SIPA SUPPORT TO VIET NAM FOR THE IMPLEMENTATION OF THE PARIS AGREEMENT

DCC Department of Climate change

Implemented by giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

On behalf of: Federal Ministry for the Environment, Nature Conservation and Nuclear Safety of the Federal Republic of Germany

Vietnam NDC Sectoral Report

Energy

Published by the
Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

Registered offices
Bonn and Eschborn, Germany

As of
July 2021

Responsibility
Kia Fariborz
Chief Technical Advisor
Support to Viet Nam for Implementation of the Paris Agreement Project (VN-SIPA).

Authors
Nguyen Minh Bao, Nguyen Duc Cuong

Editors
Dao Minh Trang, Sascha Oppowa, Ralph O. Harthan, Dan Burns

Pictures
©GIZ/Energy Support Programme

On behalf of the
German Federal Ministry for Environment, Nature Conservation, and Nuclear Safety (BMU).

Vietnam NDC Sectoral Report

Energy

Table of Content
Report

List of tables and figures
Report

Acronyms and abbreviations
Report

AAGR	Average Annual Growth Rate
ADB	Asian Development Bank
APS	Alternative Policy Scenario
AR4	The Forth Assessment Report of IPCC
ASEAN	The Association of Southeast Asian Nations
BAU	Business As Usual
BF	Blast Furnace
BMU	German Ministry for the Environment, Nature Conservation, and Nuclear Safety
BTU	British Thermal Unit
CCT	Combined Cycle Turbine
CDM	Clean Development Mechanism
CH4	Methane
CMA	Conference of Parties to the Paris Agreement
CNG	Compressed Natural Gas
CO2e	Carbon dioxide equivalent
COP	Conference of the Parties
DO	Diesel Oil
EAF	Electric Arc Furnace
EE	Energy Efficiency
EF	Emissions Factor
EIA	Energy Information Administration
EVN	Electricity of Vietnam
FIT	Feed-in Tariffs
FO	Fuel Oil
GDP	Gross Domestic Product
GEF	Global Environment Facility
GHG	Greenhouse Gas
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH German International Cooperation
GWP	Global Warming Potential
HCV	High Capacity Vehicle
IEA	International Energy Agency
IIEC	International Institute for Energy Conservation
INDC	Intended Nationally Determined Contribution
IPCC	Inter-governmental Panel on Climate Change

IRENA	The International Renewable Energy Agency
JCM	Joint Credit Mechanism
JICA	Japan International Cooperation Agency
KTOE	Kiloton Oil Equivalent
LCV	Low-Capacity Vehicle
LEAP	Long-range Energy Alternatives Planning System
LED	Light-emitting Diode
LPG	Liquefied Petroleum Gas
LULUCF	Land use, Land Use Change and Forestry
MARD	Ministry of Agriculture and Rural Development
MCF	Maximum Capacity Factor
MEPS	Minimum Energy Performance Standards
MJ	Mega Joule
MOC	Ministry of Construction
MOIT	Ministry of Industry and Trade
MONRE	Ministry of Natural Resources and Environment
MRV	Measurement, Reporting and Verification
MSW	Municipal Solid Waste
MtCO2e	Million tons of carbon dioxide equivalent
NAMA	Nationally Appropriate Mitigation Action
NDC	Nationally Determined Contribution
NDS	National Development Strategy
NEDS	National Energy Development Strategy
NFB	Non-Fired Brick
NTDS	National Transport Development Strategy
O&M	Operation and Maintenance
PDP	Power Development Plan
PV	Photovoltaic
PVN	Petro-Vietnam
RE	Renewable Energy
REDF	Renewable Energy Development Facility
REDS	Renewable Energy Development Strategy
SHP	Small hydropower
SWH	Solar water heater
Tce	Tons of coal equivalent
TNC	Third National Communication to UNFCCC
TOE	Tons of Oil Equivalent
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNIDO	United Nations Organisation for Industrial Development
USD	United States Dollar
USCPP	Ultra-supercritical Coal Power Plants
VACVINA	Association of Vietnamese Gardeners
VNEEP	Vietnam - National Energy Efficiency Programme
VSA	Vietnam Steel Association
WB	World Bank

Executive Summary

The following paper is part of a five-report series, produced in the context of the 2017-2020 revision and update of Vietnam's Nationally Determined Contribution (NDC).

Each of these works addresses a different sector, covering agriculture, energy, industrial processes and product use (IPPU), land use, land-use change and forestry (LULUCF), and waste. They all provide extensive trend analyses of a sector's projected greenhouse gas (GHG) emissions for the period of 2014-2030, which take current policy measures into consideration and assume no major changes moving ahead (*business-as-usual scenario*, BAU). On the basis of selected mitigation options, each paper outlines feasible *mitigation scenarios* that would see signification GHG emission reductions for the respective sector until 2030, as well as associated marginal abatement costs.

These five reports have informed the Government of Vietnam's updated and revised NDC, which is available at UNFCCC, https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Viet%20Nam%20First/Viet%20Nam_NDC_2020_Eng.pdf. A technical background report, published by the Ministry of Natural Resources and Environment (MONRE), comprises more information.

In this study for energy, the Long-range Energy Alternatives Planning system (LEAP) model was applied to a combination of top-down and bottom-up approaches. The BAU scenario was developed to outline future GHG emissions levels for the 2014-2030 period based on activity data derived from the Revised PDP VII, recent World Bank (WB) studies, a GIZ (2019) study, emissions factors in the revised 1996 and 2006 IPCC Guidelines, and existing policies likely to impact GHG emissions.

Mitigation scenarios (or options) are designed based on the mitigation potential of renewable energy sources and energy efficient technologies under the assumption that additional action plans or policies are developed or considered. The effects of existing policies in the period 2010-2014 are considered as mitigation actions for Vietnam's contribution. The differences between the BAU and mitigation scenarios in the period 2015-2030 demonstrate potential fossil fuel savings and potential GHG reductions.

There were 39 different mitigation options assessed, including 28 renewable energy (RE) and energy efficiency (EE) options on the energy demand side (06 EE and RE options for the residential sector, 10 EE options in the industrial sector, 11 EE and RE options for the transport sector, and 01 EE option in the commercial and services sector) and 11 RE and EE options on the energy supply side. The selection of priority technologies among these options classified as unconditional or conditional contributions were selected based on criteria such as: government priorities, GHG reduction potential, marginal abatement costs and technology readiness, and whether available or already applied in the energy sector.

The study's results show that 25 prioritized mitigation technologies were selected as unconditional contribution and 14 remaining mitigation technologies were selected as conditional contribution of energy sector to the NDC based on each option's mitigation potential, cost-effectiveness and the maturity of technology development, as well as Government priorities.

In order to achieve its mitigation targets, the study also recognized the barriers and constraints on policy, technology, finance and capacity building with the needs of human and financial resources to overcome these barriers.

The total amount of domestic funding needed is US$ 19,850.4 19,887.7 million to achieve the GHG reduction of 7.69% of total GHG emission of BAU by 2030. An additional US$ 35,990.4 35,803.2 million would need to be mobilized from international sources in order to achieve the total GHG emissions reduction of 23.05% of total GHG emission of BAU scenario by 2030.

01. Introduction

1.1. Background Information on the Paris Agreement and NDCs

The Paris Agreement on Climate Change was adopted by the states in COP 21 as the first global legal document regulating responses to climate change. The focus of the Paris Agreement is on the introduction of regulations concerning the responsibility for developing and implementing a Nationally Determined Contribution (NDC) of each of the Parties to the United Nations Convention Framework on Climate Change (UNFCCC). So far, the Agreement has been signed by 195 countries, ratified by 179 parties, and officially entered into force on 4 November 2016.

Although countries had submitted NDCs by the end of 2015, even if all NDCs are fully implemented the global average temperature may still increase by 2.9°C to 3.4°. Achieving a target of 1.5°C will require zero global GHG emissions between 2060-2080 and around 2080-2090 for the 2°C target. Therefore, Decision No. 1/CP21 of the Paris Agreement on Climate Change requires all parties to review and update their NDCs at least every five years with the expectation of increasing their ambition to contribute to mitigating GHG emissions. All States are required to submit their NDC (new or updated) by 2020 and every five years thereafter at least 9-12 months prior to the Conference of the Parties to the Paris Agreement (CMA). Consequently, countries are required to continually review their NDCs in order to identify options to raise ambition and mitigate the current contribution. The UNFCCC requires the parties to submit a revised NDC for the first time by 2020. The NDC revisions should consider a medium-term plan as well as a long-term plan to reduce GHG emissions. In addition, Article 13 of the Paris Agreement on Climate Change requires States to develop a transparent framework that requires parties to regularly submit GHG inventory reports and provide information on the NDC implementation process, support, and adaptation efforts. Technical assessments will be made for all parties to analyse the consistency of the information, identify areas in need of improvement, and strengthen capacity. The parties will also participate in facilitative, multilateral considerations of progress with respect to the respective implementation and achievement of their NDC's goals.

Recently, Vietnam planned to review and update its NDC with a view to submitting an updated NDC to UNFCCC in 2019. Thereby, Vietnam is fulfilling a requirement of the Paris Agreement – outlined in decision 1/CP21). Reviewing and updating its NDC is also an official requirement of the Vietnam Government. In 2016, the Prime Minister approved the Plan for the Implementation of the Paris Agreement on Climate Change. In that plan, task No. 1 requires updating of the NDC's mitigation component and task No. 17 requires updating the NDC's adaptation component.

1.2. Overview of the Energy Sector in Vietnam

Vietnam is rich in a variety of energy sources. However, the capacity for energy extraction, production and distribution is limited, especially in the electricity sector, which is holding back production, the improvement of living standards and the increase of incomes.

Although Vietnam is a crude oil exporter, its capacity to refine oil is still limited. As a result, Vietnam has to import oil products, with estimates expecting this to continue until 2020. With oil product prices continuing to rise, this import dependency is having a negative effect on Vietnam's socio-economic development objectives.

In 2014, 17,392,000 tons of oil were extracted, of which 9,306,000 tons were exported. Coal production reached 41,086,000 tons, of which approximately 7,265,000 tons were used for export.

By the end of 2014, the total installed capacity of all power plants was 34,080 MW. Overall electricity consumption per capita is estimated at 1,416 kWh per year, which is considered as average in the region.

The total primary energy supply by types of energy was 58,023 KTOE in 2012, increasing to 62,894 KTOE in 2014. Final energy consumption by types of energy was 49,302 KTOE in 2012, increasing to 52,248 KTOE in 2014, as shown in Table 1 and Table 2.

Table 1: Total primary energy consumption during 2012 – 2014 by types of energy

Unit: KTOE

Year	Types of energy						
	Coal	Crude oil	Total oil products	Natural gas	Non-commercial fuels	Electricity	Total
2012	15,785	6,297	8,902	8,253	14,121	4,665	**58,023**
2013	17,239	6,918	7,757	8,522	13,669	5,097	**59,202**
2014	19,957	6,345	9,453	9,124	12,745	5,270	**62,894**

Source: Vietnam Energy Statistics 2014, MOIT, 2016; Technical report on GHG inventory in energy sector for 2013, MONRE, 2017; Technical report on GHG inventory in energy sector for 2014, MONRE, 2018

Table 2: Total end-use energy consumption during 2012 -2014 by types of energy

Unit: KTOE

Year	Types of energy					
	Coal	Total oil products	Natural gas	Non-commercial fuels	Electricity	Total
2012	9,678	15,036	1,438	14,086	9,064	**49,302**
2013	10,559	14,971	1,460	13,628	9,988	**50,606**
2014	11,457	15,592	1,458	12,696	11,045	**52,248**

Source: Viet Nam Energy Statistics 2014, MOIT, 2016; Technical report on GHG inventory in energy sector for 2013, MONRE, 2017; Technical report on GHG inventory in energy sector for 2014, MONRE, 2018

The rural electrification Programme has been effectively implemented since 1988 with the support of international organisations such as WB, ADB and JICA. According to reports by Electricity of Vietnam (EVN), by the end of 2014 approximately 99.6 percent of communes and 98.2 percent of households had access to electricity from the national grid, higher than most countries with the same level of GDP.

Vietnam has great potential for renewable energy (RE), such as small-scale hydropower, biomass energy, wind energy, and solar energy, which can be utilised to meet the national energy demand in general and the need for electricity in remote areas in particular. However, due to limited budgets and lack of technology, the majority of rural residents rely on biomass, a non-commercial source of energy. As a result, Vietnam has a low level of commercial energy consumption per capita compared to other Asian countries.

Vietnam's fast-paced economic development and GDP growth have resulted in high energy demand, especially for natural gas, electricity and coal in the manufacturing industries and for residential consumers. This trend is expected to continue in the future. Thus, energy generation and consumption will be the main source of GHG emissions in the decades to come.

Based on the current strategies and policies, the following priorities for energy development can be determined and used to identify mitigation options as mentioned in Table 3 below:

Table 3: Government priorities for energy development

Scope	Priority	Sources
At national level	To promote EE and conservation	Law on EE and Conservation, 2010
In the energy sector	1. Reduce GHG emissions in the energy sector by around 5% by 2020, 25% by 2030 and 45% by 2050 compared to BAU 2. To increase the share of RE-based electricity to 4.5% in 2020, 15% in 2030 and 33.1% in 2050	The Renewable Energy Development Strategy, 2015
	3. To increase the proportion of households using solar water heating devices to 12% in 2020, 26% in 2030 and 50% in 2050	
	3. To scale up the application of biogas technologies with a construction volume to 8 million m3 in 2020, approximately 60 million m3 in 2030 and 100 million m3 in 2050	
	4. To increase the production of bio-fuels to meet 5%, 13% and 25% of the transport sector's fuel demand in 2020, 2030 and 2050, respectively.	
In the transport sector	1. To restructure the domestic transportation market by reducing the market share of road transportation and increasing the market shares of railway and inland waterway transportation 2. To develop mass transit in Ha Noi and Ho Chi Minh cities to meet around 35-40% of total passenger transportation	Strategy for development of transportation services through 2020, with an orientation toward 2030

1.3. Objectives and Scope of the Study

In 2015, under leadership from the Ministry of Natural Resources and Environment (MONRE) and with support from the German Ministry for the Environment, Nature Conservation, and Nuclear Safety (BMU) through Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) and the United Nations Development Programme (UNDP), Vietnam successfully submitted its Intended Nationally Determined Contribution (INDC) to the Secretariat of the UNFCCC. Vietnam's INDC sets mitigation targets at the national level in relevant sectors, including the energy sector, agriculture, Land Use, Land Use Change and Forestry (LULUCF), and waste.

However, there have been some changes in the Vietnamese context, such as the Revised Power Development Plan VII (PDPVII), abandoned nuclear power plants, and especially the new targets on RE development mentioned in the Renewable Energy Development Strategy (REDS) that was approved in November 2015. These changes may affect the potential and costs of GHG reduction as well as the targets in Vietnam' INDC. Therefore, it is necessary to review and update the INDC for the energy sector for the period 2020-2030. The goal of this study is to develop BAU and mitigation scenarios for the energy sector in the 2020-2030 period, which will be inputs for the review and update of Vietnam's INDC.

The scope of this study is as follows:

Sector: All activities of the energy sector, from energy exploitation to energy conversion and final energy consumption (including fuel combustion in transport activities).

The base year: The year 2014 was selected since this is the latest year for which national data is available for modelling. However, the year 2010 was chosen as the base year for the INDC. Therefore, energy conservation activities from 2010 to 2014 could be considered as GHG mitigation measures for Vietnam's contribution. Moreover, efforts and achievements obtained in GHG mitigation activities after INDC submission are also updated and evaluated.

Types of GHGs: This study includes Carbon dioxide (CO_2), Methane (CH_4) and Nitrous oxide (N_2O).

02. Mitigation efforts in the energy sector

2.1. Mitigation Efforts in the Energy Sector before INDC Submission

In the 2010-2014 period, Vietnam has expended considerable efforts in GHG reduction in the energy sector through EE activities and RE development on both demand and supply sides, and achieved remarkable successes.

2.1.1. The demand side

The Government has assigned ministries/ branches to carry out solutions on energy efficiency, especially on saving electricity. Light-emitting diode (LED) lamps were piloted by a Ministry of Industry and Trade (MOIT) project in the 2011-2012 period that demonstrated energy savings of 50% compared to traditional lamps. Based on household surveys conducted by the International Institute for Energy Conservation (IIEC), LED lamps have been used to replace traditional lamps, accounting for 17% of the total lamp stock in the residential sector in 2014 and thus have contributed to a considerable decrease in electricity demand for residential lighting.

The Vietnam - National Energy Efficiency Programme (VNEEP) under MOIT has achieved positive impacts. According to the assessment report on the impacts of energy saving projects under VNEEP in the 2006-2010 period, total energy savings accounted for 2-3% of total energy consumption for the period[1].

The VNEEP in the period 2012-2015 (VNEEP2) was approved by the Government under Decision No.1427/

[1] Revised PDPVII, 2016

QD-TTg dated 2 October 2012. The programme aims at saving 5-8% of the country's total energy consumption in the period 2012-2015 compared to the forecast for energy demand of the PDP in the period 2011-2020, with a vision to 2030, approved by the Prime Minister. For VNEEP2, evaluation results show that the actual savings are 5.65%, equivalent to 10,610 KTOE[2]. According to the results on GHG inventory, the total GHG emissions for the year 2014 (on the demand side) was 96.2 million tons CO_2e ($MtCO_2e$). Based on the evaluation results of VNEEP2, it could be assumed that around 5.6% of the total energy consumption in 2014 were saved, which is equivalent to the reduction of around 5.4 $MtCO_2e$. Moreover, Vietnam's EVN and the Energy Efficiency and Conservation Office began the promotion programme for solar water heater (SWH) development in 2009 with the goal of reducing electricity consumption in peak hours. The programme supported 60,000 SWHs units during the period 2010-2012, providing VND one million per unit for households installing SWH.

Due to the efforts described above, energy consumption, and especially electricity consumption, had been reduced by a significant amount by 2014 (Table 4). As regards electricity consumption, according to EVN's Annual Report 2015, electricity savings in 2011 totaled 1.3 billion kWh, which increased to 2.8 billion kWh in 2014, equivalent to around 1.85 $MtCO_2e$ (with the grid emissions factor of 0.6612 kg CO_2e/kWh by 2014).

From the above analysis, with EE measures on the demand side, Vietnam could reduce emissions by around 7.25 $MtCO_2e$.

Table 4: Efforts to reduce GHG emissions through saving electricity in the period 2010-2014

Item	2011	2012	2013	2014
Total electricity consumption (million kWh)*	94,657	105,475	115,283	128,627
Annual electricity savings*	1,310	1,670	2,799	2,800
Grid emissions factor (kgCO2e/kWh)**	0.6244	0.5603	0.5657	0.6612
GHG reduction (MtCO2e)	0.82	0.94	1.58	1.85

*Source: * EVN Annual Report 2015; ** MONRE*

2.1.2. The supply side

Efforts to reduce GHG emissions on the supply side include measures on the development of renewable power resources and the reduction of power losses in transmission and distribution processes.

a) Development of renewable power resources

- **Development of small hydropower:** In this period, the development of small hydropower (SHP) is assisted by avoided cost electricity tariff schedule; therefore, there was an acceleration in investment. If there was only 400 MW of installed capacity of SHP in 2010, then by the end of 2014 (after 5 years), this increased by almost 5 times, reaching 1,836 MW. This reflects the significant impact of price subsidy policy on investment, on the construction of small hydropower plants in Vietnam, and on hydropower's contribution to achieving national GHG reduction targets.

[2] MOIT- Energy Outlook Report 2017

- **Development of wind power:** Decision No. 37/2011/QD-TTg provides support mechanisms for the development of wind power projects. However, the development of wind power from when the support tariff schedule came into effect at the end of 2014 was not as strong as expected. Over this period only one wind power project with installed capacity of 16 MW was added, increasing the total installed capacity of wind power to 46 MW.
- **Development of biomass power resources:** Because tariff support mechanisms were promulgated for biomass power projects in March 2014, increases of capacity in the period 2011-2014 were negligible.

