

GUIDELINES FOR ESTIMATING GREENHOUSE GAS EMISSIONS OF ASIAN DEVELOPMENT BANK PROJECTS

ADDITIONAL GUIDANCE FOR CLEAN ENERGY PROJECTS

GUIDELINES FOR ESTIMATING GREENHOUSE GAS EMISSIONS OF ASIAN DEVELOPMENT BANK PROJECTS

ADDITIONAL GUIDANCE FOR CLEAN ENERGY PROJECTS



Creative Commons Attribution 3.0 IGO license (CC BY 3.0 IGO)

© 2017 Asian Development Bank
6 ADB Avenue, Mandaluyong City, 1550 Metro Manila, Philippines
Tel +63 2 632 4444; Fax +63 2 636 2444
www.adb.org

Some rights reserved. Published in 2017.
Printed in the Philippines.

ISBN 978-92-9257-779-7 (Print), 978-92-9257-780-3 (e-ISBN)
Publication Stock No. TIM178659-2
<http://dx.doi.org/10.22617/TIM178659-2>

Cataloging-In-Publication Data

Asian Development Bank.

Guidelines for estimating greenhouse gas emissions of Asian Development Bank projects: Additional guidance for clean energy projects.

Mandaluyong City, Philippines: Asian Development Bank, 2017.

1. Clean energy. 2. Greenhouse gas emissions. 3. Climate change. I. Asian Development Bank.

The views expressed in this publication are those of the authors and do not necessarily reflect the views and policies of the Asian Development Bank (ADB) or its Board of Governors or the governments they represent.

ADB does not guarantee the accuracy of the data included in this publication and accepts no responsibility for any consequence of their use. The mention of specific companies or products of manufacturers does not imply that they are endorsed or recommended by ADB in preference to others of a similar nature that are not mentioned.

By making any designation of or reference to a particular territory or geographic area, or by using the term “country” in this document, ADB does not intend to make any judgments as to the legal or other status of any territory or area.

This work is available under the Creative Commons Attribution 3.0 IGO license (CC BY 3.0 IGO) <https://creativecommons.org/licenses/by/3.0/igo/>. By using the content of this publication, you agree to be bound by the terms of this license.

This CC license does not apply to non-ADB copyright materials in this publication. If the material is attributed to another source, please contact the copyright owner or publisher of that source for permission to reproduce it. ADB cannot be held liable for any claims that arise as a result of your use of the material.

Attribution—You should always acknowledge ADB as the source using the following format:

[Author]. [Year of publication]. [Title of the work in italics]. [City of publication]: [Publisher]. © ADB. [URL or DOI] [license].

Translations—Any translations you create should carry the following disclaimer:

Originally published by ADB in English under the title [title in italics]. © ADB. [URL or DOI] [license]. The quality of the translation and its coherence with the original text is the sole responsibility of the translator. The English original of this work is the only official version.

Adaptations—Any adaptations you create should carry the following disclaimer:

This is an adaptation of an original work titled [title in italics]. © ADB. [URL or DOI] [license]. The views expressed here are those of the authors and do not necessarily reflect the views and policies of ADB or its Board of Governors or the governments they represent. ADB does not endorse this work or guarantee the accuracy of the data included in this publication and accepts no responsibility for any consequence of their use.

Please contact pubsmarketing@adb.org if you have questions or comments with respect to content, or if you wish to obtain copyright permission for your intended use that does not fall within these terms, or for permission to use the ADB logo.

Corrigenda to ADB publications may be found at <http://www.adb.org/publications/corrigenda>

Contents

Abbreviations	iv
I. Introduction	1
II. General Methodology	2
A. Baseline Emissions	2
B. Project Emissions	4
C. Leakage Emissions	4
D. Emissions Factors	5
E. Detailed General Equations for Calculating GHG Emissions	5
III. Specific Methodologies	7
A. Renewable Power Generation Projects (Solar, Wind, Small, Run-of-River Hydro)	7
B. Renewable Power Generation Projects (Large Hydro)	8
C. Renewable Power Generation Projects (Geothermal)	8
D. Energy Efficiency Projects (Introduction of New and Efficient Equipment)	9
E. Energy Efficiency Projects (Improvement of Existing Equipment/Facilities)	11
F. Energy Efficiency Projects (Introduction of New and Efficient Electricity T&D System)	12
G. Energy Efficiency Projects (Improvement of Existing Electricity Transmission and Distribution System)	13
H. Energy Efficiency Project (Conversion of Open Cycle Gas Turbine into Combined Cycle Power Plant)	14
I. Energy Efficiency Project (Rehabilitation of Fossil-fired Power Plants)	17
J. Methane Capture and Use for Power Generation	19
K. Solid Wastes Management/Waste-to-Energy Projects/Landfill Gas Recovery	20
IV. Illustrative Examples	21
A. Illustrative Example #1	21
B. Illustrative Example #1A	22
C. Illustrative Example #2	23
Appendixes	
A. Direct Global Warming Potentials of Selected Greenhouse Gases	25
B. Default Net Calorific Values and CO ₂ Emission Factors for Combustion	26
C. Grid Emission Factors for Selected Countries	27
D. Default Efficiency Factors for Power Plants	28
E. Density of Common Fuels	29
F. Conversion Factors	30
G. IFI Approach to GHG Accounting for Energy Efficiency Projects	31
H. IFI Approach to GHG Accounting for Renewable Energy Projects	35

Abbreviations

ADB	Asian Development Bank
CDM	Clean Development Mechanism
GHG	Greenhouse Gas
JBIC	Japan Bank for International Cooperation
MWh	Megawatt hour
tCO ₂	ton of carbon dioxide
tCH ₄	ton of methane
TJ	terajoules

I. Introduction

1. International Financial Institutions (IFIs) are increasingly becoming aware of the need to estimate and report on the impacts of their climate-related investment—specifically, on the gross GHG emissions and GHG emission reduction attributable to their projects. To address this need, a group of IFIs including ADB, through its technical working group came up with two harmonized guidance documents on GHG accounting: one for energy efficiency projects and another for renewable energy projects (See Appendixes E and F). The harmonized methodologies will improve consistency and comparability of GHG accounting results across IFIs. These guidance documents are broad and general and need to be supplemented with more detailed, project-specific guidelines. This paper, *Guidelines for Estimating Greenhouse Gas Emissions of Asian Development Bank Projects: Additional Guidance for Clean Energy Projects*, provides those detailed guidelines. It aims to help project officers at ADB estimate GHG emissions reductions attributable to their energy projects in a manner consistent with the IFIs' guidance documents.
2. Within ADB, there are policies and practices where GHG emission estimates are needed. The 2009 Safeguard Policy Statement requires that GHG emissions from projects emitting 100,000 tons CO₂eq or more be monitored.¹ Greenhouse gas emission reduction is being monitored and reported as one of the Level 2 Results Framework Indicators.² Furthermore, the project classification system³ requires that CO₂ emission reduction be estimated and inputted in the project at a glance, an integral part of the concept papers and the RRP.
3. The methodologies included here are consistent with the IFI approaches and based on CDM methodologies and JBIC's J-MRV guidelines. They are to be used to estimate GHG emissions during project appraisal/development stage.
4. Recognizing that it is not possible to include here all methodologies for all conceivable ADB projects, these guidelines explain through narratives and show through examples the basics of developing other methodologies.

¹ ADB. 2009. *Safeguard Policy Statement*. <https://www.adb.org/sites/default/files/institutional-document/32056/safeguard-policy-statement-june2009.pdf>

² ADB. 2017. *Results Framework Indicator Definitions, February 2017*. <https://www.adb.org/documents/results-framework-indicator-definitions>

³ Pages 6–7, March 21, 2014, Staff Instruction on Project Classification System.

II. General Methodology

5. This section provides methods for calculating, ex-ante, the GHG emissions reductions attributable to ADB climate change mitigation projects. Selected greenhouse gases commonly found in the energy sector are listed in Appendix A.
6. The general approach involves:
- (i) defining project boundary. Only those emissions that are result of, and directly attributable to the project activity should be counted as project emissions. All emissions which are unaffected by the activity should be disregarded, most importantly the non-captured CO₂ and methane emissions. The approach supports the definition: “the project boundary shall encompass all anthropogenic emissions by sources of GHGs under the control of project participants that are significant and reasonably attributable to the project activity”. In a nutshell, project boundary encompasses relevant activities in projects funded by ADB.
 - (ii) identifying the most plausible baseline scenario and quantifying baseline emissions (BE) based on that scenario,
 - (iii) quantifying emissions attributable to ADB mitigation project (PE)
 - (iv) estimating leakage emissions (LE)
 - (v) estimating emissions reductions (ER) using the general equation below.

$$\text{Emissions reduction (ER)} = \text{baseline emissions (BE)} - \text{project emissions (PE)} - \text{leakage emissions (LE)} \quad (\text{Equation 1})$$

A. Baseline Emissions

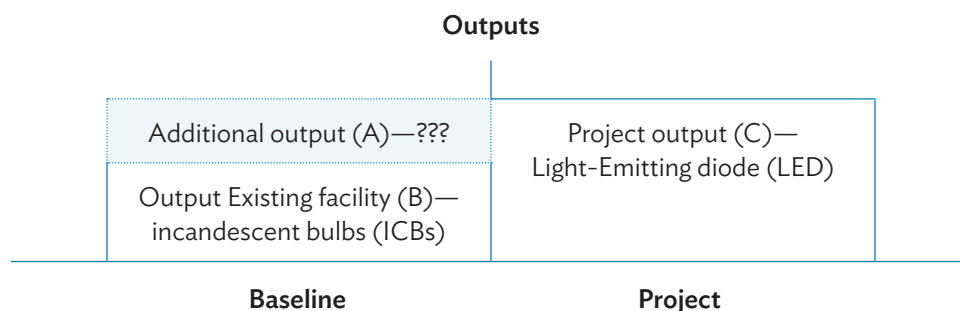
7. Baseline emissions (BE) refer to GHG emissions that would occur in the baseline scenario—a hypothetical scenario that can reasonably represent the GHG emissions that would occur in the absence of the ADB project. In other words, baseline scenario is the “without project” scenario.

