Assessing Abatement Costs of Green House Gas (GHG) Emission Reduction Opportunities in Hanoi

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Abstract

The Green House Gas emissions from human activities are driving climate change - one of the biggest challenges for the mankind in the 21 century - and continue to rise. To address CC, countries should join hands to make efforts to reduce GHG emissions.

The realization the nation's comitments to international community requires Hanoi – the Capital of Viet Nam, to formulate the City Green Growth Action Plan (GGAP) towards 2030, which identifies potentials and solutions to achieve GHG emission reduction targets in the City.

This study aims to identity GHG reduction opportunities in Hanoi, assess costs of these opportunities with expert-based marginal abatement cost curve (MACC) model, in accordance with the approaches of economic management profession.

There are 35 GHG emission reduction opportunities identified in Hanoi, they are mainly in 2 key sectors of Energy (30 opportunities) and Agriculture & Forestry (5 opportunities). By 2025, the GHG reduction from these 35 opportunities will be 15,689,386 tons CO_2e, with estimated capital demand is VND 11,674,929,657 thousands. By 2030, the GHG reduction potential will be 29,822,350.92 tons CO_2e, estimated capital demand is VND 28,843,554,618.95 thousands.

The Government of Hanoi should announce the list and information of GHG abatement opportunities to attract investors; review financial policy framework and other related policies to promote the GGAP implementation.

Key Words*:* Green House Gas, abatement cost, energy sector, agriculture & forestry sector, Hanoi

1. Introduction

Climate change (CC) is one of the biggest challenges for the mankind in the 21 century. CC destabilises the Earth's temperature equilibrium and has far-reaching effects on human beings and the environment. During the course of global warming, the energy balance and thus the temperature of the earth change, due to the increased concentration of Green House Gases (GHGs), which has a significant impact on humans and the environment. CC is now affecting every country over the world. It is disrupting national economies and affecting lives, costing people, communities and countries today and future generations.

The GHG emissions from human activities are driving CC and continue to rise. There are several types of GHGs: CO_2, N_2O, CH_4, HFC, PFC, SF_6, CFC…. The emissions of GHGs are converted into volume of CO_2 equivalent (CO_2e) via global warming potential index (GWP) guided by Intergovernmental Panel on Climate Change (IPCC). Global emissions of GHG in CO_2e increased from 2 billion tons in 1900 to over 36.2 billion tons in 2017 (Hannah Ritchie and Max Roser, 2019). GHG emissions are now at their highest levels in history and are projected to increase in the coming decades. Without action, the world's average surface temperature is projected to rise over the 21st century and many areas of the world expected to warm even more.

Addressing climate change requires two types of responses: mitigation (defined as an anthropogenic intervention to reduce anthropogenic forcing of the climate system (IPCC, 2007)) and adaptation (defined as: the "adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects that moderates harm or exploits beneficial opportunities" (IPCC, 2007). Mitigation includes actions designed to remove GHGs from the atmosphere or to change Earth's radiation balance.

To address CC, countries should join hands to make efforts to reduce GHG emissions. At the Paris climate conference (COP21) in December 2015, 195 countries adopted the first-ever universal, legally binding global climate deal. Governments agreed, among others, to undertake rapid reductions thereafter in accordance with the best available science. Before and during the Paris conference, countries submitted comprehensive national climate action plans (INDCs).

Althought the CO_2 emissions in total and per capita are comparatively low, Viet Nam is one of the countries which are most vulnerable to CC. Viet Nam is also very active in joint global efforts to mitigate GHG. The country committed to working with the international community to respond to CC, which is reflected in the range of national policies and specific actions that have been or are being taken to combat CC. On September 30th, 2015, Viet Nam sent the UNFCCC Secretariat "*Viet Nam's Intended Nationally Determined Contribution* (INDC)". Viet Nam signed the Paris Agreement on CC on April 22nd, 2016 and approved the Paris Agreement on November 3rd, 2016. From that time, Viet Nam's INDC has officially become its NDC. According to Viet Nam's NDC, with domestic resources, by 2030, Viet Nam will reduce GHG emissions by 8% compared to the Business as Usual (BAU) scenario. The contribution could be increased to 25% if international support is received.

Vietnam is among some of pioneer developing countries that have issued National Green Growth Strategy (GGS, Decision No. 1393/QĐ-TTg dated 25/9/2013) and the National GG Action Plan (GGAP, Decision No. 403/QĐ-TTg dated 20/3/2014). The GGAP requests every province/ city to study and develop suitable GHG reduction plan. Thus, it is required every province/ city to assess GHG emissions, GHG reduction potentials/ opportunities and develop suitable GHG reduction plan.

The Prime Minister, in Decision No. 622/QD-TTg dated May 10th, 2017 issued the National Action Plan to implement the 2030 Agenda for Sustainable Development. This Action Plan identified 17 sustainable development goals of Viet Nam by 2030, of which goal No. 13 is to take timely and efficient actions to respond to CC and natural disasters.