Efforts to reduce GHG emissions in electricity generation from RE sources in Vietnam in the period 2010-2014 are presented in Table 5.

Table 5: Efforts to reduce GHG emissions from RE sources in the period 2010-2014

Item	2011	2012	2013	2014
Electricity generated from RE resources (billion kWh)	3.62	4.49	5.12	5.17
Assumption on electricity generation in the BAU of INDC (billion kWh)	3.3	3.3	3.3	3.3
Efforts to increase electricity generation from RE (billion kWh)	0.32	1.19	1.82	1.87
Total net GHG emissions reduction compared to BAU	**0.31**	**1.13**	**1.74**	**1.78**

** Note: EF: GHG emissions factor of coal power plants; EF = 0.9536 kg CO_2/kWh, estimated on the assumptions that coal power efficiency is 35% and coal heat value is 5,805 kcal/kg.*

Source: EVN, 2015.

b) Reduction of power losses in transmission and distribution processes

During implementing of the power development strategy for the period 2004-2020, EVN has carried out technical and management measures to reduce power losses in transmission and distribution processes. In 2014, power losses were reduced to 8.6% from 10.15% in 2010. The total electricity generation output in 2014 reached 142.25 billion kWh, thus EVN saved around 2.2 billion kWh in 2014 when power losses were reduced by 1.55% compared to 2010.

The efforts to reduce GHG emissions through measures to reduce power transmission and distribution losses are presented in Table 6.

Table 6: Efforts to reduce GHG emissions by reducing the power losses in the period 2010-2014

Item	Calculating	2011	2012	2013	2014
Total power generation output (billion kWh)	A	106.5	117.85	127.73	142.25
Power losses (%)	B	9.23	8.85	8.87	8.6
Reduction of power losses compared to 2010*(%)	C	0.92	1.3	1.28	1.55
Electricity savings from reduction in power losses (billion kWh)	D=C*A	0.98	1.53	1.63	2.20
Grid emissions factor (kgCO2e/kWh)	EF	0.6244	0.5603	0.5657	0.6612
GHG reduction efforts (MtCO2e)	**E=DxEF**	**0.61**	**0.86**	**0.92**	**1.46**

**Note: Power losses in 2010 = 10.15%*

Source: EVN, 2015.

The results above show that about 3.24 $MtCO_2e$ could be reduced through efforts on the supply side. Including efforts on the demand side, total GHG emissions reduction could reach around 10.5 $MtCO_2e$.

2.2. Mitigation Efforts in the Energy Sector after INDC Submission

2.2.1. Policies related to mitigation in the energy sector

Immediately after submission of the INDC (in September 2015), the Government of Vietnam promulgated a series of new policies on EE and RE development, with the promotion of available RE resources together with energy saving and reduction of GHG emissions, diversification of energy supply resources, and the reduction of imported coal and oil for electricity generation.

Table 7 summarises the legal documents relating to EE and RE development.

Vietnam

Table 7: Legal documents related to energy efficiency and renewable energy development

Policy	Legal document	Time approval	Related contents
National Energy Efficiency Programme for the period 2019-2030	Decision No.280/QD -TTg	13/03/2019	Main targets: Ensuring and stabilizing national energy security and fulfilling Vietnam's commitment to reducing greenhouse gas emissions in Vietnam's NDC with the concrete targets as follows: By 2025: to save 5-7% of national energy consumption in the period 2019-2025; to reduce power loss to less than 6.5%. By 2030: to save 8-10% of national energy consumption in the period 2019-2030; to reduce power loss to less than 6.0%.
Mechanisms to support wind power	Decision No.39/2018/ QD -TTg (replacing the outdated Decision No. 37/2011/QD -TTg approved in 2011)	10/09/2018	- 20-year power purchase agreement - Investment incentives, taxes, fees, land infrastructure - Support for electricity prices (grid): purchase price equivalent to 8.5 US cents/kWh for onshore and 9.8 US cents/kWh for offshore wind projects in operation before November 2021.
Promulgation of the list of and roadmap for elimination of low efficient energy consuming equipment and prohibition of development of new power generating units with low efficiency	Decision No.24/2018/ QD-TTg	18/5/2018	Implementation roadmap for coal and gas-fired power generating units in power plants to be applied from 10 July 2018: - It is not permitted to build coal, gas-fired power generating units with outdated technologies, with efficiency at the start of commercial operation lower than regulated efficiency corresponding to each range of unit capacities as specified in the Appendix. - It is not permitted to import old, backward equipment for power generating units with capacity beyond the range of capacities specified in the Appendix. - No approval for investment in coal, gas-fired thermal power plants with EE lower than efficiencies corresponding to capacities of power generating units specified in the Appendix.

Policy	Legal document	Time approval	Related contents
Mechanisms to support solar PV power	Decision 11/2017/QD-TTg	11/04/ 2017	- 20-year power purchase agreement - Investment incentives, taxes, fees, land infrastructure - Support for electricity prices (grid): purchase price equivalent to 9.35 US cents /kWh
Ending investment in nuclear power project	National Assembly Resolution No. 31/2016/ QH14	22/11/2016	The National Assembly entrusted the following tasks to the Government: - Apply solutions related to ending investment in nuclear power projects. - Focus on development of new and renewable energy resources, safe and efficient energy resources, and environmental protection in order to supply sufficient energy for socio-economic development.
Revised National Power Development Plan for the period 2011-2020, with an outlook to 2030 (Revised PDP VII)	Decision No.428/QD-TTg,	18/03/2016	Objectives and targets: - Increase the share of renewable energy in power generation to 9.9% in 2020, 12.5% in 2025 and 21% in 2030 in terms of installed capacity. - Increase the share of electricity generated from renewable resources to 6.5% in 2020, 6.9% in 2025, and 10.7% in 2030 in terms of electricity generation.
The Vietnam Renewable Energy Development Strategy to 2030, with an outlook up to 2050	Decision No. 2068/QD-TTg	25/11/2015	Objectives and targets: - Reduce GHG emissions in the energy sector by around 5% by 2020, 25% by 2030 and 45% by 2050 compared to BAU. - Small hydropower: Encourage development of small hydropower plants (SHP) suitable with local SHP sources based on environmental assessments. - Biomass power: to reach 3%, 6.3% and further increase to 8.1% of total electricity output by 2020, 2030 and 2050, respectively. - Wind power: to reach 1.0%, 2.7% and further increase to 5.0% of total electricity output by 2020, 2030 and 2050, respectively. - Solar power: to reach to 0.5%, 6.0% and further increase to 20.0% of total electricity output by 2020, 2030 and 2050, respectively. - Increase the production of bio-fuels to meet 5% and 13% of the transport sector's fuel demand in 2020 and 2030, respectively.

Moreover, the Government and ministries have promulgated circulars and decisions on implementing EE measures (on the demand side), including:

» Decision 802/QD-BXD of the Ministry of Construction in 2017 on promulgation of the „Action Plan for GHG emissions reduction in the cement industry to 2020 with orientation to 2030".

- Decision 04/2017/QĐ-TTg on regulations for vehicles and equipment with obligatory labelling and minimum energy performance standard and roadmaps.
- Circular 15/2017/TT-BXD on national technical standards for energy efficient buildings.
- Circular 40/2017/TT-BGTVT on guidance for labelling for cars with 7 to 9 seats.
- Decision No. 1456/QD-BGTVT of the Ministry of Transport in 2016 on approval of „Action plan to respond to climate change and green growth of the Ministry of Transport in the period 2016-2020".
- Circular No. 19/2016/TT-BCT of the Ministry of Industry and Trade in 2016, stipulating „Energy consumption norms in the beer and beverage production industry".
- Circular No. 20/2016/TT-BCT of the Ministry of Industry and Trade in 2016, stipulating „Energy consumption norms in the steel industry".
- Circular No. 38/2016/TT-BCT of the Ministry of Industry and Trade in 2016, stipulating „Energy consumption norms in the plastic industry".
- Circular 36/2016/TT-BCT on labelling for energy consuming equipment under the management of MOIT; Circular No.24/2017/TT-BCT of the Ministry of Industry and Trade in 2017, stipulating „Energy consumption norms in paper production".
- Prime Ministerial Decision No.1468/QD-TTg in 2015, on approval of the adjusted master plan on development of Vietnam's railway transport through 2020, with a vision to 2030.
- Prime Ministerial Decision No. 13/2015/QD-TTg in 2015 on approval of „Incentive mechanisms and policies for development of public transport bus services".

2.2.2. Mitigation actions

Energy policies, especially the Renewable Energy Development Strategy (REDS), together with Feed-in Tariffs (FITs), and fiscal and financial incentives contributed significantly to the growth of the renewable energy sector (Table 8).

Table 8:The effectiveness of policies on energy efficiency and renewable energy development

Area/sub-area	Existing policies	Effectiveness
Renewable energy	FIT for wind power	304.6 MW in operation 5,000 MW approved for additional planning Many more under application
	FIT for biomass power	250 MW under review (F/S reports)
	FIT for MSW	Not - effectiveness
	FIT for solar	4,464 MW in operation 630 MW under construction 10,300 MW approved for additional planning Many more under application
	Avoided cost tariff for small hydro power (SHP)	Increasing installed capacity by 5 times (from 1,8368 MW in 2014 to 2.970 MW in 2017)
Bio-fuels	Bio-fuel programme	06 operating ethanol plants are providing 535 million litres ethanol/year. However, many plants are in difficulties due to high production costs.

Source: compiled from EVN and MOIT (2019)

Some key mitigation actions in the energy sector (focusing on the mitigation actions which took place after Vietnam submitted the INDC) are summarised in Table 9.

Table 9: Key mitigation actions in the energy sector

Mitigation action	Description	Period	Budget	Quantitative goals
Development and promotion of LED technology for general lighting in Vietnam	The goal of the project is to reduce GHG emissions through converting the lighting market towards LED lighting products made in Vietnam	2016 – 2019	USD 8,146,794, of which: (i) USD 1,517,400 is from a GEF grant, ii) USD 100,000 is from the UNDP; (iii) USD 440,000 is from the State budget as counterpart funding; and (iv) USD 6,089,394 is from private sector funding	(i) Direct emissions reduction of 623 tCO_2e from demonstration projects; (ii) Direct emissions reduction of 69,380 tCO_2e from LED lighting product applications; (iii) Indirect emissions reductions of 6,000 tCO_2e (bottom-up method) and 5,145,000 tCO_2e (top-down method) during the period 2019-2028
Energy Efficiency for Industrial Enterprises Project in Vietnam	The project aims to improve EE for industries, contributing to national targets on EE and GHG emissions reduction	2017 - 2022	USD 158 million, of which USD 101.7 million is a concessional loan from WB and USD 56.3 million is co-financing from the State budget	Estimated emissions reduction of 5.027 $MtCO_2e$/year from 2022
Low Carbon Transition in Energy Efficiency project	The project aims to support and contribute to achieving the energy-saving targets of 5-8% in the VNEEP	2013 - 2017	Support from the Government of Denmark of DKK 65 million (equivalent to USD 12 million) through the Green Investment Fund (GIF)	i) Capacity is built for 30-50 organisations working on energy-efficient equipment and services; ii) Improved awareness on EE options and measures for 500-1000 SMEs; iii) Support to implement EE measures for 150-250SMEs; iv) Capacity is strengthened for implementation of the QC 09:2013/BXD

Mitigation action	Description	Period	Budget	Quantitative goals
Energy-efficiency improvement in commercial and high-rise residential buildings in Vietnam	This project is funded by GEF and includes three components: 1) Improve and implement the standard QC 09:2013/BXD; 2) Initiatives to support the development of the construction market; 3) Demonstration and replication of energy-saving technologies and options in the construction industry and in buildings, such as using solar water heaters, insulation material and high efficiency air conditioners	2016-2019	USD 33,562,459, of which: USD 3,198,000 from GEF; USD 2,070,000 from the ongoing UNDP project; USD 2,700,000 from the Government; and USD 25,594,459 from other sources (for demonstration projects)	Direct emissions reduction of 37,383 tCO_2e in the period 2016-2019. Indirect emissions reduction (10 years after project completion) of 197,512 tCO_2e
Promotion of non-fired brick production and utilisation in Vietnam	The project is funded by GEF and includes four components: 1) Policy support for NFB development; 2) Technical capacity building for the application and operation of NFB production and the use of NFB products; 3) Sustainable finance support for NFB application; 4) NFB production technology demonstration, investment and replication	2016- 2019	USD 38,880,000	Estimated emissions reduction of 1,652,532 tCO_2e by 2028

Source: MONRE, 2017

03. Development of the business-as-usual scenario for the energy sector in the period 2014 - 2030

3.1. Assumptions, Methodology, and Input Data

3.1.1. Assumptions

Business-as-Usual scenario (BAU): GHG emissions in the BAU is the reference level to develop mitigation scenarios and determine the GHG reduction potential in Vietnam's NDC. For the energy sector, the BAU scenario assumes that there are no additional policies or plans that would affect the spread of mitigation technologies or practices.

Electricity demand: Electricity demand refers to the projected electricity demand in the Revised PDPVII, which has already accounted for the effects of electricity measures; therefore, in this study we do not count these electricity measures or add the amount of electricity savings (around 5% of total electricity demand by 2030) as they are already estimated by the Revised PDPVII in the BAU.

RE development: As regards power generation, the RE sources will account for a significant share of the total of power capacity by 2030 as planned in the Revised PDPVII. However, RE development is considered as mitigation measures in this study; therefore, RE sources are not included in the BAU but are replaced by imported coal and natural gas power plants to meet electricity demand to 2030.

GDP: Vietnam's GDP growth rate in the period 2010-2015 was 5.91%, which is projected to reach 7.0%[3] for the period 2016-2030.

Population: Vietnam's total population was 90.73 million in 2014. This is projected to increase at an average annual rate of approximately 0.8% to around 103.12 million in 2030. The urban population is expected to increase from 30.04 million in 2014 to 45.80 million in 2030, accounting for 44.4% of the total population (see Table A.1). Household numbers were calculated based on an average family size of 3.7 family members in 2014 and a projected average family size of 3.43 in 2030[4]. It is assumed that there will be no difference in population between the BAU scenario and the mitigation scenarios.

Fuel prices: Fuel prices for power generation in 2014 and projected to 2030 are updated from WB-MOIT's report (2019). The prices of petroleum products for transportation were referenced and updated from WB-GIZ's report (2019). The price of CNG was referenced from the actual prices of CNG in Ho Chi Minh City, estimated at around 80% of the DO price (see Table A.2 and Table A.3).

3.1.2. Methodology

In this study, the Long-range Energy Alternatives Planning system (LEAP) is used as a tool to calculate GHG emissions in the BAU and develop GHG mitigation scenarios (or options) for the 2014-2030 period.

LEAP is an integrated modelling tool that can be used to track energy consumption, production and resource extraction in all sectors of an economy. It is a demand-driven tool in that the user first describes the current and future energy requirements for households, transport, industry, and other sectors, and then uses LEAP to model different processes, such as electricity generation, coal mining and other energy supply systems that provide fuel for consumption.

The BAU scenario was developed to outline future GHG emissions levels for the 2014-2030 period based on the projected energy demand and supply sources in the Revised PDPVII (for 2015-2030), and the updated MOIT and MOT studies conducted by WB and GIZ[5].

For the demand side, GHG emissions were calculated based on the projected energy demand for each sector, such as industry, transport, agriculture, commercial, and residential sectors.

For the supply side, GHG emissions were calculated based on the data of energy exploitation and production in sub-sectors such as coal milling, oil and natural gas exploitation, power generation and oil refineries.

3.1.3. Input data

Activity data

Activity data, including actual energy consumption data in 2014, were derived from Vietnam's annual energy statistics, and projected energy demand in the period 2015-2030 was derived from the Revised PDP VII. Particularly, the data on electricity demand in the period 2014-2030 included the annual electricity savings data estimated to 2030 (see Table A.4 and Table A.5), and the data for petroleum products used for the transport sector were derived from the Ministry of Transport[6].

On the supply side, the GHG emissions sources include activities such as coal milling, oil and natural gas exploitation, power generation, and oil refineries as follows:

- Power generation: Activity data were derived from the Revised National Power Development Plan for the period 2011-2020, with a vision to 2030, approved by the Prime Minister in Decision No. 428/QD-TTg dated 28 March 2016.
- Coal exploitation: Activity data were derived from the Revised Vietnam Coal Sector Development Plan to 2020, with a vision to 2030, approved by the Prime Minister in Decision No. 403/QD-TTg, dated14 March 2016.

[3] Revised PDP, 2016
[4] ADB, 2014
[5] WB-MOIT, 2019, Viet Nam – Getting on a Low-Carbon Energy Path to Achieve NDC Target; WB-GIZ, 2019- Pathway to Low-Carbon Transport
[6] Project: Advancing transport climate strategies (TraCS) 2016-2019

- Natural gas exploitation and processing: Activity data were derived from the Vietnam Gas Industry Development Plan to 2025, with an orientation to 2035, approved by the Prime Minister in Decision No. 60/QD-TTg, dated 16 January 2017.

Emissions factors

GHG emissions in the energy sector are mainly from fuel combustion. During fuel combustion the GHG types such as carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) are emitted.

The values of Global Warming Potential (GWP) of GHGs for 100 years, which have been used in the development of the BAU and mitigation scenarios for the energy sector, are shown in Table 10.

Table 10:The values of Global Warming Potential of GHGs

Gas	GWP
CO2	1
CH4	25
N2O	298

Source: AR4 Report, IPCC, 2007

GHG emissions factors applied for the BAU scenario were referenced from the following sources:

- The default emissions factor in the revised 1996 and 2006 IPCC Guideline used for calculating emissions from fossil fuel combustion (such as coal, petroleum products and natural gas) and fugitive emissions from exploiting and processing surface coal mining, crude oil and natural gas.

- Vietnam's emissions factor used for underground coal mining.

The details on emissions factors and heat values of fuel types used in each sector are listed in Table A.6, Table A.7, Table A.8, Table A.9, and Table A.10.

3.2. Results

3.2.1. BAU scenario of the energy sector in the period 2014-2020

GHG emissions in energy uses for the period 2014-2030 can be calculated based on activity data and emissions factors for fuel types. Table 11 shows GHG emissions in energy uses for the period 2014-2030.

Table 11: Greenhouse gas emissions in energy demand

Unit: Thousand tons CO_2e

	2014	2020	2025	2030
Industry	49,368.3	71,963.2	91,578.2	111,645.9
Transport	30,552.3	46,984.2	64,291.4	88,043.9
Agriculture	1,398.4	5,315.0	6,151.0	7,266.3
Commercial	3,621.8	4,876.9	6,373.9	7,816.2
Residential	10,337.5	10,840.4	11,344.8	11,338.0
Non-energy*	871.5			
Total	**96,149.8**	**139,979.7**	**179,739.3**	**226,110.3**

** From 2015, non-energy was included in the industrial sector*

Source: The GHG inventories (2014) and calculation results from LEAP (2015-2030)

Energy production in Vietnam for the period 2014-2030 consists of five sub-sectors: i) power generation; ii) oil refineries; iii) exploiting and processing gas; iv) crude oil exploitation; and v) coal mining exploitation. GHG emissions under the BAU scenario for energy supply are shown in Table 12.

Table 12: Greenhouse gas emissions from energy supply

Unit: Thousand tons CO_2e

Sources	2014	2020	2025	2030
Electricity generation	52,401.0	174,571.2	280,516.4	406,581.0
Oil refineries	1,935.2	6,215.4	10,079.1	13,438.8
Exploiting and processing gas	4,223.5	4,574.6	6,653.9	7,901.5
Crude oil exploitation	14,139.2	18,506.6	19,400.7	19,400.7
Coal milling exploitation	2,733.6	3,618.5	4,268.6	4,928.4
Total	**75,432.6**	**207,486.3**	**320,918.6**	**452,250.3**

Source: The GHG inventories (2014) and calculation results from LEAP (2015-2030)

Based on the results of calculating GHG emissions to 2030 from energy use and supply, GHG emissions from the energy sector are presented in Table 13.