8. Defining plausible baseline scenarios and computing baseline emissions based on them can range from simple to complex processes depending on the types of projects, conditions/assumptions considered and availability of data. To simplify the process, these guidelines follow the approach taken by “J-MRV Guidelines” by JBIC.⁴ ADB mitigation projects involve either (i) installing new facility or (ii) retrofitting, improving, replacing existing facility; suggested baseline emissions for each are provided as follows:

⁴ JBIC. 2016. *Guidelines for Measurement, Reporting and Verification of GHG Emission Reductions in JBIC GREEN Operation Revised, July 2016*. http://www.jbic.go.jp/wp-content/uploads/page/2016/04/49256/201607_jmrv-guideline_en.pdf

- (i) Suggested baseline for Installing New Facility
 - **New Power plant projects:** The baseline emissions for grid-connected power plant projects will be based on the combined margin emission factor for the electrical grid in DMCs where the project will be implemented. Grid emission factors for selected DMCs are in Appendix C.
 - **All other new projects including, but not limited to, district heating, district cooling, transmission and distribution and cogeneration projects:** The baseline emissions for these other projects will be based (i) on emissions of similar projects or facilities (or technologies) most prevalent in the DMC or the region where the project will be implemented or (ii) on emissions of recently built, similar projects or facilities in the DMC or the region where the project will be implemented. Use whichever is smaller.
- (ii) Suggested baseline for Retrofitting, Improving, Replacing Existing Facility
 - Retrofitting or replacing existing facility without capacity expansion. The baseline emissions are the emissions of the existing facility prior to retrofitting, replacement or improvement.
 - Retrofitting or replacing existing facility with capacity expansion. The baseline emissions will have two components: (a) emissions based on existing capacity and technology and (b) emissions based on the additional capacity and the most prevalent technology in the DMC or region where the project will be implemented. The additional capacity will be produced by a technology different from the existing; it is akin to putting up a new facility—with a technology most prevalent in the project area—to generate this additional output.

9. To illustrate this concept, consider the lighting project represented by the figure below. The lighting project has an output (C) that exceeds the baseline output (B) by an amount equal to additional output (A). Output (A) is for lighting additional area constructed as part of the project. Output (C) is to be generated by LED (most efficient); output (B) by incandescent bulbs (ICBs) (least efficient); and additional output (A) by a technology yet to be determined. Baseline output equals (A) + (B) which is equal to (C), the project output; baseline scenarios are (i) continuation of use of ICBs for (B) and (ii) use of the most prevalent technology in



the project area for (A)—it can LED, or compact fluorescent lamp (CFL) whichever is most common in the project area but not ICBs.

10. Another example is the replacement or rehabilitation of existing old boilers for heat supply to municipal or industrial users. The efficiencies of the existing old boilers, as reported in the project feasibility study reports, might not be justified as the reasonable representatives of baseline levels. This is because the efficiencies of the old boilers, which might already be obsolete and even subject to scrappage in a few years, could be significantly lower than the currently prevailing efficiency level of the more modern boilers widely installed in the local area. In such a case, the prevailing efficiency best representing the technology advancement and market situation in local circumstances should be used, instead of the efficiencies of the target old boilers of the project activity. Doing this avoids inflated baseline emissions. Furthermore, the remaining lifetime of the existing old boilers shall be considered when estimating the aggregate emissions reductions over the lifetime of the proposed project activity.

11. Replacement is assumed to take place well before the end of economic life of existing facility. If done at the end of the economic life, the replacement project should be treated as equivalent to installing new facility. Also, emissions reductions count only up the end of the remaining economic life of the replaced assets.

B. Project Emissions

12. Project emissions correspond to GHG emissions that would result if the proposed project activity is implemented. The project emissions can be more explicitly compared with the emissions of the hypothetical baseline scenario, since the project emissions are directly associated with the specific project activities being conceptualized, designed, or constructed.

13. The project emissions can be derived from project-related documents, which should contain major technical parameters in connection with project energy and fuel consumption since they are fundamental elements of a project's design. For example, the feasibility study of a landfill gas recovery project normally would have the estimate of the electricity consumption associated with the extraction, transportation, and pretreatment of the landfill gas.

14. Similar to baseline emissions, default values can be used for calculating project emissions where applicable, as annotated in individual methodologies. Default values may be particularly useful for parameters relating to grid or fuel emission factors, net calorific values of fuels, and electricity transmission and distribution loss ratio. The magnitude of potential loss in accuracy on account of using default values is considered to be insignificant and is acceptable for estimating future project emissions.

C. Leakage Emissions

15. Leakage emissions refer to the net change of GHG emissions that occurs outside the project boundary, and which is measurable and attributable to the project activity. In most methodologies covered by this paper, the leakage emissions are assumed to be negligible.

D. Emissions Factors

16. An emission factor is defined as an average emission rate of a given GHG for a given source, relative to units of activity.⁵ It is usually stated as GHG emission rate per unit of input or per unit of output. For example, for power generation projects emission factor in terms of inputs or fuels can be stated as tons GHG/ton of coal, kg GHG/liter of oil or kg CO₂/TJ of gas; for the same projects, emission factor stated in terms of output electricity can be in tons GHG/MWh of electricity generated.

17. Different systems can have different units for emission factors. Cement makers may have it in terms of kg GHG/ton of cement made; steel makers will have it in tons GHG/ton of steel manufactured, district heating system will have it in tons GHG/sq m of space heated, and so on.

18. One of the most useful emission factors is the grid emission factor or “combined” emission factor. It is the measure of CO₂ emissions intensity per unit of electricity generation in the grid system (tons CO₂/MWh).⁶ It represents the CO₂ emission from grid-connected power plants—those currently operating and those that are expected to be built.

19. The use of emission factors facilitates GHG emissions calculations whether in the baseline or project scenario. In its simplest form, the GHG emission is equal to the input or output of the activity/project multiplied by the appropriate emission factor.

E. Detailed General Equations for Calculating GHG Emissions

20. The following general equations are used to estimate GHG emissions both in the project and baseline scenarios.

- (i) When fuel is burned/used (in power plants, district heating, etc.)

$$\text{GHG Emissions} = FC \times E_{\text{fuel}} \quad (\text{Equation 2})$$

Where: FC = fuel consumption, tons/year, liters/year, TJ/year
 E_{fuel} = fuel emission factor, tCO₂/ton, tCO₂/liter, tCO₂/TJ

- (ii) When electricity is used

$$\text{GHG Emissions} = EC \times E_{\text{elec}} / (1 - \%L) \quad (\text{Equation 3})$$

Where: EC = electricity consumption, MWh/year
 E_{elec} = electricity emission factor, tCO₂/MWh; if electricity is from the grid, this refers to the grid emission factor; if electricity is from specific, identified power plant, this emission factor should be computed using equation 6 below.

⁵ UNFCCC. 2017. *Definitions*. http://unfccc.int/ghg_data/online_help/definitions/items/3817.php

⁶ UNFCCC. Grid Emission Factor—Challenges with Calculation and Validation. http://unfccc.int/resource/webcast/collections/110309_dna/downloads/DNA-Forum11_Day2_0915_GEF_DNA_Proactive_Role_UNFCCC_Arora.pdf

%L = T&D losses expressed as decimal equivalent (i.e., 20% loss is expressed as 0.20)

- (iii) When methane is burned

$$GHG\ Emissions = Mch_4 \times Ech_4 \quad (Equation\ 4)$$

Where: Mch_4 = amount of methane burned, tCH₄/year
 Ech_4 = methane emission factor, 2.75 tCO₂/tCH₄

- (iv) When methane is released into the atmosphere

$$GHG\ Emissions = Mch_4 \times GWPch_4 \quad (Equation\ 5)$$

Where: Mch_4 = amount of methane released into atmosphere, tCH₄/year
 $GWPch_4$ = global warming potential of methane, 25 tCO₂/tCH₄

Equation 5 can be generalized to cover other non-CO₂ greenhouse gases.

- (v) The emission factor for power plants, in terms of output (electricity generated) is computed as follows:

$$E_{elec} = (E_{fuel}/\eta) \times 3.6 \quad (Equation\ 6)$$

E_{elec} = electricity emission factor (for specific power plant/technology), tCO₂/GWh

E_{fuel} = emission factor of fuel used in power plant, tCO₂/TJ (Appendix B)

η = thermal efficiency of power plants (Appendix D)

Conversion factor: 3.6 TJ/GWh

Since fuel emission factors are given in Appendix B in TJ/ton, if fuel consumption is given in tons/year for coal, in liters/year for diesel, and in cubic meters/year for gas, they must be converted to terajoules/year (TJ/year). Here's how to do it.

Coal consumption (tons/year) × NCV (TJ/ton) = _____ TJ/year

Diesel consumption (liters/year) × 1 m³/1000 liters × density (kg/m³) × 1 ton/1000 kg × NCV (TJ/ton) = _____ TJ/year

Gas consumption (m³/year) × density (kg/m³) × 1 ton/1000 kg × NCV (TJ/ton) = _____ TJ/year

Net calorific values (NCVs) and densities of common fuels are in Appendixes B and E respectively.

III. Specific Methodologies

21. These guidelines have 10 methodologies applicable to common ADB energy sector projects and a reference to one calculation/simulation model for waste-to-energy/solid waste management projects.

