Net Zero Emission Scenarios in Vietnam

Kyoko TAKE (Hoa NGUYEN)[1*], Tung Lam NGUYEN[2], Takaharu OTA[3], Tomoki HIRAYAMA[3], Yuko MOTOKI[3], Go HIBINO[4], Yuki OCHI[5] and Toshihiko MASUI[4]

[1] Strategic Management Office, Institute for Global Environmental Strategies
2108-11 Kamiyamaguchi, Hayama, Kanagawa 240-0115, Japan
[2] Vietnam Productivity Institute,
No 8 Hoang Quoc Viet street, Cau Giay district, Ha Noi, Vietnam
[3] Sustainability Consulting Division, Mizuho Research and Technologies, Ltd (MHRT)
1-5-5 Otemachi, Chiyoda-ku, Tokyo 100-8176, Japan
[4] Social Systems Division, National Institute for Environmental Studies (NIES)
16-2 Onogawa, Tsukuba-shi, Ibaraki 305-8506, Japan
[5] E-konzal
1207, EPO Shinosaka Building, 3-8-15, Nishinakajima, Yodogawa-ku, Osaka 532-0011, Japan
**E-mail: thai.hoa.nguyen@mx.iges.or.jp*

Abstract

Vietnam's Prime Minister has committed the country to developing and implementing strong greenhouse gas (GHG) emission reduction measures with its own resources, with the cooperation and support of the international community, to achieve net-zero emissions by 2050. This paper introduces three models, Extended Snapshot, AIM/Enduse and AIM/CGE, that were used to assess the emissions, technology options and economic impacts of reducing the GHG emissions in the Net Zero Emissions scenario. The results show that 1) GHG emissions will reach their peak at 511 $MtCO_2$ in 2030, and decrease to zero by 2050; 2) renewable energy and carbon capture and storage (CCS) are fundamental technologies for achieving great GHG emission reductions; and 3) the amount invested will be about 300 to 400 billion USD in the "Net Zero-CCS" (NZ-CCS) and "Net Zero-Renewable" (NZ-REN) scenarios, respectively. These findings imply that the goal of net-zero emissions is realizable in our simulations, but technological progress and diffusion as well as effective implementation of country-relevant climate policies will be indispensable.

Key words: net-zero emissions, GHG, climate change strategy, renewable energy, CCS, Vietnam

1. Introduction

Low-carbon development towards net-zero emissions by 2050 has become an inevitable global development trend accompanied by statements at the United Nations Climate Change Conference in Glasgow (COP26) on strong energy transition and low-emission development, towards achieving the goal of restricting the global temperature increase to 1.5^{o}C by the end of the century. At COP26, Vietnam's Prime Minister Pham Minh Chinh announced the country's commitment to achieving net-zero carbon emissions by 2050.

Vietnam's emissions will reach about 687 $MtCO_2eq$ by 2030 (NIES, 2014) and double that by 2050 (McKinsey, 2022a) if the country's industries continue to grow at the planned rates in the absence of technological change, industrial-base changes and successful implementation of policy changes. Vietnam derives a high proportion of its GDP from its high-carbon sectors, and much of its capital stock is tied up in fossil-fuel-based power. The country has already struggled to attract financing for planned coal-fired thermal plants (McKinsey, 2022b).

To tackle that, Vietnam has issued many legal regulations and policies to respond to climate change since 2012, gradually developing and implementing national, sectoral and local action programs. In 2015, Vietnam announced its tentative Nationally Determined Contribution (NDC) affirming its strong commitment to responding to global climate change. Vietnam was also one of the first 20 countries to complete the review and update of its NDC, and has significantly increased its contribution to GHG emission reduction in line with the country's socio-economic development up to 2030. With domestic resources, by 2030, Vietnam will reduce its total greenhouse gas emissions by 9% compared with the normal development scenario, equivalent to 83.9 million tons of CO_2, and up to 27%, equivalent to 250.8 million tons of CO_2 (equal to Vietnam's total national emissions in 2014) if it can obtain international support through bilateral and multilateral cooperation and business investment. On October 31, 2016 Vietnam's government approved the Paris Agreement under the United Nations Framework Convention on Climate Change (Paris Agreement on Climate Change).

