Low Carbon Technology Assessment Facilitating Effectiveness of Viet Nam's Nationally Determined Contributions

Volume 1: Low Carbon Technologies for 45 Mitigation Options

Ministry of Natural Resources and Environment of Viet Nam
in collaboration with
JICA Technical Assistance Project to Support the Planning and Implementation of NAMAs in a MRVable Manner (SPI-NAMA)

January, 2018

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CONTENTS

ABBREVIATIONS

ADB	Asian Development Bank
AWD	Alternative Wet and Drying
BAU	Business As Usual
BRT	Bus Rapid Transit
BUR	Biennial Update Report
CDM	Clean Development Mechanism
CFCs	Chlorofluorocarbons
CNG	Compressed Natural Gas
COP	Conference of Parties
DCC	Department of Climate Change
DMHCC	Department of Meteorology, Hydrology and Climate Change
DMI	Dry Matter Intake
DOE	Department of Environment
DoSTE	Department of Science, Technology and Environment
DoSTIC	Department of Science, Technology and International Cooperation
DSM	Demand Side Management
FIT	Feed In Tariff
FS	Feasibility Study
GDE	General Directorate of Energy
GHG	Greenhouse Gas
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH
GPU	Ground Power Unit
GWP	Global Warming Potential
HCFC	Hydrochlorofluorocarbon
HFC	Hydrofluorocarbon
IAE	Institute for Agricultural Environment
IEA	International Energy Agency
IMHEN	Institute of Meteorology Hydrology and Climate Change
(I)NDC	(Intended) Nationally Determined Contributions
IoE	Institute of Energy
IPCC	Intergovernmental Panel on Climate Change
ISEA	Industrial Safety techniques and Environment Agency, MOIT
ITPO	Investment and Technology Promotion Office (UNIDO)
JCM	Joint Crediting Mechanism
JICA	Japan International Cooperation Agency
LFG	Landfill Gas
LPG	Liquefied Petroleum Gas

LULUCF	Land Use, Land Use Change and Forestry
MARD	Ministry of Agriculture and Rural Development
MBT	Mechanical Biological Treatment
MOC	Ministry of Construction
MOF	Ministry of Finance
MOFA	Ministry of Foreign Affairs
MOIT	Ministry of Industry and Trade
MONRE	Ministry of Natural Resources and Environment
MOST	Ministry of Science and Technology
MOT	Ministry of Transport
MPI	Ministry of Planning and Investment
MRT	Mass Rapid Transit
MRV	Measurement, Reporting and Verification
NAMAs	Nationally Appropriate Mitigation Actions
NC	National Communications
NOU	National Ozone Unit
ODS	Ozone-Depleting Substances
PDP7	Power Development Master Plan No. VII
REDD+	Reduction of Emission from Deforestation and forest Degradation Plus (Reducing emissions from deforestation and forest degradation and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks)
SPI-NAMA	Project to Support the Planning and Implementation of NAMA
TAC	Technology Advisory Committee
TDSI	Transport Development Strategy Institute
TNA	Technology Needs Assessment
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
USAID	United States Agency for International Development
VAAS	Vietnam Academy of Agricultural Sciences
VAFS	Vietnamese Academy of Forest Science
VNForest	Vietnam Forest Administration

INTRODUCTION

On September 2015, the Socialist Republic of Viet Nam submitted its Intended Nationally Determined Contribution (INDC) to the Secretariat of the United Nations Framework Convention on Climate Change (UNFCCC), in which the national greenhouse gas (GHG) emission reduction target for the period of 2020-2030 is defined. This was done as part of the global, collective effort in reaching a comprehensive, fair and effective agreement on the post-2020 climate regime and in aiming to achieve the global 2°C target.

Following the submissions of country INDCs, the subsequent Conference of the Parties (COP21) to the UNFCCC has adopted the Paris Agreement on December 2015, providing an overarching framework along with a series of requirements for the post-2020 regime. With the sufficient number of instruments of ratification submitted, the Paris Agreement has successfully entered into force on 4th November 2016. Subsequently, country INDCs have transformed into Nationally Determined Contributions (NDCs), in anticipation for submitting countries to duly implement its NDCs starting 2021.

Having completed the procedural side of the Paris Agreement to enter into force, the next critical step is to elaborate country NDCs into implementable actions in order to harvest aggregated amount of GHG emission reductions. Such elaboration requires in-depth technical and realistic assessment of implementation method for each mitigation option presented.

Taking a closer look at Viet Nam's current NDC, while it succeeds in addressing its national aspiration by selecting 45 mitigation options categorized with scope, areas and mitigation potential across 4 mitigation sectors of Energy/Transport, Agriculture, LULUCF (Land use, land-use change and forestry) and Waste, the content is yet to reach the implementation stage. Given the observed gradation of maturity level and diverse scope across the identified options, further technical effort is deemed necessary to bridge the current gap between identified mitigation aspirations and what is already set in motion.

Against this backdrop, as part of activities under the Technical Assistance Project to "Support the Planning and Implementation of Nationally Appropriate Mitigation Actions in a MRVable[1] Manner (SPI-NAMA)[2]" jointly launched by the Department of Meteorology, Hydrology and Climate Change (DMHCC) [3] of Ministry of Natural Resources and Environment of Vietnam (MONRE) and Japan International Cooperation Agency (JICA), identification and in-depth assessment of applicable low carbon technologies were conducted through consultations and close cooperation with relevant line ministries (LM) and agencies, ensuring that sectoral priorities and needs are duly identified, captured and reflected.

As an initial outcome of the assessment work, Low Carbon Technology Catalogue was compiled, listing all low carbon technologies (nearly 150) that may contribute to the implementation of Viet Nam's NDC.

This document serves as a summary of the Low Carbon Technology Catalogue, focusing on the technologies corresponding to the 45 mitigation options of Viet Nam's NDC. It also provides barrier analysis in deploying the technologies with a view to the future revision of the NDC and assessment of strategies to raise ambitions to reach the global target. This document is the first volume of a series of three publications planned under the assessment work to facilitate national-level discussion on how to implement the proposed mitigation options (Figure 1).

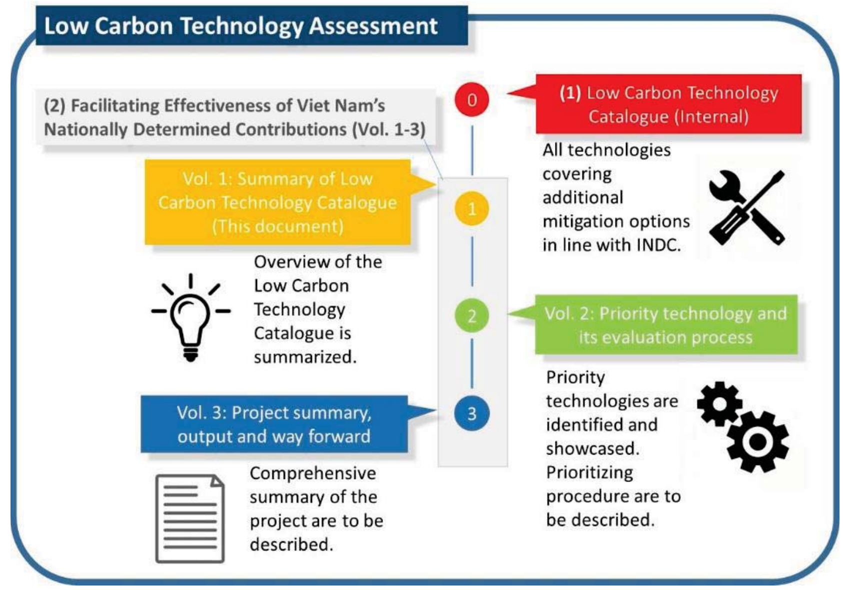
This document consists of four chapters as follows.

Chapter 1 provides a description of common approaches, principles and steps taken for the development of the Low Carbon Technology Catalogue for Viet Nam's NDC.

Chapter 2 presents low carbon technologies by mitigation sectors. Comments received from interviews and consultations with stakeholders for each and every technology are also synthesized.

Chapter 3 summarizes the barriers and gaps anticipated in low carbon technology transfer. For future consideration, barriers are sorted into policy/market barriers and technical barriers.

Chapter 4 describes approaches to be taken in the next step which is prioritization of the technologies involving relevant stakeholders.



Note: The figure shows the flow of the planned publications in SPI-NAMA Low Carbon Technology Assessment. Two types of publications are to be developed: (1) Low Carbon Technology Catalogue shows all identified technologies in line with mitigation options in the NDC (for internal reference). Technologies regarding Freon-gas (F-gas) are also considered due to its high contribution to GHG emissions reduction. The catalogue also includes additional mitigation options that were not originally considered in the INDC; (2) the publications of "Low Carbon Technology Assessment, Facilitating Effectiveness of Viet Nam's NDC" consists of three publications (vol. 1-3)" highlighting the essential components of the assessment work.

Figure 1 Overview of the Series of Publications in SPI-NAMA, Low Carbon Technology Assessment

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[1] MRV stands for Measurement, Reporting and Verification.
[2] When SPI-NAMA was launched in 2015, it featured on mitigation actions in line with NAMA (i.e. mitigation actions for developing country) under the UNFCCC. Given the global movement toward post-2020 regime and increased requirement that parties are expected to take into account, readiness for NDC implementation was also incorporated in the SPI-NAMA. Low carbon technology assessment is one of the components of the SPI-NAMA aiming to enhance national level activities and measures. For further information, please see SPI-NAMA website [https://www.jica.go.jp/project/english/vietnam/036/index.html]
[3] Currently the Department of Climate Change.

CHAPTER 1

Development Process of Low Carbon Technology Catalogue for Viet Nam's NDC

1 Development Process of Low Carbon Technology Catalogue for Viet Nam's NDC

1.1 Background

MONRE, acting as the focal point agency of UNFCCC in Viet Nam, was assigned by the Government to take the lead on development of its INDC and to cooperate with relevant ministries and agencies on its implementation[4]. Viet Nam's INDC Technical Report[5] developed with the support of Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH (GIZ) and United Nations Development Programme (UNDP) in 2015, describes 45 mitigation options across 4 sectors (Energy/Transport, Agriculture, LULUCF, Waste). The report also set the GHG emission reduction target as 8% compared to Business As Usual (BAU) (2010 as a reference year) to be achieved by domestic financial resources, while 25% reduction can be attained with international support. Furthermore, the report summarizes the mitigation potential with incremental costs for each option, providing indicative numerical basis for implementing agency to consider future plans of actions.

This assessment work draws on the options identified by the INDC Technical Report, and elaborates means of implementation through identifying all applicable low carbon technologies that can be used to further sophisticate the current NDC options.

[4] Namely, MPI, MOF, MOIT, MARD, MOT, MOC, MOFA and MOST.

[5] MONRE and Institute of Meteorology Hydrology and Climate Change (IMHEN) organized writing retreats for the preparation of INDC with assistance from GIZ and UNDP in the period from August 2014 to October 2015 resulting in the INDC Technical Report which includes primary information on Viet Nam's INDC. [http://www.noccop.org.vn/Data/profile/Airvariable_Projects_115693Technical%20report%20INDC.pdf]

1.2 Objectives

The objectives of the development of Low Carbon Technology Catalogue and this document as its summary are to identify all applicable low carbon technologies, and through the process, to develop the capacity of LMs in charge of mitigation, improve coordination among departments, and obtain sufficient inputs for future revision of the NDC. The details of the objectives are captured as followed:

Objective 1: Enhancement of capacity through the Assessment work

There are three aspects in which the assessment work can enhance capacities.

First, technical basis and inputs obtained in the assessment helps **improve the planning capacities of LMs** to develop and implement sector-based action plans.

Second, through reaching consensus, **efficient coordination capability** is developed among relevant departments within MONRE, and also between MONRE and the Ministries concerned and key stakeholders.

Lastly, **MONRE gains facilitation skill** by teasing out Viet Nam's context while revealing and clarifying policy needs and appropriate mitigation actions to enable deployment of low carbon technologies.

Objective 2: Direct inputs to further update and revise Viet Nam's NDC

Existing mitigation options under NDC are revisited to confirm legitimacy of assumptions, scope, and barriers against Viet Nam's country-specific context and conditions. Further assessment of options beyond the current scope is conducted under the ownership of LMs, taking into account sectoral needs and priorities to be reflected to the revision of NDC.

1.3 Methodologies

The assessment work was conducted based on the following scope, institutional framework and approaches.

1.3.1 Scope for "Low Carbon Technology"

The "low carbon" attribution of technology options remains a fundamental yet common challenge faced among similar and relevant assessment works conducted thus far. <u>This assessment work defines low carbon technology as both hardware (e.g. energy saving infrastructure) and software (e.g. energy management system) that can contribute to the global climate change goal through Viet Nam's GHG emissions reduction efforts, and that encourages Viet Nam to the path of sustainable low carbon society.</u>

Considering the diversity of mitigation options in Viet Nam's NDC, low carbon technology under this assessment shall consider hardware, devices, machines and facilities not only as commonly perceived technology elements, but also as techniques, practices and management tools to fit with some of the options and sectoral attributes (e.g. Agriculture, LULUCF and Waste).

It is also worth noting that most of the technologies dealt with under this assessment are in practical use except for some that are in testing stage. Some technologies can be presented as a package, rather than stand-alone, under different concepts promoted by respective LMs, as exemplified by 'green building'.

1.3.2 Institutional Framework

In order to ensure quality analysis of technology options for each and every NDC mitigation options, this assessment work was conducted in the following institutional arrangement, involving multiple stakeholders as summarized in Figure 2. Engagement of multiple stakeholders was meant to provide balanced viewpoints over technology options while ensuring sectoral needs and priorities.

The Department of Climate Change (DCC) (the former of DMHCC)[6] of MONRE and JICA jointly supervise the project through consultations and close cooperation, and provide guidance to the Assessment Team to study and evaluate the applicable low carbon technologies in-depth. Relevant LMs, academia, private sector as well as international partners actively engage in and collaborate with the assessment work through a number of dialogues, discussions and workshops. The Technology Advisory Committee which is comprised of domestic and international experts was established within the project aiming to gain expertise from the third party.

[6] Currently the Department of Climate Change.

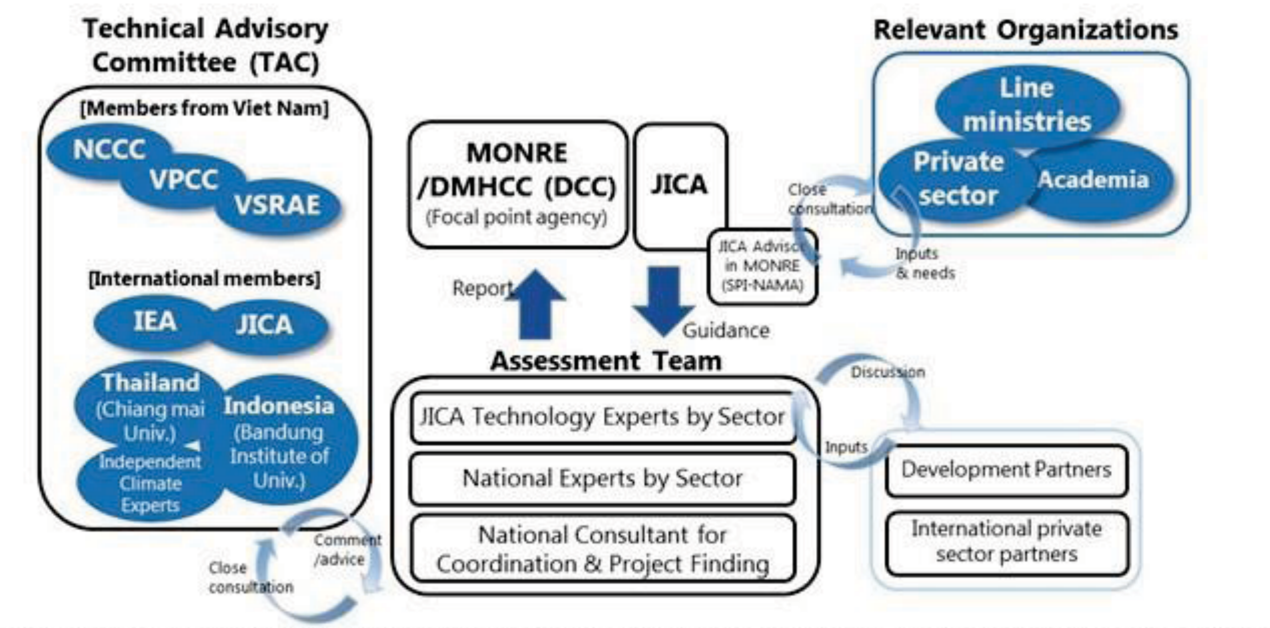
1.3.3 Approaches taken for Development of Low Carbon Technology Catalogue

The common approach adopted for all the relevant mitigation sectors to undertake the Low Carbon Technology Assessment in accordance with Viet Nam's NDC is summarized in Figure 3.

In essence, technology list was identified drawing on the 45 mitigation options of the INDC Technical Report, existing relevant technology database, and collection of mitigation needs discovered throughout stakeholder consultations by sectors. These technologies were then subjected to evaluation with universal and sector specific criteria in order to extract prioritized technologies, exploring prototype projects to seek for opportunities for future deployment.

The assessment work was conducted based on the following principles and approaches.

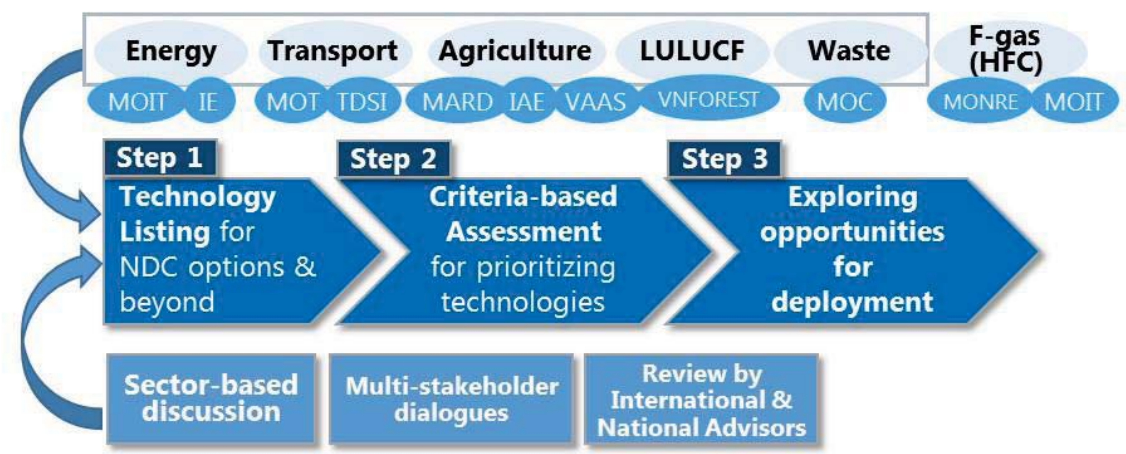
- **Bottom up Approach Align with Sectoral Needs and Priorities:** To ensure that the outcome of the assessment on low carbon technology options will not only be a mere technical information but rather provide practical information from the viewpoint of those who will be responsible for implementing the INDC mitigation options, the Assessment Team (Figure 2) has adopted a bottom-up approach to develop a technology list to fully reflect sectoral needs, priorities, strategies and actions. This entails establishing a team work with international and national experts for each sector, and a series of intensive consultations and collaboration with Ministries in charge of mitigation sector covered by this assessment, and other relevant agencies.



Note: Relevant stakeholders who were involved in the assessment work and their relationships are indicated. MONRE is the focal point of climate change in Viet Nam. The Assessment Team is consisted of experts in each sector who frequently exchange views with MONRE, relevant line ministries and other institutions. Technical Advisory committee (TAC) is an independent committee apart from the Assessment Team that provides expertise with international and domestic point of views.

Figure 2 Institutional Arrangement for Low Carbon Technology Assessement

- **No Reinventing the Wheel:** Given the wide coverage of mitigation sectors and options reviewed under this assessment, and that many mitigation options proposed under Viet Nam's NDC are inherited from the past National Communications (NC) and Biennial Update Report (BUR), it was concluded that starting the work from scratch was not considered cost-effective. Hence, the Assessment Team drew on previous and existing relevant analyses and publications, including those conducted and developed by sectoral ministries and development partners.
- **Accommodating to Future Needs for NDC Revision:** In accordance with a common understanding of country NDCs that there should be no backsliding of their mitigation target in any of the update and revision, the assessment was conducted taking ainto account that the mitigation ambition will need to be raised in future. Hence, the analysis not only covers the current 45 mitigation options but also taps on potential mitigation technologies currently not defined under the mitigation options of Viet Nam's NDC. The additional options can be used as primary technical inputs for the future updates of NDC in Viet Nam.
- **Drawing on International, Regional and National Expertise and Knowledge:** The assessment work was designed to invite similar exercises and experiences from international agencies and regions as much as possible to refine the analysis and maximize the learnings of technology options in Viet Nam. More specifically, the work invites recommendations and knowledge from the International Energy Agency (IEA) drawing on its expertise in energy sector, opportunities to learn from know-how of similar technology assessments conducted in neighboring countries including Thailand and Indonesia, engagement of experienced senior national experts, and dialogue with the private sector.



Note: The common approach for the Low Carbon Technology Assessment follows three steps: Listing technologies with a view to Viet Nam's context (**Step 1**); Evaluation of the technologies to identify priority technologies (**Step 2**); and Exploring opportunities for NDC implementation (**Step 3**). Relevant ministries and agencies in accordance with sectors in the NDC and F-gas are shown on top. In order to collect views from wide range of stakeholders, private sector, academia and research institutes were also invited to join in the assessment work process.

Figure 3 Modality of Low Carbon Technology Assessment

- **Cross-Referencing and Utilizing Relevant Technology Database:** The assessment work refers to the various existing relevant technology documents as described in Table1

1.4 Steps taken for the development of Low Carbon Technology Catalogue

1.4.1 Consultation Processes and Validation for Consensus Building

The assessment work is based fully on stakeholder consultations, and in this regard, consensus building is one of the important steps for the development of the Low Carbon Technology list. It is crucial to reflect existing strategies and action plans into identification of appropriate technologies.

Priorities and additional mitigation options were extracted through a series of consultations with relevant departments in charge of climate change action in each sector (e.g. General Directorate of Energy for energy sector) as well as MONRE which is the focal point of climate change issues in Viet Nam, and were reflected into the technology catalogue accordingly during the consensus building. Table 2 indicates LMs and departments that were mainly involved in this consensus building.

Table 1 Technology documents/database referenced in the Assessment

Existing Technology Documents/Database	Year of Publication
Environmental Technology Database（UNIDO ITPO）	2016
Low Carbon Low Emission Clean Energy Technology Transfer（UNIDO ITPO）	2016
UNEP Technology Assessment in Vietnam	2012
L2-Tech list 2016 summer edition (MOEJ)	2016
Business alliance for smart energy worldwide (JASE-World)	2016
Technologies and products in the environmental and energy sector (Kansai Economic Federation)	2016
Fluorocarbons recovery and destruction law (MOEJ and METI)	2016

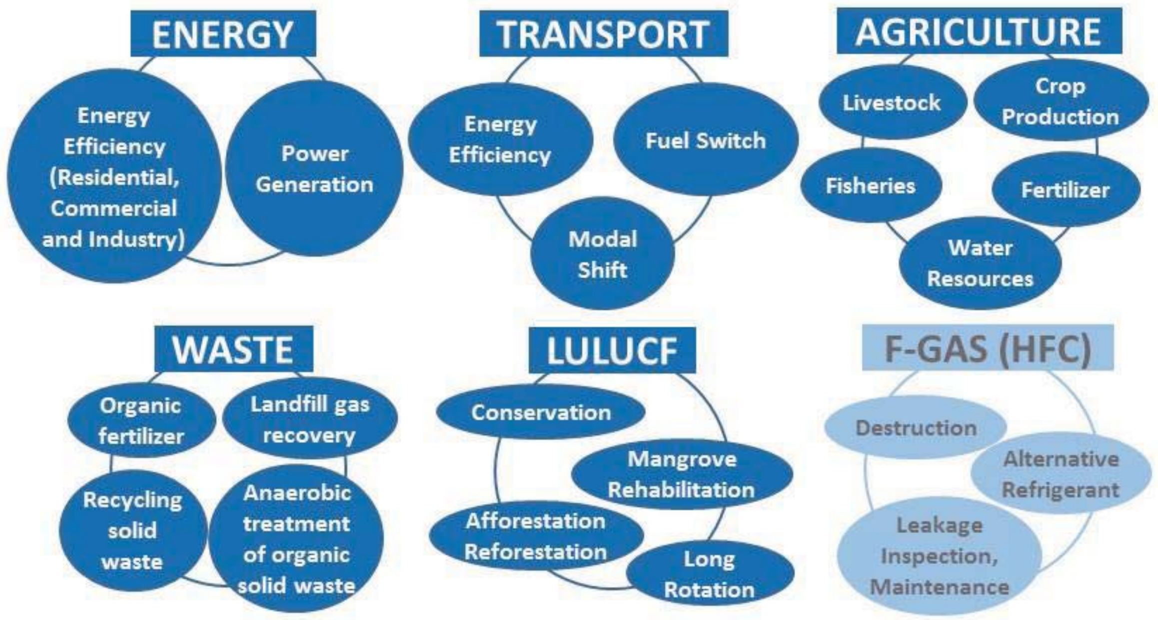
Table 2 Line Ministries and Departments Involved in the Development of Technology Lists

Sector	Stakeholders
Energy	✓ **Ministry of Industry and Trade (MOIT)** General Directorate of Energy (GDE, Renewable Energy) ✓ **Institute of Energy (IoE)**
Transport	✓ **Ministry of Transport (MOT)** Department of Environment (DOE) in collaboration with sub-sector departments ✓ **Transport Development Strategy Institute (TDSI)**
Agriculture	✓ **Ministry of Agriculture and Rural Development (MARD)** Department of Livestock husbandry production Department of Water Resources Department of Crop Production ✓ **Institute for Agricultural Environment (IAE)** ✓ **Viet Nam Academy of Agricultural Science (VAAS)**
LULUCF	✓ **Ministry of Agriculture and Rural Development (MARD)** Department of Science, Technology and Environment ✓ **Vietnamese Academy of Forest Sciences (VAFS)** Department of Training and International Cooperation ✓ **Viet Nam Forest Administration (VNFOREST)**
Waste	✓ **Ministry of Construction (MOC)** Department of Science, Technology and Environment Administration of Technical Infrastructure
F-gas (Hydrofluorocarbon: HFC)	✓ **MONRE** National Ozone Unit (NOU) ✓ **MOIT** Industrial Safety techniques and Environment Agency (ISEA)

Furthermore, the first meeting of Technical Advisory Committee (TAC) (Figure 2)[7] was held in Tokyo in January 2017 for the purpose of acquiring sectoral expert's inputs on the list of technologies. Several issues such as sector specific circumstances in deploying the technologies and the need for early development of legislations to set the right incentives for stakeholders were suggested in the committee. Further reviews to the list of technologies are to be obtained from the International Technical Advisory Committee[8] as well as from other development partners.