A. Renewable Power Generation Projects (Solar, Wind, Small, Run-of-River Hydro)

Scope

22. This methodology applies to power plant projects using solar, wind, small hydro(run-of-river) resources.

Emission Reduction (ER)

23. Emission reduction is the difference between baseline and project emissions when generating the same amount of power.

$$ER = BE - PE$$

BE = baseline emission

PE = project emission

Baseline Emission (BE)

24. BE is the amount of emissions generated by grid-connected power plants when generating the same amount of power as the RE power plants.

$$BE = EG \times EF_{grid}$$

EG = annual electricity generation by the RE project, MWh/year

EF_{grid} = combined emission factor for the grid, tCO₂/MWh

Project Emission (PE)

25. PE is the amount of emissions generated by the RE power Plants using solar, wind, and small hydro resources.

26. For the applicable RE projects, PE is considered zero.

B. Renewable Power Generation Projects (Large Hydro)

Scope

27. This methodology applies to power plant projects using large hydro resources with reservoir.

Emission Reduction (ER)

28. Emission reduction is the difference between baseline and project emissions when generating the same amount of power.

$$ER = BE - PE$$

BE = baseline emission

PE = project emission

Baseline Emission (BE)

29. BE is the amount of emissions generated by grid-connected power plants when generating the same amount of power as the large hydro power plants.

$$BE = EG \times EF_{\text{grid}}$$

EG = annual electricity generation by the large hydro project, MWh/year

EF_{grid} = combined emission factor for the grid, tCO₂/MWh

Project Emission (PE)

30. PE is the amount of emissions generated by the dam of large hydropower plant.

$$PE = EG \times EF_{\text{hydro}}$$

EG = annual electricity generation by the large hydro project, MWh/year

EF_{hydro} = Emission factor for the large hydropower to account for methane emission from dam
0.090 tCO₂/MWh⁷

C. Renewable Power Generation Projects (Geothermal)

Scope

31. This methodology applies to power plant projects using geothermal resources.

Emission Reduction (ER)

32. Emission reduction is the difference between baseline and project emissions when generating the same amount of power.

⁷ UNFCCC. 2006. *CDM Executive Board Report*. https://cdm.unfccc.int/EB/023/eb23_repan5.pdf

$$ER = BE - PE$$

BE = baseline emission

PE = project emission

Baseline Emission (BE)

33. BE is the amount of emissions generated by grid-connected power plants when generating the same amount of power as the geothermal power plants.

$$BE = EG \times EF_{\text{grid}}$$

EG = annual electricity generation by the large hydro project, MWh/year

EF_{grid} = combined emission factor for the grid, tCO₂/MWh

Project Emission (PE)

34. PE is the amount of emissions from geothermal steam.

$$BE = EG \times EF_{\text{geo}}$$

EG = annual electricity generation by the geothermal power project, MWh/year

EF_{geo} = Emission factor for the geothermal steam to account for CO₂ and CH₄ emission (default value = 0.128 tCO₂e/MWh, = 0.0 tCO₂/MWh for binary technology)⁸

D. Energy Efficiency Projects (Introduction of New and Efficient Equipment)

Scope

35. This methodology applies to projects that reduce energy consumption by introducing new equipment, facilities or appliances. This covers new equipment, facilities or appliances that use electricity or fuel. The project activity may use different fuels or energy sources than the baseline. For example, the most prevalent industrial boilers in a country run on fuel oil. The project—new, more efficient boiler—can be running on natural gas. This methodology also applies to projects that replace equipment at the end of its economic life.

Emission Reduction (ER)

36. Emission reduction is the difference between baseline and project emissions when producing the same amount of outputs (products or services). The baseline technology is the most predominant technology for the equipment, facilities or appliances used in the country.

$$ER = BE - PE$$

BE = baseline emission

PE = project emission

⁸ World Bank. 2016. *Greenhouse Gases from Geothermal Power Production*. Washington DC.

Baseline Emission (BE)

37. BE is the amount of emissions generated by electricity or fuel used by the most predominant equipment, facilities or appliances in the country when producing the same amount of products or services as the project (new, efficient equipment, facilities, appliances).

Baseline emission for electricity-consuming equipment:

$$BE_e = EC_b \times EF_{grid} / (1 - \%L_b)$$

BE_e = Baseline emission for electricity-consuming equipment, tCO₂/year

EC_b = annual electricity consumption by the most prevalent equipment, facilities or appliances in the country, MWh/year; if there are more than one equipment, then EC_b is the total consumption of all concerned electricity-consuming equipment

EF_{grid} = combined emission factor for the grid, tCO₂/MWh

%L_b = baseline T&D losses expressed as decimal equivalent (i.e., 20% loss is expressed as 0.20)

Baseline emission for fuel-consuming equipment:

$$BE_f = FC \times NCV \times EF_{fuel}$$

BE_f = Baseline emission for fuel-consuming equipment, tCO₂/year

FC_b = annual fuel consumption by the most prevalent equipment, facilities or appliances in the country, tons/year or liters/year; if there are more than one equipment, then FC_b is the total consumption of all concerned fuel-consuming equipment

NCV = net calorific value of fuel, TJ/ton or TJ/liter

EF_{fuel} = Emission factor for fuel, tCO₂/TJ or tCO₂/liter

Project Emission (PE)

38. PE is the amount of emissions generated by the electricity or fuel used by the project activity (new, more efficient equipment).

Project emission for electricity-consuming equipment:

$$PE_e = EC_p \times EF_{grid} / (1 - \%L_p)$$

PE_e = Project emission for electricity-consuming equipment, tCO₂/year

EC_p = annual electricity consumption by the project activity, MWh/year; if there are more than one equipment, then EC_p is the total consumption of all concerned electricity-consuming equipment

EF_{grid} = combined emission factor for the grid, tCO₂/MWh

%L_p = project T&D losses expressed as decimal equivalent (i.e., 20% loss is expressed as 0.20)

Baseline emission for fuel-consuming equipment:

$$PE_f = FC_p \times NCV \times EF_{fuel}$$

PE_f = Baseline emission for fuel-consuming equipment, tCO₂/year

FC_p = annual fuel consumption by the project activity, tons/year or liters/year; if there are more than one equipment, then FC_p is the total consumption of all concerned fuel-consuming equipment.

NCV = net calorific value of fuel, TJ/ton or TJ/liter
 EF_{fuel} = Emission factor for fuel, tCO₂/TJ or tCO₂/liter

E. Energy Efficiency Projects (Improvement of Existing Equipment/Facilities)

Scope

39. This methodology applies to projects that improve energy efficiency by retrofitting or replacing existing equipment, facilities⁹ before the end of their economic life. This covers existing equipment, facilities that use electricity or fuel. The project activity and the baseline may use different fuels or energy sources. For example, an existing industrial boiler in a factory runs on fuel oil. The project could be retrofitting this existing boiler to run on natural gas. This methodology is not applicable to retrofitting projects without improving efficiency (routine maintenance) or switching from less GHG-intensive fuel to more GHG-intensive fuel.

Emission Reduction (ER)

40. Emission reduction is the difference between baseline and project emissions when producing the same amount of outputs (products or services). The baseline technology is continuation of inefficient operations of existing equipment. If the project activity involves capacity expansion, the additional capacity will have a different baseline technology—usually assumed to be the most predominant technology in the project area.

ER = BE – PE
 BE = baseline emission
 PE = project emission

Baseline Emission (BE)

41. BE is the amount of emissions generated by electricity or fuel used before the project is implemented when producing the same amount of products or services (outputs)

Baseline emission for electricity-consuming equipment:

$BE_e = EC_b \times EF_{\text{grid}} / (1 - \%L_b)$
 BE_e = Baseline emission for electricity-consuming equipment, tCO₂/year
 EC_b = annual electricity consumption before project implementation, MWh/year; if there are more than one equipment, then EC_b is the total consumption of all concerned electricity-consuming equipment
 EF_{grid} = combined emission factor for the grid, tCO₂/MWh
 $\%L_b$ = baseline T&D losses expressed as decimal equivalent (i.e. 20% loss is expressed as 0.20)

⁹ Equipment and facilities may include transformers, turbines, generators, motors, pumps, compressors, boilers, lighting, air conditioning, manufacturing machineries, air conditioning and the likes.

Baseline emission for fuel-consuming equipment:

$$BE_f = FC_b \times NCV \times EF_{fuel}$$

BE_f = Baseline emission for fuel-consuming equipment, tCO₂/year

FC_b = annual fuel consumption before project implementation, tons/year or liters/year; if there are more than one equipment, then FC_b is the total consumption of all concerned fuel-consuming equipment

NCV = net calorific value of fuel, TJ/ton or TJ/liter

EF_{fuel} = Emission factor for fuel, tCO₂/TJ or tCO₂/liter

Project Emission (PE)

42. PE is the amount of emissions generated by the electricity or fuel used by the project activity (new, more efficient equipment).

Project emission for electricity-consuming equipment:

$$PE_e = EC_p \times EF_{grid} / (1 - \%L_p)$$

PE_e = Project emission for electricity-consuming equipment, tCO₂/year

EC_p = annual electricity consumption by the project activity, MWh/year; if there are more than one equipment, then EC_p is the total consumption of all concerned electricity-consuming equipment

EF_{grid} = combined emission factor for the grid, tCO₂/MWh

%L_p = project T&D losses expressed as decimal equivalent (i.e. 20% loss is expressed as 0.20)

Baseline emission for fuel-consuming equipment:

$$PE_f = FC_p \times NCV \times EF_{fuel}$$

PE_f = Baseline emission for fuel-consuming equipment, tCO₂/year

FC_p = annual fuel consumption by the project activity, tons/year or liters/year; if there are more than one equipment, then FC_p is the total consumption of all concerned fuel-consuming equipment.

NCV = net calorific value of fuel, TJ/ton or TJ/liter

EF_{fuel} = Emission factor for fuel, tCO₂/TJ or tCO₂/liter

F. Energy Efficiency Projects (Introduction of New and Efficient Electricity T&D System)

Scope

43. This methodology applies to projects that reduce electricity losses by introducing new and more efficient transmission and distribution (T&D) systems. These T&D systems could be using technologies such as high voltage direct current (HVDC), high temperature, low sag (HTLS), flexible AC transmission system (FACTS) and similar.

