Initiative for Climate Action Transparency - ICAT -

PRELIMINARY RESULTS FROM APPLICATION OF THE GACMO MODEL TO ACCESS GHG MITIGATION POTENTIAL IN ENERGY SECTOR OF VIETNAM

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Application of GACMO model to access GHG mitigation potential for Energy Sector of Vietnam

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AUTHORS

Hoang Van Tam[1], Tran Van Viet[1], Ha Quang Anh[2], Nguyen HungMinh[2]

[1]Energy Efficiency and Sustainable Development Department, Ministry of Industry and Trade of the Socialist Republic of Vietnam

[2]Center for Ozone layer protection and Low-carbon Economy Development of the Department of Climate Change, Ministry of Natural Resources and Environment of the Socialist Republic of Vietnam

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Contents

I. INTRODUCTION OF MITIGATION OPTIONS IN THE ENERGY SECTOR, VIETNAM

1.1. Overview of the mitigation options in the energy sector

Vietnam's NDC has set a target of reducing 8% of total GHG emissions by 2030 compared to BAU, equivalent to 62.65 million tons CO_2eq, with national resources. Such a reduction could increase to 25% compared to BAU, equivalent to 197.94 million tons CO_2eq in 2030, when receiving international assistance through bilateral and multilateral cooperation as well as implementation of mechanisms established by the Paris Agreement.

To achieve these goals, Vietnam has proposed 45 options to reduce GHG emissions in the four major sectors: Energy, Agriculture, Waste and LULUCF, of which 25 options are implemented by the country itself and the others need international support. Particularly, 17 mitigation options are proposed for the energy sector, with total potential of GHG emission reduction of 65.93 million tons of CO_2eq.

In this demonstration, GACMO model is selected in calculating the GHG emissions and costs for 04 solutions of reduction scenarios in the NDC regarding to the renewable energy development. For the calculation, assumptions are given in **Table 1**.

Table 1:Assumptions for mitigation options in the energy sector

Option	Assumption
E11. Biomass power plants	By 2030, the capacity for thermal biomass power will reach 2,000 MW (compared to 60MW in the BAU) to replace coal-fired thermal power
E12. Small hydropower plants	By 2025, the capacity for hydropower will increase by 2,400 MW (compared to BAU) to replace imported coal-fired thermal power.
E13. Wind power plants by national funding	By 2030, the wind power capacity will reach 100 MW (compared to BAU) to replace coal-fired thermal power.
E17. Solar PV power plants	By 2030, the solar power capacity will reach 2,000MW to replace imported coal-fired thermal power

(Source: The Technical report Vietnam's INDC in 2015)

1.2. Application of GACMO model for assessment of mitigation impacts

1.2.1. Introduction of GACMO

GACMO is a spreadsheet model which can calculate Business-As-Usual (BAU) projections, as well as GHG reduction and cost for mitigation options with the technology used in the BAU.

In addition, it allows to scale the size of mitigation options and to provide a quick overview of the total effort to reduce GHG emissions. Moreover, the calculation is transparent and easy to follow.

1.2.2. Data arrangement for operation of GACMO

- Viet Nam's BAU scenario for GHG emissions was developed based on the assumption of economic growth in the absence of existing climate change policies.

- The GHG emission factor applied to the development of the BAU mainly applies the default coefficient of IPCC.

- The 2000 "IPCC Good Practice Guidance" was used to calculate and project GHG emissions in the energy sector by 2020 and 2030 (MONRE, 2014).

- Projections on energy demand were taken from the National Master Plan for Power Development for the 2011-2020 period with a vision to 2030 (CPVN, 2011b), The emission factors set out in the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories and IPCC Good Practice Guidance were applied.

- BAU of the energy sector is calculated for the entire process of exploitation, production, processing and use of energy from fossil fuel sources.

- The base year is 2014.

- The data used for GACMO model was collected and aggregated from published data sources of the management agencies:

+ The data of population growth in the model is based on the data in the Vietnam Population Forecast 2009-2049 of the General Statistics Office in 2011.