[7] Members of the domestic TAC: Dr. Hirokazu Taniguchi (Energy Conservation Center, Japan), Mr. Takahiko Onozuka (Japanese Business Alliance for Smart Energy Worldwide), Mr. Nobuyoshi Fujiwara (Japan International Research Center for Agricultural Science: JIRCAS), Prof. Atsushi Fukuda (Nihon Univ.), Dr. Tamotsu Sato（Forestry and Forest Products Research Institute: FFPRI), Dr. Kosuke Kawai (National Institute for Environmental Studies: NIES), Mr. Niro Tohi (PREC Institute. Inc.) (also see the organization chart in Figure 2)

[8] Member of the international TAC: Mr. Tran Thuc (IMHEN), Mr. Jean-Francois Gagné (IEA), Dr. Gumilang Retno (Dew Bandung Institute of Technology), Dr. Wongkot Wongsapai (Chiang Mai Univ.), Dr. Masato Kawanishi (JICA) (also see the organization chart in Figure 2)



Note: Technologies in Low Carbon Technology Catalogue is classified based on sub-sector categories in each sector. F-gas sector was originally not included in the INDC therefore three sub-sectors are newly identified in this assessment work. Additional seven sub-sectors (Road, Railway, Inland water way and Maritime, Aviation, Biofuel, Natural Gases and Electricity) are defined in the Transport sector in addition to three sub-sectors (not shown).

Figure 4 Advanced Classification of NDC Options for Each Sector

1.4.2 Preparation of Low Carbon Technology Catalogue for NDC

As mentioned above, one of the key features of the technology catalogue is to incorporate current Viet Nam's context bearing in mind of its implementation. It is intended that the catalogue will also be used as reference when revising NDC. The Assessment Team took careful approaches when developing the list of technologies in this regard.

Figure 4 summarizes the classification of current mitigation options of Viet Nam's NDC for respective targeted mitigation sectors. Stakeholder consultations and dialogues with respective agencies revealed that some mitigation sectors were already in the internal process of reviewing mitigation options for modification (Agriculture and LULUCF), and of restructuring its sub-sectoral categories to better fit the sectoral intentions (Transport). The Assessment Team adopted those recent developments and suggestions to be reflected into the assessment work.

In addition to the original 4 sectors (Energy/Transport, Agriculture, LULUCF, Waste), F-gas sector was also included reflecting the suggestion from MONRE, and technology options to reduce F-gas (HFC) were also listed. Energy sector is divided into two categories (i.e. "Energy (Industrial, residential and commercial energy efficiency) and industrial process", and "Energy (Power generation)") in this assessment due to considerably large difference in reduction scale resulting from the implementation of technologies (i.e. residential energy saving and power generation) (also see Figure 4).

In-depth consultations with key stakeholders revealed a diverse perception on how the current mitigation options of Viet Nam's NDC are structured. Taking the Transport sector, for instance, MOT perceives that modal shift (passenger and freight), energy efficiency and fuel switching as the three main pillars of concern, rather than options identified in the INDC (i.e. E7. Substitution of ethanol for gasoline in transport; E8. Passenger transport mode shift from private to public; E9. Freight transport switch from road). In this regard, the technology catalogue of the transport sector provides an expanded view from their INDC with the three pillars followed by subsectors and selected option categories including options E7-E9.

Low carbon technology list for Viet Nam's NDC was elaborated based on the classification indicated in Figure 4. Volume of GHG emissions reduction potential was estimated by referring to standard values or data provided by past/existing projects.

On the elaborated list of technologies, LMs and experts in each sector indicated in Figure 3 held a review session aiming to obtain consensus among them. Sector-based stakeholder dialogues were held in April-June 2017 inviting research institutes, the private sector and academia, and their expertise was also included into the list.

Based on the reviewed list, Low Carbon Technology Catalogue was prepared to be utilized as internal reference for government officials.

1.5 Result of the Assessment Work - Overview of Low Carbon Technology Options for Viet Nam's NDC

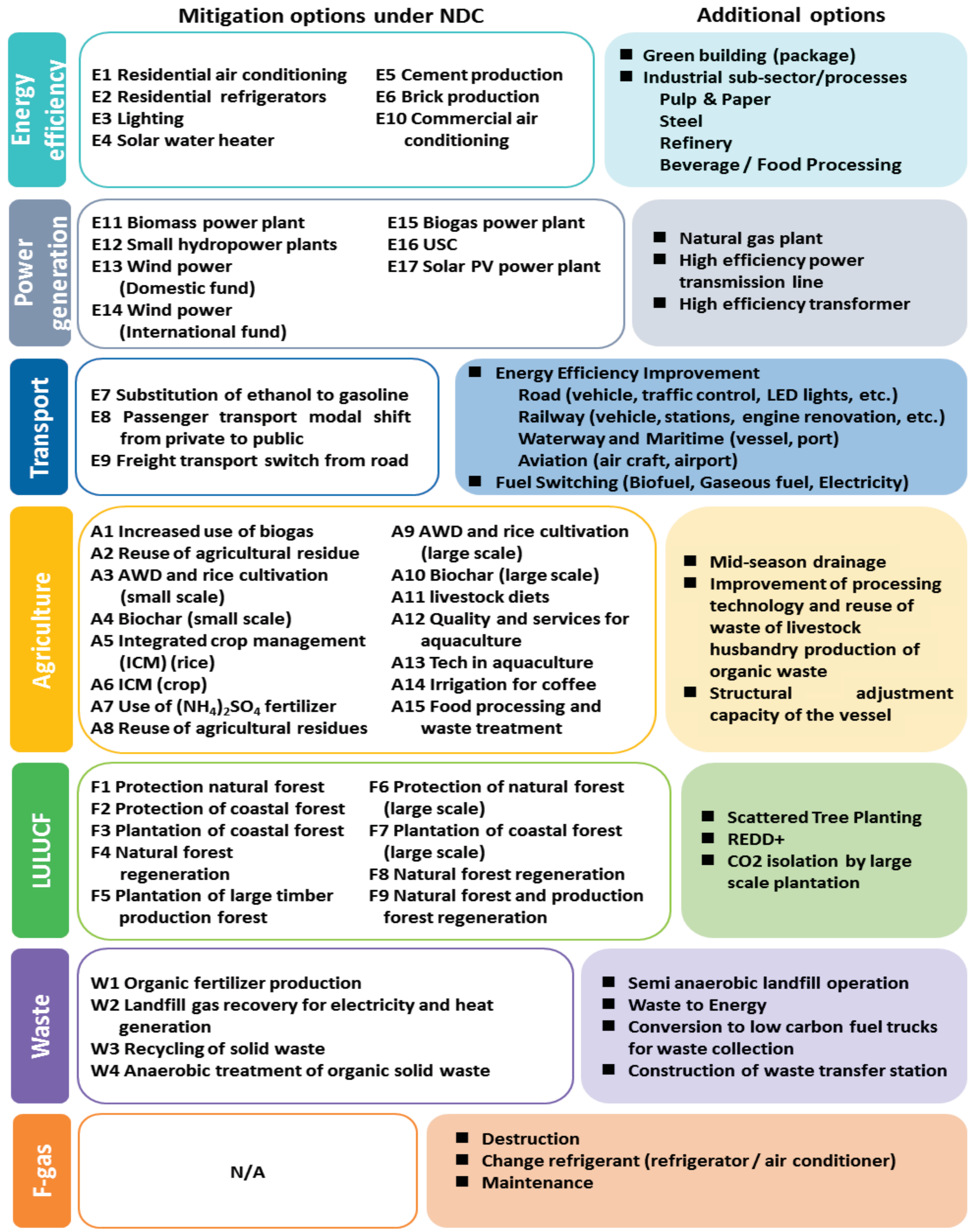
For nine items shown in Table 3, information on low carbon technologies for NDC implementation were collected. Summarized information on prospective technology in each mitigation option under NDC are highlighted and presented in Chapter 2: 'Technology Options by Sector'.

Figure 5 illustrates the overview of the additional options that were extracted in this assessment work (on right) and the mitigation options that were presented in the INDC Technical report (i.e. 45 mitigation options, namely E1-17, A1-15, F1-9, and W1-4).

Low carbon technologies for each of the extracted additional options are listed at the beginning of each sector in Chapter 2.
Detailed information on low carbon technologies are separately summarized in the Low Carbon Technology Catalogue.

Table 3 Contents in Technology list

Item	Contents
Title of Technology	✓ Identified technologies for respective NDC option. ✓ Possible technology elements identified based on subsector, INDC option category and the technology suggested by the Assessment Team.
Visual Aid	✓ Any image that explains the technology.
Summary of Technology	✓ Background and common features of the technology.
Technical Advantages	✓ Technology superiority, advantages, and assumptions.
Mitigation Potential	✓ Emission reduction volume is estimated or drawn from existing projects and analyses. ✓ Various attributions to the identified technology such as scale (industrial level, residential level), geographical features, sub-sectors (ex. animal husbandry, agricultural waste) are considered.
(Initial) Cost	✓ Estimated (initial) cost based on existing projects, initial cost per unit (e.g. USD/kw), operation cost (e.g. USD/kWh, USD/ton/day) ✓ Various aspects, such as purpose of use (industrial level, residential level), different scale, geographical features and so forth, are considered. Some conditions are noted.
Viet Nam's Context	✓ Relevant information on the technology (e.g. consumer trend, recycling rates and field condition) to be noted when introducing the technology to Viet Nam.
Existing Policy & Measures	✓ If any, relevant policy documents or conditions related to the technology to be noted.
Current State of Market and Production	✓ Market share, annual production and current development status.



Note: Number with alphabet (i.e. E1-17, A1-15 F1--9 and W1-4) and following mitigation options are corresponding to the INDC technical report as described in section 1.8. F-gas sector is set up as mitigation sector in this assessment due to high potential emission reductions. Additional mitigation options are extracted through a series of interviews with relevant stakeholders in this assessment.

Figure 5 Mitigation Options under NDC and Additional Options Identified in This Assessment

CHAPTER 2

Technology Options by Sector

Energy (Industrial, residential and commercial energy efficiency) and Industrial process

Energy (Power generation)

Transport

Agriculture

LULUCF

Waste

F-gas (HFC)

2 Technology Options by Sector

This assessment work covers the following seven mitigation sectors/sub-sectors:

(1) Energy (industrial, residential and commercial energy efficiency) and industrial process;
(2) Energy (power generation);
(3) Transport;
(4) Agriculture;
(5) LULUCF;
(6) Waste; and
(7) F-gas (HFC).

In line with the seven sectors, the Assessment Team developed the Low Carbon Technology Catalogue which includes information on low carbon technologies for all 45 mitigation options and also for additional mitigation options extracted through this assessment work. Nearly 150 low carbon technologies were identified and this document serves as its summary. Efficient communication through consultations, dialogues and workshops was a key factor in understanding Viet Nam's context, barriers and co-benefits. It also helped the Team to realize that each sector has different strategies, policies and different ideas of mitigation options in the NDC. Given these valuable insights, evaluation to prioritize technologies will be concluded and its summary published in October 2017.

While the prioritization is in progress, exchanging views in relevant stakeholder dialogues and workshops highlighted some technologies that are potentially most relevant to Viet Nam. The Assessment Team brought attention to them as prospective options that are worth focusing at this point. In this chapter, information on these technologies for each of the mitigation options are summarized.

For each mitigation sector, information on the following sub-sections are provided:

1. Overview of the NDC in the sector, including sector's priorities ,co-benefit and development effect, challenges;
2. List of technologies identified under this assessment (table); and
3. Summary of information on highlighted technologies in line with NDC mitigation options.

Edited from Energy Exchange
[https://www.eex.gov.au/industry-sectors/manufacturing/chemical-manufacturing/opportunities]

Energy

(Industrial, residential and commercial energy efficiency) and Industrial process

Energy

(Industrial, residential and commercial energy efficiency) and Industrial process

Overview of the NDC

Domestic efforts for demand side energy efficiency have been primarily guided by the National Target Program on Energy Efficiency (2006)[9] as well as the Law on Economical and Efficient Use of Energy (2010)[10], and it is expected to be enhanced by technological innovation and advanced energy management approaches in post-2020. Mitigation actions cited in the INDC include consideration of incremental cost for equipment purchases in the residential subsector. Based on the Law on Economical and Efficient Use of Energy, an energy efficiency labeling system was introduced in 2013. As measures to promote energy efficient equipment have been compiled, Viet Nam has made a gradual shift from a voluntary labelling system to a mandatory action.

Energy sector's priorities

Energy efficiency is one of the priority subsectors under mitigation policies through 2030, as described in the INDC. The MOIT has been developing energy benchmarks and setting MRV framework for major industry sub-sectors, and promoting ESCOs (Energy Service Company) to facilitate Energy Efficiency.

Co-benefits and development effect

- Energy efficiency can contribute to energy security and stable energy supply.
- Reduction in fuel consumption (including at fire power plants) can reduce air pollution.
- Modernized consumer equipment and buildings can improve citizens' quality of life.

Challenges

- Policies to disseminate energy efficient equipment in rural regions will be required.
- Low electricity price is an obstacle to introduce energy efficient equipment.
- It is difficult for ESCOs to track energy data.
- Labeling system has been established but labels are not updated regularly as required.
- Introduction of high-efficiency equipment for consumers tends to rely on foreign products rather than domestic ones.

[9] Decision No.1427/QD-TTg revised on 02 October 2012
[10] Law No. 50/2010/QH12

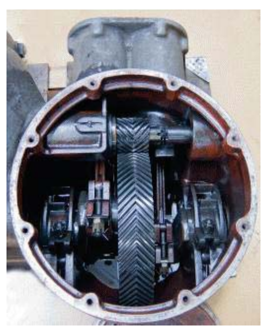
Table 4 Mitigation options in Energy (Industrial, residential and commercial energy efficiency) and Industrial process

Mitigation Options under NDC		Low Carbon Technology Options[11]
E1	High efficiency residential air conditioning	■ **Inverter air conditioner**
E2	High efficiency residential refrigerators	■ **Inverter compressed type (Insulator/ Insulation type, Twin cooling)**
E3	High efficiency residential lighting	■ **Light-Emitting Diode (LED)** ■ **Compact Fluorescent Lamp (CFL) (Bulb, F-tube)**
E4	Solar water heaters	■ **Hot water tank, Heat collection unit**
E5	Cement-making technology improvements	■ Waste heat recovery ■ **Dry kiln with multistage pre-heaters and pre-calcination/cement** ■ Vertical roller mill ■ Kiln shell heat loss reduction ■ Variable Frequency Drive (VFD) installation ■ Combustion optimization
E6	Brick-making technology improvements	■ **Traditional brick kiln replaced with vertical shaft brick kiln** ■ High efficiency vertical shaft brick kiln
E10	High efficiency commercial air conditioning	■ **Building multi air conditioner**

Additional Options		Low Carbon Technology Options
	Green building	■ Building multi air conditioner ■ LED ■ Pair glass ■ High efficiency insulator
	Pulp and paper	■ Efficient debarking ■ Batch digester modification to have indirect heating ■ Low pressure drop center cleaner ■ Falling film evaporator ■ Condebelt drying ■ Heat recovery in thermos mechanical pulping ■ Waste heat recovery from paper drying ■ Increased use of recycled pulp ■ RTS (lower Retention time, higher Temperature, higher refiner Speed) pulping ■ Black liquor gasification ■ Extended nip press
	Steel	■ Coke dry quenching ■ Waste Heat Recovery (WHR)-based power generation

[11] Information on highlighted technologies are summarized in following pages after the table. Information on Low Carbon Technology Options for Additional Options are summarized in the Low Carbon Technology Catalogue.

Additional Options	Low Carbon Technology Options
	■ Heat recuperation from hot blast stove ■ Sintering plant heat recovery ■ Basic Oxygen Furnace (BOF) gas sensible heat recovery ■ Natural gas injection in Blast furnace ■ Pulverized Coal Injection (PCI) in blast furnace ■ Continuous casting ■ Hot charging in rolling mill ■ Installation of the top pressure recovery turbine ■ Variable speed drives in steel making
Refinery	■ Online furnace cleaning ■ Optimization of power consumption in utility boiler drives and auxiliaries ■ Steam savings by trap management ■ Condensate recovery ■ Flare gas recovery and utilization for process heating requirements ■ Installation of low excess air burner ■ Oil recovery from crude tank bottom sludge by chemical treatment ■ Heat recovery from work kettle ■ Pasteurizer heat pump system
Beverage	■ Cascade cooling system ■ CO_2 recovery ■ Heat recovery from bottle washer ■ Biogas recovery boiler
Food processing	■ Combined Heat and Power (CHP) (10 MW bagasse)[12]
Fertilizer	■ Calcium silicate insulation of high pressure stream pipe line ■ Heat recovery from medium pressure decomposer vapors in urea plant by installation of Pre-concentrator ■ Isothermal CO conversion reactor ■ High conversion rate synthesis reactor ■ Installation of variable speed drives for cooling tower fans in fertilizer ■ Stream trap management



Energy Exchange [https://www.eex.gov.au/technologies/motors]

[12] Nghe An Sugar Company (NASU) conducted by Joint Crediting Mechanism project is a good example (Joint Crediting Mechanism project)

E1 High Efficiency Residential Air Conditioning

Baseline Technology	Suggested Low Carbon Technology(ies)
Air Conditioner without Inverter	■ **Inverter Air Conditioner**
Photo Image	
Summary of Technology	An inverter is an energy saving technology that eliminates wasted operation in Air Conditioner (AC) by efficiently controlling motor speed. In inverter's type AC, temperature is adjusted by changing motor speed without turning the motor ON and OFF.
Technical Advantages	■ Compared with AC without inverter, power consumption is reduced in 30%. ■ Low noise during operation[13,14].
Mitigation Potential	■ 0.27 tCO_2eq/year/unit[15]
(Initial) Cost	■ 150 USD/unit added to AC without inverter[16]
Viet Nam's Context	■ Increasing number of households is using AC. And the market share of inverter AC is expanding.
Existing Policy & Measures	**Legal Framework** ■ Law No.50/2010/QH12 (2010) ■ Decree No.21/2011/NĐ-CP (2011) **Energy Efficiency Labeling System** ■ Energy Efficiency Labeling for AC became compulsory on July 2013[17]. ■ Testing and rating method for AC were revised in 2015, and is implemented from Jan 2017 **National Technical Standards** ■ TCVN 7830:2015 ■ TCVN 10273-1:2013 (ISO 16358-1:2013) ■ TVCN 6576:2013
Current State of Market and Production	■ Market share for Inverter AC is 47% (unit sales) or 56% (sales prices)[18], 9.4 ACs per 100 households in 2010[19] ■ Annual production is 400 thousand sets (may include commercial equipment)[20]. Local companies import parts to assemble ACs. Foreign electric companies have local production sites.

[13] Mitsubishi Corporation. (2012). Feasibility Study Report on Bilateral Offset Credit Mechanism project on expanding the use of High-efficiency air-conditioners in Socialist Republic of Vietnam.
[14] Daikin. Inverter [http://www.daikin.co.jp/air/tech/inverter/summary/index.html] (Japanese)
[15] WB. (2016). Exploring a Low-Carbon Development Path for Vietnam
[16] ADB. (2013). GHG Emissions, Scenarios, and Mitigation Potentials in the Energy and Transport Sectors of Viet Nam
[17] Decision No. 03/2013/QĐ-TTg dated January 14, 2013
[18] Personal communication (interview to manufacturer)
[19] General Statistics Office of Viet Nam. (2010). Result of the Veitnam Household Living Standard Survey 2010.
[20] Personal communication (interview to manufacturer)

E2 High Efficiency Residential Refrigerators

Baseline Technology	Suggested Low Carbon Technology(ies)
Refrigerator without Inverter	■ **Compressed Inverter Type (Insulator/Insulation Type, Twin Cooling)**
Photo Image	
Summary of Technology	Inverter technology refrigerators use variable motor speed drive, efficient inverter-fed motor, and linear and scroll compressors. The inverter techonology is generally used for refrigerators with capacities ranging between 190 liters to 700 liters.
Technical Advantages	■ Around 40% reduction in power consumption compared with refrigerator made in 2015 and refrigerator of 2006 (volume: 401-450L).[21] ■ Operation noise is also reduced.
Mitigation Potential	■ 0.07 tCO_2eq/year/unit[22]
(Initial) Cost	■ 50 USD/unit added to refrigerator without inverter[23]
Viet Nam's Context	■ Increasing number of households are using refrigerators. Electricity consumption of refrigerators accounts for a large percentage of the total household electricity consumption.
Existing Policy & Measures	**Legal Framework** ■ Law No.50/2010/QH12 ■ Decree No.21/2011/NĐ-CP **Energy Efficiency Labeling System** ■ Energy efficiency labeling for household refrigerators became compulsory on Jan 2014. ■ Technical standards on energy performance testing were revised in 2016. **National Technical Standards** ■ TCVN 7828:2016 ■ TCVN 7829:2016
Current State of Market and Production	■ The market share for refrigerators with inverter is 44% (unit sales) or 64% (sale prices)[24] and 40 fridges per 100 household in 2010[25] ■ Annual production is 1.5 million unit (incl. freezer)[26]

[21] Association for Electric Home Appliances. Comparing Energy Saving Performance. [http://www.shouene-kaden2.net/try/sim_eco_perf/freezer.html](Japanese)
[22] WB. (2016). Exploring a Low-Carbon Development Path for Vietnam.
[23] ADB. (2013.) GHG Emissions, Scenarios, and Mitigation Potentials in the Energy and Transport Sectors of Viet Nam
[24] Personal communication (interview to manufacturer)
[25] General Statistics Office of Viet Nam. (2010). Result of the Veitnam Household Living Standard Survey 2010
[26] Personal communication (interview to manufacturer)

E3 High Efficiency Residential Lighting

Baseline Technology	Suggested Low Carbon Technology(ies)
Incandescent Lamp	■ **Light-Emitting Diode (LED)** ■ **Compact Fluorescent Lamp (CFL)**
Photo Image[27]	 LED  CFL
Summary of Technology	**LED:** Electricity is passed through a semiconductor, which produces photons. LED can produce more useable white light per unit of energy than metal halide, sodium vapor, and fluorescent and halogen light sources. **CFL:** Fluorescent lamps contain mercury which causes the tube to produce light mostly in the UV region of the spectrum.
Technical Advantages	■ 80% reduction in electricity consumption by CFL and 90% reduction by LED compared with incandescent lamp. ■ Their small size, durability, long operating lifetime, wavelength specificity, relatively cool emitting surfaces, and linear photon output with electrical input make these solid-state light sources ideal for use places in such as plant lighting designs. [28]
Mitigation Potential	■ 0.04 tCO_2eq/year/unit (Incandescent to LED) ■ 0.02 tCO_2eq/year/unit (Incandescent to CFL)[29, 30]
(Initial) Cost	■ LED: 5 USD/unit, CFL: 2 USD/unit[31, 32]
Viet Nam's Context	■ Electricity consumption of lighting accounts for larger percentage of the total household electricity consumption.
Existing Policy & Measures	**Legal Framework** ■ Law No.50/2010/QH12 **National Technical Standards** ■ TCVN 8249:2013 ■ TCVN 7451-1:2005 ■ TCVN 7451-2:2005 ■ TCVN 7896:2015 ■ TCVN 8248:2013 ■ TCVN 7897:2013
Current State of Market and Production	■ Now producing both LED and CFL, partly through international support such as GEF project by UNDP. ■ Quality control is still a major issue.