Emission Reduction (ER)

44. Emission reduction is the difference between baseline and project emissions when the T&D systems deliver the same amount of electrical power or energy. The baseline technology is usually taken as the most predominant technology for the T&D system used in the country.

$$ER = BE - PE$$

BE = baseline emission

PE = project emission

Baseline Emission (BE)

45. BE is the amount of emissions generated by the T&D system that use the most predominant technology in the country when delivering the same amount of electricity as the project.

$$BE_e = EC_b \times EF_{grid} / (1 - \%L_b)$$

BE_e = Baseline emission for the T&D system, tCO₂/year

EC_b = annual electricity delivered by the T&D system that use the most predominant technology in the country, MWh/year

%L_b = baseline T&D losses expressed as decimal equivalent (i.e. 20% loss is expressed as 0.20)

EF_{grid} = combined emission factor for the grid, tCO₂/MWh

Project Emission (PE)

46. PE is the amount of emissions generated the project activity (new, more efficient T&D system).

$$PE_e = EC_p \times EF_{grid} / (1 - \%L_p)$$

PE_e = Project emission from the project activity, tCO₂/year

EC_p = annual electricity delivered by the project activity, MWh/year;

%L_p = project T&D losses expressed as decimal equivalent (i.e. 20% loss is expressed as 0.20)

EF_{grid} = combined emission factor for the grid, tCO₂/MWh

G. Energy Efficiency Projects (Improvement of Existing Electricity Transmission and Distribution System)

Scope

47. This methodology applies to projects that reduce electricity losses by improving existing transmission and distribution (T&D) systems. These improvements may include reconductoring (replacing existing conductors with new conductors with better design and materials), controlling power flow, decreasing reactive power flow, increasing delivery voltage, using more efficient transformers, optimizing transformer locations, etc.

Emission Reduction (ER)

48. Emission reduction is the difference between baseline and project emissions when the T&D systems deliver the same amount of electrical power or energy. The baseline is usually taken as the continuation of existing practice—use of existing T&D system. If the project activity involves capacity expansion, the additional capacity will have a different baseline percent loss.

$$ER = BE - PE$$

BE = baseline emission

PE = project emission

Baseline Emission (BE)

49. BE is the amount of emissions generated by the existing T&D system when delivering the same amount of electricity as the project.

$$BE_e = EC_b \times EF_{grid} / (1 - \%L_b)$$

BE_e = Baseline emission for the T&D system, tCO₂/year

EC_b = annual electricity delivered by the existing T&D system, MWh/year

%L_b = baseline T&D losses expressed as decimal equivalent (i.e. 20% loss is expressed as 0.20)

EF_{grid} = combined emission factor for the grid, tCO₂/MWh

Project Emission (PE)

50. PE is the amount of emissions generated the project activity (new, more efficient T&D system).

$$PE_e = EC_p \times EF_{grid} / (1 - \%L_p)$$

PE_e = Project emission from the project activity, tCO₂/year

EC_p = annual electricity delivered by the project activity, MWh/year;

%L_p = project T&D losses expressed as decimal equivalent (i.e. 20% loss is expressed as 0.20)

EF_{grid} = combined emission factor for the grid, tCO₂/MWh

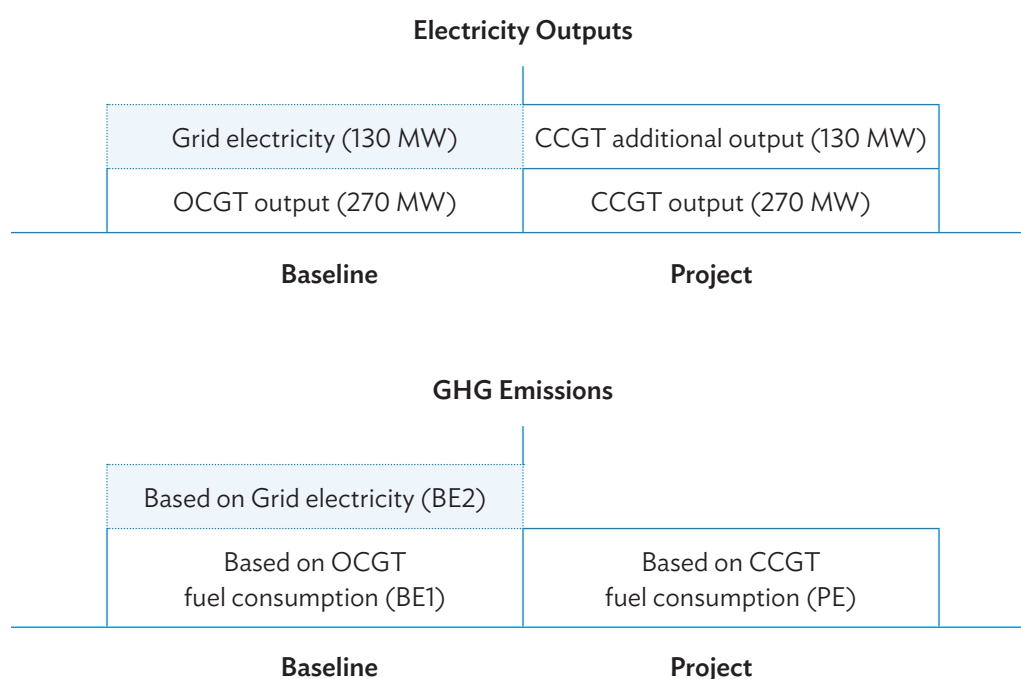
H. Energy Efficiency Project (Conversion of Open Cycle Gas Turbine into Combined Cycle Power Plant)

Scope

51. This methodology applies to energy efficiency projects that converts open cycle gas turbine (OCGT) power plant into combined cycle gas turbine power plant (CCGT) without fuel switching.

Emission Reduction (ER)

52. Emission reduction is the difference between baseline and project emissions when generating the same amount of electricity. The baseline is continuation of inefficient operations of existing equipment-OCGT. If the project activity involves capacity expansion, the additional capacity will have a different baseline. For example, a project converts an existing 270-MW open cycle gas turbine (OCGT) power plant into a 400-MW combined cycle power plant (CCGT). This results in 130-MW increase in generating capacity. The baseline emission for the 270-MW output of CCGT will be based on generation from OCGT while the baseline for the 130-MW increased capacity will be based on generation of grid-connected power plants (emission factor = grid emission factor). The typical assumption here is that the grid is the baseline for the 130-MW increased capacity. It cannot be based on the capacity of the OCGT because it is incapable of generating more than 270 MW. The baseline emissions therefore will have two components: one, based on grid electricity (BE2) and another, based on OCGT fuel consumption (BE1). The following diagrams illustrate this concept.



$$ER = BE - PE$$

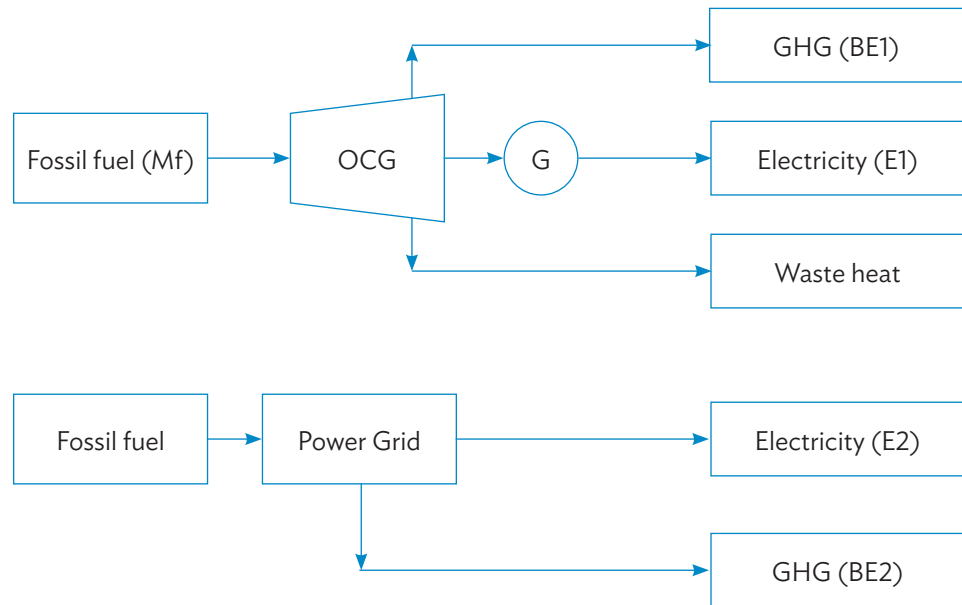
BE = baseline emission

PE = project emission

Baseline Emission (BE)

53. BE is the amount of emissions generated by fuel and electricity used before the project is implemented when it is producing the same amount of electricity (outputs).

54. The baseline scenario is continued operation of existing open cycle power plant. The project scenario generates two electrical outputs: E1, which is equal to the output of the open cycle gas turbine (baseline) and E2, which is the additional output of the CCGT. The baseline scenario should be delivering the same output as the project scenario. Under the baseline scenario, E2 is assumed to be supplied by the power grid. The baseline scenario has two parts: (i) OCGT and (ii) power grid to compensate for the additional output of CCGT.



$$BE = BE1 + BE2$$

Where :

BE1 = baseline emission OCGT, tCO₂/year

BE2 = baseline emission, electricity supply from grid

$$BE1 = Mf \times E_{fuel}$$

Where:

BE1 = baseline emission OCGT, tCO₂/year

Mf = fuel consumption per year, GJ/year

E_{fuel} = fuel emission factor, tCO₂/GJ

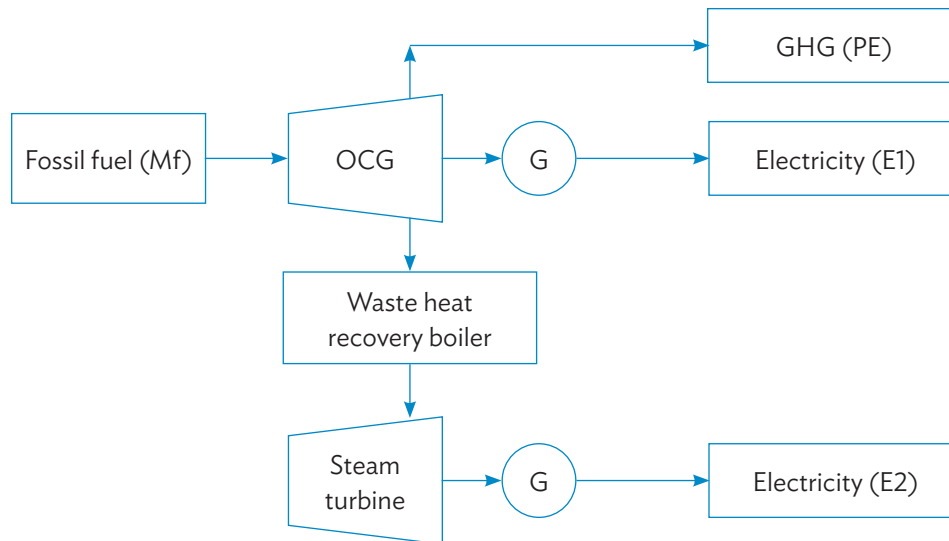
$$BE2 = E2 \times E_{grid}$$

Where:

