_{carbon}) increases, which means that the portion derived from carbon credit revenue should gradually become valued by the forest landowner. However, an increase in the rotation period also decreased the discounted revenue, and for every 10-year increase in the rotation period, the total LEV decreases by an average of 17.38%. Thus, maximum revenue can only be achieved by a timely reduction in the rotation period. This result is consistent with previously reported results (Lin and Liu 2007). If governments intend to extend the rotation period to increase forest carbon sequestration, then governments should provide forest landowners subsidies to offset the economic losses caused by increases in the rotation period, which would in turn increase their willingness to elongate rotation periods.

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Chapter 3
Turning on the Lights with Renewable Energy: Solar PV Mini-Grid System for Lighting in Myanmar

Li-Chun Chen

Abstract Myanmar targets 100% electrification by 2030 through both of grid extension and off-grid electrification under the National Electrification Plan (NEP). Despite all the policies and plans of the government, a significant population living in remote rural areas will remain far from the nation grid and unable to afford connection fees in the distant future. The Myanmar Department of Rural Development, which is the leading government agency in implementing the off-grid component of the NEP, therefore seeks assistance from advanced countries and international societies, including Taiwan. Based on the local conditions of targeted villages, the International Cooperation Development Fund proposes a tailored pilot project for rural Myanmar. The project achieved the development goals of inclusive growth and environmental protection through access to affordable and renewable energy and demonstrated that even the poor or vulnerable groups in developing countries can contribute to a net-zero society.

Keywords Myanmar · Mini-grids · Solar PV · Rural area · Sustainable · Electrification

3.1 Introduction

Countries with higher levels of poverty often have limited access to modern energy services (World Bank 2017). Universal access to electricity is widely regarded as a prerequisite for alleviating poverty to stimulate economic growth, expand employment opportunities, and support human development. Electricity access is critical for achieving the UN's 2030 Agenda for Sustainable Development, and one of the targets for Sustainable Development Goal 7 is to expand infrastructure and upgrade technology for supplying modern and sustainable energy services for all in developing countries, in particular least developed countries, small island developing states, and

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land-locked developing countries, in accordance with their respective programs of support.

The number of people worldwide without electricity fell from 1.7 billion in 2000 to 1.1 billion in 2016. By 2030, that number is expected to drop to 674 million (International Energy Agency (IEA) 2017a). Among them, developing countries in Southeast Asia have made significant progress, with a high level of electrification, approximately 90% of Southeast Asians have access to electricity (International Energy Agency (IEA) 2017b). But, due to the diversity of economic development conditions, resources endowment types, and graphical features in the region, there is still room for improving electricity access (Nakano and Naimoli 2018). In fact, 65 million people in the region remain without electricity access. Of those without access, over 95% live in four countries: Indonesia (23 million), Myanmar (22 million), Philippines (11 million), and Cambodia (6 million) (International Energy Agency (IEA) 2017a).

Myanmar is the second largest country in Southeast Asia and contains over 676,000 km^2 of land and a total population of about 53.4 million. The rural population is high, accounting for 69% of the total in 2018. The country is the fourth-smallest economy in the Association of Southeast Asian Nations (ASEAN) group, with a Gross Domestic Production (GDP) of about $69 billion in 2019. It is also one of the fastest growing economies in group. Myanmar's GDP growth rate in 2016–2018 has been robust, averaging around 7.5%. However, Myanmar is classified as a least developed country by the United Nations. The proportion of the population living under the national poverty line is 24.8% in 2017. In 2005–2017, the absolute number of poor people declined from 18.7 million to 11.8 million. Most of the poor live in rural areas, around 87% of the total population in the country. Poverty rate is 2.7 times higher in rural areas, where 30.2% of the population is estimated to be poor compared with 11.3% in urban areas (United Nations Conference on Trade and Development (UNCAD) 2021).

The power sector of Myanmar is one of the least developed in Southeast Asia with more half of the population not connected to the nation grid and the rest subject to prolonged and frequent power disruptions. The lack and reliability of power is a key constraint to doing business in Myanmar (United Nations Conference on Trade and Development (UNCAD) 2021). Only 35% of Myanmar's people had access to electricity in 2016, and the gap between urban and rural areas is huge. The highest electrification rate was 78% in Yangon, while some of the poorest districts had the lowest, between 9 and 16% (Asian Development Bank (ADB) 2018). In addition, widespread use of traditional biomass is common in rural areas. In 2014, 69% of the population uses firewood as a main energy source for cooking and 46% uses kerosene, candles, or batteries as the main energy sources for lighting (The Republic of the Union of Myanmar 2015).

To increase the nation's electricity access and support boarder economic development, the government of Myanmar launched the National Energy Policy in 2015, which outlines a comprehensive plan for how to develop the energy sector to reach full national electrification (Asian Development Bank (ADB) 2016). The policy includes plans to promote government driven community-based renewable energy projects as a means to poverty reduction. The National Electrification Plan (NEP), developed by the World Bank in collaboration with the government of Myanmar, also targets 100% electrification by 2030 through both of grid extension and off-grid electrification, particularly in areas that will not connected to the nation grid by the target date. In addition, electrifying the country is also a major national development goal in the Myanmar Sustainable Development Plan 2018–2030, in which the government aims to provide affordable low-carbon energy to all classes of consumers, especially those in rural areas.

Despite all the goals, policies, and plans of the government, a significant population living in remote rural areas will remain far from the nation grid and unable to afford connection fees in the distant future. In general, the farther the village was from the grid, the lower the average income and ability to pay for energy services. The government estimates that of the 64,000 villages in Myanmar, about 40,000 are un-electrified. The geographical diversity makes it difficult to provide grid electricity to these isolated villages.

The Myanmar Department of Rural Development (DRD) under the Ministry of Agriculture, Livestock and Irrigation, which is the leading government agency in implementing the off-grid component of the NEP, seeks assistance from advanced countries and international societies, including the Taiwanese government. The International Cooperation and Development Fund (TaiwanICDF or Fund) subsequently starts a dialogue with the DRD to understand existing government and donor off-grid electrification programs.

The TaiwanICDF, established in 1996, has been dedicated to boosting socioeconomic development, enhancing human resources, and promoting economic relations in a range of developing partner countries. It also offers humanitarian assistance and provide aid in the event of natural disasters or international refugee crises. It offers a range of assistance that centers on four core operations: lending and investment, technical cooperation, humanitarian assistance, and international education and training. The work is tailored to the local needs of each of its partner countries, with assistance covering a variety of contemporary development issues such as environment, public health and medicine, agriculture, education small and medium enterprises, as well as information and communications technology. At present, the Fund operates overseas missions and implements special projects across Africa, Latin America, the Caribbean, Asia–Pacific, and West Asia, dispatching technicians, project managers, overseas volunteers, and Taiwan youth overseas servicemen to carry out or to assist such operations.

Using off-grid systems to electrify rural Myanmar had played a key role for thousands of villages, not an endeavor unique to the Fund. The primary sources of off-grid electricity by generation type in rural areas of Myanmar are micro-hydro, diesel generators, and solar PV. Most of such solar PV means individual solar home systems (SHS), and only in very few cases signifies solar PV connected to mini-grids (Greacen 2016). We also found that the existing market for off-grid renewable energy systems was dominated by small SHS, especially in rural areas. In general, the quality of most of the SHS installations in quite low and failure rate are high (Greacen 2015). Thus, mini-grid solutions have been considered as a third alternative to rural electrification between the option of grid extension and SHS or solar lanterns (Pedersen 2016). Additionally, the generators (micro-hydro, diesel, and biomass) that energize Myanmar mini-grid are often inefficient and unsafe, and with limited access to the engineering expertise and constrained by limited budgets, they still have significant issue with quality and reliability.

Further, Myanmar has a strong solar radiation level, and around 60% of the land area suitable for solar PV installation (Asian Development Bank (ADB) 2016). Given the country's high radiation rates, of the renewable energy technologies available for off-grid use in Myanmar, solar technology has become particularly popular among international donor community. The solar PV modules has fallen by more than 80% since 2009, while the global cost of solar PV power declined over 70% from 2010 to 2017 (International Renewable Energy Agency (IERNA) 2018). With globally rapidly declining price of PV systems and widespread use of highly efficient light-emitting diode bulbs in Myanmar, renewable energy solutions may be a cost-competitive option to expand electricity access.

During the inception stage, the Fund conducts field visits to potential sites to do fact-finding and data gathering work, according to a list of several villages provided by the Myanmar government. In general, people of these villages have to rely on kerosene lamps candles for lighting their houses in the evening, only a very few better-off families could afford solar home systems. Since most villagers are engaged in subsistence agriculture and livestock rearing, although they are willing to pay for electricity services, their ability to pay is limited. Based on the local conditions of targeted villages, the Fund proposes a tailored pilot project, with the expected outcomes include: (1) design and installation of solar PV mini-grid systems; (2) community-based business models for mini-grids, including operation and maintenance, payment mechanisms, tariff settings.

The main focus of the project is the solar PV technology and the nature of mini-grids. In the policy framework of Myanmar, the primary purpose of mini-grids is to fill the time-gap for many communities in rural areas until they connect to the national grid. However, some villages are simply difficult to access, hence the grid is not likely to extend to them in near future, possibly over 10 years. This is exactly the situation faced by some of the villages in the project. Therefore, for vulnerable groups and rural areas, the sustainability of solar PV mini-grids is even more critical, and in the interests of governments and communities.

3.2 Project Assessment and Technical Design

The project team identified the specific sites from a list of villages provided by the government of Myanmar. Key parameters for site selection include geographical suitability, renewable energy resource potential, existing economic activity, population density, distance of main grid arrival, as well as the commitment and willingness of local communities. It also included a comprehensive survey of potential socioeconomic and environmental impacts. The team identified two project sites:

- Site I: Inbingan Village
- Site II: Bawdigone Village, ChiYarPinSu Village, Zeephyjim Village, Payagone Village.

These five villages are located in the Magway and Sagaing regions of the central dry zone of Myanmar. The locations of these two sites are described in Table 3.1.

The average irradiation in Site I is estimated to be approximately 5.34 kWh/m^2/day and 4.78 kWh/m^2/day in Site II—both are suitable for developing PV-based power applications.

Inbingan Village at Site I had a population of 589 residents in 128 households. The male-to-female ratio was 1:1.16. Agriculture is the major economic activity for most households in the village, and their main agricultural products are sesame and soybeans; the cultivation seasons vary by crop, but land lies fallow for an average of four months of the year. Villagers lead regular schedules in their daily lives. Almost every household is self-sufficient in terms of animal husbandry, mainly raising swine. Normally, villagers rise early at dawn and rest by approximately 17:00 in the evening. Electricity demand increases significantly at night, although there is only one 3 kW diesel-electric set in the temple. The lighting resources in this village were inadequate. Villagers commonly use candles or battery-operated portable lamps. There were 91 children in a village primary school. Village leaders expressed that if the project could provide lighting, the children could study at night.

Bawdigone Village, ChiYarPinSu Village, Zeephyjim Village, and Payagone Village of Site II have 2181 residents in 453 households. The male-to-female ratio was 1:1.07. Almost every family relies on agriculture for a living, mainly producing paddy rice. To maintain a self-sufficient food supply, almost every family keeps a small amount of livestock, mainly raising chickens. Villagers rise at dawn to work early and rest early—by approximately 17:30 in the evening. Electricity demand increases significantly at night. There were 195 primary school students and 150 junior high school students; however, the schools had no lighting devices. The lack of power might limit children's opportunities to access knowledge and information. These villages are located at a great distance from major cities. The remoteness and difficult traffic conditions have prevented villagers from engaging in other part-time jobs or performing non-agricultural work. The satellite images of these five villages illustrated in Fig. 3.1.

In the technical design process, several factors need to be accessed and considered by the project team, including the choice of generation technology, storage technology, grid size, and configuration, as well as the distribution system. A PV solution with batteries was chosen, of course, because of good irradiation levels. Due to its nature of intermittency, the choice of energy storage plays a key role in PV mini-grids. The project team chooses lithium-ion batteries because they have more life cycles than lead-acid batteries, require less maintenance, and are environmentally friendly.

The system architecture of the solar PV mini-grid system conceived in the project proposal consists of a solar PV module, PV mounting system, PV charge controller, inverter/charger, village grid, and other components required for the balance of

Table 3.1 Locations of Site I and Site II

Site	Region	District	Township	Village	Latitude/Longitude
I	Magway	Magway	Magway	Inbingan	19.902/95.25
II	Sagaing	Katha	Kawlin	Bawdigone/ChiYarPinSu/Zeephyjim/Payagone	23.753/95.432

Source Compiled by the author

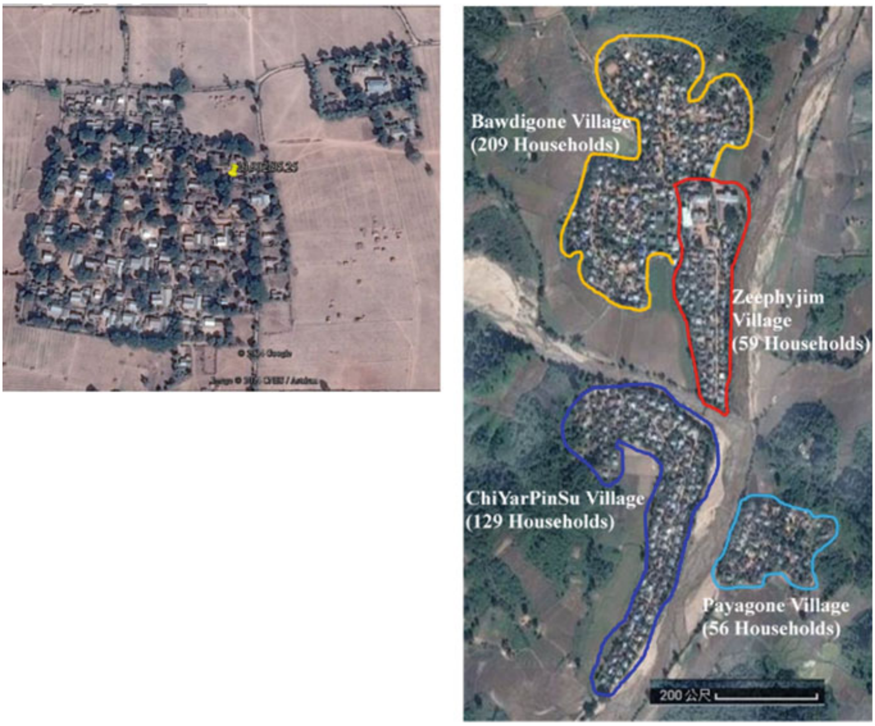

Fig. 3.1 Satellite image of villages (Left: Inbingan Village, Magway Region; Right: Bawdigone/ChiYarPinSu/Zeephyjim/Payagone Villages, Sagaing Region). *Source* Compiled by the author

the system. The system generates a centralized power supply to offer households and public facilities electricity for lighting through a newly established distribution network. Energy-saving products can also be used for lighting.

Regarding the design of the power supply system, scalable architecture was used to manage the expected increase in load in the foreseeable future, given an increase in electricity consumption. This architecture is also expandable by using an inverter/charger to optimize energy management by including and controlling different power supply sources.

In addition, considering the solar radiation conditions of the two sites, the PV arrays were mounted facing south at a 24-degree angle of inclination. In principle, the PV array should be mounted in an environment that is free of shade from approximately 08:00 to 16:00 throughout the year.

3.3 Project Implementation

The PV system was ground and mounted in the open space next to the village temple. The foundation was constructed in cement in the pile type. To encourage villager participation, the installation contractor commissioned the cement foundation construction and electrical room work to the management committee of the villages. The electrical room for Site II was built over the existing temple pavilion. All of the construction works met the required specifications and were accepted by the installing contractor.

The installation of electrical poles and power grids was next and reflected villagers' active participation. Wooden rods are required for installing electrical poles. The specified height of the poles is seven meters, and the required diameter of the poles is 0.2 m. The villagers prepared the wooden poles to meet these requirements. The poles were positioned in cooperation with the management committee and local villagers within these villages. The poles were positioned according to the design diagram, and the distance between the poles was approximately 25 m. The installation contractor instructed the management committee in the required specifications of a hole for the pole to be buried (buried depth of the electrical pole was 1–1.2 m), directed the installation of the pole with a cross pad, and demonstrated the setup operation of the electrical pole to facilitate the pole installation work by local villagers.

Regarding the power grid, the main line uses a 35 mm^2 aluminum conductor steel reinforced (ACSR) cable, the branch line uses a 25 mm^2 ACSR cable, and the service line uses a BVVB 2 $\times$ 3029 cable. Eighteen step-down transformers (460 V/230 V, 300 VA) and overcurrent protection devices were also installed in boxes on the electrical poles.

The main power supply circuit is divided into four main areas: temple area, school area, electrical room, and village power supply. All four areas are independent power supply control circuits. The installation of household lights was performed by local villagers under the guidance of the installation contractor. Installation work included connecting the service line box, fuse, LED lamp and holders, and indoor wiring. After the installation was confirmed as correct, a warning seal in Myanmar was adhered to the riding seam of the service line box to prevent users from replacing existing fuses with a larger capacity fuse and to ensure their electricity safety. Photographs of the installation and construction are shown in Figs. 3.2 and 3.3.

According to the organization chart (Fig. 3.4) designed by the project team, the committee was organized by the villagers, who were divided into two groups: technical maintenance and operation management. The former is responsible for the daily operation of the equipment, household power checks, and system component replacements. The latter is responsible for electricity tariff calculations and collection, tariff fund account management, and education advocacy. The functions of the management committees are illustrated in Fig. 3.5.

To advance the villagers' power usage knowledge and develop basic electric power engineering knowledge and technical capacity, the project team encouraged villagers

Fig. 3.2 Solar PV system and LED lights installation. *Source* Compiled by the author

to actively participate in system construction and maintenance and participate in the technology training courses offered by this project. These experiences are expected to contribute to the villagers' future development of specialty skills. Electricity tariffs collected from the villagers would be used as funding for future power supply system maintenance work, such as the replacement of battery banks, PV charge controllers, inverter equipment, fuse replacements, and power line maintenance, for the long-term operation of the power supply station to ensure the sustainability of the project.

Fig. 3.3 Village view of Site. *Source* Compiled by the author

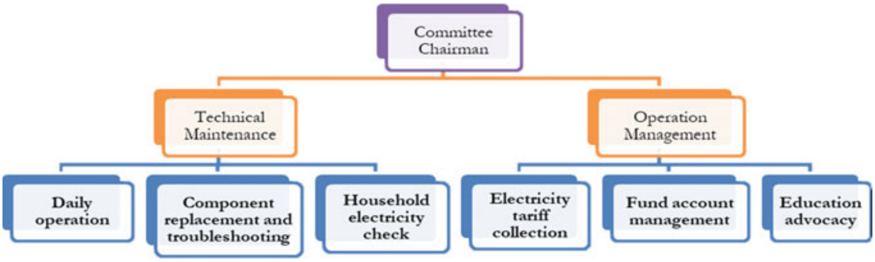

Fig. 3.4 Organization of power supply system management committee. *Source* Compiled by the author

3.4 Project Impact Assessment

The project team recorded the changes in the village lifestyle after the power systems were put into operation by interviewing villagers and distributing questionnaires. The objects include ordinary households and members of the power supply system management committee of the five villages. The questionnaire asked villagers to assess the degree of influence of their nighttime lifestyles. The impact of lighting on local lifestyles ranged from L1 to L5. The higher the number, the greater the impact, with L1 having the weakest impact and L5 having the strongest impact.

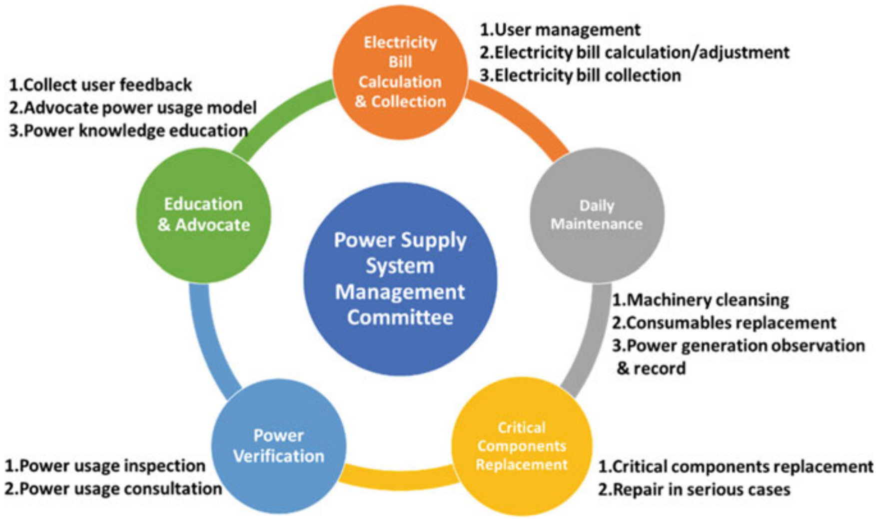

Fig. 3.5 Functions of power supply system management committee. *Source* Compiled by the author

3.4.1 Result of Site I

A total of 60 questionnaires were distributed to the villagers in the Inbingan Village of Magway Region, and 57 were collected. After filtering out questionnaires with serious omissions, 53 were considered valid. Furthermore, 15 questionnaires were distributed to and collected from the management committee. After filtering out the severely missed questionnaires, 12 questionnaires were considered valid. The data analysis results showed that nighttime lighting allows children to read at night, village shops can operate for a longer period, owners' incomes increased, village meetings could be conducted later in the evening, and some villagers continued agricultural work (Fig. 3.6).

Definition of statistical chart items:

- Study: beneficial for children to study and do homework after dark.
- Contact: beneficial for villagers to visit each other after dark.
- Shop: shop hours could be extended.
- Eating: dinner time could be postponed.
- Farming: villagers could do simple farm work after dark, such as feeding cows and arranging farm tools.
- House Keeping: housework could be done after dark.
- Sewing and Handicraft: sewing and handicraft could be done after dark as a secondary source of income.
- Bath: bath time could be postponed.

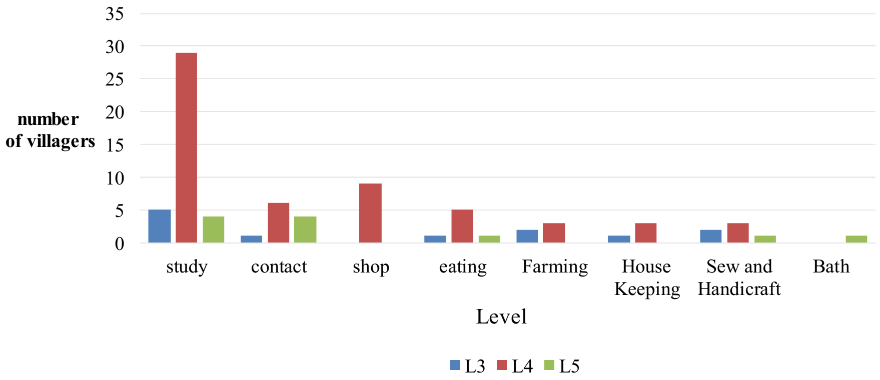

Fig. 3.6 Lifestyle impacts after system installation—Inbingan village, Magway Region. *Source* Compiled by the author

3.4.2 Result of Site II

A total of 120 questionnaires were distributed to villagers in the four villages of the Sagaing Region, and 113 were collected. After filtering out questionnaires with serious omissions, 66 were considered valid. Again, 15 questionnaires were distributed to the management committee, and 15 were considered valid. According to the data analysis, the results found that the positive impacts of nighttime lighting included allowing nighttime reading time for children, enabling villagers to continue housework or engage in light economic activities—sewing, cleaning, and farm work, such as screening peanuts—and feeding cattle. Lighting also ensures the safety of the villagers when they visit neighboring households at night, promoting better interpersonal communication within the village (Fig. 3.7).

Definition of statistical chart items:

- Study: beneficial for children to study and do homework after dark
- Shop: shop hours could be extended
- Farming: villagers could perform simple farm work after dark, such as feeding the cows, selecting peanuts, weaving ropes, and arranging farm tools
- House Keeping: housework could be done after dark
- Sew and Handicraft: sewing, weaving, and handicraft can be done after dark as a secondary source of income
- Safety and Health: increased safety for walking after dark; lighting distracts mosquitoes from biting villagers and increases general health
- Increase Income: beneficial for increasing income (income increase source and methods unspecified)
- Contact and socialization: beneficial for improving relations through general socialization and home visitations between villagers after dark
- Other benefits (such as cooking or improving mood) or if the survey taker indicated positive impacts but did not specify details.

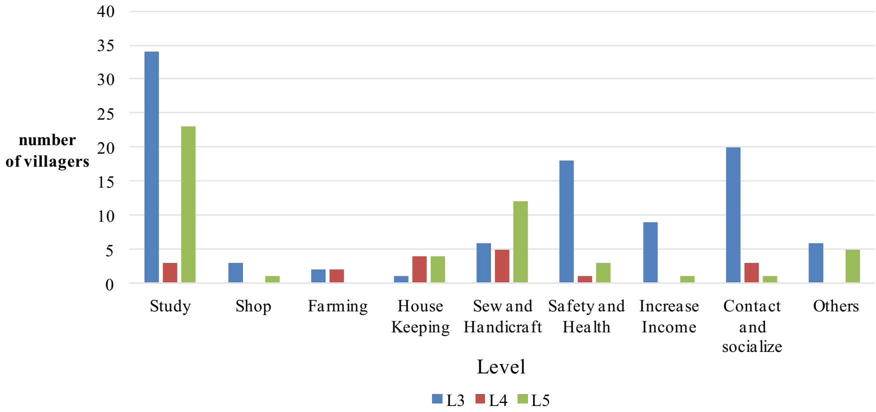

Fig. 3.7 Lifestyle impacts after system installation—Bawdigone/ChiYarPinSu/Zeephyjim/Payagone Village, Sagaing Region. *Source* Compiled by the author

In addition, all of the members of the power supply system management committee at the two sites held a positive view of the solar PV system. After participating in system installation and management, villagers have a clearer understanding of power consumption, system management, and fund management.

3.5 Project Outcomes

Solar PV mini-grid systems have been undertaken and operated since 2018 by the power supply system management committee of the two sites and provided lighting and public electricity for 560 households in those five villages. The systems improved the nighttime reading environment for school children, extended the time spent by villagers in home economic activities, increased family incomes, and improved interpersonal relationships between villagers. For participating households, the most immediate benefit is saving the cost of buying candles or kerosene. For the project level, the indirect benefit is the reduction in CO_2 emissions from burning fossil fuels. Such achievements are in line with the sustainable development goals of environmental protection and economic development. The project also demonstrated the operation model of the solar PV mini-grid system, lighting applications, and the establishment and operational mode of the power supply system management committee.

The project team believes that the success of this project is attributed to the following features:

1. Considering the remote location of the sites, once system failure occurs and maintenance is difficult, the project team designed higher-quality system equipment from the very beginning. The project's overall solution was planned by

Taiwanese experts from the Industrial Technology Research Institute who were also in charge of the formulation of the hardware specifications and construction quality supervision. The system architecture was designed to be scalable, with high-quality and reliable key components to ensure that the power supply system has high operational availability. Although the investment cost was higher, the lifespan of the equipment and storage battery was extended, and maintenance problems were reduced.

2. Based on the project sustainability goal, the project team assisted the villages in establishing a power supply system management committee and encouraged the committee to participate in the planning, design, installation, testing, and operation of the solar PV mini-grid system. Committee members also received good training on the operation and management of the power system to have sufficient skills to carry out basic troubleshooting.
3. The project team encouraged villagers to actively participate in the project startup process, including assisting in PV system installation, electrical room construction, power grid extension, installation of home lighting, and public electricity outlets, to strengthen the recognition of ownership over the system. Seminars were designed and held to train villagers in basic electric consumption safety knowledge to improve the safety and reliability of the power supply system. In addition, the project introduced the user pay mechanism and successfully assisted the power supply system management committee in establishing an electrical tariff fund management model. The fund is expected to be used for the future operation and maintenance of power supply systems.

In sum, renewable energy mini-grids can address power poverty in remote areas and enhance the awareness of energy autonomy and ownership of rural villages. Active engagement with communities from the beginning is critical. In terms of financial success, tariffs should be designed carefully to generate enough revenue to cover operational expenses yet remain affordable for villagers. These remote villages in Myanmar are similar to isolated islands in the mountains, and we believe that the project's experience and lessons can be replicated on small islands. Finally, this case shows that, in addition to developed countries, developing countries can make their own contributions to the road to achieving net-zero emissions globally.

3.6 Lesson-Learned from Project

Economic progress in Myanmar is at a quick pace, and demand for electricity is expected to increase rapidly. The planning and design of solar PV mini-grid power supply systems for similar rural areas must be considered for villagers who can afford additional electricity for the television, refrigerator, radio, mobile phone, electric fans, and other needs, in addition to basic lighting. Based on the diversified demand for electricity, the solar PV mini-grid power supply system could adopt a hybrid power supply mode, such as the PV/diesel/battery mini-grid system. Through technical and economic analysis, the most suitable power system capacity and energy mix could be selected to maintain reasonable system installation, operation, and maintenance costs. In the user pay model, smart meter applications, such as electricity prepayment mechanisms, can be introduced into rural areas to calculate electricity consumption and charges. Furthermore, in regions with good network communication, remote monitoring and system control can be introduced into mini-grid systems. System installers can troubleshoot simple problems and remotely control and adjust the system operation parameters and monitoring to strengthen the reliability and economic benefits of the power supply system.

Each village has its own characteristics, and the tariff collection model should be designed according to local needs. When guiding villagers to form their power management policies, the importance of system maintenance and fund management should also be emphasized to avoid affecting the normal operation of the system because of insufficient funds. Given the gradual development of Myanmar's economy, the demand for electrical appliances and electricity is also rising. Regarding the issue of electricity tariff collection, in addition to the current fixed charging model, other charging methods, such as surcharges based on kilowatt-hours, can also be adopted. The electrification and living conditions of the village are improved because a surcharge is imposed on those with higher electricity consumption to obtain more electricity.

Government support when communicating with villagers is important to assist with site selection, the smooth implementation of village-level communication, and on-site investigations. The Burmese government can assist the project team in choosing villages with strong teamwork and deep relationships, which might affect the sustainable operation and functioning of the power supply system management committee. Whether a village is suitable for power plant installation requires that the project team visit the village multiple times to discuss the details of the power supply and its benefits. If local government officials can accompany or support project team in their endeavor to communicate with the villagers, they will be more willing to communicate. Consequently, the site survey, villager willingness assessment, and other relevant evaluations could be conducted smoothly.

The vast territory and low population density across various villages and underdeveloped infrastructure, such as local transportation networks and power, make it difficult for private sector companies to consider investing in power generation in rural Myanmar. The initial investment cost of rural power generation plants is much higher than that of other countries. To rapidly increase the electrification level of villages in Myanmar and encourage private investments, the central and local governments should play a more active role in providing incentives, offering communication channels with villages, and lowering investment barriers to attract more private investments in power systems in villages.

The quality and capability of the hardware equipment of the power supply system, the establishment and training of the power supply system management committee, and the participation of villagers in the startup of the power supply system are all key elements for the project's sustainable operation. According to the actual implementation experience of the two sites, a positive correlation indeed exists among the sustainability of the electrification project and good quality system hardware, good execution of the power supply system management committee, and active participation of the villagers. Therefore, when conducting a pre-operation survey on the candidate villages, the willingness of villagers to participate, villagers' local commitment and responsibility, evaluation of the members of the power supply system management committee staff, electricity demand, affordability of electricity charges, and the installation environment are all important factors that should be included in the feasibility assessment. Finally, seasonal factors should be considered when implementing the project. Construction scheduling should avoid the rainy season in Myanmar. Construction might be delayed because of poor road conditions. In addition, considering that most villagers can only have income after the harvest season, it is recommended that the electricity tariff payment method and timing be designed according to the seasonal characteristics of the village.