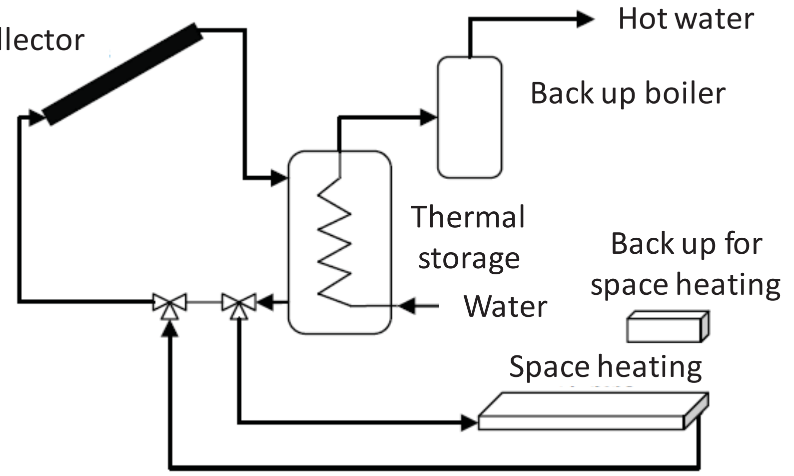
[27] New South Wales and the Office of Environment and Heritage. (2014). Energy Efficient Technology Report. [http://www.environment.nsw.gov.au/resources/business/140017-energy-efficient-lighting-tech-rpt.pdf]
[28] Massa et al. (2008). Plant Productivity in Response to LED Lighting, HORTSCIENCE 43(7)
[29] WB. (2016). Exploring a Low-Carbon Development Path for Vietnam
[30] WB. (2016). Exploring a Low-Carbon Development Path for Vietnam
[31] WB. (2016). Exploring a Low-Carbon Development Path for Vietnam
[32] Market price for LED is estimated referring market price information of "LED inside, a Business Division of Trend Force Corp" [http://www.ledinside.com/]

E4 Solar Water Heaters

Baseline Technology	Suggested Low Carbon Technology(ies)
Electric Water Heater	■ **Hot Water Tank, Heat Collection Unit**

Photo Image[33]

[forced-circulation solar system]



Summary of Technology	Solar water heater collects solar thermal energy by a solar energy absorber to warm water or air for hot water supply or air-conditioning. There are two types of systems using solar energy: one is forced-circulation solar system and the other is natural-circulation solar water heater. This solar system consists of a solar energy collector and a heat storage tank. Backup boiler may be required.
Technical Advantages	■ Solar heater reduces use of gas or power consumption.
Mitigation Potential	■ 0.46 tCO_2eq/year/unit[34]
(Initial) Cost	■ 7 million VND/unit[35]
Viet Nam's Context	■ In general, residential solar water heaters are installed on the rooftop. ■ Solar water heaters can curb the demand of electricity consumed by electric water heaters that are increasingly used by households.
Existing Policy & Measures	**Legal Framework** ■ EVN Subsidized program (1M VND/unit) **National Technical Standards** ■ TCVN 8251:2009 ■ TCVN 7898:2009
Current State of Market and Production	■ Subsidy system in place; fairly widespread use throughout the country especially in center and south. ■ Imported systems on the market, but many Vietnamese producers also use high-quality equipment at household and industrial sector & tourist resorts (e.g. from SolarBK).

[33] NEDO. (2014). Report on renewable energy technologies. (Japanese)
[34] WB. (2016). Exploring a Low-Carbon Development Path for Vietnam
[35] ADB. (2013). GHG Emissions, Scenarios, and Mitigation Potentials in the Energy and Transport Sectors of Viet Nam

E5 Cement-making Technology Improvements

Baseline Technology	Suggested Low Carbon Technology(ies)
Rotary Kilns	■ **Dry Kiln with Multistage Pre-Heaters and Pre-Calcination/Cement**

Photo Image[36]

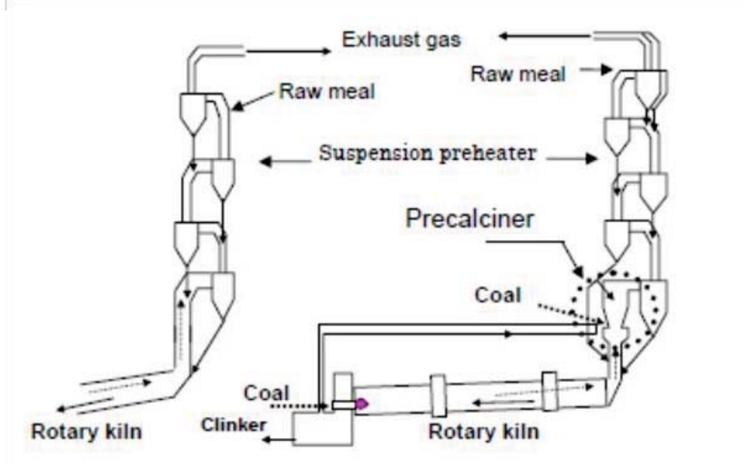
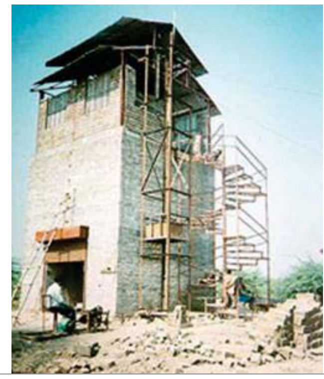


Fig.1 Suspension Preheater   Fig.2 New Suspension Preheater

Summary of Technology	New Suspension Preheater (NSP) kiln is a dry kiln with multistage pre-heaters and a separate pre-calciner installed in suspension preheater to avoid damage inside the refractory from full combustion, which reduces specific energy consumption per unit clinker by 50-60%.
Technical Advantages	■ 0.2 GJ/ton of energy saving can be expected (0.2 GJ/ton of cement). ■ Reduces heat energy consumption in rotary kiln for clinker production. ■ Enhances production level, and mitigate damage to the refractory materials in the kiln. ■ NOx emission levels are also reduced.
Mitigation Potential	■ 0.01 tCO_2eq/t-clinker (Cumulative: 2.90 $MtCO_2eq$ in 2010-2030) [37]
(Initial) Cost	■ 65 USD/ton-clinker[38]
Viet Nam's Context	■ Cement production situation (currently overcapacity) and fuel price level affect the cost effectiveness of this technology.
Existing Policy & Measures	**Legal Framework** ■ Law No.50/2010/QH12 ■ GHG emission reduction action plan for cement sector (MOC, 2016)
Current State of Market and Production	■ Annual production of cement for 2013 was 57,516 kt. ■ There are around 34 big cement factories in Viet Nam. ■ Demand of cement has fallen well below production capacity as interest rate increased. ■ Cement export volume of Viet Nam significantly declined in 2015 due to price competition in cement over-supply from countries such as China, Thailand, Indonesia, etc.

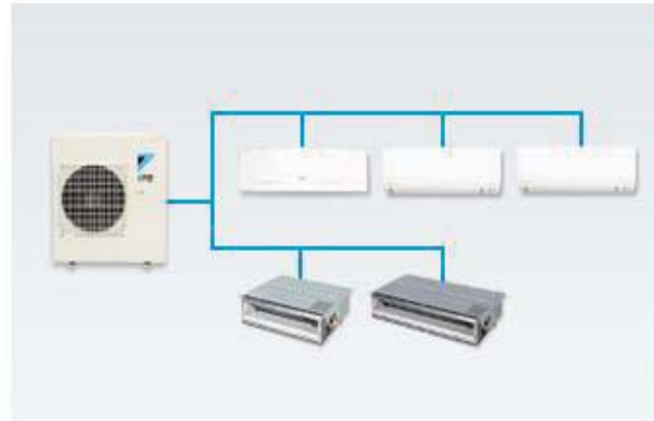
[36] Asia-Pacific Partnership on Clean Development & Climate. (2008). Energy Efficiency and Resource Saving Technologies in Cement Industry.
[37] WB. (2016). Exploring a Low-Carbon Development Path for Vietnam
[38] WB. (2016). Exploring a Low-Carbon Development Path for Vietnam, Capital expenditure only

E6 Brick-making Technology Improvements

Baseline Technology	Suggested Low Carbon Technology(ies)
Traditional brick kilns	■ **Vertical Shaft Brick Kiln (VSBK)**
Photo Image[39]	
Summary of Technology	The VSBK technology is one of the best available options for small brick manufacturers. VSBK essentially comprises one or more rectangular vertical shafts within a kiln structure.
Technical Advantages	■ Can be operated perennially as it is protected from the vagaries of weather by the kiln's roof. ■ Less fuel consumption can be expected (0.065 kg coal/unit of brick). ■ SPM (Suspended Particulate Matter) emission is minimized.
Mitigation Potential	■ 0.04 tCO_2eq/t-brick (2.4 $MtCO_2eq$/year by 2030 (for high efficiency VSBK)[40, 41])
(Initial) Cost	■ 3,088 USD/millions of brick[42]
Viet Nam's Context	■ Brick production situation and fuel price level affect the cost effectiveness of this technology.
Existing Policy & Measures	**Legal Framework** ■ Law No.50/2010/QH12
Current State of Market and Production	■ Annual production was 2,158 million bricks in 2010; 1,961 million in 2009; 2,117 million in 2008; 1,534 million in 2007; and 1,518 million in 2006. ■ There are approximately 4500 traditional rice husk fueled kilns for clay burning producing bricks, tiles and pottery. ■ The traditional brick industry is a low-investment, seasonal activity unfolding under difficult working conditions.

39 TERI. Vertical shaft brick kiln technology. [http://www.teriin.org/technology/brick-kiln-technology]
40 UNDP-MPI. (2012). Background Analysis of Marginal Abatement Costs for the Green Growth Strategy. (Unpublished)
41 ADB. (2013). GHG Emissions, Scenarios, and Mitigation Potentials in the Energy and Transport Sectors of Viet Nam. (Unpublished)
42 UNDP-MPI. (2012). Background Analysis of Marginal Abatement Costs for the Green Growth Strategy. (Unpublished)

E10 High Efficiency Commercial Air Conditioning

Baseline Technology	Suggested Low Carbon Technology(ies)
Conventional AC	■ **Building Multi Air Conditioner**
Photo Image[43]	
Summary of Technology	Building multi air conditioner is composed of a single outdoor unit and multi-indoor units. This enables the operation to be controlled by individual rooms/compartments/sections, leading to improved energy efficiency.
Technical Advantages	■ 40% reduction in power consumption compared with conventional/old central AC system.
Mitigation Potential	N/A
(Initial) Cost	■ 0.38 USD/m^2 of floor area
Viet Nam's Context	■ Operation of building multi air conditioner system is less complicated than central type AC that requires optimization of equipment, system, operation and engineering.
Existing Policy & Measures	**Energy Efficiency Labeling System** ■ N/A (Current mandatory EE standard and labeling for AC do not cover building multi air conditioner) **National Technical Standards** ■ TCVN 7830: 2015 ■ TCVN 6576: 2013 ■ TCVN 10273-1:2013
Current State of Market and Production	N/A

43 Daikin. [http://www.daikin.com/products/ac/lineup/split_multi_split/index.html]

Energy

(Power generation)

Energy (Power generation)

Overview of the NDC

The Power Development Master Plan No. VII (PDP7, revised in March 2016) is the principle strategy for the energy sector. According to the PDP7, as well as the National Energy Development Strategy, up to 2020 with 2050 Vision (2007), promoting low carbon efforts and stable energy supply have been prioritized to meet growth of electricity demand in accordance with economic development. Improvement and expansion of thermal power generation and power transmission and distribution networks are being planned. Optimization between economic performance and global warming measures must be taken into account.

Energy sector's priorities

The power supply capacity should be increased according to power demand by economic growth. In PDP7, the government shows high expectation for renewable energy and is planning extensive introduction. On the other hand, as renewable energy alone could not satisfy the power demand, coal power plants are planned in parallel due to its large capacity and low cost.

The most prospective renewable energy sources are considered to be Solar PV which can contribute to cost reduction for installation, and Biomass power which matches well with agriculture. Coal power plant is expected to be shifted to ultra-super critical and/or super critical plants.

Co-benefits and development effect

- Power supply can contribute to stable power supply and sustainable social and economic activities.
- Reduction in fuel consumption and introduction of advanced technologies can reduce air pollution.
- Energy supply for rural and remote areas may be improved by introducing renewable energy.

Challenges

- Promotion policies and/or incentives are necessary for high cost power plant because of low electricity prices.
- Policies for promoting renewable energy and fuel efficiency (ex. FIT and renewable portfolio standard) will be required.
- Life cycle cost, including environmental cost, should be anticipated.
- Capabilities of engineers in charge of EPC (Engineering, Procurement and Construction) are insufficient.
- To meet the expected demand increase, countermeasures not only from the power supply side but also from the demand side (energy saving, demand response, etc.) will need to be implemented in parallel.

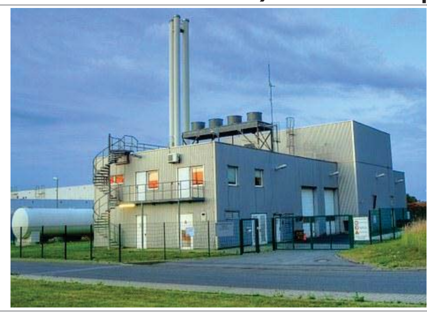
Table 5 Mitigation options in Energy (power generation) sector

	Mitigation Options under NDC	Low Carbon Technology Options[44]
E11	Biomass power plants	■ **Direct burning of wood / agricultural crops (bagasse, chaff, rice, straw) / agricultural residue (rice husk, Jatropha)** ■ **Cogeneration equipment, combustion boiler (stoker firing, fluidized bed combustion) for small capacity (<2MW)**
E12	Small hydropower plants	■ **Small Hydropower Plant (Reservoirs, Water Transfer Channel, Run-of River Type for Micro Hydropower Plant)**
E13	Wind power plants by domestic funding	■ **On-shore** ■ **Off-shore (Bottom-mounted, Floating)**
E14	Wind power plants by international support	■ **On shore** ■ **Off shore (Bottom-mounted, Floating)**
E15	Biogas power plants	■ **Sewage** ■ **Agriculture**
E16	**Ultra-supercritical coal power plants**	■ Ultra-super critical ■ Super critical
E17	Solar PV power plants	■ **Rooftop** ■ **Ground-mounted** solar with types of cell (silicon, amorphous, single-crystal) ■ **Floating on water reservoir** (Hydro power Dam) ■ **Concentrated Solar Power Plant**

	Additional Options	Low Carbon Technology Options
	Natural gas plant	■ Combined cycle gas turbine (CCGT)
	High efficient power transmission line	■ High-resistant conductor type, phase separate with large cross section ■ Upgrade gradually to smart grid ■ Low-loss conductor (Low electrical power loss aluminum)
	High efficiency transformer	■ Amorphous (non-crystalline) alloy

[44] Information on highlighted technologies are summarized in following pages after the table. Information on Low Carbon Technology Options for Additional Options are summarized in the Low Carbon Technology Catalogue.

E11 Biomass Power Plants

Baseline Technology	Suggested Low Carbon Technology(ies)
Coal-fired Thermal Power Plant	■ **Direct Burning of Wood/Agricultural Crops(Bagasse, Chaff, Rice, Straw)/Agricultural Residue(Rice Husk, Jatropha)** ■ **Cogeneration Equipment, Combustion Boiler (Stoker Firing, Fluidized Bed Combustion) for small capacity (<2MW)**
Photo Image	
Summary of Technology	Bioenergy is a form of renewable energy derived from biomass to generate electricity and heat. Biomass is any organic matter of recently living plant or animal origin, available in many forms such as agricultural/forestry products, and municipal and other waste.
Technical Advantages	■ Heat and power can be supplied by using small-scale generation capacity and cogeneration. ■ Higher fuel efficiency can be expected. ■ Biomass Power Plants do not necessarily need to be connected with power grid line. They have the potential of energy access improvement in non-electricity area.
Mitigation Potential	For Biomass and Biogas Power Plants, ■ 2020: 1,752-1,838 $ktCO_2$/year ■ 2030: 7,942-8,775 $ktCO_2$/year[45]
(Initial) Cost	■ 1,200 USD/kW for sugar mill, 1,800 USD/kW for rice husk, 2,000 USD/kW for biogas, 4,500USD/kW for municipal solid waste[46]
Viet Nam's Context	■ Source of supply may need to be stabilized due to seasonal variation or if the source is aggregated from several small farmers. ■ Applicable to cogeneration in sugar mills and food processing plants. ■ Applicable to electricity generation from solid wastes, etc. ■ Potential of power generation by renewable energy should be investigated.
Existing Policy & Measures	**Legal Framework** ■ Decision No.428/QĐ-TTg (2016) ■ Circular 29/2015/TT-BCT ■ Circular 44/2015/TT-BCT ■ Decision 942/QĐ-BCT **National Technical Standards** ■ QCVN 05:2013/BTNMT ■ QCVN 09:2015/BTNMT ■ QCVN 08-MT:2015/BTNMT ■ QCVN 10:2015/BTNMT ■ QCVN 40:2011/BTNMT ■ QCVN 22:2009/BTNMT
Current State of Market and Production	■ Market share for biomass power are 1% in 2020; 1.2% in 2025; and 2.1% in 2030. ■ Annual production of renewable energy (not including Hydro) was 3.5% and capacity was 5.4% in 2015.

45 Calculation based on grid factor (0.6612t-CO_2/MWh:2014)
46 Data from Institute of Energy in Viet Nam

E12 Small Hydropower Plants

Baseline Technology	Suggested Low Carbon Technology(ies)
Subcritical Coal-fired Thermal Power Plant	■ **Small Hydropower Plant (Reservoirs, Water Transfer Channel, Run-of River Type for Micro Hydropower Plant)**
Photo Image	
Summary of Technology	Hydroelectricity is generated when falling water is channelled through water turbines. The pressure of the flowing water on turbine blades rotates a shaft and drives an electrical generator, converting the motion into electrical energy.
Technical Advantages	■ Emits no waste products that pollutes the environment or disrupts the climate (Zero Emission). ■ Small hydropower plants do not necessarily need to be connected with power grid line. They have the potential of energy access improvement in non-electricity area.
Mitigation Potential	■ 2020: 51,689-54,225 $ktCO_2$/year ■ 2030: 58,622-64,771 $ktCO_2$/year[47]
(Initial) Cost	■ 1,700-1,900 USD/kW[48]
Viet Nam's Context	■ Applicable to multi-purpose (for flood control, water supply, electricity production) ■ Definition of "Small" Hydropower needs to be determined (i.e. capacity in kW, etc.). ■ Total capacity of hydropower: 21,600 MW in 2020; 24,600 MW in 2025; and 27,800 MW in 2030 (electricity production: 29.5% in 2020; 20.5% in 2025; and 15.5% in 2030).
Existing Policy & Measures	**Legal Framework** ■ Decision No.428/QĐ-TTg (2016) ■ Circular No.32/2014/TT-BCT
Current State of Market and Production	■ Annual production of electricity was 30.4% and capacity was less than 17,000 MW (37.3%) from hydropower sources in 2015.

47 Calculation based on grid factor (0.6612t-CO_2/MWh:2014)
48 Data from Institute of Energy in Viet Nam

E13, E14 Wind Power Plants by Domestic/International Funding

Baseline Technology	Suggested Low Carbon Technology(ies)
Coal-fired Thermal Power Plant	■ **Wind Power Plant (On-shore, Off-shore Bottom-mounted / Floating)**
Photo Image	
Summary of Technology	Wind turbines convert the force of the wind into a torque (rotational force), which is then used to propel an electric generator to create electricity. Wind energy power stations (known as wind farms) commonly aggregate the output of multiple wind turbines through a central connection point to the electricity grid. Across the world there are both on-shore (on land) and off-shore (on the sea) wind energy projects.
Technical Advantages	■ Emits no waste products that pollutes the environment or disrupts the climate (Zero Emission). ■ Wind power plants do not necessarily need to be connected with power grid line. They have the potential of energy access improvement in non-electricity area.
Mitigation Potential	■ 2020: 1,402-1,470 ktCO_2/year ■ 2030: 7,942-8,775 ktCO_2/year[49]
(Initial) Cost	■ 2,200 USD/kW[50]
Viet Nam's Context	■ Large areas with suitable wind condition in southern Viet Nam. ■ Technical development in combination with solar photovoltaic power plant is recommended. ■ Noise and bird strike control may be required. ■ There are some near shore turbines that have not been very carefully installed considering the need for mangrove protection and expansion. ■ Total capacity of wind power: 800 MW in 2020; 24,600 MW in 2025; and 27,800 MW in 2030 (electricity production: 0.8 % in 2020; 1% in 2025; and 2.1% in 2030).
Existing Policy & Measures	Legal Framework ■ Decision No.428/QĐ-TTg (2016) ■ Decision No. 37/2011/QD-TTg ■ Circular No. 06/2013/TT-BCT ■ Decree No.75/2011/ND-CP ■ Circular No. 96/2012/TT-BTC ■ Circular No. 32/2012/TT-BCT
Current State of Market and Production	■ Current wind power capacity is 140 MW.

[49] Calculation based on grid factor (0.6612t-CO2/MWh:2014)
[50] Data from Institute of Energy in Viet Nam

E15 Biogas Power Plants

Baseline Technology	Suggested Low Carbon Technology(ies)
Coal-fired Thermal Power Plant	■ **Biogas Power Plant (Using Biogas from Sewage, Agriculture)**
Photo Image	
Summary of Technology	In Biogas power plant, power is generated by burning the combustible gas from anaerobic biomass digestion. Biomass is any organic matter of recently living plant or animal origin. It is available in many forms such as agricultural products, forestry products, and municipal and other waste.
Technical Advantages	■ Heat and power can be supplied by using small-scale generation capacity and cogeneration. ■ Higher fuel efficiency can be expected. ■ Biogas power plants do not necessarily need to be connected with power grid line. They have the potential of energy access improvement in non-electricity area.
Mitigation Potential	For Biomass and Biogas Power Plants, ■ 2020: 1,752-1,838 ktCO_2/year ■ 2030: 7,942-8,775 ktCO_2/year[51]
(Initial) Cost	■ 2,000 USD/kW
Viet Nam's Context	■ Applicable sources: Agricultural crops (bagasse, rice straw, chaff and others), livestock excreta and municipal waste. ■ Source of supply may need to be stabilized due to seasonal variation or if the source is aggregated from several small farmers.
Existing Policy & Measures	Legal Framework ■ QCVN 05:2013/BTNMT ■ QCVN 08-MT:2015/BTNMT, ■ QCVN 40:2011/BTNMT ■ QCVN 09:2015/BTNMT ■ QCVN 10:2015/BTNMT ■ QCVN 22:2009/BTNMT
Current State of Market and Production	■ Annual production of renewable energy (without hydropower) was 3.5% and capacity was 5.4% in 2015.

[51] Calculation based on grid factor (0.6612t-CO2/MWh:2014)

E16 Ultra-Supercritical Coal Power Plants

Baseline Technology	Suggested Low Carbon Technology(ies)
Subcritical Coal-fired Thermal Power Plant	■ **Ultra-supercritical Coal Power Plant**
Photo Image[52]	
Summary of Technology	Ultra-supercritical (USC) power plants operate at temperatures and pressures above the critical point of water, i.e. above the temperature and pressure at which the liquid and gas phases of water coexist in equilibrium, at which point there is no difference between water gas and liquid water. This results in higher efficiencies – about 45%.
Technical Advantages	■ Compared to Sub-Critical (SC) coal power plants, up to 5.5% improvement on USC heat exchange efficiency can be expected.
Mitigation Potential	■ Up to 38 $MtCO_2eq$/year (in case of 12,720 MW of SC technology coal power generation to be replaced by USC technology)[53]
(Initial) Cost	■ USC: 1,959 USD/kW (SC: 1,781 USD/kW)
Viet Nam's Context	■ Total capacity of coal power: 26,000 MW in 2020; 47,600 MW in 2025; and 55,300 MW in 2030 (electricity production: 49.3% in 2020; 55% in 2025; and 53.2% in 2030). ■ Mixture of domestic and imported coal is needed to meet the high calorific coal requirement for USC. ■ Improvement of existing plants and capacity building may be required. ■ Power capacity needs to be scaled up for economic performance.
Existing Policy & Measures	Legal Framework ■ QCVN 05:2013/BTNMT ■ QCVN 09:2015/BTNMT ■ QCVN 08-MT:2015/BTNMT, ■ QCVN 10:2015/BTNMT ■ QCVN 40:2011/BTNMT ■ QCVN 22:2009/BTNMT
Current State of Market and Production	■ Annual production of coal power generation was 34.4% and capacity was 33.5% in 2015.

[52] HEPCO Hokkaido Electric Power Co., Inc. [http://www.hepco.co.jp/energy/fire_power/tomatou_ps.html]
[53] Unpublished

E17 Solar PV Power Plants

Baseline Technology	Suggested Low Carbon Technology(ies)
Subcritical Coal-fired Thermal Power Plant	■ **Solar Photovoltaic (PV) Power Plant (Rooftop, Ground-mounted, Floating on Water Reservoir, Concentrated Solar Power Plant)**
Photo Image	
Summary of Technology	The conversion of sunlight directly into electricity using photovoltaic cells. PV systems can be installed on rooftops, integrated into building designs and scaled up to megawatt scale power plants.
Technical Advantages	■ Emits no waste products that pollutes the environment or disrupts the climate (Zero Emission). ■ Solar PVs do not necessarily need to be connected with power grid line. They have the potential of energy access improvement in non-electricity area.
Mitigation Potential	■ 2020: 876-919 $ktCO_2$/year ■ 2030: 12,480-13,790 $ktCO_2$/year[54]
(Initial) Cost	■ 1,100-1,800 USD/kW[55]
Viet Nam's Context	■ Total capacity of solar power in Viet Nam: 850 MW in 2020, 4,000 MW in 2025 and 12,000 MW in 2030. (Electricity production: 0.5% in 2020, 1.6% in 2025 and 3.3% in 2030.) ■ Large land with suitable sunlight condition in southern Viet Nam. ■ Strength of housing and building structure should be confirmed to see if it is sufficient. ■ Capacity building for installing technique is needed. ■ Anti-theft measures may be required.
Existing Policy & Measures	Legal Framework ■ Decision No.428/QĐ-TTg (2016) ■ Decision No.11/2017/QĐ-TTg ■ Circular on draft model PPA ■ Decree No.32/2017ND-CP
Current State of Market and Production	■ Annual production of renewable energy (including large hydropower) was 3.5% and capacity was 5.4% in 2015. ■ Currently, the cost of PV system is decreasing in the global market, and also in Vietnamese market. Moreover, as government introduced FIT, PV competitiveness will be stronger in the market.