Most recently, Vietnam's National Strategy on Climate Change to 2050 was approved, including a 43.5% emission reduction target by 2030, sector-specific emission targets for 2030 and 2050, and qualitative suggestions for achieving these goals (PM, 2022). The Asia-Pacific Integrated Model (AIM) team contributed to preparation of the National Strategy. Results of the AIM model were used for reference in consultations with line ministries toward the agreement at the 6th Vietnam - Japan Environmental Policy Dialogue between the Ministry of Natural Resources (MONRE) of Vietnam and the Ministry of the Environment of Japan (MoEJ) which was held on-line on August 24 to 25, 2020. Vietnam's strategic perspective in responding to climate change up to 2050 was determined on the basis of selectively carrying over the contents of the 2011–2020 Strategy, with adjustments and additions in the spirit of the Vietnam Communist Party's point of view (such as: the Resolution 24-NQ/TW on proactively responding to climate change, strengthening natural resource management and protecting the environment (Politburo, 2012); the Strategy for Socio-economic Development in the period of 2021–2030 (The Socialist Republic of Vietnam, 2020a); the National Green Growth Strategy for the 2021–2030 period, with a vision by 2050 (PM, 2021) and Vietnam's commitment at COP26 towards net-zero emissions by 2050.

This study presents the scenarios and results of the three AIM models that were used for supporting Vietnam in preparing its National Strategy on Climate Change to 2050.

2. The Models

Three models were used in this study. First, a preliminary study was conducted using AIM/ExSS to obtain a rough understanding of the energy and emission structure and the level of countermeasures required for Vietnam to achieve deep GHG reductions. Then, based on the knowledge obtained from the preliminary study, a list of candidate countermeasure technologies was compiled, and long-term GHG emission pathways were estimated using AIM/Enduse, a model that takes into account the year of technologies' development. We explored the timing of peak emissions and combinations of technologies that could achieve GHG net-zero emissions. Finally, we analyzed the economic impact of additional investments in the countermeasures to meet the future targets with AIM/CGE. The characteristics and roles of the models are described below.

2.1 AIM/ExSS

The AIM/ExSS model is an integrated tool for assessing future economic, industrial, social and energy visions with mitigating options to design snapshots of low-carbon society visions. This tool can be effectively used to communicate a social design for significant reductions because it can instantly identify changes in energy consumption and the CO_2 emission structure resulting from changes in social and economic conditions and levels of countermeasures. In this analysis, this model is used in the preliminary study to figure out roughly the level of measures and future energy consumption required for Vietnam's deep GHG reductions. Details of AIM/ExSS are described in Gomi et al. (2010).

2.2 AIM/Enduse

The technology-selection model AIM/Enduse (v1.0) was used to estimate future energy demand. The AIM/Enduse model selects the energy equipment that would minimize cost for each year while satisfying the requirements for exogenous input service volumes. We made reasonable assumptions about the speed of new technology deployment with the vintage of technologies being considered in calculating amounts of technology substitution. We adopted this model to estimate pathways of energy consumption and CO_2 emissions from energy use and cement production processes in Vietnam. Details on AIM/Enduse (V1.0) are described in Kainuma et al. (2003).

As for estimations of GHG emissions from sectors aside from energy use and cement production, we did not use the AIM/Enduse model, but adopted a simple accounting tool with which emissions are calculated from three factors: present emissions, rate of increase of related activities and emission reduction rate through countermeasures.

2.3 AIM/CGE

The AIM/CGE model quantitatively projects future economic activity based on future economic outlook assumptions by using the pricing mechanism to ensure consistency in the interrelationships within the economy as a whole. The model can estimate the economic impact of additional investments and changes in energy inputs. Details on AIM/CGE are described in Masui (2005).

In this analysis, AIM/CGE uses the relationship between investment and energy efficiency improvements estimated by AIM/Enduse and estimates the economic impact of countermeasures to achieve GHG net-zero emissions in Vietnam.

3. Analytical Framework and Results

3.1 Preliminary Study of 2050's Deep GHG Reduction with ExSS

Prior to the analysis, the social and economic activities, energy consumption and CO_2 emissions for the base year needed to be identified. We chose 2014 as the base year for projection because the latest Vietnam GHG Inventory was for 2014. Population, transport demand and GDP were taken from GSO (2019); the input-output table, from OCED Stat (OECD, HP); the energy balance table, from IEA (2022); and emission factors, from IPCC (2006).