3.7 Conclusion

In remote area of Myanmar, kerosene lamps and candles are still widely used for lighting purposes. The illumination provided by these sources is poor. And, pollution from kerosene lamps used for lighting by rural households contributes to greenhouse gas (GHG) emissions. The generally accepted estimate is that for every liter of kerosene burned, 2.6 kg of CO_2 is released (Global Off-Grid Lighting Association (GOGLA) 2020). In addition to CO_2, kerosene lamps also produce black carbon during combustion, greatly increasing their contribution to GHGs.

As stated in the project outcomes, kerosene lamps and candles that the villagers had previously relied on have been replaced with LED lighting based on renewable energy, thus avoiding the accumulation of CO_2 and black carbon over the expected lifetime of the system. Solar PV technologies make it possible to the improvement for general CO_2 mitigation and even indoor air quality for households without energy access in rural Myanmar. In addition to reducing CO_2, increasing access to affordable, reliable and modern energy can improve productivity, increase incomes, and boost socioeconomic development, even in the results presented by the project that provides only basic light and low-power services in rural Myanmar. This consideration is especially important, as 78% of the world's poor people live in rural areas and rely on farming, livestock aquaculture, and other agricultural work (World Bank Group 2014).

As economies of scale gradually take hold in the mini-grid sector, and the costs of PV panels and batteries decrease over time, overall system costs are falling. With falling costs and increased reliability, mini-grids have become more attractive to both the public and private sectors. We can say that solar mini-grids have found their place in between solar home systems and national grid extension, depending on population density and distance from the main grid.

Sustainability in mini-grids means technically sound and reliable operation, high-quality power service and economical profitability. Without the latter, the other two sustainability criteria cannot be achieved. Solar mini-grids in particular typically face relatively high capital expenditures. Therefore, even with high grant funding, require a certain level of revenue to operate sustainably. It is noteworthy, however, that the renewable energy mini-grid sector is still largely financed through grants and non-commercial capital. Fully privately funded mini-grids are difficult to achieve in any case without subsidies due to the challenges of rural power supply. The challenges include the logistical challenges of installing systems on-site and maintaining remote operations and relatively low household affordability and willingness.

Due to modern energy access is central to achieving the Sustainable Development Goals, governments should consider all opportunities offered by mini-grid renewable energy solutions to expand access to affordable, reliable, and sustainable energy and to support livelihoods and delivery of basic services. For sustainable development, mini-grids require comprehensive, long-term political commitment and a stable, reliable policy framework. Regulation is especially important for renewable energy mini-grids in areas where governments are responsible for ensuring economic viability and ensuring that tariffs for underserved households are not too high. In terms of public assistance, there can be in the form of both direct fiscal support measures and complementary indirect incentives. For example, government can make grant contribution to subsidize some or all of the initial/upfront investment and be exempt from taxes and duties.

According to the ASEAN State of Climate Change Report, ASEAN needs to achieve net-zero CO_2 emissions by 2050 and net-zero GHG missions by 2065 for the emissions pathway aligned with the global 1.5 °C target. To achieve its goals, ASEAN also needs to adopt low- to zero-carbon energy sources in its long-term strategy. For renewable energy, a diversified renewable energy mix and accelerated diffusion are seen as crucial, and rural electrification is a priority in most countries (Association of Southeast Asian Nations (ASEAN) 2021). As for the Myanmar government, it has updated the Nationally Determined Contributions (NDCs) in 2021. Based on its NDCs, the country aims to increasing the total share of renewable energy to 53.5% by 2030, thereby achieving the conditional annual target of avoiding 144 million tCO_2e emissions. Under its national program for rural electrification, renewable energy technologies contribute 166.4 MW of electricity generation per year, of which 44.41 MW is generated through renewable energy mini-grids to power 1.8 million people of the off-grid rural population. As compared to alternative energy source using standard diesel generators, mini-grid renewable energy will generate 564,000 tons of CO_2e in emissions avoided cumulatively by 2030 (The Republic of the Union of Myanmar 2021).

Mini-grid renewable energy solutions represent a viable electrification and indeed a fast way to supply highly reliable electricity to remote rural and isolated areas. They are also environmentally sustainable solutions that support both ASEAN's efforts to achieve net-zero emission targets and Myanmar's commitment to NDCs. The project in Myanmar could be seen as a case of developing solar PV systems on mini-grids to implement rural electrification, and the lessons learned can be referenced and replicated in rural areas or island settings with similar characteristics. In addition, the project achieved the development goals of inclusive growth and environmental protection through access to affordable and renewable energy and demonstrated that even the poor or vulnerable groups in developing countries can contribute to a net-zero society.

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Chapter 4
Role of Renewable Energy Policy in Ensuring Net-Zero Carbon Emissions and Energy Sustainability: A Bangladesh Perspective

Emadul Islam, Asheer Shah, and Tariq A. Karim

Abstract The current global energy crisis along with the climate impacts of non-green energy sources has necessitated the shift toward renewable and sustainable energy. Limited fossil fuel reserves and high climate change vulnerability index of Bangladesh necessitate the country's need to achieve sustainable renewable energy governance and policy development to guarantee net-zero carbon emissions and energy sustainability. This study illustrates the implementation of national and regional policies in addressing the challenges of Bangladesh's transition to green energy from fossil fuels. The study contributes in the domain of national and inter-governmental green energy policy by developing recommendations along the Bay of Bengal region to increase the scalability of technologies and innovations, highlighting the opportunities and strengths of Bangladesh being the founding member of BIMSTEC integration.

Keywords Renewable energy policy · Net-zero carbon · Energy sustainability · Bangladesh · BIMSTEC

4.1 Introduction

The shift from conventional to clean or renewable energy for energy sustainability has been highlighted in international policy papers such as the United Nations Sustainable Development Goals (7) and the recent Conference of the Parties (COP 26) (Bouyghrissi et al. 2022; Madurai Elavarasan 2021; Murshed et al. 2021; Zeraibi et al. 2021). Rapid and fair transition to clean energy is required to maintain global warming to 1.5 °C and accomplish the goals of the Paris Agreement (Ahmed et al. 2022; Jahid 2018; Murshed and Tanha 2021; Xue et al. 2021). The transition is

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already underway—renewables accounted for more than 70% of new global power capacity additions in 2019—but they must be expedited to ensure its success. Approximately one-quarter of global greenhouse gas emissions are attributed to the electricity industry. We must accelerate the speed of the global transition to sustainable energy by at least fourfold over the next decade if we are to reach the country's Paris Agreement targets (COP26 Energy Transition Council 2021).

The current global energy crisis, as well as the climate impacts of non-green energy sources, has necessitated the shift toward renewable and sustainable energy. Furthermore, states are entitled to limited natural resources, consumption, and production units. Thus, in the current global village, the importance of renewable and sustainable energy is pivotal to countering climate change and productivity limitations. Cherry (1973) discussed the prospects and potential of solar energy in three major areas: the heating and cooling of buildings, production of clean renewable fuels, and electrical power generation. In 1974, Norman (1974) demonstrated how the thermodynamically reversible mixing of freshwater and seawater at static temperature generates free energy and how an osmotic salination converter could harness renewable energy. Similarly, Witwer (1977) analyzed solar energy and its contribution to the United States (US) energy system and how the energy is more cost-effective when compared to depletable fuels. Chisti (2007) illustrated microalgae as a source (more efficient than crop plants) of renewable biodiesel, which can potentially serve the demand for global transport fuel. Goldemberg (2007) portrayed Brazilian sugarcane ethanol as a substitute for motor gasoline and how it is suitable for implementation worldwide.

Asia and the Pacific have made considerable headway in connecting their people to power. The area has three-quarters of the 570 million people who acquired access to electricity between 2011 and 2017, although an estimated 350 million people did not gain access. Approximately two billion people in Asia and the Pacific rely on biomass, coal, and kerosene for cooking and warmth. The People's Republic of China (PRC) and India, the world's two most populated countries, account for 28% of the global primary energy supply. The Asia–Pacific has created a significant renewable energy capacity in solar photovoltaic (PV), wind power, hydropower, biofuel, and geothermal technologies (REN21 2019).

Bangladesh's economy is accelerating, and in 2019, the gross domestic product (GDP) growth rate was at an all-time high of 8.1%. Bangladesh's GDP has expanded by 188% since 2009 (Hasina 2019), per capita income has topped $2554, and it is estimated that by 2030, Bangladesh would be the world's 26th largest economy. Bangladesh has the fifth-largest internet user population in Asia–Pacific, and more than 120 enterprises export information and communications technology (ICT) products worth approximately $1 billion to 35 countries as part of its transformation into a "Digital Bangladesh" (Palak 2019). Bangladesh made remarkable progress by introducing the Climate Change Trust Fund in 2009 to foster climate change adaptation. The Honorable Prime Minister, Sheikh Hasina, is called the world's climate champion. Despite contributing less than 0.47% of the global carbon emissions, Bangladesh is one of the most climate-vulnerable countries. The country shows a continuous commitment to achieve the Paris Agreement and Sustainable Development Goals (SDGs); therefore, it canceled 10 coal-based power facilities worth 12 billion dollars in foreign investment. In terms of the transition to renewable energy, Bangladesh has set a target of 40% of its energy from renewable sources by 2041 (The Daily Star 2021).

Hence, to shift toward renewable energy, Bangladesh needs to achieve suitable energy governance and policy development, along with scientific and technological advancement. This study provides an overview of the energy in Bangladesh emphasizing on renewable energy. Following the renewable energy profile of Bangladesh, the study demonstrates the challenges and barriers to transition toward renewable energy. Post identification of the barriers, the study provides energy policy recommendations in reference to BIMSTEC that will facilitate the transition of Bangladesh toward renewable and sustainable energy, which will eventually ensure net-zero carbon emissions and energy sustainability. The study concludes by illustrating a way forward by addressing renewable energy policy innovations in Bangladesh and the BIMSTEC region. The focal themes of the study are as follows: conceptual analysis of renewable energy and energy sustainability, energy profile in Bangladesh, barriers and prospects of renewable energy in Bangladesh, and pathways to renewable energy for ensuring net-zero carbon. This study is not simply focusing on the renewable energy sources and technologies; it is also aiming to ensure net-zero carbon emissions and energy sustainability by deploying the renewable energy policies. As a result, in this study, renewable energy policy is the independent variable, and carbon emissions and energy sustainability are the dependent variables.

4.2 Conceptual Analysis of Renewable Energy and Energy Sustainability

Energy is an important aspect of modern civilization and a prerequisite for sustainable development (Islam and Khan 2017). Sakalasooriya (2021) illustrated the term sustainability as the equitable, ethical, and efficient use of natural resources for fulfilling the needs of current and future generations and enhancing their well-being. This definition suggests the rational usage of the limited resources available for human consumption. Generally, sustainable development is a course of progress wherein the double-dealing of assets, the heading of speculations, the direction of the mechanical turn of events, and institutional change are all in congruence and upgrade both the current and the future potentials to address human issues and goals (World Commission on Environment and Development 1987). Economics has always studied the scarcity of resources, and presently, the global village is transitioning to sustainability. To address scarcity, the importance of sustainability is substantial. It is noteworthy that, in economics, scarcity of resources leads to opportunity costs. Thus, transitioning toward sustainability to address scarcity incurs numerous opportunity costs. Policymakers, technocrats, negotiators, entrepreneurs, multinational companies (MNCs), civil societies, think-tanks, among others, govern the dynamics of the transition.

Düren (2017) interprets renewable energy as constantly transforming and evolving, depending on time and space dynamics. For instance, renewable energy changes structures and factors based on weather conditions, seasons, and time, among others, making renewable energy and the conditions, the dependent and independent variables, respectively. According to Düren, solar energy can be harnessed maximally in desert geographies, while wind energy can be harnessed efficiently in coastal and mountainous areas. Consequently, the dynamics of renewable energy change based on geographical locations.

Renewable energy sources, including bioenergy, direct solar power, geothermal power (including geothermal heat), hydropower (including hydroelectricity), and wind and ocean energy (including tides and waves), have been demonstrated in literature suggesting that replacing fossil fuel-based energy sources with renewable energy sources will gradually assist the world in achieving sustainability (Owusu and Asumadu-Sarkodie 2016). Tester et al. (2012) defined sustainable energy as "a dynamic harmony between the equitable availability of energy-intensive goods and services to all people and preservation of the earth for future generations". Energy sustainability refers to the utilization of renewable energy sources by ensuring that sufficient energy resources are available for future generations (Ninno Muniz et al. 2020). Notably, energy sustainability does not simply refer to the transition toward renewable energy, but rather to a reduction in the consumption of energy or the further exploration of efficient usage methods of energy by the current global village. This implies that the existing generation requires innovative methods to conduct day-to-day activities using lower amounts of energy components. Thus, it is crucial to explore the interconnectedness of energy and sustainability to formulate and implement policies governing energy sustainability with the assistance of sustainability indicators to discuss issues in the political field, as well as the general public forum (Solarin et al. 2018).

Previous research has emphasized the importance of renewable energy resources in the national energy system to maintain environmental sustainability. Several studies have investigated the relationship between renewable energy consumption and ecological footprint nexus (Xue et al. 2021; Alola et al. 2019; Naqvi et al. 2020; Sharma et al. 2021). For example, Naqvi et al. (2020) discovered statistical proof of increased renewable energy use to minimize the ecological footprint in the context of high- and upper-middle-income nations. Additionally, Destek and Sinha (2020) discovered that the adoption of renewable energy was beneficial for lowering the ecological footprint of selected Organization for Economic Co-operation and Development (OECD) nations. In studies conducted by Alola et al. (2019) for 16 European Union nations and Sharma et al. (2021) for developing countries in Asia, researchers found results similar to those reported here.

In the recent years, academics and researchers have paid close attention to the topic of renewable energy and energy sustainability according to the generated Scopus database. As shown in Fig. 4.1, a total of 10,320 publications on renewable energy and energy sustainability were included in the Scopus database between 2006 and 2021 over the period. This issue has sparked a significant increase in interest among academics and researchers all around the world, and this has been noticed in several

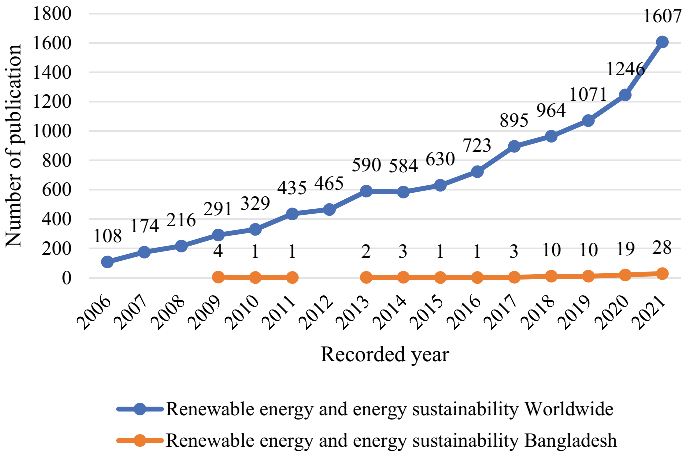

Fig. 4.1 Publication of renewable energy and energy listed in Scopus database during 2006–2021. *Source* Compiled by authors

countries. According to the Scopus database, a total of 83 papers have been published in the context of Bangladesh. Figure 4.2, on the other hand, depicts the overall trend of the mentioned literature on renewable energy and net-zero carbon emissions. A total of 406 titles were listed globally between 2006 and 2021, with just nine titles listed from Bangladesh throughout that time period. Previously, authors have mostly focused on the technological aspects and resource aspects in facilitating the transition toward renewable energy. However, the domain of policy has remained unmurmured in encouraging the transition and addressing the issues of technological advancement and resource availability. Hence, the authors of this study argue that in the development of renewable energy, net-zero carbon, and energy sustainability, innovative policies can act as the mediator of the energy transition. The paper argues that national policies lead to national energy developments; however, an integrated renewable energy policy among the neighbors can lead to a higher scale of national energy development.

4.3 Methodology

The panel data used in this research study has been collected from the International Energy Agency (IEA) database. The IEA was created to ensure and secure the supply of oil in 1974 and currently focuses on a variety of issues. There are 31 member countries in the IEA and further 8 association countries. As a result, it is a viable and noteworthy database in the domain of energy. The figures generated in this paper include and portray the statistical data present at the IEA. The data collected from the IEA was within the time frame of 1990 till 2019. The initial dimensions based

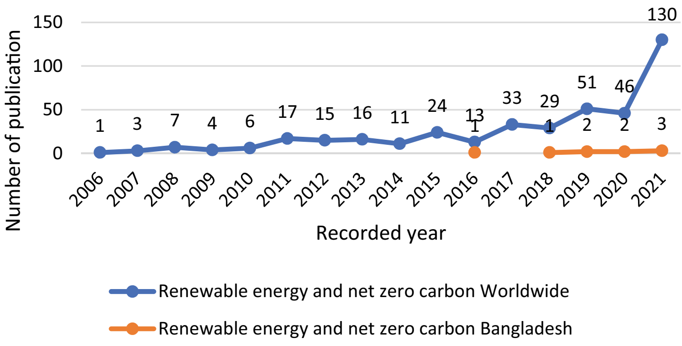

Fig. 4.2 Publication of renewable energy and net-zero listed in Scopus database during 2006–2021. Compiled by authors

upon which the data has been collected are energy supply and energy consumption in Bangladesh. Following the initial phase, the dimension shifted toward renewable energy, as well as modern renewable energy status in Bangladesh and further, segmented the dimension into solar, wind, and hydro sources.

This research utilized another secondary source of data which is the Scopus database for the purpose of literature review. A systematic approach has been followed, noted as the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA). The time frame of the data extraction was from the year 2006 till the year 2021. The initial dimensions of the search engine were "renewable energy and energy sustainability worldwide" and "renewable energy and energy sustainability Bangladesh". The later dimensions of the search engine were "renewable energy and net-zero carbon worldwide" and "renewable energy and net-zero carbon Bangladesh".

This study uses carbon emissions and energy sustainability as dependent variables and renewable energy policy as the predictor. Carbon emission and energy sustainability take into account the important dynamics related to the transition toward green energy sources; since in order to reduce carbon emission and ensure energy sustainability, transition toward renewable energy sources is mandatory. The argument this study aimed to develop is that renewable energy policy can function as a vital variable in enhancing sustainable energy. The study further encourages the idea of common regional renewable energy policy as one of the dimensions of the renewable energy policy domain. Henceforth, this paper addresses the role of BIMSTEC in facilitating the formulation and implementation process of a common BIMSTEC renewable energy policy, integrating the seven Member States tackling a common threat of the region which is limited energy.

4.4 Energy Profile of Bangladesh

Bangladesh is among the top six global economies based on the GDP growth rate of the global village according to World Bank data of 2019 (Tachev 2021). The transition of Bangladesh from the so-called basket case to the top global economies is fascinating, as well as expensive. The transition is being referred to as expensive since development follows through a number of opportunity costs and expenses. In this discussion, energy is being referred to as the expense for the development and growth of Bangladesh. In the energy sector, Bangladesh heavily relies on natural gas in the domain of electricity production. As a result, it is highly important for Bangladesh to shift toward green energy. Figure 4.3 is developed in order to provide a descriptive overview of the energy supply in Bangladesh.

Figure 4.3 illustrates the total energy supply in Bangladesh based on sources and data accumulated from 1990 to 2019. According to the figure, the energy supply in Bangladesh is divided into six segments. On one hand, the hydro, wind, solar, and similar energy sources are harnessed, which are renewable sources of energy, leading to zero carbon emissions. On the other hand, there are fossil fuels such as oil, natural gas, and coal. Fossil fuels are limited, scarce, and have negative environmental impacts with high carbon emission rates. Biofuels and waste energy are complex domains, and their environmental impacts are still under study; hence, they fall in between. The types of biofuel and waste energy are important when referring to renewable energy with positive environmental impacts (Zah et al. 2007).

Natural gas is the highest energy supply source in Bangladesh. In 2019, the supply of natural gas in Bangladesh was 1,068,016 terajoule (TJ), of which the imports amounted to 127,731 TJ. In 1990, the supply of natural gas was 156,049 TJ. The supply of natural gas increased by 911,967 TJ between 1990 and 2019. In contrast, the lowest energy supply sources in Bangladesh are wind and solar energy. In 2019, there was a supply of 1353 TJ of wind and solar energy in the country. In 2013, the

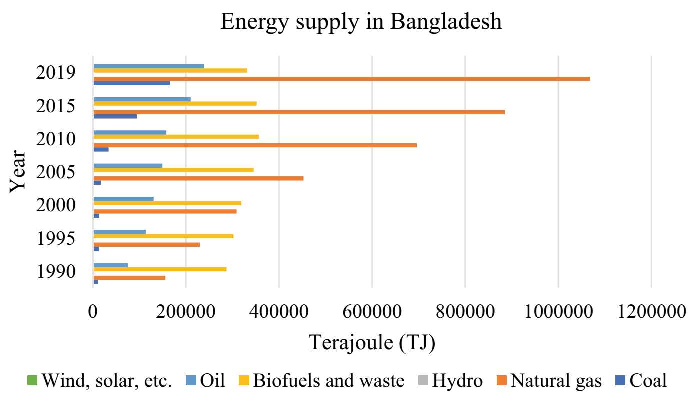

Fig. 4.3 Total energy supply (TES) by source, Bangladesh, 1990–2019. *Source* IEA World Energy Balances

country generated 504 TJ of wind and solar energy and experienced an increase of 849 TJ in 2019. The position of hydroenergy is also similar and replicates the pattern of wind and solar energy generation, which is hardly noteworthy. The generation of hydroenergy was reduced from 3182 to 2767 TJ over 29 years. Hydroenergy generation in Bangladesh appears to have a negative growth rate.

The second-highest source of energy supply in Bangladesh is biofuel and waste. In 2019, the country generated 331,716 TJ of energy from biofuel and waste. However, the generation of energy has not resulted in any notable growth. In 1990, the energy generation from biofuels and waste was 287,395 TJ, which increased by only 44,321 TJ after 29 years.

Oil is the third-highest source of energy in Bangladesh. In 1990 and 2019, the supply of oil was 75,533 TJ and 238,913 TJ, respectively. The supply of oil increased by 163,370 TJ between 1990 and 2019. The supply of coal started to increase significantly in Bangladesh from 2014, where the supply of coal increased from 38,755 TJ to 165,740 TJ in 2019. The use of fossil fuels in Bangladesh is on the rise. Following the energy supply statistics for Bangladesh, Fig. 4.4 illustrates an overview of energy consumption.

Figure 4.4 provides a complete overview of the energy consumption in Bangladesh from 1990 to 2019. According to the figure, natural gas is the most consumed energy in Bangladesh, where in 2019, the country consumed 428,979 TJ of natural gas. The consumption of natural gas has increased since 1990. Coal was among the least consumed energy at 150,000 TJ of coal energy being utilized in 2019. Coal consumption increased drastically in 2015 and again in 2019. Biofuels and waste energy are the second-most consumed energy sources in the country. In 2019, almost 300,000 TJ of biofuel and waste energy was consumed. However, its consumption started to decline from 2010 onward. Contrastingly, the consumption of electricity has risen significantly from approximately 17,000 TJ in 1990 to 284,033 TJ in 2019. The electricity demand has been increasing in the country. In the recent years, the

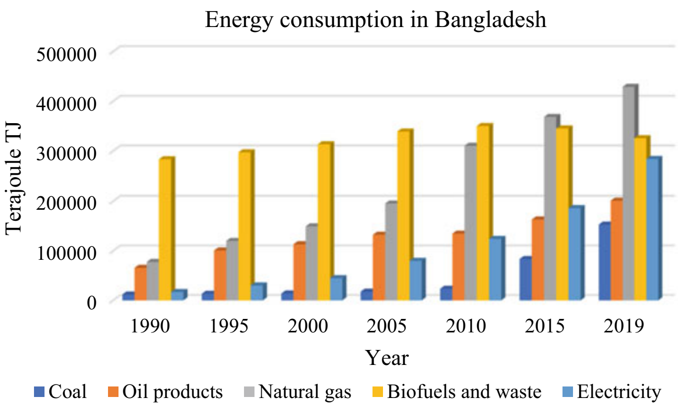

Fig. 4.4 Total final consumption (TFC) by source, Bangladesh, 1990–2019. *Source* IEA World Energy Balances (IEA 2022)

domestic sector has become the major consumer of electricity in Bangladesh (Islam and Khan 2017). Finally, the consumption of oil/oil products has also increased over the years.

The energy profile of Bangladesh has provided an overview of its energy supply and consumption. This particular heading aims to provide an analysis of the patterns and trends of energy supply and energy consumption data. The next section specifically focuses on renewable energy, highlighting the current status, prospects, and barriers to renewable energy.

4.5 Status of Renewable Energy in Bangladesh

Bangladesh has made limited and steady progress in the renewable energy sector following the publication of the renewable energy policy guidelines in 2008 by the Ministry of Power, Energy, and Mineral Resources (Tachev 2021). Currently, Bangladesh generates hydroenergy electricity, solar PV, and wind electricity. The following figures illustrate the electricity generation trend from renewable sources in Bangladesh from 1990 to 2019.

Figure 4.5 shows electricity generation in Bangladesh using hydropower. From 1990, the trajectory was on a downward slope until 1995. The electricity generation fell below half the capacity in 1990. In 1995, the figure followed an upward slope and increased electricity generation to almost 800 GWh in 2000 and remained constant from 2000 to 2010. From 2010 onward, the trend again followed a downward slope until 2015 and only reached the static electricity generation capacity by 2019. Since 1990, the hydroelectric electricity generation capacity has not surpassed the previous maximum generation capacity. In 1990, Bangladesh generated approximately 900 GWh of hydroelectric power. However, even after 29 years, the country still produces approximately 800 GWh of hydroelectric electricity, which is below its initial generation level in 1990.

Figure 4.6 shows the solar PV electricity generation trend in Bangladesh from 2013 to 2019. The figure followed an upward slope from 2013 to 2019, indicating that the generation of solar PV electricity in Bangladesh has significantly increased in the recent years. In 2013, the solar PV electricity generation capacity in Bangladesh was approximately 140 GWh. The generation capacity increased to > 350 GWh in 2019. The generation capacity increased by more than 200 GWh over these six years.

Figure 4.7 provides an overview of wind electricity generation in Bangladesh over six years. The wind electricity generation figure exhibited an upward slope from 2013 to 2015. The generation capacity increased from 4 to 6 GWh. The wind electricity generation capacity of Bangladesh has remained constant since 2015 and seems to have reached its maximum generation capacity based on existing infrastructures and technologies.

Figure 4.8 illustrates a comparison of renewable sources that generate electricity in Bangladesh. According to the figure above, hydro sources contributed the highest portion of electricity, solar PV was the second-highest contributor, and wind

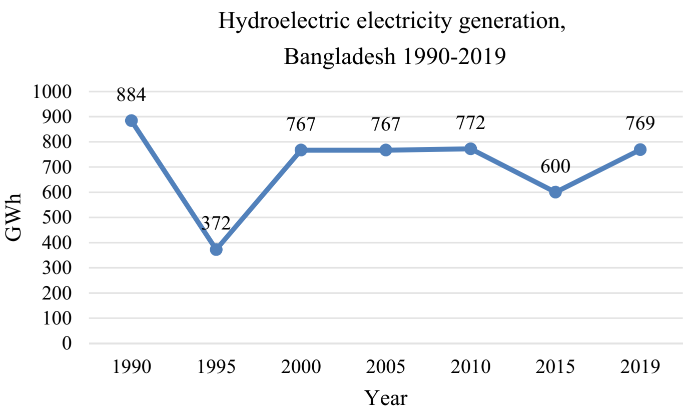

Fig. 4.5 Hydroelectric electricity generation, Bangladesh, 1990–2019. *Source* IEA World Energy Balances (IEA 2022)

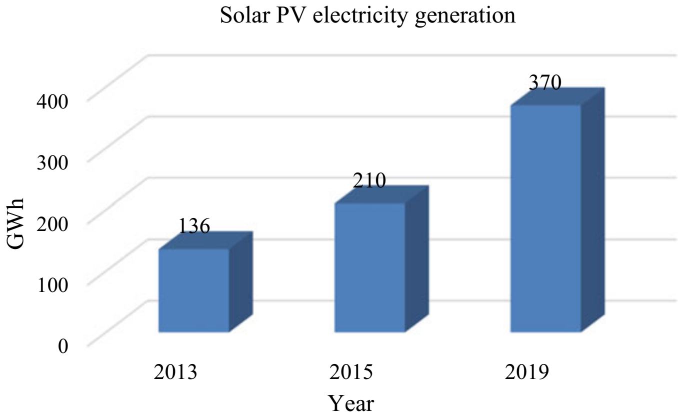

Fig. 4.6 Solar PV electricity generation, Bangladesh, 2013–2019. *Source* IEA World Energy Balances (IEA 2022)

contributed the least. However, among the three renewable sources, only the solar PV figure showed an upward trend. This means that the electricity generation capacity of solar PV sources is increasing compared to that of hydro and wind sources. The generation capacity of hydro sources has reduced over the years, and the generation capacity of wind sources has remained static over the past few years. From Fig. 4.8, it can be concluded that solar PV sources have a greater prospect of dominating the energy supply sector in Bangladesh.

Figure 4.9 captures data on the share of renewables in Bangladesh's energy sector. The figure shows data from 1990 to 2018. In 1990, approximately 70% of Bangladesh's energy consumption was from renewable energy sources. However, since 1990, the trend has been declining. In 2018, approximately 30% of the energy

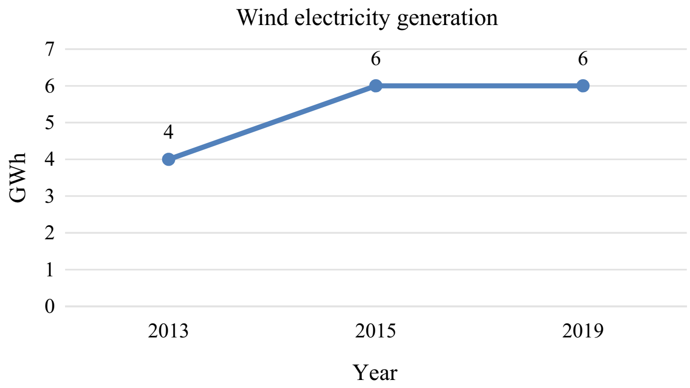

Fig. 4.7 Wind electricity generation, Bangladesh, 2013–2019. *Source* IEA World Energy Balances (IEA 2022)

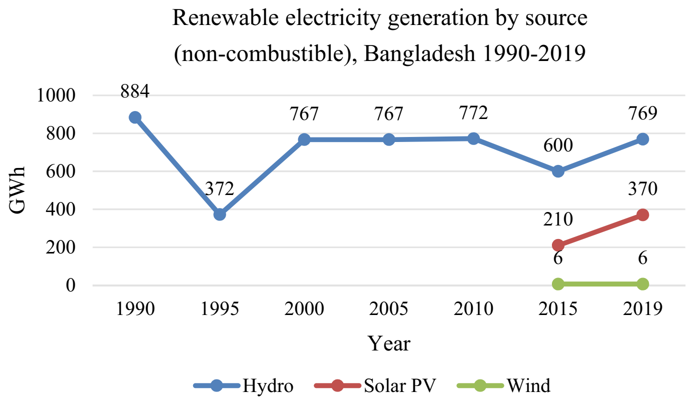

Fig. 4.8 Renewable electricity generation by source (non-combustible), Bangladesh, 1990–2019. *Source* IEA World Energy Balances (IEA 2022)

consumption in Bangladesh was from renewable energy sources. The share of renewable energy in final energy consumption in Bangladesh was reduced by 40% in 2018 compared to the 1990s.

Figure 4.10 comprises data focusing on the share of modern renewable energy in Bangladesh's final energy consumption. In 1990, modern renewable energy contributed to approximately 50% of the energy consumption. However, the contribution started to decline and dropped to approximately 20% in 1995. The share of modern renewable energy increased to 40% in 2000, following a downward slope until 2015, when it reduced to approximately 20% again. The contribution of 2018 was almost 35%, which was below the initial level in the 1990s.