+ Average GDP growth of 5 years in the 2016-2020 period will reach 6.5-7% / year (according to Resolution No.142/2016/QH13, April 12, 2016 of the National Assembly, 5-year socio-economic development plan 2016-2020).

+ Average 5-year GDP growth in the 2021-2025 period will be around 7% / year (according to the Prime Minister's Directive 18/CT-TTg of April 13, 2020 on elaboration of the socio-economic development plan meeting in 2021-2025).

+ The emission factor of Vietnam's electricity grid in 2018 is 0.9130 tCO2/MWh (as announced by the Department of Climate Change, Ministry of Natural Resources and Environment).

+ The assumption of exchange rates with the US dollar, discount rates, raw material prices for the base year are based on Vietnam's statistics published by the General Statistics Office of Vietnam.

+ Parameters of small hydroelectric plants, wind power plants, solar power plants, biomass power plants refer to Vietnam Technology Handbook 2019.

Table 2: Energy Balance of Viet Nam in 2014

Unit: Physical	Coal (Domestic)	Coal (Import)	Crude oil (Domestic)	Crude oil (Import)	LPG	Mogas	Jet fuel	Kerosene	DO	FO	Other petroleum	Natural gas	Non-Associated gas	Hydro	Solar heat	Wind power	Electricity
	1000 tons	1000 tons	1000 tons	1000 tons	1000 tons	1000 tons	1000 tons	1000 tons	1000 tons	1000 tons	1000 tons	Million m3	Million TWE	GWh	GWh	GWh	GWh
Domestic Production	45,842		17,392	0	0	0	0	0	0	0	0	11,495	39	59,841	0.93	81.0	
Import		3,096	0	0	728	2,435	1,209	29	4,961	773	1,115			0	0	0	2,326
Export	-7,265		-9,306	0	0.0	-180	-427	0.0	-387	-122	-22.0			0	0	0	-885
Stock changes	-1,260		0	0	-1.8	20	-1.4	-3	9	2.4	0			0	0	0	
TOAL PRIMARY ENERGY SUPPLY	**37,316**	**3,096**	**8,086**	**0**	**726**	**2,275**	**781**	**26**	**4,584**	**653**	**1,093**	**11,495**	**39**	**59,841**	**0.9**	**81**	**1,441**
Oil refineries	0	0	-8,086	0	357	2,208	97	0	2,892	139	143	0		0	0.0	0	
Gas processing (transfer)	0	0	0	0	169	0	0	0	0	0	0	-208		0	0.0	0	
Main activity electricity plants	-19,954	0	0	0	0	0	0	0	-55	-120	0	-8,308	-0.1	-59,841	0.0	-81.0	144,657
Loss & Own use	0	0	0	0	0	0	0	0	0	0	0	0		0	0.0	0	-16,223
TOTAL FINAL ENERGY COMSUMPTION	**17,362**	**3,096**	**0**	**0**	**1,253**	**4,483**	**878**	**26**	**6,570**	**575**	**1,236**	**2,979**	**38**	**0**	**0.93**	**0**	**128,434**
Industry	14,641	3,096	0	0	205	0	0	7	1,007	341	0	2,979	11	0	0	0	69,185
Iron & Steel	213				20.6			0.0	138	127		165					9,230
Fertilizer	1,337				1.6			0.1	6	2		1,388					965
Chemical	761				10.3			0.3	72	119		585					2,489
Cement	4,325	3,096			7			0.0	352	4		0					4,751
Building Material	1,629				53			0.7	160	54		235	3.1				2,814