E2 = electricity supplied by the grid = additional electricity output of the combined cycle power plant (MWh/year)

E_{grid} = grid emission factor, tCO₂/MWh

Project Emission (PE)



$$PE = Mf \times E_{\text{fuel}} = BE1$$

Where:

PE = project emission CCGT, tCO₂/year
 Mf = fuel consumption per year, GJ/year
 E_{fuel} = fuel emission factor, tCO₂/GJ

Summary equation for emission reduction (ER)

$$ER = (BE1 + BE2) - PE$$

But PE = BE1

$$ER = (BE1 + BE2) - BE1 = BE2$$

$$ER = BE2 = E2 \times E_{\text{grid}}$$

I. Energy Efficiency Project (Rehabilitation of Fossil-fired Power Plants)

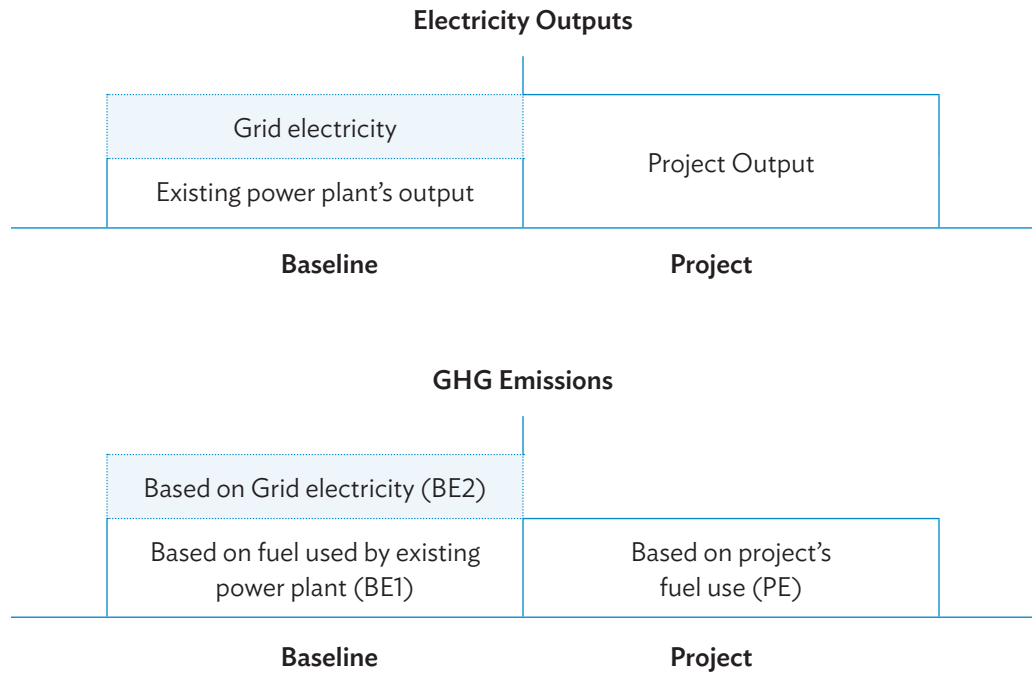
Scope

55. This methodology applies to projects that rehabilitate existing, derated fossil-fuel power plants to restore them to their original rated capacities and efficiencies.

Emission Reduction (ER)

56. Emission reduction is the difference between baseline and project emissions when the power plants generate the same amount of electrical power or energy. One part of the baseline

is usually taken as the continuation of existing practice—operation of derated power plants. The other part is electricity supplied by the grid to compensate for the loss of generation due to derating. The following diagrams show this concept.



ER = BE – PE
 BE = baseline emission
 PE = project emission

Baseline Emission (BE)

57. BE is the amount of emissions generated by the existing derated power plant when delivering the same amount of electricity as the project.

BE = BE1 + BE2
 BE1 = $FC_b \times NCV \times EF_{fuel}$
 BE1 = Baseline emission for derated power plant, tCO₂/year
 FC_b = annual fuel consumption before project implementation, tons/year or liters/year
 NCV = net calorific value of fuel, TJ/ton or TJ/liter
 EF_{fuel} = Emission factor for fuel, tCO₂/TJ or tCO₂/liter
 BE2 = $EG_b \times EF_{grid}$
 BE2 = Baseline emission for grid-supplied electricity to compensate for loss capacity due to derating, tCO₂/year
 EG_b = annual electricity delivered by the grid to compensate for loss of generation due to derating, MWh/year
 EF_{grid} = combined emission factor for the grid, tCO₂/MWh

Project Emission (PE)

58. PE is the amount of emissions generated the project activity (rehabilitated power plant).

$$PE = FC_p \times NCV \times EF_{fuel}$$

PE = Project emission for rehabilitated power plant, tCO₂/year

FC_p = annual fuel consumption by the project, tons/year or liters/year

NCV = net calorific value of fuel, TJ/ton or TJ/liter

EF_{fuel} = Emission factor for fuel, tCO₂/TJ or tCO₂/liter

J. Methane Capture and Use for Power Generation

Scope

59. This methodology applies to projects that capture and burn methane emissions and use the heat for power generation. Methane emissions can come from coal mining (coal mine methane and coal bed methane), anaerobic wastewater and sludge treatment, or anaerobic organic waste disposal/treatment.

Emission Reduction (ER)

60. Emission reduction is the difference between baseline and project emissions when delivering the same amount of electrical power or energy. Methane vented in the project scenario will not be accounted for in project emissions or in baseline emissions since it is vented in both scenarios.

$$ER = BE - PE$$

BE = baseline emission

PE = project emission

Baseline Emission (BEs)

61. BEs are composed of (i) emissions from release of methane into the atmosphere (BE1) and (ii) emissions from electricity generated by grid-connected power plants which is assumed to be the baseline for the electricity generated by the project using methane (BE2).

$$BE1 = Mm \times GWP_{ch_4}$$

BE1 = Baseline emissions from release of methane into the atmosphere, tCO₂/year

Mm = Mass of methane captured and burned under the Project scenario, tCH₄/year

GWP_{ch4} = Global Warming Potential for methane, 25 tCO₂/tCH₄

$$BE2 = EGb \times EF_{grid}$$

BE2 = baseline emissions from electricity generated by grid-connected power plants (grid is assumed to be the baseline), tCO₂/year

EGb = amount of electricity from the grid equal to the electricity to be generated by the project from burning methane, MWh/year.

EF_{grid} = combined emission factor for the grid, tCO₂/MWh
 Total baseline emissions in tCO₂/year = BE1 + BE2

Project Emissions (PE)

62. PEs are composed of the emissions (i) attributable to electricity consumed to capture and burn the methane (PE1), (ii) resulting from burning methane (PE2), (iii) resulting from unburned captured methane- usually taken as 10% of captured methane (PE3).

$$PE1 = ECp \times EF_{grid}$$

PE1 = Project emissions from electricity consumed to capture and burn the methane, tCO₂/year

EF_{grid} = combined emission factor for the grid, tCO₂/MWh

$$PE2 = Mm \times 0.90 \times EF_{ch_4}$$

PE2 = Project emissions from burning methane, tCO₂/year

Mm = Mass of methane captured and burned under the Project scenario, tCH₄/year (typical assumption: only 90% of methane is burned or 90% methane destruction efficiency)

EF_{ch_4} = Emission Factor for combusted methane, 2.75 tCO₂/tCH₄

$$PE3 = Mm \times 0.10 \times GWP_{ch_4}$$

PE3 = Emissions from unburned captured methane- usually taken as 10% of captured methane

GWP_{ch_4} = Global Warming Potential for methane, 25 tCO₂/tCH₄

Total Project Emissions = PE1 + PE2 + PE3

K. Solid Wastes Management/Waste-to-Energy Projects/ Landfill Gas Recovery

63. Use “GHG Calculator for Solid Wastes-Ver II-2013” by IGES (Institute of Global Environmental Strategies). Please see this link: <http://pub.iges.or.jp/modules/envirolib/view.php?docid=4273>

64. This GHG estimation model was developed to quantify GHG emissions from individual treatment technologies including incineration with energy recovery. This is one of the models generally applicable to Asian countries.

IV. Illustrative Examples

65. Two examples are used in these guidelines to show the details of numerical calculations that go with the methodologies. These details and nuances are typically not obvious and visible in the equations under each methodology. These include conversion from one unit to another and use of other variables such as density to make the units consistent in an equation.

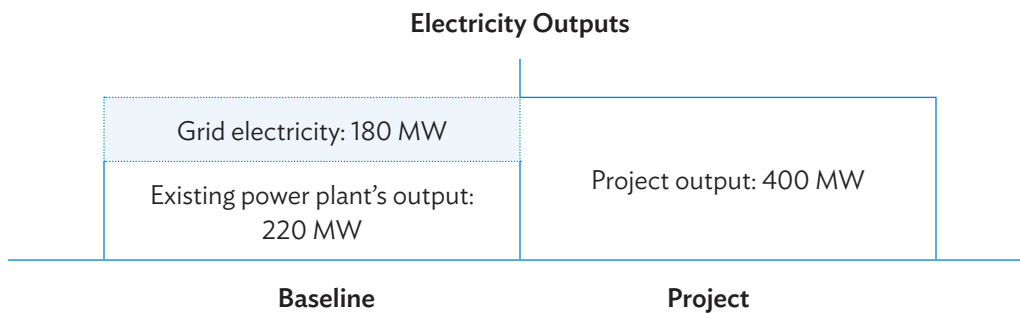
A. Illustrative Example #1

BAN: Power System Expansion and Efficiency Improvement Investment Program-Tranche 3

66. Only output #1 has emission reduction impact. It involves replacing aging gas-fired steam and gas turbine power plants of 220-MW capacity with a more efficient 400-MW gas-fired combined cycle power (CCGT) plant at the Ashuganj power station complex. The old power plants have an efficiency of 32-35%, the new power plant, 57%. Load factor is assumed to be 85%. For purposes of illustration, assume that the old power plants have not reached the end of their economic lives.