Being the Capital of Vietnam, the economic, commercial, cultural, and educational centre of the country, Hanoi also a big source of GHG emissions when acounted for about 8% of total country's GHG emissions. The realization the nation's comitments at the local level requires Hanoi to continue formulating the City Green Growth Action Plan (GGAP) towards 2030, which identifies potentials and solutions to achieve GHG emission reduction targets in the City. The City has identified its priority in enhancing the capacity to respond to CC, reducing emission while increasing sequestration potentials of GHG. Therefore, it is essential to study to assess the potentials and costs for GHG reduction, leading to the contribution for scientific foundation, proposing suitable mechanisms and policies to serve the formulation of Hanoi Green Growth Action Plan, taking important part of the national efforts in realizing the National GG Strategy and Action Plan for sustainable development in Vietnam.

This study aims to identity GHG reduction opportunities in Hanoi, assess costs of these opportunities with marginal abatement cost curve (MACC) model, in accordance with the approaches of economic management profession.

2. Literature Review and Research Methodology

This study employed both quantitative and qualitative research methodologies; synthesis methods, statistical analysis, comparison, assessment of conditions and requirements in parallel with expert consultations, conducting deep interviews with local experts and leaders. Quantitative calculations are made with the methodology of marginal abatement cost curve (MACC), with the support from softwares including Excel, and the professional MACC Builder Pro.

Marginal Abatement Cost (MAC) of GHG Abatement Opportunities

GHG abatement costs can be understood as *"costs rised to implement activities/ solutions to reduce volumes of GHG emission"*. GHG abatement costs vary according to types of gases and other factors (such as technologies, management and organization, activity, environmental conditions,...).

GHG abatement costs can be studied under different aspects. From the environmental angle, two popular approaches to identify and assess GHG abatement costs are total abatement cost (TAC) and marginal abatement cost (MAC). Marginal Abatement means the cost to reduce

or offset one unit of pollution, in this case one ton of GHG emissions. In other words, MAC presents the increase in TAC to reduce one additional GHG emission unit.

$$\textbf{Marginal Abatement Cost} = \frac{\text{Difference in the Total Abatement Costs}}{\text{Difference in the Total Emission Volume}}$$

GHG abatement opportunities are solutions proposed for consideration and if implemented, they will contribute to a certain amount of GHG reduction. MAC is based on identifying abatement opportunities according to cost/ benefit analysis achieved to reduce an unit of GHG emission (1 ton of CO_{2e}).

For each abatement opportunity (i), the MAC is calulate via the formula 1:

$$\mathbf{MAC} = \frac{C_{mi} - C_{bi}}{CO_{2ebi} - CO_{2emi}} \qquad (1)$$

Where:

C_{mi} is cost arising when implementing mitigation/ abatement opportunity (i),

C_{bi} is cost arising when implementing mitigation/ abatement activities in the normal/ usual conditions (business-as-usual BAU baseline) with the assumption that opportunity (i) is not realized,

CO_{2ebi} and CO_{2emi} are volumes of GHG emission (in the unit of ton of CO_{2e}) in the case of implement and not implement the mitigation/ abatement opportunity.

The identification and conversion of future values into present values for getting the only net cost are calculated by the formula 2:

$$\boldsymbol{PV_C} = \sum_{t=0}^{T} \frac{C_t}{(1+i)^t} \qquad (2)$$

While, PVc is the net present value of GHG mitigation cost, i is the interest rate/ discount rate and C_t is the cost at the point of time t (in Vietnam dong).

The present value of emission mitigation (PV_E) applied in this study as in formular 3:

$$\boldsymbol{PV_E} = \sum_{t=0}^{T} \frac{E_t}{(1+i)^t} \qquad (3)$$

While, PV_E is the present value of emission mitigation, i is the interest rate/ discount rate and E_t is the volume of net emission at the point of time t (in tons of CO_{2e}).

MAC can be presented as visually diagrams, that is MAC curves (MACC). On a MACC, the x-axis represents the emissions reduction, the y-axis the associated carbon value and the area under the curve the total abatement cost (TAC).

Expert Approaches for formulating MACC

MACC approach can apply in assessing and comparing costs aming solutions/ opportunities for GHG reduction at national, sectoral, local and global levels (McKinsey & Company, 2010; Mathieu Saujot & Benoit Lefèvre, 2016; Nadine Ibrahim & Christopher Kennedy, 2016).

There are two major approaches for formulating MACC: Expert-based MACC assess the cost and reduction potential of each single abatement measurebased on educated opinions, while Model-derived MACCs are based on the calculation of energy model. Expert-based approaches, sometimes also called technology cost curves, are built upon assumptions developed by experts for the baseline development of CO_2 emissions, the emission reduction potential and the corresponding cost of single measures (including new technologies, fuel switches and efficiency improvements). Another widespread approach to MAC curves is to derive the cost and potential for emission mitigation from energy models. This model-derived MAC curve makes it difficult in separating technical solutions for reducing emissions and has limitations in analyzing respective policies (Kesicki, 2011).

With the bottom-up approach in the expert model, MACC is created based on assumptions and views from experts on potentials for reducing emission as well as related costs for each respective solution. Then, all identified solutions are synthesized and presented on steps-shape MACC diagrams in lowest-to-highest costs ranking order. The expert approach is favoured in establishing climate change action plans at the local level with lack of information and data (Naucler & Enkvist, 2009; Fabian Kesickia, 2011; Nadine Ibrahim and Christopher Kennedy, 2016).