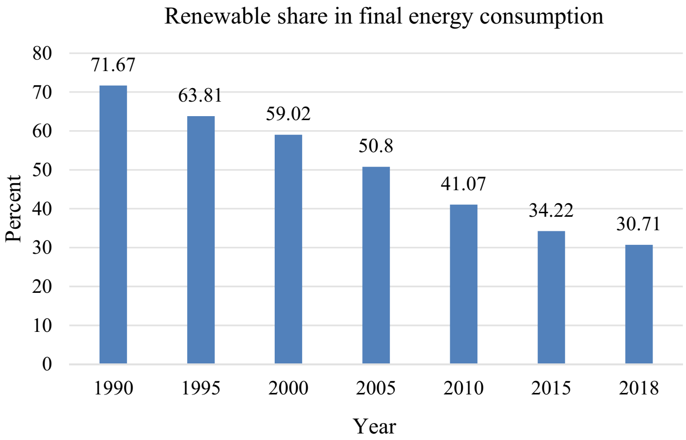

Fig. 4.9 Renewable share in final energy consumption (SDG 7.2), Bangladesh, 1990–2018. *Source* IEA World Energy Balances (IEA 2022)

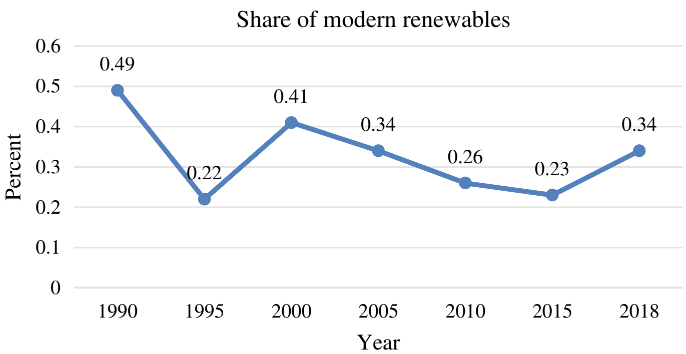

Fig. 4.10 Renewable share (modern renewables) in final energy consumption (SDG 7.2), Bangladesh, 1990–2018. *Source* IEA World Energy Balances (IEA 2022)

4.6 Barriers and Prospects of Renewable Energy in Bangladesh

4.6.1 Solar Energy

Bangladesh has an ample supply of renewable energy sources (Amin et al. 2016). The above discussions demonstrate the availability of hydro, solar, biomass, and wind as renewable sources of energy. It can be stated that the prospects of solar and biomass energy are significantly based on the data and existing trends. The prospect of solar energy is noteworthy because of the geographical location of Bangladesh and the daily amount of solar radiation received. Thus, Bangladesh can be referred to as a solar-blessed country with great prospects in the solar energy generation segment. However, progress has been limited to the solar energy generation and utilization sector in Bangladesh. Solar energy is mostly used in rural areas, with very limited implications for urban sectors. In the urban sector, buildings and constructions have varying heights. Thus, equal or similar amounts of radiation are not received by all structures, and it becomes a challenge to generate maximum solar energy in urban zones. Furthermore, the solar energy sector has rarely encountered any technological advancements since its introduction in 2013. Hence, even after the existence of great solar energy generation prospects in Bangladesh, the sector is developing within a limited range. Barriers to solar energy generation in Bangladesh include uneven building structures in urban areas and limited technological advancements. Technological advancements, research, and awareness can aid the development of the solar energy sector.

4.6.2 Limited Technology and Knowledge to Install Wind Turbine

Wind energy is one of the fastest-developing renewable energy sectors. Asia has surpassed Europe as a leading investor in renewable energy, particularly in the wind turbine sector, with China and India leading the way (Islam et al. 2014). The potential for wind energy is not promising except in certain coastal regions of Bangladesh. Bangladesh has a 724-km-long coastal strip that includes many islands in the Bay of Bengal. Commercial wind turbine power generation, in contrast, needs a thorough techno-economic analysis, which is not available.

4.6.3 Prospect of Biomass Energy

The second-largest supply of energy in Bangladesh comes from biofuels and waste. Biomass energy can be environmentally sustainable, based on the methods and materials used in the process. Thus, Bangladesh has great potential to generate electricity through biomass technology. Approximately 70% of energy consumption in Bangladesh is from biomass (Rofiqul Islam et al. 2008). If Bangladesh can implement a sustainable biomass-to-electricity conversion procedure, the country will be able to meet its rising domestic electricity demand. Figure 4.11 illustrates a conversion procedure that Bangladesh can adopt for electricity generation using biomass. However, technological advancements are barriers to the transition.

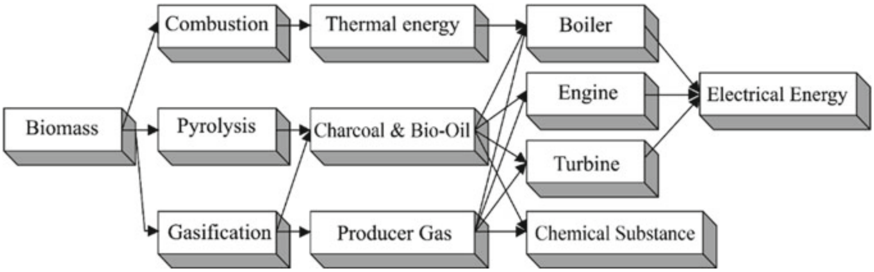

Fig. 4.11 Conversion of biomass into energy. 2007 *Source* Waewsak et al. (2007)

4.7 Pathways to Renewable Energy for Ensuring Net-Zero Carbon Emission

One of the most vital strategies for addressing a particular issue (such as the carbon emission rate) at the national level is public policy. However, the policy mileage depends on the policymaker's skills. Establishing a functional public policy requires expertise in two processes: policy formulation and implementation. The policy formulation (the basis of the specific public policy) process is under the leadership of the policymaker. Therefore, the policy implementation process requires the involvement of numerous stakeholders. In the policy implementation process, the involvement of policymakers, law enforcers, entrepreneurs, non-state actors, and most importantly, the public is crucial in enhancing the functionality of public policy. The skills of the policymaker will ensure reciprocal recognition of the policy from each of stakeholders and will ensure that the policymakers must address the stakeholder demands. These are the fundamentals of public policy and hence must be followed when formulating renewable energy and energy sustainability policies. Thus, the concluding heading will focus on how policymaking can be a pathway to renewable energy and energy sustainability, ensuring net-zero carbon emissions.

4.7.1 Role of National and Regional Renewable Energy Policy

The following analysis was based on the policy descriptions provided in the IEA database: The 1996 Private Sector Power Generation policy of Bangladesh targeted private investments in the energy sector to preserve the limited natural gas resources of the country and, hence, developed policy guidelines for small power plants in the private sector. In 2003, the BERC was established to facilitate competitive ground in the energy sector, governing transparency and accountability in management, operation, and tariff settings; countering the exploitation of consumer interests; and sustaining an environment of ease of doing business for private investors in the energy sector. The BERC dictates the wholesale and retail selling prices for electricity, gas, and petroleum. The BERC is mandated to issue licenses and implement codes, regulations, and standards that guarantee the quality of services in the energy sector. Furthermore, it accumulates, maintains, and publishes statistical data on the energy sector of Bangladesh. Thus, it can be concluded that the BERC plays a significant and active role in the policy formulation domain of Bangladesh's energy sector. In 2004, import taxes were eased for wind and solar equipment, with a maximum import duty on solar water heaters with insulated storage tanks at 10%. After five years, Bangladesh developed a renewable energy policy in 2009 carrying several objectives such as utilizing the capability of sustainable power assets and scattering of environmentally friendly power advances in the country, peri-metropolitan, and metropolitan regions; empowering, energizing, and working with both public and private areas interest in sustainable power projects; fostering economic energy supplies to substitute native non-sustainable power supplies; increasing commitments of sustainable power to electricity creation; and increasing commitments of sustainable power both to power and to warm energy. The original goal of the policy was to generate 5% of Bangladesh's total power demand by 2015 and further push it to 10% by 2020. In 2012, the Sustainable and Renewable Energy Development Authority Act led to the creation of the Sustainable and Renewable Energy Development Authority (SREDA). The Act sets up the SREDA to guarantee energy security and alleviate chances related to normal cataclysms originating from global warming. The SREDA began operations in 2014 and is currently practicing as an administration office. SREDA plans to advance sustainable power and energy effectiveness by organizing sustainable power and energy effectiveness endeavors of the public authority, normalizing and naming the sustainable power and energy effectiveness items, directing innovations, and taking drives for their extension, establishing a favorable climate for the financial backers, embedding mindfulness for sustainable power and energy effectiveness, building linkages with local and worldwide associations, among others (Table 4.1).

Post-institutional establishments came to the breakthrough when the "Energy Efficiency and Conservation Master Plan up to 2030" was developed, which aligns with the United Nations (UN) Sustainable Development Goal (SDG) 7. (SDG 7 focuses on access to clean, renewable and affordable modern energy for all.) The master plan is aimed to follow a systematic approach toward energy efficiency and conservation. This portrays how the establishment of institutes such as BERC and SREDA can lead to formulation and implementation of renewable and sustainable energy policies like the 2030 master plan which can facilitate the advancement and development of renewable energy sources ensuring net-zero carbon emission. In order to have a functional energy transition in Bangladesh, advancement in the sector of research is vital. However, Bangladesh lacks in the domain of resources and technologies, and the case is similar in the South Asian region. In order to advance in the sector of renewable energy and technology, the South Asian neighbors must collaborate and integrate. The existence of the Bay of Bengal Initiative for Multi-Sectoral Technical and Economic Cooperation (BIMSTEC) can facilitate the collaboration and integration in the energy sector among the seven Member States. Resource, data, knowledge, and expertise can be inter-exchanged, and new technologies can be easily availed for

Table 4.1 Renewable energy and energy sustainability policy status of Bangladesh

Policy	Year	Status	Jurisdiction
SREDA Standard and Labelling (Appliances & Equipment) Regulation-2018	2018	In Force	National
Energy Efficiency and Conservation Master Plan up to 2030	2015	In Force	Unknown
Scaling Up Renewable Energy Program for Bangladesh (SREP Bangladesh)	2015	In Force	National
BDS 1852:2012	2012	In Force	National
BDS 1853:2012 Performance of close control air conditioners—minimum energy performance standard (MEPS) requirements	2012	In Force	National
The Sustainable and Renewable Energy Development Authority Act 2012 (creation of the Sustainable and Renewable Energy Development Authority [SREDA])	2012	In Force	National
BDS ISO 13253:2011 Ducted air-conditioners and air-to-air heat pumps—Testing and rating for performance	2011	In Force	National
Renewable Energy Policy of Bangladesh	2009	In Force	National
Import Duty Exemptions for Solar and Wind of Bangladesh (Statutory Regulatory Order)	2004	In Force	National
Act 2003 establishing Bangladesh Energy Regulatory Commission (BERC)	2003	In Force	National
Policy Guidelines for Small Power Plants in Private Sector	1996	In Force	National
Private Sector Power Generation Policy of Bangladesh 1996	1996	In Force	National

Source IEA (2022)

testing and later, producing in terms of scalability. For instance, the Bay of Bengal can be utilized for renewable wind and hydroenergy potentials. The South Asian region needs to have an integrated renewable energy policy, in order to best flourish in the domain of green energy with the existing technological resources. Bangladesh must portray the innovative policy frameworks at the upcoming fifth BIMSTEC summit. As a result, a number of policy recommendations are being outlined for Bangladesh to address the issue of renewable energy.

4.7.1.1 Key Policy Recommendations for Bangladesh

- Establishing renewable energy research center in Bangladesh
- Establishing specialized research centers on wind, solar, hydro, and biomass energy in Bangladesh
- Formulating Bay of Bengal renewable energy policy frameworks focusing on wind and hydroenergy

- Utilizing Bay of Bengal Initiative for Multi-Sectoral Technical and Economic Cooperation (BIMSTEC) membership to facilitate the formulation and implementation of a granting renewable energy policy among the seven Member States addressing BIMSTEC priority three (Energy) and 14 (Climate Change) **
- Accessing and utilizing technological advancements in the sectors of solar and wind, such as *Smartflower.*

4.8 Conclusion

The paper aimed to illustrate an overview of the energy profile of Bangladesh, addressing the barriers and prospects of renewable energy sources in the country. A common issue of the South Asian countries has been the limited availability of renewable energy technologies. On the other hand, when the technology and data are available, affordability and scalability are absent. Bangladesh as a country can transit toward green energy; however, it requires technology, research, and data. Hence, this paper illustrated the role of national policy innovations in governing the energy climate of Bangladesh and the role of regional policy innovations in solving the energy limitations of South Asia.

In the twenty-first-century global village, only globalization can lead to renewability and sustenance.

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Chapter 5
Opportunities and Challenges in Sustainable Development and Governance in South Asia: Case Study of Bhutan

Shanawez Hossain and Ahmad Tousif Jami

Abstract The future of the post-COVID, climate "red code" world, hugely depends on good governance and a transition to low carbon. World leaders have repeatedly stated a unified goal of establishing a carbon–neutral society by mid-century. Analysis shows that South Asia's strong economic expansion has paved the way toward sustainable development, yet the region still has many unsustainable practices, except for Bhutan. As the first-only carbon-negative country globally, it is vital to extensively study, learn, and optimize Bhutan's best practices to improve global climate practices. Bhutan's three G model (gross domestic product—GDP, greenhouse gasses—GHG, gross national happiness—GNH) expands development metrics beyond GDP to people's happiness and environmental well-being. This study demonstrates how adapting practices from Bhutan, which have been molded by local experiences, problems, and opportunities, would effectively bolster green climate practices in the South Asian region.

Keywords Bhutan · Carbon negative · Governance · South Asia · Sustainable development · Three G model

5.1 Introduction

The world has reached a tipping point of climate change, where we can no longer afford to further trade-off environmental well-being. Environmentalists, politicians, policymakers, and global leaders all reached a consensus in the recent United Nations Climate Change Conference (COP26) held in 2021 at Glasgow, United Kingdom, that everyone must work together to address climate change. However, the recent pandemic of COVID-19 has caused massive economic and social harm. Therefore, environmental policies up ahead must resonate in adjustment with economic

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and social development. This framework also aligns with the United Nations (UN) Sustainable Development Goals (SDGs).

Although the goals are similar globally to work toward a more green planet, specific economic, social, and political disparities across regions, countries, and other local contexts make future policy requirements dynamic. So, the challenges for each region and country are uniquely different. The South Asian region here is uniquely crucial given the diverse economic, environmental, and political situations. Most importantly, the world's only carbon-negative country Bhutan is also located in South Asia. Since 1999, Bhutan has embraced a policy framework of development that focuses on social, economic, and ecological sustainability by using the three G model: gross domestic product (GDP), greenhouse gasses (GHG), and gross national happiness (GNH).

This paper presents a case study that analyzes how Bhutan achieved its negative carbon status and examines the lessons that other South Asian countries can put into practice through an extensive literature review. As many South Asian countries continue their path toward sustainable development, this study extracts relevant practices from Bhutan, considering the scope of requisites for local optimization.

5.2 Bhutan: World's First Carbon-Negative Nation

A place is considered carbon negative if its greenhouse gas emissions consist of less than zero carbon dioxide (CO_2) and carbon dioxide equivalent (CO_2e), based on the net emissions produced, as it is impossible to emit a negative amount of carbon (or any other physical material). Bhutan's greenhouse gas pollution is mitigated by its vast forests covering nearly three-fourths of its total area and reduced by creating and exporting renewable energy. Bhutan is a special case in exporting renewable energy, especially clean energy, from its hydropower resources. Bhutan produces 2.2 million tons of carbon per year, but its wood absorbs three times, creating a carbon sink (Rao 2016).

Such phenomenal achievement of Bhutan is led by strong political agenda and related actions such as banning log exports, a constitutional amendment to keep at least 60% of the country under forest cover, promotion of electric cars, limiting the number of tourist entry in a given time, reducing waste generation, providing free electricity to rural farmers to reduce their dependence on wood stoves for cooking, and replacing fossil fuel-based electricity by renewable sources such as wind, biogas, and solar power among other actions.

Further, Bhutan sets a unique example of sustainable development by establishing three main aims of development: social, economic, and environment, each of which includes quantitative indicators, and adopted a metric of the three Gs sustainability rose as a new worldwide idea in the 1980s due to the failure of single-minded economic expansion (World Commission on Environment and Development (WCSD) 1987). Although economic development is necessary, it should not be the only dictating factor while creating a development framework. Instead, environmental and social factors must be adjusted while the frameworks are created. So, as countries plan for sustainable development, climate change is a major concern that must be addressed besides economic development. This necessitates nationally determined contributions (NDCs) that demonstrate how each country may fulfill its economic objectives while significantly reducing greenhouse gas emissions. Based on these initiatives and actions carried forward by the government in collaboration with private institutions, Bhutan successfully implemented a sustainable development agenda. This effectively makes Bhutan a country with a net carbon sink and means that they are on track to achieve sustainability in a way that their citizens are also happy.

5.3 How Bhutan Became Carbon Negative

In recent decades, the economic growth has been steady, with a 7.6% GDP increase each year. This means that the Bhutanese economy is on a proper track. Furthermore, Asian Development Bank anticipates Bhutan's GDP growth trajectory which will continue to be high until 2030, ranging from 6.6% to 7.4% across potential scenarios (Mitra et al. 2014). The Bhutanese economy underwent major reformations to balance economic development with environmental well-being in the past half a century. Bhutan's economic policies do not compromise the environment and aim to mitigate harm in the most effective ways possible. This suggests that the GNH's socio-environmentally oriented development philosophy has not yet hampered economic progress. As the three G model has not hampered their economic development and is predicted to continue to be helpful even in future, the Bhutanese government will continue to support this model in future as well. The major takeaway here is that the Bhutanese model of three Gs has worked successfully for Bhutan thus far.

One of the three worldwide issues in the twenty-first century is the growing concentration of GHG due to human activity, which contributes to climate change (Newton and Newman 2015). These human activities on a micro-level include unnecessarily using air conditioners and increased consumption of products that require carbon burning. Furthermore, on a macro level, this includes using carbon in instances such as factory production, which also contributes to increased carbon emission. All of this has contributed mainly to environmental shifts, such as changing our climate. This shift will have various consequences on cities, countries, and societies, impacting the citizens.

Bhutan, a small country with a net carbon sink and sparse population, perceives environmental challenges as a danger to sustainable progress despite contributing very little to the phenomenon compared to other significant contributors. That is to say, countries such as the United States of America, China, and Russia contribute to climate change significantly more than Bhutan. If anything, with Bhutan's current net carbon sink status, it is safe to assume that Butan is no longer contributing to climate change at all. Therefore, Bhutan is not as responsive to protecting the environment as other countries harming the environment. Nevertheless, Bhutan has actively tried to follow its three G model to safeguard environmental well-being. Under the three G model, Bhutan has crafted its policy framework from the national level with local indicators. In fact, the practice of maintaining indicators has been a trend for Bhutan for nearly half a century now. Bhutan created a policy in 1974 to increase total forest coverage by 60% in total, which may be attributed to its strong forest conservation strategy in light of its small population and limited geographical accessibility due to its rugged terrain and the stringent policy mentioned above. According to Bhutan's most recent National Forestry Inventory available to the public, the nation has a forest cover of 71% (Ministry of Agriculture and Forestry 2017). This means that Bhutan was not only able to live up to its initial indicator of maintaining the forest coverage to 60% of its total area, but they have successfully gone beyond that, and now they have a forest coverage of 71%. This also means that Bhutan takes its indicators seriously and tries its best actually to achieve them. Therefore, the policymaking of Bhutan is presumably made realistically as opposed to just having goals that they cannot achieve. Furthermore, this also means Bhutan adapts its local indicator requirements over time given factors such as capacity is subject to change across timelines given the initial 60% forest coverage plan that they had is now at 71%, and they are trying to preserve it further as opposed to stopping it at 60%.

The philosophy of Bhutan's three G model was first discussed and adopted by Majesty Jigme Singye Wangchuck, Bhutan's Fourth King, in the 1970s (Munro 2016). From that point onwards, Bhutan always remained committed to maintaining the three G framework through proper policy support, such as the renaming of the Planning Commission as the GNH Commission (Givel 2015). This renaming is significant because it signifies the heavy importance Bhutan gives to its citizens' happiness. It is worth noting that such renaming measures are unique to the case of Bhutan as well. Furthermore, Bhutan's Constitution currently directs the government to improve the circumstances for pursuing the GNH (Royal Government of Bhutan 2008). This means the foundation of Bhutan requires the country to prioritize people's happiness through securing environmental protection. The GNH is an alternative development model and is seen by Bhutanese people as a paradigm for attaining sustainable development initiatives in Bhutan (Brooks 2013). That is to say that an average Bhutanese citizen would categorize environmental improvement as a nation's development. It is worth noting that the GNH is well known for its innovative approach to well-being policies (Alkire 2015). Because to include the GNH metric in its policy framework, Bhutan being the only country to do this, they do not have the scope to take lessons from other countries. Instead, they have to carefully design their policies and practices such that the success possibility is high and remains sustainable. It is also important to note that these measures have resulted in Bhutan being a very equitable and sustainable country with a mostly happy population despite its low per capita GDP (Ura 2015).

Thus, as a country without a robust economy, Bhutan is still balancing economic growth to allow it to decrease greenhouse gas emissions (Hayden 2015). Environmental policies are still expensive because it requires massive investment from the government. However, with its limited resources, Bhutan found a balance to prioritize the required investment without compromising the happiness of its citizens and their economic development. Therefore, Bhutan is an example to countries worldwide that are facing challenges in prioritizing environmental policies given the economic limitations. Moreover, Bhutan's efforts have unquestionably elevated the country to the forefront of environmental stewardship globally, which is now inspiring the rest of the globe to follow in its footsteps as well. Before, the goal of becoming a carbon-negative country was unthinkable for many countries, and therefore, they would not even craft policies in that direction. Bhutan successfully achieving the carbon-negative status has changed this, and now, countries can imagine what the direction toward a net carbon sink nation looks like.

5.4 Understanding Environmental Practices of South Asia

Over the past few decades, South Asia has experienced significant economic improvements (Bloom and Rosenberg 2011). Countries such as Bangladesh, Maldives, India, Nepal, and Bhutan have achieved mostly good economic development trajectories. Although the degree of development varies within these countries, given that some countries have higher growth rates than others, the overall region has seen substantive improvement. However, many of these developments have come at the cost of significant harm to the region's environment, and South Asia is now plagued by many environmental issues (Alauddin 2002). In addition, it is worth noting that South Asia, with its limited resources, cannot invest heavily in environmental policies.

Besides, the region has seen many political shifts and challenges over the past few decades. Although the nations are mostly of democratic practices, the system has many flaws. Many political leaders do not have the goodwill to do well but instead want to be in power. In instances where they do have goodwill, it is not often to the required extent to overcome the challenges of unhealthy politics and limited resources. Therefore, although the economic development is still in a good track record, the environmental track record, unfortunately, is not as good. The air quality index records of many South Asian countries are literally at the bottom end as well.

Many factors, including urbanization, industrialization, and the combustion of fossil fuels, contribute to increasing CO_2 levels in the atmosphere and creating additional greenhouse gasses (Khwaja et al. 2012). Increasing population increases the usage of the land, the amount of burned fossil fuels, and the need for industrialization that negatively impacts the environment. The lack of attention toward forestation practices and climate-oriented frameworks at the national level are significant contributors to harmful climate impacts in most South Asian countries. For instance, deforestation is not punishable by law in most countries.

Most importantly, South Asian countries other than Bhutan do not consider happiness and environmental well-being part of their development indexes. Therefore, they often do not have a solid balance between the SDGs and their overlapping modalities with the environment. Moreover, because environmental well-being is not considered a key development indicator, other traditional metrics such as GDP are more important. So, the priority to protect the environment is heavily compromised. Hence, there is a mismatch between economic development and environmental development in the South Asian region.

5.5 Conclusion and Policy Recommendations

Most South Asian countries have achieved overall economic growth; however, many unsustainable practices remain. For instance, decreasing the usage of fossil fuels and adopting clean energy are still unadopted practices. Despite some efforts by other South Asian countries to create a sustainable environment, Bhutan is the only country to actualize it by becoming a first-ever carbon-negative country both within the region and in the world.

5.5.1 Balancing GDP Growth

Bhutan considers the three Gs (GDP, GHG, and GNH) and ensures that they are balanced with one another. Although other South Asian countries use GDP as a growth metric, the unique difference is that those countries do not consider GHG and GNH as balancing metrics, unlike Bhutan. So, countries need to determine local indicators and a framework that adjusts the focus on GDP, GHG, and GNH. The metrics should be created based on the local requirements of each country. However, there should be an effort to prioritize all three indicators to the greatest extent possible equally.

5.5.2 Focusing on GHG

Reducing greenhouse gas usage is another major factor that South Asian countries must prioritize. Often, these countries fail to take strict measures here to prioritize the growth of GDP, given that many actions required have an economic tieback. Therefore, if GDP is considered the primary factor with a balance of GHG reduction, greenhouse gasses can be reduced more. That is to say, while the requirements of GHG reduction may seemingly harm the growth of GDP in the short term, it may plausibly be beneficial in the long term when the country can reach a relatively sustainable environmental situation. Moreover, greenhouse gas may be fought by ensuring more forestation. Although most countries may fail to attain a high forestation percentile of 71%, such as that of Bhutan, it is still beneficial if they can increase the percentile from whatever they have in the status quo. Even if the countries can achieve only 33% of their area to be forest-covered, that would be a massive improvement. Over time, these indicators may be adjusted with higher goals. So, an initial goal of 33% may go up to 50% and higher eventually, just as Bhutan's initial 60% goal has resulted in a 71% forest coverage.

5.5.3 *Incorporating GNH*

Adopting the model of GNH is not limited by financial concerns, unlike GHG, because people's happiness in this metric is contingent on citizens' contentment, and it ties back to the environment instead of economic metrics only. South Asian countries should prioritize GNH in their sustainable development pathway and can have a dedicated authority to measure the GNH of their respective countries. They should use this data to balance GDP and GHG so that there remains a balance between people's happiness and sustainable development. Countries may acknowledge GNH as a constitutional requirement if feasible. If not, countries may have dedicated ministries to protect and uplift the GNH metric. If that is also not feasible, then countries must ensure GNH is at least being considered in drafting GDP and GHG improvement policies.

5.5.4 *Political Goodwill*

Although South Asian countries face many challenges in their political environment, there must be a strong will to overcome those challenges of the political leaders. Efforts must be taken at national and regional levels to address challenges of common interest and the maintenance of public goods. For this, the development of the political situation and action is needed both at the local and regional levels. Countries may take inspiration from Bhutan's goodwill in protecting the environment. It is worth noting that often the demand for the citizen's carbs is the priority of the political leaders. Therefore, awareness programs regarding environmental sustainability for the citizens may also be considered. Additionally, environmental concerns may be included in election mandates and discussed more in the parliament sessions. Non-government actors can also carry forward their advocacies independently and in collaboration with the government actors. Accurate data reports of the actual status of the environment, citizens' well-being, and economic progress should be recorded as well. All of this would strengthen the scope to carry forward goodwill of proper environmental protection.

To conclude, Bhutan's government aims to secure people's happiness and subsequently considers environmental well-being a key development agenda. Furthermore, they ensure that GHG emissions are neutral while ensuring a steady rise in their GDP. Bhutan has systematically achieved this by creating dedicated ministries, including the aims in the constitution, political goodwill, and ensuring that there is available data to track the progression and balance it with the SDGs to reach its carbon-negative status. Unfortunately, most other South Asian countries are yet to adopt such strict and realistic measures for environmental sustainability and implement them. By incorporating such practices, South Asian countries can secure economic development and increase environmental well-being while also contributing to the global fight against climate change, enhancing the region's holistic approach to global environmental sustainability.

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Part II
Net-Zero Measure from the Ocean

Chapter 6
Sustainable Fisheries Under Net-Zero Emissions: A Case Study of the Taiwan Fishery Administration

Ching-Hsien Ho and Kuanting Lee

Abstract This study focuses on the marine fishing industry, takes Taiwan's fishery authorities as the subject of discussion, collects and compiles documents related to international trends and policy implementation in various countries, incorporates the implemented or planned policies and measures by Taiwan fishery authorities to conduct a comparative analysis on fishery policies in Taiwan and other developed countries, and determines the green policy strategies and opportunities for a low-carbon economy in the context of net-zero emissions. The comparative analysis results were used to examine the gap between the current situation and the future policy goals through the goal, reality, options, and will (GROW) evaluation method. Possible implementation directions to address the gap are discussed. Finally, policy issues within short-, medium-, and long-term plans and possible opportunities are determined through Global Reporting Initiative (GRI) standards materiality analysis and the priority research direction determination method. Priority stakeholders to be considered or involved in each policy stage are identified using the boundary identification method.

Keywords Carbon neutrality · Carbon reduction · Carbon sink · Fishery · Low-carbon economy · Net-zero carbon emissions

6.1 Introduction

Since 1980, the global climate hazards caused by human-made greenhouse gas (GHG) emissions have been confirmed in numerous studies, and after 1990, their threats and impacts on human society have gradually intensified. In 1992, to reduce the possible impact of GHG emissions, the United Nations issued the "United Nations

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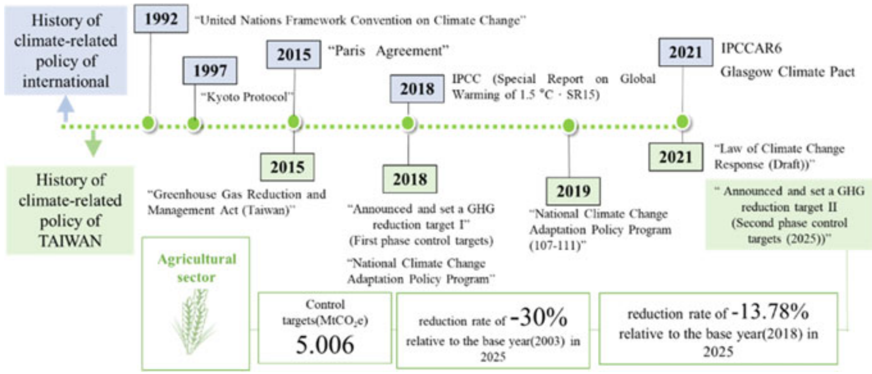

Fig. 6.1 Policy development history of international and Taiwanese agricultural departments in response to climate change and greenhouse gas emissions. *Source* Authors complied from the release of Executive Yuan (Council of Agriculture, Executive Yuan 2021; Ministry of Economic Affairs 2020)

Framework Convention on Climate Change (UNFCCC)". In 1997, the UNFCCC Convention's Third Conference of States Parties passed the Kyoto Protocol to the United Nations Framework Convention on Climate Change, which restricted and negotiated GHG emissions to mitigate the possible damage and impact of GHG emissions (Fig. 6.1) (United Nations 1992).

In response to the international trends and goals of coping with climate change and reducing GHG emissions, the Central Government of Taiwan delegated the Executive Yuan to establish the National Sustainable Development Council in 1997 as well as the Kyoto Protocol Group on Climate Change and the Energy Conservation, Carbon Reduction and Climate Change Group. In 2010, the National Development Council of Taiwan established the "Planning and Promoting Climate Change Adaptation Policy Program and Action Plan" task force and promulgated the "National Climate Change Adaptation Policy Program" in 2012. In 2014, the National Development Council approved the "National Climate Change Adaptation Action Plan (2013–2017)" (Environmental Protection Administration, Executive Yuan 2015a).

The United Nations Framework Convention on Climate (UNFCCC) adopted the Paris Agreement in 1995, which calls on all countries to propose specific reduction and adaptation management measures to address climate change and GHG emissions (United Nation 2015). Taiwan's Central Government appointed the Executive Yuan to take charge of environmental protection. The Environmental Protection Administration of the Executive Yuan issued the "Greenhouse Gas Reduction and Management Act" (Fig. 6.1) (Environmental Protection Administration, Executive Yuan 2015b), which also incorporated climate change adjustments into laws and regulations, laid the legal foundation for Taiwan's response to climate change, and clarified the 2050 long-term reduction targets and related adjustment mechanisms as well as the overall mitigation and adjustment actions required to address climate change (Fig. 6.1) (Environmental Protection Administration, Executive Yuan 2021).

