LOW CARBON TECHNOLOGY ASSESSMENT FOR CLIMATE CHANGE MITIGATION IN VIET NAM

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Abstract: *This paper presents a multicriteria low carbon assessment for seven sectors identified in the Nationally Determined Contribution (NDC) of Viet Nam including energy efficiency, power generation, transport, agriculture, land use, land-use change and forestry (LULUCF), and waste, plus F-gas. Specific technologies for sectoral mitigation options identified in Viet Nam's NDC were selected and assessed. An analysis and discussion on policy and investment barriers for deploying the identified low carbon technologies for seven sectors is also presented. Key sector-specific challenges for implementation of the identified low carbon technologies for enabling Viet Nam's NDC are discussed. For future steps, the sharing of information between stakeholders prior to the planning of technology introduction would help to promote effective deployment of the technologies in Viet Nam.*

Keywords: *low carbon technology, climate change mitigation, multi-criteria assessment, nationally determined contribution.*

1. Introduction

1.1. Background

The Nationally Determined Contributions (NDC) of Viet Nam has identified 45 mitigation options for seven sectors including energy efficiency, power generation, transport, agriculture, land use, land use change and forestry (LULUCF), waste, and here F-gas is also considered. With the support of JICA's Technical Assistance Project on the Planning and Implementation of NAMAs ("SPI-NAMA"), a low carbon technology assessment project was implemented. The Ministry of Natural Resources and Environment (MONRE), the focal point for climate change, has cooperated with relevant line ministries (MOIT, MOT, MARD, MOC and MPI) on the project implementation. The aims was to identify all applicable low carbon technologies, develop the capacity of line ministries in charge of mitigation, improve coordination among departments, and obtain sufficient inputs for future review and update of NDC [1]. The objectives are as follows:

o Objective 1: Enhancement of Planning, Implementation and Coordination Capacity. The work aims to enhances capacities of the Government in multiple ways as (1) planning capacities of relevant line ministries (LMs) to develop and implement sector-based action plans for NDC; (2) effective coordination capability within related LMs, and also between MONRE and key stakeholders through reaching internal consensus; (3) facilitative capacity of MONRE by pointing out Viet Nam's context and clarifying policy needs, mitigation actions to enable the deployment of low carbon technologies.

o Objective 2: Direct inputs to further review and update Viet Nam's NDC. Existing proposed mitigation options under the NDC are to be revisited to confirm legitimacy of assumptions, scope, and barriers against Viet Nam's country-specific context and

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conditions. Further assessment and identification of potential options beyond the current scope, as presented in the Assessment work, will be the direct inputs to the revision process of NDC.

The 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 through stakeholder consultations per sector. These technologies were then subjected to evaluation with universal and sector specific criteria in order to extract prioritized technologies, exploring prototype projects to find opportunities for future deployment.

These options were identified by the INDC Technical Report, and the elaboration of means of implementation through identifying all applicable low carbon technologies. 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). In order to collect views from a wide range of stakeholders, private sector, and research institutes were also invited to join in the assessment work process [2].

The institutional arrangement, involving multiple stakeholders to ensure quality analysis of technology options for each mitigation options, is summarized in Figure 2. Engagement of multiple stakeholders was meant to provide balanced viewpoints over technology options while ensuring sectoral needs and priorities. MONRE and JICA jointly supervised the project through consultations and close cooperation, and provided guidance to the Assessment Team to study and evaluate the low carbon technologies. A number of dialogues, discussions and workshops were held with the participation of relevant line ministries (LMs), private sector stakeholders as well as international development partners. Besides, a Technology Advisory Committee comprising domestic and international experts was also established in order to benefit from third party expertise.