In this study, the expert approach with five simplified steps was employed in indentifying assessing and building the MACC, namely:

(1) Consult with experts to identify abatement technologies/ opportunities in appropriate areas/ sectors;

(2) Refer to market prices and experts' information on investment and operation costs, project life cycles… of the abatement opportunities;

(3) Develop Excel-based calculation sheet for calculating cost-benefit of those selected opportunities;

(4) Import calculated data to MACC Builder Pro to present MAC of mitigation opportunities in the ranking order;

(5) Adjust prioritization of opportunities based on the outputs from MACC Builder Pro.

Identify Opportunities for GHG Emission Reduction and Inputs for MACC Assessment

Two rounds were conducted in identifying GHG emission reduction opportunities in Hanoi.

(1) Round 1 involved discussing with experts from Energy Institute, Ministry of Industry and Trade; Agriculture Environment Institute; Institute of Strategy and Policy for Agriculture and Rural Development; Ministry of Construction… A "long list" of emission abatement opportunities were defined, which included opportunities in energy sector (transportation, tourism, buildings, hotels, restaurant, households, industry, aquaculture,…); agriculture, forestry and land use (infrastructure, environment, high-tech, …); in industry sector and in institutional area.

(2) Round 2 is opportunities screening, which employed consultation with Hanoi City's departments and agencies (Departments of Planning and Investment; Industry and Trade; Agriculture and Rural Development; Natural Resources and Environment; Tourism; Transportation; Construction...),

making analysis in all aspects of economic, social and environment, institution; strength, weaknesses, opportunities, threats (SWOT) for groups of opportunities and each opportunity; using questionnaire for selecting opportunities. After all, a "short list" of opportunities are considered as practical and get more than > 50% of votes from local experts. These opportunities were further considered to assess the costs and benefits to develop MACC for ranking and selecting.

During the experts' consultation, the following inputs also be discussed with experts before putting them in the model for MACC assessment:

- Costs (capital, operational and maintenance) associated with the proposed opportunities and decommissioning any technology the opportunities replaces;
- Weighted average cost of capital (or the discount rate) if relevant;
- Expected project life span and the technology to be replaced;
- Current electricity or energy prices;
- Expected electricity or energy savings in % of BAU baseline.

Selection of Time Frame and Discount Rate

Time frame for MACC calculation and analysis serves for establishing Hanoi's GGAP towards 2030.

The discount rate applied for all calculation and analysis is 10%, which has been applied in Vietnam's national Green Growth Strategy and GG Action Plan.

Assessing and Building the Marginal Abatement Cost Curve (MACC)

MAC can be presented as visually diagrams, that is MAC curves (MACC). On a MACC, the x-axis represents the emissions reduction, the y-axis the associated carbon value and the area under the curve the total abatement cost (TAC).

A MACC can be a useful visual tool to compare potential opportunies for GHG reduction and prioritise them based on their economic feasibility and potential impact.

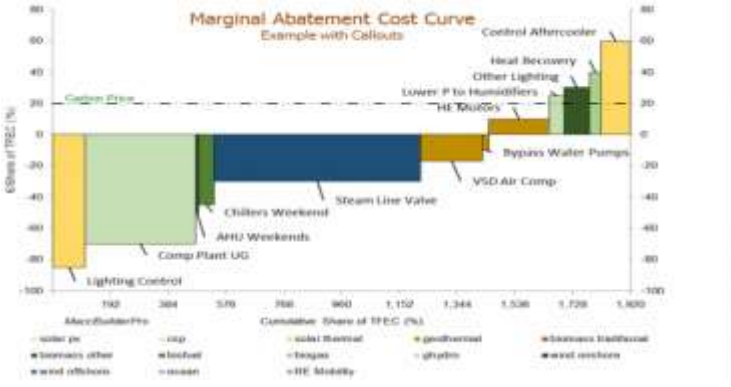

Figure 1: An illustration of step-shape MACC

Source: http://www.sustainsuccess.co.uk/macc-builder-pro

This study was supported by official MACC Builder Pro to build MACC.

MACC Builder Pro is a soft ware that allows to present MAC under diagram with each mitigation/ abatement opportunity in the ranking order, from the lowest to highest cost, and from left to right on the horizontal axis. The width of the horizontal axis (X) presenting the mitigation volume achieved in the targeted. The vertical axis (Y) represent MAC of the opportunity.

Data Sources

Sources of data used in assessing GHG emission abatement in Hanoi came from the City Statistics Office; City Department of Industry and Trade, Department of Planning and Investment, Department of Construction; Department of Transportation; Department of Agriculture and Rural Development; Electricity Corporation; Expert consultations as described above.

3. Research Results and Discussion

Based on reference to market prices, in discussion with experts and related departments in Hanoi on paramenters and essential asumptions during the calculation of investment capital, annual costs/ benefits, project cycle, emission intensity, volume of CO_{2e} emission reduced, … for each opportunity in the short list, costs/ benefits and investment parameters for each opportunity will be enterd into Excel calculated sheet established by the author. Then this result continues to be imported to MACC Builder Pro software. There are just 35 opportunities with potential to come to final results since they meet the requirements of the Excel sheet and of MACC Builder Pro, with 30 opportunities in energy sector and the other 5 in agriculture and forestry.