Unit: Physical	Coal (Domestic)	Coal (Import)	Crude oil (Domestic)	Crude oil (Import)	LPG	Mogas	Jet fuel	Kerosene	DO	FO	Other petroleum	Natural gas	Non-Associated gas	Hydro	Solar heat	Wind power	Electricity
	1000 tons	1000 tons	1000 tons	1000 tons	1000 tons	1000 tons	1000 tons	1000 tons	1000 tons	1000 tons	1000 tons	Million m3	Million TWE	GWh	GWh	GWh	GWh
Beverage	77				3.0			0.0	10	11.4		15					2,349
Food & Tobacco	208				41				39	7		11	8.0				9,809
Textile & Leather	1,073				4			0.1	47	1		92					8,791
Paper products	407				2			0.0	15	11		11					986
Pulp & Printing	3,929				1			1.5	152	2							768
Plastic	0				1			0.1	14	0		0					1,691
Non-specific sub-sectors	682				61			4.3	2	1		477					24,541
Agriculture	36		0	0	0	110	0	0	310	0.0	0	0		0	0	0	1,893
Transport	0		0	0	0	4,373	878	0	4,950	234	0	0		0	0	0	0
Commerce	680		0	0	403	0	0	3	289	0.0	0	0	0	0	0	0	14,812
Household	2,005		0	0	644	0	0	16	15	0.0	0	0	27	0	0.93	0	42,544
Non-energy use	0		0	0	0	0	0	0	0	0	1,236	0		0	0	0	0

(Source: Vietnam Energy Statistics 2015 - Energy of Institute)

II. DEMONSTRATION RESULTS OF GACMO FOR ENERGY SECTOR

2.1. Evaluation for GHG reduction by selected mitigation options

Results of cost calculation and GHG emission reduction potential using GACMO model are as follows:

Table 3: Calculation results of cost and mitigation potential of mitigation options in the energy sector when using the model

No.	Options	Scale capacity (compared to BAU) (MW)	Emission reduction in 2030 (kt/year)	Investment (Millions USD)	Investment rate ($/MW)	Cost reduction ($/TonCO2)	Potential of emission reductions per unit of capacity (TonCO2/MW)
1	E11. Biomass power plants	2,000	6,391.00	3,400	1.70	41.94	3,196
2	E12. Small hydropower plants	2,400	8,764.80	3,360	1.40	-21.57	3,652
3	E13. Wind power plants by national funding	100	301.29	160	1.60	4.46	3,013
4	E17. Solar PV power plants	2,000	3,332.45	2,200	1.10	12.95	1,666

According to the calculation results of the model in ***Table 3***, the total GHG emission potential in 2030 of the solutions is as follows: E11 reaches about 6,391.00 kt/year, E12 reaches about 8,764.80 kt/year, E13 reach 301.29 kt/year and E17 reaches 3,332.45 kt/year. In particular, E12 has the potential to reduce GHG emissions per unit of highest capacity of about 3,652 TonCO_2/MW more than 2 times higher than the lowest E17 of about 1.666 TonCO_2/MW.

2.2. Comparison of GACMO results with Vietnam NDC

According to Vietnam's INDC 2015 report, the mitigation costs and potential of 04 mitigation options in energy sectors are considered as follows:

Table 4: Calculation results of cost and mitigation potential of mitigation options in the energy sector in Vietnam's INDC 2015 report

No.	Options	Emission reduction in 2030 (kt/year)	Incremental costs (Millions USD)	Cost reduction ($/TonCO2)
1	E11. Biomass power plants	7,002.20	46.2	3.9

No.	Options	Emission reduction in 2030 (kt/year)	Incremental costs (Millions USD)	Cost reduction ($/TonCO2)
2	E12. Small hydropower plants	7,994.90	-70.2	-3.3
3	E13. Wind power plants by national funding	180.20	43.2	49.1
4	E17. Solar PV power plants	2,162,40	409.7	160.1

(Source: The Technical report Vietnam's INDC in 2015)

Comment:

- In Vietnam's INDC report 2015, to develop GHG emission reduction scenarios for the energy sector, experts used the Long-term Energy Alternative Plan (LEAP) model. The LEAP model allows analysis of energy supply and demand - the environment of the energy system, including: primary energy sources, conversion, distribution and use of energy on the basis of input assumptions such as: GDP growth, population growth, past energy consumption and fuel prices refer to US Information Agency forecasts, last updated 2014 with base year 2010. Therefore, there is a little difference between the results from calculating the mitigation potential in the GACMO model and from the technical report Vietnam's INDC in 2015. Nevertheless, the differences in ktCO2e seem to be limited and in line with expectations: GACMO provides slightly higher estimates.