Additionally, the Taiwanese government established a GHG reduction target (relative to the base year 2005), which was divided into four major implementation phases for gradual implementation, i.e., Phase I (from 2016 to 2020), with an annual reduction rate of 2% relative to the base year; Phase II (from 2021 to 2025), with an annual reduction rate of 10% relative to the base year; Phase III (from 2026 to 2030), with an annual reduction rate of 20% relative to the base year; and Phase VI (from 2031 to 2050), striving for an annual reduction rate of 25–30% relative to the base year, to achieve the GHG reduction target set in the "Paris Agreement" (Fig. 6.1) (Environmental Protection Administration, Executive Yuan 2022).

In 2017, the Environmental Protection Administration provisioned and issued the "National Action Plan for Climate Change" in accordance with Item 1 of Article 9 of the Greenhouse Gas Reduction and Management Act to ensure sustainable social, economic, and environmental development through mitigation and adjustment policies (Environmental Protection Administration, Executive Yuan 2021). On October 21, 2021, the Environmental Protection Administration of the Executive Yuan announced that the "Greenhouse Gas Reduction and Management Act" had been amended to the "Law of Climate Change Response (Draft)", which stipulates that the long-term GHG reduction goal for 2050 is net-zero emissions, raises the management level of climate control, and provides future development direction and work items by adding a dedicated chapter on climate change adaptation (Fig. 6.1) (Environmental Protection Administration, Executive Yuan 2021). The draft also incorporates the "carbon tax" levy system, which concerns all walks of life; in the future, carbon fees will be levied on domestic emission sources and imported products with high carbon content (Environmental Protection Administration, Executive Yuan 2021). The Office of Energy and Carbon Reduction of the Executive Yuan also formulated the second phase control targets for six major sectors; i.e., the GHG emissions of the agricultural sector (including agriculture, forestry, animal husbandry, and fishery) must be reduced by 5.006 $MtCO_2e$ by 2025 (by 30% relative to emissions in the base year (2014) and by 13.78% relative to those in 2018) (Environmental Protection Administration, Executive Yuan 2022), of which the fishery industry has a carbon reduction liability quota of 252 $MtCO_2e$ by 2025 (Fisheries Agency of the Council of Agriculture, Executive Yuan 2021).

Net-zero emissions, climate change, GHG emissions, carbon neutrality, and low-carbon economies have increasingly attracted the attention of countries around the world. In order to comply with the overall goal of international net-zero emissions policies (Intergovernmental Panel on Climate Change 2022), in addition to GHG reduction measures that are already in place in fishery entities, it is necessary to continue to include more specific and feasible issues and potential adjustments in the future and strive to achieve the designated reduction target in 2030 as a part of the net-zero and carbon–neutral targets of 2050 in line with international trends.

Regarding coping with climate change and GHG emissions policy planning and adaptation policy development, countries around the world are divided into developed countries, developing countries, and undeveloped countries based on the degree of national development. The degree of national development may affect the feasibility of policy implementation and adaptation options in a particular region (Intergovernmental Panel on Climate Change 2022). However, most countries in the world that have explicitly included net-zero emissions, climate change, GHG emissions, and carbon neutrality in their fishery policy plans are developed countries (e.g., the United States, United Kingdom, the European Union) (European Commission 2020; Climate Watch 2021; Stephenson and Johnson 2021; Ministry of Agriculture 2022). However, relevant information and studies for developing countries are still lacking or are still in the planning stage. Therefore, this study selects Taiwan, which is categorized as a country that is between the developed and developing stages, as the subject of study and analysis, hoping that the results of this study will provide a reference for countries with development levels similar to that of Taiwan.

The specific objectives of this study are as follows:

(1) Introduce the actions of Taiwan's fisheries authorities related to GHG reduction policies and the benefits of actual policy implementation.
(2) Introduce policy plans or regulations formulated by developed countries for fisheries, such as the United States, Japan, the European Union, Germany, and the United Kingdom, and compare those policies with Taiwan's current policies.
(3) Determine feasible future operational issues, priority research directions (PRDs), and sustainable development opportunities for the industry surrounding this issue.

6.2 The Policy Planning and Potential Opportunity of Taiwan's Fishery Administration to Develop a Low-Carbon Economy

6.2.1 Policy Evaluation Framework and Process

The research object of this study is the "fisheries industry". It formulates the "Net-zero Emissions policy for fishery industry" main assessment framework, referring to the "Rolling Amendment to Risk Management Processes in Response to Climate Change" proposed by the Organization for Economic Co-operation and Development (OECD) in 2013 as the main assessment framework, method, and process for this plan through three steps: step 1—define the evaluation objectives and assess the current situation; step 2—identify policies and international integration; and step 3—explore potential policy opportunities. In addition, based on common practice, we categorize the policy implementation path into two modes of operation: "top-down" and "bottom-up" (Fig. 6.2).

Step 1: Define evaluation objectives and assess the current situation

In step 1, a bottom-up issue identification method is adopted. The issue of concern is mainly the industry's views of the issue and how to maintain production in

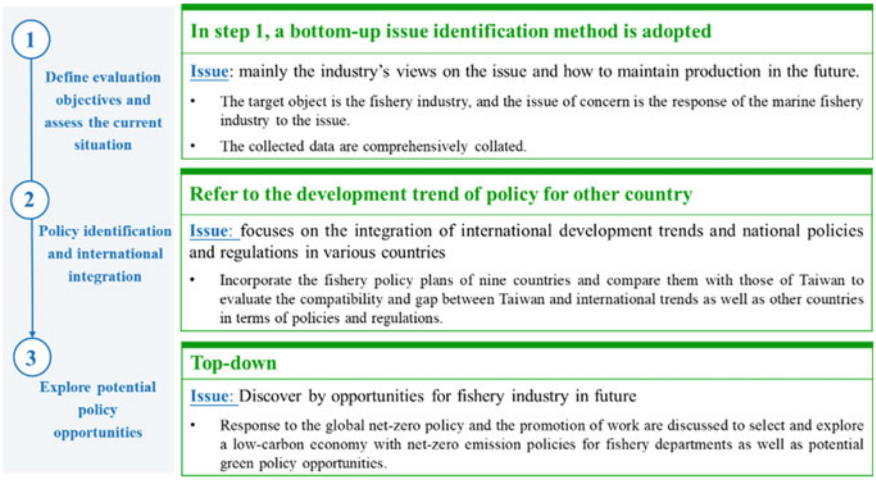

Fig. 6.2 Evaluation framework and process of the marine fishing industry in response to net-zero emission policies

the future. The target object is the fishery industry, and the issue of concern is the response of the marine fishery industry to the issue; the collected data are comprehensively collated (Fig. 6.2).

Step 2: Policy identification and international integration

This step focuses on the integration of international development trends and national policies and regulations in various countries. In this step, we incorporate the fishery policy plans of nine countries and compare them with those of Taiwan to evaluate the compatibility and gap between Taiwan and international trends in terms of policies and regulations (Fig. 6.2).

Step 3: Explore potential policy opportunities

Based on the overall integration and analysis results for steps 1 and 2, the future development trends for the marine fishery industry in response to the global net-zero policy and the promotion of work are discussed to select and explore a low-carbon economy with net-zero emission policies for fishery departments as well as potential green policy opportunities.

6.2.2 Methods of Policy Evaluation

To complete steps 1–3 described above, various methods, such as document analysis, materiality and topic boundary assessments of the Global Reporting Initiative (GRI) standards, and qualitative comparative analysis, are used.

(1) Document analysis

This research project addresses Objectives 1 and 2 by identifying the issues and collecting the results of studies in China and abroad on net-zero policies or national policies for the marine fishery industry to understand the current policy and regulatory situation at the legal level in countries around the world. It also summarizes and comparatively analyzes the gaps between current policy planning by Taiwan's fishery administration units and policies in other countries to formulate specific development goals for future technological, regulatory, and administrative tools.

(2) Materiality and topic boundary assessment of the GRI standards

To address Objective 2, the standards issued by the GRI are used as a framework to establish a process for identifying major topics for the development of Taiwan's fishery authorities and for identifying potential major issues. We also comparatively analyze the policies or governance practices implemented by Taiwan's fishery management units relative to current planning policies or the legal directions of various countries in the world for the results of document analysis.

(3) Evaluate future policy implementation goals

When implementing net-zero emission policies and scientific studies in the future, fishery authorities will face potential issues regarding target gaps, target discrepancies, current situation analysis, existing resources, feasibility planning, and specific and feasible action plans. In this context, we refer to the four elements of reflection of the "GROW" communication and dialogue model proposed (i.e., goal, reality, options, and will) to evaluate future policy implementation goals in the Taiwan Fisheries Agency (John 1992).

(4) Boundary identification and evaluation of PRDs and stakeholders

To address Objective 3, this study uses PRDs to make recommendations on technological development issues necessary for future policies and uses the stakeholder boundary identification and evaluation method to determine the short-term (within 3–5 years) and medium- and long-term (6–10 years) priorities and the recommended internal boundary (including other central-level and local-level units) of participants and external boundary of stakeholders (including fishery operators and communities) to be considered and incorporated when formulating policies.

6.2.3 Overview of GHG Reduction Policies of the Taiwan Fisheries Agency

The fisheries authorities of Taiwan (i.e., the Fisheries Agency of the Agricultural Council of the Executive Yuan) are subordinate to the agricultural department (i.e., the Agricultural Council of the Executive Yuan) based on the administrative powers and responsibilities of the administrative department. In terms of business scope, it is divided into two categories: marine capture fisheries and aquaculture fisheries. In terms of legal classification standards for the operating sea area, marine fishing can be divided into three subcategories: coastal fisheries, offshore fisheries, and pelagic fisheries.

Based on the current adjustment strategy framework of Taiwan's agricultural sector in response to climate change, net-zero policies are divided into five categories: "adjustment measures", "agricultural green energy", "agricultural carbon sinks", "recycling agriculture", and "reduction measures". The policy planning paths can be subdivided into three sub-issues, i.e., "Conservation", "Ecology", and "Industry," based on the presence or absence of issues related to agricultural (fishing) industry operations (Council of Agriculture, Executive Yuan 2021). This study focuses on "agricultural (fishery) operation issues" and "industry" and selects "reduction measures" as the main research topic for subsequent exploration.

In response to the international trend of reducing GHG emissions, the current policies of the Taiwan Fisheries Agency are aimed at reducing the amount of fuel burned during fishery production, processing, transportation, and marketing. Specific administrative actions have also been adopted with respect to four directions, i.e., "fishing vessel fuel reduction", "energy-saving equipment", "reward for a fishing moratorium", and "fishing vessel (raft) buy-out", to achieve low-carbon economy goals by reducing carbon emissions through GHG reducing measures while maintaining fishery economic activities (Fisheries Agency of the Council of Agriculture, Executive Yuan 2021).

From 1990 to 2018, among CO_2 emissions from combustion in the energy sector in Taiwan, those from fuel combustion in the first-tier industries of agriculture, forestry, fishery, and animal husbandry accounted for approximately 16.27% (approximately 4000 thousand metric tons (CO_2 equivalent)). The items included in the calculation included connection tools, pump fuel combustion, and other uses of fuel for agriculture, forestry, fishery, and animal husbandry. To achieve the 252,000 metric ton CO_2 target of the fishery sector's carbon reduction liability quota in 2025 (Fisheries Agency of the Council of Agriculture, Executive Yuan 2021), relevant carbon reduction measures and practices have been implemented since 2002 (Environmental Protection Administration, Executive Yuan 2021). The following are the carbon reduction measures and the implementation effects of the measures for the marine fishing industry:

(1) Buy-out of fishing vessels (rafts) and reduction in fishing vessel fuel use

The primary aim of this policy is to reduce CO_2 emissions during fishery operations through the buy-out of fishing vessels (rafts) to reduce fuel and energy use while easing the pressure on fishery resources caused by fishery operations. Since 2000, Taiwan's fishery administration units have begun to implement a plan to decrease the number of fishing vessels; since 2007, they have begun to encourage fishery operators to install voyage recorders [Voyage Data Recorder (VDR) and Vessel Monitoring System (VMS)] to conduct fuel calculations for operations; and from 2016 to 2020, a total of eight fishing vessels and 166 fishing rafts have been bought out, resulting in a total carbon reduction of 21.33 thousand metric tons of CO_2. It is estimated that 200 fishing vessels will be bought out from 2023 to 2025, with an expected carbon reduction of 45.7 thousand metric tons of CO_2 by 2025 (EQUATION: Emissions (kg/CO_2) = the amount of fuel consumed by each fishing vessel and raft type between the activities of the fishing operation (in megajoules, MJ) × Emission Factor for each fishery type (kg CO_2/MJ) (Intergovernmental Panel on Climate Change 2022) (Figs. 6.3 and 6.4) (Fisheries Agency of the Council of Agriculture, Executive Yuan 2021).

(2) Reward for a fishing moratorium

In 2018, the Taiwan Fisheries Agency revised Article 59-1 of the Fisheries Law and established the "Voluntary Fishing Moratorium Incentive Measures" to increase the incentives for fishing moratoriums and the willingness of Taiwan's production fisheries (including coastal and offshore fisheries) to cease fishing. This policy measure relies on owners of fishing vessels (rafts) voluntarily adjusting the number of operating days at sea and the number of days of berth in harbors, actions that will not only reduce fuel consumption but also allow fishery resources more time to grow and regenerate. For example, in 2020, CO_2 emissions were reduced by 80.4 thousand metric tons through fishing moratorium incentives in coastal fisheries, and this decrease will be maintained every year through 2025. Regarding fishing moratoriums and taking the net fishing industry as an example, which accounts for the highest proportion of Taiwan's coastal fishery production, if the current fishing moratorium is maintained, CO_2 emissions will be reduced by 3.674 thousand metric tons each year, and the total annual reduction in CO_2 emissions through fishing moratorium incentives will be 84.074 thousand metric tons of CO_2 (EQUATION: Emissions (kg/CO_2) = the amount of fuel consumed by each fishing vessel and raft type between the

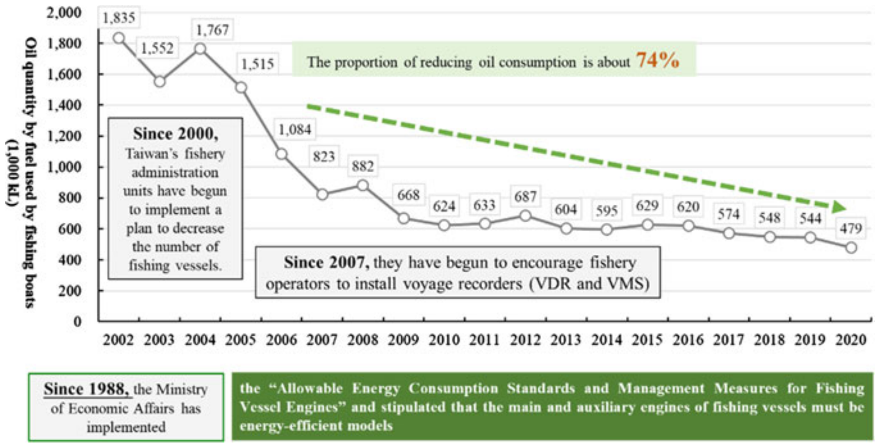

Fig. 6.3 Effectiveness of Taiwan's fishery administration units in implementing fishing vessel (rafts) buy-outs and reducing fuel used by fishing boats for reducing carbon emissions. *Source* Authors complied from the release of Executive Yuan (Council of Agriculture, Executive Yuan 2021)

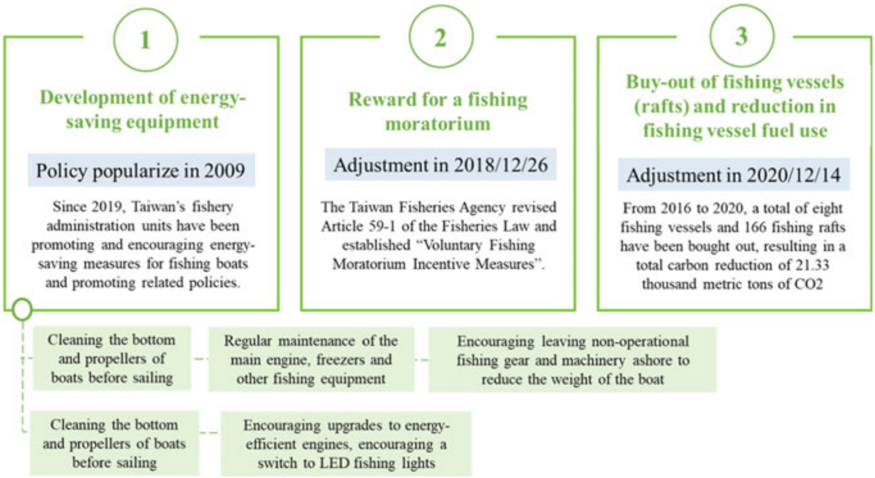

Fig. 6.4 Effectiveness of Taiwan's fishery administration units in implementing policy measures by fishery industries for other low-carbon economies for reducing carbon emissions. *Source* Authors complied from the release of Executive Yuan (Fisheries Agency of the Council of Agriculture, Executive Yuan 2021)

activities of the fishing operation (megajoules, MJ) × Emission Factor for of each fishery type (kg CO_2/MJ) (Intergovernmental Panel on Climate Change 2022) (Fig. 6.4) (Council of Agriculture, Executive Yuan 2021).

(3) Development of energy-saving equipment

Since 1988, the Ministry of Economic Affairs has implemented the "Allowable Energy Consumption Standards and Management Measures for Fishing Vessel Engines" and stipulated that the main and auxiliary engines of fishing vessels must be energy-efficient models (Ministry of Economic Affairs 1988). Since 2019, Taiwan's fishery administration units have been promoting and encouraging energy-saving measures for fishing boats and promoting related policies. The main implementation projects include encouraging upgrades to energy-efficient engines; encouraging a switch to LED fishing lights; counseling for low-interest loan applications; cleaning the bottom and propellers of boats before sailing; regular maintenance of the main engine, freezers, and other fishing equipment; and encouraging leaving non-operational fishing gear and machinery ashore to reduce the weight of boats (Fig. 6.4) (Fisheries Agency of the Council of Agriculture, Executive Yuan 2021).

6.2.4 Comparative Analysis of Implementation Policies of Taiwan's Fishery Administration Units and Reduction Policies of Other Countries

To cope with the impact of climate change on the industry and to achieve the global net-zero goal by 2050, Taiwan's fishery administration units have implemented relevant policies or administrative measures to reduce carbon emissions while maintaining the economic activities of its fishery industry (Fig. 6.5). However, in addition to the implemented policies and measures, to achieve the overall policy planning goals of Taiwan's agricultural sector, it is still necessary to identify potential issues regarding fishery production, the environment, the community, and the economy.

In this regard, this study uses the standards issued by the GRI as a framework to construct a process for identifying major issues related to the development of Taiwan's fisheries and compares the implementation direction of current plans of various countries with Taiwan's implemented or planned policies to identify the potential issues of the net-zero emission reduction path. The following major issues were identified:

(1) With respect to the environment and production, the main planning topics include applying fishery machinery, electrifying fishing vessels, introducing hydrogen fuel cells, adopting low-carbon fishery practices, developing smart agriculture (fisheries), introducing smart fisheries technology, developing data-driven smart supply chains, developing aquatic products with low GHG emissions, and improving fishery production equipment. The main countries for

	Major issues	Countries of have used or planned to relevant policy	Policy path	Taiwan
Environment and production	Planning topics of the applying fishery machinery	UK, Canada, France, Germany, Denmark	Carbon reduction	V
	Planning topics of the applying fishery machinery and electrifying fishing vessels	Japan	Carbon reduction	V
	Introducing hydrogen fuel cells	Japan	Carbon reduction	-
	Adopting low-carbon fishery practices	Japan, U.S.A.	Carbon reduction	V
	Developing smart agriculture (fisheries)	South Korea	Carbon reduction	V
	Developing data-driven smart supply chains	Japan	Carbon reduction	-
	Developing aquatic products with low GHG emissions	Japan, New Zealand, Germany	Carbon reduction	V
	Improving fishery production equipment	Japan, UK	Carbon reduction	V
Community and the economy	Establishing energy systems for local producing and consuming	Japan	Carbon reduction	V
	Innovating material recycling industries	Japan	Carbon reduction	V
	Introducing recycling economy models	Japan	Carbon reduction	V
	Establishing a global growth scenario ratio conversion system	Denmark	Carbon reduction	-
	Establishing a mechanism for offsetting emission quotas	Denmark	Carbon reduction	-

Fig. 6.5 Results regarding the major policy planning issues for developed countries and Taiwan's fishery authorities. *Source* European Commission (2020), Climate Watch (2021), Stephenson and Johnson (2021), Ministry of Agriculture (2022), Ho (2021)

comparative analysis are the United Kingdom, Canada, South Korea, Germany, Denmark, the United States, Japan, the European Union, etc. (Fig. 6.5) (European Commission 2020; Climate Watch 2021; Stephenson and Johnson 2021; Ministry of Agriculture 2022).

Regarding the abovementioned important international carbon reduction policy issues, those applicable to the policies implemented by Taiwan's fisheries authorities include improving feed formulation, applying fishery machinery, adopting low-carbon aquaculture operations, developing smart agriculture (fishery), introducing smart fisheries technologies, using feed additives, developing a data-driven intelligent supply chain, developing aquatic products with low GHG emissions, and improving fishery production equipment (Fig. 6.5) (Council of Agriculture, Executive Yuan 2021).

(2) With respect to the community and the economy, the main planning topics of the reduction policy include establishing energy systems for local producing and consuming fishing villages, innovating material recycling industries, introducing recycling economy models, establishing a global growth scenario ratio conversion system, and establishing a mechanism for offsetting emission quotas. The countries for comparative analysis are Japan and Denmark (Fig. 6.5) (Climate Watch 2021; Ministry of Agriculture 2022).

Regarding the abovementioned important international carbon reduction policy issues, those applicable to Taiwan's fisheries authorities include establishing energy systems for local producing and consuming fishing villages, innovating material recycling industries, and introducing recycling economy models (Fig. 6.5) (Council of Agriculture, Executive Yuan 2021).

6.2.5 Gaps and Specific Action Plans of Carbon–Neutral Targets of Fishery Policy Implementation in the Future

The core goal of the 2050 international net-zero policy and the overall goal of establishing a policy strategy and path in line with the characteristics of Taiwan's marine fishing industry will be achieved from the perspective of the current policy objectives and state of the policy implementation of Taiwan's fishery administration units. The gap between national policy objectives and fisheries authorities is mainly due to six major issues: (1) insufficient relevant information (primary reason); (2) prioritization of technological development needs; (3) applicability of policy issues to the industry; (4) lack of supporting administrative tools and regulations; (5) lack of a specific assessment methodology for Taiwan; and (6) integrating the policy tools used by other countries into international trends (Fig. 6.6).

Based on the existing resources of the fishery administration units and the results regarding the key topics of target audiences, the communication channels between experts and scholars, the collection and collation of relevant literature, and the construction of a fishery policy evaluation framework, it is necessary to focus on

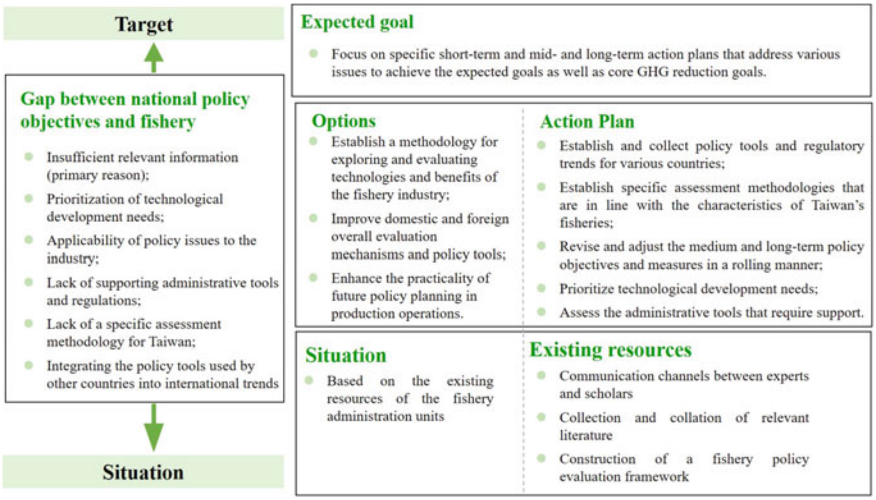

Fig. 6.6 Gap and specific action plan analysis of carbon–neutral and low-carbon economic policy goals implemented by Taiwan's fishery authorities

specific short-, medium-, and long-term action plans that address various issues to achieve the expected goals as well as core GHG reduction goals. The plans include the following: (1) establish a methodology for exploring and evaluating technologies and benefits of the fishery industry; (2) improve domestic and foreign overall evaluation mechanisms and policy tools; and (3) enhance the practicality of future policy planning in production operations (Fig. 6.5).

To implement these core goals, specific objectives, and action plans, the following tasks need to be accomplished: (1) establish and collect policy tools and regulatory trends from various countries; (2) establish specific assessment methodologies that are in line with the characteristics of fisheries industry; (3) revise and adjust the medium- and long-term policy objectives and measures in a rolling manner; (4) prioritize technological development needs; and (5) assess the administrative tools that require support (Fig. 6.6).

6.3 Conclusion and Policy Recommendations

To focus on future ocean carbon sinks to facilitate subsequent investigations, shorten the research period, and effectively promote studies, PRD recommendations are provided regarding the issues of implementing a "low-carbon economic policy" and of development opportunities for Taiwan's fishery authorities based on GROW model results and the identification of stakeholder boundaries. The priority stakeholders to be included in joint participation and discussions must be determined when implementing sub-policy issues or emissions reduction measures to improve the compatibility between the implementation of fishery policies and "the fishery industry" and the applicability of these policies in the industry. The priority recommendations for major issues or specific action issues are divided into short-term immediate priority issues (3–5 years) and medium- and long-term governance (6–10 years) policy issues. The specific content is described below.

Short term (3–5 years): Policy planning recommendations for prioritizing the implementation of short-term policy measures include establishing specific evaluation methodologies for Taiwan's marine fishing industry, collecting and collating policy tools of and regulatory trends for various countries, evaluating the prioritization of technological development needs, establishing a cooperative participation mechanism for the industry and stakeholders, facilitating continuous communication and discussion among ministries and councils, and establishing policy strategies and paths in line with the characteristics of Taiwan's marine fishery industry. In the implementation process, priority should be given to external industry stakeholders, including front-line personnel in the industry, such as fishery operators, fishing village communities, suppliers, and sellers (Fig. 6.7).

Medium and long term (6–10 years): Policy planning recommendations for implementing medium- and long-term policy measures include revising and adjusting medium- and long-term policy objectives and measures in a rolling manner, evaluating administrative tools that require support, facilitating continuous communication

Priority research directions (PRDs)	Recommendations for prioritizing		Internal stakeholders		External industry stakeholders	
	Short-term	Mid- and long-term	other central ministries	local fishery administration units	Fishery operators	Fishing village communities
Establishing specific evaluation methodologies for Taiwan's marine fishing industry;	V	-	-	-	V	-
Collecting and collating policy tools of and regulatory trends for various countries;	V	-	-	-	-	-
Evaluating the prioritization of technological development needs	V	-	V	-	V	-
Establishing a cooperative participation mechanism for the industry and stakeholders;	V	-	-	-	V	V
Revising and adjusting mid- and long-term policy objectives and measures in a rolling manner;	-	V	V	-	-	-
Evaluating administrative tools that require support;	-	V	-	V	-	-
Facilitating continuous communication and discussion among ministries and councils;	V	V	V	V	-	-
Revising and adjusting policies in a rolling manner;	-	V	V	-	-	-
Establishing policy strategies and paths in line with the characteristics of Taiwan's marine fishery industry.	V	-	V	-	V	-
Achieve the expected goals as well as core GHG reduction goals	-	-	V	V	V	V

Fig. 6.7 Low-carbon economic policy implementation PRD recommendations for Taiwan's fishery authorities and stakeholder boundary identification and evaluation

and discussion among ministries and councils, and revising and adjusting policies in a rolling manner. In the implementation process, priority should be given to external industry stakeholders (e.g., fishery operators) and internal stakeholders (e.g., other central ministries and local fishery administration units) (Fig. 6.7).

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Chapter 7
The Environmental and Economic Potential of Kelp as Blue Carbon: Case of Hakodate, Japan

Hajime Tanaka, Michael C. Huang, and Atsushi Watanabe

Abstract Kelp forests are a non-negligible blue carbon resource that has gained global attention as an ocean carbon source. In addition to the role of carbon storage, kelp forests have certain economic impact in Japan for a long time. However, the environmental and economic effects of kelp forests are not yet clear. Therefore, this chapter introduces the environmental and economic impacts of kelp forests in Hakodate City, Hokkaido Prefecture, Japan, as a case study. The study suggests promoting cultivation of kelp from both ecological and economic aspects by financial schemes for conservation and restoration of natural kelp.

Keywords Kelp · Blue carbon · Blue economy · Economic evaluation · Input–output analysis

7.1 What is Blue Carbon?

The term “blue carbon” was first coined by the United Nations Environment Programme (UNEP) in a report (hereafter referred to as the UNEP report) published in 2009 (Nellemann et al. 2009). In the climate change debate, forests have been well known as sinks for carbon dioxide (CO_2), but the important function of the ocean as a sink has been overlooked. The CO_2 fixed by marine organisms is referred to as blue carbon. The UNEP report pointed out that the ocean is responsible for 55% of all biological sinks worldwide, and that coastal vegetation, such as mangrove forests, seagrass beds, and salt marshes, which cover less than 0.5% of the ocean, is responsible for 50–71% of all ocean carbon sinks. The three main ecosystems that sequester blue carbon are referred to as traditional blue carbon ecosystems.

Most of the blue carbons are stored and sequestered in the sediment but not in the plant biomass. This is evident from the fact that the plant biomass of blue carbon ecosystems is only approximately 0.05% of the plant biomass on land, yet they sequester the equivalent amount of CO_2 per year. The CO_2 sequestered on the

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seabed is stored without being decomposed for several thousand years and is thus extremely highly preserved.

In contrast, blue carbon ecosystems are the most rapidly disappearing ecosystems on the planet. As of 2009, when the UNEP report came out, it was estimated that an average of 2–7% of blue carbon ecosystems were lost annually. This means that we are losing an important CO_2 sink and are risking CO_2 emission into the atmosphere, which has accumulated there for thousands of years. These facts have made an international appeal for the urgent need to conserve the existing blue carbon ecosystems and to restore or rehabilitate lost or degraded ecosystems.

Since the UNEP report of 2009, blue carbon has been integrated into the international climate change agenda. The Intergovernmental Panel on Climate Change (IPCC) developed the national greenhouse gas inventory guidelines in 2006, but in 2010, the United Nations Framework Convention on Climate Change (UNFCCC) requested for clarification of the calculation method for wetlands, with a primary focus on the re-wetting and restoration of peatlands. In 2011, the IPCC established a task force to develop guidelines for wetlands. In 2013, the IPCC General Assembly adopted and published the "2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventory: Wetlands" (Hiraishi et al. 2014), which presents a methodology for calculating the amount of blue carbon accumulated in the soils of coastal ecosystems as CO_2 emissions from coastal ecosystems. This is thought to have increased the momentum for reflecting the blue carbon in the policy.

7.2 Kelp as Overlooked Blue Carbon

As of 2009, underwater macroalgal beds were not considered blue carbon ecosystems, with the UNEP report stating. "Most macroalgal (or seaweed) beds (including kelp forests) do not bury carbon, as they grow on rocky substrates where burial is impossible." This situation is attributable to the lack of scientific knowledge on the distribution area of macroalgal beds and the carbon sequestration process and its amount. However, with increasing scientific evidence, the treatment or perception of macroalgae has changed significantly in recent years.