3.1. Potential for Emission Reduction in Hanoi towards 2025

In Energy Sector: the total potential for emission reduction in energy sector in Hanoi towards 2025 is 10.33 million tCO_{2e} ; the total investment capital need for 30 opportunities (in present value) is around 11,24 thousand billion VND as shown in Table 1 and illustrated in Figure 2.

Table 1: Potential for Emission Reduction in Energy Sector towards 2025

#	Opportunity	Implementation budget (thousands VND)	Volume of emission reduction (tCO_{2e})	Project cycle (year)
1	High energy efficiency motor and smart control of irrigation pump stations	17,943,750	9,300	5
2	Improve the efficiency of boilers and steam systems in industrial facilities	15,000,000	2,114,808	8
3	Change heat treatment equipment in industrial facilities	5,175,000	2,014,103	15
4	Energy management system for industrial facilities	5,000,000	33,285	20

5	Promote and pilot heat recovery models during the smelting process in a number of industrial facilities	49,500,000	1,107,756	15
6	High energy efficiency lighting systems for households	990,104,513	190,699	5
7	High energy efficiency refrigerators for households	1,069,312,874	204,288	5
8	High energy efficiency air conditioners for households	522,775,183	99,116	5
9	Apply energy-saving glass in civil use	478,800,000	39,353	15
10	Solar water heating systems for households	1,089,114,965	110,620	7
11	Solar battery application for civil use	36,000,000	1,966	26
12	Solar water heating systems for service facilities	15,007,200	1,524	15
13	Energy control system in commercial and service areas	479,318	4,504	5
14	High energy efficiency and smart control lighting systems for service facilities	9,904,752	1,734	5
15	High energy efficiency air conditioners for service facilities	928,571	160	5
16	Improve the efficiency of boilers and steam systems in hotel and restaurant facilities	675,000	3,884,341	8
17	High energy efficiency refrigerators for accommodation facilities	1,513,226	263	5
18	Apply energy-saving glass in Building	18,900,000	24,413	15
19	Solar battery application for office buildings	12,656,250	1,210	25
20	Eco-vehicles with digital journey monitoring	5,040,000	14,925	15
21	Expand routes and increase bus frequency	35,000,000	15,360	15
22	Develop electric bicycles and electric motorbikes	1,200,000	49,353	5

23	System of smart public lighting management and monitoring	68,195,298	1,543	20
24	Using high efficient amorphous for the electricity transmission network	5,124,000,000	232,693	15
25	High energy efficiency public lighting and solar power	138,702,300	14,162	20
26	Using CNG	362,996,558	16,419	15
27	Develop Rapid Bus Transit (BRT)	253,890,000	72,334	20
28	Construction of the subway systems	333,450,000	25,920	50
29	Develop irrigation pump stations using renewable energy	506,250,000	34,560	25
30	Smart control and inverter for dynamic equipment in construction	69,074,556	12,713	5
	Total	**11,236,589,314**	**10,333,425**	

Source: CEGR (2018); Calculation results from Excel and MACC Builder Pro

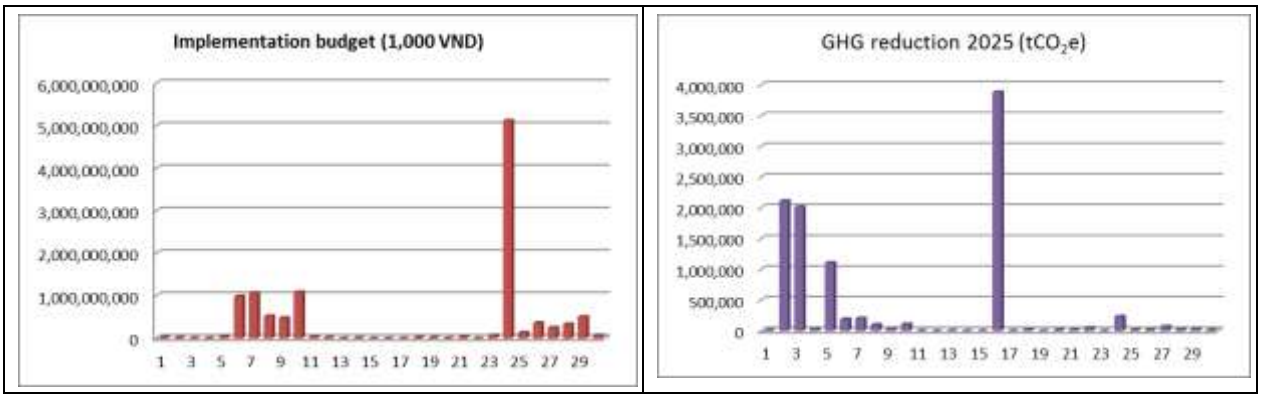

Figure 2: GHG Reduction and Implementation Budget towards 2025 by Opportunities, Energy Sector

Source: Synthesized by the authours

By comparing opportunities in Energy sector, opportunities 2, 3, 5 and 16 (improve the efficiency of boilers and steam systems in industrial facilities; change heat treatment equipment in industrial facilities; promote and pilot heat recovery models during the smelting process in a number of industrial facilities; improve the efficiency of boilers and steam systems in hotel and restaurant facilities) have potential to achieve the highest reduction with relatively low cost. Meanwhile, opportunities 24, 6, 7, 8, 9, 10 and 29 cost much more with low emission reduction potentials. Therefore, priority should be given to early implementation of opportunities 2, 3, 5, 6.