- The incremental costs in the technical report Vietnam's INDC in 2015 is an increase compared to the baseline scenario (BAU scenario), while the model is calculated for total investment. Therefore, it is difficult to compare the calculation results of the two methods.

III. CONCLUSIONS AND RECOMMENDATIONS

3.1. Conclusions:

- The options of emission reduction have the potential to reduce high GHG emissions in the energy sector. However, to balance investment costs and the potential to reduce GHG emissions, it is necessary to consider applying many effective solutions.

- It is convenient and easy to use the GACMO model, given that relevant factors in the model is designed in accordance with the national energy statistic book of Vietnam which is annually published.

- If the database is available and sufficient, the model can help verify the results of past National GHG mitigation efforts and allow the development of mitigation approaches in the future to give an overview of mitigation efforts.

3.2. Recommendations:

- The GACMO model requires a lot of input data and the accuracy of the input data will greatly affect the calculation results. Therefore, to ensure legal basis of data, in line with the Vietnam's context and the IPCC guidelines, a deeper research is highly recommended to be conducted.

- The remaining options of the energy sector mentioned in the Vietnam's INDC report that do not have any calculation options in the model, so it is proposed to build more options consistent with the options in the report of Vietnam. In order for Vietnamese experts to build their own spreadsheets for new options to take the initiative in calculation, specific guidelines should be included in developing the model.

- The parameters in the calculation outputs of the model need to be built based on the evaluation criteria in the INDC Report of Vietnam to facilitate the evaluation and comment.

IV. REFERENCES

Emission factor of Vietnam's power grid in 2018 is announced by the Department of Climate Change, Ministry of Natural Resources and Environment.Vietnam's INDC – Government of Viet Nam, 2015;

Prime Minister, November 25, 2015, Decision 2068/QD-TTg approving Vietnam's renewable energy development strategy to 2030, vision to 2050;

Prime Minister, March 18, 2016, Decision 428/QD-TTg approving the adjustment of the National Electricity Development Plan for the period of 2011-2020 with a vision to 2030;

Prime Minister's Directive 18 / CT-TTg of April 13, 2020 on elaboration of the socio-economic development plan Meeting in 2021-2025;

Resolution No. 142/2016 / QH13, April 12, 2016 of the National Assembly, 5 years socio-economic development plan 2016-2020;

Technical Report on Vietnam's INDC – MONRE (Vietnam), 2015;

Technology Handbook 2019 – Institute of Energy (Vietnam), 2019;

Vietnam Energy Statistics 2015 – Institute of Energy (Vietnam), 2015;

Vietnam population forecast 2009-2049 - General Statistics Office 2011;

APPENDIX

Appendix A: Fossil fuel energy balance in 2014

TJ units	LPG	Gasoline	Jet Fuel	Diesel	HFO	Kerosene and other	Total oil products	Coal	Lignite	Natural Gas	Coke	Petrocoke	Total energy
Unit	TJ	TJ	TJ	TJ	TJ	TJ	TJ	TJ	TJ	TJ	TJ	TJ	TJ
Total	57,160	197,090	37,850	319,270	32,810	1,120	645,300.0	780,330	0	439,470	0	0	1,865,100
Fossil power plants	0	0	0	2,370	4,960	0	7,330.0	385,300	0	323,490	0	0	716,120
FINAL CONSUMPTION	57,160	197,090	37,850	316,900	27,850	1,120	637,970.0	395,030	0	115,980	0	0	1,148,980
Industry - steel	940	0	0	5,910	5,260	0	12,110.0	4,110	0	6,420	0	0	22,640
Industry - chemical	570	0	0	3,940	5,030	10	9,550.0	40,530	0	76,820	0	0	126,900
Industry - non metallic mineral		0	0			0	0.0		0		0	0	0
Industry - food processing and beverage	2,000	0	0	2,100	780	0	4,880.0	5,500	0	1,030	0	0	11,410
Industry - construction	2,730	0	0	21,850	2,430	30	27,040.0	174,730	0	9,150	0	0	210,920
Industry - mining		0	0			0	0.0		0		0	0	0
Industry - machinery		0	0			0	0.0		0		0	0	0
Industry - non ferrous metals		0	0			0	0.0		0		0	0	0
Industry - paper and pulp	140	0	0	7,140	510	70	7,860.0	83,730	0	430	0	0	92,020
Industry - transport equipment		0	0			0	0.0		0		0	0	0
Industry - textile and leather	190	0	0	2,010	50	0	2,250.0	20,710	0	3,570	0	0	26,530
Industry - miscellaneous	2,790	0	0	70	60	180	3,100.0	13,170	0	18,560	0	0	34,830
Transport - road		192,250	0	196,018	9,700	0	397,968.0		0		0	0	397,968
Transport - rail		0	0	1,616		0	1,616.0		0		0	0	1,616
Transport - domestic air		0	37,850	13,746		0	51,596.0		0		0	0	51,596
Transport - navigation		0	0			0	0.0		0		0	0	0
Households	29,390	0	0	640		700	30,730.0	38,720	0		0	0	69,450
Services	18,410	0	0	12,330		130	30,870.0	13,130	0		0	0	44,000
Agriculture & Fishery		4,840	0	49,530	4,030	0	58,400.0	700	0		0	0	59,100
Non energy - chemical feedstocs		0	0			0	0.0		0		0	0	0