Then, we prepared data on the future volume of socio-economic activities for analyzing future emissions with AIM/ExSS. Since this was before we had communicated with the Vietnamese government about specific prerequisites for analysis, we proceeded with our calculations based on our own assumptions. The data for the main activities used in AIM/ExSS are shown in Table 1. Population figures were taken from GSO (2016) and GDP, from the Socialist Republic of Vietnam (2011, 2020a). The population was projected to reach 108 million by 2050. The GDP in 2050 was projected to be about six times its value in 2014. Future industrial output by sector and transportation volumes were calculated endogenously based on the base year's data and the future population and GDP assumptions using AIM/ExSS. As for GDP and industrial output by sector, the output of the service sector was predicted to grow remarkably.

Table 1 Socio-economic activities for AIM/ExSS.

	2014	2050	'50/'14	CAGR
Population ('10^3 pp)	90,493	108,464	1.20	0.5%
Households ('10^3 hhs)	24,248	36,154	1.49	1.1%
GDP ('10^9 VND)	3,580	21,507	6.01	5.1%
GDP in Tertiary ('10^9 VND)	1,407	10,997	7.81	5.9%
Passenger transp. ('10^6 p-km)	104,353	182,011	1.74	1.6%
Freight transp. ('10^6 t-km)	52,501	321,049	6.12	5.2%

Transport demand was predicted to increase in proportion to population and economic growth.

We set three scenarios, the BaU (Business as Usual) scenario, CM1 (Countermeasure 1) scenario and CM2 (Countermeasure 2) scenario. No low-carbon measures were applied in the BaU scenario. "Low-carbon measures" referred to Vietnam's current national development plans in the CM1 scenario. While CM2 assumed a higher penetration of efficient technology and renewable energy than CM1. Assumptions on socio-economic activities were the same in all three scenarios. As for the increase in renewable energy in the energy mix, its share for 2050 in the CM1 scenario was set at 43% with reference to PM (2015). In CM2, the share was set at 59% with reference to the C4 scenario of EREA & DEA (2019).

The C4 scenario illustrates one development pathway for Vietnam's energy system, which combines the renewable energy development strategies target, coal restriction from 2025 and high uptake of energy-efficient technologies. Since CM1 and CM2 mainly focus on diffusion of the best available technologies, large-scale deployment of innovative technologies is not assumed. For example, some power and industrial plants are not equipped with CCS, and new green fuel only applies to fuel-cell vehicles in the transport sector in low amounts. Regarding innovative technologies essential to achieving net-zero emissions, the next section provides a detailed analysis conducted using AIM/Enduse.

Figure 1 shows the estimations for final energy consumption and CO_2 emissions arrived at by using AIM/ExSS. Energy consumption in BaU increases by a factor of 3.4 times compared to 2014. It is lower by 35% in CM1 and 39% in CM2 compared to BaU. Energy consumption from transport can be reduced by more than 50% in CM2. Electricity demand increases by a factor of up to four times from 2014 in the BaU scenario, and five times in the CM1 and CM2 scenarios. In the CM1 and CM2 scenarios, power demand is larger than in the BaU scenario because of progress in electrification. With

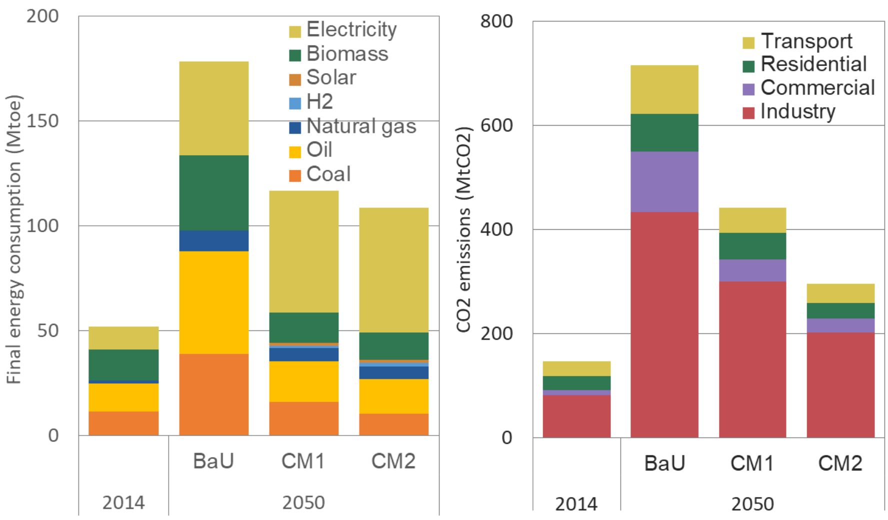

Fig. 1 Final energy consumption (left) and CO_2 emissions* (right) simulated by ExSS.