Table 13: BAU scenario of the energy sector in the period 2014-2030

Unit: Thousand tons CO_2e

	2014	2020	2025	2030	AAGR (2010-30)
Energy use	96,189.8	139,979.7	179,739.3	226,110.3	5.6%
Energy supply	75,432.6	207,486.3	320,918.6	452,250.3	11.6%
Total	**171,622,4**	**347,466.0**	**500,658.0**	**678,360.6**	**8.9%**

It can be seen from Table 13 that GHG emissions from energy supply increase sharply from 75,432,0006 tons CO_2e in 2014 to 452,250,000.3 tons CO_2e in 2030 with an annual average growth rate of 11.6% per year due to emissions from coal thermal power plants, which represent the largest source of power generation.

3.2.2. Comparison with NDC1

In NDC1, development of the BAU scenario for the energy sector was based on that in the BUR1. The Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories and IPCC Good Practice Guidance (GPG 2000) were used to calculate and project GHG emissions in the energy sector by 2020 and 2030 (MONRE, 2015). According to the IPCC Guidelines, the energy sector includes the following sub-sectors: 1A1. Energy industries; 1A2. Manufacturing industries and construction; 1A3. Transport; 1A4a. Commercial/institutional; 1A4b. Residential; 1A4C. Agriculture/Forestry/fishing; 1B1. Solid fuels; and 1B2. Oil and natural gas.

Table 14:Assumptions on power generation according to BAU

Unit: billion kWh

	2010	2020	2030
Large-scale hydropower	27.8	64.6	64.6
Coal-fired thermal power	17.9	163.5	422.4
Gas-fired thermal power	45.3	81.5	107.8
Renewable energy	3.3	3.3	3.3
Nuclear power	0	6.9	70.1
Imported energy	0	9.9	26.4
Total	**94.3**	**329.7**	**694.6**

However, during the process of revising the NDC1, the BUR2 and the TNC did not develop the national BAU scenario for the 2020-2030 period. Therefore, the BAU scenario for the energy sector was developed by the deployment of the LEAP model based on the updated data from projected energy demand and supply sources in the Revised PDPVII (for 2015-2030), and the updated MOIT and MOT studies implemented by WB and GIZ. Therefore, the major reason for the different GHG emissions between BAU in NDC1 and the revised NDC1 is different reference sources. The comparison between the results of the BAU scenario in INDC and the revised NDC are presented in Table 15.

Table 15: Comparison between the BAU scenario for the energy sector in Vietnam's NDC1 and the revised NDC1

Unit: $MtCO_2e$

Category	2010	2014	2020		2030	
	NDC1[1]	The revised NDC1[2]	NDC1[3]	The revised NDC1[4]	NDC1[3]	The revised NDC1[4]
1 Total	**141.2**	**171.6**	**389.3**	**347.5**	**675.45**	**678.3**
1A. Fuel Combustion	**124.3**	**148.6**	**355.77**	**314.6**	**620.37**	**632.6**
1A1. Energy industries	41.1	52.4	171.37	174.6	404.47	406.6
1A2. Manufacturing industries and construction	38.1	50.3	69.3	72.0	92.5	111.6
1A3. Transport	31.8	30.6	87.9	47.0	87.9	88.0
1A4a. Commercial/institutional	3.3	3.6	8.4	4.9	12.1	7.8
1A4b. Residential	7.1	10.3	16.5	10.8	20.5	11.3
1A4c. Agriculture/forestry/fisheries	1.6	1.4	2.3	5.3	2.9	7.3
1B. Fugitive Emissions	16.9	23.0	33.5	32.9	55.1	45.7
1B1. Solid fuels	2.2		16.0		18.5	
1B2. Oil and natural gas	14.7		17.5		36.6	

Source: [1]MONRE (2014b); [2]MONRE (2019)[3] BAUmax, [4]Calculated result from LEAP (2015-2030)

It can be seen from Table 15 that in Vietnam's revised NDC1, according to the BAU scenario, GHG emissions in 2020 are lower than in the NDC1. Particularly, in the revised NDC1, the forecast for GHG emissions in 2020 is 347.4 $MtCO_2e$, which is 41.8 $MtCO_2e$ lower than in the NDC1. In 2030, GHG emissions in Vietnam's revised NDC1 are slightly higher than in the NDC1. The forecast for GHG emissions in 2030 in the revised NDC1 is 678.3 $MtCO_2e$, which is 2.85 $MtCO_2e$ higher than in the NDC1.The key reason for the difference between the BAU scenario in the NDC1 and the revised NDC1 are changes in the assumptions when developing the BAU scenario and the reference sources.

04. Development of the mitigation scenario for the energy sector in the period 2020-2030

This section focuses on the development of GHG mitigation scenarios that determine GHG reduction potential in the energy sector. These mitigation scenarios show how the sector can contribute to Vietnam's NDC for the 2020-2030 period compared to the BAU scenario. Cost-benefit calculations were conducted and prioritised mitigation technologies were selected.

4.1. Criteria for Determination and Prioritisation of Mitigation Options

The determination and selection of technology options was implemented through consultant group meetings and based on criteria, such as: GHG reduction potential, cost-effectiveness, maturity of technologies, and alignment with government policies:

- *GHG reduction potential*: Options with an abatement potential large enough to significantly impact the sector or the national level.
- *Cost-effective*: Options with low abatement costs and investment feasibility.
- *Maturity of technologies*: Technologies that are ready, available and already applied domestically and internationally.
- *Government priorities*: Options that conform to national strategies, sectoral development priorities and plans.

Based on the above criteria, 39 mitigation technology options for Vietnam's NDC were determined and evaluated as follows:

- 06 EE and RE options for the residential sector
- 10 EE options in the industrial sector
- 11 options on fuel substitutions and mode shifts for the transport sector
- 01 EE option in the commercial and services sector
- 11 RE and EE options in the power generation sector
- The criteria for selection of priority technologies are classified as unconditional or conditional contributions as in Table 16.

Table 16: Criteria for prioritisation of mitigation options in the energy sector

	Criteria
Prioritised mitigation options	GHG reduction potential Alignment with government policies Cost-effectiveness Maturity of technologies
Unconditional contribution	Low abatement costs Already implemented in Vietnam Aligned with sectoral plans for the 2021-2030 period
Conditional contribution	Higher abatement costs New technologies Currently implemented in developed countries

The evaluation and ranking of mitigation technologies was based on the available data for each mitigation technology.

4.2. Methodology, Assumptions and Input Data

4.2.1. Methodology

The LEAP model was used to assess 39 different GHG emissions reduction options, including 28 RE and EE options on the energy demand side and 11 RE and EE options on the energy supply side.

Mitigation scenarios were developed using a combination of top-down and bottom-up approaches. By using a bottom-up approach, energy-using sectors were broken down into sub-sectors, end-uses and technologies. Because of limited time and resources, the bottom-up approach was only used for sectors with available data (such as transport and residential sectors) while some sub-sectors in the industrial sector and the remaining sectors used a top-down approach.

Mitigation scenarios are designed based on the potential of RE sources and EE technologies under the assumption that additional action plans or policies are developed or considered. The differences between the BAU and mitigation scenarios demonstrate potential fossil fuel savings and potential GHG reductions.

4.2.2. Assumptions and input data

Based on the assumptions on input data and the application of a 10% discount rate, the following mitigation potential and costs per ton of CO_2e savings were calculated.

Renewable energy and efficient energy use in households

- **Option E1: High efficiency residential air conditioning**

In the BAU, it is assumed that the numbers of households using standard air conditioning in urban areas will increase from 32.0[7] in 2014 to 80% in 2030 and similarly from 4.5% in 2014 to 50% in 2030 in rural areas.

Option E1 assumes that by 2030 the use of high efficiency air conditioning units that replace standard air conditioning units could be increased from 15% in 2014 to 75% in 2030 of the total households using air conditioning in urban areas, and from 8% to 55% in rural areas.

According to the results of a market survey in 2013, almost all air conditioning units used in Vietnam were popular types (non-invertors), which have an average capacity of 12,000 BTU[8] corresponding to a power capacity of 1,200W and cost around USD 400[9] per unit. High efficiency air conditioning units with the same cooling capacity cost around 30% more but can reduce power consumption by approximately 30%. Both types have a lifespan of 10 years.

The total additional investment cost of implementing option E1 is USD 681.7 million[10], while the option saves USD 504.1 million[11] from electricity savings and reduced emissions of 23.9 $MtCO_2e$ at an abatement cost of USD 7.4/tCO_2e.

» **Option E2: High efficiency residential refrigerators**

In the BAU, it is assumed that the number of households using refrigerators in urban areas will increase from 81.1%[12] in 2014 to 95 % in 2030 and from 50.2% to 80% in rural areas, in which high efficiency refrigerators will account for around 15% and 10%, respectively.

Option E2 assumes that by 2030 the percentage of households in urban areas that replace standard refrigerators with high efficiency refrigerators can be increased from 15% (in 2014) to 80% and similarly from 10% to 65% in rural areas.

According to the results of the market survey, around 72% of refrigerators currently used have an average storage capacity ranging from 121 to 300 litres and 53% of users spend from USD 200 to USD 400 to purchase refrigerators. Thus, it is assumed that standard refrigerators have an average storage capacity of 250 litres, which corresponds to power consumption of around 460 kWh per year and cost around USD 300 per unit.

High efficiency refrigerators with the same storage capacity cost around 15% more but can reduce power consumption by approximately 30%. Both types have a lifespan of 10 years, and the average storage capacity of new refrigerators is expected to increase (to approximately 350 litres) by 2030.

The total additional investment cost to implement this option is USD 298.1 million, while the option can save USD 273.4 million from electricity savings and reduce emissions by 11.3 $MtCO_2e$ at an abatement cost of USD 2.2/tCO_2e.

» **Option E3: High efficiency residential lighting**

Based on the household surveys conducted by the International Institute for Energy Conservation (IIEC) in 2015, the average number of lamps installed in each household in Vietnam was estimated to be around 13 in 2014 equivalent to a total lamp stock in the residential sector of about 315 million lamps. Fluorescent lamps have been the most popular in Vietnamese households, accounting for around 39% of the total lamp stock, or around 123 million lamps. CFLs are the second most popular technology and make up around 32% (100 million lamps), followed by LED lamps (17%), incandescent light bulbs (11%) and halogen lamps (1%)

It is assumed that by 2030 the use of high efficiency lighting (or LED lighting) can be increased from 17% (in 2014) to 70% of the total lamp stock in the residential sector, thus replacing incandescent light bulbs (or other similar traditional lighting).

Based on the specifications of the two types of lighting,

[7] GSO - Results of the Viet Nam household living standards survey 2014
[8] ASEAN-SHINE: Promotion of high efficiency air conditioners in ASEAN-A regional policy roadmap, 2015
[9] MATSUMOTO Shigeru- Consumer Valuations of Energy Efficiency Investments: The case of Viet Nam's air conditioner market
[10] At 2014 prices with a discount rate of 10%
[11] See Table 20
[12] GSO - Results of the Viet Nam household living standards survey 2014

a 7W LED light is as bright as a 60W incandescent light bulb, costing approximately USD 5 more with an average lifespan of 10 years, more than 10 times longer than an incandescent light bulb.

The total additional investment cost to implement this option is USD 360.2 million, while it can save USD 1,128.4 million and reduce emissions by 47.0 $MtCO_2e$ at an abatement cost of USD -16.3/tCO_2e.

Option E4: Solar water heaters

Solar water heater (SWH) systems have been studied for many years in Vietnam. The number of SWHs has rapidly increased in recent years, as electricity prices have risen significantly.

EVN, EE and the Conservation Office started the promotion programme for SWHs in 2009 with the goal of reducing electricity consumption in peak hours. The programme supported 60,000 SWH units during 2010-2012 by providing one million VND per unit for each household installing SWH. Around 10,000 SWH units were installed in 2010, mainly in urban residential areas.

There has not been a national survey on using SWHs in residential areas; however, it could be estimated that there were around 100,000 SWH units in 2014, mainly in urban residential areas, equal to 1% of total households in urban areas and around 0.3% in rural areas.

The Renewable Energy Development Strategy (REDS) has set up a plan to develop SWHs in residential areas to enable the proportion of households using solar water-heating devices to reach 12% in 2020 and 26% in 2030. Thus, SWHs could gradually replace electric heaters. The percentage of total households effectively using SWH could be increased from 1% in 2014 to 30% in 2030 in urban areas, and from 0.3% to 5% in rural areas.

Because of the fluctuation in solar radiation by season, especially in winter in the northern region of Vietnam, SWHs were assumed to save electricity by around 60%. The cost of an electricity heater is USD 120, while SWHs cost USD 450[13]. Both have life spans of 15 years.

The total additional investment cost to implement this option is USD 216.1 million, while it can save USD 108.2 million from electricity savings and reduce emissions by 5.1 $MtCO_2e$ at an abatement cost of USD 21.3/tCO_2e.

» **Option E5: Biogas replacing coal for residential cooking in rural areas**

These technologies were introduced in Vietnam in the early 1960s. Many biogas digester models were developed and widely disseminated by various local researchers and development institutions. There are three main types of anaerobic digesters - fixed dome, floating cover and bag digesters - that were developed and field tested and then disseminated in several provinces. Biogas project development was limited due to high its investment cost and low rural incomes until 2003, when the "Support to the biogas programme for the animal husbandry sector of some provinces in Vietnam" project, funded by the Government of the Netherlands, was implemented by the Department of Agriculture under the Ministry of Agriculture and Rural Development.

The overall objective of the project was "to further develop the commercial and structural development of biogas, at the same time avoiding the use of fossil fuels and biomass resource depletion".

The biogas programme has been implemented nationwide in 50 provinces. By the end of 2010, the programme had supported the construction of 103,000 units in the country[14]. Besides MARD's Biogas Programme, there are several other organisations that support the development of biomass technologies, such as the National Centre for Agriculture Extension and the Vietnamese Gardeners Association (VACVINA), resulting in tens of thousands of units used for household cooking.

For cooking purposes, it is estimated that there are around 130,000 households using biogas, equivalent to around

[13] Based on Ariston SWH price with average capacity of 175 litres
[14] MARD-SVV, 2011- Biogas User Survey 2010-2011

0.8% of total households in rural areas in 2014. Thus, the biogas potential for cooking is still significant. Therefore, it needs the support of policies to encourage rural households to invest in biogas digesters.

By 2030, it is assumed that 5% of households in rural areas (compared with 0.8% in 2014) will use biogas to replace coal for cooking.

The average cost of a biogas digester with a normal volume of $10m^3$ is around USD 550[15]. The annual average production is around 1200 m^3/year, and the investment cost is estimated at USD 850/TOE/year (with calorific value of biogas of 5380 kcal/m^3). The O&M cost is estimated at around 3% of investment cost or USD 25/TOE/year.

The average efficiency of coal stoves is around 20%, consuming 0.42 TOE/year, while the average efficiency of biogas stoves is around 60%, consuming 0.14 TOE/year[16]. The average price of coal stoves is around USD 5 with a lifetime of 2 years, while the average price of biogas stoves is around USD 40 and both biogas stoves and digesters have a lifetime of 10 years.

Calculations show that the total additional investment costs for biogas is USD 118.8 million, while biogas can save USD 117.4 million from fuel savings and reduce 9.5 $MtCO_2e$ at an abatement cost of USD 0.1/tCO_2e.

» **Option E6: Cleaner cooking fuels**

By 2030, it is assumed that the share of households in rural areas using LPG to replace coal for residential cooking will increase from 30% (in BAU) to 50%.

The average efficiency of coal stoves is around 20%, consuming 0.42 TOE/year, while the average efficiency of LPG stoves is around 60%, consuming 0.14 TOE/year. The average price of coal stoves is around USD 5 with a lifetime of 2 years, while the average price of LPG stoves is around USD 40 with a lifetime of 10 years.

Calculations show that the total additional investment cost for cleaner cooking is USD 1,158.6 million (including fuel costs of USD 1,130.7), while it can save USD 453.6 million from fuel savings and reduce 31.9 $MtCO_2e$ at an abatement cost of USD 22.1/tCO_2e.

Efficient Energy use in the industry sector

a) Technology improvement in cement production

The cement industry is one of the largest consumers of energy in Vietnam's industry sector. There are two basic types of cement production process - wet and dry processes - and also two types of kilns: vertical shaft and rotary kilns.

Total cement production in 2014 was 60.98 million tons[17], in which the amount of cement produced from vertical shaft kilns accounted for about 0.9% with the remaining produced by rotary kilns. Vertical shaft kilns are a backward technology that the Government plans to substitute with modern technology by the end of 2015[18].

As planned, cement production will reach 112.02 million tons by 2020, 131.42 million tons by 2025, and 140.12 million tons by 2030 (see Table A.12).

For rotary kiln technology, there are two types of production processes: dry and wet. Most cement products are produced using dry production processes. Only around 840,000 tons was produced by wet production processes in 2014 (accounting for 1.4 percent of total cement production produced by rotary kiln technology) due to its low efficiency in using energy.

Energy consumed in cement production is mainly coal for producing (burning) clinker and electricity for grinding clinker and cement. According to survey data, dry rotary kilns consume coal at approximately 3,500 MJ/tone of clinker and electricity at around 59 kWh/ton of clinker and 87 kWh/ton of cement[19]. Clinker content in one ton of cement is 85.5%[20].

[15] MONRE, 2018
[16] Institute of Energy survey data
[17] Based on statistical data
[18] Prime Minister's Decision No. 1488/QD-TTg dated 29 August 2011
[19] NORDIC-NAMA Cement Project, 2016
[20] NORDIC-NAMA Cement Project, 2016

Based on the current status of cement production technologies, three mitigation options are proposed:

» **Option E7: Combustion optimisation**

The clinker burning process consumes great amounts of thermal energy to make clinker. Fuel combustion management, such as fuel grinding management, maintaining the appropriate primary air ratio and the optimum combustion conditions, is the most fundamental energy-saving activity to be conducted every day at cement plants. It is assumed that this option will be applied to 50% of clinker production by 2030.

The initial investment cost of this option is around USD1/ton clinker but can save 2% of energy for making clinker[21].

The total investment costs for this option are USD 22.9 million, resulting in savings worth USD 42.9 million. The potential to reduce emissions is estimated at 3.1 $MtCO_2e$ at an abatement cost of USD -6.4/tCO_2e.

» **Option E8: Kiln shell heat-loss reduction**

For high temperature burning in the burning process, refractoriness is used for the internal walls of various facilities. Various heat insulation measures are taken to prevent heat radiation losses from walls. The use of improved kiln-refractoriness may also lead to improved reliability of the kiln and reduced downtime, reducing production costs considerably, and reducing energy needs during start-ups.

It is assumed that this option will be applied to 40% of clinker production by 2030. The initial investment cost of this option is around USD 0.25/ton clinker, but it can save energy at 0.12 GJ/ton clinker for making clinker (MONRE, 2018).

The total investment cost for this option is USD 3.3 million, resulting in savings worth USD 52.4 million. The potential to reduce emissions is estimated at 4.3 $MtCO_2e$ at an abatement cost of USD -11.5/tCO_2e.

» **Option E9: Waste heat recovery from cement**

Waste Heat Recovery (WHR) systems consist of heat exchangers or heat recovery steam generators that transfer heat from the exhaust gases in clinker burning to the working fluid inside turbines, electric generators, condensers, and a working fluid cooling system. Currently, WHR is a proven technology with no significant technological challenges.

It is assumed that this option will be applied to 50% of clinker production by 2030.

The initial investment cost of this option is around USD 2000/kW. Operations and maintenance is USD 80/kW, but the option can save energy by 35 kWh/ton clinker (MONRE, 2018).

The total investment costs for this option are US$89.8 million, resulting in savings worth US$191.7 million. The potential to reduce emissions is estimated at 15.0 $MtCO_2e$ at an abatement cost of US$-6.8/$tCO_2e$.