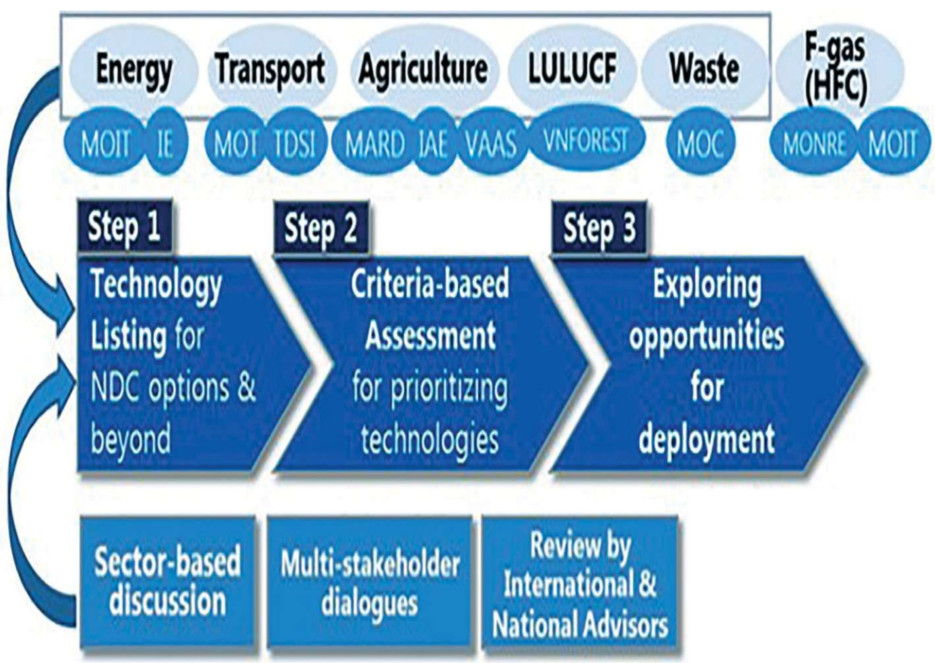

Figure 1. Modality of Low Carbon Technology Assessment

(Source: MONRE and JICA, 2018)

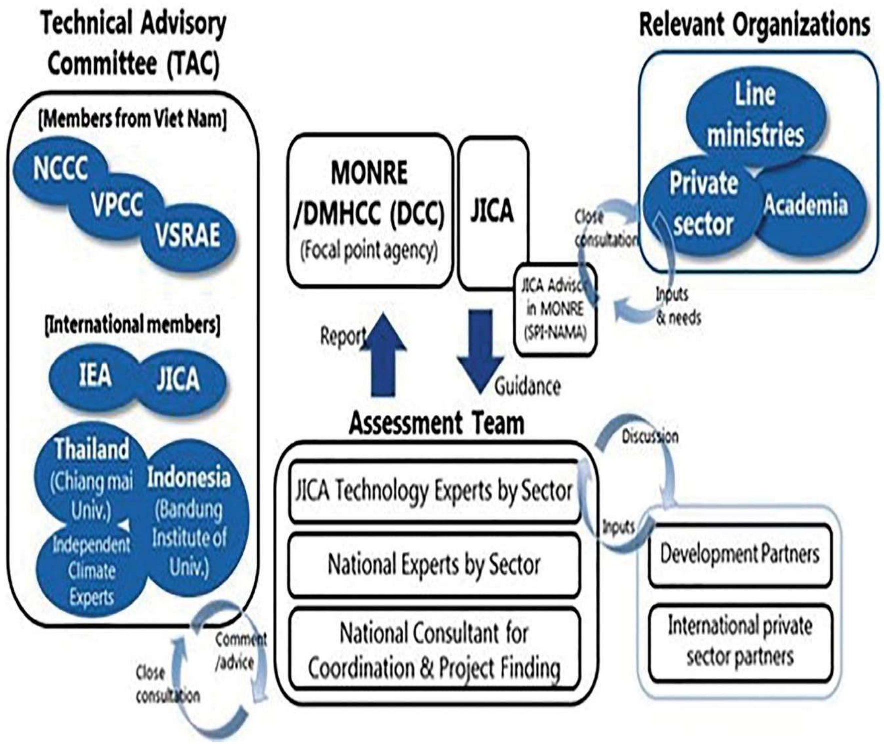

Figure 2. Institutional arrangement for Low Carbon Technology Assessment

(Source: MONRE and JICA, 2018)

1.2. Methodology

Three methods were employed for this study, namely desk-based literature review, expert consultation, and multi-criteria assessment.