In Agriculture & Forestry sector, GHG emission reduction potential for 2025 of 5 opportunities is about 5.36 million tCO_2e; the total investment capital need for 5 opportunities (in present value) is around 438 billion VND as shown in Table 2 and Figure 3.

Table 2: Potential for Emission Reduction in Agriculture & Forestry Sector towards 2025

#	Opportunity	Implementation budget (thousands VND)	Volume of emission reduction (tCO_2e)	Project cycle (year)
1	Application of Biogas in livestock	173,263,775.54	471,125.60	20
2	Protect, restore, and sustainably management protection forests	43,652.88	38,803.15	20
3	Enrich and regenerate natural forests	962,427.25	855,503.88	20
4	Planting trees to prevent erosion	979,980.35	392,514.63	7
5	Increase the area of green parks and pedestrian streets	447,182	275,918	7
	Total	**438,340,343**	**5,355,961**	

Source: CEGR (2018); Calculation results from Excel and MACC Builder Pro

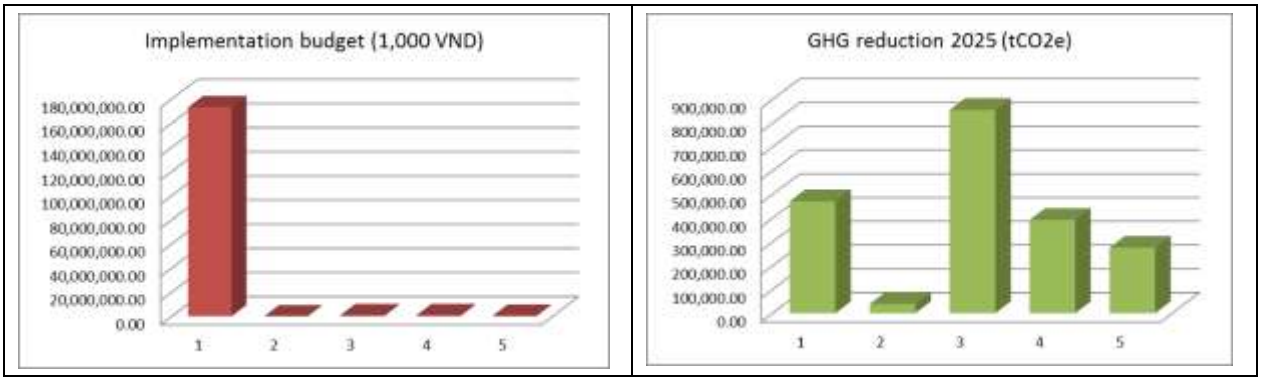

Figure 3: GHG Reduction and Implementation Budget towards 2025 by Opportunities, Agriculture & Forestry Sector

Source: Synthesized by the authours

In this sector, priority should be given to opportunities 3 (enrich and regenerate natural forests) 4 (planting trees to prevent erosion) and 5 (increase the area of green parks and pedestrian streets). These opportunities have the highest potential to reduce emissions at a much lower cost than the remaining opportunities.

3.3. Potential for Emission Reduction in Hanoi towards 2030

In Energy Sector: the total potential for emission reduction in energy sector in Hanoi towards 2030 is 24.32 million tCO_{2e} as shown in Table 3 and Figure 4.

Table 3: Potential for Emission Reduction in Energy Sector towards 2030

#	Opportunity	Implementation budget (thousands VND)	Volume of emission reduction (tCO_2e)	Project cycle (year)
1	High energy efficiency public lighting and solar power	277,404,600.00	28,324.76	20
2	System of smart public lighting management and monitoring	136,390,595.00	3,085.91	20
3	High energy efficiency refrigerators for households	1,782,188,123.90	340,480.43	5
4	High energy efficiency air conditioners for households	871,291,971.68	165,192.87	5
5	High energy efficiency lighting systems for households	1,980,209,026.55	381,397.68	5
6	Solar water heating systems for households	2,178,229,929.21	221,240.45	7
7	High energy efficiency refrigerators for service facilities	2,751,320.00	477.84	5
8	High energy efficiency air conditioners for service facilities	2,063,490.00	355.66	5
9	High energy efficiency and smart control lighting systems for service facilities	16,507,920.00	2,890.46	5
10	Solar water heating systems for service facilities	37,518,000.00	3,810.66	15
11	Energy control system in commercial and service areas	958,635.00	9,008.88	5
12	Smart control and inverter for dynamic equipment in construction	138,149,112.25	25,425.19	5
13	Promote and pilot heat recovery models during the smelting process in a number of industrial facilities	90,000,000.00	2,014,102.57	15
14	High energy efficiency motor and smart control of irrigation pump stations	35,887,500.00	18,599.10	5