» **Option E10: Vertical roller mills**

Grinding systems using vertical roller mills have been applied in the cement grinding process since the 1980's. In this process, materials such as clinker and gypsum that are fed into the mill are ground by compression and shearing forces between the grinding table and two or four rollers, which are hydraulically loaded and controlled. Ground cement materials are sent to separators installed in the mill's upper area by air and classified into coarse particles and fine product. Coarse particles are returned to the grinding table to be re-ground and the fine product is sent to dust collectors such as cyclone and/or bag filters.

It is assumed that this option will be applied to 50% of cement production by 2030 to replace conventional technology.

The initial investment cost of this option is around USD 18.89/ton cement, but it can save energy by 20 kWh/ton cement (MONRE, 2018).

[21] MONRE, 2018- Low Carbon Technology Catalogue

The total investment costs for this option are USD 368.2 million, resulting in savings worth USD 164.9 million. The potential to reduce emissions is estimated at 6.8 $MtCO_2e$ at an abatement cost of USD 29.8/tCO_2e.

b) Technology substitutions in brick-making

According to the MOC's plan[22], the total design capacity for building material plants will reach around 27.5 billion pieces by 2020, 30.5 billion pieces by 2025 and 35.9 billion pieces in 2030, in which non-baked bricks will account for at least 40% in 2020. The Government encourages investment for development of energy-saving tunnel kiln technology and is taking steps to eliminate manual brick kilns.

In 2014, total baked-brick production reached 17,368 million pieces[23]. A non-baked brick programme began in 2010 and reached around 4,100 million pieces[24] in 2014 (accounting for 19.1 % of total brick production).

On the technology aspect, baked bricks are made by tunnel and traditional technologies, in which tunnel technologies accounted for 53%[25] of total baked-brick production in 2014, the remaining was traditional technologies consisting of Hoffmann kilns, vertical shaft brick kilns, and manual brick kilns. Based on the integrated development plan for building materials in economic areas in the whole country to 2020 and other related study papers, the share of each fuel type and the energy requirements for each technology in 2014 are estimated in Table A.15.

» **Option E11: Brick-making technology improvements**

Brick-making technology improvements along with energy use reduction to (2.6 MJ per brick) will be applied to 70% of traditional brick production by 2030. The main traditional technology applied in brick making in Vietnam is the manual type of kiln (accounting for 47% of total baked brick production), which consumes approximately 4.3 MJ per brick. Additional investment costs under the mitigation scenario are estimated at USD 6,000 per annual capacity per million bricks, with an assumed lifespan of 15 years.[26]

The total additional investment costs for technology improvements are USD 18.4 million, resulting in savings worth USD 145.9 million. The potential to reduce emissions is estimated at 10.8 $MtCO_2e$ at an abatement cost of USD -11.8/tCO_2e.

c) Energy-efficient use and fuel substitution in steel production

The iron and steel industry is one of the largest industrial energy consumers.

There are two main technologies to produce iron and steel in Vietnam: Blast Furnaces (BF) and Electric Arc Furnaces (EAF). In both cases, the energy consumed comes from fuel (mainly coal and coke) and electricity.

Blast furnaces that used to produce pig iron from iron ore for subsequent processing into crude steel bars and finished steel products would be oriented for the development of Vietnam's steel industry, especially for areas with concentrated sources of iron ore[27]. However, EAF has used electricity as heat energy to melt steel scrap for steel production at small scales, backward technologies and high energy consumption.

In steel production, energy is mainly used in processes for melting iron and making crude steel bars. Moreover, because of insufficient data on making finished steel products, this study focused mainly on melting iron and making crude steel bars.

Manufacturing pig iron: In 2010, pig iron production achieved 0.3 million tons and increased to 1.4 million tons in 2014[28]. According to "the steel manufacturing and distribution system development planning by 2020 with a vision to 2025" approved in 2013, "Manufacturing pig

[22] MOC, 2019
[23] Statistic Yearbook, 2015
[24] https://baomoi.com/phat-trien-vat-lieu-khong-nung-can-giai-phap-dong-bo-de-phat-trien/c/17838740.epi
[25] Estimated based on the report of the Building Material Institute, 2016- Input data for greenhouse gas reduction by improvement of production technology of building materials
[26] ADB, 2014
[27] Decision No.694/QD-BCT, 2013 on Approving the steel manufacturing and distribution system development planning by 2020 with a vision to 2025
[28] Viet Nam Steel Association

iron and sponge iron shall reach approximately 6 million tons by 2015; approximately 17 million tons by 2020 and approximately 28 million tons by 2025". However, pig iron production achieved was 1.7 million tons[29] by 2015, accounting for only 30% of the proposed plan (in 2013). Therefore, based on this, it could be estimated that pig iron production will account for around 35%, 40% and 50%, equivalent to around 6 million tons, 10 million tons and 16 million tons in 2020, 2025 and 2030, respectively (see Table A.16).

Manufacturing crude steel bars: According to statistical data, crude steel bar production achieved 4.3 million tons in 2010 and increased to 5.8 million tons in 2014. Based on the list of designed capacity of steel plants (as in the proposed 2013 plan), it is estimated that crude steel bar production could achieve around 22.0 million tons in 2020 and 47.5 million tons in 2030 (see Table A.17).

Currently, energy consumption for manufacturing iron (including the sintered process) is around 19.0 GJ/ton[30](in which, coke is around 500kg/ton and coal is around 100kg/ton). It is expected this energy consumption could be decreased significantly (coke to around 400kg/ton, coal to around 200 kg/ton)[31] due to blast furnaces with capacities ranging from 500 m^3 to 1000 m^3 (for areas located in coastal regions)[32]. Regarding EAF technology, energy consumption for manufacturing steel is around 3.0 GJ/ton (in which, electricity consumption is around 600 kWh/ton or 2.2 GJ/ton).

According to Circular No. 20/2016/TT-BCT, energy consumption for manufacturing iron by BF has to drop to under 14 GJ/kg and for manufacturing crude steel bars by EAF has to drop to under 2.6 GJ/kg. This shows that the potential of EE for manufacturing iron and crude steel bars is significantly high.

This study proposes two regular measures with high energy saving potential.

» **Option E12: Pulverised coal injection in blast furnaces**

Pulverised coal injection is a process that involves blowing large volumes of fine coal granules into the BF. This provides a supplemental carbon source to speed up the production of metallic iron, reducing the need for coke production. As a result, energy use and emissions can be reduced.

Based on Circular No. 20/2016/TT-BCT on energy norms for manufacturing iron and steel, it is assumed that using pulverised anthracite coal to inject into BF (with around 230 kg/ton iron) to reduce coke (to around 350 kg/ton iron)[33] will be achieved and this option will start from 2020 and account for 50% of total iron production in 2030.

The initial investment cost of this option is around USD 11/ton iron but can save 0.75GJ/ton of energy for making iron.

The total investment cost for technology improvements is USD 11.8 million, resulting in savings worth USD 40.9 million. The potential to reduce emissions is estimated at 2.7 $MtCO_2e$ at an abatement cost of USD -10.8/tCO_2e.

» **Option E13: Scrap preheating**

In this option, scrap is continuously preheated by waste heat from EAF exhaust gases before putting into the EAF. This technology has huge implementation potential due to low investment costs, shortened steel smelting time, and electricity savings.

It is assumed that this option will account for 75% of total steel production by EAF technologies in 2030. The additional investment cost of this option is around USD 9.4/ton steel but can save 0.43GJ/ton of energy[34].

The total additional investment cost for this technology is USD 18.5 million, resulting in savings worth USD 100.0 million. The potential to reduce emissions is estimated at 4.1 $MtCO_2e$ at an abatement cost of USD -19.9/tCO_2e.

[29] FPT Securities- Steel Sector Report, 2017
[30] Based on UNIDO's survey and VSA's estimation
[31] Based on VSA's estimation
[32] Decision No. 694/QD-BCT
[33] Estimated based on the related data from regional countries and VSA's expert advice
[34] World Bank, 2016

» **Option E14: Hot charging in rolling mills**

The conventional process requires a large amount of energy because the slab is temporarily cooled, inspected for flaws and defects, conditioned, and then reheated in a heating furnace. In contrast, in hot charging, the hot slab is transported as hot to the rolling mill via the heating furnace without passing through the cooling process, and in direct rolling, the hot slab is transported as hot directly to the rolling mill. The energy saving potential of this option increases with the capacity of a continuous caster.

It is assumed that this option will account for 75% of total steel production by EAF technologies in 2030. The additional investment cost of this option is around USD 23.5/ton steel, but can save 0.52GJ/ton of energy[35].

The total additional investment cost for this technology is USD 46.2 million, resulting in savings worth USD 120.9 million. The potential to reduce emissions is estimated at 4.9 $MtCO_2e$ at an abatement cost of USD -15.1/tCO_2e.

» **Option E15: Recovering gas heat from Basic Oxygen Furnace (BOF)**

Recovery of basic oxygen furnace (BOF) gas is the single most energy-saving improvement in the BOF process, making it a net energy producer. BOF gas produced during oxygen blowing leaves the BOF through the converter mouth and is subsequently caught by the primary ventilation. The gas produced in the BOF has a temperature of approximately 1200°C, which can be used for steel-making processes.

It is assumed that this option will account for 75% of total steel production by BF technologies in 2030. The additional investment cost of this option is around USD 35.21/ton steel but can save 0.73GJ/ton of energy[36].

The total additional investment cost for this technology is USD 56.7 million, resulting in savings worth USD 55.5 million. The potential to reduce emissions is estimated at 4.3 $MtCO_2e$ at an abatement cost of USD 0.3/tCO_2e.

» **Option E16: EE improvement in other industrial sub-sectors**

Besides industrial sub-sectors such as cement, brick, and iron and steel production as shown above, other industrial sub-sectors account for around 65% and 70% of the total energy consumption in 2014 and 2030, respectively.

According to WB estimations[37], if the measures to improve the efficiency of boilers, electricity motors and other equipment with investment costs of USD 1,498 million were applied, they could save around 6.5% of energy demand in the other industrial sub-sectors by 2030.

The total additional investment costs for this measure are USD 1,469.2 million, resulting in savings worth USD 2,039.0 million. The potential to reduce emissions is estimated at 87.4 $MtCO_2e$ at an abatement cost of USD -6.5/tCO_2e.

Mode shift and fuel substitution in transport

» **Option E17: New vehicle fuel economy and emissions standards**

The rapid growth of private vehicles is one of the main causes of many problems in society. As the number of private vehicles increases rapidly, fuel consumption (gasoline, diesel) and total national GHG emissions increase. It is possible to apply fuel economy for small cars under 9 seats in the future.

According to survey data, by 2014, the average fuel consumption of motorbikes was 2.7l/100km and for small cars 8.1l/100km. It is assumed that motorbike sales and small car (under 9 seats) sales will apply fuel economy from 2022 to achieve 2.3 l/100km for motorbikes, 4.7l/100km, 5.3l/100km and 6.4l/100km for small cars (<1400cc), medium cars (1400-2000cc) and large cars (>2000cc), respectively, by 2030. The only expected costs associated with the deployment of vehicle fuel economy standards is the administrative cost, such as the cost for formulation of regulations and costs for setting up an administrative unit. Total costs are estimated at around USD 45,000 per year[38].

[35] World Bank, 2016
[36] World Bank, 2016
[37] WB-MOIT, 2019
[38] WB-GIZ, 2019- Pathway to Low-Carbon Transport

The total investment costs for this measure are USD 0.4 million, resulting in savings worth USD 1,027.9 million. The potential to reduce emissions is estimated at 15.8 $MtCO_2e$ at an abatement cost of USD -65.2/tCO_2e.

» **Option E18: Passenger transport mode shift from private to public**

Public passenger transport in Vietnam is divided into four categories: air, water, rail (electric and diesel), and road (HCV buses, HCV coaches, LCV passenger), while private passenger transport is mainly motorbikes and private cars. In 2014, the total number of passenger traffic was 385.49 billion passenger-km, estimated to increase to 960.15 billion passenger-km in 2030, in which private passenger transport accounted for 66.8% in 2014, slightly deceasing to 65.8% in 2030[39].

For this mitigation option, to 2030, the expansion of bus systems will be developed in 5 cities under central management (Hanoi, Ho Chi Minh City, Hai Phong, Da Nang, and Can Tho). Four new BRT systems will be developed in Hanoi, Da Nang and Ho Chi Minh cities and 03 new metro lines will be developed in Hanoi and Ho Chi Minh City. Therefore, it is assumed that additional public transport passengers will switch from private passenger transport, thus reducing individual road transport by around 4% in 2030 modelled as a reduction in passenger-km of private transport (mostly motorbikes).

The additional cost of this mode shift is mainly from costs for bus infrastructure. In this study, the costs of roads were extracted from IEA estimates (2012)[40], with USD 0.02 per passenger-km for investment costs and USD 0.0003 per passenger-km for annual O&M cost.

The total additional investment costs for mode shift of passenger transport are USD 724.9 million, resulting in savings worth USD 744.7 million, mainly from fuel savings. The potential to reduce emissions is estimated at 4.6 $MtCO_2e$ at an abatement cost of USD -4.3/tCO_2e.

» **Option E19: Modal shift of freight transport from road to inland water and marine waterways**

The total volume of freight traffic will reach 621.2 billion ton-km by 2030, in which road transport accounts for 23.4%, and inland water and marine water account for 20.6% and 54.5% of the total volume of freight traffic, respectively. For this mitigation option, freight transport by inland water ways will increase from 127.8 to 128.8 billion ton-km (to 20.6% to 20.8% of the total volume) and the modal share for roads will decrease from 23.4% to 23.0% in 2030. The freight transport shifted from road to marine waterways is assumed to be equivalent to the freight transport shifted from roads to inland water ways in the same time frame.

The additional cost of the freight transport mode shift is mainly from costs for marine water and inland water infrastructure. In this study, the costs of marine water and inland water infrastructure are referenced from WB reports[41], with USD 0.06 per ton-km for investment cost and the cost for annual O&M estimated at around 0.5% of investment cost.

The total additional investment costs for mode shift of freight transport are USD 282.7 million, resulting in savings worth USD 1,767.6 million, mainly from fuel savings. The potential to reduce emissions is estimated at 16.0 $MtCO_2e$ at an abatement cost of USD -93.0/tCO_2e.

» **Option E20: Introduction of electric motorbikes**

By 2030, the share of gasoline-fuelled motorbikes in the total of private vehicles is still high at around 60%.

The assumption is that electric motorbikes (EM) will account for 7% of annual new motorbike sales from 2015 to replace gasoline-fuelled motorbikes mainly in big cities. The average energy consumption of gasoline-fuelled motorbikes is around 0.27 litre/km while EM consumes around 0.032 kWh/km[42].

[39] GIZ, 2018
[40] Energy Technology Perspectives 2012-Pathways to a Clean Energy System, IEA-2012
[41] WB, 2014-Facilitating Trade through Competitive, Low-Carbon Transport: The Case for Viet Nam's Inland and Coastal Waterways
[42] GIZ, 2018

Investment cost for EM is (rather lower than or) equal to gasoline-fueled motorbikes but requires an additional cost for batteries at around USD 0.005/vehicle-km[43].

The total additional investment costs for this option are USD 266.3 million, resulting in savings worth USD 573.3 million. The potential to reduce emissions is estimated at 4.6 $MtCO_2e$ at an abatement cost of USD -67.2/tCO_2e.

» **Option E21: Substitution of ethanol for gasoline in transport**

Bio-fuel production in Vietnam will complement traditional energy sources and will contribute to energy security and environmental protection. Conditions in Vietnam are favourable for producing bio-fuel from biomass. Bio-ethanol can be produced from rice, maize, cassava, sweet potato, and sugarcane.

In Vietnam, Cassava has great potential for bio-ethanol production. The yield of cassava in 2015 was around 10.7 million tons, which can produce around 1,530 million litres or 1,210,000 tons of bio-ethanol.

According to the Ministry of Industry and Trade (MoIT), in 2018, there were seven ethanol plants operating in Vietnam, with a combined production capacity of 600,000 tons, including three plants owned by Petro-Vietnam (PVN), in Phu Tho, Quang Ngai, and Binh Phuoc, each with an annual production capacity of 100,000 tons.

According to Vietnam Oil and Gas Group, the total production of E5 used in Vietnam in 2014 was 55,000 m^3, equivalent to 2,750 m^3 ethanol or around 1,393 TOE, accounting for 0,03% of the transport sector's gasoline consumption in 2014.

Ethanol is mixed with gasoline in two fractions, known as E5 and E10. E5 contains 5% ethanol and 95% gasoline, while E10 contains 10% ethanol and 90% gasoline.

Ethanol sales in 2018 for transport totalled 145,000 tons, and during the first six months of that year, E5 accounted for 40.18% of gasoline sales.

Based on the above analysis, assumptions could be proposed as follows:

In the BAU scenario, it is assumed that the ethanol share of 0,03% in 2014 would be maintained to 2030. In the mitigation option, it is assumed that the 145,000 tons of ethanol consumed in 2018 would be maintained to meet demand for E5 in the transport sector from 2019 to 2030. The investment cost

of ethanol plants is around USD 1,200/TOE[44], with O&M costs estimated at around 30% of investment costs or USD 36/TOE/year. Variable O&M (or operational) costs are around USD 20/TOE[45].

Cassava roots can be used as feedstock for bio-ethanol production. Cassava roots are often transformed readily to a dried form called cassava chips, which can be less costly for transportation and stored for a year. In 2014, the price of cassava chips was around USD 210/ton and estimated to increase by around 2% per year due to increasing demand for bio-ethanol. The ethanol factories have lifetimes of 30 years.

The total additional costs for ethanol production are USD 470.2 million, resulting in gasoline savings worth USD 332.9 million. The potential to reduce emissions is estimated at 3.1 $MtCO_2e$ at an abatement cost of USD 44.1/tCO_2e.

» **Option E22: Introduction of CNG buses**

Compressed natural gas (CNG) buses are an attractive option for investment and for implementation in Vietnam's main cities. There were 473 CNG buses in Ha Noi and Ho Chi Minh cities in 2018. It is assumed that CNG buses will increase to 623 units in 2030 (423 units in Ho Chi Minh City and 200 units in Ha Noi) to replace DO buses.

[43] Estimated based on the costs of the regular battery type of lithium 36V-10ah
[44] Joseph B. Gonsalves (2006), An Assessment of the Bio-fuels Industry in Thailand (table 2, page 14)
[45] Thu Lan T. Nguyen et al. (2006), Life Cycle Cost Analysis of Fuel Ethanol Produced from Cassava in Thailand (table 2, page 5)

Diesel Oil (DO) buses cost around USD 70,000, while CNG bus costs are higher by around 30%[46]; however, CNG fuel consumption can be reduced by approximately 10%, while the cost of CNG is equal to around 80% of DO.

Based on an assumption that both buses run at 45,000 km/year, the additional investment cost for CNG buses is around USD 0.025 passenger-km and additional O&M costs around USD 0.0025 passenger-km. Both buses have a lifespan of 10 years.

The total additional investment costs for this option are USD 6.5 million, resulting in fuel savings worth USD 5.3 million. The potential to reduce emissions is estimated at 0.03MtCO_2e at an abatement cost of USD 34.1/tCO_2e.

» **Option E23: Promotion of electric cars**

By 2030, the share of private cars in the total of private vehicles is still high at around 40%. Currently, the investment and production of electric cars is growing around the world. Vietnam's Vinfast group intends to manufacture electric cars in the coming years.

For this mitigation option, it is assumed that electric cars will account for 5% of annual new car sales in 2025, increasing to 30% of annual new car sales to replace gasoline-fuelled cars by 2030.

For electric cars in Vietnam, the analysis takes the popular electric Nissan LEAF as its reference. The Nissan LEAF retails in Vietnam for approximately USD 30,000, which is higher than standard gasoline fuelled cars by around USD 10,000. However, the price of a Nissan LEAF could drop in real terms to USD 25,000 in 2025 and to USD 23,000 in 2030[47]; therefore, it could be assumed that the Nissan LEAF or electric car prices will be higher than gasoline fuelled cars by around USD 7,500 (averaged for the period 2014-2030).