The desk-based literature review included an analysis of related documents in the field of study with both qualitative or quantitative design to gain a solid theoretical foundation for the research [3]. Some important documents, scholarly articles, journal and book publications were analyzed to provide different perspectives along with the use of data collecting instruments like interview and consultation [4]. The significant sources included publications on low carbon technology development from the Ministry of Environment and Natural Resources (MONRE), Ministry of Agriculture and Rural Development (MARD), Ministry of Planning and Investment (MPI), Ministry of Trade and Industry (MOIT), World Bank, Asian Development Bank, United Nations Development Programme, EX Research Institute Ltd., Ministry of Environment - Japan, etc,...

Climate change measures are often cross-sectoral, and the cooperation among related ministries was essential for actions that are effective timewise and also financially [6]. Furthermore, to reflect these measures in future national plans and legislations, it was vital to reach agreement not just among officials inside the leading ministry but more so between related ministries. Five joint workshops in dialogue format had been conducted by November 2017 to receive comments from related ministries and advisory committee in order to promote the effective implementation of climate change measures [1].

Multi-criteria assessment (MCA) is a decision-making tool to evaluate the current problems and identify the best option regarding different objectives, alternatives and expectations [6]. The MCA aims to deal with complicated issues which involves various environmental, social and economic problems, and different group interests in the context of environmental and natural resource management [7,8]. In relation to the approach adopted for the prioritization of suitable technologies, it is divided into four major steps.

+ Step 1: Conduct stakeholder interviews with line ministries on 45 mitigation options.

+ Step 2: With the current situation and directions of the climate change measures in Viet Nam, technologies applicable in Viet Nam's context have been selected from existing technology lists.

+ Step 3: Determination of assessment criteria and technology prioritization. Qualitatively evaluation was divided into high, middle or low (A, B or C) for each criterion [2].

2. Low carbon technologies for 45 mitigation options in Viet Nam

2.1. Energy efficiency

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 Monitoring, Reporting, Verification (MRV) framework for major industry sub-sectors, and promoting ESCOs (Energy Service Companies) to facilitate energy efficiency.

The first choice among low carbon technologies is high efficiency residential air conditioning. An inverter is an energy saving technology that eliminates operation waste in air conditioners (AC) by efficiently controlling motor speed. In inverter ACs, temperature is adjusted by changing motor speed without turning the motor on and off. When compared with ACs without inverter, power consumption is reduced by 30% and operation noise is reduced. The mitigation potential is at 0.27tCO_2eq/year/unit.

The second is the high efficiency residential refrigerators. Inverter technology also applied to these refrigerators (inverter-fed motor, and linear and scroll compressors), with capacities between 190 to 700 litres. This provides around 40% reduction in power consumption by a refrigerator made in 2015 compared to one of 2006, to 0.07tCO_2eq/year/unit (volume: 401-450L). The operation noise is also reduced.

High efficiency residential lighting is the third technological option. LED lighting can produce more useable white light per unit of energy compared to metal halide, sodium vapor, and fluorescent and halogen light sources. Fluorescent lamps (CFL) contain mercury which causes the tube to produce light mostly in the UV region of the spectrum. There is a 50% reduction in electricity consumption by CFL and 80% reduction by LED lighting compared with incandescent bulbs. 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 in places in such as plant lighting designs. The mitigation potential is at 0.04tCO_2eq/year/unit (incandescent to LED) and 0.02tCO_2eq/year/unit (incandescent to CFL).