15	Improve the efficiency of boilers and steam systems in hotel and restaurant facilities	1,500,000.00	8,631,868.17	8
16	Improve the efficiency of boilers and steam systems in industrial facilities	50,000,000.00	7,049,359.01	8
17	Change heat treatment equipment in industrial facilities	10,350,000.00	4,028,205.15	15
18	Energy management system for industrial facilities	10,000,000.00	66,570.94	20
19	Solar battery application for office buildings	28,125,000.00	2,687.96	25
20	Solar battery application for civil use	90,000,000.00	4,915.14	26
21	Apply energy-saving glass in civil use	798,000,000.00	65,588.47	15
22	Apply energy-saving glass in Building	63,000,000.00	81,375.62	15
23	Eco-vehicles with digital journey monitoring	11,200,000.00	33,167.21	15
24	Construction of the subway systems	666,900,000.00	51,840.00	50
25	Expand routes and increase bus frequency	70,000,000.00	30,720.00	15
26	Develop Rapid Bus Transit (BRT)	362,700,000.00	103,334.40	20
27	Using CNG	558,456,242.35	25,260.00	15
28	Develop electric bicycles and electric motorbikes	2,000,000.00	82,255.28	5
29	Using high efficient amorphous for the electricity transmission network	17,080,000,000.00	775,642.32	15
30	Develop irrigation pump stations using renewable energy	1,125,000,000.00	76,799.00	25
	Total	**28,547,498,965.95**	**24,333,540.92**	

Source: CEGR (2018); Calculation results from Excel and MACC Builder Pro

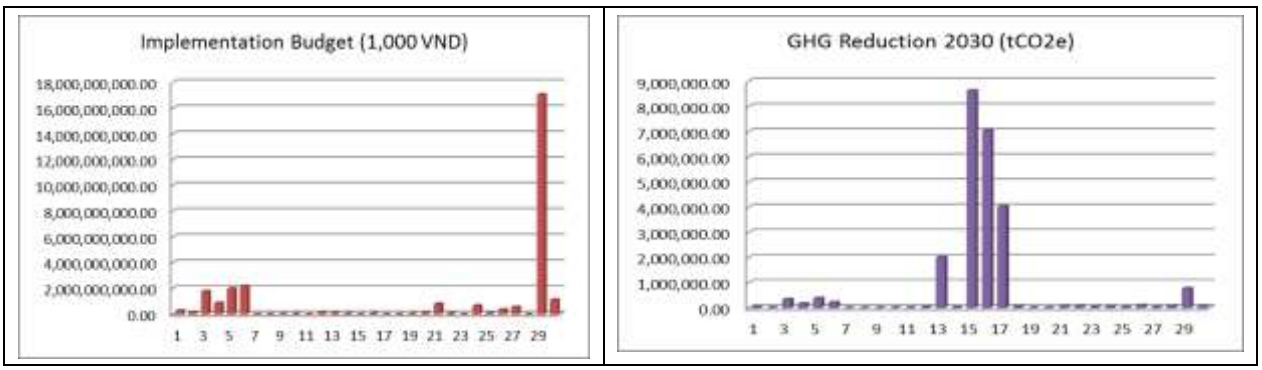

Figure 4: GHG Reduction and Implementation Budget towards 2030 by Opportunities, Energy Sector

Source: Synthesized by the authours

The total investment capital need for 30 opportunities (in present value) is around 24.3 thousand billion VND.

MACC of those opportunities are presented in the Figure 5.

Opportunities 13, 15, 16 and 17 have potential to achieve the highest reduction with relatively low cost. Meanwhile, opportunities 3, 5, 6 and, especially opportunity 29, cost much more money but emission reduction potential is relativle low. Once again, priority should be given to early implementation of opportunities 13, 15, 16 and 17 (they are: Promote and pilot heat recovery models during the smelting process in a number of industrial facilities; Improve the efficiency of boilers and steam systems in hotel and restaurant facilities; Improve the efficiency of boilers and steam systems in industrial facilities; Change heat treatment equipment in industrial facilities).