Based on an assumption that both cars drive around 18,000 km/year, the additional investment cost for electric cars is around USD 0.208 passenger-km and additional O&M cost is around USD 0.008 passenger-km. Both cars have a lifespan of 15 years.

The total additional investment costs for this option are USD 1,499.9 million, resulting in fuel savings worth USD 837.8 million. The potential to reduce emissions is estimated at 7.7 MtCO_2e at an abatement cost of USD 86.1/tCO_2e.

» **Option E24: Improvement of truck load factor**

For this mitigation option, it is assumed that the average truck loading factor will increase from 56% to 60% in 2030[48].

The deployment of logistics parks near industrial parks and seaports is anticipated to enable multi-modality and freight aggregation, at a cost of around VND 9,500 billion (WB-GIZ, 2019).

The total additional investment costs for this option are USD 343.4 million, resulting in fuel savings worth USD 666.9 million. The potential to reduce emissions is estimated at 7.9 MtCO_2e at an abatement cost of USD -40.8/tCO_2e.

» **Option E25: Freight transport shift from road to railway**

In accordance with Decision 318/QĐ-TTg on transport service development, freight transport is expected grow at a rate of 12.5%. This considers the volume of freight traffic shifted from road to railway.

Based on the above assumption, this option estimates that rail freight traffic will grow at an annual rate of 4.4% for the period 2014-2030 (BAU) to 8.5% (mitigation option) at the same period, equivalent to increasing the share of rail freight traffic in the total freight traffic from 1.4% (in BAU) to 2.6% (mitigation option) by 2030. This additional increase in railway traffic will be equal to the decrease in road freight traffic.

[46] https://nld.com.vn/ban-doc/bai-toan-kho-ve-xe-buyt-sach-20161129222854226.htm
[47] WB-GIZ, 2019
[48] WB-GIZ, 2019

The shift to railway will require investment in train carriages and railway infrastructure, including development and improvement of railway freight terminals and inland container depots, railway expansion, access ports, and cargo handling facilities. In this study, the costs of rail infrastructure follow IEA reports (2012) at USD 0.02 per ton-km for investment cost and USD 0.009 per ton-km for annual O&M cost.

The total additional investment costs for this option are USD 168.5 million, resulting in fuel savings worth USD 634.2 million. The potential to reduce emissions is estimated at 6.9 $MtCO_2e$ at an abatement cost of USD -67.8/tCO_2e.

» **Option E26: Increased promotion of bio-fuel in transport**

The promotion of bio-fuel considers increasing the share of ethanol in gasoline sales in Vietnam. Ethanol sales in 2018 to transport totaled 145,000 tons, and during the first six months of that year, E5 accounted for 40% of gasoline sales[49].

For this mitigation option, it is assumed that ethanol production will increase further (compared with Option 19), so that E5 keeps on accounting for 40% of total gasoline sales in the period of 2019-2030 and assume no supply constraint.

The total additional investment costs for this option are USD 230.2 million, resulting in fuel savings worth USD 137.4 million. The potential to additionally reduce emissions (compared to E19) is estimated at 1.8 $MtCO_2e$ at an abatement cost of USD 52.8/tCO_2e.

» **Option E27: Increased penetration of electric motorbikes**

In option E18, it is assumed that EM accounts for 7% of annual new motorbike sales. For this option, it is assumed that the numbers of EM will increase further (compared to E18) to achieve 14% of annual new motorbike sales from 2015 to replace gasoline-fuelled motorbikes.

The total additional investment costs for this option are USD 452.6 million, resulting in fuel savings worth USD 974.9 million. The potential to additionally reduce emissions (compared to E19) is estimated at 7.8 $MtCO_2e$ at an abatement cost of USD -67.2/tCO_2e.

Energy efficiency in the commercial sector

Energy used in the commercial sector is mainly electricity. As projected, electricity demand in the commercial sector will increase sharply with an annual average growth rate of 9.4% in the period 2014-2030, from 11.7 billion kWh in 2014 to 49.5 billion kWh in 2030, accounting for 62.5% of total energy demand in the commercial sector by 2030. Electricity in the commercial sector is mainly used for air conditioners, water heating and lighting. Therefore, this sector has great potential for energy saving.

» **Option E28: Promotion of high efficiency electricity equipment in the commercial sector**

Based on the WB's study results[50], it is assumed that high efficiency electricity equipment would be applied in commercial sector and electricity demand would reduce around 12% compared to BAU, with investment costs for these measures estimated around US$137 million.

As result of calculations showed that the total additional investment cost to implement this option is US$134.4 million, generating savings of US$529.5 million. This option has the potential to reduce GHG emissions by 23.3 $MtCO_2e$ at an abatement cost of US$ -16.9/tCO_2e.

Renewable energy and energy efficiency in power generation

As mentioned above, GHG emissions in power generation increased sharply from 52,401,000 CO_2e in 2014 to 406,581,000 tCO_2e in 2030 with an annual average growth rate of 13.7% per year; therefore, this sector has the greatest potential for GHG reduction. There are 11 Options on RE and EE technologies applied in this sector.

In the electricity generation module, data on power capacity, process efficiencies, capital cost, and O&M costs were taken from the Revised PDP VII, WB-MOIT's report

[49] WB-GIZ, 2019
[50] WB-MOIT, 2019

2019, published research results, and relevant projects.

It is assumed that all EE and RE technologies could replace coal-fired power thermal plants. The fuels used for these coal-fired power plants include both domestic and imported coal. The cost of domestic coal in 2014 was USD 81.4/ton while the cost of imported coal was USD 101.6/ton[51].

Coal-fired thermal power plant efficiency is 35% and the maximum capacity factor (MCF)[52] is 75%. The investment costs for coal power plants are USD 1,568/kW and the O&M costs are USD 46.94/kW, with additional variable O&M costs of USD 2.99/MWh. The lifespan of coal-fired thermal power plants is expected to be 30 years.

» **Option E29: Small hydropower plants**

The potential for small hydropower (SHP) (with a capacity of less than 30 MW per site) is estimated to be about 7000 MW mainly in the North and Central areas of Vietnam. By 2014, the total installed capacity of SHPs was 1,836 MW.

It was assumed that the total capacity of small hydro power plants (SHP) could reach 3,800 MW by 2020, 4,700 MW by 2025 and 5,000 MW by 2030 to replace coal power plants.

The efficiency of SHP is 100% and the MCF of SHPs is 50%. The investment cost for SHP is US$2,144/kW and the O&M cost is estimated at US$17.87/kW with additional variable O&M costs of US$2.99/MWh[53]. The lifespan of SHP is 30 years.

The total additional investment and O&M costs to implement this option are US$1,691.5 million resulting in fuel savings of US$1,375.2 million. This option has the potential to reduce GHG emissions by 100.7 $MtCO_2e$ at an abatement cost of US$ 3.1/tCO_2e.

» **Promotion of solar photovoltaic power plants**

Currently, solar technologies are benefiting from supportive policies that help create the conditions for market development and reduce the cost of solar photovoltaic (PV). The recent costs of small PV systems in Germany fell to just USD 2,200/kW in 2012 from an average of USD 3,800/kW in 2010. With continued rapid growth in solar PV deployment, the International Renewable Energy Agency (IRENA) estimated that the global average total installed cost of utility-scale PV systems could fall from around USD 1.8/W in 2015 to USD 0.8/W in 2025, a 57% reduction in 10 years. In this study, the average price of PV systems in Vietnam is estimated at USD 1,563/kW in 2014 and projected to decrease to USD 1,362/kW by 2020 and to USD 1,160/kW by 2030[54]. This trend of cost reduction could make PV systems competitive in the future. Average total solar radiation of 5 kWh/m^2/day in most of the central and the southern provinces of Vietnam could be exploited to meet the increasing electricity demand and market for power generation. In 2015, REDS was approved with ambitious targets for solar PV development: Solar power generation to reach to 1.4 billion kWh or 0.5% of total electricity output in 2020, to 35.4 billion kWh or 6% of total electricity output in 2030.

By June 2019, the total installed capacity of solar PV was 4,464 MW mainly in the southern and central areas of Vietnam, where there is high solar radiation. Currently, there are several projects with total capacity of 630 MW under construction and around 10,300 MW approved for additional planning to 2025.

» **Option E30: Voluntary solar photovoltaic power plants**

For this mitigation option, it is assumed that solar PV projects achieve 5,000 MW in 2020 (maintained to 2030) to replace imported coal power plants.

The efficiency of solar PV is 100% and the MCF of PV power plants is 18%. PV power plants had investment costs of USD 1,563/kW in 2014 (which is expected to decline to USD 1,160/kW in 2030) and O&M costs of USD 1.19/MW with additional variable O&M costs of USD 0.43/MWh[55].

[51] WB-MOIT, 2019
[52] MCF referred to as the maximum availability of a process is the ratio of the maximum energy produced to what would have been produced if the process ran at full capacity for a given period (expressed as a percentage)
[53] WB-MOIT, 2019
[54] WB-MOIT, 2019
[55] WB-MOIT, 2019

The lifespan of solar PV systems is around 25 years.

Calculations show that the total additional investment costs for grid connected solar PV power plants are USD 2,529.8 million, while they can save USD 871.1 million from fuel for power generation and reduce 60.8 MtCO_2e at an abatement cost of USD 27.3/tCO_2e.

» **Option E31: Conditional solar photovoltaic power plants**

For this mitigation option, it is assumed that solar PV projects would be carried out after 2020 (increasing the capacity further to 4,500 MW in 2025 and 11,600 MW in 2030 compared to E31) to achieve 9,500 MW in 2025 and 16,600 MW in 2030 to replace imported coal power plants. These solar PV projects would be implemented in areas of normal solar radiation with MCF of PV power plants of 16% (and other PV's economic and technical parameters the same as E30).

Calculations show that the total additional investment costs for these connected grids of PV power plants are USD 2,945.2 million, while they can save USD 554.1 million from fuel for power generation and reduce 51.3 MtCO_2e at an abatement cost of USD 46.6/tCO_2e.

» **Promotion of wind power plants**

With more than 3,000 km of coastline and plenty of islands, the total potential of wind energy in Vietnam is estimated to be as high as 26.7 GW[56] (at speeds over 6m/s).

Wind energy for power generation is a priority area as planned in the REDS with the aim of achieving 2.5 billion kWh in 2020, representing 1% of total electricity output, and further increasing to 16 billion kWh or 2.7% of total electricity output by 2030.

By June 2019, there were 09 wind power plants with a total installed capacity of 304.6 MW. In addition, 18 projects with a total capacity of 812 MW are under construction.

» **Option E32: Voluntary wind power plants**

For this option, it is assumed that wind power projects will be implemented in areas with high wind energy potential to achieve 1,010 MW in 2020[57] (and maintained to 2030) to replace imported coal power plants.

Wind power plants have an efficiency of 100% and a MCF of 28%. The investment costs for wind power plants are USD 2,100/kW (which is expected to decline to USD 1,800/kW in 2030) and the O&M costs are USD 89/kW[58]. The lifespan of wind power plants is 25 years.

Calculations show that the total additional investment costs for wind power plants is USD 1,112.4 million, while they can save USD 267.6 million from fuel for power generation and reduce 18.2 MtCO_2e at an abatement cost of USD 46.5/tCO_2e.

» **Option E33: Conditional wind power plants**

For this mitigation option, it is assumed that wind power projects would be carried out after 2020 increasing the additional capacity (compared to E32) to achieve 3,500 MW in 2025 and 8,200 MW in 2030to replace imported coal power plants. These wind power projects would be implemented in areas of normal wind speed.

Wind power plants have an efficiency of 100% and a MCF of 25%. The investment costs for wind power plants are US$2,380/kW (which is expected to decline to US$2,100/kW in 2030) and the O&M costs are US$ 93/kW[59]. The lifespan of wind power plants is 25 years.

As result of calculations showed that the total additional investment costs for wind power plants is US$ 4,101.7 million, while it can save US$ 509.1 million from saving fuel for power generation and reduce 47.6 MtCO_2e at an abatement cost of US$ 75.5/tCO_2e.

» **Option E34: Biomass power plants**

The main biomass sources that can be used to generate

[56] World Bank (2001) Wind Energy Resource Atlas of Southeast Asia
[57] MOIT plan, 2019
[58] WB-MOIT, 2019
[59] WB-MOIT, 2019

electricity are sugarcane trash, rice husks, and rice straws. Based on the production of bagasse and paddy in 2014, this study estimates that 6.0 million tons of bagasse, 9.0 million tons of rice husks, and 54.0 million tons of rice straws are available for power generation.

However, currently biomass is generally treated as a non-commercial energy source, source, collected, and used and used locally. In particular, there are 38 bagasse-based biomass power plants that have been developed in Vietnam that are using biomass for electricity and heat production with a total capacity of around 352 MW[60]. Among these, only eight plants are grid-connected with a total capacity of 82.51 MW (22.4%), selling 15% of electricity produced from biomass to the grid at US 5.8 cents/kWh[61]. Due to abundant biomass resources, the REDS has set up a plan to develop biomass power with ambitious targets: Biomass power planned to reach 7.8 billion kWh or 3% of total electricity output in to 37 billion kWh or 6.3% of total electricity output by 2030.

For this option, the assumption is that biomass power capacity for grid connection could reach 110 MW by 2020, 550 MW by 2025 and 1,200 MW by 2030 to replace coal power plants. All sites of biomass power plants were supposed to locate near the supply biomass sources to reduce the transportation costs.

Biomass power plant's efficiency is 31% and MCF is 60%. The investment costs for biomass power plants are US$2,254/kW and the O&M costs are US$ 55/kW[62]. The fuel cost for biomass thermal power is US$75/TOE and expected to increase around 1.7%/year[63]. The lifespan of biomass power plants is expected to be 30 years.

The result of calculations showed that the total additional investment cost to implement this option is US$999.9 million, resulting in savings of US$247.4 million. This option has the potential to reduce GHG emissions by 22.5 MtCO_2e at an abatement cost of US$ 33.5/tCO_2e.

» **Promotion of municipal solid waste-based power plants**

Vietnam has a large potential for solid waste, especially municipal solid waste (MSW) generated from daily activities in urban areas. According to MONRE reports in 2015, MSW generated in Vietnam was about 23 million tons/year. This figure increases by around 8-10 % per year[64]. The proportion of collected and treated domestic solid waste in urban areas is around 85% of the waste potential, reaching nearly 35,000 tons/day in 2015. This number is expected to reach 47,500 tons/day in 2020. In suburban areas, the collection rate was about 60% and even lower in rural areas at about 40-55%.

Regarding MSW treatment, landfills, compost fertilizer and combustion, three main technologies are commonly used in Vietnam. However, pollution is still not controlled properly and affects the environment through large numbers of landfill facilities in big cities. In 2014, the Government issued the mechanisms for MSW-based power projects[65] with the purchase price of 10.05 US cents/kWh for direct solid waste-fired power plants and 7.28 US cents/kWh for landfill gas power plants.

At present, there is only one waste treatment plant which produces electricity from landfill gas recovery. It is located in Go Cat, Ho Chi Minh City, and has an installed capacity of 2.4 MW. There are, however, a number of projects in the pipeline. These have a combined installed capacity of 105 MW and are in various phases of development. Three technologies are proposed: (i) landfill, (ii) incineration, and (iii) plasma gasification. The technology mix is as follows: land fill: 15.3 MW (14.6%), incineration: 31.9 (30.4%), and plasma gasification 57.7 MW (55.0%). Amongst these technologies, landfill is less attractive as large land areas are required and the sites can release bad odours and cause water and air pollution.

[60] Viet Nam Sugarcane and Sugar Association statistics
[61] The Global Green Growth Institute, 2018-Sweetening the Deal for Biomass Energy in Viet Nam's Sugar Industry
[62] IEA, 2016
[63] WB-MOIT, 2019
[64] MOIT/GIZ, Project Development Guidelines for grid-connected power generation projects using solid waste in Viet Nam
[65] Decision No. 31/2014/QD-TTg dated 5 May 2014

» **Option E35: Municipal solid waste-fired power plants**

For this MSW power option, the assumption is that MSW power capacity could reach 70 MW by 2020, 210 MW by 2025 and 350 MW by 2030 exclusively replacing imported coal power plants.

MSW power plant efficiency is 25% and the MCF is 70%. The investment costs for MSW power plants are USD 2,935/kW and the O&M costs are USD 50.2/kW[66]. The cost for MSW processing and classification is around USD 20/TOE. The lifespan of MSW power plants is expected to be 30 years.

Calculations show that the total additional investment cost to implement this option is USD 335.9 million, resulting in savings of USD 107.9 million. This option has the potential to reduce GHG emissions by 9.1 $MtCO_2e$ at an abatement cost of USD 25.1/tCO_2e.

» **Option E36: Landfill gas power plants**

For this mitigation option, the assumption is that landfill gas power capacity could reach 10 MW by 2020, 30 MW by 2025 and 50 MW by 2030 exclusively replacing imported coal power plants.

Landfill gas power plant efficiency is 35% and the MCF is 50%. The investment costs for landfill gas power plants are USD 1,191/kW and the O&M costs are USD 194.46/kW[67]. The lifespan of landfill gas power plants is expected to be 20 years.

Calculations show that the total additional investment cost to implement this option is USD 17.3 million, resulting in savings of USD 11.0 million. This option has the potential to reduce GHG emissions by 0.9 $MtCO_2e$ at an abatement cost of USD 6.7/tCO_2e.

» **Option E37: Biogas power plants**

For large-scale biogas power plants, only one has been installed – in a San Miguel Food Company pig farm in Ben Cat District, Binh Duong Province. The total capacity of the biogas project is 17,000 m^3 and power generation capacity is 2.0 MW (500kW per unit). The plant was put into operation in April 2011 and is used for internal power use.

Another biogas power project with a capacity of 9 MW is being developed by the TH-True Milk Company. The plant is planned for installation in 2020 to deal with cow waste in Nghia Dan District, Nghe An Province.

There are still no biogas power plants connected to the national grid due to high investment requirements and the small size of biogas power plants. Therefore, support mechanisms for biogas power plants are needed. Because of the reasons mentioned above, BAU assumes no biogas power plants.

For this mitigation option, the assumption is that biogas power capacity could reach 10 MW by 2020, 20 MW by 2025 and 30 MW by 2030 exclusively replacing imported coal power plants.

Biogas power plant efficiency is 35% and the MCF is 50%. The investment costs for landfill gas power plants are USD 1,191/kW and the O&M costs are USD 194.46/kW[68]. The lifespan of landfill gas power plants is expected to be 20 years. Calculations show that the total additional investment cost to implement this option is USD 26.1 million, resulting in savings of USD 7.6 million. This option has the potential to reduce GHG emissions by 0.6 $MtCO_2e$ at an abatement cost of USD 30.6/tCO_2e.

» **Option E38: Ultra-supercritical coal power plants**

Currently, the efficiency of coal-fired thermal power plants is low at around 30%, and the use of domestic coal will be difficult in the future from the standpoint of environmental load reduction and the increase in mining costs due to a switch from open-pit mining to underground mining. In this context, more plans have been developed in recent years for ultra-supercritical coal-fired thermal power plants that use imported coal, especially for the central to southern regions on the country. So far, there are some thermal coal

[66] WB-MOIT, 2019
[67] WB-MOIT, 2019
[68] WB-MOIT, 2019

power projects using the ultra-supercritical technology such as Vinh Tan 4 and extension Duyen Hai 3 put in operation in 2018 with a total capacity of 1800 MW.

From the above analysis, the assumption is that the ultra-supercritical coal power plants (USCPPs) will reach 2,400 MW by 2020, 10,800 MW by 2025 and 27,600 MW by 2030 to replace imported coal power plants.

USCPPs have an energy efficiency of 43% and MCF of 75%. The investment costs for coal power are USD 2,072/kW, and the O&M costs are USD 65.41/kW, with additional variable O&M costs of USD 0.47/MWh[69]. The lifespan of USCPPs is expected to be 30 years.