Baseline Emission Calculations

67. The project's capacity is 180 MW higher than the capacity of the old power plants to be replaced. It is assumed that the 180 MW will be supplied by the existing grid. This is the same as saying that the grid is the baseline for the 180 MW. Hence, the baseline has two parts: 180 MW from the grid and 220 MW from the old power plants. It is assumed that the old power plants are being replaced well before their economic life end. The following diagram helps visualize the baseline condition.



Baseline generation from the old power plant: $220 \text{ MW} \times 8760 \text{ hrs/yr} \times 85\% = 1,638,120 \text{ MWh/yr}$
 Baseline generation from grid: $180 \text{ MW} \times 8760 \text{ hrs/yr} \times 85\% = 1,340,280 \text{ MWh/yr}$
 Emission factor for gas: $56.1 \text{ kgCO}_2/\text{GJ} = 0.0561 \text{ tCO}_2/\text{GJ}$
 Grid emission factor for BAN: $0.648 \text{ tCO}_2/\text{MWh}$
 Fuel consumption—old power plant: $(1,638,120 \text{ MWh/yr} / 35\%) \times 3.6 \text{ GJ/MWh} = 16,849,234 \text{ GJ/yr}$
 Baseline emission—old power plant: $16,849,234 \text{ GJ/yr} \times 0.0561 \text{ tCO}_2/\text{GJ} = 945,242 \text{ tCO}_2/\text{yr}$
 Baseline emission—grid: $1,340,280 \text{ MWh/yr} \times 0.648 \text{ tCO}_2/\text{MWh} = 868,501 \text{ tCO}_2/\text{yr}$
 Total baseline emission: $945,242 + 868,501 = 1,813,743 \text{ tCO}_2/\text{yr}$

Project Emission Calculations

The project emission comes from the CCGT when running at full load at an efficiency of 57%.
 Project electricity generation = $400 \text{ MW} \times 8760 \text{ hrs/yr} \times 85\% = 2,978,400 \text{ MWh/yr}$
 Project fuel consumption: $(2,978,400 \text{ MWh/yr} / 57\%) \times 3.6 \text{ GJ/MWh} = 18,810,947 \text{ GJ/yr}$
 Project Emission: $18,810,947 \text{ GJ/yr} \times 0.0561 \text{ tCO}_2/\text{GJ} = 1,055,294 \text{ tCO}_2/\text{yr}$

Emission Reduction Calculations

Emission Reduction = $1,813,743 \text{ tCO}_2/\text{yr} - 1,055,294 \text{ tCO}_2/\text{yr} = 758,449 \text{ tCO}_2/\text{yr}$

B. Illustrative Example #1A

68. The same conditions as Illustrative Example# 1, except that the old power plants are being replaced at the end of their economic life. The project emissions remain the same as the previous example. However, the baseline scenario changes such that the entire 400-MW will be generated by the grid-connected power plants. The grid with its grid emission factor become the baseline. Baseline emissions, project emissions and emission reductions are calculated as follows:

Baseline Emissions Calculations

Total generation: $2,978,400 \text{ MWh/yr}$ (see illustrative example 1 above)
 Grid emission factor for BAN: $0.648 \text{ tCO}_2/\text{MWh}$
 Baseline emission—grid: $2,978,400 \text{ MWh/yr} \times 0.648 \text{ tCO}_2/\text{MWh} = 1,930,003 \text{ tCO}_2/\text{yr}$

Project Emission Calculations

Project emission: $1,055,294 \text{ tCO}_2/\text{yr}$ (see illustrative example 1 above)

Emission Reduction Calculations

Emission Reduction = $1,930,003 \text{ tCO}_2/\text{yr} - 1,055,294 \text{ tCO}_2/\text{yr} = 874,709 \text{ tCO}_2/\text{yr}$

C. Illustrative Example #2

FSM: Yap Renewable Energy Development Project

69. The whole power supply for Yap runs on diesel fuel. It generates electricity at 13.8 kWh/gallon of fuel. The project has three outputs relevant to estimating CO₂ emission reduction: (i) 1.4-MW wind power plant expected to generate 2.12 GWh/year, (ii) 300-kW grid-connected solar expected to generate 0.46 GWh/year and (iii) 1.8-MW diesel generator expected to generate 9.9 GWh/year at 15 kWh/gallon of fuel.

Baseline Emission Calculations

70. The project will generate a total of 12.48 GWh/year: 2.12 GWh/year from wind, 0.46 GWh from solar, and 9.9 GWh from energy-efficient diesel generator set. The baseline is continuation of electricity generation of 12.48 GWh/yr from existing diesel generators at 13.8 kWh/gallon of fuel. It is assumed that the existing power plants have not reached the end of their economic life.

Electricity Outputs	
Existing diesel power plants: 12.48 GWh/yr (at 13.8 kWh/gallon)	Solar: 0.46 GWh/yr
	Wind: 2.12 GWh/yr
	New diesel genset: 9.9 GWh/yr (at 15 kWh/gallon)
Baseline	Project

Baseline generation from the existing power plant: 12.48 GWh/yr = 12,480 MWh/yr
 Diesel fuel consumption: 12,480 MWh/yr × 1000 kWh/MWh × (1 gallon/13.8 kWh) × 3.7854 liters/gallon = 3,423,318 liters/year
 Net Calorific Value of diesel fuel: 35.94 MJ/liter
 Emission factor for diesel: 74.1 kgCO₂/GJ = 0.0741 tCO₂/GJ
 Baseline emission: 3,423,318 liters/year × 35.94 MJ/liter × (1 GJ/1000 MJ) × 0.0741 tCO₂/GJ = 9,117 tCO₂/yr

Project Emission Calculations

71. The project emission is the sum of emissions from solar, wind, and new diesel (at 15 kWh/gallon).

Project emission—solar generation = 0 tCO₂/year
 Project emission—wind generation = 0 tCO₂/year
 Project emission—energy-efficient diesel gen set

Generation from new, energy-efficient diesel gen set: 9.9 GWh/yr = 9,900 MWh/yr

Diesel fuel consumption: 9,900 MWh/yr × 1000 kWh/MWh × (1 gallon/15 kWh) ×

3.7854 liters/gallon = 2,498,364 liters/year

Net Calorific Value of diesel fuel: 35.94 MJ/liter

Emission factor for diesel: 74.1 kgCO₂/GJ = 0.0741 tCO₂/GJ

Project emission-new diesel genset: 2,498,364 liters/year × 35.94 MJ/liter × (1 GJ/1000 MJ) ×

0.0741 tCO₂/GJ = 6,654 tCO₂/yr

Total Project Emission = solar + wind + diesel = 0 + 0 + 6,654 = 6,654 tCO₂/yr

Emission Reduction Calculations

Emission Reduction = 9,117 tCO₂/yr - 6,654 tCO₂/yr = 2,463 tCO₂/yr

APPENDIX A

Direct Global Warming Potentials of Selected Greenhouse Gases

Gases	Chemical Formula	GWP for Given Time Horizon (100 Years)
Carbon Dioxide	CO ₂	1
Methane	CH ₄	25
Nitrous oxide	N ₂ O	298

Source: Intergovernmental Panel on Climate Change, 2007. *IPCC Fourth Assessment Report: Climate Change 2007 Synthesis Report*. Geneva.

APPENDIX B

Default Net Calorific Values and CO₂ Emission Factors for Combustion

Fuel type	NCV (TJ/ton)	Default carbon content (tons/TJ)	Effective CO ₂ emission factor (tCO ₂ /TJ)
	A	B	Default value C=B*100%* 44/12
Solid			
Anthracite	0.0267	26.8	98.30
Coking coal	0.0282	25.8	94.60
Sub-bituminous coal	0.0189	26.2	96.10
Other bituminous coal	0.0258	25.8	94.60
Lignite	0.0119	27.6	101.00
Brown coal briquettes	0.0207	26.6	97.50
Coke	0.0282	29.2	107.00
Liquid			
Crude oil	0.0423	20.0	73.30
Natural gas liquids	0.0442	17.5	64.20
Gasoline	0.0443	18.9	69.30
Gas/Diesel oil	0.0430	20.2	74.10
Residual fuel oil	0.0404	21.1	77.40
Petroleum coke	0.0325	26.6	97.50
Other petroleum products	0.0402	20.0	73.30
Gas			
Gas works gas	0.0387	12.1	44.40
Coke oven gas	0.0387	12.1	44.40
Blast furnace gas	0.0247	70.8	260.00
Oxygen steel furnace gas	0.0071	49.6	182.00
Natural gas	0.0480	15.3	56.10
Liquefied petroleum gases	0.0473	17.2	63.10
Refinery gas	0.0495	15.7	57.60

Source: IPCC, 2006. *IPCC Guidelines for National Greenhouse Gas Inventories*. Japan.