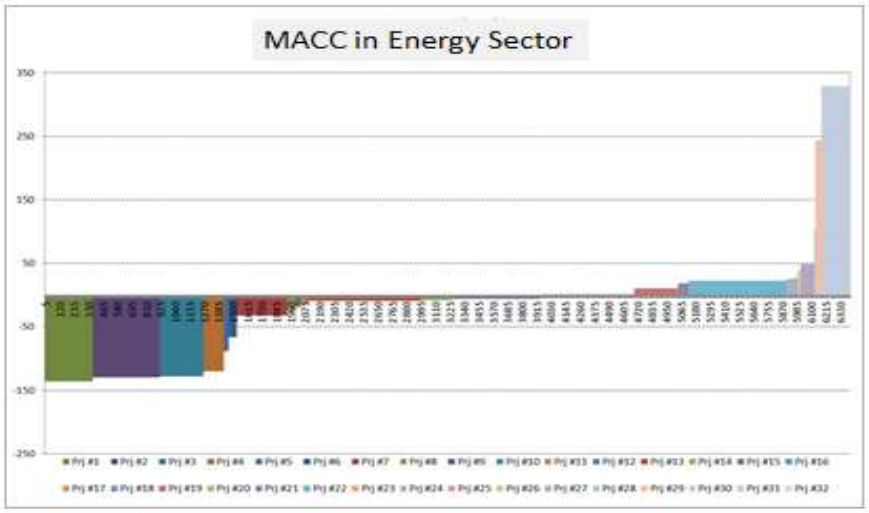

Figure 5: Synthesis of MACC in Energy Sector in 2030

Source: CEGR (2018); Prosessed in MACC Builder Pro

In Agriculture & Forestry sector, GHG emission reduction potential for 2030 of 5 opportunities is about 5.49 million tCO_2e ; the total investment capital need for 5 opportunities (in present value) is around 296 billion VND as shown in Table 4 and Figure 6.

Table 4: Potential for Emission Reduction in Agriculture & Forestry Sector towards 2030

#	Opportunity	Implementation budget (thousands VND)	Volume of emission reduction (tCO_2e)	Project cycle (year)
1	Application of Biogas in livestock	288,772,959	785,209	20
2	Protect, restore, and sustainably management protection forests	145,510	129,344	20
3	Enrich and regenerate natural forests	3,208,091	2,851,680	20
4	Planting trees to prevent erosion	3,266,601	1,308,382	7
5	Increase the area of green parks and pedestrian streets	662,492	408,768	7
	Total	**296,055,653**	**5,488,810**	

Source: CEGR (2018); Calculation results from Excel and MACC Builder Pro

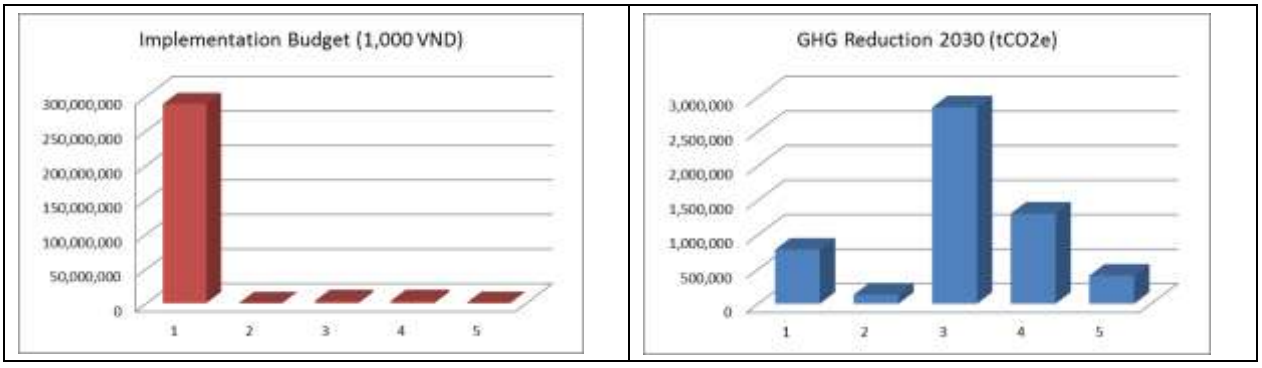

Figure 6: GHG Reduction and Implementation Budget towards 2030 by Opportunities, Agriculture & Forestry Sector

Source: Synthesized by the authours

Once again, 3 opportunities, that are (3) enrich and regenerate natural forests; (4) planting trees to prevent erosion and (5) increase the area of green parks and pedestrian streets keep having the highest potential to reduce emissions at a much lower cost than the remaining opportunities.

4. Conclusion and Recommendations

There are 35 GHG emission reduction opportunities selected in Hanoi, they are mainly in 2 key sectors of Energy (30 opportunities) and Agriculture & Forestry (5 opportunities).

By 2025, the GHG reduction from 35 selected opportunities will be 15,689,386 tons CO_2e, of which the GHG reduction from energy is expected to be 10,333,425 tons CO_2e (65.8% of total reduction), from agriculture & forestry is 5,355,961 tons CO_2e (34.2% of total reduction).

Estimated capital demand for the period to 2025 is VND 11,674,929,657 thousands, of which capital for agriculture & forestry sector is VND 438,340,343 thousands (3.75% of total capital); capital for the energy sector is VND 11,236,589,314 thousands (96.25% of total capital).

Table 5: Synthesis of Capital Needs and GHG Reduction Potentials by Sector

	Capital Needs		GHG Reduction	
	1,000 VND	%	tons CO2e	%
2025				
Energy sector	11,236,589,314	96.25	10,333,425	65.8
Agriculture & forestry sector	438,340,343	3.75	5,355,961	34.2
Total	***11,674,929,657***	***100***	***15,689,386***	***100***
2030				
Energy sector	28,547,498,965.95	99	24,333,540.92	81.6
Agriculture & forestry sector	296,055,653	1	5,488,810	18.4
Total	***28,843,554,618.95***	***100***	***29,822,350.92***	***100***

Source: Authours' calculation

By 2030, the GHG reduction from 35 selected opportunities will be 29,822,350.92 tons CO_2e, of which the GHG reduction from energy is expected to be 24,333,540.92 tons CO_2e (81.6% of total reduction), from agriculture & forestry is 5,488,810 tons CO_2e (18.4% of total reduction).