[54] Calculation based on grid factor (0.6612t-CO2/MWh:2014)
[55] Data from Institute of Energy in Viet Nam

Transport

Transport

Overview of the NDC

A distinctive point of the (I)NDC in the transport sector is that measures on modal shift (passenger and freight), which requires large infrastructure projects, are set as major activities. These measures are promoted under the National Transport Development Strategy and together with related strategies/plans, with consideration of efficiency and diversification of passenger and freight transportation. However, these measures also have the potential to reduce large amounts of GHG emissions and thus significantly contribute to the (I)NDC. The utilization of ethanol, which is a biofuel production using cassava and sugar cane as main feedstocks, can also contribute in decreasing agricultural wastes such as cassava pulp.

Transport sector's priorities

The MOT's suggestion on climate change mitigation measures in the transport sector is to set three pillars of measures, i.e. modal shift (passenger and freight), energy efficiency (in 5 subsectors: road, railway, inland waterway, maritime and aviation) and fuel switch, thus it should not be limited to the three measures indicated in the INDC Technical Report. Furthermore, measures should be developed in more details and be categorized depending on conditional and unconditional contributions in terms of NDC context as well as the timeframe (i.e. short and mid-term). Localization of low carbon technologies is an important aspect as well as economic, social, and environmental benefits. MOT is considering to propose mitigation measures in order to assist the updated NDC in near future. Modal shift is very important and need to be emphasized in the updated version of the NDC.

Co-benefits and development effects

- Passenger modal shift: Development and promotion of public transport in a city such as Mass Rapid Transit (MRT), Bus Rapid Transit (BRT), etc. can bring about social and economic benefits such as reduced travel time, less traffic congestion, and fewer traffic accidents.
- Freight modal shift: It can decrease air pollutants and noise levels through less usage of motor vehicles, ease traffic congestion, decrease traffic accidents, and lower transportation costs (e.g., long-distance transportation).
- Energy efficiency: Introducing low emission motor vehicles, railways, ships, and aircrafts will contribute reducing fuel costs compared with traditional vehicles.
- Fuel switch: Utilization of Compressed Natural Gas (CNG) and replacement with electric or hybrid vehicles can promote the reduction of local air pollution and noise levels as well as fuel costs.

Challenges

- Lower priority in the national action plan makes limited allocation of investment. (Railway)
- Concrete action plans on GHG emissions reduction for implementation into several sub-sectors is still missing.
- Lack of financial resources and technical knowledge limits activities (all subsectors).

Table 6 Mitigation options in Transport sector

	Mitigation Options under NDC	Low Carbon Technology Options[56]
E7	Substitution of ethanol for gasoline in transport	■ **Production of Ethanol** ■ Introduction of Ethanol Compatible Motor Vehicles
E8	Passenger transport modal shift from private to public	■ **Urban railway** - Metro, Light Rail Transit (LRT), monorail ■ Inter-city railway - Renovation of rail tracks - High speed railway ■ **Bus** - Bus Rapid Transit (BRT) - Bus route development/improvement ■ **Inland waterway** - River bus/boat ■ Promotion of public transportation - IC card, automatic ticket gate - Bus location system - Park and ride (e.g. mechanical parking tower) ■ Multi-modal promotion - Connection of multiple measure
E9	Freight transport switch from road	■ **Shift from road to railway** - Development of access railway to ports - Introduction of new freight railway car, large size container - Renovation of rail tracks - Development/improvement of railway freight terminal/ Inland Container Depot (ICD) card and set up necessary equipment (e.g. high-top lifter at rail freight terminals) ■ **Shift from road to water way** - Development/ improvement of waterway freight terminal, - Development of harbor road - Canals - Port and related equipment ■ Multi-modal promotion - Combination of multiple measures

	Additional Options	Low Carbon Technology Options
Energy Efficiency	Road	■ Improvement of fuel efficiency of vehicle - Low emission vehicle (High fuel economy vehicles not including hybrid/electric/Compressed Natural Gas (CNG)/Liquefied Petroleum Gas (LPG)) - Fuel car labelling - Eco driving (safety and environmental friendly driving) for drivers - Eco-driving for freight vehicle ■ Improve traffic flow - Intelligent Transport Systems (ITS) (Traffic control center, Intelligent traffic signals (incl. LED) etc.), Internet of Things (IOT) - Traffic management (truck ban, road pricing) - Parking management - Infrastructure (road (bypass, ring-road), pavement utilizing recycled material, fly-over, bridges, tunnels) ■ Others - LED lights for highways - High efficiency transformer for electricity supply for tunnel - Promotion of bicycle use - Freight exchange center
Energy Efficiency	Railway	■ Urban and inter-city railway - Every efficient railway vehicle (light weight vehicle, Variable Voltage Variable Frequency (VVVF), regenerative braking system, electric diesel hybrid railway vehicles) - Energy efficient appliances and renewable energy for stations/depots (e.g. LED, photovoltaic (PV) system) ■ Inter-city railway - Engine and locomotive renovation - Improve fuel economy ■ Electrification
Energy Efficiency	Inland waterway and maritime	■ Port - Energy efficient cargo handling machinery - On-shore power supply system - Energy efficiency chiller container - Renewable energy (e.g. PV system) ■ Vessel - Technical renovation transformation waterway, utilize vessels ■ Improve energy efficiency in ship building yard
Energy Efficiency	Aviation	■ Air port - Auxiliary Power Unit (APU) ->Ground Power Unit (GPU) - Renewable energy (e.g. PV system) - Electric vehicles - LED lights ■ Air craft ■ Modernize aircraft
Fuel switching	Biofuel	■ Biodiesel
Fuel switching	Gaseous fuel	■ CNG, LPG
Fuel switching	Electricity	■ Electricity - Electric bus/taxi/motorcycle ■ Hybrid - Hybrid bus/taxi

[56] Information on highlighted technologies are summarized in following pages after the table. Information on Low Carbon Technology Options for Additional Options are summarized in the Low Carbon Technology Catalogue.

E7 Substitution of Ethanol for Gasoline in Transport

Baseline Technology	Suggested Low Carbon Technology(ies)
Gasoline	■ **Production of Ethanol (Fuel Switch from Fossil-based Gasoline to Bioethanol)**
Photo Image[57]	 
Summary of Technology	Bioethanol is a type of alcohol that can be produced using feedstock containing sugar such as sugar cane, or starch such as cassava and wheat. Bioethanol can be blended with conventional gasoline fuel and be used for vehicles.
Technical Advantages	■ Using biofuel as alternative fuel for gasoline can reduce fossil-based gasoline usage. ■ Utilization of agricultural waste for ethanol can also contribute to effective use of and decreased amount of agricultural wastes such as cassava pulp.
Mitigation Potential	■ 888 gCO_2eq/liter of ethanol[58] (Highly dependent on the project, e.g. feedstock, technologies selected for waste treatment processes.)
(Initial) Cost	■ Highly dependent on the project.
Viet Nam's Context	■ In the period 2007-2015, there was an exemption/reduction of income tax for biofuel production. ■ The feedstock of bioethanol is mainly cassava, and its production does not meet demand for ethanol production, and cost is usually high. ■ Available land for biomass production is limited in Vietnam, due to existing agriculture and policies on maintaining a sufficient forest cover. ■ The impact of the cultivation of cassava roots as input for ethanol production should be clearly analyzed in terms of sustainability including environment and food security.
Existing Policy & Measures	**Legal Framework** ■ Decision No.177/2007/QĐ-TTg ■ Decision No.53/2012/QĐ-TTg
Current State of Market and Production	■ Introduction of E5 (5% blend to gasoline) in Viet Nam has been explored, however, currently, only one producer supplies ethanol and many ethanol plants have been shut down or left idle. ■ The Ministry of Industry and Trade has proposed to re-start the E5 use on January 1, 2018.

[57] NEDO website, Ethanol plant (Right)
[58] Loan T. LE et al. (2013). Energy and greenhouse gas balances of cassava-based ethanol in Vietnam, Biomass and Bioenergy 51:125–135.

E8 Passenger Transport Modal Shift from Private to Public

Baseline Technology	Suggested Low Carbon Technology(ies)
Private Cars/Bikes	■ **Public Transportation (Railways/Buses/Inland Waterways)**
Photo Image	
Summary of Technology	Various measures to promote passenger modal shift, such as development of urban/inter-city railways (e.g. metro, LRT (Light Rail Transit), tram, monorail, high-speed railway), development/improvement of bus routes/ BRT, and inland waterways. Related technologies are to improve energy efficiency of vehicles, such as light weight vehicle using aluminum body, Variable Voltage Variable Frequency (VVVF) inverter, regenerative braking system, and low emission vehicles for buses. To promote the use of public transportations, it is important to introduce technologies to enhance user-friendliness and safety. Examples are IC cards, automatic ticket gates, common ticketing system, bus location system, and park & ride.
Technical Advantages	■ Urban railways have high transportation capacity, high speed, less travel time, and less local air pollutants. ■ Reliability for travel time is increased from minimizing traffic congestions and accidents.
Mitigation Potential	■ **Examples of urban railways:** 38,267 tCO_2/year for Hanoi Line 1; 41,579 tCO_2/year for Hanoi Line 2; 88,678 tCO_2/year for HCMC Line 1.[59]
(Initial) Cost	■ **Examples of urban railways**: 1,455 million USD (Hanoi Line 1); 1,363 million USD (Hanoi Line 2); 2,183 million USD (HCMC Line 1) (1 USD= 110 JPY) [60]
Viet Nam's Context	■ Significant efforts/investments for developing new urban railway lines and BRT, however public transportation networks including normal bus routes or other means of transportation are urgently needed for cities. ■ Urban development must be integrated with public transport development and based on public passenger transportation.
Existing Policy & Measures	**Legal Framework** ■ Decision No.280/QĐ-TTg (2012) ■ Decision No.4088/QĐ-BGTVT (2013) ■ Decision No.214/QĐ-TTg (2015) ■ Decision No.1456/QĐ-BGTVT (2016)
Current State of Market and Production	■ Urban railway: (Hanoi) 2 Metro lines under construction, 8 Metro lines planned. (HCMC) 1 Metro line under construction, 8 Metro lines, 1 tramway, 2 monorails planned. BRT: 1 route operated in Hanoi.

[59] Mitsubishi Research Institute. (2013). Promotion of Modal Shift from Road-based Transport to Mass Rapid Transit (MRT) System. (Report of JCM/BOCM Feasibility Study)
[60] Mitsubishi Research Institute. (2013). Promotion of Modal Shift from Road-based Transport to Mass Rapid Transit (MRT) System. (Report of JCM/BOCM Feasibility Study)

E9 Freight Transport Switch from Road

Baseline Technology	Suggested Low Carbon Technology(ies)
Road	■ **Freight Mode Shift from Road to Railway/Waterway**
Photo Image	 
Summary of Technology	Various measures should be taken to promote shift of freight transportation from road (trucks) to railways and waterways, such as development/ improvement of railway/waterway freight terminals, renovation of railway tracks/ports, and access roads to these terminals. Also, necessary equipment/ facilities should be introduced to handle cargo from trucks to railways/ships.
Technical Advantages	■ Through the mode shifts, road traffic will be reduced thus local air pollution, noise and traffic accidents caused by trucks will be reduced.
Mitigation Potential	**Examples**: ■ 305 tCO_2/year (Transportation of rubber products; shift from truck 810km -> Railway 859 km + Truck 35 km), ■ 405 tCO_2/year (Transportation of miscellaneous goods; shift from truck to railway), ■ 3,320 tCO_2/year (Transport of chemicals; shift from truck to waterway), 2,116 $MtCO_2eq$/year (Transport of electronic parts; shift from truck to waterway)[61]
(Initial) Cost	■ 3,555 thousand USD (for tractor head, crawler crane, spreader, etc.) ■ 796 thousand USD (for container carrier) (1 USD= 110 JPY)[62]
Viet Nam's Context	■ Weak infrastructure and less investment for freight railways than urban passenger railways. ■ Many of the ports have old systems, poor access roads/infrastructure.
Existing Policy & Measures	**Legal Framework** ■ Decision No.4088/QĐ-BGTVT (2013) ■ Decision No.214/QĐ-TTg (2015) ■ Decision No.4146/QĐ-BGTVT (2015) ■ Decision No.1456/QĐ-BGTVT (2016)
Current State of Market and Production	■ Modal share by railway and waterway is 1.2% and 29.05% in ton-base. It is targeted to reach up to 4.3% and 32.4% by 2020, respectively. ■ Developing canal routes for waterway. Development of infrastructure for ports/inland waterway terminal in association with physical distribution system and relevant infrastructure is encouraged.

[61] Green Partnership. (2009). Report on Green Partnership Projects [http://www.greenpartnership.jp/pdf/proposal/result_list/case.pdf] (Japanese)
[62] World Bank Group. (2016). Exploring a low-carbon development path for Vietnam. Capital expenditure only

Agriculture

Agriculture

Overview of the NDC

15 mitigation options were identified in the agriculture sector. 11 of them were prioritized and eventually adopted in the Plan for Implementation of the Paris Agreement that the MARD submitted to MONRE in August 2016. They are in line with the Action Plan on Climate Change Response of Agriculture and Rural Development Sector in the Period 2011-2015 and Vision to 2050 (March 2011), and Decision on Approving Programme of GHG Emissions Reduction in the Agriculture and Rural Development Sector up to 2020 (December 2011). It is underlined that some of these 11 mitigation options show higher marginal abatement costs, which would require a careful implementation plan for the NDC.

Agriculture sector's priorities

MARD put emphasis on that profitability and food security for farmers are the first priority rather than GHG reduction. Profitability ensures economic sustainability of mitigation actions especially for farmers, while a slightest burden or lower yield will prevent them from adopting measures even if marginal abatement costs for measures at national level are acceptable.

Co-benefits and development effects

Rural development is one of the mandates of MARD. "Co-benefits" should be prioritized over GHG emission reduction, such as income increase, products with better quality and safety, stable production and productivity, less environmental pollution, lower labor burden and so on.

Agricultural waste/residues and wastewater treatment measures can add more values to agricultural production, improve rural environment, prevent soil and water pollution, and increase sanitation.

Challenges

- Capacity building in addition to the financial burden are critical issues for farmers.
- The time scale of financing schemes for green agriculture project is often not appropriate.
- A comprehensive technology transfer plan including maintenance management, beyond a purchase of single equipment for beneficiaries is required.
- A policy for dissemination of advanced irrigation technology is still not strong enough.

Table 7 Mitigation options in Agriculture sector

	Mitigation options under NDC	Low Carbon Technology Options[63]
A1	Increased use of biogas	■ **Biogas digester** - Fixed-dome Plants with internal gas storage up to 20 m^3 (large) - Floating-drum Plants with internal gas storage drum size (small) - Low-Cost Polyethylene Tube Digester with internal eventually external plastic bags - Balloon Plants with internal gas storage drum sizes (small) - Horizontal Plants - Earth-pit Plants - Ferro-Cement Plants ■ Biomethanation and power generation (Industrial scale)
A2	Reuse of agricultural residue as organic fertilizer	■ **On-farm or in field composting from agriculture residues**
A3	Alternate wetting and drying, and improved rice cultivation system (small scale)	■ **Alternate Wetting and Drying (AWD)** ■ Rehabilitation of infrastructure - High efficiency pump (horizontal shaft and diagonal flow) - Solar pump - Rehabilitation of irrigation canal
A4	Introduction of biochar (small scale)	■ **Biochar manufacturing equipment**
A5	Integrated crop management (ICM) in rice cultivation	■ **High efficiency pump**
A6	Integrated crop management (ICM) in upland annual crop cultivation	■ **Biochar manufacturing equipment**
A7	Substitution of urea with SA fertilizer (Sulfate Amon $(NH_4)_2SO_4$)	■ **Energy efficient gas-based production unit**
A8	Reuse of upland agricultural residues	■ **On-farming composting** - Sheet composting - Biodynamic composting - Static pile composting ■ Biochar manufacturing equipment - Barrel type bio-stove - Batch type bio-stove - Batch kiln (brick, TPI transportable metal, Missouri-type charcoal, continuous multiple hearth, small scale biochar plant)
A9	Alternate wetting and drying, and improved rice cultivation system (large scale)	■ **Alternate Wetting and Drying (AWD)** ■ Rehabilitation of infrastructure - High efficiency pump (horizontal shaft and diagonal flow) - Solar pump - Rehabilitation of irrigation canal
A10	Introduction of biochar (large scale)	■ **Improvement of biochar manufacturing equipment**
A11	Improvement of livestock diets	■ **Lipid supplements for Ruminants** ■ **Feed-use amino acid (lysine) for pigs and chickens**

[63] Information on highlighted technologies are summarized in following pages after the table. Information on Low Carbon Technology Options for Additional Options are summarized in the Low Carbon Technology Catalogue.

Mitigation options under NDC		Low Carbon Technology Options[63]
A12	Improvement of quality and services available for aquaculture, such as inputs and foodstuff	■ **Effluent treatment** - Up-flow anaerobic sludge blanket (UASB) - Rotating biological contractor ■ Biomethanation - Wet fermentation - Dry fermentation - Biogas co-generation system
A13	Improvement of technologies in aquaculture and waste treatment in aquaculture	■ **Biomethanation and power generation (Industrial scale)**
A14	Improved irrigation for coffee	■ Irrigation method - **Drip irrigation** ■ Water pumping - High efficiency pump - Solar pumping system
A15	Improved technologies in food processing and waste treatment in agriculture, forestry and aquaculture	■ **High efficiency cooling for chilling and freezing facilities in cold chain process**

Additional Options		Low Carbon Technology Options
	Mid-season drainage	■ Rehabilitation of infrastructure - High efficiency pump (horizontal shaft and diagonal flow) - Solar pump - Rehabilitation of irrigation canal
	Improvement of processing technology and reuse of waste of livestock husbandry production for organic fertilizer	■ Solid waste from pigs, cattle, chickens - Composting system (wind-row composting system, In-vessel system, vermicomposting, sheet composting) ■ Slurry from pigs, cattle, chickens - Biomethanation ■ Livestock wastewater from pigs, cattle, chickens - Purification - Aerobic treatment - Biomethanation - All in one system for manure from pigs, cattle, chickens - Microbes fermentation
	Structural adjustment capacity of the vessels	- High efficiency diesel and gas engine - LED lighting for squid-fishing vessel

Photo by OECC

A1 Increased Use of Biogas

Baseline Technology	Suggested Low Carbon Technology(ies)
N/A	■ **Biogas Digester (Small Scale Use for Pigs, Cattle, Chickens and Buffalo**
Photo Image	
Summary of Technology	Biogas digester is a technology which captures the gas from the anaerobic fermentation of biomass from animal dung and night soil. A small scale basic biogas digester is consisted of a tank in which the organic material is digested and combined with a system to collect and store the biogas produced.
Technical Advantages	■ Simple but powerful sanitation technology to reduce groundwater contamination, needs for fuelwood, and indoor air pollution caused by fuelwood burning. ■ Eliminates methane emissions created during fermentation of openly-discharged sewage.
Mitigation Potential	■ 6.4 $x10^{-3}$ $kgCO_2eq$/unit/year[64]
(Initial) Cost	■ 500-1,000 USD for 8-15 m^3 biogas digester
Viet Nam's Context	■ A need to support mid/large scale farmers and factories for biogas use is increasing. ■ Surplus biogas produced by digester is not fully utilized.
Existing Policy & Measures	**Legal Framework** ■ Decision No.3119/QĐ-BNN-KHCN (2011) ■ Decision No.543/QĐ-BNN-KHCN (2011) ■ Decision No.24/2014/QĐ-TTg
Current State of Market and Production	■ MARD has been implementing the project "Biogas Program for the Animal Husbandry Sector of Viet Nam" to exploit effectively biogas technology and develop a commercial viable biogas sector in Viet Nam. ■ Produced biogas is mainly used for kitchen use at rural households. Approx. 500,000 small scale biogas digesters (< 50 m^3) have been installed.

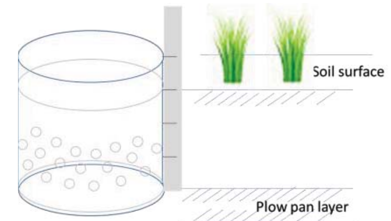
[64] MONRE. (2015). INDC Technical report Viet Nam's Intended Nationally Determined Contribution.

A2 Reuse of Agricultural Residue as Organic Fertilizer

Baseline Technology	Suggested Low Carbon Technology(ies)
Burning or Dumping Agricultural Residues	■ **On-farm and in-field Composting from Agriculture Residue**
Photo Image	 
Summary of Technology	**Sheet composting:** is a method which can provide the benefits of decayed organic material without building a composting pile. **Biodynamic composting:** is an inexpensive method to produce a large amount of compost by using dry and green farm biomass piled in a heap within a relatively short time compared to other methods. **Static pile composting:** can produce compost relatively quickly (within three to six months). This method is suitable for a relatively homogenous mix of organic waste except animal byproducts or grease from food processing industries.
Technical Advantages	■ Easy to prepare on farm and low cost.
Mitigation Potential	■ 1.07 $x10^{-4}$ $kgCO_2eq/ha/year$[65]
(Initial) Cost	■ 3-30 USD/m^2 (e.g. sheet composting)
Viet Nam's Context	■ Rice, maize, cassava, coffee, sugarcane, vegetables, banana and pineapple are the major upland crops and they are cultivated on small and steep farm land.
Existing Policy & Measures	**Legal Framework** ■ Decision No. 3119/QĐ-BNN-KHCN (2011) ■ Decision No. 543/QĐ-BNN-KHCN (2011) ■ Decree No. 108/2017/ND-CP
Current State of Market and Production	■ Use of Chemical fertilizer has been rapidly increased to increase agriculture productivity since 1990s which was one of cause for environment pollution due to use of unappropriated manner. ■ Composting technique using municipal solid waste has been developed as a solution to deal with the large amount of solid waste in the medium and big cities rather than a composting solution to produce an environmentally friendly fertilizer like compost fertilizer. Yet still highly demand of chemical fertilizer. ■ Most of agricultural residue is not fully reused by small scale farmers but used for animal feed or wasted.

[65] MONRE. (2015). INDC Technical report Viet Nam's Intended Nationally Determined Contribution.

A3, A9 Alternate Wetting and Drying (AWD), and Improved Rice Cultivation System (Small scale, Large scale)

Baseline Technology	Suggested Low Carbon Technology(ies)
Conventional Continuous Flooding	■ **Alternate Wetting and Drying (AWD)**
Photo Image	
Summary of Technology	Under AWD practice, rice field is drained periodically to enhance aeration of the soil, inhibiting methane-producing bacteria thereby reducing methane emissions. Water depth of the rice field is monitored using a perforated water tube "pani-pipe". At 1 to 2 weeks after transplanting, field is drained until the water level reaches 15cm below the soil surface. Then, the field is re-flooded to the depth of around 5cm before re-draining. This procedure is continued throughout the cropping season except from 1 week before and 1 week after flowering.
Technical Advantages	■ Reduces the number of irrigations significantly, thereby lowering irrigation water consumption up to 30%. ■ Increase net return for farmers by promoting more effective tillering and strong root growth of rice plants.[66] ■ Reduces fuel consumption for pumping water by 30 liters per hectare.[67]
Mitigation Potential	■ 1.46 (spring-summer) - 2.93 (summer-autumn) $tCO_2eq/ha/season$[68] ■ Reduces methane emission by 48% (IPCC methodology)
(Initial) Cost	■ 20 USD/tCO_2eq (India), more than 45 USD/tCO_2eq (Philippines, China)[69]
Viet Nam's Context	■ Development of irrigation canal and use of high efficiency pump may be required to solve the drainage issues during the rainy season. ■ Due to the additional labor requirement measuring the water level by plastic "pani-pipe", disparity between the standardized AWD developed by IRRI and adapted AWD being practiced also during rainy season by farmers in Viet Nam is still found.[70]
Existing Policy & Measures	**Legal Framework** ■ Decision No. 3119/QĐ-BNN-KHCN (2011) ■ Decision No. 543/QĐ-BNN-KHCN (2011)
Current State of Market and Production	■ Very low adoption of AWD: Uptake level is increasing in Viet Nam while there are still large differences between districts. ■ Irrigated area of rice paddy in Viet Nam in 2013 was 7.2 million ha.[71]

[66] IRRI. (2016). Overview of AWD. IRRI Brochure [http://books.irri.org/AWD_brochure.pdf]
[67] Palis FG, Cenas PA, Bouman BAM, Lampayan RM, Lactaoen AT, Norte TM, Vicmudo VR, Hossain M, Castillo GT. 2004. A farmer participatory approach in the adaptation and adoption of controlled irrigation for saving water: a case study in Canarem, Victoria, Tarlac, Philippines. Philipp. J. Crop Sci. 29(3)
[68] Taminato T, Matsubara E. 2014. Comparison of greenhouse gas emissions from paddy fields with two types of water-saving irrigation in the Mekong Delta
[69] Wassmann R., Pathak H. (2007) Introducing greenhouse gas mitigation as a development objective in rice-based agriculture. 11. Cost-benefit assessment for different technologies, regions and scales. Agric. Syst. 94:826-840
[70] Yamaguchi T, Tuan LM, Minamikawa K, Yokoyama S. 2016. Alternate Wetting and Drying (AWD) Irrigation Technology Uptake in Rice Paddies of the Mekong Delta, Viet Nam: Relationship between Local Conditions and the Practiced Technology
[71] MARD 2013. Statistical Yearbook of Agriculture and Rural Development 2013

A4, A10 Introduction of Biochar (Small scale, Large scale)

Baseline Technology	Suggested Low Carbon Technology(ies)
Burning or Dumping Agricultural Residues	■ **Improvement of Biochar Manufacturing Equipment**[72]
Photo Image	 
Summary of Technology	Biochar can improve soil's storage ability for nutrient, water and air. Size and type of equipment to produce biochar depends on stock volume and available area for installation of equipment: Barrel type bio stove (small size), Batch type bio stove (small to middle size) and Batch kiln (Brick kiln, TPI transportable metal kiln, Missouri-type charcoal kiln, Continuous multiple hearth kiln, Small scale Biochar plant) (small to large size).
Technical Advantages	■ Less black smoke, tar and smoke generated during system operation ■ Low cost
Mitigation Potential	■ 50-65% reduction of CO_2 emission (Carbon sequestration)[73]
(Initial) Cost	■ 1,700 USD/unit (Barrel type) [74] ■ >26,261 USD/unit (Batch kiln of 1.2 m high x 1.5 m diameter, 100 kg biochar/burn) [75] ■ 300,000-550,000 USD/unit (Batch kiln, 4 t of biochar/day) [76]
Viet Nam's Context	■ Biochar is not used by farmers on commercial basis but on an experimental basis.
Existing Policy & Measures	Legal Framework ■ Decision No. 3119/QĐ-BNN-KHCN (2011) ■ Decision No. 543/QĐ-BNN-KHCN (2011) ■ Decree No. 108/2017/ND-CP
Current State of Market and Production	■ Most of agricultural residue is not fully reused by farmers. ■ No local biochar manufacturer for agriculture use is found in Viet Nam market.