APPENDIX C

Grid Emission Factors for Selected Countries

Country	Grid Emission Factor (tCO ₂ /MWh)	
	For Wind and Solar Projects	For Other Projects
Armenia	0.4340	0.428
Azerbaijan	0.5020	0.437
Bangladesh	0.6350	0.648
Bhutan–India	0.8920	0.779
Cambodia	0.8560	0.800
China, People’s Republic of	0.8860	0.790
Fiji	0.3790	0.510
Georgia	0.2580	0.197
India	0.8780	0.754
Indonesia	0.6790	0.635
Kazakhstan	0.5820	0.606
Korea, Republic of	0.5440	0.507
Kyrgyzstan	0.1760	0.133
Lao PDR	0.5600	0.560
Malaysia	0.5660	0.543
Myanmar	0.4410	0.332
Mongolia	1.2610	1.192
Nepal	0.0270	0.019
Pakistan	0.6000	0.501
Papua New Guinea–Milne Bay Grid	0.6570	0.655
Papua New Guinea–Popondetta Grid	0.7790	0.753
Philippines	0.5510	0.592
Singapore	0.4750	0.461
Sri Lanka	0.7350	0.746
Tajikistan	0.0130	0.009
Thailand	0.4470	0.439
Turkmenistan	0.8670	0.689
Uzbekistan	0.5510	0.533
Viet Nam	0.4800	0.479

Source: ADB database. *The IFI (Interim) Dataset of Harmonized Grid Factors—July 2016.*

APPENDIX D

Default Efficiency Factors for Power Plants

Grid-Connected Power Plants (%)

Technology	Old Units (before 2000)	New Units (after 2000)
Coal		
Subcritical	37.0	39.0
Supercritical	–	45.0
Ultra-supercritical	–	50.0
IGCC	–	50.0
FBS	35.5	–
CFBS	36.5	40.0
PFBS	–	41.5
Oil		
Steam turbine	37.5	39.0
Open cycle	30.0	39.5
Combined cycle	46.0	46.0
Natural gas		
Steam turbine	37.5	37.5
Open cycle	30.0	39.5
Combined cycle	46.0	60.0

Source: UNFCCC. 2013. *Tool to calculate the emission factor for an electricity system*. <https://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-07-v4.0.pdf>

Off-Grid Power Plants (%)

Technology	Nominal Capacity of Power Plants (CAP, in kW)						
	CAP	10<	50<	100<	200<	400<	CAP
	≤10	≤50	≤100	≤200	≤400	≤1000	>1000
Reciprocating engine system	28	33	35	37	39	42	45
Gas turbine systems	28	32	34	35	37	40	42
Small boiler, steam, or turbine system	7	7	7	7	7	7	N/A

Source: UNFCCC. 2013. *Tool to calculate the emission factor for an electricity system*. <https://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-07-v4.0.pdf>

APPENDIX E

Density of Common Fuels

Fuels	Form	Density (kg/m ³)
Crude Oil	liquid	856
Petrol/Gasoline	liquid	741
Diesel	liquid	837
Fuel oil	liquid	959
LPG	liquid	533
Kerosene	liquid	807
Natural Gas	Gas	0.7 to 0.9

APPENDIX F

Conversion Factors

Length	Area	Energy and Power
2.54 cm/inch	10.76 ft ² /m ²	4.1868 kJ/kcal
3.28 ft/m	929 cm ² /ft ²	252.98 cal/BTU
Volume	6.452 cm ² /in ²	1.055 kJ/BTU
231 in ³ /gal	Density	1 J/W-s
7.481 gal/ft ³	16.018 kg/m ³ = 1 lb/ft ³	1 kW-s/KJ
1000 liters/m ³	1000 kg/m ³ = 1 g/cm ³	3,600 kJ/kWh = 3,600 MJ/ MWh=3.6 GJ/MWh=3.6 TJ/GWh
3.7854 liters/gal	Pressure	860 cal/W-hr
28.317 liters/ft ³	14.696 psi/atm	0.746 kW/hp
35.31 ft ³ /m ³	1.01325 bar/atm	3412.2 BTU/kWh
Mass/Force	101325 n/m ² = 1 atm	2544.4 BTU/hp-hr
2.205 lb/kg	14.504 psi/bar	1 toe = 41.87 GJ = 11630 kWh = 1.43 tce
1000 kg/metric ton	760 mmHg/atm	778.16 ft-lb/BTU
453.6 g/lb	0.0731 kg/m ² = 1 psi	

APPENDIX G

IFI Approach to GHG Accounting for Energy Efficiency Projects

November 2015

Overview:

This note sets out a common approach of accounting for net greenhouse gas GHG emissions of energy efficiency (EE) projects in accordance with the International Financial Institution (IFI) Framework for a Harmonised Approach to Greenhouse Gas Accounting.¹

Scope:

This document, developed by a Technical Working Group (TWG)² of IFIs, provides guidance for net (against a baseline) emissions accounting for EE projects and/or EE project components, including as defined in the joint MDB-IDFC principles document under the categories “low carbon and energy efficient generation” and “energy efficiency projects” respectively.³

The proposed approach is primarily focused on accounting for the reduction of energy intensity induced by investments in the rehabilitation, retrofitting and/or replacement with more efficient technologies at the recipient facility.⁴ Where the project design and operation considers efficiency gains from demand-side measures, including process and behaviour change, these impacts can also be taken into account in the calculations. The proposed approach is also applicable to the rehabilitation or retrofitting of renewable energy plants.⁵

For the purposes of this note, to be considered as energy efficiency investment, a project must be expected to reduce the energy or carbon intensity⁶ at the recipient facility.

A characteristic of EE rehabilitation/retrofit projects is that they frequently involve an increase of production and/or an extension of the facility’s lifetime. This note defines a methodology that takes into account these characteristics as well.

¹ International Finance Corporation. 2012. *International Financial Institution Framework for a Harmonised Approach to Greenhouse Gas Accounting*. https://www.ifc.org/wps/wcm/connect/518623004dc5f53c8e36aeab7d7326c0/IFI+Harmonisation+Framework+for++GHG+Accounting_Nov+2012.pdf?MOD=AJPERES

² The TWG for this methodology includes technical specialists from ADB, AfDB, AFD, EBRD, EIB, GEF, GIB, NIB, NEFCO, IDB, IFC, and WB, with support from the UNFCCC secretariat; to be widened to include more IFIs as work progresses. This note will be reviewed and updated periodically by the IFIs.

³ International Finance Corporation. *Common Principles for Climate Mitigation Finance Tracking*. <http://www.ifc.org/wps/wcm/connect/65d37952-434e-40c1-a9df-c7bdd8ffcd39/MDB-IDFC+Common-principles-for-climate-mitigation-finance-tracking.pdf?MOD=AJPERES>

⁴ Facility’ is used to denote the operations, site, equipment, etc., that is the subject of the IFI-financed project.

⁵ Applicable renewable energy technologies are defined in the “IFI Approach to GHG Accounting for Renewable Energy Projects”.

⁶ Some projects may result in fuel switching. In such cases, the emissions factors for the fuels replaced are used.

The impacts of the project on GHG emissions will be calculated by comparing the forecasted post-investment emissions with a pre-investment baseline scenario. The difference between the baseline and the project emissions constitutes the GHG emissions and/or emissions reductions referred to as net emissions accounting for the purposes of this note.

Assumptions on the project's energy use and energy intensity (MWh or GJ) are based on information collected during the appraisal conducted by each IFI for its environmental, technical and/or investment due diligence.

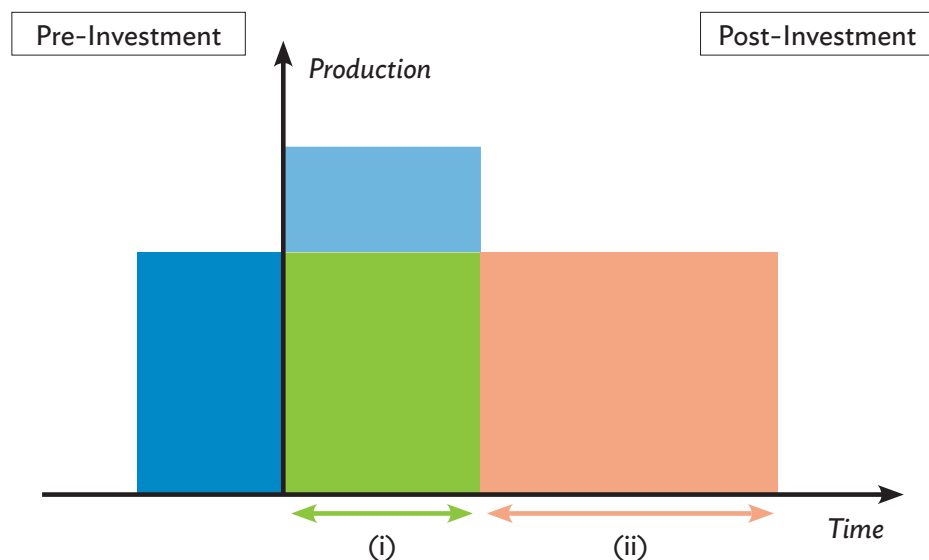
Project GHG emissions from construction, other upstream and downstream activities, leakage, and the rebound effect can be excluded as per the Framework,⁷ unless these are deemed as significant and assessed in the project appraisal.

Representative Year:

Greenhouse gas emissions are calculated on an annual basis for a representative year at the expected average output of the post-investment facility. In some cases it is not possible to point out a single representative year, for example, when the project lifetime exceeds the lifetime of the pre-investment facility. In that case two or more representative years may be chosen, each with its own baseline, and a weighted average will be calculated for the emissions.

Baselines:

The baseline should be viable for the expected project lifetime. Equipment that is evidently operationally unviable (e.g. at the end of equipment life, or expected to cease operating due to high costs or other market barriers, or not conforming to legal requirements), do not constitute an acceptable baseline.



⁷ International Finance Corporation. 2012. *International Financial Institution Framework for a Harmonised Approach to Greenhouse Gas Accounting*. https://www.ifc.org/wps/wcm/connect/518623004dc5f53c8e36aeab7d7326c0/IFI+Harmonisation+Framework+for++GHG+Accounting_Nov+2012.pdf?MOD=AJPERES

In the above diagram, area “A” represents the pre-investment production, area “B” represents the increased production compared to the pre-investment production during the expected remaining lifetime of the pre-investment facility and area “C” represents the production beyond the pre-investment facility lifetime.

For projects where the pre-investment and post-investment production levels are broadly equivalent, the actual emissions at the pre-investment facility prior to the investment can be used as a baseline, but only until the end of the expected lifetime of the pre-investment facility. In the above diagram, area “A” represents this production.

For projects where the investment is expected to result in an increase of production, the output of the retrofitted/rehabilitated facility should be sub-divided into the following components:

- (i) Output of the pre-investment facility during its remaining technical/economic life (A); and
- (ii) Additional output related to increased capacity and extended operating life (B+C).