The total investment and operational costs of this option are USD 6,676.1 million, resulting in fuel savings worth USD 1,394.6 million. This option has the potential to reduce GHG emissions by 120.7 $MtCO_2e$ at an abatement cost of USD 43.8/tCO_2e.

» **Option E39: Liquid natural gas combined cycle gas turbines**

Combined cycle gas turbine (CCGT) is an advanced power generation technology which allows improved fuel efficiency for natural gas or liquid natural gas (LNG). A gas turbine generates electricity, and the waste heat is used to make steam to generate additional electricity via a steam turbine. CCGT heat exchange may have 10% increased efficiency in comparison with simple turbines.

In order to diversify imported fuel sources, besides coal, liquid natural gas (LNG) is considered as a major import fuel in the coming years to compensate for limited domestic natural gas. According to the Vietnam Gas Industry Development Master Plan to 2035[70], the import of LNG will begin by 2021 and import demand will increase to around 5 million tons by 2025, 10 million tons by 2030, and 15 million tons by 2035.

From the above analysis, the assumption is that output from LNG power plants will reach 750 MW by 2021, 3,000 MW by 2025 and 12,750 MW by 2030 to replace imported coal power plants.

CCGTs have an energy efficiency of 50% and MCF of 75%. The investment costs for CCGT are USD 1,048/kW, and the O&M costs are USD 10.59/kW, with additional variable O&M costs of USD 2.12/MWh[71]. The lifespan of CCGTs is expected to be 30 years. The fuel used for CCGTs is LNG with the price of USD 9.75/PJ while the cost of imported coal is USD 4.18/PJ[72].

Calculations show that the total investment and operational costs of CCGT are less than coal power plants at USD 2,208.2 million, while fuel costs (for LNG) are more at USD 5,771.6 million. This option has the potential to reduce GHG emissions by 138.9 $MtCO_2e$ at an abatement cost of USD 25.7/tCO_2e.

4.3. Results

4.3.1. Mitigation potential and the cost of mitigation options in the energy sector

Based on the results outlined above, the mitigation potential and costs of each option in the period 2015-2030 can be summarised in Table 17.

[69] WB-MOIT, 2019
[70] Decision No. 60/QD-TTg, 2017.
[71] WB-MOIT, 2019
[72] WB-MOIT, 2019

Table 17: Mitigation potential and cost of options in the energy sector

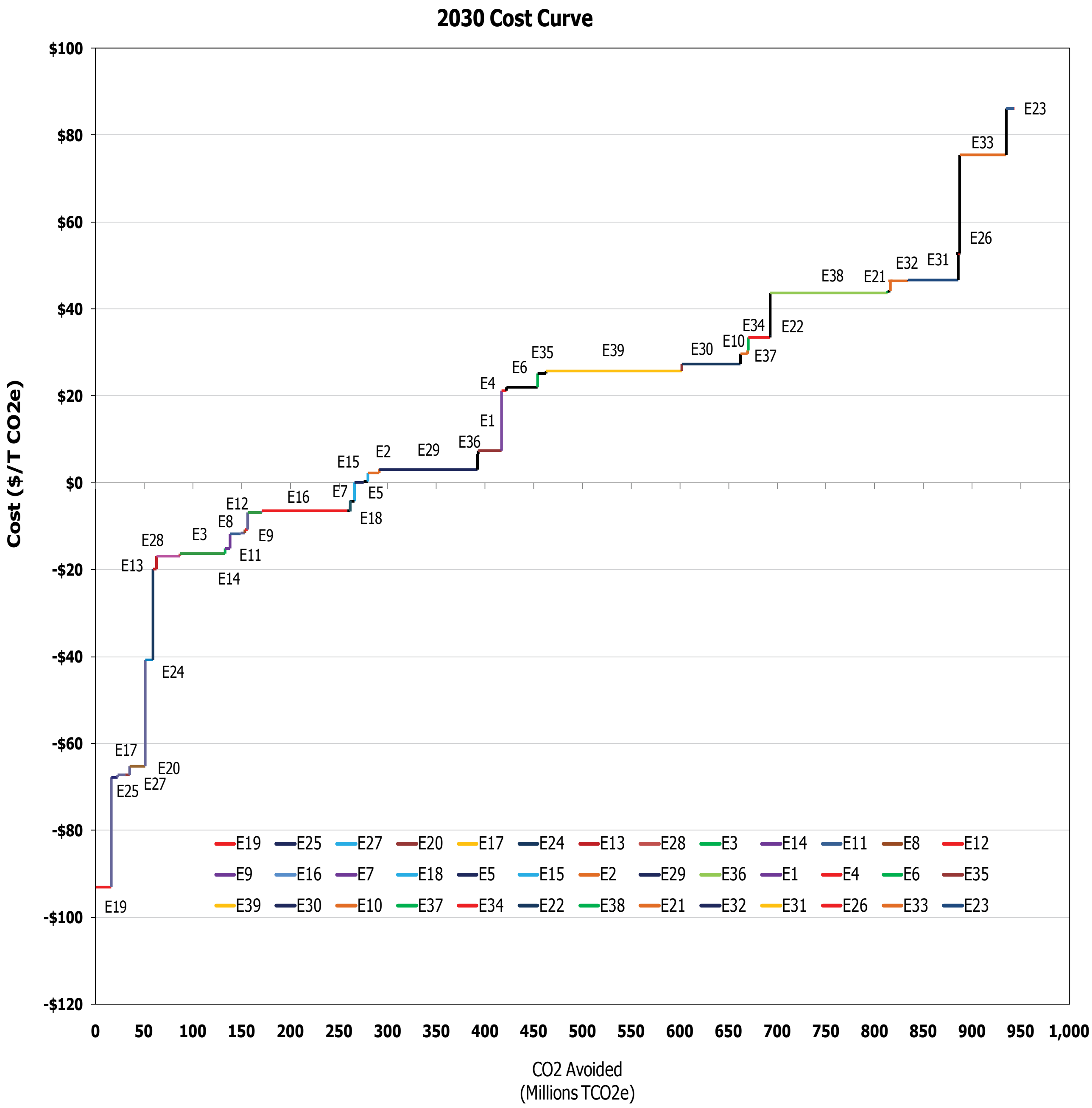
Options	Mitigation Potential (MtCO2e)		Incremental Costs* (Mil. US$)	Mitigation cost (US$/ tCO2e)
	2015-2030	2030	Constant price 2014	Constant price 2014
E1. High efficiency residential air conditioning	23.9	4.6	177.6	7.4
E2. High efficiency residential refrigerators	11.3	1.6	24.7	2.2
E3. High efficiency residential lighting	47.0	6.4	-768.2	-16.3
E4. Solar water heaters	5.1	1.0	107.9	21.3
E5. Biogas replacing coal for residential cooking in rural areas	9.5	1.1	1.3	0.1
E6. Cleaner cooking fuels	31.9	3.8	704.9	22.1
E7. Combustion optimization	3.1	0.4	-19.9	-6.4
E8. Kiln shell heat loss reduction	4.3	0.6	-49.0	-11.5
E9. Waste heat recovery from cement	15.0	1.8	-102.0	-6.8
E10. Vertical roller mill	6.8	0.9	203.2	29.8
E11. Brick-making technology improvements	10.8	1.4	-127.5	-11.8
E12. Pulverized coal injection in blast furnace	2.7	0.7	-29.0	-10.8
E13. Scrap preheating	4.1	0.6	-81.5	-19.9
E14. Hot charging in rolling mill	4.9	0.7	-74.7	-15.1
E15. Basic oxygen furnace gas sensible heat recovery	4.3	0.9	1.3	0.3
E16. EE improvement in other industrial sub-sectors	87.4	15.0	-569.9	-6.5
E17. New vehicle fuel economy and emissions standards	15.8	5.1	-1,027.6	-65.2
E18. Passenger transport mode shift from private to public	4.6	0.4	-19.9	-4.3
E19. Modal shift of freight transport from road to inland water and marine water way	16.0	1.6	-1,484.9	-93.0
E20. Introduction of electric motorbikes	4.6	0.6	-307.0	-67.2
E21. Substitution of ethanol for gasoline in transport	3.1	0.3	137.3	44.1
E22. Introduction of CNG buses	0.03	0.01	1.2	34.1

Options	Mitigation Potential (MtCO2e)		Incremental Costs* (Mil. US$)	Mitigation cost (US$/ tCO2e)
	2015-2030	2030	Constant price 2014	Constant price 2014
E23. Promotion of electric cars	7.7	1.9	662.2	86.1
E24. Improvement of truck load factor	7.9	1.3	-323.5	-40.8
E25. Freight transport shift from road to railway	6.9	1.1	-465.7	-67.8
E26. Increased promotion of bio-fuel in transport	1.8	0.3	92.9	52.8
E27. Increased penetration of electric motorbikes	7.8	1.0	-522.3	-67.2
E28. Promotion of high efficiency electricity equipment in commercial sector	23.3	3.8	-395.2	-16.9
E29. Small hydropower plants	100.7	9.1	316.3	3.1
E30. Voluntary solar photovoltaic power plants	60.8	5.0	1,658.7	27.3
E31. Conditional solar photovoltaic power plants	51.3	10.3	2,391.1	46.6
E32. Voluntary wind power plants	18.2	1.5	844.8	46.5
E33. Conditional wind power plants	47.6	10.0	3,592.6	75.5
E34. Biomass power plants	22.5	4.0	752.5	33.5
E35. Municipal solid waste-fired power plants	9.1	1.4	228.1	25.1
E36. Landfill gas power plants	0.9	0.1	6.3	6.7
E37. Biogas power plants	0.6	0.1	18.5	30.6
E38. Ultra-supercritical coal power plants	120.7	22.4	5,281.5	43.8
E39. LNG combined cycle gas turbine	138.9	33.0	3,563.4	25.7
Total	**942.9**	**155.8**		

** Net present value discounted with a discount rate of 10%*

Source: Calculation results from LEAP model

Figure 1: Marginal abatement cost curve for mitigation options in the energy sector



4.3.2. Mitigation scenario for the energy sector

a) Unconditional contribution

Unconditional mitigation options in the energy sector are mostly highly-feasible options, with high availability of infrastructure or technology and funding that can be allocated by Vietnam in order of priority as shown in Table 18 below:

Table 18: Unconditional mitigation options in the energy sector

Unit: $MtCO_2e$

No.	Mitigation options in order of priority	GHG reduction potential by 2030
1	E17. New vehicle fuel economy and emissions standards	5.1
2	E3. High efficiency residential lighting	6.4
3	E11. Brick-making technology improvements	1.4
4	E19. Modal shift of freight transport from road to inland water and marine water way	1.6
5	E28. Promotion of high efficiency electricity equipment in commercial sector	3.8
6	E5. Biogas replacing coal for residential cooking in rural areas	1.1
7	E18. Passenger transport mode shift from private to public	0.4
8	E20. Penetration of electric motorbikes	0.6
9	E1. High efficiency residential air conditioning	4.6
10	E2. High efficiency residential refrigerators	1.6
11	E8. Kiln shell heat loss reduction	0.6
12	E13. Scrap preheating	0.6
13	E14. Hot charging in rolling mill	0.7
14	E12. Pulverized coal injection in blast furnace	0.7
15	E9. Waste heat recovery from cement	1.8
16	E7. Combustion optimization	0.4
17	E15. Basic oxygen furnace gas sensible heat recovery	0.9
18	E29. Small hydropower plants	9.1
19	E4. Solar water heaters	1.0
20	E30. Voluntary solar photovoltaic power plants	5.0
21	E32. Voluntary wind power plants	1.5
22	E21. Substitution of ethanol for gasoline in transport	0.3
23	E22. Introduction of CNG buses	0.01
24	E10. Vertical roller mill	0.9
25	E35. Municipal solid waste-fired power plants	1.4
	Total	**51.5**

The above selection result showed that the total GHG reduction implemented by domestic sources is around51.3 $MtCO_2e$, accounting for 7.6 % of total GHG emission of BAU by 2030.

b) Conditional contribution

Conditional mitigation options in the energy sector are mostly options with higher costs that need international support in finance, technology, and capacity building (Table 19).

Table 19: Conditional mitigation options in the energy sector

Unit: $MtCO_2e$

No.	Mitigation options in order of priority	GHG reduction potential by 2030
1	E16s. EE improvement in other industrial sub-sectors	15.0
2	E6s. Cleaner cooking fuels	3.8
3	E25s. Freight transport shift from road to railway	1.1
4	E27s. Increased penetration of electric motorbikes	1.0
5	E24s. Improvement of truck load factor	1.3
6	E31s. Conditional solar photovoltaic power plants	10.3
7	E34s. Biomass power plants	4.0
8	E36s. Landfill gas power plants	0.1
9	E37s. Biogas power plants	0.1
10	E39s. LNG combined cycle gas turbine	33.0
11	E38s. Ultra-supercritical coal power plants	22.4
12	E33s. Conditional wind power plants	10.0
13	E26s. Increased promotion of bio-fuel in transport	0.3
14	E23s. Promotion of electric cars	1.9
	Total	**104.3**

The above results show that the total GHG reduction implemented with international support is around 105.5 $MtCO_2e$, accounting for 15.6% of total GHG emissions of BAU by 2030.

4.3.3. Impact assessment of mitigation options on the socio-economy and environment

Implementation of the various mitigation technologies will help Vietnam not only achieve its GHG reduction targets in line with its international commitments, but also bring about various social, economic, and environmental benefits.

Economic benefits

The economic benefits from implementation of mitigation options in the energy sector are as follows:

- Development of EE technologies on the demand side will result in the reduction of energy demand, therefore reducing of Vietnam's dependence on fuel imports and increasing the export of surplus domestic fuels.
- Reduction of energy import dependency, which will contribute to stable and sustainable economic development.
- Contribution to economic development by developing new industries, creating investment opportunities, building and maintaining infrastructure, reducing costs, and opening up more opportunities for business.

Based on the input data and assumptions as mentioned in Section 4.2.2, such as investment costs, O&M costs, potential for energy saving and the lifetime of each mitigation technology etc., the costs, benefits, GHG mitigation potential, and costs of GHG reduction can be calculated as follows:

a) Social costs and benefits of unconditional mitigation options

Table 20 presents a summary of the impact of social-economics of mitigation options, including costs and benefits of the mitigation options implemented in the 2014-2030 period (with discounted at 10.0%), GHG emission reduction potentials and cost of avoiding GHGs of technologies.

From the calculation results, some comments could be drawn, as follows:

- The total costs (including investment costs and O&M costs) of mitigation measures are approximately US$ 9,865.7 million[73], resulting in social benefits of almost US$ 10,649.6 million, with the majority accounted for by reduced fuel imports (US$ 7,770.6 million).
- The implementation of these mitigation measures can save US$ 783.9 million, thus significantly contribute to GHG reduction and sustainable economic development.

b) Social costs and benefits of conditional mitigation options

The calculation results presented in Table 21 show that the total social costs (including investment costs and O&M costs) of mitigation measures are US$ 25,860.3 million, resulting in social benefits of US$ 10,675.8 million. Reducing dependency on fuel imports is the most significant benefit (US$ 6,064.1 million). The additional costs of implementing these mitigation measures are US$ 15,184.6 million, thus requiring international support with regard to finance, technology and capacity building.

[73] Price 2014

Table 20: The impact of unconditional mitigation options on society and the economy

	E1	E2	E3	E4	E5	E7	E8	E9	E10	E11	E12	E13	E14	E15	E17	E18	E19	E20	E21	E22	E28	E29	E30	E32	E35	Total
Costs	681.7	298.1	360.2	216.1	118.8	22.9	3.3	89.8	368.2	18.4	11.8	18.5	46.2	56.7	0.4	724.9	282.7	266.3	470.2	6.5	134.4	1691.5	2529.8	1112.4	335.9	9865.7
At the demand side	681.7	298.1	360.2	216.1	7.0	22.9	3.3		368.2	18.4	11.8	18.5	46.2	56.7	0.4	411.5	282.7	251.2	-	6.5	134.4	-	-	-		3195.8
At the supply side					111.8	-	-	89.8		-	-	-	-		-	313.4	-	15.0	470.2	-		1691.5	2529.8	1112.4	335.9	6669.8
* Electricity generation								89.8										3.4	-	-		1691.5	2529.8	1112.4	169.7	5596.6
* Biogas production	-	-	-	-	111.8	-	-			-	-	-	-		-	-	-	-	-	-	-	-	-	-		111.8
* Bio-fuel production	-	-	-	-	-	-	-			-	-	-	-		-	-	-	-	93.0	-	-	-	-	-		93
* MSW processing																									166.2	166.2
* Energy production																313.4		11.6	377.2	-						702.2
Benefits	-504.1	-273.4	-1128.4	-108.2	-117.4	-42.9	-52.4	-191.7	-164.9	-145.9	-40.9	-100.0	-120.9	-55.5	-1027.9	-744.7	-1767.6	-573.3	-332.9	-5.3	-529.5	-1375.2	-871.1	-267.6	-107.9	-10649.6

Electricity generation	-30.4	-16.3	-68.9	-6.5	-	-0.5	-		-9.9	-1.3	-	-5.9	-7.2		-	-	-				-32.0					-178.9
Indigenous resource	-116.8	-56.8	-247.0	-24.8	-	-1.7	-		-34.3	-4.3	-	-20.6	-24.9		-	-0.8	-	-	-	-	-118.2	-	-	-	-	-650.2
* Imports	-357.0	-200.3	-812.6	-76.9	-117.4	-40.6	52.4	-191.7	-120.8	-140.3	-40.9	-73.5	-88.8	-55.5	-186.7		-1745.0	-237.9	-225.8	-5.3	-379.4	- 1375.2	-871.1	-267.6	-107.9	-7770.6
* Exports									-		-	-	-		-841.2	-743.9	-22.6	-335.4	-107.1	-	-	-	-	-	-	-2050.2
Net Present Value	177.6	24.7	-768.2	107.9	1.3	-19.9	-49.0	-102.0	203.3	-127.5	-29.0	-81.5	-74.7	1.3	-1027.6	-19.9	-1484.9	-307.0	137.3	1.2	-395.2	316.3	1658.7	844.8	228.1	-783.9
GHG savings (Mt.CO2e)	23.9	11.3	47.0	5.1	9.5	3.1	4.3	15.0	6.8	10.8	2.7	4.1	4.9	4.3	15.8	4.6	16.0	4.6	3.1	0.03	23.3	100.7	60.8	18.2	9.1	409.03
Cost of avoiding GHGs ($/t. CO2e)	7.4	2.2	-16.3	21.3	0.1	-6.4	-11.5	-6.8	29.8	-11.8	-10.8	-19.9	-15.1	0.3	-65.2	-4.3	-93.0	-67.2	44.1	34.1	-16.9	3.1	27.3	46.5	25.1	

Unit: 2014 USD million (discounted at 10.0% to year 2014)

Source: Calculated results from LEAP model

Table 21: The impact of unconditional mitigation options on society and the economy

Unit: 2014 USD million (discounted at 10.0% to year 2014)

	E6	E16	E23	E24	E25	E26	E27	E31	E33	E34	E36	E37	E38	E39	Total
Costs	1,158.6	1,469.2	1,499.9	343.4	168.5	230.2	452.6	2,945.2	4,101.7	999.9	17.3	26.1	6,676.1	5,771.6	25,860.3
At the demand side	27.9	1,469.2	1,467.0	343.4	168.5	-	427.1	-	-	-	-	-	-		3,903.1
At the supply side	1,130.7	-	32.9	-	-	230.2	25.5	2,945.2	4,101.7	999.9	17.3	26.1	6,676.1	5,771.6	21,957.2
* Electricity generation			6.2	-	-	-	5.7	2,945.2	4,101.7	816.9	17.3	11.9	6,676.1	5,771.6	20,352.6
* Biogas production		-	-	-	-	-	-	-	-	-	-	14.3	-		14.3
* Bio-fuel production		-	-	-	-	51.8	-	-	-	-	-	-	-		51.8
* MSW processing		-	-	-	-	-	-	-	-	-	-	-	-		0.0
* Energy production	1,130.7		26.7			178.4	19.8			183.0		1.4			1,540.0
Benefits	-453.6	-2,039.0	-837.8	-666.9	-634.2	-137.4	-974.9	-554.1	-509.1	-247.4	-11.0	-7.6	-1,394.6	-2,208.2	-10,675.8
Electricity generation		-103.5												-2,208.2	-2,311.7
Indigenous resource		-821.7	-	-	-	-	-		-	-	-	-	-		-821.7
* Imports	-453.6	-1,113.8	-30.6	-666.9	-632.8	-44.1	-398.5	-554.1	-509.1	-247.4	-11.0	-7.6	-1,394.6		-6,064.1
* Exports		-	-807.1	-	-1.4	-93.3	-576.4	-	-	-	-	-	-		-1,478.2
Net Present Value	704.9	-569.8	662.2	-323.5	-465.7	92.9	-522.3	2,391.1	3,592.6	752.5	6.3	18.5	5,281.5	3,563.4	15,184.6
GHG savings (Mt.CO2e)	31.9	87.4	7.7	7.9	6.9	1.8	7.8	51.3	47.6	22.5	0.9	0.6	120.7	138.9	533.9
Cost of avoiding GHGs ($/t. CO2e)	22.1	-6.5	86.1	-40.8	-67.8	52.8	-67.2	46.6	75.5	33.5	6.7	30.6	43.8	25.7	

Source: Calculated results from LEAP model

Social security

- Contribution to social development, improvement of labour conditions and public health, creation of employment opportunities and improvement of incomes through a stable supply of energy.