* CO_2 emissions from power generation are allocated to each sector based on electricity consumption.

regard to CO_2 emissions, about 300 $MtCO_2$ will be remaining even in CM2.

We obtained the following implications from the preliminary studies with ExSS.

- While an increase in energy consumption associated with increased socio-economic activities is inevitable, it can be significantly reduced through countermeasures. Energy conservation and electrification are important.
- The growth of electricity consumption is particularly large. Therefore, decarbonization in power generation is extremely important.
- CO_2 emissions remain around 300 $MtCO_2$ in 2050. Therefore, further introduction of renewable energy, carbon capture, usage and storage (CCUS), and hydrogen fuel will be necessary.

3.2 Emission Pathways toward Net Zero with AIM/Enduse

Table 2 shows the socio-economic activities for the AIM/Enduse model in Vietnam. After the analysis using AIM/ExSS, our communication with Vietnamese stakeholders progressed regarding specific prerequisites for analysis, and we were able to share and refer to other outlooks regarding Vietnamese transportation and material production. The demand for the industry sector excluding the steel and cement, residential, commercial and agriculture sectors was derived from the AIM/ExSS analysis.

In this study, we developed two countermeasure scenarios, namely, the "Net Zero-CCS" (NZ-CCS) scenario and "Net Zero-Renewable" (NZ-REN) scenario. CCS is introduced at a higher rate in NZ-CCS and renewables are introduced at a higher rate in NZ-REN. As mentioned above, we gained insight from the AIM/ExSS study that introduction of CCS, more renewables and hydrogen would be essential to achieving net-zero GHG emissions. To consider the highly uncertain feasibility of these technologies, we prepared two alternative scenarios, NZ-CCS and NZ-REN. The countermeasures considered in AIM/Enduse are listed in Table 3. They include measures where the amount introduced is common across the scenarios and measures where the amount introduced differs across the scenarios. For renewable energy, the share in the preliminary study with AIM/ExSS is at most 59% in 2050, while in NZ-CCS it is 80% and in NZ-REN, 90%.

In addition to energy-use and industrial-process-related CO_2 emissions, we calculated other future GHG emissions exogenously. The assumptions in reduction of other GHGs are described in Table 4. These assumptions are based on the Socialist Republic of Vietnam (2020b, 2021).

Table 2 Socio-economic activities for the AIM/Enduse analysis.

Amount of activities	2014	2030	2050
Crude steel production (Mt)	6	48	64
Cement production (Mt)	61	140	100
Other industries ('14=100)	100	336	661
Residential ('14=100)	100	195	333
Commercial ('14=100)	100	295	935
Passenger transport ('14=100)	100	280	585
Freight transport ('14=100)	100	239	550
Agriculture and forestry ('14=100)	100	199	322

Note that these projections are for the purpose of this estimate and are not official projections by Vietnam's government.

Table 3 Countermeasures in the AIM/Enduse analysis.

	Sector	Penetration of countermeasure (share or efficiency improvement in 2050)
Industry	Iron & Steel	Share of EF, BF and H2-DRI: 50%, 25%, 25% (NZ-CCS) 50%, 0%, 50% (NZ-REN) Rate of CCS usage in BF: 100%
	Cement	Rate of CCS usage: 100% Biomass share of fuels for cement production: 10% (NZ-CCS), 25% (NZ-REN)
	Furnace	Share of furnaces with H2 burners and IH heaters: 50%, 10% (NZ-CCS), 55%, 30% (NZ-REN) Share of biomass furnaces:15% (NZ-REN)
	Boiler	Heat pump share: 50% H_2 boiler share: 35% (NZ-CCS), 15% (NZ-REN)
	Other	Combustion efficiency improvement: 30% Motor efficiency improvement: 35%
Res. and Com.	Hot water	Heat pump share: 100%
	Cooking	IH heater share: 75% Biogas stove share: 12.5% (NZ-CCS), 25% (NZ-REN)
	Other	Motor efficiency improvement: 35%
Transportation	Passenger road	EV share: 100%
	Freight road	Logistic system efficiency improvement: 10% FCV share: 50%, EV: 25% Share of ICV with biofuel: 25%
	Rail	Shift from diesel to FC rail
	Aviation Navigation	Hydrogen-based fuel share: 50% Biofuel share: 50%
Energy production	Power generation	Transmission loss reduction: 50% Share of gas-fired with CCS, biomass-fired with CCS(BECCS), biomass-fired without CCS and other renewables: 20%, 5%, 0%, 75% (NZ-CCS) 10%, 2%, 3%, 85% (NZ-REN)
	Hydrogen generation	Water electrolysis share: 100%, assumed to be produced domestically