Appendix B: Growth from start year 2014[1]

Growth from the start year	Annual % increase in the period		
Growth and multiplication factors	**2014-2020**	**2020-2025**	**2025-2030**
Population growth	1.05%	0.87%	0.69%
GDP growth	6.73%	7.00%	7.00%
Industry - fuel in steel	7.0%	7.0%	7.0%
Industry - fuel in chemical	7.0%	7.0%	7.0%
Industry - fuel in non metallic mineral	7.0%	7.0%	7.0%
Industry - fuel in food and beverage	7.0%	7.0%	7.0%
Industry - fuel in construction	7.0%	7.0%	7.0%
Industry - fuel in mining	7.0%	7.0%	7.0%
Industry - fuel in machinery	7.0%	7.0%	7.0%
Industry - fuel in non ferrous metals	7.0%	7.0%	7.0%
Industry - fuel in paper and pulp	7.0%	7.0%	7.0%
Industry - fuel in transport equipment	7.0%	7.0%	7.0%
Industry - fuel in textile and leather	7.0%	7.0%	7.0%
Industry - fuel in miscellaneous	7.0%	7.0%	7.0%
Industry - electricity consumption	7.0%	7.0%	7.0%
Transport - fuel in road	7.0%	7.0%	7.0%
Transport - fuel in rail	7.0%	7.0%	7.0%
Transport - fuel in air	7.0%	7.0%	7.0%
Transport - fuel in navigation	7.0%	7.0%	7.0%
Transport - electricity consumption	7.0%	7.0%	7.0%
Households - LPG	7.0%	7.0%	7.0%
Households - Kerosene	7.0%	7.0%	7.0%
Households - electricity consumption	7.0%	7.0%	7.0%
Services - fuel	7.0%	7.0%	7.0%
Services - electricity consumption	7.0%	7.0%	7.0%
Agriculture - fuel	6.0%	6.0%	6.0%
Agriculture - electricity consumption	6.0%	6.0%	6.0%
Non energy - fuel in chemical feedstocks	7.0%	7.0%	7.0%
Livestock emissions	6.4%	1.8%	1.8%
Rice emissions	-2.0%	0.2%	0.2%
N2O from agricultural soils	0.0%	0.0%	0.0%
Biomass burning	5.3%	0.7%	0.7%
Forestry emission	0.0%	-20.6%	0.6%
Solid waste emissions	12.6%	14.1%	14.1%
Liquid waste emissions	6.6%	2.9%	2.9%
Industrial processes	0.0%	0.0%	0.0%

[1] Vietnam Population Forecast 2009-2049 of the General Statistics Office in 2011;
Prime Minister's Directive 18 / CT-TTg of April 13, 2020 on elaboration of the socio-economic development plan Meeting in 2021-2025.