Solar water heaters collect solar thermal energy by a solar energy absorber to warm water or air for hot water supply or air-conditioning. One type is a forced-circulation solar system and the other is the natural-circulation solar water heater. This solar system consists of a solar energy collector and a heat storage tank. Solar heaters reduce gas or power consumption. The mitigation potential is 0.46tCO_2eq/year/unit.

Fifthly, a cement-making technology, the 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%. The NOx emission level is expected to reduce as well, and damage mitigation is enhanced to the refractory materials in the kiln. The mitigation potential remains at 0.01tCO_2eq/t-clinker.

Sixth, the vertical shaft brick kiln (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. It can be operated perennially as it is protected from the vagaries of weather by the kiln's roof; reduced suspended particulate matter emission; and less fuel consumption can be expected (0.065kg coal/unit of brick). The mitigation potential is 0.04 tCO_2eq/t-brick (2.4 $MtCO_2eq$/year by 2030 (for high efficiency VSBK) [1].

Last but not least, building high efficiency commercial air conditioning composes 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, 40% reduction in power consumption compared with conventional/old central AC system.

2.2. Power generation

Viet Nam's power supply capacity must be increased because of power demand for economic growth. The government has high expectations of renewable energy (including solar PV with steady cost reductions, and biomass power), and is planning extensive introduction. On the other hand, as renewable energy alone cannot satisfy the power demand, coal power plants are planned in parallel due to its large capacity and low cost.

Firstly, bioenergy is a form of renewable energy derived from biomass to generate electricity and heat. Biomass is any organic matter, available in many forms such as agricultural/forestry products, and municipal and other waste. Biomass power plants can supply electricity in non-grid areas. For biomass power plants, the mitigation potential is 1,752-1,838$ktCO_2$/year by 2020 and 7,942-8,775$ktCO_2$/year by 2030.

Hydroelectricity is generated when falling water is channelled through turbine blades which that drive an electrical generator, converting the motion into electrical energy. Small hydropower plants have the potential of electricity access improvement in non-grid areas, and they emits no waste. The mitigation potential is 51,689-54,225$ktCO_2$/year and 58,622-64,771$ktCO_2$/year in 2020 and 2030 respectively.

Also useful is wind power plant development with domestic or international funding. There are on-shore (on land) and off-shore (on the sea) wind power potentials. Wind turbines convert the force of the wind into a torque (rotational force), which is then used to propel an generator to create electricity. Wind power stations (wind farms) commonly aggregate the output of multiple wind turbines through a central connection point to the electricity grid. This plant is zero emission. They have the potential of electricity access improvement in non-grid areas. The mitigation potential is 1,402-1,470$ktCO_2$/year in 2020, and 7,942-8,775$ktCO_2$/year in 2030.

In biogas power plants, power is generated by burning the combustible gas from anaerobic biomass digestion. Heat and power can be supplied by using small-scale generation capacity and cogeneration. Biogas power plants do not necessarily need to be connected with the power grid have the potential of electricity access improvement in non-grid areas. The mitigation potential is similar for biomass power plants.

Ultra-supercritical (USC) coal 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. In comparison with sub-critical (SC) coal power plants, there is up to 5.5% improvement on USC heat exchange efficiency. The mitigation potential is 38$MtCO_2eq$/year (in case 12,720 MW of SC technology coal power generation would be replaced by USC technology).

Lastly, solar PV power systems convert sunlight directly into electricity using photovoltaic cells. Solar PV systems can be installed on rooftops, integrated into building designs and applied in megawatt scale power plants. This technology is zero emissions and can improve access to electricity in non-grid areas. The mitigation potential is 876-919 $ktCO_2$/year by 2020, and 12,480-13,790$ktCO_2$/year by 2030 [1].

2.3. Transport

Climate change mitigation measures in the transport sector three sets of measures: Modal shifts (passenger and freight); energy efficiency (road, railway, inland waterway, maritime and aviation); and fuel switching.