Recently, the focus on macroalgae as a blue carbon source has rapidly increased. According to a recent estimate, the area of macroalgal beds is 10–40 times larger than that of other blue carbon ecosystems (Table 7.1). The primary production rates and CO_2 absorption coefficients of macroalgal beds have also been estimated; in particular, large macroalgae, such as kelp beds, are reported to have absorption coefficients as high as or higher than those of seagrass beds (Kuwae et al. 2022; Table 7.2). One study estimated that 10.1% of the net primary production of large macroalgal beds is transported into the deep sea at depths of 1000 m or more, leading to a long-term sink (Krause-Jensen and Duarte 2016). Research in Japan has shown that macroalgae release carbon as refractory dissolved organic matter, which is transported outside the ecosystem (Watanabe 2021). Based on this scientific evidence, the carbon sequestration potential of macroalgal beds is estimated to be equivalent to that of all other blue carbon ecosystems combined. However, since macroalgal beds are distributed in a slightly deeper photic layer than traditional blue carbon ecosystems, it is difficult to accurately understand their distribution area and dynamics, and further development of observation techniques and monitoring networks are required in future. The ecosystem areas cannot be simply compared because of differences in estimation methods and years, but they can be used for semi-quantitative comparison.

Another feature of macroalgae that is not found in traditional blue carbon ecosystems is that they are also used as food. Thus, the development of cultivation technology for some macroalgal species has been ongoing for a long time. This trend is particularly noticeable in East Asia, including Japan. Macroalgae have been used as a food source in Japan and other parts of East Asia since ancient times. The most commonly consumed macroalgae in Japan are wakame (*Undaria pinnatifida*), nori, and kelp. We will now look at cold-temperate kelp (or kombu), which is the subject of this paper.

Table 7.1 Area of blue carbon ecosystems

	Japan	Australia	Indonesia	World
Seagrass beds	620	93,000–128,000	30,000	350,000
Salt marshes	470	14,000–15,000	Unknown	380,000
Mangrove forests	30	3,000–11,000	42,550	81,849
Macroalgal beds	1720	35,000–71,000	Unknown	3,400,000
Coastline extension (km)	35,307	25,760	54,716	1,593,137
Coastal area	160,470	1,976,110	2,039,381	27,000,000

All area units are in km^2

Source Prepared based on Watanabe et al. (2020) (in Japanese)

Table 7.2 Estimated CO_2 absorption coefficient

Ecosystem		Net primary production rate (tCO_2/ha/year)		Residual rate (%)		Absorption coefficient (tCO_2/ha/year)	
		Average	Upper limit	Average	Upper limit	Average	Upper limit
Seagrass bed	Eelgrass bed	26.7	65.0	18.5	51.4	4.9	33.4
Macroalgal bed	Sargassum bed	24.0	44.7	11.3	11.3	2.7	5.1
	Cold-temperate kelp bed	90.8	318.1	11.3	11.3	10.3	36.0
	Warm-temperate kelp bed	36.9	69.6	11.3	11.3	4.2	7.9
Mangrove		–	–	–	–	68.5	68.5
Tidal flat		–	–	–	–	2.6	2.6

Source Prepared based on Kuwae et al. (2022) (in Japanese)

In Japan, natural kelp beds are found only at high latitudes, such as Hokkaido, but their products are transported by Kitamae-bune cargo ships to Kansai, Hokuriku, and even Okinawa, influencing the economy and food culture of each region (Fukutome 2018). Kelp forests form a vast coastal ecosystem from Japan to Alaska, Canada, the northwestern coast of the United States, and Mexico, with the food resources from these forests being considered the reason for human migration to the New World, called "Kelp Highway Hypothesis" (Erlandson et al. 2007). In this way, kelp has influenced the flow of goods and people over a wide area, or in modern terms, the supply chain.

In recent years, kelp decline and "isoyake" (sea desertification) have been reported in many regions worldwide. The main causes are an increase in sea temperature and damage due to feeding by herbivorous organisms. Japan is no exception, and natural kelp beds in Hokkaido and other areas continue to decline, resulting in a marked decrease in natural kelp production. As will be discussed later, the decline in natural kelp production is compensated by the relatively stable production of cultivated kelp. The decline in natural kelp beds will not only have a direct impact on the kelp fishery but will also lead to a decrease in marine resources such as abalone, sea urchins, and turban shells that feed on kelp, leading to concerns about the impact on coastal fisheries.

Kelp forests have a high potential for blue carbon, and it is important to make efforts and policies to sustainably use this coastal resource, which produces various other economic and environmental benefits. In the following section, we review the economic value and economic ripple effects of kelp production in Hakodate, a city with a particularly large kelp production volume in Hokkaido.

7.3 Economic Importance of Kelp in Hakodate City, Japan

Blue carbon provides job opportunities and coastal prosperity (Nellemann et al. 2009). In particular, kelp has a high economic impact on regions where it is consumed as a food resource. Among these regions, Kelp created one of the pillars of Japanese cuisine and had a sizable economic impact. Japanese seaweed production accounted for 1.15% of the world's total production and sixth highest in 2019 (The Food and Agriculture Organization of the United Nations (FAO) 2021). Shoku Nihongi, an imperially commissioned Japanese history text completed in 797, reported that kelp was devoted to the imperial court for a long time in the area of current Hokkaido Prefecture.

Hakodate City, located in southwestern Hokkaido Prefecture, especially contributed to kelp production in Japan by supplying Ma-kelp (*Laminaria japonica*) and Gagome-kelp (*Saccharina sculpera*). The total production and sales, however, have decreased over the last two decades (Fig. 7.1). The three major factors causing the decrease of total production include (1) decreasing natural resource kelp by changing weather, (2) decreasing number of fishermen, and (3) low working efficiency of labor due to aging (Hatamiya 2014).

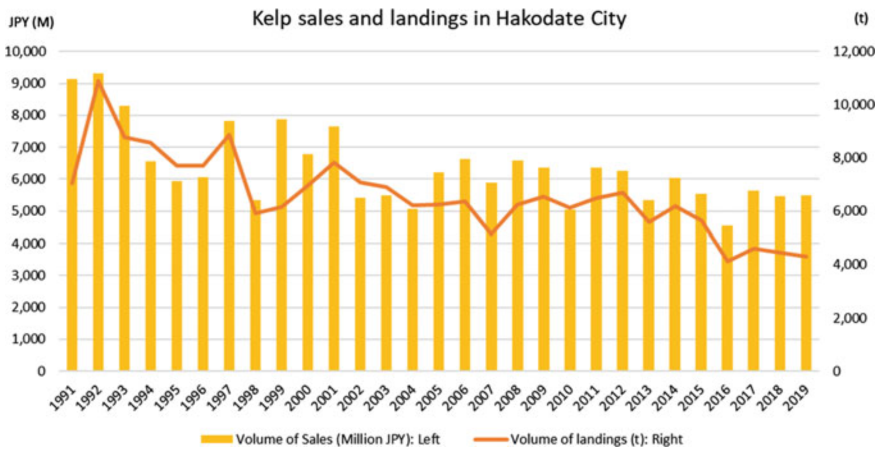

Fig. 7.1 Trend of kelp volume of sales and landings in Hakodate. *Source* Created from Hokkaido Research Organization (HRO) (2022)

Hakodate succeeded in cultivating kelp from natural kelp in the 1960s as the first city in Japan (City of Hakodate 2021a). The amount of cultivated kelp was relatively sustainable, whereas that of natural kelp decreased dramatically. Kelp aquaculture is the main employment resource in Hakodate, with 1312 fishery operating units, of which 541 are mainly kelp aquaculture (City of Hakodate 2021b).

7.3.1 Input–Output Analysis

7.3.1.1 Inverse Coefficient Matrix

The numbers mentioned above suggest the importance of kelp as a blue carbon resource from both cultural and economic aspects. To further analyze the economic importance of kelp in the Hakodate City, this study used an input–output table analysis. The input–output table explains the economic structure of the region as a matrix of sectors; the row shows the sales of each industry to other industries; and the column explains the expenditure factors of each industry.

One of the important analyzes using the input–output table is to analyze the direct and indirect economic effects of particular final demands that occur in an individual sector in other industrial sectors. Thus, the inverse coefficient matrix in the respective industry sectors could play a crucial role. The Hakodate City regional input–output table created by Furuya et al. (2006) separated fishery-related industries into groups by fishing type, and kelp-related industries were separated into natural kelp-fishery, aquaculture kelp-fishery, and kelp-processing sectors.

To make the input–output table applicable to the current Hakodate City, we updated it with the national statistics of 2015 and interview surveys on related sectors

Table 7.3 Inverse matrix coefficients of kelp-related sectors

Sector	Inverse matrix coefficients
Kelp-fishery (natural)	1.18
Kelp-fishery (aquaculture)	1.21
Kelp-processing	1.41

Source Compiled by authors

in 2021. The input–output table shows that each kelp-related industry imports goods from outside regions with sizable portions; thus, the study applied inverse matrix coefficients that incorporate imports. The formula for the inverse matrix coefficient is as follows:

$$\left[I - \left(I - \breve{M}\right)A\right]^{-1} \tag{7.1}$$

where I is the unit vector, $\breve{M}$ the import ratio vector, and A is input coefficient vector.

Table 7.3 shows the inverse matrix coefficient of the kelp-related sectors. The inverse matrix coefficient depicts the magnitude of the ultimate direct and indirect production repercussions on various industrial sectors when one unit of final demand exists for a particular sector. The kelp-processing industry has the highest impact among kelp-related industries, and there is little difference in economic impacts between natural and aquaculture kelp industries.

7.3.1.2 Index of the Power of Dispersion and Index of the Sensitivity of Dispersion

To further analyze the economic importance of kelp-related industries with other industries, the index of the power of dispersion and sensitivity of dispersion was calculated.

The index of the power of dispersion is called to be the "first category index of the power of dispersion," which is the vertical sum of each column sector in the inverse matrix coefficients table divided by the mean value of the entire vertical sum in the inverse matrix coefficient table to produce a ratio. This indicates the relative magnitude of production repercussions. If the index of the power of dispersion of the sector is higher than 1, the sector exerts great production repercussions on all industries; whereas, if the value is lower than 1, the sector has fewer production repercussions for all industries.

The index of sensitivity of dispersion is referred as the "primary index of the sensitivity dispersion," which is the horizontal sum of each row sector in the inverse matrix coefficient divided by the mean value of the mean value of the entire sum in inverse matrix table to produce a ratio. This indicates the relative influence of one unit of final demand for a row of sectors. If the index of the sensitivity of dispersion of the sector is higher than one, the sector is relatively sensitive to fluctuations in business cycles in all industries; however, if the value is lower than one, the sector is less sensitive to fluctuations in business cycles in all industries.

The results are summarized in Fig. 7.2. To compare the economic importance of kelp-related industries in all industries, Fig. 7.2 shows the results of only fishery-related industries with the index of power of dispersion on the horizontal axis and index of sensitivity of dispersion on the vertical axis. Each sector is categorized according to industry type and is allocated to four quadrants.

All fishery-related sectors, which are not influenced by the business cycle of other sectors, are plotted in the second and third quadrants. For the fishery industry, all the fishery sectors are located in the third quadrant. The fixed net fishery, gill and sink net fishery, which caught squid, salmoniformes, codfish, and mackerel, had a strong influence on other sectors. Squid fishery, the symbolic fishery in Hakodate City, has a different magnitude by fishing type; the coastal squid fishery has a higher economic impact as compared to the offshore squid fishery, which is ranked the lowest. The kelp fishery also has a different economic influence on the type of fishery, and aquaculture kelp fisheries have a higher economic influence than natural kelp fisheries; however, the aquaculture kelp fishery is the most sensitive fishery industry. In terms of the processing industry, kelp processing has a higher economic impact

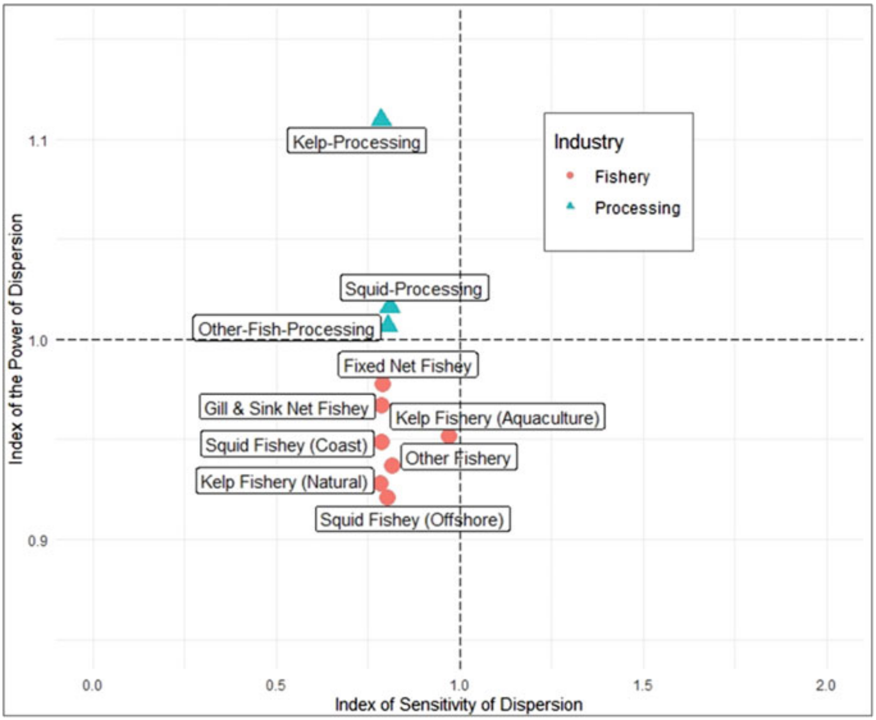

Fig. 7.2 Sectors by index of power dispersion and sensitivity dispersion. *Source* Compiled by authors, created from a new input–output table

than squid processing and other fish processing, which suggests its importance as the core fishery business of the kelp-processing sector in Hakodate.

The results suggest the importance of kelp-related sectors as economic resources in Hakodate. Squid is an iconic fishery as it is a Hakodate city symbol; however, the kelp-related sector has higher economic authority than the squid-related sector as a whole.

7.3.1.3 Economic Ripple Effect

To evaluate the ripple economic impact of kelp industries, we calculated the additional output of the scenario in which one billion JPY occurred as additional final demand in each sector, but net exports did not change. The formula used is as follows:

$$\Delta X = \left[\mathrm{I} - \left(\mathrm{I} - \breve{M}\right)\mathrm{A}\right]^{-1}\left[(\mathrm{I} - \breve{M})\Delta Y + \Delta E\right] \tag{7.2}$$

where X is domestic production, Y is domestic final demand, and E is net export.

The ripple economic impact comprises indirect and induced economic impacts. The average consumption propensity and employment coefficient followed those of the Donan region located in the southern part of Hokkaido Prefecture, which includes the Hakodate City. Table 7.4 revealed the total economic impact, including the first and second economic ripple effects, and job opportunities created for all sectors from each kelp-related sector. The total economic impact and job opportunity created are the highest for aquaculture kelp-fishery. In terms of income, however, the natural kelp fishery brings the highest increase (0.13), mainly because the sector has the highest ratio of employee compensation to total outputs in fishery sectors (49%), which is 32% in aquaculture kelp fishery and 10% in kelp processing.

Table 7.4 Economic impacts with 1 billion JPY final demand

Sector	First ripple effect	Income increase	Second ripple effect	Total ripple effect	Employment effect
Kelp-fishery (natural)	0.30	0.13	0.12	0.42	20
Kelp-fishery (aquaculture)	0.37	0.11	0.10	0.47	21
Kelp-processing	0.31	0.05	0.04	0.35	17

Unit JPY billion
Source Compiled by authors

7.4 Concluding Remarks

7.4.1 Policy Implication

This chapter introduces the role of blue carbon resources as a sink for CO_2 and presents the economic role of the kelp sector in Hakodate City, Hokkaido Prefecture, Japan, as a case study. Blue carbon plays a critical role as an ocean carbon sink, and our focus on macroalgal beds, including kelp forests, is highly expected because of their high absorption coefficients. As a food resource, kelp domains have critical economic importance in Hakodate City as a fishery sector. Aquaculture kelp sector, among kelp-related sectors, would bring the highest economic impacts to Hakodate City. The production of the cultivated kelp has relatively sustainable production for recent years compared with natural kelp has. In addition, around 40% of the kelp cut on the process of harvesting flows into the seabed sinks CO_2 (Motomatsu et al. 2009). Promoting cultivation of kelp, therefore, would bring the most ecological and economical profits to Hakodate City in the sustainable manner. In order to promote aquaculture kelp sector, conservation and restoration of natural kelp which releases swarm spores are preferentially required.

Our empirical study using input–output analysis provides evidence on the economic effect of kelp-related industries, as well as its growing potential in food manufacturing and its underestimated potential for blue carbon capture. Under the circumstance of the declining fishery sector in Hakodate due to complex reasons such as diminishing fishery resource stock and climate change, Kelp is highly expected to be promoted as a sector with multiple functions of aquaculture, food processing, and most importantly, a sector of blue carbon capture for ecosystem conservation.

7.4.2 Research Limitation and Future Work

For further research, as fishing operations emit CO_2 via fossil fuel consumption, a comprehensive analysis of the reduction effects of CO_2 by promoting kelp fishing is required. Using the waste input–output table, Motomatsu et al. (2009) estimated that 31,940 tons of CO_2 are stored and sequestered annually in fishing villages. Asakawa et al. (2008) quantified the reduction effects of CO_2 by improving the efficiency of fisheries and CO_2 fixation in coastal areas from the physical and biological aspects using a waste input–output table.

In Japan, a system to generate carbon credits for activities that contribute to the conservation and restoration of natural macroalgal beds and the sustainability of cultivated macroalgae has been demonstrated (Kuwae et al. 2019). In future, it is important to develop and implement initiatives and policies that support the sustainable continuation of the local kelp industry by utilizing new sources of funding, using these credits.

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Chapter 8
The Legitimacy and Effectiveness of Local Content Requirements: A Case of the Offshore Wind Power Industry in Taiwan

Yachi Chiang

Abstract This study begins with a background introduction to the development of the offshore wind power industry and the local content requirement policies in Taiwan. Subsequently, it discusses the conflict and exceptions between local content requirement (LCR) policies and World Trade Organization (WTO) rules, further to probe into the pros and cons discussed in the literature about LCR policies, with particular emphasis on the energy sector. In the conclusion and policy recommendations section, the author suggests that the effectiveness of LCR policies differs across countries, and that the Taiwanese government should find its own way on a trial-and-error basis. It should also be considered that the government could align the LCR policies with the WTO framework to avoid conflict by designing them more carefully.

Keywords Offshore wind power industry · Local content requirements (LCR) · World Trade Organization (WTO) · Taiwan

8.1 Introduction

To comply with the climate goals set by the Paris Agreement and achieve the green energy future, the Taiwanese government has actively used policy tools to attract foreign investment to help establish the wind power industry in Taiwan. Simultaneously, the Taiwanese government also attempts to distribute the economic benefits of the new energy industry to the local companies and people through the deployment of local content requirements (LCR) policies like many other countries. Nonetheless, the efficiency and the legality of LCR policies in this context have been highly debated. The aim of this paper is to discuss the compatibility with WTO rules and effeteness of LCR policies in the energy sector through documentary analysis. Coming through the government reports, news and academic literature, the author wishes to provide a

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fair check on the Taiwan model in developing its offshore wind power industry with particularly emphasis on LCR policies.

8.2 Local Content Requirements of Offshore Wind Power in Taiwan

8.2.1 The Development of Offshore Wind Power Industry in Taiwan

The Taiwanese government has designed an ambitious development plan for its offshore wind power industry (Jones Day 2018). In 2016, Taiwan's electricity that was generated from renewable energy power plants accounted for 4.8% of the aggregate electricity produced and 9.4% of the aggregate installed capacity in Taiwan. The Taiwanese government has proposed an "energy transition" plan, which aims to progressively phase out nuclear power plants and have an energy mix containing 50% natural gas, 30% coal, and 20% renewable energy by 2025 (Jones Day 2018, p. 1). To achieve the electricity target for renewable energy, the Taiwanese government has emphasized the development of solar photovoltaic (PV) generation and offshore wind power. Regarding the wind power energy development, the government announced the "Thousand Wind Turbines Project" in 2012. The Program drafted a 20-year long map for the development of offshore wind power industry in Taiwan as shown in Table 8.1. These plan of three phases begins with demonstration projects, moving to the application round of commercial wind power farms and then expected to complete the development of wind power zones across Taiwan (Jones Day 2018, pp. 1–2).

Based on the TEB Zonal Development Round rules (TEB 2021), interested applicants were expected to undergo a two-phase selection process. The first phase was the eligibility examination phase, in which interested applicants were required to pass a review of their technology capabilities, financial strength, and local industry promises. Only those who passed the review would be eligible to participate in the following price-bidding phase. The capacity would be allocated to the winning parties based on the bid price and the wind farm connection date (Buljan 2021).

The maximum capacity to be allocated for a single offshore wind farm and to a single developer is 500 MW, plus an additional 100 MW of capacity, depending on conditions such as wind farm integrity, development benefits, domestic industrial capacity, and grid-connection capacity. According to the latest announcement publicized by the Ministry of Economic Affairs (MOEA) in August 2021, 9 GW of capacity would be added in three phases from 2026 to 2031 (Buljan 2021). The bid price for the first phase of the development is limited between TWD 2.49/kWh and TWD 0/kWh. For the subsequent development phases, the average of all the winning bid prices in the previous period will be used as the price cap.

Table 8.1 Three phases of the 20-year long map for the development of offshore wind power industry in Taiwan

	Details and Goals of each Round
Demonstration Round (2016–2020)	Three projects were awarded contracts for the demonstration round with an aggregate capacity of approximately 360 MW. These projects include the Formosa Demonstration Project (expected capacity of 120 MW with 32 installed wind turbines), the Fuhai Demonstration Project (expected capacity of approximately 120 MW and 30 installed wind turbines), and the Taiwan Power Company (TPC) Demonstration Project (expected capacity of approximately 108 MW and 22–36 installed wind turbines). Each of these projects entails a 20-year power procurement agreement (PPA) with fixed feed-in tariff pricing
Wind Farms Application Round (2020–2025)	In July 2015, the Taiwan Energy Bureau (TEB) released 36 zones for the potential development of future commercial wind farms. Offshore wind power developers who received preliminary approval of their environmental impact assessment (EIA) can could submit an application to develop the relevant zones. Recently, the TEB increased the offshore wind energy target for the Transition Round from 3 GW to 5.5 GW. Projects for 3.8 GW of this amount have been guaranteed at a fixed feed-in tariff for 20 years (Taiwan Energy Bureau Report 2020), while the remainder of the projects will go through a competitive auction to sell power at a lower price in a tender held by Taiwan Power Company (TaiPower). The government announced that projects that accounted for 10.5 GW had passed EIA and 5.5 GW were expected to be operational by 2025

(continued)

8.2.2 *Foreign Investment Incentive Policies and Local Content Requirements for the Offshore Wind Power Industry in Taiwan*

Knowing that it would require the technology and expertise of established foreign companies to help achieve the goal, the Taiwanese government provided a set of incentive policies to attract more foreign investments to develop the offshore wind power industry as quickly as possible (Jones Day 2021). Two major incentive policies offered by the government are lifting foreign ownership restrictions and assuring 20-year long feed-in tariff contracts.

Table 8.1 (continued)

	Details and Goals of each Round
Zonal Development Round (2026–2035)	According to the "Offshore Wind Power Zonal Development Capacity Allocation Rules" released by TEB in 2021, this Zonal Development Round will be divided into four stages from 2026–2035. In the first stage, 1.5 GW will be allocated to developers each year during 2026–2027. In the second stage, 1.5 GW will be allocated to developers each year during 2028–2029. In the third stage, 1.5 GW will be allocated to developers each year during 2030–2031. In the fourth stage, 6 GW shall be allocated to the developers during 2031–2035, but more specific rules will be released later in responding to the international technological developments and the results of the previous stages.

Source: Complied by the author

Regarding the first incentive policy (Jones Day 2021, pp. 13–14): In Taiwan, foreign-owned companies that are engaged in certain industries are subject to foreign ownership limits. However, to encourage foreign investors to enter the Taiwanese offshore wind farm market, the foreign ownership limits and other additional restrictions were lifted.

Regarding the second incentive policy (Jones Day 2021, pp. 13–14): As mentioned above, a wind power project developer would sign a PPA with TaiPower. In December 2017, TaiPower published a standard-form PPA for offshore wind farm projects. The PPA provides for either a 20-year fixed feed-in tariff that is set on the PPA signing date, or a 20-year tariff of the winning price in a competitive auction covenanted by and between the project developer and the Taiwanese government. According to the Offshore Wind Power Farms Capacity Application Rules released by MOEA in 2017 (MOEA 2017), these applications to develop offshore wind power farms will follow a "Selection Period First, then Auction Period Next" procedure. In the selection period, 10 projects that were selected and allocated 3.836 GW by the government were guaranteed a 20-year fixed feed-in tariff price announced by the MOEA. These selected projects would be required to meet the standard of local content requirements. In the following auction period, other project developers who were selected via a competitive auction entered into PPAs with TaiPower under their winning bid price for 20 years. The difference between the selection period and the auction one, is that the developers who compete in the auction period don't need to meet a certain local content requirements standard but have to win the contract with a competitive price.

In addition to the economic incentives, the Taiwanese government has prioritized the development of the wind power industry since 2019; it has been estimated that the new electricity generated by wind power equipment will amount to up to 9 GW per year, which will rank 4th in the world (MOEA 2021a). The government's determination and strong incentive policies have undoubtedly helped to attract foreign investment to contribute to Taiwan's development of the local wind power industry.

The Taiwan director of a well-established wind power company that is related to a Danish company, K2 Management (MOEA 2021b), remarked that "Taiwan may be the only country in Asia that allows foreign investors to own 100% of stocks," implying that this is a huge incentive to attract foreign investment to contribute to Taiwan's wind power industry. In 2020, due to the rapid development of the wind power industry in Taiwan, the EU became Taiwan's 5th biggest trade partner, with the total annual investment from the EU amounting to 46.2 billion dollars, calculated from January to October. In short, the EU became the biggest source of foreign investment in Taiwan, thanks to Taiwan's policies to fully support the development of the wind power industry (Business Today 2020).

While increasingly more foreign companies expressed their willingness to invest in the wind power industry, the Taiwan Ministry of Economic Affairs (TMEA) presented a detailed set of LCRs for various sectors of this industry, ranging from underwater engineering and maritime engineering to turbine configuration. The TMEA asked all interested companies to ensure that the various LCR levels were applied. The purpose of the LCRs, from the TMEA's point of view, is to promote international technology transfer and local industries.

LCRs, defined as one type of performance requirements, are industrial policy measures that condition the granting of a benefit, by means of subsidies or other kinds of incentives, on the use of domestic products and services (Junior 2019). In short, LCRs require that a minimum level of goods and services is bought and/or manufactured locally. Conceivably, LCRs are not always welcomed by foreign investors (Bazilian et al. 2020).

The Director of the Taiwan office of Copenhagen Infrastructure Partners (CIP), which invested in developing Taiwan's wind power farm, has stressed that European countries have their respective strengths in different sectors of the offshore wind power industry (Commercial Times 2021). For example, the Netherlands and Belgium focus on maritime engineering, Denmark excels at turbine manufacturing, and East European countries are responsible for component production. The division of the works was driven by the free market. By contrast, as appealing as the incentive policies provided by the Taiwanese government are, Taiwan lacks the foundation to support a full and complete wind power industry chain. For example, the production of one single turbine includes the production of leaves, electricity generator, and other underwater engineering works, all of which require professional knowledge and high expertise. It would be very challenging for Taiwan to develop a wind power farm on its own land, especially when tied up by many LCR rules.

Table 8.2 Evaluation standard of wind power farms application rules

	Total score	Selection Criteria	LCR
Technology Capabilities	60	1. Construction Ability (25)	1.Construction Ability (25): (Cooperation with local companies)
		2.Engineering Design (20)	2.Engineering Design (20) (Cooperation with local companies)
		3.Operation and Maintenance (15)	3.Operation and Maintenance (15) (Cooperation with local companies)
Financial Strength	40	1.Financial Soundness (30)	1.Local Financial Institution Relevance (10): 20% of wind power farms developing funds come from local financial institutions will get the full score in this examination criteria.
		2.Local Financial Institution Relevance (10)	

Source: compiled by the author

8.3 The Rules of LCRs in Taiwan

8.3.1 Local Industry Relevance Execution Plans in the Offshore Wind Power Farms Application Round

According to the MOEA's plan, the total electricity generated by offshore wind power systems in Taiwan will reach up to 5.6 GW by 2025. Although it is a huge market, there are certain requirements for foreign investors to enter the wind power industry.

The Offshore Wind Power Farms Capacity Allocation Application Rules (Wind Power Farms Application Rules) was promulgated by the Taiwanese government in 2017 as aforementioned (MOEA 2017). In the first selection stage, the MOEA planned to select the wind power site proposals that generated no more than 0.5 GW of electricity by 2020. At this stage, foreign investors were required to present many evidential documents to prove that their proposals were feasible. Subsequently, the TMEA planned to select the wind power site proposals that would generate up to 3 GW by 2025 and asked foreign investors to present "substantial local industry relevance execution plans." The final decision would be made based on the technology capabilities (60%) and financial strength (40%) of the applicants. The applicants would be required to undertake to comply with the substantial local industry relevance execution plans in time. The details of these local relevance requirements are provided in the Appendix 8 of the Wind Power Farms Application Rules and reorganized by the author as shown in Table 8.2.

The pledge to execute the substantial local industry relevance plans would not only include the LCR plans, but also contracts with local providers. Foreign investors would be penalized if they failed to keep their LCR promises without justified grounds. In that case, they might be penalized 3% of the contract performance bond each month, while their contractual positions might be replaced by the next company in the waiting line.

8.3.2 Local Industry Relevance Execution Plans in the Offshore Wind Power Farms Application Round

In August 2021, the MOEA again announced the "Offshore Wind Power Zonal Development Capacity Allocation Rules" (MOEA 2021a). According to the Industry Relevance Policy Order released by the Industry Bureau of MOEA later in December 2021 (MOEA 2021b), in this third phase of Offshore Wind Power Zonal Development, it stipulated that LCR would be examined by a "promise before, execute afterwards" standard (MOEA 2021b). This suggested that foreign investors would have to present substantial local industry relevance execution plans that were approved by the government body. Bound by the LCR promises, foreign investors would have to complete the establishment of wind power farms and LCR items in time; else they would be penalized for failing to meet the contractual obligations.

According to the Article 4 of this Allocation Rules, from 2026–2031, each year will allocate 1.5 GW wind power capacity to qualified developers. From 2032–2035, it is planned to allocate 6 GW but the details of the allocation will be decided afterwards based on the development of global technologies and outcomes of the previous allocations.

The selection standard of developers during this zonal development round (2026–2035) is stipulated in Article 8 of this Application Rules. It suggests that technology capabilities accounted for 60% and financial strength accounted for 40%, same as the wind power farms application round, but adding the third criteria "Industry Relevance Execution Plan" as a value added item.

Based on the details shown in the Appendix 7 and Article 8 of this Allocation Rules, the selection criteria and LCR are highlighted by the author in the Table 8.3 below. Comparing the Table 8.2 and Table 8.3, it is shown that the LCR specified in the evaluation criteria in the second Round have been moved to the value-added column in the Zonal Development Round. Nonetheless, it is not surprising that these LCR regulations have triggered some criticisms. The Chief of the EU Energy Policy and Coordination Office, Cristina Lobillo Borrero, once pointed out that LCR rules in Taiwan ought to adhere to international trade rules for Taiwan to help the global value chain without interfering with the rules of the international economy (Junior 2019).