Table 4 GHG emission reduction rates from countermeasures, aside from energy-use and industrial-process-related CO_2 emissions.

Emission source		Reduction rate 2030	Reduction rate 2050
Fugitive	Solid fuels	30%	50%
	Oil and natural gas	30%	76%
Agriculture	Enteric fermentation	25%	40%
	Manure management	25%	40%
	Managed soils	25%	40%
	Rice cultivation	25%	40%
Waste	Managed waste disposal sites	50%	60%
	Wastewater treatment and discharge	45%	60%
LULUCF	Forest lands *	30%	40%
	Croplands	10%	30%
	Grasslands	5%	20%
	Wetlands	5%	20%
	Settlements	10%	30%
	Other land	5%	20%

* The percentage of forest land represents the rate of increase in absorption.

Figure 2 shows the GHG emission pathways toward 2050 simulated by AIM/Enduse. In both the NZ-CCS and NZ-REN scenarios, GHG emissions peak at 511 $MtCO_2$ in 2030 and achieve GHG neutrality by 2050. These emission pathways fulfill the updated NDC target of 524.2 $MtCO_2$ in 2030. Non-CO_2 emissions remain about 100 $MtCO_2eq$ in 2050, but negative CO_2 emissions from energy use and LULUCF offset the positive non-CO_2 emissions. The introduction of bioenergy with carbon capture and storage (BECCS) contributes to a negative conversion of CO_2 emissions from energy use.

CCS is introduced in the power, industry and industrial process sectors after 2035. To achieve net zero emissions in 2050, the necessary amount of CCS will be 246 Mt-CO_2 in NZ-CCS. In comparison, increasing renewables in the power sector and decreasing fossil gas consumption allows the amount to be limited to 150 $MtCO_2$ in NZ-REN (Fig. 3).

Both scenarios show very large increases in the amount of electricity generated. The share of electricity in final energy consumption grows from 20% in 2014 to 49% (NZ-CCS) or 52% (NZ-REN) in 2050 due to the penetration of air conditioners in the building sector and EVs in the transport sector and greater service demand in manufactured goods production. All new sales of passenger cars will be EVs after 2030 and freight cars will be BEVs or FCVs after 2040. Hydrogen demand equivalent to 25% of total final energy consumption in 2020 will be required by 2050. If all the hydrogen is assumed to be generated through water electrolysis domestically, electricity demand for hydrogen production will reach 26 TWh (NZ-CCS) to 41 TWh (NZ-REN) in 2050 (Fig. 3).

The amount of electricity generated from renewable energy sources will be 1,025 TWh (NZ-CCS) to 1,363 TWh (NZ-REN), which means that by 2050, it will be necessary to introduce renewable energy generation that is 7.0 to 9.3 times greater than the current total amount of electricity generated. On the other hand, electricity generation by coal-fired power plants will peak in 2025 and then begin to decline to zero toward 2050. Gas-fired power plants will remain in operation in 2050, but all of them will be equipped with CCS. In addition, for the achievement of net-zero emissions about half of the biomass-fired power plants will also have to be CCS-equipped. This can contribute as negative emissions, offsetting the residual GHGs from other sources (Fig. 3).

The cumulative amount of additional annual investment estimated by the model in both scenarios from 2022 to 2050 using the 10% discount rate is 308 billion USD in NZ-CCS and 394 billion USD in NZ-REN. The investment in renewables and batteries in the power sectors will account for 65% (NZ-CCS) to 73% (NZ-REN) and EV in transport sector will account for 13% (NZ-REN) to 17% (NZ-CCS). That information on the amount of investment, together with information on changes in energy consumption, was passed to an economic model to analyze the economic impact (Fig. 3).

We obtained the following implications from the development of the emission pathway towards to GHG net zero using AIM/Enduse.