Appendix C: Assumptions

Country:		Vietnam	
Start year (latest inventory):		2014	
Currency:		VND	
Exchange rate used:	1 US$=	21285.71062	VND
Discount rate =		10.0%	

Energy prices used for the whole period[2]:		
Crude oil	51.52	US$/bbl
Crude oil	0.32	US$/litre
LNG	4.4	US$/MBTU
Natural gas	4.170616114	US$/GJ
Coal	60	US$/ton

Fuel prices

2020 prices	Distillate price/crude oil price (litre/litre)	US$/litre	US$/GJ	t/m3	GJ/t
LPG	0.90	0.29	11.4	0.54	47.3
Gasoline	1.40	0.45	13.5	0.75	44.8
Bioethanol		0.83		0.76	26.8
Jet Fuel	1.40	0.45	12.7	0.80	44.6
Diesel Oil	1.20	0.39	10.7	0.84	43.3
Biodiesel		1.20		0.88	26.8
Heavy Fuel Oil	0.80	0.26	6.6	0.98	40.2
Kerosene	1.40	0.45	12.7	0.80	44.8
Coal			2.5		25.0
Coke			2.5		28.0
Petroleum coke			2.5		31.0
Lignite					18.3
Natureal Gas			4.2	(MJ/Nm3)	39.0

Electricity	Isolated grids	Grid 1	Grid 2
US$/kWh		0.07	
	tCO2/MWh (=kCO2/kWh)		
Operating margin (OM)			
Build Margin (BM)			

[2] The Statistics Portal http://www.statista.com/statistics/262858/change-in-opec-crude-oil-prices-since-1960/

Combined Margin (CM) Solar & Wind		0.9130	
Combined Margin (CM) Other[3]		**0.9130**	
Heat	District heat	Industry	
US$/GJ	6.7	8.7	
Electricity grid losses & own consumption	18.6%		

kg/GJ	**Emission factors**	CO2	CH4	N2O
Power plant	Fuel oil	77.4	0.003	0.0006
	Diesel oil	74.1	0.003	0.0006
	Gasoline	69.3	0.003	0.0006
	Jet fuel	71.5	0.003	0.0006
	Kerosene	71.9	0.003	0.0006
	LPG	63.1	0.001	0.0001
	Natural gas	56.1	0.001	0.0001
	Coal	94.6	0.001	0.0014
	Lignite	101.2	0.001	0.0014
Industry	Oil	as	0.002	0.0006
	Natural gas	above	0.005	0.0001
	Coal		0.010	0.0014
	Charcoal		0.200	0.0040
Residential	Oil	as	0.010	0.0006
	Natural gas	above	0.005	0.0001
	Coal		0.300	0.0014
	Charcoal		0.200	0.0040

Global warming potentials:	SAR	AR4	AR5	GWP used		TAR
1 Ton CH4 =	21	25	28	21	Ton CO2	23
1 Ton N2O =	310	298	265	310	Ton CO2	296

[3] Document No. 263 / Climate Change-TTBVTOD of the Department of Climate Change, Ministry of Natural Resources and Environment dated March 12th, 2020 on notification of emission factors of Vietnam's electricity grid in 2018

Appendix D: Parameters for Option E11. Biomass power plants[4]

General inputs:		
Discount rate	10%	
Reference electricity price	0.07	US$/kWh
CO2-eq. emission coefficient	0.91	tCO2/MWh
Reduction option: Biomass residues power plant		
O&M	2.8%	
Activity	1	MW
Investment in Activity	1.7	Million US$
Capacity factor	3500	Full time hours
Electricity production	3500	MWh/ year
Calorific value of biomass	13.0	GJ/t
El. efficiency of power plant	31.0%	
Specific use of biomass	0.90	ton biomass/MWh
Use of biomass	3134	ton/year
Price of biomass	36.6	$/ton
Cost of electricity produced	0.057	US$/kWh
Reference option: No Biomass power		