[72] In a course of review by line ministries, this technology is identified as infeasible in context of Viet Nam.
[73] California Energy Commission. (2010). Carbon Market Investment Criteria for Biochar Projects
[74] KANSAI corporation website [http://www.kansai-sangyo.co.jp/pr-smg.html]
[75] Carbon Zero website [https://www.biochar.info/biochar.large-scale-biochar-production.cfml]
[76] Carbon Zero website [https://www.biochar.info/biochar.large-scale-biochar-production.cfml]

A5 Integrated Crop Management (ICM) in Rice Cultivation

Baseline Technology	Suggested Low Carbon Technology(ies)
Low Efficiency Pump	■ **High Efficiency Pump**
Photo Image	  
Summary of Technology	**ICM:** ICM was developed based on several crop management practices. Major Components of ICM includes: Site and variety selection, Seed quality and health, Site, Crop Rotation and Varietal Choice, Soil Management and Crop Nutrition, Crop Protection, Wildlife and Landscape Management, and Energy efficiency. ICM practice can contribute to promote GHG reduction by focusing on energy efficiency in rice cultivation. **High efficiency water pump**: It can reduce a total energy usage and save cost and maximum irrigation and drainage capacity and unit which satisfy the idea of ICM in particular "detailed analysis of energy use, especially fossil fuels".
Technical Advantages	■ Higher pump efficiency (78-83%) can reduce need of fuel in operation
Mitigation Potential	■ 5.2 tCO_2eq/unit/year[77]
(Initial) Cost	■ Approx. 7,000 USD/unit
Viet Nam's Context	■ During the dry season, farmers use personal power pumps to irrigate their fields because the water level in the irrigation channels is lower than in the soil surface of the paddy field in Mekong Delta area.[78] ■ Huge drain pumps of the full-dike system are operated to drain excess water from the dike into the primary canal in some area such as a commune of Chau Phu Districts controlling irrigation and drainage during the middle of the rainy season, therefore, most farmers do not have personal pumps.
Existing Policy & Measures	Legal Framework ■ Decision No. 3119/QĐ-BNN-KHCN (2011) ■ Decision No. 543/QĐ-BNN-KHCN (2011)
Current State of Market and Production	■ Most of irrigation pumping stations were established before 1986 causing low pumping efficiency and hence requiring rehabilitation work to maintain their functionality. ■ It needs to improve the efficiency of canal sytem.

[77] Nippon Koei Co., Ltd. and EBARA Corp. (2014). Energy Saving for Irrigation Facility by Introducing High Efficiency Pumps (Viet Nam), (Report of JCM Feasibility Study)
[78] Yamaguchi T, Tuan LM, Minamikawa K, Yokoyama S. 2016. Alternate Wetting and Drying (AWD) Irrigation Technology Uptake in Rice Paddies of the Mekong Delta, Viet Nam: Relationship between Local Conditions and the Practiced Technology

A6 Integrated Crop Management (ICM) in Upland Annual Crop Cultivation

Baseline Technology	Suggested Low Carbon Technology(ies)
Burning or Dumping Agricultural Residues	■ **Biochar Manufacturing Equipment**
Photo Image	  
Summary of Technology	Biochar can improve soil's storage ability for nutrient, water and air. Size and type of equipment to produce biochar depends on stock volume and available area for installation of equipment: Barrel type bio stove (small size), Batch type bio stove (small to middle size) and Batch kiln (Brick kiln, TPI transportable metal kiln, Missouri-type charcoal kiln, Continuous multiple hearth kiln, Small scale Biochar plant) (small to large size).
Technical Advantages	■ Less black smoke, tar and smoke generated during system operation ■ Low cost
Mitigation Potential	■ 50-65% reduction of CO_2 emission (carbon sequestration) [79]
(Initial) Cost	■ 1,700 USD/unit (Barrel type) [80] ■ >26,261 USD/unit (Batch kiln of 1.2 m high x 1.5 m diameter, 100 kg biochar/burn) [81] ■ 300,000-550,000 USD/unit (Batch kiln, 4 t of biochar/day) [82]
Viet Nam's Context	■ Efficiency of inputs such as fertilizer is low in Viet Nam. ■ A practice of recycling of agriculture residue such as Biochar can improve soil chemical and physical structure resulting in improved nutrient holding ability of soil.
Existing Policy & Measures	Legal Framework ■ Decision No. 3119/QĐ-BNN-KHCN (2011) ■ Decision No. 543/QĐ-BNN-KHCN (2011)
Current State of Market and Production	■ Most of agricultural residue is not fully reused by farmers but used for animal feed, wasted and burned.

[79] California Energy Commission. (2010). Carbon Market Investment Criteria for Biochar Projects
[80] KANSAI corporation website [http://www.kansai-sangyo.co.jp/pr-smg.html]
[81] Carbon Zero website [https://www.biochar.info/biochar.large-scale-biochar-production.cfml]
[82] Carbon Zero website [https://www.biochar.info/biochar.large-scale-biochar-production.cfml]

A7 Substitution of Urea with SA Fertilizer (Sulfate Amon $(NH_4)_2SO_4$)

Baseline Technology	Suggested Low Carbon Technology(ies)
Coal-based Urea Production Unit	■ **Energy Efficient Gas-based Production Unit**[83]
Photo Image	
Summary of Technology	As part of fertilizer manufacturing plant, the following production units can save use of energy: Calcium Silicate Insulation of High Pressure Steam Pipe Line (0.78 GJ/t), Isothermal CO Conversion Reactor (0.418 GJ/t), Installation of Variable Speed Drives for Cooling Tower Fans in Fertilizer (2.77 kWh/ton), and Steam Trap Management (0.0003 GJ/t).
Technical Advantages	■ It can reduce a total energy usage and save cost.
Mitigation Potential	■ Calcium Silicate Insulation of High Pressure Steam Pipe Line: 0.47 $MtCO_2$ ■ Isothermal CO Conversion Reactor: 0.09 $MtCO_2$ ■ Installation of Variable Speed Drives for Cooling Tower Fans in Fertilizer: 0.02 $MtCO_2$ ■ Steam Trap Management: 0.01 $MtCO_2$ [84]
(Initial) Cost	■ Calcium Silicate Insulation of High Pressure Steam Pipe Line: N/A ■ Isothermal CO Conversion Reactor: 15.9 USD/t ■ Installation of Variable Speed Drives for Cooling Tower Fans in Fertilizer: 0.20 USD/t ■ Steam Trap Management: 0.017 USD/t
Viet Nam's Context	■ Coal-based urea accounts for 83% of urea based GHG emissions. [85] Ammonium Sulfate is used less because of low concentration of Nitrogen, its higher transfer cost and high import dependency.
Existing Policy & Measures	Legal Framework ■ Law No. 50/2010/QH12 ■ Decision No. 1621/QĐ-TTg (2013)
Current State of Market and Production	■ Due to intensive cultivation, consumption of chemical fertilizers has steadily been increasing by around 4-5% per year during the last years. ■ Net revenue of fertilizer enterprises reached the average percentage of more than 17%. ■ Owing to pricing decrease of fertilizers worldwide as well as the upward trend of raw material cost, revenue growth of fertilizer sector is predicted to slow down but still remains positive.

[83] In a course of review by line ministries, this technology is identified as infeasible in context of Viet Nam.
[84] WB. (2016). Exploring a Low-Carbon Development Path for Vietnam
[85] UNDP. (2015). Strengthening Capacity on Climate Change Initiatives in the Industry and Trade Sectors (CCIT)

A8 Reuse of Upland Agricultural Residues

Baseline Technology	Suggested Low Carbon Technology(ies)
Burning or Dumping Agricultural Residues	■ **On-farm Composting for Upland Crop Residue**
Photo Image	 
Summary of Technology	**Sheet composting:** is a method which can provide the benefits of decayed organic material without building a composting pile. **Biodynamic composting:** is an inexpensive method to produce a large amount of compost by using dry and green farm biomass piled in a heap within a relatively short time compared to other methods. **Static pile composting:** can produce compost relatively quickly (within three to six months). This method is suitable for a relatively homogenous mix of organic waste except animal byproducts or grease from food processing industries.
Technical Advantages	■ Easy to prepare on farm and low cost.
Mitigation Potential	■ 1.07 x10^{-4} kgCO_2eq/ha/year[86]
(Initial) Cost	■ 3-30 USD/m^2 (e.g. sheet composting)
Viet Nam's Context	■ Maize, banana, pineapple, coffee, sugarcane, and cassava are the major upland crops and they are cultivated on small and steep farm land.
Existing Policy & Measures	**Legal Framework** ■ Decision No. 3119/QĐ-BNN-KHCN (2011) ■ Decision No. 543/QĐ-BNN-KHCN (2011)
Current State of Market and Production	■ Most of agricultural residue is not fully reused by farmers but used for animal feed or waste.

[86] MONRE. (2015). INDC Technical report Viet Nam's Intended Nationally Determined Contribution.

A11 Improvement of Livestock Diets

Baseline Technology	Suggested Low Carbon Technology(ies)
N/A	■ **Lipid supplements for Ruminants** ■ **Feed-use Amino Acid (Lysine) for Pigs and Chickens**
Photo Image	 
Summary of Technology	Large portion of enteric methane and nitrous oxide comes from fermentation processes in ruminants. Sheep and goats produce 10 to 16 kg CH_4/yr and cattle 60 to 160 kg CH_4/yr, depending on their size and DMI (Dry Matters Intake).[87] Although, long-term effect still need to be confirmed, dietary lipids (e.g. fatty acids, medium to long chain) are reported to suppress CH_4 production. For monogastric farm animals, adding Lysine in feed is effective in reducing the total volume of CO_2 produced in the process from manufacture of raw materials to production (life cycle) as well as excretion of nitrogen.
Technical Advantages	■ Does not affect other ruminal parameters. Safe to the animals. (Lipid supplement) ■ Amino acid balance and efficiency of feeds can be improved, resulting in reduction of the amount of animal waste and methane gas.
Mitigation Potential	■ Mean decrease in CH_4 of 3.8% with each 1% addition of supplemental fatty acid.[88] ■ 1 t of Life-cycle-CO_2/2.4 kg of added Lysine[89]
(Initial) Cost	■ 3.6 USD/kg of linseed oil (1USD=110 JPY) [90] ■ 2.15 USD/kg of Lysine (as of FY2012)
Viet Nam's Context	■ In Viet Nam ruminant production is based on small households; there are few large commercial units. ■ The marginal abatement cost (MAC) curve demonstrated in the INDC indicates that feeding Lysine for pigs/chickens is financially attractive.
Existing Policy & Measures	**Legal Framework** ■ Decision No. 3119/QĐ-BNN-KHCN (2011) ■ Decision No. 543/QĐ-BNN-KHCN (2011)
Current State of Market and Production	■ Total cattle population in Viet Nam was 5,436,000 head (2009). ■ Raw material of lysine is imported from other Asian countries to Viet Nam for animal feed.

[87] Hristov AN. et al. 2014. Mitigation of methane and nitrous oxide emissions from animal operations: I A review of enteric methane mitigation options, Journal of Animal Science 91: pp. 5045-5069

[88] Martin C, Morgavi DP, Doreau M. 2010. Methane mitigation in ruminants: from microbe to the farm scale. Animal, Vol.4, No.3, pp. 351-365

[89] Ajinomoto. (2016). Life Support Business [https://www.ajinomoto.com/en/ir/library/fact/main/01/teaserItems1/0/file/Life_Support-Oct2016.pdf]

[90] Kato Y. Oishi K. Kumagai H. Ishida S. Aihara Y. Iwama E. Enishi O. Ikeguchi A. Ogino A. HIrooka H. 2011. Life cycle assessment of beef-fattening production systems using least cost rations with different amount of calcium soaps of linseed oil fatty acids, Journal of the Japanese Agricultural Systems Society 27(2), pp. 35-46

A12 Improvement of Quality and Services Available for Aquaculture, such as Inputs and Foodstuff

Baseline Technology	Suggested Low Carbon Technology(ies)
Anaerobic/Open Lagoon Treatment	■ **Effluent Treatment for Livestock Wastewater, Food Processing Wastewater Including Aquaculture**
Photo Image	
Summary of Technology	Purification, aerobic treatment, microbe fermentation, up-flow anaerobic blanket process and rotating biological contactor are the series of methods to reduce/remove impurities in wastewater generated from the livestock production, food and aquaculture processing. It can also recover methane gas for power generation.
Technical Advantages	■ Quick and high efficiency processing can be implemented resulting in reduced fuel cost and other production costs.
Mitigation Potential	■ 7,739 tCO_2eq/system/year[91]
(Initial) Cost	■ 108,208 USD/unit (for biogas co-generation system of 25 kW) ■ 324,624 USD/unit (for Up-flow anaerobic sludge blanket (UASB))
Viet Nam's Context	■ Effluent contains highly concentrated organic matter and is disposed into river/sea without sufficient treatment causing odor and water pollution.
Existing Policy & Measures	**Legal Framework** ■ Decision No. 3119/QĐ-BNN-KHCN (2011) ■ Decision No. 543/QĐ-BNN-KHCN (2011)
Current State of Market and Production	■ Key aquaculture regions in Viet Nam are Mekong River Delta, South East, Central Coastal and Red River Delta Regions. ■ Aquaculture is increasing in line with economic growth in Viet Nam. ■ Modernization of factories is in high demand due to the rise of needs for environmental protection: industrial effluent, waste or by-product reuse.

[91] Tepia Corporation Japan Co., Ltd. (2012). Methane Recovery and Effective Use in Wastewater Treatment in Viet Nam. (Report of JCM/BOCM Feasibility Study)

A13 Improvement of Technologies in Aquaculture and Waste Treatment in Aquaculture

Baseline Technology	Suggested Low Carbon Technology(ies)
Anaerobic/Open Lagoon Treatment	■ **Biomethanation and Power Generation (Industrial Scale)**
Photo Image	
Summary of Technology	Biogas plant can capture the methane gas that results from the anaerobic fermentation of biomass from aquaculture waste. An industrial scale of basic biogas digester usually consists of five equipment: 1) Pretreatment system; 2) Sterilization system; 3) Methane Fermentation system; 4) Gas Utilization system; and 5) Post-Treatment system.
Technical Advantages	■ Quick and high efficiency process ■ Energy saving
Mitigation Potential	■ 22,806 tCO_2eq/year (from the plant: one anaerobic digester with biogas production of 3,000 m^3/day, and one 500 kW biogas generator with power generation of 3,285 MWh/year)[92]
(Initial) Cost	■ 1,125 USD/ton (initial cost is subject to the scale of plant system, etc.)
Viet Nam's Context	■ Effluent contains highly concentrated organic matter and is disposed into river/sea without sufficient treatment causing odor and water pollution.
Existing Policy & Measures	**Legal Framework** ■ Decision No. 3119/QĐ-BNN-KHCN (2011) ■ Decision No. 543/QĐ-BNN-KHCN (2011)
Current State of Market and Production	■ Key aquaculture regions in Viet Nam are Mekong River Delta, South East, Central Coastal and Red River Delta Regions. ■ Aquaculture is increasing in line with economic growth in Viet Nam. ■ Modernization of factories is in high demand due to the rise in need for environmental protection: industrial effluent, waste or by-product reuse

[92] CDM project. (2011). Waste to Energy Project of SURE VN in Binh Duong Province, Viet Nam

A14 Improved Irrigation for Coffee

Baseline Technology	Suggested Low Carbon Technology(ies)
Surface Irrigation	■ **Drip Irrigation**
Photo Image	 
Summary of Technology	It is the most efficient irrigation method with a high efficiency of over 90% and an advantage of reducing water and fertilizer use by allowing water to drip slowly to the plant root zone.
Technical Advantages	■ Water consumption can be reduced resulting in reduced cost of fuel and other production costs.
Mitigation Potential	■ 5.3x10^{-3} $kgCO_2eq$/ha/year[93]
(Initial) Cost	■ 800-2,500 USD/ha
Viet Nam's Context	■ Surface irrigation is traditionally used by farmers for coffee cultivation.
Existing Policy & Measures	**Legal Framework** ■ Decision No. 3119/QĐ-BNN-KHCN (2011) ■ Decision No. 543/QĐ-BNN-KHCN (2011)
Current State of Market and Production	■ Coffee cultivation area is increasing due to its demand both inside and outside the country. ■ Priority area for coffee cultivation is located at Central Highlands where they have been experiencing more serious droughts and flashfloods. ■ Coffee farmers traditionally use a simple irrigation method (spraying). Due to water scarcity and demand to reduce GHG emissions (fuel consumption), water and energy-saving irrigation practices need to be introduced.

[93] MONRE. (2015). INDC Technical report Viet Nam's Intended Nationally Determined Contribution.

A15 Improved Technologies in Food Processing and Waste Treatment in Agriculture, Forestry and Aquaculture

Baseline Technology	Suggested Low Carbon Technology(ies)
Low Efficiency Cooling for Chilling and Freezing Facilities	■ **High Efficiency Cooling for Chilling and Freezing Facilities in Cold Chain Process**
Photo Image	
Summary of Technology	Ammonia and CO_2 are used as primary refrigerant and secondary refrigerant, respectively. It can save electricity consumption due to its higher efficiency in cooling, chilling and frozen process (more than 25% reduction). No ammonia leakage on the load side.
Technical Advantages	■ Energy efficiency is higher (food processing) resulting in reduced fuel cost and other production costs.
Mitigation Potential	■ 165 tCO_2eq/year[94]
(Initial) Cost	N/A
Viet Nam's Context	■ Cold chain is not sufficiently developed while consumer demand in food quality is increasing.
Existing Policy & Measures	**Legal Framework** ■ Decision No. 3119/QĐ-BNN-KHCN (2011) ■ Decision No. 543/QĐ-BNN-KHCN (2011) ■ Decision No. 24/2014/QĐ-TTg (2014)
Current State of Market and Production	■ Number of food processing factories (e.g. sugarcane, cassava, beer, fish processing) is increasing in line with economic growth of Viet Nam. ■ Modernization of factories is in high demand due to the need for environmental protection: industrial effluent, waste or by-product reuse.

[94] MAYEKAWA MFG. CO., LTD. (2013). Energy Efficient Refrigerants to Cold Chain Industry, Indonesia (JCM Model Project report)

LULUCF

LULUCF

Overview of the NDC

Viet Nam has been keen on afforestation/reforestation since the 1970s and gained forest area over time. The INDC target to increase in forest coverage up to 45% in total (equal to 15 million ha of forest) during 2021 to 2030, is ambitious from the viewpoint of achievement in forest coverage until present. In the course of discussions on climate change, mangrove forest protection drew renewed attention not only for its mitigation effect but also for its co-benefits with adaptation.

Reducing emissions from deforestation and forest degradation and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks (REDD+) is a new instrument under the UNFCCC for forest protection as well as rural development. However, REDD+ is not included as an option in the (I)NDC.

LULUCF sector's priorities

MARD expects to achieve the options of F1 to F5 (with domestic efforts) under their strategies/plans. However, to implement measures with international support, options (F6 to F9) and relevant technologies need to be further considered for application.

Co-benefits and development effects

- Forest management also contributes to the Aichi Target of the Convention on Biological Diversity.
- Employment and income source generation, biodiversity and watershed conservation, food security, provision of timber and fiber, and aesthetic, cultural and recreational services.
- Forest protection activities can be integrated into rural development strategies.

Challenges

- Intensive agriculture practices cause land degradation on sloping land.
- Measures against poverty and sustainable livelihoods need to be considered for those who inhabit in forest conservation areas.
- Scarcity of suitable land areas caused by development of large timber plantation is a concern.
- Long-term rotation plantation is increasing the risk of damages by natural disasters and/or pests.
- Loss of mangroves because of establishment of agricultural/residential areas and shrimp farms along the coastline or the river.
- Training with a view of rural people is still not in place.

Table 8 Mitigation options in LULUCF sector

	Mitigation options under NDC	Low Carbon Technology Options[95]
F1	Protection of natural forest (1 million ha)	**Conservation** ■ Reforestation ■ Forest fire control ■ Insect and pest control ■ Invasive species prevention ■ Forest degradation and deforestation prevention
F2	Protection of coastal forest (100,000 ha)	**Rehabilitation of Mangrove** ■ Conservation of existing forests ■ Enrichment planting ■ Reforestation ■ Silvo-fishery practices
F3	Plantation of coastal forest (10,000 ha)	■ (Same as F2)
F4	Natural forest regeneration (200,000 ha)	**Afforestation and Reforestation** ■ Planting technique ■ Plant selecting ■ Proper site suitability assessment for tree species selection ■ Seedling production and quality
F5	Plantation of large timber production forest (150,000 ha)	■ **Business models for the restoration of long-rotation Acacia plantation**
F6	Protection of natural forest (2.2 million ha)	■ (Same as F1)
F7	Plantation of coastal forest (30,000 ha)	■ (Same as F2)
F8	Natural forest regeneration (200,000 ha)	■ (Same as F4)
F9	Natural forest and production forest regeneration (400,000 ha)	■ (Same as F4)

	Additional Options	Low Carbon Technology Options
	Scattered Tree Planting	■ Planting tree seedlings on unplanted lands by individuals and/or organizations
	Reducing emissions from deforestation and forest degradation and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks (REDD+)	■ Sustainable forest use and management ■ GHG reduction by protection and reforestation of forest deteriorated by slash and burn agriculture, and utilization of wood supplied by sustainably managed forest ■ Power generation from utilization of biomass residue obtained as a result of agro-silvicultural promotion
	CO_2 isolation by large scale plantation: Forest Management	■ Development of growth increment measurement technology for individual tree species and forest ■ Development of forest fire prevention technology (appropriate thinning, remote monitoring)

[95] Information on highlighted technologies are summarized in following pages after the table. Information on Low Carbon Technology Options for Additional Options are summarized in the Low Carbon Technology Catalogue.

LULUCF

Additional Options	Low Carbon Technology Options
CO_2 isolation by large scale plantation: Increase in volume of CO_2 fixation per unit area	■ Cloning technology to select superior tree species, soil improvement technology ■ Elucidation of the group of genes which suppresses photosynthesis capacity in plant and acquisition of transformants that double photosynthesis
CO_2 isolation by large scale plantation: Expansion of vegetation to arid land and others	■ Water catchment and irrigation technology ■ Breeding without using genetically modified organism ■ Elucidation of group of gene for environmental tolerance and acquisition of its transformants ■ Safety assessment of transgenic plant for environment
CO_2 isolation by large scale plantation: Expansion of vegetation by industrial use	■ Improvement of production for useful industrial plants such as fat and oil, wax, gum and food, etc.
CO_2 isolation by large scale plantation: Expansion of vegetation by innovative use of biomass	■ Efficient glycation technology for biomass (cellulosic) ■ Highly efficient transduction technology for lignin ■ Development and system building to produce various sorts of energy resource (alcohol and hydrogen) and useful substance product family

F1, F6 Protection of Natural Forest (1 million ha and 2.2 million ha)

Baseline Technology	Suggested Low Carbon Technology(ies)
Non-managed Natural Forest	■ **Conservation**
Photo Image[96]	
Summary of Technology	In association of silvicultural methods, this technology includes: 1) Reforestation; 2) forest fire control; 3) insect and pest control; 4) invasive species prevention; 5) forest degradation and deforestation prevention; 6) restoring the degraded forest ecosystems; and 7) development of non-timber forest products.
Technical Advantages	■ Sustainably-verified timber trading contributes to increase in income (economic benefit). ■ Number of jobs and income in local areas can increase (social benefit). ■ Conservation technologies lead to sustainable forest use and management (environmental benefit).
Mitigation Potential	■ 70.6 $MtCO_2eq$/year, (Cumulative aggregation: 1,413 $MtCO_2eq$ in 20 years)[97]
(Initial) Cost	■ Protection of natural forest (1 million ha): 0.66 USD/$MtCO_2$ ■ Protection of natural forest (2.2 million ha): 0.70 USD/$MtCO_2$
Viet Nam's Context	■ Only 2% of the Country's production forests have been certified for Sustainable Forest Management (SFM) as of November 2016 in an effort to mainstream SFM with target of 30% by 2020[98].
Existing Policy & Measures	**Legal Framework** ■ Decision No.18/2007/QĐ-TTg ■ Decision No.57/QĐ-TTg (2012) ■ Decision No.1565/QĐ-BNN-TCLN (2013) ■ Decision No. 886/QĐ-TTg (2017)
Current State of Market and Production	■ Since 2011, the total value of Viet Nam's exported forest products has been fourth among Southeast Asian nations, of which sawn wood and wood-based panel exports have considerably increased (FAOSTAT-Forestry 2015)[99].