Estimated capital demand for the period to 2030 is VND 28,843,554,618.95 thousands; of which capital for agriculture & forestry sector is VND 296,055,653 thousands (1% of total capital); capital for the energy sector is VND 28,547,498,965.95 thousands (99% of total capital).

For longer-term assessment, towards 2030, due to differences in capital demand and project life cycle, the effectiveness of GHG emission abatement opportunities in energy and sector changed. In general, the opportunities in agriculture & forestry sector show more effective and sustainable manner than those in energy sector.

It is important for the City to design plan and roadmaps for implementing opportunities, starting from simple ones with small capital need; and at the same time, it is essential to establish institutions and strategy to promote mobilization from enterprises, local and foreign investors for big and long-term opportunities. The Government of Hanoi should complete and announce the City Green Growth Action Plan (GGAP) with the list and information of GHG abatement opportunities to create concensus as well as attract investments from private sector and the

community; review financial policy framework and other related policies to promote the GGAP implementation locally.

Due to the requirements of very high quality data related to production sectors to support the Model-derived MACCs, this study used the bottom-up expert MACC approach for assessing GHG emission reduction costs. This approach holds some weaknesses: excluding "non-technical" GHG emission reduction opportunities such as urban complexion, public transportation, changes of behaviors in households and individulas; interactions among opportunitiest – for example, impacts from transportation solutions on landuse and agriculture & forestry, or energy policies on energy prices… which have not been taken into account, even though they may have great impacts on emission reduction potentials and related.

Therefore, the direction for future study of the authors as well as interested people in assessing emission reduction costs and implementing Green Growth Action Plan are: (i) Testing the Model-derived approach in assessing emission abatement costs to overcome the limitations of the expert approach, especially in treating related interactions among emission reduction opportunities as well as taking into account "non-technical" solutions; (ii) Identify and more comprehensively together with objectively assess related costs and benifits (especially those benifits of environment quality improvement, community health, improved management efectiveness of related organizations, saving and efficient using of natural resources), clearer interpretion of uncertainty in cost-benifit estimation for GHG abatment opportunities.

Reference

1. Ackerman, F.; Bueno, R. (2011), *Use of McKinsey Abatement Cost Curves for Climate Economics Modeling,* Stockholm Environment Institute, Sweden.
2. Centre for Energy and Green Growth Research (CEGR) (2018), *Building A Green Growth Action Plan for Hanoi City*, Hanoi.
3. Clapp, C., Karousakis, K., Buchner, B., & Chateau, J. (2009), *National and Sectoral GHG Mitigation Potential: A Comparison Across Models.* OECD/IEA: COM/ENV/EPOC/IEA/SLT(2009).
4. Fabian Kesickia & Strachan, N. (2011), "Marginal abatement cost (MAC) curves: Confronting Theory And Practice. Environ", *Sci. Policy,* Vol.14, pp.195–204.
5. Hanoi Statistics Office, *Hanoi Statistical Yearbook* (several years).
6. IPCC (2006), *Guidelines for National Greenhouse Gas Inventories Volume 1, 2, 3,4,* Institute for Global Environmental Strategies, Japan, ISBN 4-88788-032-4.
7. IPCC (2007). *Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.* Geneva, Switzerland: Intergovernmental Panel on Climate Change.
8. Le Thu Hoa et al (2017), Research on Application of Carbon Balance Apsaisal in Agriculture and Land Use Change, Resarch project, National Economics University.

9. Le Thu Hoa, Nguyen Thi Dieu Trinh (2019), "Mainstreaming Green House Gas (GHG) Emission Reduction Assessment Into Green Growth Action Plan (GGAP) In Quang Ninh Province", *10th International Conference On Socio-Economic and Environmental Issues In Development (ICSEED 2019)*, ISBN: 978-604-65-4174-5, pg 1127-1139
10. McKinsey & Company (2009), *Pathways to a Low-Carbon Economy. Version 2 of the Global Greenhouse Gas Abatement Cost Curve*, New York..
11. McKinsey & Company (2010), *The Low Carbon Economics Tool*, Climate Change Special Initiative, New York.
12. Nadine Ibrahim and Christopher Kennedy (2016), *A Methodology for Constructing Marginal Abatement Cost Curves for Climate Action in Cities*, Faculty of Applied Science and Engineering, University of Toronto, Energies 2016, 9, 227 (www.mdpi.com/journal/energies).
13. Prime Minister of Vietnam (2011), Decision No. 1081/QĐ-TTg on "*Master Plan for Socio-Economic Development of Hanoi City to 2020, Orientations to 2030*", Hanoi, 06/07/ 2011.
14. Nguyen Thi Dieu Trinh, Le Thu Hoa, Ha Dang Son (2017), *A Systematic Approach To Quantify Green House Gas Targets In Provincial Green Growth Action Plans: An Illustration With Energy Portfolio*, 8th International Conference on Socio-Economic and Environmental Issues in Development, 12-13 May 2017, Hanoi.