- To achieve carbon neutrality without an unreasonable transition, it will be necessary to set the peak year before 2035 with more than 150 $MtCO_2$ of CCS and 80% renewables.
- Vietnam has a relatively abundant potential for PV and wind power and is expected to overcome technological, economic and social barriers and achieve a large amount of deployment for PV and wind power.
- Power generation in coal power plants will peak in 2025 and decline to zero by 2050. Plants built after

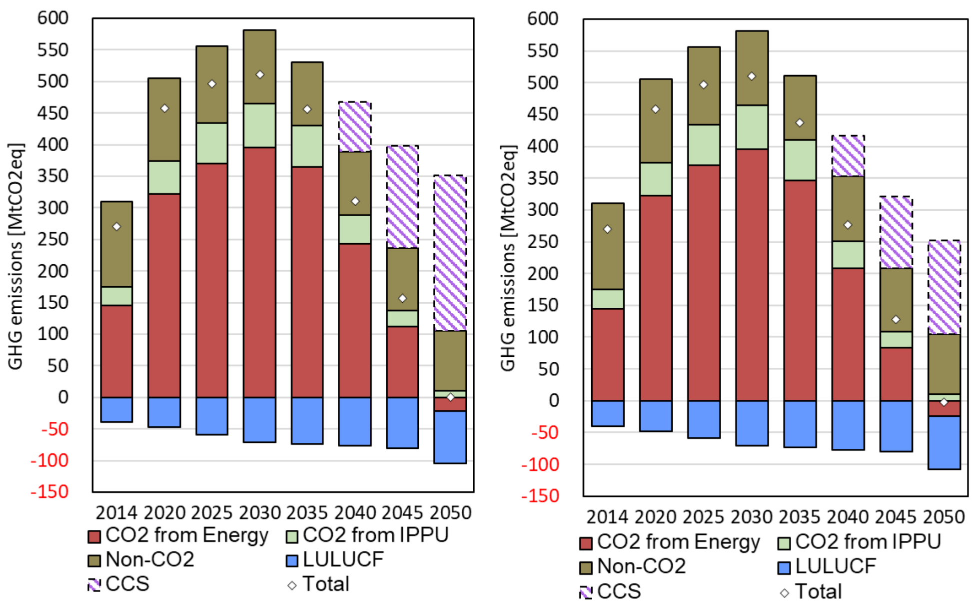

Fig. 2 GHG emission pathways (left: NZ-CCS, right: NZ-REN) simulated by AIM/Enduse.

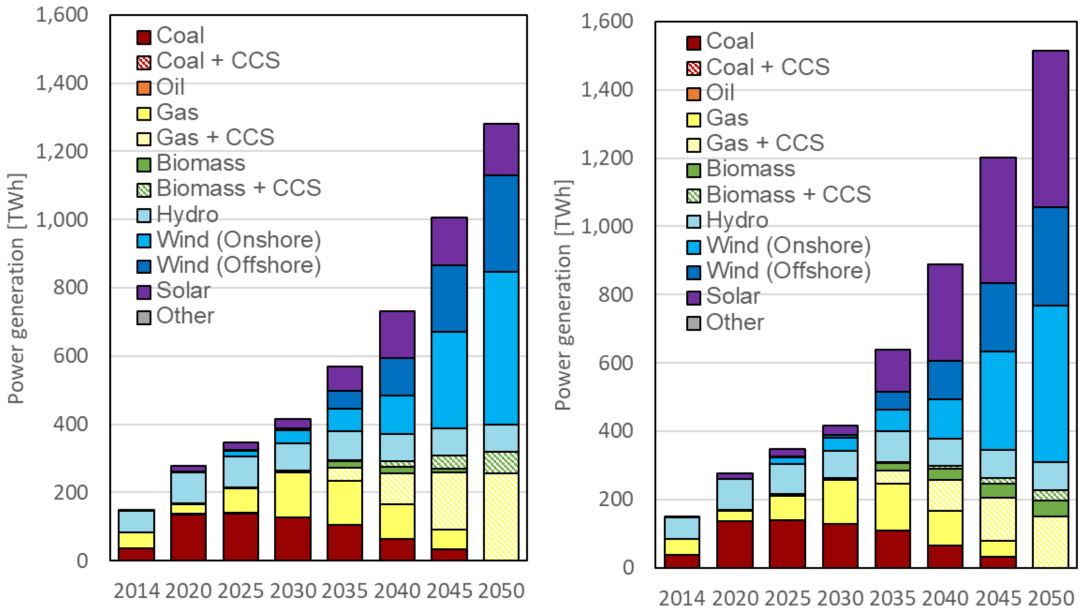

Fig. 3 Power generation transition (left: NZ-CCS, right: NZ-REN) simulated by AIM/Enduse.