[96] S-Hoshino.com
[97] MONRE and UNEP. (2012). Technology Needs Assessment for Climate Change Mitigation, Viet Nam, Synthesis report
[98] Phuong V.T. et al. (2012). Final Report on Development of Marginal Abatement Cost Curve for Forestry in Viet Nam
[99] Masuda M. et al. (2016). Forest Conservation and Rehabilitation Policies in Vietnam: their Assessments and Local Responses, Tropics. 24, 139-140.

F2, F3, F7 Protection of Coastal Forest (100,000, 10,000, and 30,000 ha)

Baseline Technology	Suggested Low Carbon Technology(ies)
Non-managed Mangrove	■ **Rehabilitation of Mangrove (Conservation of Existing Forests, Enrichment Planting, Reforestation, Silvo-Fishery Practices)**
Photo Image	
Summary of Technology	This technology is a combination of the following techniques: 1) conservation of existing forests; 2) enrichment planting; 3) reforestation; and 4) silvo-fishery practices.
Technical Advantages	■ Plants and aquaculture products benefit the local economy as source of income (economic benefit). ■ Number of jobs and income in local area is increased through growing aquatic resources (fish, shrimp, crab etc.) by creation and enrichment of mangrove forests, and planting and management of mangroves on a long-term basis. (social benefit). ■ Mangrove swamps are considered a low-cost, efficient "green dyke" to prevent wave or storm. It can protect sea dykes, increase sedimentation rates, and farm shrimps. Degraded shrimp farming areas can be rehabilitated. (environmental benefits).
Mitigation Potential	■ 12.5 $MtCO_2eq$/year(Cumulative aggregation 250 $MtCO_2eq$ in 20 years)[100]
(Initial) Cost	■ Protection of coastal forest (100,000 ha): 0.95 USD/$MtCO_2$ ■ Plantation of coastal forest (100,000 ha): 5.72 USD/$MtCO_2$ ■ Plantation of coastal forest (30,000 ha): 5.88 USD/$MtCO_2$
Vietnam's Context	■ Mangroves are facing overexploitation to the point of destruction due to establishment of agricultural/residential areas, shrimp farms along the coastline or rivers, and sometimes mineral extraction facilities. ■ Expansion of rice cropland into mangrove swamps decreases the amount of sediment deposits on tidal zones, leading to coastal erosion.
Existing Policy & Measures	**Legal Framework** ■ Decision No.120/QĐ-TTg (2015) ■ Decision No. 38/2016/QĐ-TTg
Current State of Market and Production	The deltas of Ca Mau province, for example, are now pockmarked with failed shrimp ponds, abandoned because of high costs and decreasing returns due to erosion, pollution, and shrimp disease[101].

[100] MONRE and UNEP. (2012). Technology Needs Assessment for Climate Change Mitigation, Viet Nam, Synthesis report
[101] CCAFS. The 'Markets and Mangroves' (MAM) project in Vietnam. [https://csa.guide/csa/the-markets-and-mangroves-mam-project-in-vietnam]

F4, F8, F9 Natural Forest / Production Forest Regeneration (200,000 ha)

Baseline Technology	Suggested Low Carbon Technology(ies)
Non-managed Forest	■ **Afforestation and Reforestation**
Photo Image	
Summary of Technology	This technology is a combination of the following techniques: 1) planting technique; 2) plant selecting; 3) proper site and suitability assessment for tree species selection; 4) seedling production and quality. Associated technologies include creating new cultivars, tissue culture, and seeding, etc.
Technical Advantages	■ Increase in carbon sinks, protection of environment, and watershed conservation are some of many advantages of afforestation and reforestation.
Mitigation Potential	■ 37.5 $MtCO_2eq$/year (Cumulative aggregation: 750 $MtCO_2eq$ in 20 years)[102]
(Initial) Cost	■ Natural forest regeneration (200,000 ha): 1.18-1.20 USD/$MtCO_2$ ■ Natural forest and production forest regeneration (400,000 ha): 1.20 USD/$MtCO_2$
Viet Nam's Context	■ If possible, a careful consideration at gene level should be given in order not to disturb biodiversity in Viet Nam.
Existing Policy & Measures	**Legal Framework** ■ Decision No.18/2007/QĐ-TTg ■ Decision No.57/QĐ-TTg (2012) ■ Decision No.1565/QĐ-BNN-TCLN (2013) ■ Decision No.1560/ QĐ-BNN-TCLN (2017)
Current State of Market and Production	■ Unused hilly land is needed for forest rehabilitation, mostly found in the Northwest, Northeast, North Central, Central Coast and Central Highland regions.

[102] MONRE and UNEP. (2012). Technology Needs Assessment for Climate Change Mitigation, Viet Nam, Synthesis report

F5 Plantation of Large Timber Production Forest (150,000 ha)

Baseline Technology	Suggested Low Carbon Technology(ies)
Short Rotation	■ **Long Rotation**
Photo Image[103]	
Summary of Technology	This is a business model for transformation and restoration of short-rotation acacia plantations (commonly 5-6 years), in which the rotation length is increased (up to 12-15 years) to make the forest suitable for high-value sawn log production.
Technical Advantages	■ Enhancing carbon storage and other environmental services (i.e. soil fertility etc.). ■ Promotes sustainable forest management. ■ Significant increase in profitability of forests designated for production.
Mitigation Potential	■ 10 tCO_2eq/ha/year (Cumulative aggregation: 60 tCO_2eq in 6 years) (conservative)[104]
(Initial) Cost	■ Plantation of large timber production forest (150,000 ha) 2.67 USD/$MtCO_2$
Viet Nam's Context	■ In 2014, pure acacia plantations covered more than 1.1 million ha. ■ Over 10 million m^3 is harvested annually from acacia plantations. ■ Appropriate piloting area has been confirmed by MARD (NCC agro-ecological region of Viet Nam).
Existing Policy & Measures	**Legal Framework** ■ Decision No.774/QĐ-BNN-TCLN (2014) ■ Decision No.83/QĐ-BNN- TCLN (2016) ■ Decision No. 886/QĐ-TTg (2017)
Current State of Market and Production	■ A large share of acacia production is processed as woodchips, although acacia has high demand from the export-oriented furniture industry. ■ 80% of the timber that is used for export products is imported due to high demand in export-oriented furniture industry ■ Large number of wood industry enterprises exists due to high demand for domestic wood supply

[103] Photo by Dr. Vu Tan Phuong (VAFS, Viet Nam)
[104] Ministry of Agriculture and Rural Development, Viet Nam and Forest Carbon Partnership Facility (FCPF). (2016). Emission Reductions Program Document (ER-PD) Draft Version 1.2

Waste

Waste

Overview of the NDC

INDC options in the waste sector are based on the mitigation measures identified in the policy document of the waste sector in Viet Nam, "The National Strategy for the Integrated Solid Waste Management by 2025 and a Vision Towards 2050" (Decision No.2149/QĐ-TTg).

Option	Mitigation Potential by 2030 (million tCO_2e)
W1 Organic fertilizer production	Domestic resources: 3.58 International support: 10.29
W2 Landfill gas (LFG) recovery for electricity and heat generation	Domestic resources: 0.33 International support: 1.93
W3 Recycling of solid waste	Domestic resources: 0.25 International support: 0.93
W4 Anaerobic treatment of organic solid waste with methane recovery for power and heat generation	International support: 2.91

Waste sector doesn't contribute much to the national total GHG emissions nor has large mitigation potential in Viet Nam, however, these options are expected to solve compelling needs in issues related to landfill and urban traffic.

Waste sector's priorities

In accordance with the previous study conducted by the Ministry of Construction (MOC) and United States Agency for International Development (USAID), the priority given to waste management technologies are: 1st priority: composting, 2nd priority: incineration, and 3rd priority: landfill. However, the MOC is currently reviewing this priority with attention to the national development priority in the waste sector and applicabilities of each technology in terms of different conditions in solid waste management at local level.

Co-benefits and development effects

- The most important policy objective of waste management sector is to minimize/eliminate potential negative impacts upon human health and environment arising from waste generated from human activities. In this respect, the relevant technologies are primarily evaluated in terms of their efficiency in waste reduction. The so-called 3R (Reduce, Reuse and Recycle) conceptualizes this sector priority.
- The climate change mitigation/GHGs emission reduction technologies identified in this sector are expected to have the following co-benefits by types of technologies.
    - Redcution of waste volume (composting, recycling, waste-to-energy)
    - Mitigation of negative impacts from waste itself upon human health and environment (sanitary landfill operation combined with GHGs emission reduction technologies such as landfill gas capture/energy utilization and semi-anaerobic landfill operation)
    - Mitigation of negative environmental impacts from waste collection/haulage activities (low-emission collection trucks, collection/haulage efficiency improvement, etc.)

Challenges

- Each climate change mitigation technology identified in waste sector has its unique requirement for its application, e.g. the minimum amount of waste required, composition of waste (calorific value of waste) and so forth. Therefore, technological applicability will be different by local conditions such as population, socio-economy, current waste management practice, and so forth.
- The current conditions of relevant technology development in the country needs to be carefully considered easpecially introducing some advanced technologies, e.g. waste-to-energy.
- The unit cost of each technology (such as unit cost per ton of waste treated) is also the important key to assess its financial viability in the country.
- Some of the technologies in this sector may have social barriers in its introduction (such as social opposition or NIMBY syndrome against waste incineration).
- More detailed technology issues, obstacles, co-benefits, and development effects are specified in the Low Carbon Technology Catalogue.

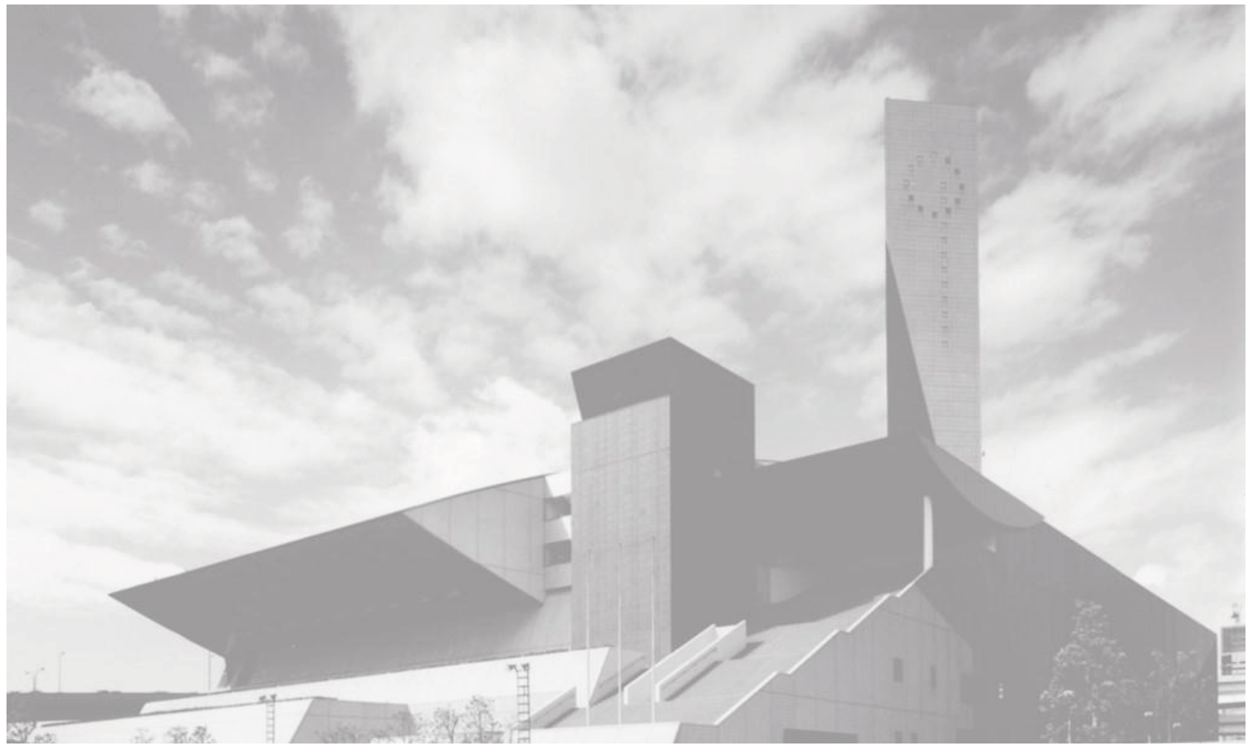


Photo by Satoshi Sugimoto

Table 9 Mitigation options in Waste sector

Mitigation options under NDC		Low Carbon Technology Options[105]
W1	Organic Fertilizer Production	**Production of Organic Fertilizers from Organic Waste (Composting)** **Mechanical technologies** ■ Separation/sorting technologies ■ Mixing/sieving window, compost, turner) ■ Catalyzing fermentation (vermi-compost, aeration, etc.) **Operation technologies** ■ Temperature control ■ Process control for catalyzing
W2	Landfill gas recovery for electricity and heat generation	■ **Landfill Gas (LFG) capture and recovery technology (LFG gas capture and piping network)** ■ LFG refining technology ■ LFG based power generation ■ Heat production
W3	Recycling of solid waste	■ **Material recovery of recyclables from solid waste**
W4	Anaerobic treatment of organic solid waste with methane recovery for power and heat generation	■ **Anaerobic fermentation technology** ■ Methane recovery ■ Heat production

Additional Options		Low Carbon Technology Options
	Semi anaerobic landfill operation (Fukuoka Method)	■ Landfill design and operation technology
	Waste to Energy	■ Stoker type furnace ■ Gasification ■ Plasma arc ■ Methanization
	Conversion to low-carbon fuel trucks for waste collection/haulage vehicles	■ Natural gas ■ LPG ■ Hybrid ■ Electric vehicle ■ Bio diesel fuel ■ Bio-methane
	Construction of waste transfer station	■ Waste transfer facility ■ Large scale compactors/trailer

[105] Information on highlighted technologies are summarized in following pages after the table. Information on Low Carbon Technology Options for Additional Options are summarized in the Low Carbon Technology Catalogue.

W1 Organic Fertilizer Production

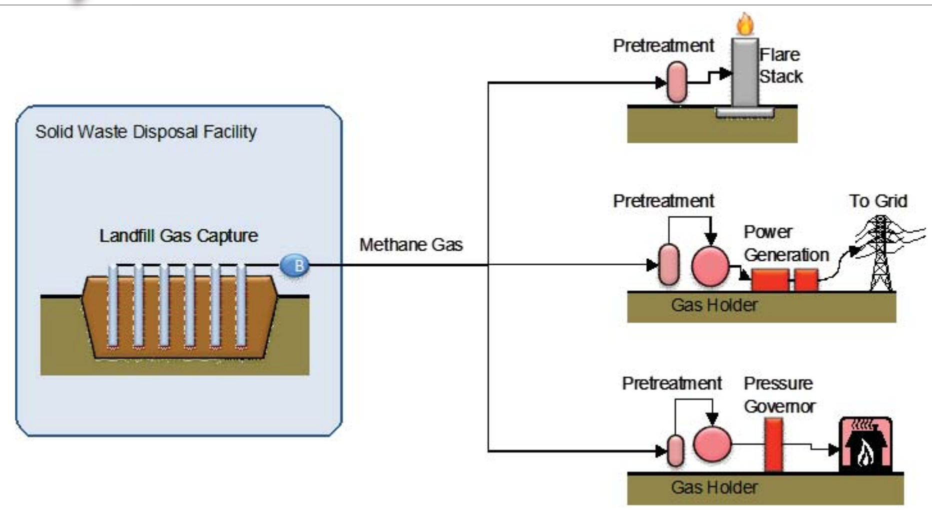
Baseline Technology	Suggested Low Carbon Technology(ies)
N/A →	**Production of Organic Fertilizers from Organic Waste (Composting)** ■ Mechanical Technologies (Separation/sorting, Mixing/sieving （Windrow, Compost Turner, etc.）, Catalyzing fermentation (Vermi-compost, aeration, etc.)) ■ Operational Technologies (Temperature control, Process control for catalyzing fermentation)
Photo Image	
Summary of Technology	Composting is a method of decomposing organic solid waste. The process involves decomposition of organic waste into humus known as “compost” which can be utilized as organic fertilizer for plants or conditioners of agricultural/horticultural soil.
Technical Advantages	■ Low-cost and relatively simple (easy-to-apply) technologies. ■ There are various combinations of technologies for composting that can be applied in small as well as in large scale.
Mitigation Potential	■ 17,000 MtCO_2eq/year (from 200 ton/day of municipal solid waste)[106]
(Initial) Cost	■ USD 3.3 million (for handling municipal solid waste of 200 ton per day)
Viet Nam's Context	■ Compost technologies are widely known and applied in Viet Nam (ranging from manual-based to mechanical-based technologies). ■ The Government sets the goal for 2025 that household wastes generated in the urban area shall be collected and treated, and that 90% of it will be recycled, reused, and processed into organic fertilizer or energy recovered. ■ Strict separation of organic waste (removal of impurities) is generally not sufficient to compete with chemical fertilizer. ■ Insufficient scale of economy due to low market price, limited market size especially in northern area, and limited commercial suppliers.
Existing Policy & Measures	**Legal Framework** ■ Decree No.59/2007/ND-CP ■ Decision No.1440/QD-TTg ■ Decision No.2149/QĐ-TTg (2009 ■ Decision No.986/QĐ-BXD (2011) ■ Decision No.798/QĐ-TTg (2011)
Current State of Market and Production	■ Due to low market price of compost, application potential of composting technologies is limited. ■ Strategy for commercializing compost products should be in place.

[106] EX Research Institute Ltd. (2012). Introduction of Mechanical Biological Treatment (MBT) of Municipal Solid Waste and Landfill Gas Capture, Flaring and Utilization (Lao PDR), (Report of JCM/BOCM Feasibility Study).

W2 Landfill Gas Recovery for Electricity and Heat Generation

Baseline Technology	Suggested Low Carbon Technology(ies)
N/A	■ **Landfill Gas (LFG) Capture/Recovery and Energy Utilization**

Photo Image



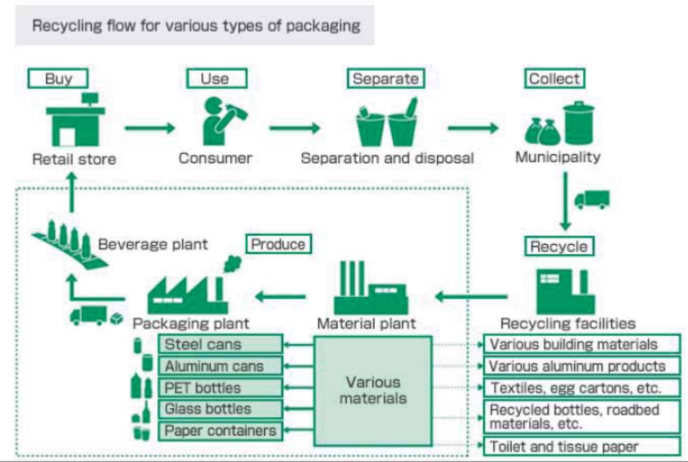
Summary of Technology	LFG capture/recovery and energy utilization is process consisting of LFG collection, refining and conversion into energy. The quality of LFG highly depends on the composition of waste and presence of oxygen in the decomposition process of organic waste at landfills. The collected LFG can be utilized for generating power and/or heat while reducing methane that might have otherwise been released to the atmosphere. Just flaring of the collected LFG also contributes to methane emissions reduction.
Technical Advantages	■ It can be applied to various types of landfills (existing, closed, and newly built final disposal landfills of waste).
Mitigation Potential	■ 7,000 $MtCO_2eq$/year (from the landfill of disposing 200 ton/day)[107]
(Initial) Cost	■ 5 million USD (for handling municipal solid waste of 200 ton /day)
Viet Nam's Context	■ There is no large scale application of this technology in Viet Nam. ■ Small scale application in some landfills (Hue and Nam Song Landfills)
Existing Policy & Measures	**Legal Framework** ■ Decree No.59/2007/ND-CP ■ Decision No.1440/QD-TTg ■ Decision No.986/QĐ-BXD (2009) ■ Decision No.798/QĐ-TTg (2011) ■ Decision No.986/QĐ-BXD (2011) ■ Decision No.31/2014/QĐ-TTg ■ Circular No. 32/TT-BCT
Current State of Market and Production	■ Due to low market price of compost, application of composting technologies is limited.

[107] EX Research Institute Ltd. (2012). Introduction of Mechanical Biological Treatment (MBT) of Municipal Solid Waste and Landfill Gas Capture, Flaring and Utilization (Lao PDR), (Report of JCM/BOCM Feasibility Study).

W3 Recycling of Solid Waste

Baseline Technology	Suggested Low Carbon Technology(ies)
No Recycling	■ **Material Recovery of Recyclables from Solid Waste**

Photo Image

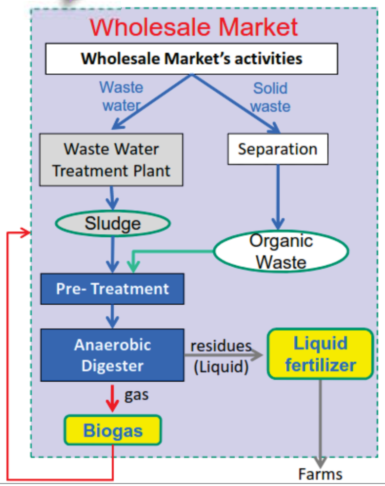
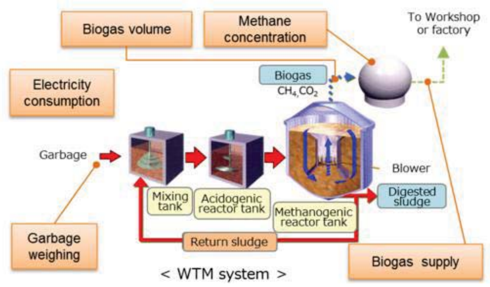


Summary of Technology	Recycling needs proper separation of recyclable items from solid waste at the source of waste generation. If it is carried out in accordance with the requirements set by the receiving recyclers, the incremental cost can be minimized. A series of manual or mechanical separation technologies are required when the solid waste is collected in the mixed state.
Technical Advantages	■ The cost of recycling can be minimized by making use of the existing recycling industry at its maximum. ■ Separation of recyclables at sources is the key to feasible recycling operation.
Mitigation Potential	■ 3 $MtCO_2eq$/year[108]
(Initial) Cost	■ The cost for recycling facilities will be different depending upon the types of materials used, types of products manufactured and technologies/processes to be applied.
Viet Nam's Context	■ Government sets the goal for 2025 that household wastes generated in the urban area shall be collected and treated, and that 90% of it will be recycled, reused, and processed into organic fertilizer or energy recovered.
Existing Policy & Measures	**Legal Framework** ■ Decree No.59/2007/ND-CP ■ Decision No.1440/QD-TTg ■ Decision No. 2149/QĐ-TTg, (2009) ■ Decree 38/2015/NĐ-CP (2015) ■ Decision No.798/ QĐ -TTg (2011) ■ Decree No. 19/2015/ND-CP ■ Circular 128/2016/TT-BTC
Current State of Market and Production	■ For some of the recyclables such as waste paper, scrap metal, and plastics, recycling are carried out as part of business operation; however, they are not carried out for the purpose of GHG emission reduction. ■ Carbon finance to such recycling activities may encourage further recycling of waste that are not regarded as financially viable under the current market mechanism of some recyclable materials.

[108] MONRE and UNEP. (2012). Technology Needs Assessment for Climate Change Mitigation, Viet Nam, Synthesis report

Waste

W4 Anaerobic Treatment of Organic Solid Waste with Methane Recovery for Power and Heat Generation

Baseline Technology	Suggested Low Carbon Technology(ies)
N/A	■ **Anaerobic Fermentation of Organic Waste with Heat Recovery and Utilization**
Photo Image[109]	 
Summary of Technology	This technology is specifically designed to treat organic waste generated from considerably large sources (wet markets, restaurants, hotels, etc.) and wastewater treatment sludge. It treats the waste with anaerobic digestion system to produce high quality fertilizers while collecting the biogas to produce heat or electricity, depending on the amount collected.
Technical Advantages	■ It can be applied to similar wet market (vegetables and fish market) with sufficient scale to capture methane for continuous heat production.
Mitigation Potential	■ 1,680 $MtCO_2eq$/year (from 50 ton/day of waste collected)[110]
(Initial) Cost	■ 654,545 USD (USD 1=JPY 110) (to treat 50 ton/day of waste)
Viet Nam's Context	■ It can be applied to the large scale market such as the case of HCMC.
Existing Policy & Measures	**Legal Framework** ■ Decree No.59/2007/ND-CP ■ Decision No.1440/QD-TTg ■ Decision No.2149/QĐ-TTg (2009) ■ Decision No.798/QĐ-TTg (2011) ■ Decision No.986/QĐ-BXD (2011) ■ Decision No.31/2014/QĐ-TTg (2014)
Current State of Market and Production	■ There is only one example of technology application as JCM project (Anaerobic fermentation of organic waste with heat recovery and internal utilization in a wet market in Ho Chi Min City (Hitachi Zosen). ■ No other application of this technology in Viet Nam so far although it can be applied to similar scale and type of wet market probably in big cities such as Hanoi, Hai Phong, and Da Nang.