Table 8.3 Evaluation standard of offshore wind power zonal development capacity allocation rules

	Total score	Selection Criteria	LCR
Technology Capabilities	60	1.Construction Ability (25)	
		2.Engineering Design (20)	
		3.Operation and Maintenance (15)	
Financial Strength	40	1.Financial Soundness (30)	
		2.Local Financial Institution Relevance (10)	
Industry Relevance Execution Plan	Value Added		Details of the evaluation standard, evaluation procedure and documents requirements…etc., will be publicized by MOEA later

Source: complied by the author

8.3.3 Updated Local Industry Relevance Execution Plan for the Zonal Development Round

Following the first version of the substantial local industry relevance execution plan for wind power clusters in August 2021, the TMEA again announced an updated version in December 2021. The main difference in this version was that the LCR rules would be examined every two years instead of five years. Another major difference was that some LCR items were more flexible. Especially regarding some difficult LCR items, the new rules allowed foreign investors to choose the LCR items voluntarily instead of compelling them to fulfill all the LCR items. Should foreign investors choose to implement the "voluntary" LCR items, they would be awarded more points under the government examination. The rules also allow more flexibility for foreign companies to fulfill LCR items, including ways of purchase, cooperation, and investment.

8.4 The Compatibility of LCR Policies and WTO Rules

The Organization for Economic Cooperation and Development (OECD) published an "Emerging Policy Issues: Localization Barriers to Trade" report in May 2015, which summarized various types of LCR rules and stated their potential negative impact on international trade. Nonetheless, many countries use LCR rules to promote local economies and increase employment opportunities. According to the "Local Content Requirements: A Global Problem" (Hogan 2021) report published by the Peterson Institute for International Economics in 2013, LCR policies have become increasingly popular among countries to protect local industries and increase job opportunities. In the last two decades, LCR policies have gained increasing prominence, especially in the renewable energy sector (Hogan 2021). LCR rules may include the use of a certain amount of local products or services, tax discounts for local purchases, companies should be run by local people, etc.

According to the Peterson report, it was estimated that LCR rules impacted almost 928 billion dollars' worth of global trade (5%), causing trade losses worth 93 billion dollars. It is concluded that these LCR rules may be substituted by other "localization" mechanisms, such as corporate social responsibilities, staff training programs, more investments in fundamental infrastructures, tax deductions, subsidies, etc.

There are quite a few agreements of the World Trade Organization (WTO) that prohibit LCR rules but have never been taken seriously. For example, the Agreement on Subsidies and Countervailing Measures (SCM), the Trade-Related Investment Measures (TRIMs), and the General Agreement on Tariffs and Trade (GATT), all of which contain prohibitions on the use of LCRs by WTO members (Junior 2019). Nonetheless, as much as these WTO agreements clearly prohibit the application of LCR rules, it would be very difficult for companies involved to quote these agreements against LCR policies in a disputed country. First, only members of the WTO are entitled to file complaints to the dispute settlement body of the WTO; however, only governments are WTO members and not corporations. Second, for a government to file an international complaint through the WTO mechanism, the decision would be based on many complicated issues and would not consider the mere interests of a single company, not to mention the difficulty for the company at dispute to prove its losses. Eventually, it would take years to obtain a ruling from the WTO dispute settlement mechanism, while the corporations involved would not receive any compensation under the current legal framework of the WTO.

Despite the fact that the main principle of the WTO is in favor of international free trade and even prohibits LCR policies in several agreements, there remain legal exceptions to the WTO rules that allow LCR policies.

Article XX of GATT states the general exceptions of LCR (WTO/GATT Article XX), some of which are closely related to the energy sector: *(b) necessary to protect human, animal, or plant life or health*; and *(g) relating to the conservation of exhaustible natural resources if such measures are made effective in conjunction with restrictions on domestic production or consumption.* In addition, although the paragraph, "*(j) essential to the acquisition or distribution of products in general or local short supply*" seems unrelated to the energy industry at face value, it was adopted by the Indian government to defend its LCR policies in the solar power industry (DS456).

In addition, Article III of GATT regulates the National Treatment on Internal Taxation and Regulation; however, it offers an exception in paragraph 8[1]:

> 8. (a) The provisions of this article shall not apply to laws, regulations, or requirements governing the procurement by governmental agencies of products purchased for governmental purposes and not with a view to commercial resale or with a view to use in the production of goods for commercial sale.

[1] https://www.wto.org/english/res_e/booksp_e/gatt_ai_e/art3_e.pdf. Accessed 21 June 2022.

(b) The provisions of this article shall not prevent the payment of subsidies exclusively to domestic producers, including payments to domestic producers derived from the proceeds of internal taxes or charges applied consistently with the provisions of this article and subsidies effected through governmental purchases of domestic products.

The Canadian government quoted this paragraph 8 of Article III to defend its LCR policies against Japan. Nonetheless, the WTO dispute panel ruled that Canada was not justified because LCR policies shall not be used in a commercial market (Batra and Bafna 2018).

Judging by the previous cases of Canada and India, although it is unlikely, it is possible that the LCR policies in Taiwan risk being challenged by other members of the WTO. Nonetheless, as argued by Huang (2021), LCR policies can be designed as a WTO-compatible industrial policy if (1) the LCR in services is prioritized; (2) the LCR and government support scheme (such as FIT) are severable; and (3) Article XX of the [in particular, paragraph (b)] is used wisely, in which case the LCR is closely connected to the objectives pursued, thorough effectiveness analysis on the implementation of the LCR has been provided, and the due process of law has been honored.

8.5 The Effectiveness of LCR Policies

The LCR policies may not only be challenged through the WTO dispute settlement body but can also bring unintended economic results. A research study that uses Brazil, India, and South Africa as examples evaluates whether LCR rules have helped create local manufacturing capacity or benefited local companies (Bazilian et al. 2020). The study concludes that companies in all three countries have tended to take on roles that are more easily borrowed from other industries, such as project development or ancillary services. Consequently, it is more difficult to set up manufacturing capacity in more sophisticated components (Bazilian et al. 2020). This research also finds that local content rules have contributed to increasing project costs.

Another disadvantage of LCR is that costs may increase because of the compulsory requirements to purchase local items. As mentioned previously, the Indian government applied LCR policies in building up its local solar power industry. A study that used data on Indian government-run solar PV auctions held in India between 2014 and 2017 found that not all of the auctioned contracts entailed LCRs (Probst et al. 2020). By comparison, it was concluded that LCR policies caused a 6% per kWh increase in the cost of solar PV power compared to similar projects that were not subject to the same LCR policy. In addition, during these three years, Indian solar panels remained approximately 14% more expensive than international panels. Although the empirical data analyzed in this study also suggested short-term increases in domestic manufacturing capacity, during the same period, Indian firms did not increase market share or enter international markets.

Although the economic impact of LCR policies is sometimes challenged by empirical data, many countries still favor LCR policies to build up local industry. In addition to economic advantages, LCR policies can also be justified on social grounds. The exceptions of the WTO agreements signal the same message: international free trade is not absolute if there are other justifiable considerations.

As suggested in this study, one of the most common and effective methods that governments apply to support clean energy remains LCR policies. The author emphasizes that the prohibition of LCR policies without any quality assessment and analysis of its impacts on the environment will conceivably draw criticism from environmentalists. The study analyzes the GATT regulations and the results of the dispute settlement body and concludes that, due to a lack of clarity, generality, and flexibility, and failure to meet the positive and negative requirements, the aforementioned sources are deficient in justifying the removal of the legal prohibition. Therefore, the best solution is to revise the regulations of the Agreement on Subsidies and Countervailing Measures.

In particular, support for a global free market does not necessarily contradict LCR policies. The conclusion in this study is that globalization goes hand-in-hand with localization. To compete in large markets (India, China, the US, and Brazil), EU companies have to grow local manufacturing and supply chains (Lacal-Arántegui 2019).

Professor Meyer (2015) has argued that the WTO prohibition fails to account for the public goods that are generated by LCR programs and suggests that local subsidy programs can help balance international trade with the valuable global public goods such programs can contribute.

Meyer used an original 50-state survey and identified 44 state renewable energy programs in 23 states within the United States that could violate WTO rules. Nonetheless, Meyer argued that these programs could increase global welfare despite their discriminatory nature. In other words, LCR policies help local governments internalize a few of the benefits of providing global public goods, such as reducing greenhouse gas emissions through investments in renewable energy technology. Local efforts to address global public goods would create benefits in other jurisdictions. To sum up, it is imperative to reform international trade law so that local governments can play a role in solving global problems.

In another study that examines the role of industrial policy in developing renewable energy (RE) to cope with climate mitigation mandates (Lewis 2021), Lewis finds that to justify investments in clean energy sources, an increasing number of countries are linking the political rationale for RE development to local economic benefits, such as job creation, local manufacturing, and technological innovation. Consequently, industrial policies are being strategically deployed to allow countries to capture economic benefits from RE deployment beyond what deployment policies alone may bring. Under these circumstances, LCR policies are often used as an industrial policy tool to support the localization of RE technology manufacturing by mandating the use of a certain portion of locally manufactured components. As LCR has been the most widely studied green industrial policy in the literature to date, it demonstrates that the effectiveness of LCR policies in promoting local industrial development may differ across countries and technologies.

According to a document released by the OECD (OECD 2022), LCR policies may help local governments achieve certain short-term objectives; however, they may undermine the long-term competitiveness of a country. While echoing some criticisms that LCR policies may cause inefficiencies in the affected sector, the OECD study highlights the subsequent costs imposed on the rest of the economy as well (Stone et al. 2015). In sum, the OECD study argues that the disadvantages due to the LCR policies can offset its potential benefits, such as job growth and the scaling of the local economy. Nonetheless, the OECD also points out that the world has favored LCR policies since the 2008 economic crisis: a decade after the financial crisis, more than 340 localization measures, including over 145 new LCRs, have been implemented by governments largely to improve domestic employment and industrial performance.

In another paper released by the OECD in 2015 (Stone et al. 2015), it was concluded that despite the predominately "negative evidence" of the impact of LCRs on trade, they continued to play a significant role in trade policy. The study concluded that the "negative impact" of LCR policies could cause a decrease in exports in non-LCR affected sectors and a growing concentration of domestic activity in a few targeted sectors, undermining potential growth and innovation on a broader scale. Therefore, the study recommends that countries replace LCR with alternatives. Nonetheless, OECD offers an overall insight focusing on the economic growth; it should be noted that since the effectiveness of LCR policies differs across countries, some might enjoy more benefits than harm. In addition, there may be other social justifications for adopting LCR policies, as mentioned earlier.

For the overall economic situation in Taiwan, according to the data shown on the Taiwan economy official website (Taiwan government website 2022): Following the financial crisis in 2009, Taiwan's export-oriented economy suffered another downturn in 2015 due to the weak global demand for consumer electronics products coupled with the falling price of crude oil. However, since 2016, the situation has improved. While the recent years' economic growth rate has been modest due to the impact of the U.S.- China trade dispute, expanding domestic production driven by the reshoring of manufacturing companies has helped to offset the drag. The economic growth had rebounded by January and February of 2020, with exports and imports respectively increasing by 6.4 percent and 5.3 percent, and the overall trade value rising 5.9 percent year on year. Intriguingly, the statistics showed that 2016 was the turning point, which was also the year of the demonstration round of Taiwan's offshore wind power industry development. There is no sign that Taiwan's overall economic growth was affected by the LCR policy in the offshore wind power energy sector. On the contrary, Huang, in an insider commentary published in January 2020, described Taiwan's offshore wind market as the most open one in East Asia, while acknowledging that national protectionism was no secret when doing business in Asian markets (Qiao 2020; cited in Huang 2021).

Table 8.4 Job opportunities and production value of the offshore wind power industry in Taiwan

	2013 (year)	2020	2025
Net production value (NTD Billion)	8	130	1200
Job opening (job)	1400	4640	20,000
Investment (NTD Billion)	2	100	1000

Source Data collected from Taiwan Wind Power Industry Association

8.6 Conclusion and Policy Recommendations

As discussed in the previous section, two main issues surround the LCR policy: legitimacy and its effectiveness. Many who argue against the LCR policy adopted by countries claim that it is against the international free trade rules or that it negatively impacts countries' economic or job growth. Nonetheless, the author of this study argues that it is possible to have a WTO-compatible LCR policy, considering the exceptions. The effectiveness of the LCR policy may differ from country to country. From the data provided by the Taiwan Offshore Wind Power Association, as shown in Table 8.4, the production value and job opportunities both seem promising.

This study concludes that Taiwan's efficient development of its offshore wind power industry from ground zero has set a good example for other countries. The LCR policy helps mitigate the economic incentives to attract foreign investors, build up the local industry, and create job openings. Thus far, there is no evidence of a significant negative impact. As much as the author considers that the LCR policy is not necessarily negative or illegal in the context of international free trade, the policy recommendations in this study are to design the LCR rules carefully to ensure its compatibility with international trade rules and effectiveness in the local economic and social contexts.

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Chapter 9
Impact Assessment of Eco-Friendly Cooling System Implementation on Sea Transportation: A GTAP-E-Power Model Application

Michael C. Huang, Yoko Iwaki, and Ming-Huan Liou

Abstract Climate change and global warming have significantly threatened food security and the global supply chain. As the trade volume of bulk commodity grains has been growing steadily, ensuring quality while minimizing losses during long-distance shipping between warm and cold seawater has become a critical issue. An evidence-based approach to provide quantified implications is needed to illustrate a roadmap toward a net-zero-carbon society. This study applied the GTAP-E-Power model to examine the economic and welfare impacts of eco-friendly cooling system implementation on sea transportation in Japan, Australia, and New Zealand. By creating scenarios of Japan's technology change calibrated from SPIAS-e and capital-use subsidy on sectors of electronics, solar power, and sea transportation as cooling system implementation, the simulation results showed a GDP growth of 0.09% in Japan and 0.11% in Australia and New Zealand. Moreover, Japan's welfare could improve by USD 4,219 million, while greenhouse gas emissions might be reduced to 8.4 million tons, equivalent to 0.9% of the total emission of Japan's sea transportation sector.

Keywords Eco-friendly cooling system · Global food supply chain · Electronics · Renewable energy · Sea transportation

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9.1 Introduction

9.1.1 Global Crops Supply and Shipping Vulnerability

Climate change has already impacted food security through increased temperatures, changes in precipitation patterns, and increased frequency of extreme meteorological events, such as intense storms and droughts, resulting in massive losses in agriculture (Intergovernmental Panel on Climate Change 2019). When climate change was examined in isolation from other factors affecting crop yields in recent decades, it was observed that climate change had harmed crop yields and deepened income disparity in many low-latitude developing countries. In contrast, it had a positive impact on crop yields in high-latitude countries. These features have contributed to the global food supply chain (Table 9.1), accounting for a significant 38% of commodity demand in 2019.

Regarding the global food supply through sea transportation, cereals are one of the most produced crops globally. They are one of the most complex and dangerous crops to transport. Compared to iron ore and coal, grain is an agricultural commodity that is highly dependent on commodity tonnage in the charter market (Australian Competition and Consumer Commission 2021). This is because its trade is seasonal, and its volumes and routes are irregular, making it challenging to optimize transportation (Hellenic Shipping News 2021). To transport wheat safely, specific temperature, humidity, moisture, and ventilation conditions are required. There is no lower limit to the temperature, but the preferred transport temperature is approximately 20 °C. This is because mold growth is highest in the range of 20–30 °C, and above 25 °C, metabolic processes become more active, CO_2 production increases, and wheat self-heats with a relative humidity of 80% (Ocean Route 2020).

Table 9.1 Ranking of wheat's trade by volume of 2021

	Export		Import
1	Russia	1	Indonesia
2	Australia	2	China
3	USA	3	Türkiye
4	Canada	4	Algeria
5	Ukraine	5	Italy
6	France	6	Iran
7	Argentia	7	Bangladesh
8	Germany	8	Nigeria
9	Romania	9	Brazil
10	India	10	Philippines

Source FAO statistics (Food and Agriculture Organization of the United Nations Statistics 2022)

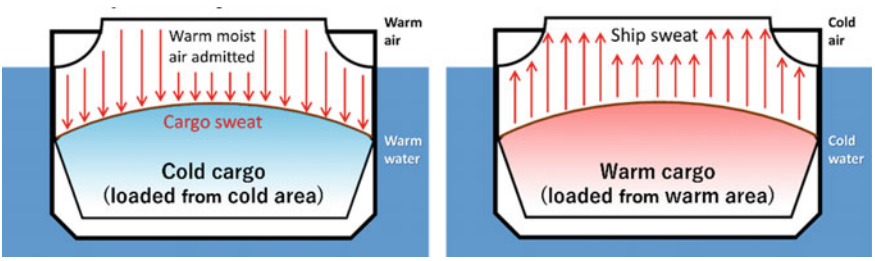


Fig. 9.1 Cargo's and ship's sweat. *Source* Illustrated by authors

According to International Maritime Organization (IMO), the share of shipping emissions in global anthropogenic emissions has increased from 2.76% in 2012 to 2.89% in 2018, while NO_x and SO_x account for 15% and 13% total emissions, respectively (International Maritime Organization 2020). For these reasons, it is crucial to reduce shipping losses to ensure a resilient global food supply chain by minimizing the losses caused by cargo and ship sweats during long-distance voyages (Fig. 9.1).

9.1.2 Cooling System and Greenhouse Gas (GHG) Emission of Sea Transportation

Cargo sweat is a common problem that occurs when warm, moist air comes into contact with the surface of cold cargo, often resulting from loading bulk cargo in a cold environment and transporting it to a warmer one. The resulting condensation can cause the cargo to deteriorate, affecting its quality and value. The proper operation of the cooling and ventilation system is crucial for preserving the quality of the cargo on board a ship. According to regulations, the cooling and ventilation system must remain operational until the cargo is unloaded, even while the ship is waiting at the berth. To avoid claims related to damaged cargo, accurate records of the ventilation system's use must be maintained, including the periods when ventilation is active and when it is not available or appropriate. The purpose of the cooling and ventilation system is to reduce moisture levels in the cargo hold by replacing humid air with drier air. This helps prevent the formation of cargo and ship sweats, which can damage cargo by as much as 15-20% (DNV 2021). Therefore, proper operation and maintenance of the cooling and ventilation system are essential for mitigating cargo sweat and preserving the quality of the cargo during transport. Accurate record-keeping is also critical for ensuring that the system is operated correctly and that any issues can be identified and resolved promptly to prevent cargo damage and claims.

As of 2017, more than 85% of cargo ships and 64% of cargo tonnage were powered by internal combustion engines, and the cost of energy was between 20 and 60% of the operating cost (Saidyleigh et al. 2019). To promote eco-friendly shipping while achieving the goal of reducing greenhouse gas GHG emissions, the shipbuilding industry has been developing electronic systems by improving more efficient propulsion and power supply systems with hybrid energy inputs sourced from renewable energy, such as solar photovoltaic applications (Danfoss 2016; Visa et al. 2016; Mircea 2021). While still in the experimental stage, a hybrid-powered vessel has been developed with the potential for solar energy efficiency to reduce fuel consumption cost by 28% and CO_2 emissions reduction of 77% (Lan et al. 2015). Based on the International Energy Agency (IEA)'s projection, the cost of electricity from PV may decrease from 25% in 2020 to 65% by 2050 (International Energy Agency 2014).

Utilizing more renewable energy with electronic equipment for transportation could also increase overall welfare in Japan (Huang and Kim 2022). Long-distance voyages between large temperature disparities are unavoidable in global food supply chains. There is a need to use more fuel for ventilation and cooling systems, but bulk carriers give less priority owing to the fuel cost performance in terms of commodity value (Thakur and Hurburgh 2022; Theotokatos et al. 2017). Nevertheless, under looming severe climate change threats urgent and innovative measures to improve grain shipping quality are needed to help eliminate food insecurity while reducing GHG emissions.

To capture the investment effect on the implementation of cooling system improvement into sea transportation sector and its impact on global trades and CO_2 emission, this study aims to apply the electricity-specified model developed by the Global Trade Analysis Project (GTAP-E-Power) by the Purdue University (Peters 2016a) to examine the implementation of an eco-friendly, more efficient electronic system with ventilation and cooling systems on bulk carriers for agricultural product shipping. The simulation results are expected to provide key economic indicators from insights into sectoral output, changes in the global supply chain, GHG emissions, and welfare analysis.

9.2 Methodology and Scenarios

9.2.1 Classification of Sector and Region

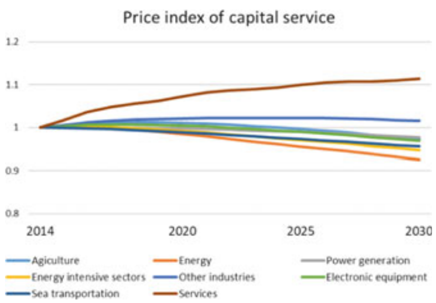
The GTAP database is commonly used for international trade and tariff analysis (Hertal 1997). It has many extensive databases, such as GTAP-E, which contains GHG emission data, and GTAP-Power, which specifies power generation, including the renewable energies of hydro, solar, and wind power. To merge the power generation and GHG emission features, we followed Peters (2016a, b) to construct a GTAP-E-Power model to capture the impact of electronic equipment investment on the sea transportation sector. The study categorized eight major sectors—agriculture, energy, power generation, energy-intensive sectors, other industries, electronics, sea transportation, and services—from 76 sectors in the GTAP database version 10. We analyzed ten regions, including Japan, East Asia, ASEAN, South Asia, the rest of Asia, Australia and New Zealand, the US, Mexico and Canada, the rest of America, Europe, and the rest of the world, from 140 regions.

9.2.2 Scenario of Technology Change

To create a scenario of technology change, we calibrated the parameters from the SciREX Policy Intelligence Assistance System (SPIAS-e), which serves as a comprehensive platform, based on a computable general equilibrium model based on Japan's input–output table of 1995–2011 with the economic development projection of 2011–2050 and distinguishes tangible and intangible capital stock into 93 sectors (Kuroda et al. 2018).

Using the price index of tangible capital stock (PSK) of the base run, in which public research and development (R&D) investment is constant as of 2005, we created a scenario of technology change (Fig. 9.2), where a higher index implies a higher cost in specific sectors. The SPIAS-e is also based on Japan's demographic changes due to aging and shrinking population. The rising price index of capital services indicates that the service sector's costs are rising; in contrast, the declining price index of the energy sector, power generation, energy-intensive sectors including transportation equipment, and heavy industry indicates that the sector's technology has changed allowing it to operate with less capital input.

The projection of SPIAS-e has indicators from 2011 to 2050 (Huang and Kuroda 2021). After aggregating the 93 categories into eight major sectors (the energy source and power generation are still distinguished as independent sectors), we standardized the index based on 2014, which is consistent with the GTAP database base year. For policy simulation, we calibrated the price index for 2020–2025 as our simulation period (Table 9.2). Although GTAP-E-Power is a static model, the parameters enabled us to proceed with the investment as a policy intervention with the technology change assumption (Huang et al. 2021).



Sector	2020-2025
Agriculture	1.42%
Energy	3.03%
Power generation	0.79%
Energy intensive sectors	2.05%
Other industries	-0.06%
Electronics	1.47%
Sea transportation	1.60%
Services	-2.57%

Fig. 9.2 Price index of service goods. *Source* SPIAS-e (Kuroda et al. 2018)

Table 9.2 Policy shocks of cooling system implementation

Capital-use subsidy	Efficiency improvement	Target region
20% in maritime transportation, electronics, and solar energy	20% more efficiency in agriculture, electronics, and solar power for maritime transportation	Japan; Australia and New Zealand (OZ & NZ)

9.2.3 Scenario of Cooling System Implementation

To create the scenario for impact assessment of a cooling system implementation in the sea transportation sector, we use of a capital-use subsidy in the electronic, solar power, and sea transportation sectors, coupled with an efficiency improvement in intermediate inputs. To incentivize the industry and strengthen the synergy of the sectors, the assumed subsidy and efficiency improvement rates were set at 20%, based on the above literature for simplicity to specify the impact assessment of the stimulus renovation project.

To provide regions for policy shocks, we focus on Japan, Australia, and New Zealand based on their complementary connections in the electronics, sea transportation, and agriculture sectors. Australia's crop exports have experienced significant issues related to cargo and ship sweating, which can damage the quality of exports, while Japan has expertise in electronic systems and shipbuilding capacities for global logistics. By focusing on these complementary connections, the study aimed to determine the potential impact of policy shocks on these sectors and their interactions. Table 9.2 presents the policy shocks.

9.3 Simulation Results

The implementation of better fuel and cooling systems in the shipping industry has been hindered by the unpredictability of costs, profit, and GHG emission reduction. To address this issue, this study employs the GTAP-E-Power model to assess the potential consequences on output, the impact on the global supply chain, and the effect of GHG emission reduction. The objective of the study is to provide stakeholders with a comprehensive view of technological improvement and its spillover effect on eco-friendly shipping in the agricultural sector, which can help them manage their resources better and enhance household welfare. The quantified results of this study will also have ramifications for trading partners and relationships in the agriculture, sea transportation, and electronics sectors.

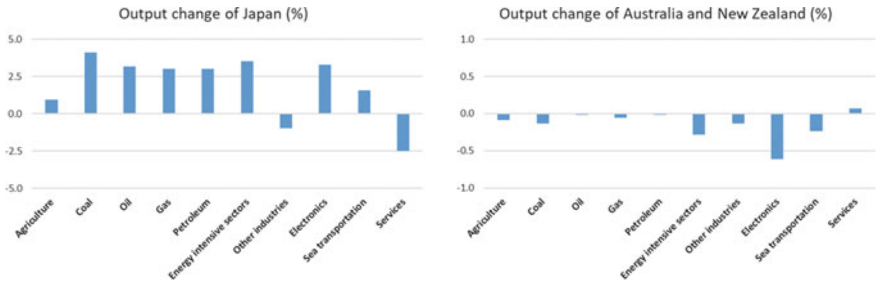


Fig. 9.3 Output changes of Japan, Australia, and New Zealand

9.3.1 Sectoral Output Change

To understand the impact of the technology change and implementation in the cooling system in maritime transportation, we demonstrated the sectoral output change after policy shocks in Japan, Australia, and New Zealand in Fig. 9.3.

Simulation results show that higher output in energy-intensive sectors, such as coal, oil, gas, and petroleum, leads to higher productivity, but given Japan's relatively small output in these sectors, changes are negligible. Moreover, Japan's electronics and sea transport sectors grew by 3.3% and 1.6%, respectively, with the policy shocks, indicating their competitiveness in these sectors. Additionally, agriculture grew by 0.9%, supported by technological improvements and better shipping logistics. However, investment in electronics for sea transportation caused a slight decrease in the agriculture sector in Australia and New Zealand, indicating that less production could now satisfy global demand. Similarly, energy-intensive sectors and electronics showed a decrease of 0.25-0.6%, indicating that Australia and New Zealand are focusing on their core industries, while service sector show slight growth. These results have implications for policymakers and stakeholders in various sectors, especially in terms of resource management and boosting household welfare.

9.3.2 Change of Global Supply Chain

The findings of our study suggest that Japan has undergone a transition in the global supply chain as evidenced by the changes in import destinations (Fig. 9.4), our analysis reveals that this transition has been driven by Japan's significant reduction in imports from other regions due to increased productivity resulting from technological improvements. Additionally, our study highlights that Japan's investments in electronics, solar power, and cooling systems have had spill-over effects on other regions, further contributing to changes in the global supply chain with a greater degree of trade interdependence among regions, with potential implications for global trade patterns and economic growth. We thus highlights the importance of considering the

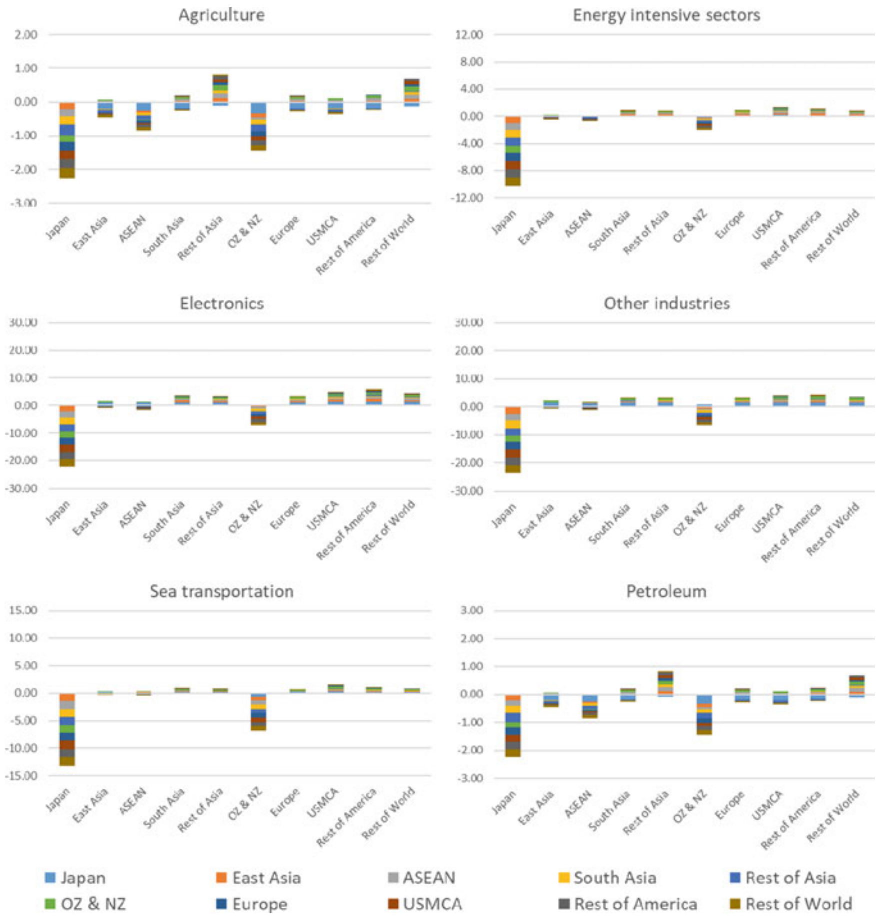


Fig. 9.4 Change of import by trading region (%)

broader impacts of technological and investment decisions on trade interdependence and global supply chains.

9.3.2.1 Agriculture

The agriculture sector has experienced significant impacts by the policy shocks. The findings reveal that Japan could become more self-sufficient in agricultural products as productivity rises, leading to lower imports from all regions, and vice versa. However, it is interesting to note that regions such as the rest of Asia, the rest of the world, South Asia, USMCA, and Europe slightly increased their imports from Australia and New Zealand by 0.05–0.15%. This implies that the implementation of electronics and cooling systems resulted in a more effective improvement in the agriculture export-oriented region. Such changes in the agricultural sector can have significant implications for regional trade and welfare. The results of this study can help policymakers and stakeholders better understand the spillover effects of technological improvements on the agricultural sector, enabling them to manage their resources more efficiently and sustainably.

9.3.2.2 Energy-Intensive Sectors

In terms of the energy-intensive sectors, higher productivity in Japan has led to a boost in competitiveness in sectors such as chemical and metal production. Japan decreased its imports from all regions by 1%, while there was a slight increase in imports of Japanese products from rest of Asia, South Asia, rest of world, USMCA, and Europe by 0.09-0.17%. This suggests that the policy shock had a positive impact on the energy-intensive sectors in Japan, which in turn has contributed to increased demand for Japanese products in various regions. The increase in imports from Japan by these regions can be attributed to the improvement in productivity in the energy-intensive sectors, as well as the policies implemented to promote competitiveness.

9.3.2.3 Electronics

The electronics sector in Japan has experienced an increase in demand for its products due to technological advancement and investment. This resulted in a rise of 1-1.5% in demand for Japanese electronics products in most countries. As a consequence of its self-sufficiency policy, Japan reduced imports from other regions. However, interestingly, imports from East Asia, ASEAN, Australia, and New Zealand increased by 0.5-0.8%. This has resulted in a spillover effect on Japan's electronics sector, which can further consolidate the integration of regional electronic production networks.