Using biofuel as alternative, such as ethanol for gasoline, can reduce fossil use. Bioethanol can be produced using feedstock containing sugar, such as sugar cane and cassava and wheat starch. Bioethanol can be blended with conventional gasoline fuel and be used for vehicles. Utilization of agricultural waste for ethanol can decrease the amount of wastes such as cassava pulp. The mitigation potential is 888gCO_2eq/litre of ethanol (but this is highly dependent on feedstock and technologies for waste treatment).

The passenger transport modal shift from private to public, with various measures as development of urban/inter-city railways (e.g. metro, LRT (light rail transit), tram, monorail, high-speed railway), bus/BRT, and inland waterways. Related technologies are to improve energy efficiency of vehicles, such as light weight vehicle using aluminium body, variable voltage variable frequency (VVVF) inverter, regenerative braking system, and low emission buses. It is important to introduce technologies that enhance user friendliness and safety, e.g. IC cards, automatic ticket gates, common ticketing systems, bus location system, and park & ride. There are multiple advantages such as urban railways have high transportation capacity, high speed, less travel time, traffic congestions and accidents reduction and less local air pollutants. For urban railways, the mitigation potential is 38,267tCO_2/year in Ha noi line 1; 41,579 tCO_2/year in Ha Noi line 2; and 88,678tCO_2/year in Ho Chi Minh line 1.

Freight transport switch from road to railways and waterways, can include development/improvement of railway/waterway freight terminals, renovation of railway tracks/ports, and access roads to these terminals. Accordingly, local air pollution, noise and traffic accidents caused by trucks will be reduced. The mitigation potential is 305tCO_2/year (for rubber products, shift from truck 810km to railway 859km+truck 35km), 405tCO_2/year (for miscellaneous goods, shift from truck to railway), 3,320tCO_2/year (for chemicals, shift from truck to waterway), 2,116MtCO_2eq/year (for electronic parts, shift from truck to waterway) [1].

2.4. Agriculture

Profitability and food security for farmers are the first priority rather than GHG emission reduction that ensures economic sustainability of mitigation actions especially for farmers.

The first option is increased use of biogas. A small scale biogas digester consists of a tank in which the organic material is digested combined with a system to collect and store the biogas. This technology reduces groundwater contamination, needs for fuelwood, and indoor air pollution caused by fuelwood burning. This technology eliminates methane emissions created during fermentation of openly-discharged sewage. The mitigation potential is 6.4 x10^{-3}kgCO_2eq/unit/year.

The second and third proposed options are the reuse of agricultural residue as organic fertilizer in rice and upland crops. Through using dry and green farm biomass piled in a heap in a relatively short time, biodynamic composting is an inexpensive method to produce a large amount of compost. 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 by-products or grease from food processing industries. These easy to prepare and low cost technologies have a reduced potential of 1.07x10^{-4}kgCO_2eq/ha/year.

The fourth option is alternate wetting and drying (AWD), and improved rice cultivation system (small and large scale). Flooded rice fields are a large source of methane emission. In AWD, the rice field is drained periodically to enhance aeration of the soil, inhibiting methane-producing bacteria thereby reducing methane emissions. This technology shows other advantages such as lowering irrigation water consumption by 25%; reducing fuel consumption for pumping water; no yield difference from continuous flooding but heavier and bigger grains; more tillers; fewer pests/diseases; and it saves time and labour. The mitigation potential is 1.46-2.93tCO_2eq/ha/season and 48% reduction of methane emission.

The fifth method is integrated crop management (ICM) in rice cultivation. Major components of ICM include 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 can contribute to GHG emissions reduction in particular through energy efficiency in rice cultivation with high efficiency water pumps. It can reduce a total energy usage, save cost and maximise drainage capacity. Higher pump efficiency can reduce 78-83% of fuel needs. The mitigation potential is 5.2tCO_2eq/unit/year.