[109] Hitachi Zosen Corporation and K.K. Satisfactory International. (2013). Anaerobic digestion of organic waste for cogeneration at market (Viet Nam), (Report of MOEJ/GEC JCM Project Planning Study)
[110] Hitachi Zosen Corporation and K.K. Satisfactory International. (2013). Anaerobic digestion of organic waste for cogeneration at market (Viet Nam), (Report of MOEJ/GEC JCM Project Planning Study)

F - gas

F-gas

Overview of the NDC

Measures on F-gases are not identified in the INDC of Viet Nam. Scarce and scattered information on consumption of HFC prevented Government of Viet Nam to plan mitigation options for INDC on these gases. However, some energy options are relevant, namely high efficiency air conditioner for household (E1), high efficiency commercial air conditioning (E10) and high efficiency residential refrigerators (E2). Consumption of HFC is likely to increase over time after the ban of Chlorofluorocarbons (CFC) and Hydrochlorofluorocarbons (HCFC), and phasing down the use of HFCs will soon be necessary under the Kigali Amendment to the Montreal Protocol as well as UNFCCC. Thus, wider options on F-gases should be considered in addition to the energy efficiency options.

F-gas sector's priorities

NOU of MONRE and ISEA of Ministry of Industry and Trade (MOIT) expressed interests on F-gas destruction at cement kiln using existing facilities (to reduce initial cost), changing to low Global Warming Potential (GWP) refrigerant and leakage inspection / maintenance as prioritized technologies. The ISEA also pointed out that inflammable refrigerant may not be suitable for Viet Nam.

Co-benefits and development effects

Preparation for the Kigali Amendment to the Montreal Protocol will be one of the main co-benefits. Safer and energy-saving products can also be expected.

Challenges

- There are no incentives for collection and destruction or specific facilities for destruction.
- Limited capacity in servicing sector in Viet Nam.
- Energy-saving equipment is not attractive to consumers compared to cheap equipment at the moment.
- ODS and GHG are not major criteria for most consumers for choosing electric equipment.
- Security of basic information on HFC use wakes the planning of quantitative mitigation targets difficult.

F-gas

Table 10 Mitigation options in F-gas sector

F-gas	Low Carbon Technology Options
F-gas destruction	■ Combustion at Cement Kiln
Residential refrigerator	■ Alternative device with low GWP refrigerant (R600a/Isobutene)
Commercial refrigerator/cold storage	■ Alternative device with low GWP refrigerant ($R744/CO_2$) ■ Alternative device with low GWP refrigerant (R290/Propane)
Residential air conditioner	■ Alternative device with low GWP refrigerant (R32)
Commercial air conditioner	■ Alternative device with low GWP refrigerant (R32)
Automobile air conditioner	■ Alternative Refrigerant (HFO-1234yf)
Maintenance	■ Leakage prevention/maintenance of commercial refrigerator/cold storage and AC

F-gas

F-gas 1 F-gas Destruction

Baseline Technology	Suggested Low Carbon Technology(ies)
N/A	■ **Destruction of F-gas at Cement Kiln**
Photo Image	 
Summary of Technology	There are several destruction methods for F-gas, such as the rotary kiln method, waste combustion method, submerged combustion method, plasma method, catalytic method, overheated steam method, etc. In Viet Nam, there are no specific facilities and/or equipment for F-gas destruction purpose, however, LaFarge Holcim (cement factory) has a pilot project experience of F-gas destruction with cement kiln method. There are three steps in the process of destruction of F-gas by cement kiln: (1) recovery of refrigerant; (2) refilling and transporting F-gas cylinders; and (3) thermal destruction at destruction site, where recovered F-gas is injected into cement kiln and combusted at over 1,000 degrees. Detention time of at least 6 seconds is needed as combustion time in the kiln.
Technical Advantages	■ There is no need to construct a new plant as destruction of F-gas utilizes existing facilities of cement kiln. The only modification required is to attach pipes and flowmeters for sending F-gas to cement kiln.
Mitigation Potential	■ Decomposition of over 99.9% of F-gas.[111]
(Initial) Cost	■ Low (Attachment cost of pipes and flowmeters for sending F-gas to cement kiln.)
Viet Nam's Context	■ There is no incentive for the private sector to move for collection and destruction of F-gas in Viet Nam. Establishment of policy and legal frameworks that enhances stakeholder incentives to adopt F-gas collection and destruction is needed.
Existing Policy & Measures	**Legal Framework** N/A
Current State of Market and Production	■ F-gas destruction pilot project is implemented at LaFarge Holcim in Kien Giang Province. (LaFarge Holcim has a license for treating waste including F-gas (CFC/HCFC/HFC).

[111] MOEJ. (2016). Act on rational use and proper management of fluorocarbons [https://www.env.go.jp/en/earth/ozone/laws/ozone4.pdf]

F-gas 2 Residential Refrigerator

Baseline Technology	Suggested Low Carbon Technology(ies)
Refrigerators with R134a (GWP=1,430) Refrigerant	■ **Changing Refrigerant of Refrigerator in Household Sector**
Photo Image[112]	
Summary of Technology	Changing high GWP (Global Warming Potential) refrigerant to low GWP refrigerant (R600a/ isobutane) in refrigerators in the household sector. Hydrocarbons are not implicated in ozone depletion, and the majority of Hydrocarbon refrigerants have a low GWP. Refrigerators using R600a, non-Freon and low GWP refrigerant, are widely available at home electronics mass retailers in Viet Nam.
Technical Advantages	■ Low GWP refrigerant R600a (isobutene, GWP=4) is widely available in Viet Nam. ■ Limited to less than 100g use of R600a for refrigerators in the household sector (to prevent explosion). ■ Refrigerators with R600a and R-134a have the same power consumption and cooling performance.
Mitigation Potential	■ 99.7% reduction by changing refrigerant from R-134a (GWP=1,430) to R600a (GWP=4). Calculation: 4 / 1,430 = 0.00279 → 99.7 % reduction[113]
(Initial) Cost	■ 100–3,000 USD/household refrigerator (from 1 door small type to luxury type)
Viet Nam's Context	■ Using R134a (GWP=1,430) and R600a (GWP=4/isobutene) as refrigerants.
Existing Policy & Measures	**Legal Framework** ■ Technical standards on energy performance testing for household refrigerator. **Energy Efficiency Labeling System** ■ Mandatory Energy Efficiency labeling for household refrigerator (January 2014) **National Standards** ■ TCVN 7828: 2016 ■ TCVN 7829: 2016
Current State of Market and Production	■ Media Group has reduced house hold refrigerators using HC-600a since 2011. Viet Nhat Sanaky Company is in the process of testing HC-600a refrigerators for commercialization.

[112] Pixabay (https://pixabay.com/)
[113] MONRE and UNEP. (2012). Technology Needs Assessment for Climate Change Mitigation, Viet Nam, Synthesis report

F-gas 3 Commercial Refrigerator/Cold Storage

Baseline Technology	Suggested Low Carbon Technology(ies)
R404a (GWP=3,920) and R410a (GWP=2,090)	■ **Changing Refrigerant of Refrigerator in Commercial Sector (to R744 (GWP=1) and R290 (GWP<dozens))**
Photo Image	
Summary of Technology	Changing high GWP refrigerant to low GWP refrigerant (CO_2) in refrigerators in the commercial sector. Most of Hydrofluorocarbons (HFC) emissions are from commercial refrigerators and cold storage sector. Twice as much amount of refrigerant is needed for commercial refrigerators compared to commercial air conditioner.
Technical Advantages	■ Electricity saving is 2,400 USD/year[114] (reach–in type 15HP showcase freezer). ■ Low GWP refrigerant, CO_2 (GWP=1) is developed by Japanese manufacturers and already available in the Japanese market. ■ Freezer would be smaller in size and lightweight. ■ Easiness of workmanship and reduction in cost of installation can be expected.
Mitigation Potential	■ Data Not Available
(Initial) Cost	Non Freon, CO_2 refrigerant freezer (suggested retail price, excluding installation fees): ■ 37,000 USD / 10HP (Horsepower) type ■ 55,000 USD / 15HP type ■ 68,000 USD / 20HP type
Viet Nam's Context	■ Using R410a (GWP=2,090), R404a (GWP=3,920), R407c (GWP=1,770), R507c (GWP=3,990) and R717 (GWP=less than 1) as refrigerants.
Existing Policy & Measures	**Legal Framework** ■ Technical standards on energy performance testing for household refrigerator. **Energy Efficiency Labeling System** ■ Mandatory EE labeling for household refrigerator (2014) **National Standards** ■ TCVN 7828: 2016 ■ TCVN 7829: 2016
Current State of Market and Production	■ Commercial refrigerators with CO_2 are expensive, and there is no installation and production in Viet Nam.

[114] Panasonic Eco Solutions Commercial Equipment Systems Co., Ltd. (2014). CO_2 refrigerant freezer. [https://panasonic.co.jp/ap/pces/news/141127.pdf]

F-gas 4, 5 Air Conditioner (Residential sector and Commercial sector)

Baseline Technology	Suggested Low Carbon Technology(ies)
R410a (GWP=2,090)	■ **Changing Refrigerant of Air Conditioner in Household and Commercial sector (to R32)**
Photo Image	
Summary of Technology	Changing high GWP refrigerant to low GWP refrigerant (R32) in air conditioner in the household and commercial sectors. R32 has zero ozone depletion potential, and 1/3 GWP of R410a. The density of R32 is much smaller than R410a, making the amount of charge smaller. Since the GWP is measured per kg, the total climate impact from the refrigerant in the system is even smaller than suggested by the GWP. R32 is classified as mildly flammable refrigerant, however several manufacturers has already overcome technical challenges and succeeded in commercializing it.
Technical Advantages	■ Air conditioners with R32 and R410a have the same cooling performance. ■ R410a is a mixed refrigerant whereas R32 is a single component refrigerant that is easy to handle and recover. ■ Zero ozone depletion and low toxicity.
Mitigation Potential	68% reduction by changing refrigerant from R410a (GWP=2,090) to R32 (GWP=675). Calculation: 675/2,090 = 0.3229 → 68% of reduction
(Initial) Cost	■ 515-550 USD: 9,000 BTU with R32 ■ 677-695 USD: 12,000 BTU with R32 ■ 947-1,072 USD: 18,000 BTU with R32 ■ 1,247-1,481 USD: 24,000 BTU with R32
Viet Nam's Context	■ Using R410A (GWP=2,090) as a refrigerant. ■ All R32 is imported in Viet Nam.
Existing Policy & Measures	**Legal Framework** ■ AC testing and rating method (revised in 2015, implementation from 2017) **Energy Efficiency Labeling System** ■ Mandatory Energy Efficiency labeling for AC (2013) **National Standards** ■ TCVN 7830: 2015 ■ TCVN 10273-1:2013 (ISO 16358-1:2013) ■ TCVN 6576: 2013
Current State of Market and Production	■ ACs with R32 for household use are widely available in Viet Nam. ■ ACs with R32 for commercial use are limited in the market due to technical and safety reasons.

F-gas 6 Automobile Air Conditioner

Baseline Technology	Suggested Low Carbon Technology(ies)
R134A (GWP=1,430)	■ **Changing Refrigerant of Air Conditioner for Automobiles**
Photo Image	
Summary of Technology	Changing high GWP refrigerant to low GWP refrigerant (HFO-1234yf) in automobile AC consists of re-filling the low GWP refrigerant gas into AC and recovering the old high GWP refrigerant. HFO-1234yf was developed by Honeywell and Du Pont in 2008 and has been installed into automobiles manufactured after 2011.
Technical Advantages	■ Easiness of changing the cooler gas. (Can be used with the existing standard equipment configuration and materials.) ■ Zero ozone depletion potential and low toxicity
Mitigation Potential	■ 99.7% reduction by changing refrigerant from R134a (GWP=1,430) to HFO-1234yf (GWP=4) (amount of gas in car AC: 300-1,000g/car) Calculation: 4 / 1,430 = 0.00279 → 99.7 % reduction[115]
(Initial) Cost	■ 300-400 USD/400 g of cooler gas (HFO-1234yf (GWP=4)) ■ 1,500-2,000 USD for changing the whole car AC system
Viet Nam's Context	■ Using R134A (GWP=1,430) as a refrigerant.
Existing Policy & Measures	**Legal Framework** ■ No specific policy ■ No specialized national standards ■ TCVN 5687:2010 ■ TCXD 232: 1999
Current State of Market and Production	■ Only imported luxury cars has AC with HFO-1234yf refrigerant. ■ HFO-1234yf refrigerant is not available in Viet Nam's market.

[115] Honeywell International Inc., Solstis yf (HFO-1234yf) (Product information). [https://www.honeywell-refrigerants.com/japan/product/solstice-yf-refrigerant/]

F-gas 7 Maintenance

Baseline Technology	Suggested Low Carbon Technology(ies)
No Regular Inspection	■ **Leakage Inspection (Maintenance) of Refrigerator, Cold Storage and Air Conditioner of Commercial Sector**
Photo Image[116]	
Summary of Technology	There are three steps for leakage inspection: (1) exterior check: visual inspection, (2) indirect inspection: monitoring of gas pressure, discharge temperature, etc. and (3) direct inspection: using bubbling liquid, electronical gas detection machine, etc. Based on the results of above inspections, required maintenance and repairs to prevent leakage are conducted.
Technical Advantages	■ Proper management of refrigerant can prevent reduction of equipment's energy efficiency and save cost for refilling of lost refrigerant.
Mitigation Potential	■ Data Not Available
(Initial) Cost	■ 100-2,000 USD/inspection and repairing ■ 5,000–20,000 USD/training seminar for inspection and maintenance of F-gas device
Viet Nam's Context	■ Several companies organizing training programs on installation and maintenance for their operation staff to train.
Existing Policy & Measures	**Legal Framework** ■ QTKĐ: 05-2014/BLĐTBXH (2014) ■ Circular07/2014/TT-BLĐTBXH (2014) **National Standards** ■ QCVN 01:2008, BLĐTBXH ■ TCVN 8366:2010 ■ TCVN 6155/6156:1996 ■ TCVN 6104-1:2015 ■ TCVN 6008:2010
Current State of Market and Production	■ Some companies train their staff, however, there is no mandatory certification system for maintenance technicians. Training curriculum and materials to prevent F-gas leakage are needed.

[116] Nichiei Denki CO.,LTD.

CHAPTER 3

Barrier Analysis of the Current Options under Viet Nam's NDC and Identified Low Carbon Technologies

3 Barrier Analysis of the Current Options under Viet Nam's NDC and Identified Low Carbon Technologies

Following the identification of low carbon technology options corresponding to each and every mitigation options under Viet Nam's NDC, this chapter further explores Viet Nam's context associated with those mitigation options, by providing more in-depth analysis of practical barriers and challenges associated with the identified technology options.

Potential barriers were collected through interviews with relevant Line Ministries and by referring to sectoral documents. The summarized table was reviewed and analyzed by experts (shown in 3.1 to 3.7).

Barrier analysis for each identified low carbon technologies corresponding to NDC mitigation option provides essential information not only to help the Team to assess the applicability and feasibility of identified low carbon technology per se, as well as on robustness of the current mitigation options themselves, but also to establish a basis for criteria-based assessment in prioritizing low carbon technologies to support implementation of mitigation options.

The analysis explores the barriers from two different angles: Policy and market barriers; and technical/technology specific barriers. Provided some mitigation options and identified low carbon technologies are inter-related to each other, cross-cutting issues and considerations were also discussed.

3.1 Energy

NDC Mitigation Options	Policy & Market Barriers	Technical Barriers
RESIDENTIAL & COMMERCIAL		
E1 High efficiency residential air conditioning	● **Low incentive for energy efficiency** with current utility cost (7 cents/kwh). Price may vary depending on the group of interest, yet still lower compared to that of developed countries. ● **Awareness of household owners** to make informed decisions for purchase or replacement ● **Price competitiveness** of energy efficient products ● **Limitation of expanding market** to rural area ● **Consumer interests** in additional high-spec functions (e.g. air cleaner and humidity controller).	● Envelop insulation may need to be added to achieve the level of efficiency performance required.
E2 High efficiency residential refrigerators	● **Low incentive for energy efficiency** with current utility cost (7 cents/kwh) ● **Price competitiveness** of energy efficient products ● **Consumer interests** in additional high-spec functions (ex. long term security of food quality and economical operation system)	● Limited energy saving options for small capacity refrigerators.
E3 High efficiency residential lighting	● **Low incentive for energy efficiency** with current utility cost (7 cents/kwh) ● **Price competitiveness** of energy efficient products	● For CFL, careful handling of heavy metal (mercury) is obligatory.
E4 Solar water heaters	● **Low consumer demand** for replacing electricity heater to solar water heaters	● Less insolation in northern areas in wintertime when demand for heat increases.
E10 High efficiency commercial air conditioning	● **No mandatory energy efficiency standard and labeling** ● **Less market competitiveness** ● **High initial cost**	● Lower performance by simultaneous operation in multi air conditioner. ● Multiple impact on connected equipment by single unit damage.
INDUSTRIAL		
E5 Cement-making technology improvements	● **High initial cost** for some technologies ● **Reluctant investment**	● Limited applicability of certain technologies to old plants due to predesigned concrete

Chapter 3

	behavior of manufacturers to Energy Efficiency measures with payback period more than 2 years. ● **Low incentive for energy efficiency measures** due to current global market trend (oversupply). ● **Improvement of energy efficiency in the existing whole production cycle** a priority than replacing rotary kiln from the scratch.	strength, thermal profile and insulation. ● High maintenance requirement (e.g. vertical roller mill) ● Technical management requirements (fuel, fuel material grinding, air ratio, exhaust gas, kiln burner, cooler operation).
E6 Brick-making technology improvements	● Traditional brick industry is considered low investment, with seasonal activities.	● VSBK presents low productivity and poor fired brick quality with certain clays. Suitable only for firing solid bricks with long pay-back period.
E7 Substitution of ethanol for gasoline in transport	See *Transport Sector*	
E8 Passenger transport modal shift from private to pubic		
E9 Freight transport switch from road		
POWER GENERATION		
E11 Biomass power plants	● **Subject to payment** for forest ecosystem services (PFES).	● Stable supply of quality biomass to the plant is needed. ● Efficient collection of fuel biomass is needed. ● Environmental safeguard: Compensatory measures for forest loss areas may be required.
E12 Small hydropower plants	● **Subject to Payment** to PFES. ● Legal preparedness governing small hydropower.	● Compensatory measures for forest loss areas.
E13 Wind power plants (domestic) **E14** Wind power plants (international support)	● **Sufficiency of existing fiscal incentive scheme (FIT)** to promote investment. ● **Running cost** consideration.	● **Regular maintenance** to secure operational efficiency. ● **Low frequency noise control measures** if installed nearby households. ● **Safeguard measures** (site location distant from e.g. habitat of bird species). ● **Infrastructure** to transport equipment (turbines, blades, building materials, etc.) is required. ● **Strengthening of grid line network** is required.
E15 Biogas power plants	● Current MOIT Circular (No.32/2010/TT-BCT) not	● **Stable supply of quality biogas** to the plant.

	providing provisions for grid connection less than 1 MW ● Fiscal/tax incentives. ● **No environmental standard** for CH_4 emission to atmosphere for existing QCVN for pig farm. ● **Subject to payment** to PFES	● **Environmental safeguard**: Compensatory measures for **forest loss areas.**
E16 Ultra-supercritical coal power plants	● **High initial cost** (life cycle cost consideration required)	● **Coal type** requirement ● **Stable supply** of required coal
E17 Solar PV power plants	● **Workable tariff** is important (level of tariff, indexation, etc.) ● **Draft PPA is not clear** about term, extension, grid connection ● **Simplification of permit procedure** is required. ● The incentives after June 2019 are not clear. ● Protection/countermeasure against theft of valuable parts may be necessary.	● **The grid connection requirement** is not clear ● **Proper installation and maintenance** of PV cells ● **Land acquisition** for large-scale installation. ● **Applicability:** Less insolation in northern area in wintertime ● Less roof area per population density in urban regions

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3.2 Transport

While the proposals regarding the transport sector have been broken down further into 3 mitigation options (E7, E8, and E9 as below), most technology options in the Transport sector share the same barriers. The following matrix collectively shows these common barriers.

NDC Mitigation Options	Policy & Market Barriers	Technical Barriers
E7 Substitution of ethanol for gasoline in transport	● **Standard not yet available** for bioethanol (quality, safety etc.). ● **Awareness of consumers** regarding the benefits of using bioethanol is not wide-spread.	● Domestic production capacity available but not commercially viable (production cost is too high). ● Currently lacking service supplier/distribution network. ● Insufficient expertise and infrastructure of fuel quality control.
E8 Passenger transport modal shift from private to public	● **Delayed disbursement of project budget** (national and local government), affecting delivery of infrastructure. ● **Demand Risk:** In introducing railways and buses, the main issue generally is to secure the planned demand to fulfill project profitability. ● **Coordination** among various stakeholders and related plans is necessary. ● **Awareness raising** and behavioral change of using public transportations need to be promoted.	● Land acquisition and high land price for construction in urban area.
E9 Freight transport switch from road	● **Delayed disbursement of project budget** (national and local government), affecting delivery of infrastructure. ● **Coordination** among cargo owners and freight shippers is necessary.	● Infrastructures should be well established for smooth connection between road, rail and waterway. ● Various facilities/equipment to handle and transport cargoes should be installed. ● While there are service providers, capacity increase is a challenge for responding to possible demand shift/increase.

3.3 Agriculture

NDC Mitigation Options	Policy & Market Barriers	Technical Barriers
LIVESTOCK		
A1 Increased use of biogas	● **Medium to high initial cost** required to construct a bio digester, biomethanation and power generation system.	● **Skilled and trained labor** required to construct a bio digester. ● **Proper handling (incl. safety measures) and maintenance** during operationalization of installed digesters to avoid accidents.
A11 Improvement of livestock diets	● Lysine cost depends on the cost of input (maize), but method of amino acid fermentation by bacteria is widely accepted. ● **Cross sectoral issue** may occur when using maize and soybean as amino acid source (i.e. food security).	● No negative effect on overdose lysine intake is observed, yet diet with balanced amino acid is desired. ● Proper application by farmers is needed to maximize effectiveness.
WATER RESOURCES		
A3 Alternate wetting and drying, and improved rice cultivation system (small scale 0.2M ha) **A9** Alternate wetting and drying, and improved rice cultivation system (large scale 1.5M ha)	● **High initial investment cost** for high efficiency pump for drainage system (suits medium-large scale farming). ● **Coordination challenge** Among farmers on prioritizing water usage.	● **Technical training requirement** on high efficiency pump (horizontal shaft, diagonal flow) especially, for famers and water users. ● **Regular maintenance** to ensure functionality and pump efficiency.
A13 Improvement of technologies for aquaculture and waste treatment in aquaculture	● **High initial investment cost is required to construct biomethanation and power generation system.**	● **Skilled and trained labor** is required to construct biomethanation and power generation system. ● **Proper handling (incl. safety measures) and maintenance** during operationalization of installed system to avoid accidents.
CROP PRODUCTION		
A5 Integrated crop management (ICM) in rice cultivation **A6** Integrated crop management (ICM) in upland annual crop cultivation	● Since the ICM system is developed for environmental impact rather than for producing commercial returns, **there is no premium available.**	● Balancing the requirements of running a profitable business with responsibility and sensitivity to the environment that includes practices to avoid waste, enhance energy efficiency and minimize pollution. ● Awareness to disseminate ICM concept among farmers. ● Yield of production reported is varied and further study is

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		required.
A8 Reuse of upland agriculture residues	• **High Cost** for collection and transport.	• **Land area requirement** to store residues and compost. • **Technical training requirement** for on-farm composting. • **Awareness of farmers** to fully reuse upland crop residues.
A14 Improved irrigation for coffee	• **High initial investment cost** for solar pump for coffee irrigation (suits medium-large scale farming).	• Relatively **high technical know-how requirement** for solar pump. • Precise management of irrigation scheduling to meet crop demands (drip irrigation).
A15 Improved technologies in food processing and waste treatment in agriculture, forestry and aquaculture	• **High initial investment cost** for installing high efficiency cooling for chilling and freezing facilities in cold chain process.	• Regular maintenance to ensure functionality of the system.
FISHERIES		
A12 Improvement of quality and services available for aquaculture such as inputs and foodstuff	• **High initial investment cost** for installing effluent treatment facilities.	• **Technical training requirement** for operationalizing effluent treatment facilities.
FERTILIZER		
A2 Reuse of agricultural residue as organic fertilizer	• **Stable supply is difficult** (depending on yield of agricultural material, weather and other geographical feature).	• **Technical training** requirement for on-farm composting. • **Awareness** of farmers to fully reuse upland crop residues. • It emits Methane, thus appropriate facility is required. • Quality of organic fertilizer highly depends on raw material and farmer's practice.
A7 Substitution of urea with SA fertilizer (Sulfate Amon $(NH_4)_2SO_4$)	• High dependency on import.	• Depending on SA synthesis method, it requires for high calories for SA production leading to CO_2 emission.
BIOCHAR		
A4 Introduction of biochar (small scale) **A10** Introduction of biochar (large scale)	• **Information on effectiveness of Biochar is lacking.** • **Cost performance is limited.**	• **It may cause deforestation** due to utilization of virgin forest as resources when applied at cow farm. • Awareness of farmers to fully reuse upland crop residues.

3.4 LULUCF

NDC Mitigation Options	Policy & Market Barriers	Technical Barriers
CONSERVATION		
F1 Protection of natural forest (1 million ha.) **F6** Protection of natural forest (2.2 million ha)	• **Limited financial resources** for conservation activities.	• Low modernization level of data collection and archiving (manual rather than IT-based, digital data availability). • Outdated forest fire warning systems need to be updated.
AFFORESTATION & REFORESTATION		
F4 Natural forest regeneration (200,000 ha) **F8** Natural forest regeneration (200,000 ha) **F9** Natural forest and production forest regeneration (400,000 ha)	• **Limited state budget** for forestry. • **Land use prioritization:** Limited room for further extension of forest area competing with arable land and urbanization.	• **Limited access to quality seed** for local residents and foresters.
MANGROVE REHABILITATION		
F2 Protection of coastal forest (100,000 ha) **F3** Plantation of coastal forest (10,000 ha) **F7** Plantation of coastal forest (30,000 ha)	• **High capital costs** in some areas of Viet Nam: Mangrove restoration by excavation and fill is expensive due to the high costs of large scale earthmoving[117]	• The technologies to plant and recover mangrove forest have not been invested for further research. • The map and data system designed to manage mangrove forest are still new and not in order. (TNA)
LONG ROTATION		
F5 Plantation of large timber production forest (150,000 ha)	• Income from forest harvest is delayed due to elongated rotation period which causes **liquidity gap.**	• Maintaining resistance of trees to pest and diseases as they will be exposed longer period than short-term rotation.