1 MW Biomass power from biomass residues			
Costs in US$	Reduction Option	Reference Option	Increase (Red.-Ref.)
Total investment	1,700,000		
Project life	20		
Lev. investment	199,681		199,681
Annual O&M	47,000		47,000
Annual fuel cost	114,851	227,500	-112,649
Total annual cost	361,532	227,500	**134,032**
Annual emissions (tons)	Tons	Tons	Reduction
Fuel CO2-eq. emission		3,196	3,196
Other			
Total CO2-eq. emission	0	3,196	**3,196**
US$/ton CO2-eq.			**41.9**

[4]Technology Handbook 2019 – Institute of Energy, 2019;

Appendix E: Parameters for Option E12. Hydro power plants[5]

General inputs:		
Discount rate	10%	
Reference electricity price	0.07	US$/kWh
CO2-eq. emission coefficient	0.91	tCO2/MWh
Reduction option: Hydro Power		
O&M	1.2%	Of investment
Activity	1	MW
Investment in Activity	1400	US$/kW
Capacity factor	4000	Full time hours
Electricity production	4000	MWh/ year
Reference option: No hydro power plant		

1 MW Mini hydro power connected to main grid			
Costs in US$	Reduction Option	Reference Option	Increase (Red.-Ref.)
Total investment	1,400,000		
Project life	20		
Lev. investment	164,443		164,443
Annual O&M	16,800		16,800
Annual fuel cost		260,000	-260,000
Total annual cost	181,243	260,000	**-78,757**
Annual emissions (tons)	Tons	Tons	Reduction
Fuel CO2-eq. emission		3,652	3,652
Other			
Total CO2-eq. emission	0	3,652	**3,652**
US$/ton CO2-eq.			**-21.6**

[5] Technology Handbook 2019 – Institute of Energy, 2019;

Appendix F: Parameters for Option E13. Wind power plants[6]

General inputs:		
Discount rate	10%	
Reference electricity price	0.07	US$/kWh
CO2-eq. emission coefficient	0.91	tCO2/MWh
Reduction option: Wind Power		
O&M	2.50%	
Activity	1	MW
Investment in Activity	1600	US$/kW
Capacity factor	3300	Full time hours
Electricity production	3300	MWh/ year
Cost of electricity produced	0.069	US$/kWh
Reference option: No wind turbines		

1 MW Wind turbines connected to main grid (on-shore)			
Costs in US$	Reduction Option	Reference Option	Increase (Red.-Ref.)
Total investment	1600000		
Project life	20		
Lev. investment	187935		187935
Annual O&M	40000		40000
Annual fuel cost		214500	-214500
Total annual cost	227935	214500	**13435**
Annual emissions (tons)	Tons	Tons	Reduction
Fuel CO2-eq. emission		3012.9	3012.9
Other			
Total CO2-eq. emission	0.0	3012.9	**3012.9**
US$/ton CO2-eq.			**4.5**

[6] Technology Handbook 2019 – Institute of Energy, 2019;

Appendix G: Parameters for Option E17. Solar PV power plants[7]

General inputs:		
Discount rate	10%	
Reference electricity price	0.07	US$/kWh
CO2-eq. emission coefficient	0.91	tCO2/MWh
Activity: Solar PV		
Size of solar PV	1.0	MW
Investment in Activity	1100	US$/kW
Daily insolation	5	hours
Annual capacity factor	1825	Full time hours
Efficiency factor	1	
O&M	1.0%	Of investment
Electricity production	1825	MWh
Cost of electricity produced	0.077	US$/kWh
Reference option: No solar PVs		
Electricity production	1825	MWh

Solar PVs, large grid, 1 MW			
Costs in US$	Reduction Option	Reference Option	Increase (Red.-Ref.)
Total investment	1,100,000		
Project life	20		
Lev. investment	129,206		129,206
Annual O&M	11,000		11,000
Annual fuel cost		118,625	-118,625
Total annual cost	140,206	118,625	**21,581**
Annual emissions (tons)	Tons	Tons	Reduction
Fuel CO2-eq. emission		1,666	1,666
Other			
Total CO2-eq. emission	0	1,666	**1,666**
US$/ton CO2-eq.			**13.0**

[7] Technology Handbook 2019 – Institute of Energy, 2019;