2010 may become stranded assets.

- New gas power plants should be equipped with CCS or be prepared to install CCS. CCS should be started after 2030 at the latest.
- More than half of new biomass power plants should be equipped with CCS or be prepared to install CCS by 2050.
- All new sales of passenger cars should be EV after 2030 and freight cars should be BEV or FCV after 2040.

3.3 Economic Impact of Decarbonization Countermeasures with AIM/CGE

For the AIM/CGE analysis, we prepared four scenarios of measures in addition to the reference scenario. First, NZ-CCS and NZ-REN were the same scenarios as in the AIM/Enduse analysis, and the information on the relationship between investment and energy efficiency was based on the AIM/Enduse output. Then, for each scenario, we prepared a scenario in which the investment was made without international cooperation (sub1) and a scenario in which all additional investment was assumed to be provided through international cooperation (sub2).

Figure 4 shows future trends in the GDP. In the Ref scenario, the annual GDP growth rate from 2020 to 2050 would be 5.8% per year. In the cases of both NZ-CCS and NZ-REN, the GDP would increase continuously and the annual GDP growth rate would be 5.7% per year. The GDP in 2050 in the NZ-CCS (sub-1) scenario would be 3.9% smaller compared to the Ref scenario, and that in NZ-REN (sub-1), 3.8% smaller than that of the Ref scenario. In the case of the sub-1 scenarios, additional investment would be needed to introduce the GHG mitigation options. As a result, production investment would be affected and production activities would decrease compared to the Ref scenario.

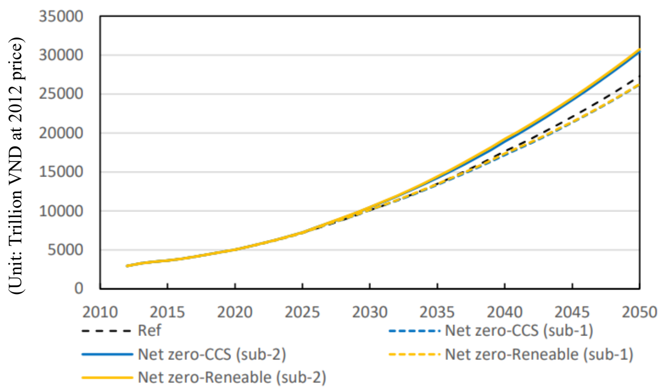

Fig. 4 GDP simulated by AIM/CGE.

On the other hand, in the sub-2 scenarios, the annual GDP growth rate from 2020 to 2050 would be 6.2% per year. In these cases, since the production investment would be kept to the same level in as the Ref scenario, and, in addition, energy-efficient technologies would be introduced with international support, more economic growth would be realized compared to the Ref scenario. In 2050, the GDP in the sub-2 scenarios would be 12% larger than that in the Ref scenario. The larger the scale of economic activity, however, the larger the potential GHG emissions, making it more difficult, as a result, to achieve carbon neutrality by 2050.

We obtained the following implications from our analysis of the economic impact of additional investment to achieve net zero GHG.

Investments to achieve net zero will have the impact of reducing GDP by about 4% by 2050. It is possible to reduce this impact, however, by utilizing international cooperation.

4. Conclusions

While it is true that it will be difficult to achieve the pathway proposed by this AIM analysis, other pathways would not be easy either. These results, however, at least indicate that the earlier hydrogen and CCS can be introduced, the earlier GHG emissions will peak, making it possible to avoid a rapid emission reduction in a short time after the peak. To avoid stranding assets, CCS must be ready for installing in industrial and power plants well in advance.

To achieve net-zero emissions, renewable energy and CCS technologies will be fundamental for reducing the enormous GHG emissions. The amount of investment will be around 300 to 400 billion USD (investment costs after 2022 are discounted at a rate of 10%). Investment in renewables and batteries in the power sectors and EV in the transport sector will account for the majority of the additional costs. International support will accelerate the peak out, helping Vietnam achieve both GDP growth and GHG emission reduction.