[117] Lewis. (2001). Mangrove Restoration - Costs and Benefits of Successful Ecological Restoration

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3.5 Waste

NDC Mitigation Options	Policy & Market Barriers	Technical Barriers
W1 Organic fertilizer production	● **Insufficient scale of economy** due to low market price, limited market size especially in northern area, and limited commercial suppliers. ● **Strategy for commercializing** compost products should be in place.	● **Product quality**: Strict separation of organic waste (removal of impurities) generally not sufficient. Most of the compost product does not suit agricultural use (mostly for industrial application, e.g. production forest). ● **Land area requirement** for large-scale production.
W2 Landfill gas recovery for electricity and heat generation	● **Limited application**: No large-scale application of this technology in Viet Nam. Some small-scale application in some landfills (Hue, Nam Song Landfills).	● **Overestimation risk**: Difficulty in estimating landfill gas potential. Overestimation may lead to overcapacity of energy utilization potential. ● **Proper control of landfill** in an anaerobic condition may prove difficult. ● **Proper installation** of LFG capture/collection infrastructure may prove difficult.
W3 Recycling of solid waste	● **No standard cost** for recycling facility operation.	● **Proper separation of recyclable items** in municipal level.
W4 Anaerobic treatment of organic solid waste with methane recovery for power and heat generation	● **Limited demand**: sufficient number of heat users in proximity of the facility is required.	● Collection of sufficient amount of organic waste with similar. Composition is required for heat production. ● Small scale (pilot) application in Hanoi and Hai Phong.

3.6 F-gas (HFC)

NDC Mitigation Options	Policy & Market Barriers	Technical Barriers
Option 1 **F-Gas Destruction**	● **Lack of policy framework** guiding collection, re-use, recycle of HFCs from Existing appliances, and penalty for releasing gas into the atmosphere.	● **System to collect and transport HFCs** to a designated destruction site needs to be established. ● Technical issues remain in the previous pilot destruction project in Viet Nam (incl. combustion temperature control in the kiln).
Option 2 **Change Refrigerant** - Refrigerator (residential, commercial)	● **Price competitiveness** of low GWP refrigerant.	● **Training** on maintenance and safety measures and requirements is needed. ● **Performance degradation** under high temperature **due to hazardous** nature of refrigerant (NH_3).
- Air Conditioner (residential, commercial)	● **Synchronization** with existing certification system on ACs (Viet Energy Star).	● **Flammability** (safety concerns) associated with alternative refrigerant (R32). ● **Insufficient number of skilled technicians** for maintenance and safe handling of refrigerant.
- Automobile Air Conditioner	● **Price competitiveness** of low GWP refrigerant (HFO-1234yf) ● **Insufficient supply** of HFO-1234yf	● **Insufficient number of skilled technicians** to safely handle refrigerant (HFO1234yf). ● **Difficulty in monitoring** old refrigerants (high GWP).
Option 3 **Leakage Inspection and Maintenance**	● **Lack of policy framework** in place guiding especially collection, re-use, and recycle of HFCs from EXISTING appliances. ● **Lack of guidelines** for inspection, maintenance and repairing. ● **Low awareness of stakeholders** for the need to address HFC. ● **High Cost** of collecting HFCs and lack of financial incentives.	● **Insufficient number of skilled technicians** to properly conduct maintenance and repairing (e.g. tightening of bolts, changing air joints, brazing patching of pipes, renewal, on-site confirmation of leakage).

3.7 Cross-Cutting Consideration

The barrier analysis also revealed that some mitigation options in Viet Nam's NDC and associated low carbon technologies present cross-cutting issue in their contents, calling for cross-sectoral discussions and coordination among concerned stakeholders to enable effective implementation.

Table 11 Summary of Cross-cutting issues and Concerned Stakeholders

Mitigation Options /Technologies	Cross-cutting Considerations	Concerned stakeholders
Energy Efficiency (Demand Side Management)	● As compared to power generation sub-sector where identification of low carbon technology options are relatively straightforward, Demand Side Management (DSM) for energy efficiency (residential, commercial) encompasses diverse technologies/devices/appliances over different jurisdictional boundaries, signifying that mitigation potential in DSM in the context of climate mitigation requires holistic approach and inter-agency collaboration.	● MOC, MOIT, MOT (Cross jurisdictional boundaries)
Biogas and Composting/Fertilizer (**A1, A8, A15, E15** and **W3)**	● Coordination is required for treatment and use of organic waste from agriculture and food processing, when considering biogas collection, power generation, and composting/fertilizer production and application.	● Energy, Agriculture, Waste (Cross sectoral boundaries)
Afforestation, Reforestation and Agricultural Land Use (**F4, F8, F9 and Agriculture**)	● Coordination is required for prioritization of land use at national and regional level for forest regeneration (afforestation/reforestation) and expansion of agricultural lands. In addition, it is essential to maintain the integrity of the life of indigenous people who highly rely on products from natural forests.	● Forestry, Agriculture (Cross sectoral boundaries) ● Indigenous people (Consideration to social environment)
Biomass, Biofuel and Protection of Forest (**E7, E11, F9 and F5**)	● Coordination is required for wood biomass power plant, biofuel production and protection of forests, particularly in regeneration of production forest and large timber production.	● Energy, LULUCF (Cross sectoral boundaries)
F-gas (HFC), Cement, EE Appliances, Cold Chain (**E5 and F-gas**) (**E1/E10, E2 and F-gas**) (**A15 and F-gas**)	● Energy-F-gas (HFC) Coordination is required for collaboration with cement sector in working on destruction of collected HFC, replacement of refrigerant and/or refrigerator/air conditioner. Agriculture-F-gas (HFC) Coordination is required when replacing cooling medium used in cold chain (commercial, mobile refrigerator, freezer) as part of food processing technology.	● Energy, F-gas ● Agriculture, F-gas (Cross sectoral boundaries)
Clean Power Generation and Protection of Natural Forests (**E13, 14, E17, F1 and F16**)	● Construction of large size power plants calls for large flat space (PV), proprietary rights (PV, wind and hydro-power), and building additional access road in mountains (hydro-power). In most cases, when cutting down trees in mountain and coordinating for inhabitant migration, cross-sectoral discussion is required at an early stage.	● Energy, LULUCF (Cross sectoral boundaries) ● Local government (Cross jurisdictional boundaries, Consideration to social environment)
Replacement to Energy Efficient Equipment and its Recycling (**Energy Efficiency sector, E7, W3**)	● When promoting energy efficient devices such as air conditioner with inverter, LED, and energy saving refrigerators, appropriate recycling system needs to be considered in the waste sector to achieve sufficient separation and collection depending on materials (i.e. organic waste, metal and refrigerants). Utilization of biofuel can also be a beneficial option for transferring wastes between stations.	● Energy Efficiency, Waste (Cross sectoral boundaries)
Food/Water Security and Mitigation Options in Transport and Agriculture **(E7, A11 and A14)**	● Food and water security is one of the issues that came out as a result of climate change. To prevent the demand competition in future between food/water securities and low carbon technology (e.g. biodiesel production, improving animal feed, hydropower generation), alternative resources need to be considered. Also, in cases where International River is involved, it may come to an international conflict.	● Energy, Agriculture (Cross sectoral boundaries) ● Neighboring countries (Cross national boundaries)

CHAPTER 4

Next Step: Approach for Prioritizing Technology Options

4 Next Step: Approach for Prioritizing Technology Options

Identification of potential low carbon technologies for mitigation options is considered an initial step for further elaboration of Viet Nam's NDC, and prioritization of low carbon technology is considered the next critical step of the assessment work.

While the stakeholder consultation on criteria is still on-going, in-depth assessment of priorities identified technology options for NDC that will be covered in the next volume of the publication. It is indispensable to explore and develop potential criteria for prioritization that is acceptable to sectors of concern, and also suitable for specific sectoral conditions and circumstances, at an early stage of the assessment. In this regard, the Assessment Team embarked on sector-wide consultation on appropriate criteria for 7 target sectors, and took stock of stakeholder views as an appropriate set of prioritization criteria for each sector.

In advancing prioritization and criteria setting work, the Assessment Team engaged in communication with identified key stakeholders in each sector, consulted with officials from MONRE and LMs to confirm views, and facilitated coordination to reach a common agreement on the criteria. The image of stakeholders involving in this assessment work is depicted in Figure 6.

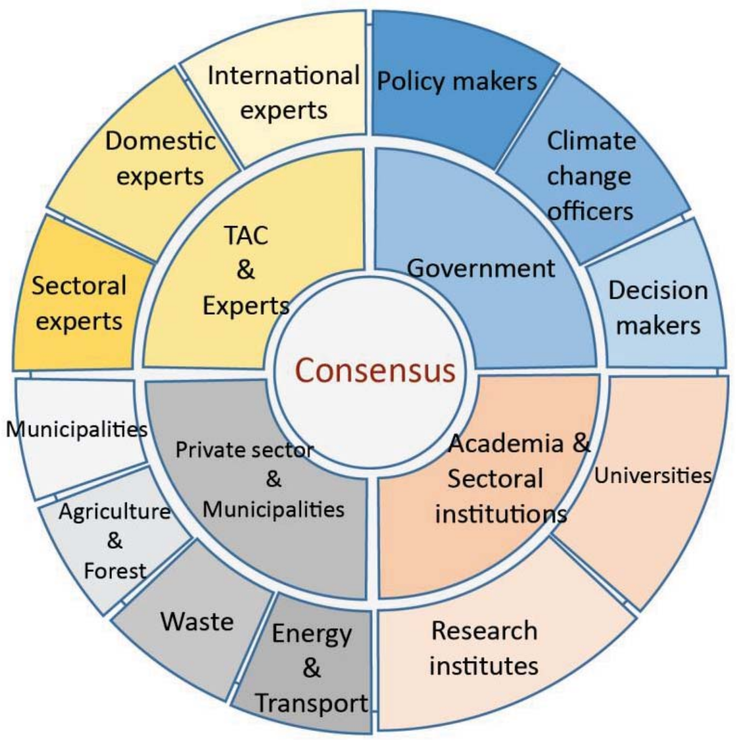

Figure 6 Key stakeholders for building consensus

Table 12 Five Common Criteria Proposed for Prioritization

Criteria	Contents
Economic performance	Consider economic impact by implementation, such as initial cost, operational cost, and lifecycle cost.
GHG emissions reduction impact	Assess emissions reduction impact by referential value which can be found in existing catalogues, case studies or benchmarks, taking emission reduction scenario into account.
Versatility	Evaluate versatility such as maintenance performance and flexibility setting.
Other environmental impact	Verify if any negative impact on the environment exists (e.g. leakage of F-gas from energy saving equipment).
Acceptability in Viet Nam's Context	Confirm conditions for technical acceptance such as distribution and available service center.

Table 12 suggests the prioritization criteria initially proposed by the Assessment Team commonly applicable to all target sectors. Stakeholder consultations with respective LMs and agencies revealed that while the suggested criteria is deemed useful, adopting a different set of criteria for each sector would be more suitable in view of diverse sectoral circumstances and needs. Following this direction, the assessment work adopted a tailored approach for each sector for selecting and coming up with a set of prioritization criteria on top of the proposed criteria, with following approaches;

Key Steps for Stakeholders Consensus Building on prioritization

- ✓ Apply common process to determine evaluation criteria for all sectors. This entails identification of key stakeholders (e.g. policymakers, private sector, and market participants); followed by consultation with the identified key stakeholders and experts and agreeing on prioritization criteria for the sector.
- ✓ Explore and adopt sector-specific criteria to respond to sectoral circumstances and conditions.
- ✓ Embark on assessment of prioritized technology based on a mixed set of common and sector-specific criteria for all 7 sectors.

As a result of the Stakeholders Consensus Building on prioritization, following comments were shared.

On cost, it was pointed out that operation cost should also be considered as an evaluation factor; however, others noted that this may result in some inconsistency between sectors.

- For waste treatment, cost per kilogram of waste need to be calculated.

- For power generation, evaluating renewable energy and coal-fired power plants with comparing only their initial costs does not make much sense.
- In transport sector, projects are usually not launched as a climate change measure; hence initial cost does not make a significant difference for technology prioritization. Comparison should be made by comparing the additional cost.

Also, there were some comments regarding private investment; that investment possibility needs to be considered because good technology does not always have good investment environment; and policy framework accelerates private investment for some sectors, but for others government subsidy is essential.

Other comments by the stakeholders include;

- local government should also be included as stakeholder;
- using different units for the evaluation of economic performance and GHG reduction may be confusing;
- analysis of the barriers when introducing the low carbon technologies to Viet Nam would bring added value; and
- annotations to describe the process should be added for evaluation by data, value and quantity.

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ANNEX I

Law/Decree/Decision/Standard referred in this publication are listed.

#	Decree/ Decision No.	Subject	Option No.
1	Decision No.1427/QD-TTg (2012)	Prime Minister on the approval of the National Targeted Program on Energy Efficiency and Conservation for the period 2012–2015	
2	Law No. 50/2010/QH12	Law on Economical and Efficient Use of Energy No: 50/2010/QH12 (as regulated by Decree No.21/2011/NĐ-CP on the Law on Economical and Efficient Use of Energy and Measures for its Implementation) (17 Jun, 2010)	E1, E2, E3, E5, E6, A7
3	Decree No. 21/2011/NĐ-CP	Detailing the Law on Economical and Efficient Use of Energy and measures for its implementation (29 Mar, 2011)	E1, E2
4	Decision No. 03/2013/QĐ-TTg	Amending and supplementing a number of articles of the Prime Minister's Decision No. 51/2011/QĐ-TTg of September 12, 2011, promulgating the list of devices and equipment subject to energy labeling and application of the minimum energy efficiency, and the implementation roadmap (14 Jan, 2013)	E1
5	Decision No.428/QĐ-TTg	The approval of revisions to the national power development plan from 2011 to 2020 with visions extended to 2030 (18 Mar, 2016)	E11, E12, E13/14, E17
6	Decision No. 37/2011/QĐ-TTg	On the mechanism supporting the development of wind power project in Vietnam	E13/14
7	Decree No.75/2011/ND-CP	On state investment credit and export credit	E13/14
8	Decision No.11/2017/QD-TTg	On the mechanism for encouragement of the development of solar power projects in Vietnam	E17
9	Decree No.32/2017ND-CP	On state investment credit	E17
10	Decision No.177/2007/QĐ-TTg	Project of biofuel development to 2015, vision to 2025 (20 Nov, 2007)	E7
11	Decision No.53/2012/QĐ-TTg	Roadmap applied percentage of biofuels blended with traditional fuels (22 Nov, 2012)	E7
12	Decision No.280/QĐ-TTg	Development of urban public transport by bus for period 2012 to 2020 (8 Mar, 2012)	E8
13	Decision No.214/QĐ-TTg	Adjustment of Viet Nam railway development strategy to 2020, vision to 2050 (10 Feb, 2015)	E8, E9
14	Decision No.1456/QĐ-BGTVT	Green Growth and Climate Change Action plan of Ministry of Transport for period 2016-2020 (11 May, 2016)	E8, E9
15	Decision No.4088/QĐ-BGTVT	Sustainable Development Action Plan of Ministry of Transport for period 2013-2020 (12 Dec, 2013)	E9

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16	Decision No.4146/QĐ-BGTVT	Planning for development of Inland waterway transportation flot from 2015 to 2020, with an orientation to 2030 (19 Nov, 2015)	E9
17	Decision No.3119/QĐ-BNN-KHCN	Green House Gas (GHG) emissions reduction in the Agriculture and Rural Development sector up to 2020, the Ministry of Agriculture and Rural Development (16 Dec, 2011)	A1, A2, A3/9, A4/10, A5, A6, A8, A11, A12, A13, A14, A15
18	Decision No.543/QĐ-BNN-KHCN	To promulgate the Action Plan on Climate change response of agriculture and rural development sector in the period 2011-2015 and vision to 2050, the Minister of Agriculture and Rural Development (23 Mar, 2011)	A1, A2, A3/9, A4/10, A5, A6, A8, A11, A12, A13, A14, A15
19	Decision No.24/2014/QĐ-TTg	Support mechanism for development of biomass power projects in Viet Nam, the Prime Minister of Government (24 Mar, 2014)	A1, A15
20	Decision No. 1621/QĐ-TTg	Approving the master plan on development of Vietnam's chemical industry through 2020, with a vision to 2030 (Sep. 18, 2013)	A7
21	Decree No. 108/2017/ND-CP	On fertilizer management	A2, A4/10
22	Decision No.18/2007/QĐ-TTg	Viet Nam Forest Development Strategy for 2006-2020 (5 Feb,2007)	F1/6, F4/8/9
23	Decision No.57/QĐ-TTg	Forest Protection and Development Plan for 2011-2020 (9 Jan, 2012)	F1/6, F4/8/9
24	Decision No.1565/QĐ-BNN-TCLN	Approving "Scheme to Restructure the Forestry Sector" (8 Jul, 2013)	F1/6, F4/8/9
25	Decision No. 886/QĐ-TTg	Approving target program on sustainable forestry development (2017)	F1/6, F5

#	Decree/ Decision No.	Subject	Option No.
26	Decision No.120/QĐ-TTg	Approving the Project on Protection and Development of Coastal Forests to Cope with Climate Change in 2015-2020 Period" (22 Jan, 2015)	F2/3/7
27	Decision No. 38/2016/QĐ-TTg	Incentive policy on forest protection and development and infrastructure development.	F2/3/7
28	Decision No.1560/QĐ-BNN-TCLN	Promulgating the list of high technologies applied in forestry (25 April, 2017)	F4/8/9
29	Decision No.774/QĐ-BNN-TCLN	Approval of Action Plan to Improve the Productivity, Quality and Value of Planted Production Forest in the Period 2014-2020 (18 May, 2014)	F5
30	Decision No.83/QĐ-BNN-TCLN	Approval of the Scheme of implementation of sustainable forest management and forest certification period 2016-2020 (2016)	F5
31	Decree No. 59/2007/ND-CP	Solid waste management	W1, W2, W3 W4
32	Decision No. 1440/QD-TTg	the Prime Minister approving the Planning on construction of solid waste treatment facilities in three Northern, Central Vietnam and Southern key economic regions up to 2020.	W1, W2, W3 W4
33	Decision No.2149/QĐ-TTg	Approving the national strategy for the integrated management of solid waste by 2025 and a vision towards 2050 (17 Dec, 2009)	W1, W2, W3 W4
34	Decision No.798/QĐ-TTg	Approving the Program for Investment in Solid Waste Treatment during 2011-2020 (25 May, 2011)	W1, W2, W3 W4
35	Decision No.986/QĐ-BXD	Promulgating action plan of solid waste treatment investment program in period of 2011-2020 (2011)	W1, W2, W4
36	Decree No. 38/2015/ NĐ-CP	Regulating waste and scrap management	W3
37	Circular 128/2016/TT-BTC	providing the exemption of export duty for environmentally friendly products	W3
38	Decree No. 19/2015/ND-CP	Detailing the implementation of a number of articles of the Law on Environmental Protection	W3
39	Decision No.31/2014/QĐ-TTg	Supporting mechanism for the development of waste-to-energy projects (5 May, 2014)	W2, W4
40	Circular No. 32/2015/TT-BCT	Standard Power Purchase Agreement (PPA) for waste-to-energy facility	W2
41	Circular No. 7/2014/TT-BLĐTBXH	The issuance of 27 technical safety inspection procedures for machinery and equipment subject to strict work safety requirements under the management of the ministry of labor - invalids and social affairs	F-gas7

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42	Circular 29/2015/TT-BCT	On contents, procedures for developing and approving the master plans for development and use of biomass energy	E11
43	Circular 44/2015/TT-BCT	On Project development, Avoided Cost Tariff and Standardized Power Purchase Agreement for biomass power projects	E11
44	Decision 942/QD-BCT	Promulgation of Regulation on Avoided Cost Tariff for 2016 Biomass Power Projects	E11
45	Circular No. 32/2014/TT-BCT	Producing on establishmentand application of avoidable cost tariff schedule and promulgation of specimen power purchase agreement (PPA) to small hydropower plants	E12
46	Circular No. 06/2013/TT-BCT	Promulgating the content, order, procedure, appraisal and approval for wind power development planning	E13/14
47	Circular No. 32/2012/TT-BCT	Regulations on implementation of wind power projects development and Standardized Power Purchase agreement for wind power projects	E13/14
48	Circular No. 96/2012/TT-BTC	Guidelines for financial mechanism to support electric price for wind power projects on grid tie	E13/14
49	TCVN 7830:2015	Non-ducted air conditioners. Energy Efficiency (2015-11-09,3185/QĐ-BKHCN)	E1,E10 F-gas4/5
50	TCVN 10273:2013	Air-cooled air conditioners and air-to-air heat pumps -- Testing and calculating methods for seasonal performance factors -- Part 1: Cooling seasonal performance factor	E1, E10, F-gas 4/5
51	TVCN 6576:2013	Non-ducted air conditioners and heat pumps. Testing and rating for performance (2013-12-31; 4264/QĐ-BKHCN)	E1, E10 F-gas 4/5
52	TCVN 7828:2016	Refrigerator, refrigerator-freezer, and freezer, Energy Efficiency (2016)	E2, F-gas 2, F-gas 3
53	TCVN 7829:2016	Refrigerator, refrigerator-freezer, and freezer. Method for determination of energy efficiency (2016)	E2, F-gas 2, F-gas 3
54	TCVN 8249:2013	Linear tubular fluorescent lamps - Energy efficiency (2013-12-31, 4252/QĐ-BKHCN)	E3
55	TCVN 7451-1:2005	High efficiency lighting products. Part 1: Minimum energy performance (2006-03-13, 514/QĐ-BKHCN)	E3
56	TCVN 7451-2:2005	High efficiency lighting products. Part 2: Methods for determination of energy performance (2006-03-13, 514/QĐ-BKHCN)	E3
57	TCVN 7896:2015	Compact Fluorescent Lamps. Energy efficiency (2015-03-31,595/QĐ-BKHCN)	E3
58	TCVN 8248:2013	Electromagnetic ballasts for fluorescent lamps. Energy efficiency (2013-12-31, 4250/QĐ- BKHCN)	E3
59	TCVN 7897:2013	Electronic ballasts for fluorescent lamps. Energy efficiency (2013-12-31, 4250/QĐ-BKHCN)	E3

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60	TCVN 8251:2009	Solar water heaters. Technical requirements and testing methods (2009-12-31, 3060/QĐ-BKHCN)	E4
61	TCVN 7898:2009	Storage water heaters. Energy efficiency (2009-04-20, 632/QĐ-BKHCN)	E4
62	QCVN 05:2013/BTNMT	National technical regulation on ambient air quality (2013-10-25, 32/2013/TT-BTNMT)	E11,E15, E16
63	QCVN 22:2009/BTNMT	National Technical Regulation on Emission of Thermal Power industry	E11,E15, E16
64	QCVN 23:2009/BTNMT	National Technical Regulation on Emission of Cement Manufacturing Industry (2008-11-16, 25/2009/TT-BTNMT)	E11,E15, E16
65	QCVN 08:2015/BTNMT	National technical regulation on surface water quality (2015-12-21 65/2015/TT-BTNMT) (replace QCVN 08:2008/BTNMT)	E11,E15, E16
66	QCVN 09:2015/BTNMT	National technical regulation on underground water quality	E11,E15, E16
67	QCVN 10:2015/BTNMT	National technical regulation on coastal water quality (2008-12-31, 16/2008/QĐ-BTNMT)	E11,E15, E16
68	QCVN 40:2011/BTNMT	Industrial waste water – Discharge standards	E11,E15, E16
69	TCVN 6576:2013	Non-ducted air conditioners and heat pumps. Testing and rating for performance (2013-12-31; 4264/QĐ-BKHCN)	F-gas 4/5
70	TCVN 5687:2010	Ventilation-air conditioning. Design standards (2010)	F-gas 6
71	TCXD 232:1999	Ventilating, Air-Conditioning and Cooling System - Manufacture, Installation and Acceptance	F-gas 6
72	QTKĐ: 05-2014/BLĐTBXH	Procedures for inspection on technical safety of refrigerant system(QTKD: 05-2014/BLDTBXH)promulgated together with Circular07/2014/TT-BLDTBXH dated 06March 2014	F-gas 7
73	QCVN 01:2008/BLĐTBXH	National technical regulations on safe work of Steam boiler and pressure vessel	F-gas 7
74	TCVN 8366:2010	Pressure vessels. Requirements of design and manufacture (2010-05-13, 804/QĐ-BKHCN)	F-gas 7
75	TCVN 6155:1996	Pressure vessels. Safety engineering requirements of erection, use, repair (1996-07-26, 1596/QĐ-TĐC)	F-gas 7
76	TCVN 6156:1996	Pressure vessels. Safety engineering requirements of erection, use, repair. Testing method (1996-07-26, 1596/QĐ-TĐC)	F-gas 7
77	TCVN 6104-1:2015	Refrigerating systems and heat pumps -- Safety and environmental requirements -- Part 1: Definitions, classification and selection criteria (2015-12-31, 4074/QĐ-BKHCN)	F-gas 7
78	TCVN 6008:2010	Pressure equipment - Welded - Technical requirements and testing methods (2010-05-13, 804/QĐ-BKHCN)	F-gas 7

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