9.3.2.4 Other Industries

For other industries, such as food, manufacturing, and transportation equipment, simulation results indicate that Japan's imports to most regions were robust, showing an increase of 1.3-1.7%. This growth can be attributed to the country's high productivity and competitiveness, which has led to the production of high-quality goods. However, the spillover effect to other Asian regions was not as significant as that of the electronics sector. On the other hand, Australia and New Zealand witnessed higher growth in exports compared to other regions. This trend can be attributed to the increase in demand for their products, which are likely to be complementary to Japan's production.

9.3.2.5 Sea Transportation

The implementation of a capital-use subsidy on sea transportation has had a positive impact on the imports from Japan, Australia, and New Zealand, as they increased by 0.16–0.3% to all other regions. This suggests that more efficient sea transportation is preferable for the industry. The increase in imports from these countries to other regions could be attributed to the lowered transportation costs due to the subsidy, making it more cost-effective to import goods from these regions. This increased efficiency in sea transportation could also have positive spillover effects on other sectors that rely on international trade, such as manufacturing and agriculture, by reducing costs and increasing competitiveness.

9.3.2.6 Petroleum

Because of improved energy efficiency, there has been a decrease in the import of petroleum products to Japan by 0.6-1.06%, and to Australia and New Zealand by 0.3-0.5%. This decrease can be attributed to Japan's increased efforts to transition to renewable energy sources, which have resulted in a reduction in the demand for petroleum products. The positive impact on GHG emissions is significant, as this transition to renewable energy has contributed to lower emissions.

9.3.3 GDP Change and Welfare Analysis

We presented GDP and welfare changes to interpret the total impact of policy shocks. Welfare is demonstrated in the form of equivalent variation, which indicates the utility difference of the region under the price change after the policy shocks (Fig. 9.5).

Based on the technology change scenario, the capital-use subsidy in electronics, solar power, and sea transportation of higher efficiency implementation has stimulated Japan's sectoral output, which contributed to a growth of 0.09% in Japan's

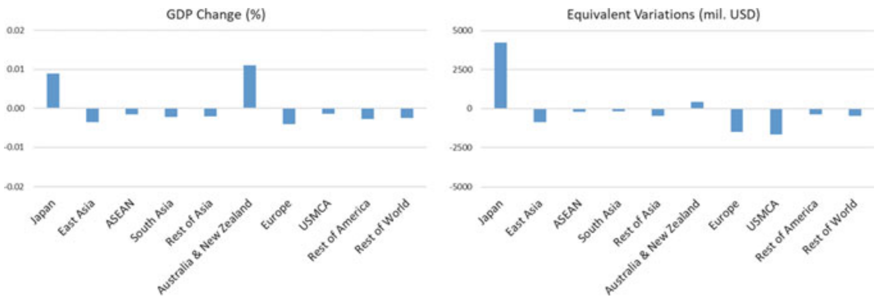


Fig. 9.5 Change on GDP and welfare

GDP. On the other hand, Australia and New Zealand, as Japan's counterparts with the same level of investment in the three target sectors of sea transportation, interestingly, grew faster than Japan, implying that investment's spillover effect has boosted Australia and New Zealand's competitiveness in sectors such as agriculture and other industries.

Moreover, the study found that the capital-use subsidies significantly led to the welfare improvement in Japan by USD 4,219 million. The implementation of more efficient systems of electronics and renewable energy in the sea transportation sector could substantially improve the quality of life for people, providing them with higher purchasing power and satisfaction. Additionally, as collaborative partners, Australia and New Zealand partially enjoyed co-benefits, as they saw a slight improvement in welfare of USD 417 million, while all other regions experienced a decline. Although the impact on welfare was relatively small compared to GDP growth, the results suggest that capital-use subsidies could lead to substantial improvements in the welfare of countries, as well as promoting growth and competitiveness in target sectors.

9.3.4 Reduction of Greenhouse Gas

The technological improvement has led to increased productivity and efficiency in sea transportation-related sectors in Japan has contributed to reduce 8.4 million tons of GHG emissions under the policy intervention, which is equivalent to 0.9% of the total emission of Japan's sea transportation sector. This indicates that capital-use subsidies and policy interventions can play a crucial role in promoting sustainable practices and reducing GHG emissions in the sea transportation sector. Furthermore, the study also found that East Asia had a reduction of more than 3.0 million tons of GHG emissions, suggesting that the impact of such policy interventions can extend beyond national boundaries, potentially contributing to regional and global efforts to combat climate change (Fig. 9.6). For Australia and New Zealand, the effect was not significant, which may be partially due to the lower share of sea transportation by the two countries.

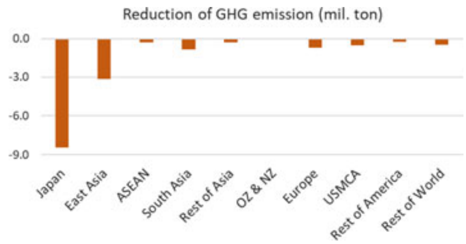


Fig. 9.6 Reduction of greenhouse gas emission (mil. ton)

9.4 Discussion and Concluding Remarks

9.4.1 Discussion and Policy Implications

The study employs the SPIAS-e indicators to generate a technology improvement scenario for Japan, specifically focusing on the impact of R&D. The simulation results could offer policymakers and stakeholders with a quantified reference of the combined effect of industrial competitiveness between countries, highlighting the importance of data acquisition infrastructure for evidence-based policy-making. Additionally, the capital-use subsidy on sectors such as electronics, solar power, and sea transportation, has demonstrated significant policy shocks, directly affecting the visualization of sectoral output, GDP, and welfare analysis.

The simulation results also address the implication on the economic partnership agreements between Australia, New Zealand, and Japan have not only focused on investment and technology transfer but also on strengthening collaboration towards more sustainable and environmentally-friendly practices, particularly in the area of shipping. The global shipping industry has been identified as a significant contributor to greenhouse gas emissions and climate change. Eco-friendly shipping practices such as the use of low-carbon fuels, energy-efficient design, and improved logistics can reduce the sector's carbon footprint and contribute to global efforts towards achieving net-zero emissions.

More importantly, the impact assessment is expected to incentivize collaboration towards a net-zero carbon society for the study's focus on agricultural trade is particularly relevant to the global food supply chain, which is a crucial aspect of sustainable development. Ensuring the resilience of the global food supply chain is essential to achieving a sustainable future, particularly in light of the challenges posed by climate change, increasing demand for food, and the need for more efficient and environmentally-friendly production practices.

Thus, the scenarios and policy consequences of the study can be applicable to other regions that are involved in the global food supply chain, emphasizing the importance of collaboration towards achieving sustainable and eco-friendly practices in the industry.

9.4.2 Future Prospective

The study presented comprehensive simulation results, utilizing calibrated scenarios from the GTAP database v10 and SPIAS-e to model the impact of technology change on greenhouse gas (GHG) emissions. However, to provide a more comprehensive analysis, technology parameters from other regions are required. The development of a consistent technology parameter benchmark is crucial to address the gap in technological change and ensure accurate and reliable analysis. The implications of the benchmark would enable policymakers and researchers to better understand the role of technology in achieving a net-zero carbon society.

Moreover, to effectively invest in strategic sectors, GHG emission reduction data must be considered. Developing a carbon credit mechanism would be an essential step towards creating a roadmap to achieve a net-zero carbon society. Additionally, connecting the effect of GHG reduction with welfare can serve as an indicator for a net-zero society. This approach would enable policymakers to evaluate the economic, environmental, and social implications of investments in strategic sectors and prioritize areas that have the potential to achieve the greatest benefits for society as a whole.

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Part III
Net-zero Measures Under International Framework

Chapter 10
Moving Toward Net-Zero Emission Society: With Special Reference to the Recent Law and Policy Development in Some Selected Countries

Hsing-Hao Wu

Abstract By the Sixth IPPC Report issued in August 2021, man-made greenhouse gases emission is responsible for approximately 1.1 °C of warming between 1850 and 1900, and the global temperature is expected to reach or exceed 1.5 °C by 2041. The IPPC thus urges world leaders to adopt substantial and sustained reductions to reduce carbon dioxide (CO_2) and other greenhouse gas emissions to stabilize global temperature by the next 20–30 years. In East Asia, the Former Prime Minister of Japan, Yoshihide Suga, declared that Japan will become carbon–neutral by 2050. The commitment has been further endorsed by his successor Prime Minister Kishida Fumio. Korea enacted the Carbon Neutrality Act, which requires the government to cut greenhouse gas emissions in 2030 by 35% or more from the 2018 levels in August 2021. In China, President Xi Jinping committed to achieving carbon neutrality by 2060 at the U.N. General Assembly in September 2020. In Taiwan, President Tsai Ing-wen announced on April 22, 2021, that Taiwan will achieve carbon neutrality by 2050. The road to achieving net-zero emissions is an ambitious but challenging goal for each significant GHGs emitter in the Asia–Pacific region. Each country has its own economic, social, and technological foundation and capabilities and thus requires different approaches to achieve the same goal. This chapter explores the recent global trends with particular references to EU, U.S., and Japan's law and policy development aiming to achieve carbon neutrality goals by 2050.

Keywords Carbon neutrality · Net-zero emission · Climate change mitigation · Climate law · Energy transition · Carbon sink

10.1 Introduction

The increasing industrial development and global population have caused enormous greenhouse gas emissions to the atmosphere in the post-WWII era. In the past three

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decades, the intensifying global warming has resulted in extreme weather events that have resulted in severe and frequent natural disasters worldwide. The most recent Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report was issued in August 2021, stating that the human-induced greenhouse gases emission is responsible for an approximately 1.1 °C increase compared to the pre-industrial level, and the global temperature is expected to reach or exceed 1.5 °C by 2041 (Intergovernmental Panel on Climate Change 2021). The most recent report issued by the IPCC entitled "Climate Change 2022: Impacts, Adaptation, and Vulnerability" indicates that if the world could achieve the net-zero emission goal by 2050, the global temperature rise would reach 2.5 °C. The intensifying global warming has resulted in extreme weather events that have resulted in severe and frequent natural disasters worldwide. In response to escalating climate risks, there is urgency for an international society to seek more robust and more ambitious GHGs emission reductions measures; IPPC also urges world leaders to adopt substantial and sustained reductions measures to reduce carbon dioxide (CO_2) and other GHGs emissions to stabilize global temperature rising by the next 20–30 years (Intergovernmental Panel on Climate Change 2022). The recently concluded COP26 in November 2021 has established the Glasgow Climate Pact, urging contracting parties to reduce global carbon dioxide emission by 2030 relative to the 2010 level and further seek net-zero emission by mid-century to limit global temperature rise to 1.5 °C (UNFCCC 2021).

In achieving the NCDCs set by states by 2030 or even the net-zero emission commitments by 2050, energy transitions are deemed the priority to reduce CO_2 emissions significantly. In addition, the enhancement of carbon sink from forest conservation, soil protection, and the ocean is also vital in climate actions. Major carbon-emitting countries or entities such as the EU, U.S., Japan, Korea, China, and India have proposed specific timetables for net-zero carbon emissions and carbon neutrality before or at the COP26. In achieving the net-zero emission commitment, there is a great necessity to establish a comprehensive policy framework outlining a clear roadmap and appropriate policy instruments such as the development of carbon tax, carbon pricing, carbon trade schemes, and other carbon–neutral policies to achieve carbon neutrality targets. Global GHG emissions could break into four major sectors: energy, agriculture, industry, and transportation. A recent survey reveals that 73% of global GHGs emissions come from energy consumption (Our World in Data 2020). Shifting energy consumption from fossil fuel combustion to clean energy sources plays a crucial role in achieving carbon neutrality. The carbon reduction in the industry includes the carbon footprint calculation, introduction of innovative carbon capture technology, and adjustment of the manufacturing process. However, the energy transition process requires significant government incentives to promote renewable energy development.

This chapter will first explore the global trends of incorporating net-zero emission targets into legal and policy frameworks. Law and policy development aiming to achieve net-zero emission targets in Japan, Korea, and Taiwan will be explored. The chapter will discuss and analyze legal issues and practical challenges concerning the energy transition, carbon sink enhancement, green transportation, and energy transition legal and policy development. Some policy suggestions will be provided for policymakers regarding the future legal and policy.

10.2 Global Trends in Achieving Net-Zero Emission Goals

10.2.1 International Trends in Moving Toward Net-Zero Emission Goal

The Glasgow Climate Pact, as mentioned earlier, urges contracting parties to reduce global carbon dioxide emissions by 45% by 2030 relative to 2010 and to net-zero around mid-century to limit global temperature rise to 1.5 °C (UNFCCC 2021). Glasgow Climate Pact is the first international climate agreement that sets explicitly the goal for phasing down coal usage within the next decade. However, more than forty states have developed more ambitious plans for phasing out coal usage at the COP26 (Guardian 2021). It is also notable that the COP26 encourages governments and enterprises to work coherently toward a "zero-carbon economy". There are several remarkable climate mitigation initiatives made during the COP26, including the joint initiative reached by the U.S. and the E.U., the Global Methane Pledge signed by 105 countries, and the Glasgow Leaders' Declaration on Forest and Land Use endorsed by hundreds of world leaders that pledges to end deforestation and land loss by 2030 (International Energy Agency 2022). In addition to sovereign states, 11 large international automakers announced that they will eliminate fuel vehicles by 2040, and 22 significant airlines signed the "Clydebank Declaration", aiming to establish six green routes by 2025 (Department of Transport U.K. 2021). The Glasgow Climate Pact has sent a clear signal for ending the era of coal usage and moving toward a low-carbon economy. In the face of global trends in achieving net-zero emission to limit global temperature rise by 2.1 °C by 2050, there is a great necessity and urgency for states to accelerate the progress in phasing down fossil fuel combustion in the energy sector. The improvement of the energy transition, electrified transportation and industry sectors, and the enhancement of natural carbon sinks has thus become critical for many significant GHGs emission states committed to reaching net-zero emission by mid-century.

10.2.1.1 EU Experience

EU has committed to moving toward a carbon–neutral economy and society by 2050 while signing and ratifying the Paris Agreement in 2015. As required by the Paris Agreement, the EU submitted its long-term greenhouse gas emission reduction strategy and climate plans pledging to reduce EU emissions by at least 55% by 2030, compared to 1990 levels in 2020. Thus, the EU must establish a clear and ambitious law and policy framework to achieve the net-zero emission goal by 2050. On July 14, 2021, the EU Commission adopted a comprehensive package, namely the Delivering the European Green Deal, which aims at setting a clear plan and ambitious goals and actions in response to urgent global climate risks. Under the European Green Deal, the EU commits to reducing GHG emissions by at least 55% by 2030, compared to 1990 levels, and reaching the first carbon–neutral continent by 2050 and this proposed goal (EU Commission 2021).

European Green Deal is developed to become a legal development plan aligned with the 2030 Climate Target Plan published in September 2020. As discussed earlier, the GHGs emission by the energy sector contributes the largest share of the overall GHGs emission at the global and state level. Twofold approaches should be conducted to decrease fossil fuel combustion in the energy sector. They enhance energy efficiency and increase the ratio of energy mix's ratio of low-carbon energy sources achieving the GHGs emission target set by any state or regional organization such as the EU, and decarbonized production and consumption play a vital role in climate change mitigation. EU's initiative of FIT-55 is a comprehensive law and policy package aiming to achieve the EU's GHGs emission reduction target of reducing 55% GHGs emissions compared to the 1990 level and net-zero emission commitment. The EU's GHGs emission long-term goal has also been incorporated in European Climate Change Law as a legally binding goal (EU Parliament 2021).

The FIT-55 is a comprehensive legal and policy package encompassing climate, energy, building, carbon trade, land use and planning, transportation, and other areas to achieve the EU's carbon neutrality goal by 2050. The main features of the FIT-55 are as follows:

1. The EU Emissions Trading Scheme (EU ETS) will be further expanded. From 2030, the free emission allowances of the aviation industry will be cancelled. The practical experience of relevant laws and the impact on the international aviation industry will be further assessed.
2. EU "Carbon Border Adjustment Mechanism" (CBAM) will be applied to imported steel, aluminum, cement, and other high carbon emission commodities. If importers do not pay the carbon fee at host countries or have a value gap with the EU carbon tax, they must purchase quotas (carbon rights) from the EU ETS market.
3. In 2035, the sale of fuel vehicles will be banned; in 2025, construction and road transportation will include fuel suppliers in the new emissions trading mechanism.
4. Revise the Renewable Energy Directive to increase the proportion of renewable energy. By 2030, the proportion of renewable energy will reach 40% (the original target is 32%).
5. Amend the Energy Tax Directive to implement the reform of the energy tax system. Home heating, shipping, aviation, fishing, and electricity supply will be included in the scope of taxation.
6. Adopt the EU Land Use, Land-Use Change and Forest Conservation Act (LULUCF), requiring the Member States to reduce less natural-based management, forest conservation, restoration, and prohibition of deforestation solutions)

climate action reduces 310 million tons of carbon dioxide (CO_2) emissions to the atmosphere. A specific target is to plant more than 3 billion trees in Europe by 2030.
7. Create a Social Climate Fund to subsidize house efficiency improvements and alleviate vulnerable households' burden of energy costs.

EU energy law and policy development are thus incorporated as a core part of the FIT-55 package to ensure EU's increasing renewable energy share target to 40% by 2030 and relevant policy measures adopted to achieve EU's overall climate policy objectives. In addition to the FIT-55 package, the EU also established a "cap-and-trade" mechanism governed by public institutions to limit the total amount of GHGs emissions, which can be carried out through emission rights trading scheme. Regulated industrial activities include the energy industry, steel manufacturing, mining industry (including cement, glass, ceramics, and other sectors), and other sectors (including pulp and paper industry) (EU Commission 2021).

10.2.1.2 US Experience

On April 22, 2021, U.S. President Joe Biden officially announced that the U.S will achieve a 50–52% reduction from 2005 levels in economy-wide net greenhouse gas pollution by 2030 and reach net-zero emission by 2050. President Biden also asks that federal actions seek to achieve 100% carbon pollution-free electricity by 2030, 100% zero-emission vehicle acquisitions by 2035, and a net-zero emissions building portfolio by 2045. In 2021, the U.S. government established an updated 2021 Long-Term Strategy of the U.S that provides multiple pathways for the American economy to achieve net-zero emissions by 2050 (U.S. Department of States and the U.S Executive Office of the President 2021).

In response to global trends for an energy transition from fossil fuel as a primary energy source to renewable energy sources, there is an urgent need for the federal government to set a national renewable energy ratio target and clear implementing schedule. However, the federal power in promoting renewable energy development is somehow limited. The States, on the other hand, take the leading role in taking climate action. California, for instance, took the lead by establishing the Global Warming Solutions Act in 2006 (UpLiftCA 2020). The Global Warming Solutions Act sets the goal of reducing GHGs emissions back to 1990 by 2020, reducing statewide GHGs emissions to 40% below 1990 levels by 2030 (California Assembly 2006). The 2012 amendment of the state legislature imposed a carbon tax scheme for significant carbon emitters in financing air quality, affordable housing, access to clean transportation, and energy-saving projects for disadvantaged communities. As for energy transition, California has made remarkable progress in renewable energy, establishing the renewable energy portfolio standards that set escalating renewable energy procurement requirements for certain state entities to procure electricity generation from

RPS-certified facilities (California Energy Commission 2021). In addition, California also leads the nation in establishing market-based mechanisms such as the feed-in tariff and carbon cap-and-trade systems (California Public Utilities 2021).

10.2.2 The Role of Law and Policy Development in Moving Toward Net-Zero Emission Goal

In achieving the net-zero emission goal, the cap-and-trade system requires a solid legal foundation for many policies and measures adopted by the government at various levels, such as carbon emission reporting, carbon tax, and economic incentives. Establishing a comprehensive legal and policy framework to achieve net-zero emission goals is vital in providing a legal foundation for supporting climate-related policy measures and selecting an appropriate institutional framework. For instance, the energy transition policy, decreasing fossil fuel dependency for energy use and promoting renewable energy development, requires in-depth legal action in the face of urgent climate risks. The role of law in achieving net-zero emission goals is thus critical because setting mandatory renewable energy ratio targets, carbon emission reduction for each emitter, and market-based mechanisms may impact economic, environmental protection, spatial management, and even spatial management social transformation and thus requires legal endorsement. In addition, the widespread installation of wind power and solar PV may impose significant legal challenges to the existing legal framework. A comprehensive legal and policy framework that addresses renewable energy development is thus vital in achieving the energy transition goal.

10.3 Overview of Net-Zero Emission Policy in Asian Countries

10.3.1 Japan's Law and Policy Development Toward Net-Zero Emission

The Paris Agreement requires all contracting parties to submit their nationally determined contributions (NDCs) illustrating each country's climate change mitigation policies and implementation measures (United Nations Climate Change 2021). In response, Japan's "intended nationally determined contributions (INDCs)" was at the level of a reduction of 26% in 2030 when compared to the 2013 emission level (Ministry of the Environment of Japan 2021). Prime Minister Suga declared in 2020 that Japan would aim to achieve carbon neutrality by 2050 (Ministry of Economy, Trade and Industry 2020). Specifically, Japan commits to reduce 46% GHGs emissions from the 2013 emission level by 2030 and complete the long-term goal of carbon neutrality in 2050. To reach the carbon neutrality goal, the Japanese government initiated the "Green Growth Strategy Through Achieving Carbon Neutrality in 2050" (Green Growth Strategy) in December 2020. (Ministry of Economy, Trade and Industry 2021) The Green Growth Strategy is the primary policy framework that outlines action plans for 14 priority industries, including energy, commercial, industrial, and transportation, to achieve carbon neutrality. Each action plan sets specific carbon neutrality goals and time frame, research and development financing mechanisms, and regulatory and institutional arrangement for overseeing and implementing each action plan. The Japanese government commits to establishing a large-scale fund of two trillion yen to provide financial support to enterprises attempting to adopt carbon neutrality solutions by 2030.

The decarbonization of the power sector is the primary target and essential task for the Japanese government in achieving the carbon neutrality goal. The Green Growth Strategy commits to introducing various renewable energy sources to the maximum extent possible. The promotion of solar PV, offshore wind power, and storage batteries technology has been highlighted. Thermal, hydrogen, and even nuclear power have been encouraged as decarbonized power options. Notably, the Japanese government deems atomic force an established decarbonization technology to enhance safety and reduce reliance during the energy transition period. The Green Growth Strategy sets a power generation target from renewable sources accounting for 50–60%; thermal and carbon recycling for 30–40%; and hydrogen and ammonia for 10%. In addition to significantly increasing the renewable energy sources for electric power generation, the Japanese government also seeks research and development of innovative low-carbon power technology. For instance, the Green Growth Strategy also calls for the electrical action of electrical automobiles, hydrogen storage batteries, and carbon capture and storage technologies in power systems, such as establishing the intelligent power grid system to achieve energy-efficiency goals.

After the start of the feed-in tariff (FIT) system in July 2012, the introduction of renewable energy expanded mainly to solar photovoltaic (PV) power. Japan's Ministry of the Environment has implemented a nationwide Japan voluntary Emission Trading Scheme (JVETS) since 2005. JVETS subsidizes manufacturers in exchange for more energy-efficient production equipment and is based on carbon rights issuance and emissions trading to meet carbon reduction targets. Japan started the Tokyo-Emission Trading Scheme (Tokyo ETS) in 2010. Tokyo ETS uses the 2000 emission level as the base year to reduce greenhouse gas emissions by 25% in the Tokyo area by 2020. Tokyo ETS is a mandatory carbon trading system driven by a compulsory specification to include carbon emission caps. There are currently about 1100 commercial facilities and 300 factories with high carbon emissions to be regulated, accounting for 20% of total emissions in the Tokyo area. The now controlled greenhouse gas is mainly CO_2, which will be expanded to other greenhouse gases in the future.

10.3.2 Korea's Law and Policy Development Toward Net-Zero Emission

Since Korea has doubled its GHGs emissions between 1990 and 2008 due to rapid industrialization and economic growth, Korea has become one of the top ten emitters globally and one of the countries with the highest growth in GHG among the OECD member countries. In 2008, President Lee Myung-bak announced that Korea would become a low-carbon/green growth country in the next 50 years to improve the international community's perception of lacking substantial climate change mitigation efforts from the Korean government. Following President Lee's commitment, the Korean government initiated the "National Green Growth Strategy" (2009–2050) and the five-year green growth action plan (2009–2013) in 2009 to provide a comprehensive policy framework aiming to promote green growth. In providing the National Green Growth Strategy legal endorsement, the Korean National Assembly passed the "Framework Act on Low-Carbon Green Growth Law" in January 2010 (UNEP, Law and Environment Assistance Platform 2021).

The Framework Act on Low-Carbon Green Growth (Green Growth Act) serves as the primary legal framework to implement the Green Growth Strategy policy objectives to enhance the energy transition, carbon reduction policies, institutional arrangements, and related implementation strategies. The Green Growth Act stipulates that government should set medium-term GHGs emission reduction goals, annual GHGs emission reduction targets, and energy-efficiency targets for various sectors. The Green Growth Act requires the central government to establish the Presidential Green Growth Committee regarding the institutional arrangement. In contrast, local governments set up local green growth committees in 16 cities and provincial governments. Based on each local green growth committee shall formulate the "local green growth implementation plan" based on regional characteristics Year Plan requires the Korean government to designate specific tasks for involved ministries and local authorities and invest an annual budget of about 2% of Korea's total GDP in implementing the detailed plans and projects.

The Green Growth Strategy identifies energy transition as a priority and vital policy objective. It thus requires coordinated support from establishing a comprehensive energy law and policy framework to reduce fossil fuel consumption within the time frame. Accordingly, Korea amends its energy legal and policy framework to promote energy transition. The energy legal framework adopts a relatively top-down approach to guide general energy development for the nation. First, the government should propose the "National Energy Basic Plan" as the comprehensive and basic energy policy framework, which provides the policy objectives and implementation measures to enhance overall energy security, setting the targets in terms of the energy mix, renewable energy ratio, electricity pricing, and GHGs reduction in the power sector. According to the policy guidelines of the National Energy Basic Plan, the subordinate implementation plans for various energy dimensions, such as renewable energy development, shall also be initiated. Green Growth Act also urges the government to draft the Emission Trading Scheme (ETS) and carbon tax-related regulations and policies and submit them to Korean Parliament for consideration.

Since President Moon Jae-in won the general election in 2017, Korea's energy policy has changed significantly compared with the previous government. During the election, President Moon Jae-in committed that his administration would dramatically reduce the energy dependence on coal and nuclear power if he could be successfully elected. After being the elected president, he promoted the "zero nuclear power policy" and replaced petrochemical and nuclear power with the increasing use of renewable energy and natural gas power generation. In response to the recent international trends in seeking GHGs net-zero emissions by mid-century, President Moon Jae-in officially committed to net-zero emissions by 2050 in one speech to Korea's national assembly in October 2020. The carbon neutrality goal has been incorporated in the Carbon Neutrality and Green Growth Act for the Climate Change (Carbon Neutrality Act) which the Korea National Assembly passed in August 2021. The Carbon Neutrality Act requires the government to reduce 37% of GHGs emissions by 2030 compared to the 2008 emission levels. In October 2021, Korea provided roadmaps on identified sectors and potential policy measures to achieve the carbon emission reduction goals by 2030, aiming to achieve the National Determined Contribution target required by the Paris Agreement and further the carbon neutrality target set to reach by 2050. To accomplish the INDCs submitted by Korea on June 30, 2015: the goal of reducing GHGs emissions by 37% in 2030 compared with the current development trend (Business as Usual, BAU). Since Korea's industrial sector accounts for more than half of energy consumption, reducing fossil fuel consumption with alternative energy sources, enhancing energy efficiencies, and introducing low-carbon technology in the industrial sector have become the primary policy objective to achieve the net-zero goal.

In achieving the legally binding GHGs emission reduction goal, the Korean government has adopted the updated Green New Deal to serve as a basic policy framework to implement specific measures on a sector basis, increasing the budget to 61 trillion won (52 bn USD). The New Green Deal aims to support the development of innovative climate technologies to expand the use of clean powers, improve energy efficiency, and enhance carbon sinks. In 2020, the share of coal-fired power generation decreased from 43 to 39%, while increasing the energy sources from LNG, nuclear, and renewable sources, mainly from solar PV. This shift resulted in a record-low emissions intensity of Korea's electricity sector. Nevertheless, the share of fossil fuels accounts for 67%, while renewables in the electricity sector are only 6%. In accelerating the progress of energy transition, the Korean government published the Ninth Electricity plan in December 2020. The plan sets clear electricity mix targets, confirming the Moon administration's intention to shift electricity generation away from coal. The plan sets a power mix of 30% coal, 25% nuclear, 23% LNG, 21% renewables, and 1% from other sources by 2030. Under the draft 2050 carbon–neutral scenarios, coal is phased out before 2050. The recent revision of the Renewable Energy Law in March 2021 has strengthened Korea's Renewable Portfolio Standard requiring major electric utilities to increase their renewables share to 10% by 2023 and 25% by 2034. The introduction of RPS is expected to significantly contribute to energy transition progress since mega-enterprises consume much electricity in Korean society.

10.3.3 Taiwan's Law and Policy Development Toward Net-Zero Emission

Taiwanese President Tsai Ing-wen announced on April 22, 2021, to achieve carbon neutrality by 2050. To achieve that goal, the Taiwanese government is taking a two-pronged approach: pushing for energy transition and reducing GHG emissions from manufacturing, transportation, residential construction, and agriculture**.** The Net-zero Pathway Task Force has been formulated to achieve the climate goal since declaring Taiwan's commitment to attaining net-zero emissions in 2050. The Task Force is mainly conducted by the National Development Council, overseeing four divisions: decarbonization of energy, energy efficiency and industry, green transportation, and carbon sink. The INDCs announced by the Executive Yuan in September 2015 are based on the INDCs submitted by significant countries and on 2005 emissions. The 20% of GHGs emissions shall be reduced by 2030. To establish a legal basis for GHGs emission reduction in response to the high pressure of the international community on energy conservation and carbon reduction in the future, Taiwan Congress passed the law "Greenhouse Gas Reduction and Management Act" in July 2015. "Greenhouse Gas Reduction and Management Act" sets the national GHGs long-term reduction target to reduce GHG emissions to more than 50% of 2005 GHG emissions by 2050. In response to President Tsai's net-zero commitment, the Executive Yuan proposed the "Climate Change Action Act" Bill to replace the existing "Greenhouse Gas Reduction and Management Act" in 2021. The Climate Change Responsive Action Bill expressly incorporates emission goals as a legally binding obligation to the government. The Bill also refines the GHGs emission reduction mechanisms as established under the "Greenhouse Gas Reduction and Management Act", including institutional rearrangement in overseeing the implementation of net-zero emission policy, carbon fees collection, the establishment of climate mitigation fund, and clear mid-term and long-term GHGs emission reduction goals (Taipei Times 2021).

Similar to other jurisdictions such as Japan and Korea, the energy sector accounts for The Ministry of Economic Affairs that is responsible for policy initiated for Renewable Energy Development. The Energy Management Act requires the government to create an Energy Basic Plan to increase electricity production from renewable sources to 20% by 2025. However, the renewable sources' electricity percentage accounts for only 5.47% in 2. A comprehensive and sound regulatory framework is critical in promoting the sustainable development of renewable energy. Taiwan has established laws on promoting the development of renewable energy through the revision of the "Greenhouse Gas Reduction and Management Act", the "Renewable Energy Development Act", and the amendments to the "Energy Management Law" since 2009. The "Greenhouse Gas Reduction and Management Act" requires the government to develop medium- and long-term strategies to reduce fossil fuel dependence and set medium- and long-term goals for renewable energy development. The Renewable Energy Development Act is a special law for promoting the use of renewable energy. The Act aims to encourage private investment in renewable energy power generation equipment and related industries through economic incentives, loosening of regulations, and government subsidies (FIT). The significant expansion of large-scale solar PV park, offshore wind power, and fishery and electricity symbiosis projects has been planned and installed nationwide.