- Small renewable power projects are usually located in rural areas, including remote areas. Investment and development of renewable power projects will catalyse rural agriculture development and create more job opportunities than big coal fired power plants.

- Activities to develop renewable power projects in rural, remote areas require local transportation development and, therefore, access roads to communities in these areas will be improved, facilitating trade conditions (faster and easier selling of agricultural products at higher prices because of freshness/better quality, etc.).

- Biomass power projects usually use waste in processing plants, which would have to be disposed of (such as rice husks in rice milling plants, bagasse in sugar plants, etc.). They produce energy (electricity and heat) and may not only be sufficient for household use but there may be surplus electricity to sell to the local power grid or neighbouring consumers. This brings in high effectiveness not only for the country but also for the plants themselves. Especially, farmers can sell waste to biomass power plants, providing additional post-harvest income for farmers.

Environmental protection

- GHG emission reduction by application of GHG mitigation technologies can reach about 958.6 $MtCO_2e$ for the 2015-2030 period and 158.8 MtCO2e in 2030, and at the same time reduce local environmental pollution.

- Renewable power plants will replace coal fired power plants; therefore, reducing environmental impacts of coal burning, including emissions with global impacts (GHG) and locally harmful emissions such as acid rain (SOx, NOx gases), fine dusts and ash etc. The extent of these impacts has not yet been determined. However, the consequences of emissions due to fossil fuels on human health and quality of crops are well evidenced.

- In order to meet electricity demand for socio-economic development, Vietnam needs to exploit and develop its available RE resources as a major substitute for coal power plants.

4.3.4. Comparison with NDC1

The LEAP model was also used for the development of mitigation scenarios in the energy sector in the NDC1. This model allowed for the analysis of the energy system in terms of supply and demand, including sources of primary energy, as well as the transformation, distribution and use of energy. The calculations were based on assumptions of GDP growth, population growth, historical energy consumption and future energy prices published by the U.S. Energy Information Administration in 2014 (US EIA, 2014).

The GHG mitigation options were developed based on the BAU scenario, assuming that new policies will be developed to support the application of mitigation technologies, including energy-saving and the deployment of renewable energy. Mitigation options were assessed in terms of efficiency, incremental costs, mitigation potential and co-benefits compared to the BAU.

In NDC1, 17 mitigation options were identified: 4 on energy-saving and renewable energy in households; 2 on energy-saving and renewable energy in industry; 3 on energy-saving and renewable energy in transport; 1 on energy-saving and renewable energy in commercial services; and 7 on energy-saving and renewable energy for electricity production. The options were assessed based on the current state of technology and its application, as well as the objectives set out in sectoral development strategies, such as the National Energy Development

Strategy, the Transportation Development Strategy and the Power Development Plan VII.

The revised NDC1 also applied the LEAP model to develop the mitigation scenario for the energy sector in the 2020-2030 period. 39 mitigation options in the energy sector were identified, including: 06 EE and RE options for the residential sector; 10 EE options in the industrial sector; 11 options on fuel substitutions and mode shifts for the transport sector; 01 EE option in the commercial and services sector; and 11 RE and EE options in the power generation sector.

As can be seen from Table 22, besides 17 mitigation options in the energy sector which were already proposed in the NDC1, the revised NDC1 proposed 22 additional mitigation options. In terms of GHG emissions, the mitigation potential of mitigation options in the revised NDC1 compared to the BAU scenario in 2030 and in the 2015-2030 period is higher than that of the NDC1. Particularly, the mitigation potential in 2030 in the revised NDC1 is 158.8 $MtCO_2e$, which is 92.8 $MtCO_2e$ higher than that in NDC1. Regarding the whole period, the mitigation potential of mitigation options in the energy sector compared to the BAU scenario in 2015-2030 in the revised NDC1 is 958.6 $MtCO_2e$, which is 476.4 $MtCO_2e$ higher than that in NDC1. That is because the revised NDC1 proposed 22 additional mitigation options: E5, E6, E7, E8, E9, E10, E12, E13, E14, E15, E16, E17, E20, E22, E23, E24, E25, E26, E27, E30, E35, E36 and E39.

Table 22: Comparison between mitigation options of the energy sector in NDC1 and the revised NDC1

Mitigation option	Mitigation potential (tCO2e)				Mitigation cost (USD/tCO2e)	
	2015-2030		2030			
	NDC1	The revised NDC1	NDC1	The revised NDC1	NDC1*	The revised NDC1**
E1: High efficiency residential air conditioning (NDC1-E1)	12.4	23.9	2.3	4.6	-4.3	7.4
E2: High efficiency residential refrigerators (NDC1-E2)	12.4	11.3	1.7	1.6	5.8	2.2
E3: High efficiency residential lighting (NDC1-E3)	38.3	47.0	4.6	6.4	-43.6	-16.3
E4: Solar water heaters (NDC1-E4)	16.6	5.1	2.6	1.0	1.9	21.3
E5: Biogas replacing coal for residential cooking in rural areas		9.5		1.1		0.1
E6: Cleaner cooking fuels		31.9		3.8		22.1
NDC1-E5: Cement-making technology improvements	16.6		2.2		-40.7	
E7: Combustion optimization		3.1		0.4		-6.4
E8: Kiln shell heat loss reduction		4.3		0.6		-11.5
E9: Waste heat recovery from cement		15.0		1.8		-6.8

Mitigation option	Mitigation potential (tCO2e)				Mitigation cost (USD/tCO2e)	
	2015-2030		2030			
	NDC1	The revised NDC1	NDC1	The revised NDC1	NDC1*	The revised NDC1**
E10: Vertical roller mill		6.8		0.9		29.8
E11: Brick-making technology improvements (NDC1-E6)	19.0	10.8	2.1	1.4	-33.4	-11.8
E12: Pulverized coal injection in blast furnace		2.7		0.7		-10.8
E13: Scrap preheating		4.1		0.6		-19.9
E14: Hot charging in rolling mill		4.9		0.7		-15.1
E15:Basic oxygen furnace gas sensible heat recovery		4.3		0.9		0.3
E16: EE improvement in other industrial sub-sectors		87.4		15.0		-6.5
E17: New vehicle fuel economy and emissions standards		15.8		5.1		-65.2
E18: Passenger transport mode shift from private to public (NDC1-E8)	9.9	4.6	1.2	0.4	-342.6	-4.3
E19: Modal shift of freight transport from road to inland water and marine water way (NDC1-E9)	26.7	16.0	3.6	1.6	-295.5	-93.0
E20: Introduction of electric motorbikes		4.6		0.6		-67.2
E21: Substitution of ethanol for gasoline in transport (NDC1-E7)	14.2	3.1	1.5	0.3	40.3	44.1
E22: Introduction of CNG buses		0.03		0.01		34.1
E23: Promotion of electric cars		7.7		1.9		86.1
E24: Improvement of truck load factor		7.9		1.3		-40.8
E25: Freight transport shift from road to railway		6.9		1.1		-67.8
E26: Increased promotion of bio-fuel in transport		1.8		0.3		52.8
E27: Increased penetration of electric motorbikes		7.8		1.0		-67.2

Mitigation option	Mitigation potential (tCO2e)				Mitigation cost (USD/tCO2e)	
	2015-2030		2030			
	NDC1	The revised NDC1	NDC1	The revised NDC1	NDC1*	The revised NDC1**
E28: Promotion of high efficiency electricity equipment in commercial sector (NDC1-E10)	11.1	23.3	1.1	3.8	-15.5	-16.9
E29: Small hydropower plants (NDC1-E12)	83.7	100.7	8.0	9.1	-3.3	3.1
E30: Voluntary solar photovoltaic power plants		60.8		5.0		27.3
E31: Conditional solar photovoltaic power plants(NDC1-E17)	12.3	51.3	2.2	10.3	160.1	46.6
E32: Voluntary wind power plants (NDC1-E13)	2.7	18.2	0.2	1.5	49.1	46.5
E33: Conditional wind power plants (NDC1-E14)	71.8	47.6	10.9	10.0	50.4	75.5
E34: Biomass power plants (NDC1-E11)	50.3	22.5	7.0	4.0	3.9	33.5
E35: Municipal solid waste-fired power plants		9.1		1.4		25.1
E36: Landfill gas power plants		0.9		0.1		6.7
E37: Biogas power plants (NDC1-E15)	4.4	0.6	0.6	0.1	2.9	30.6
E38: Ultra-supercritical coal power plants (NDC1-E16)	79.8	120.7	14.2	22.4	32.1	43.8
E39: LNG combined cycle gas turbine		138.9		33.0		25.7
Total	**482.2**	**942.9**	**66.0**	**155.8**		

**: Discounted 2010 Million U.S. Dollars*
***: Discounted 2014 Million U.S. Dollars*

05. Needs for implementation of mitigation options in the energy sector

5.1. Policies

Barriers:

- Vietnam still does not have a clear legal framework guiding policies on RE projects. The policies are separately stipulated in different laws leading to confusion in their application.
- The existing financial support mechanisms for RE development are not strong enough to encourage entrepreneurs to invest in RE projects.
- The price at which EVN purchases electricity from RE projects is currently lower than electricity production costs for wind or SHP; this is a major obstruction for investors and affects returns on investment.
- There is no comprehensive policy or plan for enhancing access to all forms of thermal energy for households (such as biogas digester, solar water heater, etc.) in national energy policies.
- In many cases, investors have encountered difficulties in securing loans for renewable power projects, although legal documents confirm that they are eligible to access available soft loans.
- No mandatory regulations for minimum energy performance standards (MEPS).
- Lack of policy framework and comprehensive roadmap for energy standards and labelling.

Needs:

- The Law on RE development to address the barriers mentioned above should be prioritised for elaboration in the coming years.
- Finalisation of the reasonable price mechanism: FIT can be adjusted periodically for each type of RE to make it a drive to promote RE development. The FIT mechanism should be evaluated at fixed periods to ensure an appropriate level of support to accomplish RE development targets at the lowest possible cost.
- A policy framework and incentive mechanisms to support RE in Vietnam should be developed adequately and cover all types of RE technologies.
- Creating a sustainable financial source for RE development via funds from international donors, preferential loans from financial institutions, and developing the capital market from commercial banks for RE development investments.
- Improving the MEPS and expanding energy labelling.
- Energy standards and labelling should receive strong support from policy makers for development of a policy framework, regulations and a comprehensive roadmap for energy standards and labelling.
- Developing strategies, a road map and action plans for Vietnam's NDC implementation.

5.2. Technologies

Barriers:

- High investment costs for transport infrastructure and mitigation technologies.
- Price of electricity produced using RE sources, such as wind, solar power and biomass, is higher than using fossil fuels.
- Limited domestic technological capacities, low quality and lifespan of products.
- Lack of infrastructure and technical support services to repair, maintain and replace equipment.
- Lack of bus system operations to integrate rail and bus transport.
- Lack of electronic ticketing systems for public transit and logistics systems for freight transport.

Needs:

- Set up mechanisms and policies that encourage investment and support domestically produced EE and RE technologies in order to reduce investment costs and the price of electricity produced from RE sources.
- Develop testing and standards for EE and RE technologies to improve their reliability.
- National standards for services and equipment of renewable energy should be established and applied to ensure the quality of services and products, and security for consumers.
- Develop infrastructure on transport and maintenance services for mitigation technologies.

5.3. Finance

The funding needed to implement the mitigation options in the 2015-2030 period to achieve GHG emissions reduction targets is summarised in Table 23:

Table 23: Necessary funding for achieving GHG emissions reduction targets in the period 2015-2030

Unit: Discounted 2014 Million U.S. Dollars

	Un-conditional contribution	Conditional contribution
E1. High efficiency residential air conditioning	4,150.5	
E2. High efficiency residential refrigerators	3,334.7	
E3. High efficiency residential lighting	891.4	
E4. Solar water heaters	345.9	
E5. Biogas replacing coal for residential cooking in rural areas	129.4	
E6s. Cleaner cooking fuels		160.5
E7. Combustion optimization	22.9	
E8. Kiln shell heat loss reduction	3.3	
E9. Waste heat recovery from cement	354.8	
E10. Vertical roller mill	368.2	
E11. Brick-making technology improvements	36.8	
E12. Pulverized coal injection in blast furnace	11.8	
E13. Scrap preheating	18.5	
E14. Hot charging in rolling mill	46.2	
E15s. Basic oxygen furnace gas sensible heat recovery	56.7	
E16s. EE improvement in other industrial sub-sectors		1,469.2
E17. New vehicle fuel economy and emissions standards	0.4	
E18. Passenger transport mode shift from private to public	411.5	
E19. Modal shift of freight transport from road to inland water and marine water way	282.7	
E20. Penetration of electric motorbikes	251.2	
E21. Substitution of ethanol for gasoline in transport	93.0	
E22. Introduction of CNG buses	6.5	
E23s. Promotion of electric cars		1,467.0
E24s. Improvement of truck load factor		343.4
E25s. Freight transport shift from road to railway		168.5
E26s. Increased promotion of bio-fuel in transport		51.8
E27s. Increased penetration of electric motorbikes		427.1
E28. Promotion of high efficiency electricity equipment in commercial sector	134.4	
E29. Small hydropower plants	3,592.9	
E30. Voluntary solar photovoltaic power plants	3,891.0	
E31s. Conditional solar photovoltaic power plants		4,350.6

	Un-conditional contribution	Conditional contribution
E32. Voluntary wind power plants	1,088.4	
E33s. Conditional wind power plants		4,584.1
E34s. Biomass power plants		859.1
E35. Municipal solid waste-fired power plants	364.6	
E36s. Landfill gas power plants		21.1
E37s. Biogas power plants		27.9
E38s. Ultra-supercritical coal power plants		18,166.1
E39s. LNG combined cycle gas turbine		3,706.8
Total	**19,887.7**	**35,803.2**

Table 24 shows that the total amount of domestic funding needed is US$ 19,887.7 million. An additional US$ 35,803.2 million will need to be mobilized from international sources in order to achieve the GHG emissions reduction by 2030. Funding will need to be sourced from Viet Nam's domestic economic sectors and international support, including bilateral and multilateral sources in order to implement the GHG reduction targets effectively.

5.4. Capacity building

Barriers:

- Lack of a national data collection system for GHG inventory and mitigation measures.
- Lack of experts, technical knowledge and skills to implement EE and RE projects.
- Limited ability to receive and apply new technologies.
- MRV systems at the national and sectoral level are still only in the research and development phase.
- Ministries, economic sectors, localities and the private sector have limited organisational capacity to apply environmentally sound technologies and implement NAMAs based on an MRV approach.
- Lack of an effective coordination mechanism between line ministries, economic sectors, localities and the public and private sectors to develop and implement inter-sectoral NAMAs.

Needs:

- Develop a database that can be integrated into the General Statistics Office database to meet the demands of GHG inventories, as well as climate change adaptation and mitigation measures.
- Develop capacities of technical experts involved in climate change response, such as GHG emissions reduction, NAMAs and MRV.
- Study and develop country-specific emissions factors for GHG inventory; improve the capacity for measuring and quantifying GHG mitigation programmes and projects at the local and regional level.
- Improve capacities among local authorities and businesses to develop a low-carbon economy.

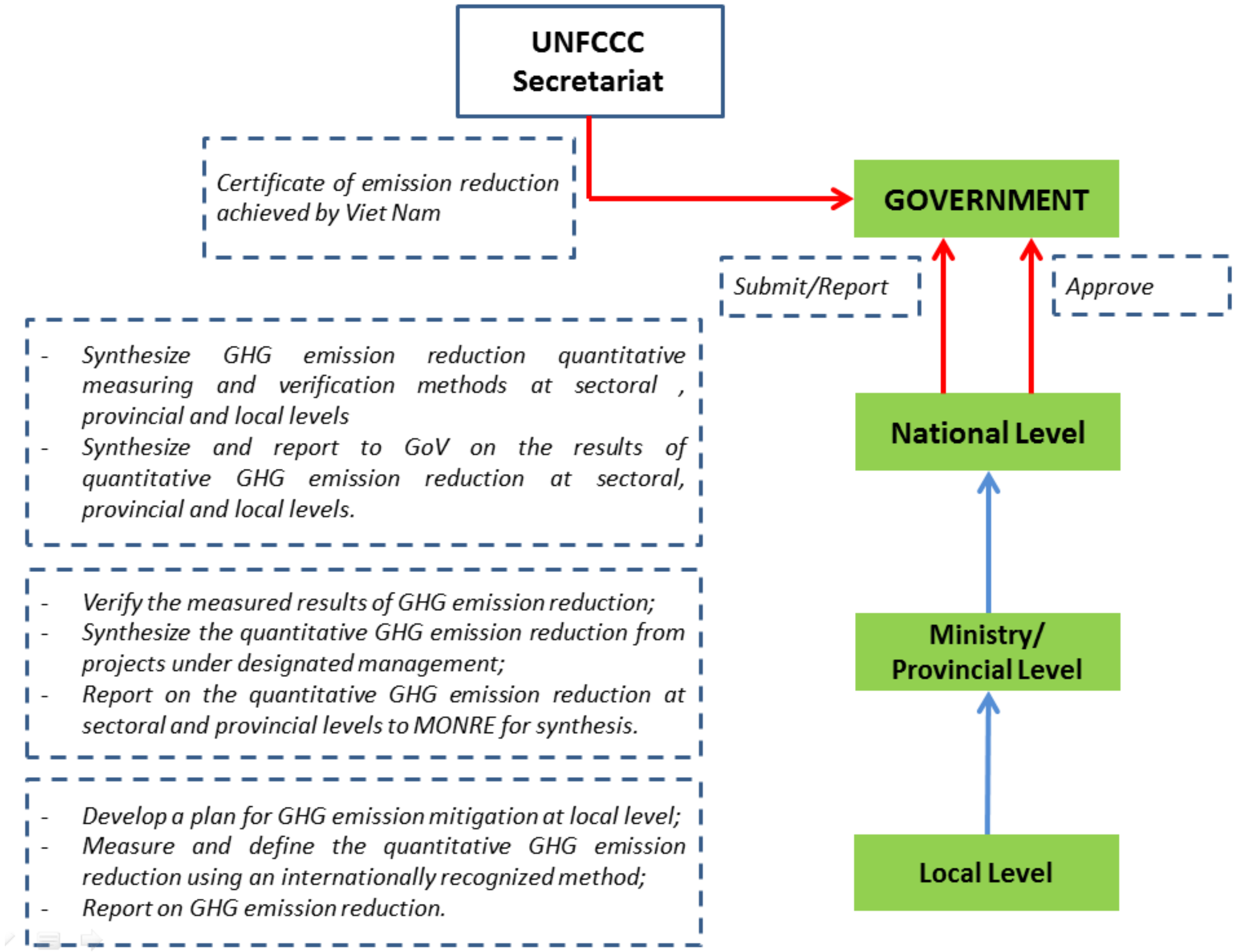
06. Measurement, reporting and verification for mitigation activities in the energy sector

6.1. Measurement, Reporting and Verification at National Level

The establishment of a Measurement, Reporting and Verification (MRV) system at the national, sectoral and local level is necessary in order to assess the implementation and impact of each action to reduce GHG emissions as well as ensure achievement of the GHG emissions reduction targets in the NDC. Decision No. 2053/QD-TTg dated 28 October 2016 of the Prime Minister approving the Plan for Implementation of the Paris Agreement stipulated the tasks to be executed in the period 2016-2020, in which the establishment of the MRV system is one of the key tasks in the period 2018-2010.