Even though the National Strategy on Climate Change to 2050 has been approved, it will still need good and effective coordination amongst the line ministries, with direction from the top leadership in implementing existing climate change policies. Regular review and update of the ministries' action plans will be important for achieving Vietnam's net-zero emissions target by 2050.

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Kyoko TAKE (Hoa NGUYEN)

Dr. TAKE (Hoa NGUYEN) is a Research Fellow at the Strategic Management Office of the Institute for Global Environmental Strategies (IGES) in Japan. She holds a PhD from the Department of Environmental Engineering, Graduate School of Engineering, Kyoto University. Her research interests cover using the Asia-Pacific- Integrated Model (AIM) to design and analyze the Asian net-zero carbon scenarios. She has engaged in developing the Vietnam net-zero carbon scenario; and developed the number of scenarios at the city level such as Hai Phong, Da Nang, Can Tho, Ha Noi, Khon Khen-Thailand, and Luang Prabang-Laos.

Tung Lam NGUYEN

Dr. Nguyen Tung Lam is formally working in the Ministry of Environment and Natural Resources and Environment of Vietnam, and currently he is working at Ministry of Science and Technology. He has involved with the process of preparing the Vietnam National Strategy on Climate Change as well as other related climate change documents. His works are based on the modeling of GHG emissions using AIM models and it is not limited to the national level but also at the local provinces and cities of the country.

Takaharu OTA

Takaharu Ota is a consultant for the Sustainability Consulting Division of Mizuho Research & Technologies Co., specializing in quantitative analysis using models. His research with the National Institute for Environmental Studies AIM project includes the use of energy supply and demand, technology selection models for estimating emissions, and investigation of innovative decarbonization technologies, such as the use of hydrogen for direct reduction ironmaking.

Tomoki HIRAYAMA

Tomoki Hirayama is a meteorologist engaged mainly in supporting formulation of the Ministry of the Environment's mid- to long-term plans and research with the National Institute for Environmental Studies' AIM project. His work includes estimating GHG and air pollutant emissions using energy supply and demand and technology selection models and analyzing the emission reduction effectiveness of measures and policies. He is currently senior consultant for Sustainability Consulting Division 1 at Mizuho Research & Technologies, Ltd.

Yuko MOTOKI

Dr. Motoki received her Ph.D. in policy and media. She is responsible for energy supply and demand analysis for the National Institute for Environmental Studies' AIM project, research on implementation of carbon pricing in Japan and overseas, support for review committee operation, including that of the Central Environment Council's subcommittees as well as lecturing and consulting for private sector companies. She currently serves as chief consultant for Sustainability Consulting Division 1 at Mizuho Research & Technologies, Ltd.

Go HIBINO

Go Hibino received his master's degree from the Graduate School of Science, Tokyo University of Science. From 1991, he worked at the now Mizuho Information & Research Institute, Mizuho Research & Technologies, Ltd. He has served in his current position since July 2020. Since the early 1990s, he has been involved in the Asia-Pacific Integrated Model (AIM) Development Project, primarily with the development of AIM/Enduse and its application to Japan. He has also been a long-time contributor to reviews on Japan's emission reduction targets and reduction plans. He is currently the research collaboration coordinator (Asia-Pacific Integrated Model) for the Decarbonization Measures Assessment Section, Social Systems Division, National Institute for Environmental Studies (NIES).

Yuki OCHI

Yuki Ochi received his master's degree from the Graduate School of Engineering, Kyoto University. He joined E-Konzal Co. Ltd. in 2013 and served as a researcher. He works with local governments and NPOs to achieve a decarbonized society from the local level. He has engaged in calculating and analyzing municipal greenhouse gas emissions and developing future scenarios for decarbonization. He conducts decarbonization scenario studies with the Asia-Pacific Integrated Assessment Model.

Toshihiko MASUI

Prof. Masui received his Ph.D. from the Graduate School of Engineering Osaka University. He joined NIES as a researcher in 1998. He has held his current position since April 2022 after serving as senior researcher and director. He has a concurrent appointment as a visiting professor at the Tokyo Institute of Technology School of Engineering. His research focuses on development of the Computable General Equilibrium Model, one of the component models of the Asia-Pacific Integrated Model being developed at the National Institute for Environmental Studies, and application of the model to assessing climate change mitigation measures. Prof. Masui currently serves as Social Systems Division Director at NIES.

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