The sixth and seventh technologies are biochar introduction and ICM in upland crops. Biochar is produced with low cost methods that generated less black smoke and biochar incorporation in soils improves nutrient, water and air accessibility. 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). The mitigation potential is 50-65% reduction of CO_2 emissions (carbon sequestration).

Eighth is the substitution of urea with SA fertilizer (Ammonium Sulphate $(NH_4)_2SO_4$). As part of fertilizer manufacturing plants, the following production units can save energy and reduce operation cost, such as calcium silicate insulation of high pressure steam pipe line (0.78GJ/t) with the mitigation potential at 0.47MtCO_2; isothermal CO conversion reactor (0.418GJ/t) with 0.09MtCO_2, installation of variable speed drives for cooling tower fans in fertilizer (2.77kWh/ton) at 0.02MtCO_2;and steam trap management (0.0003GJ/t) at 0.01MtCO_2.

The ninth option is livestock diet improvement. A large portion of enteric methane and nitrous oxide comes from fermentation processes in ruminants. It was demonstrated that dietary lipids (e.g. fatty acids, medium to long chain) can 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. The results show that it is safe for the animals and does not affect other ruminal parameters. Amino acid balance and efficiency of feeds can be improved, resulting in reduction of the amount of animal waste and methane gas at 3.8% reduction of CH_4 with each 1% addition of supplemental fatty acid. The mitigation potential is 1t of life-cycle-CO_2/2.4kg of added lysine.

Tenth is the improvement of available quality and services for aquaculture such as inputs and foodstuff, purification, aerobic treatment, microbe fermentation, up-flow anaerobic blanket process and rotating biological contactor are the series of methods to remove impurities in wastewater generated from the livestock production, food and aquaculture processing. It can also recover methane gas for power generation and reduce production costs. The mitigation potential is 7,739tCO_2eq/system/year.

Eleventh is the improvement of technologies in aquaculture and waste treatment in biogas plants that capture the methane gas from the anaerobic fermentation of biomass from aquaculture waste. An industrial scale biogas digester consists of five items, including: pre-treatment system; sterilization system; methane fermentation system; gas utilization system; and post-treatment system. These high efficiency, energy saving processes have a mitigation potential of 22,806tCO_2eq/year (from the plant: one anaerobic digester with biogas production of 3,000m^3/day, and one 500kW biogas generator with power generation of 3,285MWh/year).

Twelfth is improved irrigation for coffee by allowing water to drip slowly to the plant root zone. Drip irrigation has a high efficiency of over 90% and reduces water, as well as fertilizer use, fuel and other production costs. The mitigation potential is $5.3x10^{-3}kgCO_2eq/ha/year$.

Finally, there are improved technologies in high efficiency cooling (chilling and freezing) facilities in cold chain process in agriculture, forestry and aquaculture. Ammonia and CO_2 are used as primary and secondary refrigerant, respectively (more than 25% reduction), no ammonia leakage on the load side, and reduced fuel cost, as well as other production costs. The mitigation potential is $165tCO_2eq/year$ [1].

2.5. Land Use, Land-Use Change and Forestry (LULUCF)

The methods for protection of natural forest (1 and 2.2 million ha) include: reforestation; forest fire control; insect and pest control; invasive species prevention; forest degradation and deforestation prevention; restoring degraded forest ecosystems; and development of non-timber forest products. For economic benefit, sustainable timber trade increases average income. For social benefits, the number of jobs and income in local areas can increase. For environmental benefits, conservation technologies lead to sustainable forest use and management. The mitigation potential is $70.6MtCO_2eq/year$.