The national MRV system was proposed in the Third National Communication of Vietnam, which is illustrated in Figure 2.

Figure2: The proposed MRV system at the national level **Figure2: The proposed MRV system at the national level**



Source: MONRE, 2019

6.2. Measurement, Reporting and Verification for Mitigation Activities in the Energy Sector

MRV of mitigation actions in production activities and EE uses relates to ministries, business activities and household living. Therefore, it is necessary to complete the legal framework for implementing Decision No. 2053/QD-TTg dated 28 October 2016 of the Prime Minister on the approval of the Implementation Plan of the Paris Agreement, in which line ministries have been assigned to develop sectoral MRV systems.

The following are proposals for MRV systems in the energy sector:

6.2.1. Development of an energy statistics system

The energy statistics system, including data on energy uses and supplies to meet the monitoring/reporting requirements of new obligations of energy sector on GHG emissions reduction, should be developed based on the national statistics system (official statistics). The following are necessary data for MRV activities:

- Equipment efficiencies or energy consumption norms of residential electric equipment such as air conditioners, refrigerators, electric water heaters, lighting lamps, etc.

» Amount of electrical equipment and the share of EE equipment used in the residential sector.

» Number of vehicles and their energy consumption norms.

» Floor areas and average energy consumption per square meter in commercial buildings.

» Number of industrial products, manufacturing technologies and energy consumption per major industrial product.

» Data from EVN's annual operations.

» EVN purchases of electricity from power sources including wind power plants, solar, biomass, waste and biogas, small hydropower and coal-fired power plants - supercritical steam parameters).

The above data can also be verified through annual reports of power plants (similar to data collected annually to calculate GHG emissions factor of the VN power grid). Electricity meters (kWh) and electricity bills from power plants are also reliable sources of data for MRV activities.

6.2.2. Development of a legal framework for sectoral MRV systems

Elaboration of the legal framework for sectoral MRV systems is required to support Vietnam's NDC implementation. Sectoral legal frameworks should include the following components:

» A policy framework for operating MRV that describes guiding principles, and the roles of the various institutions involved in the MRV process.

» Guidelines for developing measurement plans and approaches to data measurement and storage, including methods for data collection and measuring emissions.

» Guidelines for reporting information to ensure transparent, consistent, comparable and complete reporting, including reporting frequency, reporting requirements and formats.

» Guidelines and processes for undertaking verification.

6.2.3. Responsibility of agencies in the sectoral MRV systems

The responsibility of agencies in the sectoral MRV systems is proposed as follows:

» Developing methodology and establishing relevant documents on implementation of monitoring, reporting and verification.

» Implementing monitoring and supervising activities of climate change programmes and projects.

» Reporting on progress and outcomes of climate change projects and programmes periodically based on monitoring and verification outcomes for certification of achievements.

Conclusion

This study determined the GHG emission reduction potential compared to the BAU and the contribution of the energy sector to Viet Nam's revised NDC1 for the 2021-2030 period based on the results of LEAP's calculation and the selection of prioritized mitigation technologies for the energy sector.

There are 25 prioritized mitigation technologies selected as unconditional contribution and 14 mitigation technologies selected as conditional contribution of energy sector, which are selected based on option's mitigation potential, cost-effectiveness and the maturity of technology development, as well as Government priorities.

The total GHG emission reduction in case of unconditional contribution is 51.5 $MtCO_2e$ accounted for 7.6% of total GHG emission of BAU scenario by 2030. Regarding conditional contribution, the total GHG emission reduction is 104.3 $MtCO_2e$ accounted for 15.4% of total GHG emission of BAU scenario by 2030.

The total additional social costs of mitigation measures for the unconditional contribution are approximately US$ 9,865.7 million, resulting in social benefits of almost US$ 10,649.6 million. The total additional social costs of mitigation measures for the conditional contribution are US$ 25,860.3 million, resulting in social benefits of US$ 10,675.8 million.

In order to achieve its mitigation targets, the study also recognized the barriers and constraints in terms of technology, finance and capacity building with the proposed additional policies to overcome these barriers. Some recommendations are proposed as follows:

- Develop a roadmap including activities, timeframes and responsibilities by different stakeholders to address the exiting barriers for implementing the mitigation actions of energy sector.
- Set up mechanisms and policies that encourage investment and support domestically produced energy efficiency and RE technologies in order to reduce investment costs and the price of electricity produced from RE sources;
- Develop capacities of technical experts involved in climate change response, such as GHG emissions reduction, NAMA and MRV;
- Label energy-saving equipment and issue national standards for the quality of equipment;
- Develop a renewable energy technology market, domestic industries and local service providers;
- Arrange and regulate institutional framework for mitigation actions by the law, in which, the Ministry of Industry and Trade should have decisive role on all mitigation issues with the supports and assistant of other Ministries.

References

1. ADB (2018). *Pathways to Low-Carbon Development for Vietnam.*
2. ASEAN-SHINE (2015). *Promotion and Deployment of Energy Efficient Air Conditioners in ASEAN.*
3. Building Material Institute (2016). *Input Data for Greenhouse Gas Reduction by Improvement of Production Technology of Building Materials.*
4. EVN (2015). *Vietnam Electricity, Annual Report, 2015.*
5. GIZ (2018). *Transport Sector Contribution on GHG Emissions Reduction Commitment to Vietnam NDC.*
6. Government of Vietnam (2015). *Decision No. 2068/QD-TTg on Approving 'The Vietnam Renewable Energy Development Strategy to 2030, Outlook to 2050'.*
7. Government of Vietnam (2016). *Decision No. 428/QD-TTg on Approving the Revised Power Development Plan for the Period 2010-2020 with Perspective to 2030 (Revised PDP VII).*
8. Government of Vietnam (2017*). Decision No. 60/QD-TTg on Approving the Vietnam Gas Industry Development Plan to 2025, with Orientations to 2035.*
9. IEA (2012). *Energy Technology Perspectives 2012-Pathways to a Clean Energy System.*
10. IEA (2016). *World Energy Outlook 2016.*
11. IRENA (2016). *The Power to Change: Solar and Wind Cost Reduction Potential to 2015.*
12. IPCC (2007). *Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.*
13. Joseph B. Gonsalves (2006). An Assessment of the Bio-fuels Industry in Thailand (table 2, page 14).
14. Thu Lan T. Nguyen et al. (2006). Life Cycle Cost Analysis of Fuel Ethanol Produced from Cassava in Thailand (table 2, page 5).
15. MATSUMOTO Shigeru (2015). Consumer Valuations of EE Investments: The case of Vietnam's air conditioner market.
16. MOC (2019). *Projection on building material production.*

17. MOIT (2019). *Vietnam Energy Outlook Report*.

18. MOIT/GIZ (2017). *Project Development Guidelines for grid-connected power generation projects using solid waste in Vietnam*.

19. MONRE (2014a). *The Initial Biennial Update Report of Vietnam to the United Nations Framework Conventional on Climate Change*.

20. MONRE(2014b). *Report on National Greenhouse Gas Inventories in 2010*, Project title "Enhancing capacity for greenhouse gas inventories in Vietnam".

21. MONRE (2015). *Technical Report on Intended Nationally Determined Contribution*.

22. MONRE (2017). *The Second Biennial Updated Report of Vietnam to the United Nations Convention on Climate Change*.

23. MONRE (2018). *Low Carbon Technology Catalogue*.

24. MONRE (2019).*Vietnam's Third National Communication to the United Nation Framework Convention on Climate Change*.

25. MONRE and JICA (2018). *Low Carbon Technology Catalogue*.

26. WB-GIZ (2019). *Pathway to Low-Carbon Transport*.

27. WB-MOIT (2019). *Vietnam – Getting on a Low-Carbon Energy Path to Achieve NDC Target*.

28. World Bank (2016). *Exploring a Low-Carbon Development Path for Vietnam*.

29. World Bank (2001). *Wind Energy Resource Atlas of Southeast Asia*.

Annex. Input data for calculation

Table A.1: Population projection

	2014	2020	2025	2030
Population (Mil. Persons)	90.729	96.179	100.129	103.117
Number of persons per household (Person/household)	3.70	3.60	3.51	3.43
Population in rural areas (Mil. Persons)	60.693	60.525	59.386	57.313
Population in urban areas (Mil. Persons)	30.036	35.654	40.743	45.804

Source: GSO-Statistical Yearbook 2015; GSO-Vietnam Population Forecasts 2009-2049; GSO- Midterm surveys on population and housing, 2014

Table A.2: Fuel prices for power generation projected to 2030

Unit: USD 2015M/PJ

	2014	2015	2020	2025	2030
Domestic coal	3.47	3.47	3.56	3.71	4.09
Imported coal	4.18	4.18	3.61	3.5	3.74
Natural gas	4.92	4.92	7.53	9.45	10.73
Imported natural gas	9.75	9.75	10.48	11.06	11.82

Source: WB-MOIT, 2019

Table A.3: Fuel prices for transportation projected to 2030

Unit: 1000 VND/ton

	2014	2015	2020	2025	2030
FO	14,589	12,705	15,995	21,966	23,898
DO	20,693	17,516	22,391	31,007	33,734
Jet kerosene	18,943	14,326	26,511	30,808	32,864
Gasoline	25,631	19,218	25,476	28,684	29,555
CNG*	11,671	10,164	12,796	17,573	19,118

Source: WB-GIZ, 2019; Actual price at HCM city (estimated equal to 80% of DO price).*

Table A.4: Electricity consumption in the period 2010-2014

Unit: Million kWh

	2010	2011	2012	2013	2014
Industry	44,668	50,328	55,568	61,277	69,524
Agriculture	947	1,079	1,266	1,502	1,892
Commercial	3,896	4,334	4,988	5,374	6,131
Residential	31,971	34,212	38,421	41,483	45,468
Other	4,187	4,704	5,232	5,647	5,612
Total	85,669	94,657	105,475	115,283	128,627
Annual electricity saving	1,189	1,310	1,670	2,799	2,800

Source: EVN- Annual report, 2015

Table A.5: Electricity demand by sector in the 2014-2030 period

Unit: Million kWh

	2014*	2020	2025	2030
Industry	69,524	145,457.6	225,722.9	319,897.5
Agriculture	1,892	2,634.2	3,279.7	4,013.5
Commercial and other	11,742	24,365.4	34,335.5	49,479.5
Residential	45,468	71,715.3	106,207.1	157,579.3
Total	128,627	244,172.5	369,545.2	530,969.8

** Source: EVN, 2015 and Revised PDPVII (not including electricity saving measures)*

Table A.6: Emissions factors, calorific value and each fraction for industries

Fuel	CO_2 EF (tC/TJ)	CH_4 EF (kgCH_4/TJ)	N_2O EF (kgN_2O/TJ)	Calorific value (kcal/unit)	unit	Fraction carbon stored	Fraction oxidized
Anthracite	26.8	10	1.4	5,600	kg	-	0.98
Bituminous	25.8	10	1.4	5,805	kg	-	0.98
Coke	29.5	10	1.4	7,500	kg	-	0.98
Peat	28.9	2	1.5	4,536	kg	-	0.99
Kerosene	19.6	2	0.6	10,320	kg	-	0.99
DO	20.2	2	0.6	10,150	kg	0.50	0.99
FO	21.1	2	0.6	9,910	kg	-	0.99
LPG	17.2	2	0.6	10,880	kg	0.80	0.99
Gas (including associated gas)	15.3	5	0.1	9,000	10^3m^3	-	0.995

Source: Revised 1996 IPCC Guidelines, 2006 IPCC Guidelines, 2014 Vietnam's National Greenhouse Gas Inventory

Table A.7: Emissions factors, calorific value and each fraction for transport

Fuel	CO_2 EF (tC/TJ)	CH_4 EF ($kgCH_4$/TJ)	N_2O EF (kgN_2O/TJ)	Calorific value (kcal/unit)	Unit	Fraction Carbon stored	Fraction oxidized
Mogas	18.9	20 (road), 5 (Navigation)	0.6	10,500	kg	-	0.99
Jet Fuel	19.5	0.5	2	10,320	kg	-	0.99
DO	20.2	5	0.6	10,150	kg	0.50	0.99
FO	21.1	5	0.6	9,910	kg	-	0.99

Source: Revised 1996 IPCC Guidelines, 2006 IPCC Guidelines, 2014 Vietnam's National Greenhouse Gas Inventory

Table A.8: Emissions factors, calorific value and each fraction for commercial

Fuel	EF_{CO2} (tC/TJ)	EF_{CH4} ($kgCH_4$/TJ)	EF_{N2O} (kgN_2O/TJ)	Calorific value (kcal/unit)	unit	Fraction Carbon stored	Fraction oxidized
Anthracite	26.8	10	1.4	5,600	kg	-	0.98
Kerosene	19.6	10	0.6	10,320	kg	-	0.99
DO	20.2	10	0.6	10,150	kg	0.50	0.99
FO	21.1	10	0.6	9,910	kg	-	0.99
LPG	17.2	10	0.6	10,880	kg	0.80	0.99

Source: Revised 1996 IPCC Guidelines, 2006 IPCC Guidelines, 2014 Vietnam's National Greenhouse Gas Inventory

Table A.9: Emissions factors, calorific value and each fraction for Residential

Fuel	EF_{CO2} (tC/TJ)	EF_{CH4} ($kgCH_4$/TJ)	EF_{N2O} (kgN_2O/TJ)	Calorific value (kcal/unit)	Unit	Fraction Carbon stored	Fraction oxidized
Anthracite	26.8	300	1.4	5,600	kg	-	0.98
Kerosene	19.6	10	0.6	10,320	kg	-	0.99
DO	20.2	10	0.6	10,150	kg	0.50	0.99
FO	21.1	10	0.6	9,910	kg	-	0.99
LPG	17.2	10	0.6	10,880	kg	0.80	0.99
Biomass	-	300	4	3,302	TWE	-	-
Biogas	-	300	4	5,200	m^3	-	-

Source: Revised 1996 IPCC Guidelines, 2006 IPCC Guidelines, 2014 Vietnam's National Greenhouse Gas Inventory

Table A.10: Emissions factors, calorific value and each fraction for agriculture

Fuel	EF_{CO2} (tC/TJ)	EF_{CH4} ($kgCH_4$/TJ)	EF_{N2O} (kgN_2O/TJ)	Calorific value (kcal/unit)	Unit	Fraction Carbon stored	Fraction oxidized
Anthracite	26.8	300	1.4	5600	kg	-	0.98
Mogas	18.9	10	0.6	10500	kg	-	0.99
DO	20.2	10	0.6	10150	kg	0.50	0.99
FO	21.1	10	0.6	9910	kg	-	0.99

Source: Revised 1996 IPCC Guidelines, 2006 IPCC Guidelines, 2014 Vietnam's National Greenhouse Gas Inventory

Table A.11: Emissions factors, calorific value and each fraction for power generation

Fuel	EF_{CO2} (tC/TJ)	EF_{CH4} ($kgCH_4$/TJ)	EF_{N2O} (kgN_2O/TJ)	Calorific value (kcal/unit)	Unit	Fraction Carbon stored	Fraction oxidized
Anthracite	26.8	1	1.4	5,043	kg	-	0.98
Bituminous	25.8	1	1.4	5,805	kg	-	0.98
Crude Oil	20.0	3	0.6	10,180	kg	-	0.99
DO	20.2	3	0.6	10,150	kg	0.50	0.99
FO	21.1	3	0.6	9,910	kg	-	0.99
Gas (including associated gases)	15.3	1	0.1	9,000	10^3m^3	0.33	0.995
Biomass	-	30	4	3,302	TWE	-	-

(TWE: Ton of Wood Equivalent)
Source: Revised 1996 IPCC Guidelines, 2006 IPCC Guidelines, 2014 Vietnam's National Greenhouse Gas Inventory

Table A.12: Cement Production - Activity Data

	2014	2020	2025	2030
Cement product (Mil.ton)	60.98	112.02	131.42	140.12
Vertical kilns share (%)	0.90	-	-	-
Rotary kilns share (%)	99.10	100.00	100.00	100.00
In which: * Wet process (%)	1.40	0.35	-	-
* Dry process (%)	98.60	99.65	100.00	100.00

Source: GSO-Statistical Yearbook 2015
MOC, 2019-Projection on building material production

Table A.13: Cement Production - Energy Intensity

Technology		Rotary kiln
Production processes	**Wet**	**Dry**
Coal for clinker burning (MJ/Ton)	4,600	3,500
Electricity for cement production (kWh/Ton)	146	146

Source: Nordic Partnership Initiative (NPI)-Cement NAMA report, 2016

Table A.14: Brick Making - Activity Data

	2014	2020	2025	2030
Brick product (Bill. piece)	21.468	27.5	30.5	35.9
Share of baked bricks (%)	80.9	70.0	65.0	60.0
Share of non-baked bricks* (%)	19.1	30.0	35.0	40.0

** Estimated based on the programme on development of non-baked bricks*
Source: MOC, 2019- Projection on building material production

Table A.15: Brick Making – Share of technology and energy intensity in 2014

Technology	Non-baked bricks (19.1%)	Baked bricks (80.9%)		
		Tunnel (53%)	Traditional (47%)	
			Coal (65%)	Biomass (35%)
Coal (MJ/piece)	0.57*	2.8	4.3	
Electricity (kWh/piece)	0.3*	0.06	0.06	
Biomass (MJ/piece)			0.03	7.5

** Coal and electricity consumption for cement production and electricity used for operating the non-baked brick making equipment.*
Source: The Building Material Institute, 2016 and other studies

Table A.16: Proposed iron production plan to 2030

Unit: Million tons

	2014	2015	2016	2020	2025	2030 (estimated)
Pig iron and sponge iron	1.4	1.7	2.5	17	28	32
In which: Estimated pig iron	1.4	1.7	2.5	6	10	16

** Source: FPT, 2017-Report of Steel sector; Decision No.694/QD-BCT, 2013 and Proposed plan, 2016*

Table A.17: Crude steel production to 2030

Unit: Thousand ton

Year	Blast Furnace	Electric Arc Furnace	Other	Total	Source
2014	877	4,385	585	5,847	Steel Statistical Yearbook 2017, World Steel Association
2015	1,409	3,381	846	5,636	
2020	15,293	6,187	781	22,261	Decision No.694 (70%)
2030	39,093	7,687	781	47,561	Proposed plan, 2016 (70%)

Table A.18: Crude Steel Production-Energy Intensity

Technology	Blast Furnace	Electric Arc Furnace
Coal (MJ/Ton)	109	816
Electricity (MJ/Ton)	130	2,160

Source: Feasibility Study project for the JCM-2014 and checked with China's report on iron making-2017

International Climate Initiative (IKI)
This project is part of the International Climate Initiative (IKI). The Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) supports this initiative on the basis of a decision adopted by the German Bundestag

www.international-climate-initiative.com
www.bmu.de/en.

Published by:
GIZ Office Vietnam
Project "Support to Vietnam for the Implementation of the Paris Agreement"

Address
Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH
Viet Nam Office
Unit 031, 3rd Floor, Coco Building,
14 Thuy Khue, Tay Ho District,
Hanoi, Viet Nam
Phone: (+84) 2432373110
Email:: office.sipa@giz.de