Unlike Japan and Korea's use of nuclear power as alternative energy sources to fossil fuel, President Tsai Ing-wen and the ruling party of the Democratic Progress Party (DPP) under her leadership have pledged for non-nuclear homeland policy since President Tsai took office in 2016. DPP government thus has promulgated the Energy Basic Plan aiming to remove nuclear power and shift to LPG (50%), coal (30%), and renewable energy (20%) for gross electricity production by 2025 (Fig. 10.1, (Taiwan Bureau of Energy, Monthly Statistics Report 2022). However, Taiwan's energy transition plan has received enormous public opposition due to worrisome electricity shortage due to slow progress and unstable supply of renewable energy development and environmental concerns. The public opposition resulted in two referendums related to energy policy on December 18, 2021. The first referendum is whether to activate the fourth nuclear plant that was postponed for construction in 2015. The second is building a new natural gas terminal that may harm the precious algal reef biodiversity at the proposed construction sites. The results of these two referendums support the government's non-nuclear homeland policy and building sizeable, liquefied petroleum gas (LPG) terminal to use natural gas as interim energy and support the growth of the share of renewable energy in electricity production target by 2025 and eventually net-zero emission in the long run. Taiwan's experience first shows the importance of establishing open, transparent public participatory mechanisms for energy transition decision-making. It, however, lacks well-communications and informed of the net-zero policy and energy transition with the general public and renewable energy facilities onsite communities would eventually slow down the progress in moving toward a net-zero emission society and energy transition (Ho 2021).

Notably, the Council of Agriculture has taken the lead in formulating net-zero emission policies in the agriculture sector in Taiwan. Council of Agriculture first establishes the Office of Net-Zero Emission. It publishes the first comprehensive and clear net-zero emission pathway and roadmap in the agriculture sector 2040 in February 2022. However, compared to Taiwan's overall carbon emissions of 287 million tons, agricultural carbon emissions only account for 2.22%. The territory of Taiwan is covered by approximately 61% by forest and thus shows great potential for its carbon sinks. Under Taiwan's GHGs emission inventory report released in 2019, the forest carbon sink per hectare was 9.76 metric tons, a total of 21.44 million tons.

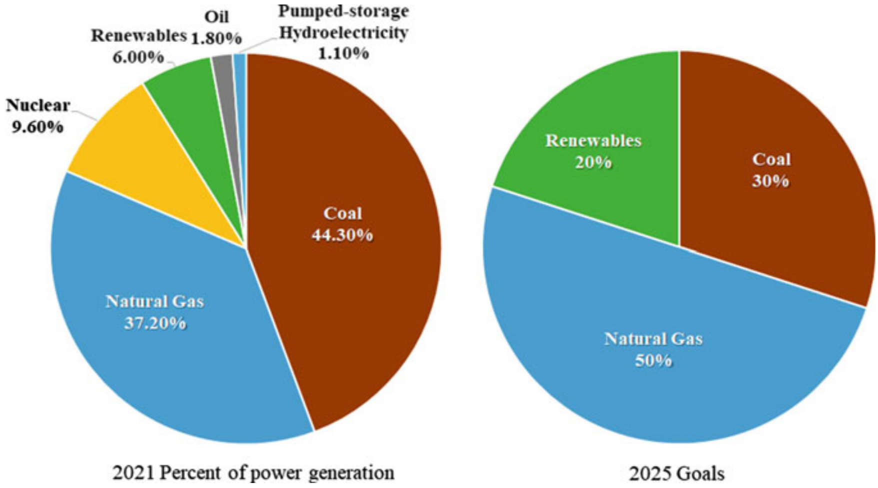

Fig. 10.1 Taiwan's energy shift *Source* Compiled by authors based on Monthly Statistics Report 2022/5 Issue, Taiwan Bureau of Energy (Taiwan Bureau of Energy, Monthly Statistics Report 2022)

The carbon sink of the forest alone could easily offset total carbon emissions in the agriculture sector.

There are four main features of agricultural net-zero emissions roadmaps aiming to achieve net-zero emission goal in agriculture by 2040: (1) The roadmap comprehensively assesses the carbon emission inventory of agricultural production and establishes a low-carbon production model of an agricultural, fishery, and livestock to achieve the GHGs emission reduction target; (2) enhancement of carbon sinks through forest management, improving the utilization of domestic wooden materials, strengthening ocean and wetland management, developing low-carbon farming methods; (3) promoting agricultural cross-domain recycling demonstration sites, enhancing scientific and technological research, developing agricultural recycling technology, and creating agricultural value-added reuse; and (4) promoting carbon pricing and carbon rights trading systems in the agricultural sector and agricultural finance and green consumption to achieve autonomous power generation and self-sufficiency in electricity consumption in farming and fishing activities.

10.4 Comparative Study and Suggestions for Policymakers in Achieving Net-Zero Emission

The comparative analysis indicates that the EU has established a comprehensive net-zero framework providing enough legal basis for institutional arrangement, apparent energy efficiency and renewable energy share target and timetable, and financial mechanism. The most crucial feature of the EU energy law is its connectivity with the

EU's latest commitment to the GHG emission goal and overall roadmap to achieving a net-zero emission goal by 2050. EU energy law constantly evolves by strengthening binding renewable energy share, financial mechanisms, and social and general public engagement as part of EU's overall climate solutions and social transformation packages aiming to become the first decarbonized continent. The energy law and policy adopted by Korea, Taiwan, and Japan seem less coherent in incorporating energy transition policy into a comprehensive climate policy framework. It is partly due to a lack of a complete net-zero emission policy and institutional framework that integrates all relevant sectors, including energy, building, transportation, and industry. Japan and Taiwan have established special legislation regulating offshore wind power development due to complicated marine spatial management, environmental impact assessment, and cross-administration authorities. The special Legislation on Offshore Wind-power Promotion and Development Act deals with permit issuing, FIT pricing arrangement, installed capacity auction, and government surveillance mechanism.

The law and policy adopted by Japan and Korea focus more on the capacity building for renewables ranging from solar, wind power, biomass, and hydrogen and promoting innovative technology development such as storage batteries and hydrogen fuel. Japan adopts a relatively top-down model in enhancing the capacity and technological development for renewable energy development. The coherent energy policy incorporated into Japan's comprehensive climate roadmap and necessary legal action requires further observation. The following chapter provides important issues and suggestions for policymakers to consider while formulating or reshaping renewable energy laws and policies.

10.4.1 Establishing a Comprehensive Climate-Related Legal and Policy Framework Aiming at Net-Zero Emission Goals

As discussed earlier, the GHGs emission by the energy sector contributes the largest share of the overall GHGs emission at the global and state level. In achieving the GHGs emission target set by any state or regional organization such as the EU, energy production and consumption decarbonization are vital in climate change mitigation. EU's initiative of FIT-55 is a comprehensive law and policy package aiming to achieve the EU's GHGs emission reduction target of reducing 55% GHGs emissions compared to the 1990 level and net-zero emission commitment. The EU's GHGs emission long-term goal has also been incorporated in European Climate Change Law as a legally binding goal (EU Parliament 2021).

The FIT-55 is a comprehensive legal and policy package encompassing climate, energy, building, carbon trade, land use and planning, transportation, and other areas to achieve the EU's carbon neutrality goal by 2050. EU energy law and policy development are thus incorporated as a core part of the FIT-55 package to ensure

EU's increasing renewable energy share target to 40% by 2030 and relevant policy measures adopted to achieve EU's overall climate policy objectives. In addition to the EU's approach, Japan, Korea, and Taiwan adopt relatively different net-zero emission strategies based on other sectors. Renewable energy development, as explored earlier, is either focusing on energy efficiency or renewable energy capacity building instead of establishing a coherent solid relationship with the nation's comprehensive climate policy framework and carbon neutrality commitment. Energy transition may significantly impact the economy, society, and politics, no less than a nation's total solution to climate change risks. This chapter thus suggests policymakers adopt the EU's legal experience in incorporating energy transition into overall long-term climate policy framework such as the FIT-55 package, establish a comprehensive and concrete climate law or policy framework, and then include renewable energy law and policy as a vital part of achieving the long-term GHG emission target and carbon neutrality goal.

10.4.2 A Necessity for Establishing a Coordinated Institutional Framework Responsible for Net-Zero Emission Policy

The regulatory and overseeing institution design varies from country to country based on various constitutional and social backgrounds. Some countries adopt the division approach to designating different governing institutions responsible for renewable development and oversight. EU sets up clear and binding GHG emission targets, the share of renewable energy targets for each Member State's overall energy mix, and the phase-out of burning coal timetable for EU In contrast, Member States can adopt appropriate and flexible legal and policy measures to achieve the GHGs emission reduction target by 2030 and the net-zero emission goal by 2050. Japan, Taiwan, and Korea adopt a similar top-down approach by incorporating net-zero emission commitments into national legislation. In achieving the net-zero emission goal, several laws and regulations have proposed legal mandates for establishing market-based mechanisms and special legislation regulating and promoting specific renewable energy sources such as offshore wind power.

Notwithstanding the various institutional arrangements concerning the supervision and promotion of decarbonized energy sources, there is an excellent necessity for establishing a solid coordinated institutional framework because net-zero emission target achievement involves a lot of legal adjustments and innovative approaches to the energy market, electricity services, energy installation regulation, building regulation, taxation, and environmental impact assessment. Moreover, central (federal) and local governments shall work closely since land development, energy installation, and building approval authorities lie on the local government. Policymakers are advised to establish a high-level, well-coordinated, cross-agency institutional framework that supervises renewable energy development. A robust, coordinated governance mechanism should also ensure transparent and effective communication between central, local authorities, and communities where major renewable energy installations are located. It is also critical to provide financial incentives for industry and businesses to their bottom-up approach for a net-zero business strategy.

10.4.3 Net-Zero Emission Strategies shall also Consider Biodiversity Conservation, Community, and Social Impacts

Japan, Korea, and Taiwan have high population densities with limited spaces in countries. Implementing net-zero policies and projects such as widespread renewable energy development may conflict with biodiversity conservation and human health concerns. Many public or private-owned lands designated initially for agriculture, aquaculture, forest protection, or biodiversity conservation purposes may turn to solar PV and wind farm facilities installation usage. Professor Liu, a renowned expert in agriculture economics in Taiwan, indicates that renewable energy development would compete with farmlands, hillslope lands, and pastoral lands. The energy transition may be critical in reaching the Taiwanese government's ambitious goal of moving toward net-zero emissions by 2050.

Establishing grounding solar PV systems on sensitive biological areas, such as agriculture or forestry lands on the hillslope, may result in environmental impacts on hillside landscape, biodiversity, and soil and water resources conservation. The large-scale installation of solar PV may result in crop-harvesting loss, biodiversity, landscape value loss, pollution damage as a result of radioactive effects, and waste handling costs for decommissioning of photovoltaic panels shall all be considered while conducting the cost–benefit analysis for specific renewable energy development projects that alters the current usage of lands and their potential damages to the environment.[1] The economic and environmental costs for renewable energy development projects on farmland and hillslope forest lands thus should be evaluated comprehensibly. In addition, the wind farm development shall also conduct an environmental impact assessment because wind energy development may negatively impact marine biodiversity for offshore windfarms and noise disturbance to local communities for onsite windfarms. In achieving the net-zero emission goal, low-carbon or green technology development plays a vital role in the energy transition context. This chapter thus suggests that energy competent authorities should cooperate with other agencies such as agriculture and environmental protection responsible authorities to conduct ecological studies and then announce the least environmentally sensitive areas suitable for renewable energy development. Policymakers should further establish an environmental and agriculture evaluation scheme to screen project-based renewable energy development outside this promulgated least environment more sensitive areas.

[1] Interview with Distinguished Professor Wan-Yu Liu, Department of Forestry, College of Agriculture and Natural Resources, National Chung-Hsing University, Taiwan. December 12, 2021.

10.4.4 The Enhancement of Carbon Sink from the Ecosystem and Public–Private Partnership

Achieving carbon neutrality mainly depends on long-term planning and intensive policy and technology development to improve renewable energy, battery storage, green transportation, energy efficiency, and carbon capture and storage. There are limitations of carbon reduction technology, notwithstanding how progressive these technologies are to be evolved within the next decades in achieving carbon neutrality goals for each country or region. The enhancement of carbon sink thus plays a vital role in offsetting remaining GHGs emissions even though utmost efforts in terms of carbon reduction and energy transition have made remarkable progress. Forests, soils, oceans, and soils have diverse ecological service values and great potential to absorb or store significant carbon dioxide. It is thus critical and beneficial to protect the ecosystems by enhancing forest management, wetland and marine conservation, and incorporating environmental considerations in land planning and usage. This article suggests that a coordinated institutional framework should be established comprising government officials, experts, industry, and NGOs to evaluate existing environmental conservation laws carefully and carbon neutrality goals, and the enhancement of carbon sink from natural resources plays a vital role in the industrial sector seeking carbon offset solutions in meeting legal binding GHGs emission reduction goals. Thus, it is critical to enhance government–private enterprises and academic partnerships in carbon evaluation, carbon pricing, and carbon credits transfer and trading. In addition to the government-led net-zero emission efforts to establish a comprehensive legal and policy framework and implementation measures, the voluntary programs conducted by private parties, especially from major CO_2 emitters, could contribute to the national net-zero emission target.

On a global scale, the Climate Group and Carbon Disclosure Program have coordinated the RE100 gathering of the world's most influential businesses committed to 100% renewable electricity. In addition to the RE100, some domestic efforts are led by private parties to initiate coordinated voluntary programs aiming to achieve net-zero emission goals. The Taiwan Climate Alliance, for instance, has been formulated by several major ICT companies in Taiwan. Members of the Alliance commit to using 100% renewable energy in the manufacturing processes by 2050. The members of the Alliance also save to leading manufacturers in their supply chain to jointly achieve the 100% green power target. Another example is the establishment of the Taiwan Alliance for Net Zero Emission. Taiwan Alliance for Net Zero Emission comprises traditional manufacturing, ICT enterprises, finance, and service industries. The Alliance aims to attain net-zero carbon emissions at office sites by 2030 and production sites by 2050. The Taiwanese government supports private stakeholders' voluntary efforts by creating a friendly legal and policy environment and policy guidance for green financial mechanisms such as green financing and green bonds to support the industry in attaining net-zero emission goals (Chang 2021).

10.5 Conclusion

In the face of the global climate crisis, world leaders have finally taken actual actions to mitigate the GHGs emission and even committed to reaching net-zero emission by the mid-century. The energy transition is an indispensable and vital part of each country or regional organization in achieving their NDC of GHGs emission target by 2030 required by the Paris Agreement and the long-term commitment to reaching the net-zero emission goal since the energy sector accounts for most of the GHGs emission globally and in most states. Energy transition may significantly impact the existing legal framework concerning the inter-agency governance mechanism, economic instruments adjustment, and even the subsidy policy for industry and disadvantaged groups. While facing the challenges of keeping the temperature rise within 1.5 °C, decarbonized energy policy should be an integral part of climate response packages aiming to achieve a state's GHGs emission reduction and net-zero emission long-term goals. The energy transition, low-carbon technology development, and natural carbon sink enhancement involve social and economic transformation. Thus, receiving public support and comprehensibility requires a strong cross-agency and central/local government coordinated institutional framework, open and transparent general participatory decision-making mechanisms, and environmental and biological loss and damages evaluation schemes implemented by competent authorities in approving renewable energy projects located in certain contested environmental sensitive areas.

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Chapter 11
Climate Impacts of Black Carbon and Methane Emissions in the Arctic and Current Frameworks for Prevention

Sakiko Hataya

Abstract Rapid environmental changes in the Arctic have brought increasing attention from the international community toward the region. Considering these circumstances, the Arctic Council (AC) provides an important vehicle for addressing Arctic issues. This paper first provides a basic overview on the Arctic Council and discusses recent organizational reforms. It also addresses how Japan is involved in the Arctic. Finally, this paper discusses what the Arctic Council, as well as other concerned countries, are doing to control black carbon emissions, which are a current problem in the Arctic.

Keywords Arctic Council · Black carbon · Japan's Arctic Policy

11.1 Recent Trends in the Arctic

The Arctic has warmed three times faster than the world as a whole, causing rapid and widespread changes in sea ice, land ice (glaciers and ice sheets), permafrost, snow cover, and other physical environmental features. The increasing impact of warmer waters and reduced sea ice in the Arctic Ocean from the Atlantic and Pacific Oceans has been associated with the northern expansion of subarctic fish and marine mammal species (Arctic Monitoring and Assessment Programme 2021). These rapid environmental changes in the Arctic have also led to the practical application of sea routes and the development of Arctic Ocean resources, which has piqued interest in the Arctic from the international community. The Arctic Council (AC) (Arctic Council 2022) is a high-level forum that provides a means to promote cooperation, coordination, and interaction among Arctic States regarding common issues.

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11.2 The Arctic Council

The Arctic Council was established by the so-called Ottawa Declaration as a "high-level forum" to provide a means for promoting cooperation, coordination, and interaction on Arctic issues by the members of the eight Arctic nations of Canada, Denmark, Finland, Iceland, Norway, Russia, Sweden, and the United States (Ottawa Declaration, Article 1). In addition to the functions mentioned above, the Council also oversee and coordinate the programs established under the Arctic Environmental Protection Strategy (AEPS) (The Arctic Monitoring and Assessment Program). In addition, the Council was established to adopt terms of reference for and oversee and coordinate a sustainable development program and disseminate information, encourage education, and promote interest in Arctic related issues (Ottawa Declaration, Article 1). A unique feature of the Arctic Council is that it grants the status of "permanent participant" to Arctic indigenous peoples' organizations (Aleut International Association, Arctic Athabaskan Council, Gwich'in Council International), and the category of permanent participation is created to provide for active participation and full consultation with the Arctic indigenous representatives within the Arctic Council (Ottawa Declaration, Article 2). Non-Arctic States, intergovernmental organizations, and non-governmental organizations that have been identified as having the ability to contribute to the work of the Council may participate in meetings as observers (Ottawa Declaration, Article 3).

The Arctic Council is a consultative forum for the eight Arctic States and usually meets every other year, although senior official meetings are held more frequently (Ottawa Declaration, Article 4). According to the Rules of Procedure of the Arctic Council (Arctic Council of Rules and of Procedure 1998), adopted at the first Arctic Council meeting in Iqaluit, Canada in 2006, the biennial meeting of the Council is named the "Ministerial Meeting," while the more frequent meetings are termed the "Senior Arctic Official (SAO)" Meetings. According to subsequent practice, SAO meetings are held approximately once a year. Article 7 of the Ottawa Declaration states that Arctic Council decisions are determined by a consensus of the member States. The Ottawa Declaration does not include the phrase "subordinate bodies" of the Arctic Council, but the 1998 Rules of Procedure explicitly States that "the Arctic Council may establish working groups, task forces or other subsidiary bodies to prepare and carry out programs, and projects under the guidance and direction of SAOs. The composition and mandates of such bodies shall be agreed to by the Arctic States in a Ministerial meeting. The activities of these bodies shall be subject to these rules." (Arctic Council Rules of Procedure 1998, Rule 28 of the Arctic Council Rules of Procedure) Even in these subordinate bodies, decisions are made by consensus among the eight Arctic States (Council Rules of Procedure, Article 30).

The Ottawa Declaration, Article 5, stipulates that "responsibility for hosting meetings of the Arctic Council, including provision of secretariat support functions, should rotate sequentially among the Arctic States." In this regard, the 1998 rules of procedure, Article 32, stipulate that "the host country shall be responsible for facilitating preparations for forthcoming Ministerial and SAO meetings, liaison, and coordination, providing secretariat support functions, and carrying out such other tasks as the Arctic Council may require or direct." As a result of this provision, the host country of the biennial Arctic Council Ministerial Meeting is designated as the chair country for the coming two years, and the SAO meetings to be held between the two biennial meetings are, in principle, to be held within the host country. Therefore, the rotating secretariat system was established, in which the Arctic Council Presidency was responsible for the annual meeting. In relation to the costs of meeting administration, which will be discussed subsequently, the 1998 rules of procedure specify that the working language of the Council shall be English (Article 41). Also, the rules of procedure says that individual may speak in a language other than English and in such cases that individual shall arrange for interpretation into English (Article 43). However, for ministerial and SAO meetings, the host country (presidency) will make reasonable efforts to provide Russian interpreters (Article 42).

It should be noted that some working groups established under the Arctic Environmental Protection Strategy (AEPS), which began in 1991, currently have permanent secretariats. These working groups and their secretariats, were successfully integrated into the Arctic Council by 1998 (Council 1998) and the Council, while expressing appreciation for the voluntary contributions of its member States to these working group secretariats, requests other Arctic States to also make voluntary, sufficient, and reliable contributions to the working group secretariats (Arctic Council Rules of Procedure 1998, para. 27). According to the Common Operational Guidelines for Arctic Council Working Groups (2016), the Working Groups and all their activities are subject to the terms of the Ottawa Declaration, the Arctic Council, the Council's Rules of Procedure, the Observer Manual, and other relevant documents of the Council (Arctic Council, Working Group Common Operating Guidelines 2016), clarifying that the Working Groups, including their secretariats, are subordinate bodies of the Arctic Council. Regarding the status of the Arctic Council under international law, the Ottawa Declaration that established the Council is not a treaty under international law.

11.3 The Recent Trend of the Arctic Council

The 12th Ministerial Meeting of the AC, held in Reykjavik, Iceland on May 20, 2021, was chaired by Iceland and included ministers of AC member states and representatives of indigenous organizations residing in Arctic nations to adopt the "Reykjavik Declaration."[1] Following the preamble, the declaration is divided into five parts: "People and Communities of the Arctic," "Sustainable Economic Development," "Climate, Green Energy Solutions, Environment, and Biodiversity," "Arctic Marine Environment," and "Stronger Arctic Council," and it gives responsibility

[1] The last time the meeting was held in Finland in 2019, a joint declaration could not be issued because the former U.S. administration of President Trump opposed the language surrounding climate change (Hokkyokuken, jizokugata no kaihatu wo hyougikai kakuryoukaigou de icchi 2021).

to the AC to maintain peace, stability, and constructive cooperation in the Arctic region. This commitment was reaffirmed. It also emphasizes the unique position of Arctic nations in promoting responsible governance and asserts the importance of immediately addressing climate change in the Arctic (Government of Iceland HP 2021). Although a joint declaration was not released at the 11th ministerial meeting in 2019, the inauguration of the Biden administration in the U.S., which emphasizes international cooperation, is considered a unifying statement of intent by the countries involved. Furthermore, at the 12th Ministerial Meeting, the “Arctic Council Strategic Plan (2021–2030)” was adopted for the first time on the 25th anniversary of the AC’s establishment, which provides guidance for that 10-year period. The plan identified seven goals: “Arctic Climate,” “healthy and resilient Arctic ecosystems,” “healthy Arctic marine environment,” “sustainable social development,” “sustainable economic development," "knowledge and communication,” and “stronger Arctic Council.”

The AC presidency was handed over from Iceland to Russia in 2021. Russia has identified “responsible governance for a sustainable Arctic” as a priority through promoting collective approaches to the sustainable development of the Arctic in a balanced way—environmentally, socially, and economically—enhancing synergy and cooperation and coordination with other regional structures, as well as the implementation of the Arctic Council’s Strategic Plan (2021–2030), while respecting international law. It also identifies priority areas as “people of the arctic, including indigenous peoples,” “environmental protection,” “socio-economic development,” and “strengthening the AC,” with particular focus on the AC in terms of, “improving its work, increasing the effectiveness of its working and expert groups, the Arctic Council Secretariat, as well as developing mechanisms for financing the Council’s activities, including its projects and programs, implementing decisions and recommendations, as well as encouraging the dialog and interaction with the observers to provide their meaningful and balanced engagement in the Council’s activities.” Also, “Russia intends to further intensify collaboration of the Arctic Council with the Arctic Economic Council, the Arctic Coast Guard Forum, and the University of the Arctic (Council 2021).”

11.4 Japan’s Recent Initiatives Concerning the Arctic

The Government of Japan considers Arctic policy to be an important issue because Japan’s geographical location makes it vulnerable to the effects of climate change in the Arctic, and also because Japan is the closest country to the Arctic Ocean in Asia and enjoys economic and commercial opportunities such as utilization of its shipping routes and resource development. The first comprehensive Arctic policy was implemented (Naikakufu (Cabinet Office of Japan) HP 2022; Cabinet Office and of Japan HP 2022a), and the Third Ocean Basic Plan, formulated in May 2018, positioned the Arctic policy as a main policy for the first time (Cabinet Office and of Japan HP 2022b).

On May 8 and 9, 2021, the governments of Japan and Iceland co-hosted the 3rd Arctic Science Ministerial (ASM3) in Tokyo that was attended by 35 countries/regions and indigenous groups, which was the largest number to date. The ASM3 aimed to promote research and observation in the Arctic, address major social issues, and further promote scientific cooperation among the countries concerned as well as indigenous groups living in the Arctic region. Co-chaired by Japan and Iceland, the discussion focused on the theme "Knowledge for a Sustainable Arctic," with "observe, understand, respond, and enhance" as a sub-theme. Agreements were made to promote international collaboration in the field of Arctic science, accelerate the understanding of the region, and support science as a basis for policymaking in the Arctic. In October 2021, a handover ceremony from ASM3 to ASM4 was held at the Arctic Circle Assembly in Reykjavik, Iceland, and the Japanese Ambassador to Iceland, Ryotaro Suzuki, who attended the ceremony, stated that it is essential to strengthen international scientific cooperation with non-Arctic countries, and that Japan has started construction of an Arctic research vessel to embody international collaboration in the Arctic.[2] Mikhail Noskov, Russian Ambassador to Iceland Ambassador, stated that the next ASM4 will focus on the priorities of the livelihood and welfare of Arctic residents, in relation to the "promotion of scientific cooperation in the Arctic," "Arctic Ocean," "biodiversity," "indigenous peoples and their traditions," "education," and "climate change."

It was also decided to begin construction of a new Arctic research vessel with icebreaking capability. The Japan Agency for Marine-Earth Science and Technology (JAMSTEC) currently has an oceanographic research vessel, Mirai, which has made many observation cruises in the Arctic and Antarctic regions; however, it cannot enter sea ice areas because it does not have icebreaker ability. The new Arctic research vessel will be capable of continuous breakage of flat ice up to 1.2 m thick, thereby enabling new observations, including sea ice study. In addition, the new research vessel is intended to serve as an "international research platform," as the importance of fostering young human resources for Arctic research has been identified not only in Japan, but also in other Arctic and non-Arctic countries. The new research vessel will be the first in the world to use dual-fuel (marine fuel oil and liquefied natural gas) engines to reduce environmental impact and will feature new equipment such as a scientific fish finder (National Institute of Polar Research HP 2022). At ASM3, then Minister of Education, Culture, Sports, Science, and Technology, Koichi Hagiuda advocated operating the new Arctic research vessel as an international platform and promoting human resource development. The use of research vessels is suggested to accelerate the development of human resources to contribute to problem-solving in this region. Since multiple ministries involve in the Arctic affairs in Japan, new guidelines are needed in order to build an integrated relationship in order to implement a coherent strategy in the science and policy fields. A strategic plan for broader and deeper involvement in AC working groups is also needed.

[2] https://www.youtube.com/watch?v=TIS0ZmymAak&list=PLI0a77tmNMvSz9UV6iIPzMfAnu8qiY7vj&index=46.

11.5 Black Carbon Reduction Initiatives in the Arctic Council

The Arctic is warming faster than other regions of the globe, leading to fundamental changes in the environment and human living conditions in both the Arctic and worldwide. Black carbon and methane are short-lived climate pollutants that contribute to atmospheric warming, and their emissions directly contribute to air pollution, thereby negatively affecting human health. In addition, black carbon that falls on snow and ice accelerates the melting of these reflective surfaces, consequently accelerating the impact of global warming in the Arctic. Arctic States are uniquely positioned to slow Arctic warming caused by black carbon emissions. Despite generating just ten percent of global black carbon emissions, Arctic States endure 30% of the related warming effects in the Arctic due to the greater impact of local emission sources. Action by non-Arctic States is also important, as black carbon emissions can be transported large distances from their source to Arctic regions (Arctic Council and expert group on black carbon and methane 2022).

Prompted by the climate impacts of black carbon and methane emissions, the Ministers of the Arctic Council adopted "Enhanced Black Carbon and Methane Emissions Reductions: An Arctic Council Framework for Action" in April 2015. The framework pronounces that the Arctic States shall commit to:

> take leadership based on this Arctic Council Framework by further reducing black carbon and methane emissions in our countries and by working with Arctic Council Observer
>
> States and others to also reduce emissions produced beyond the borders of Arctic States;
>
> take enhanced, ambitious, national, and collective action to accelerate the decline in our overall black carbon emissions and to significantly reduce our overall methane emissions; and
>
> submit biennial national reports on countries' existing and planned actions to reduce black carbon and methane, national inventories of these pollutants, and, if available, projections of future emissions (Arctic Council and enhanced black carbon and methane emissions reductions an arctic council framework for action 2022).

To help implement these commitments, the framework established an expert group on black carbon and methane that was tasked with developing a biennial "summary of progress and recommendations" based on national reports and other relevant information. These reports are submitted through the Senior Arctic Officials to ministers at Arctic Council Ministerial meetings. In developing recommendations for its summary reports, the expert group sought to identify a focused menu of priority actions from which Arctic States could select based on their national circumstances and the need for economic development of Arctic communities.

Each Arctic State and Observer State commit to submitting a national report to the Arctic Council Secretariat on emission reduction, measuring their collective progress, and jointly identifying conclusions and recommendations. According to the guidelines, the Arctic Council Secretariat will make these national reports publicly available. Each Arctic State and participating Arctic Council Observer States should submit a national report that includes six areas:

(1) Summary of current black carbon emissions and, if available, future projections;
(2) Summary of current methane emissions to the United Nations Framework Convention on Climate Change (UNFCCC), and, if available, future projections;
(3) Summary of national actions, national action plans, and mitigation strategies by sector;
(4) Highlights of best practices or lessons learned for key sectors;
(5) Projects relevant to the Arctic; and
(6) Other information, if available (e.g., climate, health, environmental, and economic effects of emissions and mitigation) (Arctic Council and enhanced black carbon and methane emissions reductions an arctic council framework for action 2022).

All of these efforts aim toward continuous improvements in the climate and health of the Arctic; therefore, this framework is important to the Arctic environment as well as the global environment.

In addition, the Arctic Council Secretariat (ACS) holds an important role in the framework. Each Arctic State commits to submitting a national report to the ACS, who makes these reports available to the public. Since this framework is important for avoiding fundamental changes to the environment and human living conditions in both the Arctic and worldwide, and there are no replacements for the ACS to support the framework, the ACS plays a crucial role within their mandate.

In practice, although not included in the framework documents, the Director of the Arctic Council Secretariat has attended the UN Climate Change Conference (COP21) and moderated the event focused on black carbon and methane. The ACS has dispatched information about black carbon and methane in international meetings, which have previously given little attention to the black carbon issue, and even the Paris Agreement has no mention of it. Therefore, this external activity of the ACS was important to disseminate information regarding black carbon and methane to the world from the Arctic perspective.

According to EU, "many issues affecting the Arctic region can be more effectively addressed through regional or multilateral cooperation. EU engagement in Arctic matters is important in the interest of the citizens of the EU and of the EU Member States, not least those who are located in the Arctic. (The European External Action Service (EEAS) HP, EU Arctic policy 2022)" In 2021, the European Union High Representative for Diplomatic Affairs and Security, Josep Borrell announced the EU's new strategy, which is aimed at preventing global warming. The policy is to stop the development of fossil fuels, such as oil and natural gas. It also advocates a multilateral legal framework to stop the development and purchase of fossil fuels produced in the Arctic. In the Arctic region, the struggle for control over natural resources and the development of new shipping routes between the U.S., Russia, and China is intensifying, and the EU, which is appealing for the realization of a decarbonized society, is looking to increase its involvement (Hokkoku News Paper HP 2022). In addition, the European Union contributes to the development of collective responses to reduce black carbon emissions in the Arctic and provides and communicates knowledge about sources and emissions of black carbon and supports relevant international policy processes (AMAP HP 2022). Thus, environmental conservation activities are becoming more active in the Arctic region.

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