The protection of coastal forest (100,000, 10,000, and 30,000 ha) is a combination of the following techniques such as conservation of existing forests; enrichment planting; reforestation; and silvo-fishery practices (e.g. a fish/shrimp pond combined with mangrove trees). For economic benefits, plants and aquaculture products are a source of income in the local economy. For social benefits, the number of jobs and income is increased through growing aquatic resources (fish, shrimp, crab etc.) by plantation and enrichment of mangrove forests in long term. For environmental benefit, mangrove swamps are considered a low-cost, efficient "green dyke" to prevent wave or storm damage, increase sedimentation rates, and protect shrimp farms. The mitigation potential is $12.5MtCO_2eq/year$.

The natural forest and production forest regeneration (200,000 ha) is a combination of the following: planting technique; tree selecting; proper site and suitability assessment for tree species selection; seedling production and quality. This increases carbon sinks, protection of environment, and watershed conservation. The mitigation reduction potential is $37.5MtCO_2eq/year$.

The plantation of large timber production forest (150,000ha) is a business model for transformation and restoration of short-rotation acacia plantations (commonly 5-6 years), in which the rotation length is up to 12-15 years if used for high-value sawn log production. It not only enhances carbon storage and other environmental services (soil fertility, etc.) but also promotes sustainable forest management. The mitigation potential is $10tCO_2eq/ha/year$ [1].

2.6. Waste

In accordance with a study conducted by the Ministry of Construction (MOC) and United States Agency for International Development (USAID), the priority for technology introduction in the waste sector is in the following order: composting, incineration, and landfill.

Organic fertilizer production 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. This is low-cost and relatively simple (easy-to-apply) technologies. The mitigation reduction is $17{,}000MtCO_2eq/year$ (from 200 ton/day of municipal solid waste).

Landfill Gas (LFG) recovery for electricity and heat generation 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. It can be applied to various landfill types (existing, closed, and newly disposal landfills). The mitigation potential is 7,000MtCO_2eq/year (the landfill of disposing 200 ton/day).

The recycling of solid waste needs proper separation of recyclable items from waste at source. A series of manual or mechanical separation technologies are required when the solid waste is collected in the mixed state. The cost of recycling can be minimized by making use of the existing recycling industry at its maximum. The mitigation potential is 3MtCO_2eq/year.

The anaerobic treatment of organic solid waste with methane recovery for power and heat generation is specifically designed to treat waste 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. The mitigation potential is 1,680MtCO_2eq/year (from 50 ton/day of waste collected) [1].

2.7. Fluorinated greenhouse gas (F-gas)

The measures on F-gases had not yet identified, with scarce and scattered information on consumption of HFC preventing the Government of Viet Nam to plan mitigation options for these gases. However, some energy options are relevant, namely high efficiency air conditioner for households, high efficiency commercial air conditioning, and high efficiency residential refrigerators. 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 the UNFCCC. Thus, wider options on F-gases should be considered in addition to the energy efficiency options.

There are several destruction methods for F-gas, such as the rotary kiln, waste combustion, submerged combustion, plasma, catalytic, overheated steam method, etc. In Viet Nam, there are no specific facilities and/or equipment for F-gas destruction. However, currently, LaFarge Holcim (cement factory) has a pilot project of F-gas destruction in their cement kiln. There are three steps in the destruction process of F-gas by cement kiln: recovery of refrigerant; refilling and transporting F-gas cylinders; and thermal destruction at destruction site, where recovered F-gas is injected into cement kiln and combusted at over 1,000 degrees during at least 6 seconds. The process results in over 99.9% of decomposited F-gas.

One technology is to change high global warming potential (GWP) refrigerant to low GWP refrigerant (R600a/isobutane) in household refrigerators. Low GWP refrigerant R600a (isobutene, GWP=4) is widely available in Viet Nam with the limitation at less than 100g use of R600a for household refrigerators to prevent explosion. The reduction reaches at 99.7% by changing refrigerant from R-134a (GWP=1,430) to R600a (GWP=4).

For commercial cold storage, the change in high GWP refrigerant to low GWP refrigerant (CO_2) (GWP=1) is necessary. It shows that electricity saving is approximately 2,400USD/year. Besides, freezer would be smaller in size and lightweight so that installation cost can be reduced.

Another technical approach is the change of high GWP refrigerant to low GWP refrigerant (R32) in air conditioners in the residential and commercial sector. R32 has zero ozone depletion potential and low toxicity, and 1/3 GWP compared to the R410a refrigerant. R410a is a mixed refrigerant whereas R32 is a single component refrigerant that is easy to handle and recover. 68% reduction is obtained by changing refrigerant from R410a (GWP=2,090) to R32 (GWP=675).

For automobile air conditioners (ACs), the change of high GWP refrigerant to low GWP refrigerant (HFO-1234yf) consists of re-filling the low GWP refrigerant gas into ACs and recovering the old high GWP refrigerant. It has zero ozone depletion potential, low toxicity and is easy- to-change cooler gas. It can be used with the existing standard equipment configuration and materials. The reduction reaches at 99.7% by changing from R134a refrigerant (GWP=1,430) to HFO-1234yf (GWP=4) (amount of gas in car AC: 300-1,000g/car) [1].

In addition, the proper management of refrigerants can prevent reduction of energy efficiency and save costs for refilling of lost refrigerant. There are three steps for leakage inspection: exterior check (visual inspection), indirect inspection (monitoring of gas pressure, discharge temperature, etc.) and direct inspection (using bubbling liquid, electronical gas detection machines, etc.). Based on the results of above inspections, maintenance and repairs to prevent leakage are conducted as necessary.

3. Barrier analysis and next step for low carbon technology implementation

The development of low carbon technologies is very important in order to reach the 8% greenhouse gas emission reduction target by domestic efforts and 25% reduction in case of international support. Regarding 45 mitigation options in Viet Nam's NDC, approximately 100 low carbon technologies were introduced. Of those, based on criteria and expert judgment, about 60 technologies are relatively easy to adopt [1]. The main challenges for the deployment of the identified low carbon technologies were also discussed. The challenges are sector-specific. It was pointed out that standards and policy framework are still not sufficient. Besides, various barriers related to investment were identified as 'low incentive' (energy, waste, F-gas), 'demand risk' (transport), and 'limited resource' (agriculture and LULUCF).

For equipment and industries, there are no mandatory energy efficiency standards, labelling, and environmental standard. In industry, incentives for energy efficiency measures are still limited. However, the hydropower sector must pay small fees for forest ecosystem services.

For transport, the bioethanol standard is not yet available. In addition, the investment in this sector requires increased demand to achieve project profitability (modal shift).

For agriculture, cross-sectoral benefits between livestock and food security may be possible but require high initial investment.

For LULUCF, there are limited financial resources, and the policy barrier of land use prioritization.

For waste, the limited demand in anaerobic treatment of organic solid waste will require a more effective strategy for commercializing compost products.

For F-gas, there is no policy framework, low awareness of stakeholders, but price competitiveness of low GWP refrigerant [2].

The promotion of private sector involvement, financial incentives for investment, awareness raising on the benefits of low carbon technologies and systems, and consultations and discussions with many stakeholders including private sector businesses are essential to remove barriers to adopt the low carbon technologies in Viet Nam.

4. Conclusion

A multicriteria assessment approach was used for assessing and selecting low carbon technologies for enabling 45 mitigation options in 7 sectors identified in Viet Nam's NDC, plus F-gas. Specific low carbon technologies with their mitigation potential calculated in CO_2 emission reduction equivalent were assessed and selected. The identified low carbon technologies could help line ministries implement their sectoral mitigation options and also to inform the NDC review.

The main challenges for deployment of the identified low carbon technologies were also discussed. The challenges are sector-specific and on both policy and investment aspects.

Necessary steps for effective deployment of the low carbon technologies enabling NDC implementation include removing barriers, promoting coordination with relevant stakeholders, and support from international cooperation.

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