The additional output would typically displace production from new capacity that would have been built in the country or elsewhere, or displace existing production. The baseline to be used for the displaced production may be based on a no project scenario; or alternatively the baseline emissions are calculated based on a similar level of service or output provided by the project. This could be based on a benchmark for energy efficient sources of existing production or for efficient new technologies or a combination of the two.⁸

For the purposes of simplification, the baseline for “B” may be represented by a benchmark comprised of existing sources of energy efficient production. The baseline for “C” should in principle comprise energy efficient new technologies; or a relevant benchmark of the most energy efficient existing technologies may be used.⁹

The IFI will document the choice of baseline and any supporting assumptions. IFIs that are reporting project or portfolio emissions data are encouraged to also disclose the associated assumptions and methodology.

For the refurbishment of renewable energy generation plants, the baseline is defined as follows: 1) if the pre-investment facility has reached the end of its technical life, the baseline methodology defined by the “IFI Approach to GHG Accounting for Renewable Energy Projects” note for new electricity production should be applied; and 2) if the pre-investment facility has significant remaining economic life, the emissions factor of the pre-investment facility is applied to A, and the emissions factors defined by the “IFI Approach to GHG Accounting for Renewable Energy Projects” note for new electricity production is applied to the sum of B and C.

In those cases where a project is replacing specific production, the IFI should transparently document and share the baseline used for this production with the TWG.

⁸ For projects involving the production or avoidance of grid electricity the baseline for the grid electricity could be defined by the renewable energy OM/BM methodologies (see IFI Approach to GHG Accounting for Renewable Energy Projects).

⁹ As a result, where the increase in production has a carbon intensity that is lower than the facility’s pre-investment level, but higher than a recognised benchmark, the increase in production should be treated as net increase in emissions.

Sector-Specific Considerations:

- *Power plants:* For project that involve retrofits/rehabilitation or efficiency improvements to power plants the baseline determined in line with the above principles can comprise the combination, of a) continuation of current situation related to energy production in the existing facility for the equipment being replaced, modified or retrofitted for the expected remaining lifetime of the existing equipment; b) a combined margin for emissions¹⁰ in the receiving electricity grid applied to the incremental increase in level of service expected from the project; and c) a combined margin for emissions¹¹ in the receiving electricity grid applied to the generation produced during the additional lifetime.
- *Industrial projects:* UNFCCC standardised baselines should be used when available.
- *Buildings:* For retrofits/rehabilitation of existing buildings, baselines could be based on pre-investment building conditions or prevailing building standards or a combination of the two.

Boundaries:

Boundaries for GHG calculations should be used according to the following principles:

- Project GHG emissions are calculated on the basis of energy use and fuel combustion at the point of project intervention and investment, e.g. installation boundaries (e.g. a facility or a building) or component boundaries (e.g. process equipment like a boiler). For facilities comprising multiple, independent processes, the boundary can be defined at this sub-process level, if the sub-process does not affect other sub-processes and has measurable inputs, outputs, and energy use.
- Where the project appraisal quantifies the impact of the investment on emissions outside the project boundary (e.g. the broader market or on the electricity grid or distribution system), then those impacts need to be factored into the calculation of project GHG emissions as leakage.
- Baseline scenarios and calculations can have boundaries that are installation/component-based or system-based component-based (e.g. electricity grid or distribution system).

Emission Factors:

In the calculation, the energy consumption (or production) of the project is multiplied by relevant emission factors in t CO₂e/MWh or t CO₂e/GJ as applicable, or the fuel emission factor for a captive power plant or a third-party combined heat and power plant.

For simplification, the emission factor for reduced electricity consumption from the grid is defined as for grid-based RE electricity, with a weighting of 50% Operating Margin (OM) and 50% Build Margin (BM).¹²

¹⁰ The combined margin is defined by the “IFI Approach to GHG Accounting for Renewable Energy Projects” for new electricity production can be used as the baseline for B and C.

¹¹ As a result, where the increase in production has a carbon intensity that is lower than the facility’s pre-investment level, but higher than a recognised benchmark, the increase in production should be treated as net increase in emissions.

¹² Over time, the TWG in coordination with the UNFCCC, will consider future modifications of the weights applied between OM and BM to account for additional factors, such as countries with high or low demand growth. Until more definitive guidance is available on weighting in countries with high demand growth, the IFI should transparently document and share with the TWG any alternative weighting proposal for a specific country.

APPENDIX H

IFI Approach to GHG Accounting for Renewable Energy Projects

November 2015

Overview:

This note sets out a harmonized approach for assessing the mitigation benefits, or net greenhouse gas (GHG) emissions, of renewable energy (RE) projects in accordance with the International Financial Institution (IFI) Framework for a Harmonized Approach to Greenhouse Gas Accounting.¹ A Technical Working Group (TWG)² of IFIs has agreed to use a common set of emission factors for GHG accounting of electricity production from Renewable Energy (RE) projects.³ The purpose is to harmonize GHG accounting through the application of common emission factors to RE GHG calculations. Further iterations of this approach note will include the treatment of off-grid RE activities.

Renewable Energy (RE) Definition:

The RE definition follows the RE project typology defined by the Common Principles for Climate Mitigation Finance Tracking:⁴

- Wind power
- Geothermal power
- Solar power (concentrated solar power, photovoltaic power)
- Biomass or biogas power
- Ocean power (wave, tidal, ocean currents, salt gradient, etc.)
- Hydropower⁵

If the pre-investment facility has not reached the end of its technical life, the approach set out in the “IFI Approach to GHG Accounting for Energy Efficiency Projects” shall be followed.

¹ International Finance Corporation. 2012. *International Financial Institution Framework for a Harmonised Approach to Greenhouse Gas Accounting*. https://www.ifc.org/wps/wcm/connect/518623004dc5f53c8e36aeab7d7326c0/IFI+Harmonisation+Framework+for++GHG+Accounting_Nov+2012.pdf?MOD=AJPERES

² The TWG for this methodology includes technical specialists from ADB, AfDB, AFD, EBRD, EIB, GEF, GIB, NIB, NEFCO, IDB, IFC, and WB, with support from the UNFCCC secretariat; to be widened to include more IFIs as work progresses. This note will be reviewed and updated periodically by the TWG.

³ This approach is generally consistent with similar approaches to account for GHG emissions from a broader set of power generation projects.

⁴ International Finance Corporation. *Common Principles for Climate Mitigation Finance Tracking*. <http://www.ifc.org/wps/wcm/connect/65d37952-434e-40c1-a9df-c7bdd8ffcd39/MDB-IDFC+Common-principles-for-climate-mitigation-finance-tracking.pdf?MOD=AJPERES>

⁵ Pumped storage hydropower plants are not considered renewable energy in this version of the note.

Scope for Calculations:

- Construction emissions for RE projects may be excluded
- Include Large Hydro reservoir emissions to balance the estimated savings
- Include biomass feedstock-related leakage emissions
- Include geothermal fugitive emissions

Project Power Output:

Assumptions for power generation capacity (MW) and project energy output (MWh) should be based on project appraisal documentation and the due diligence documentation of IFIs. Project emission calculations will also take into account adjustments for reservoir and fugitive emissions as well as leakage.

Baseline Emissions Factors:

The main principles and assumptions for baseline emissions factors include:

- Energy generated from renewable sources will avoid emissions that would otherwise be generated wholly or partly from more carbon-intensive sources.
- For the purpose of promoting greater harmonization, the IFI GHG Accounting TWG maintains a common dataset containing Baseline Emission Factors (BEFs) for countries and for sub-national and interconnected grids where applicable. The common dataset of BEFs will be updated annually under responsibility of the TWG. Where an IFI has conducted its own country or project-related baseline study, the results of this study should be submitted to the TWG for consideration of inclusion in the common dataset during future annual updates.
- In those cases where a project is replacing specific planned generation capacity, each IFI is free to conduct its own assessment, which should be shared with the TWG. In all other cases, the BEF approach and the common dataset described will apply.

Available Data Sources for the Common Data Set:

The common dataset containing BEFs will be constructed using a Combined Margin (CM) for the grid that is comprised of an *Operating Margin* (OM) and a *Build Margin* (BM). The OM represents the marginal generating capacity in the existing dispatch hierarchy that will most likely be displaced by the project. The BM is the cohort of the prospective power plants whose construction and operation would be affected by the project, based on an assessment of planned and expected new generation capacity.

The common dataset will be comprised, where available, of UNFCCC standardized baselines (SBLs), which are based on the CDM Grid Tool⁶ or other approaches approved by the CDM Executive Board; and/or drawn from official country emission data sources developed by designated national authorities.

⁶ UNFCCC. 2013. *Tool to calculate the emission factor for an electricity system*. <http://cdm.unfccc.int/methodologies/PAMethodologies/tools/am-tool-07-v4.0.pdf>

For other countries with certified and registered CDM projects, a dataset is derived from a *List of Grid Emission Factors* dataset managed and regularly updated by the Institute for Global Environmental Strategies. For each country, the following approach is used to derive the OM and BM data.

1. **Select the most recent years in which the CDM projects have been registered:** this data vintage range can be updated when IFIs review the common dataset.
2. **Calculate OM:** from the selected pool of CDM projects, identify OMs calculated by Simple OM, Simple Adjusted OM or, and Dispatch Data Analysis OM. Then average out the identified OMs.
3. **Calculate BM:** average out BMs from the selected project pool of CDM projects.
4. **Calculate CM:** add average OMs and BMs using appropriate weighting as defined below. Alternative weights may be agreed by IFIs in the future.

If new or additional CDM project data becomes available then these data will be assessed by the TWG for the annual update of the common dataset. If there is a validated project (in the current or most recent previous year) under CDM providing specific emission factor data then the IFI may consider to use these data instead of the CM on the common dataset, with the requirement that the IFI will share these data with the TWG for consideration for the next annual update of the EF common dataset of emission factors.

Constructing proxy BEF where data is not readily available:

For the remaining countries where neither relevant official UNFCCC nor applicable CDM/JI data (as defined above) is available, the alternative approach (defined below) to estimating the OM-BM will be used to populate the common dataset, based on International Energy Agency (IEA) emissions data.⁷

As better data becomes available that will feed into the process, e.g. through developing additional SBLs in collaboration with UNFCCC, then these data may be considered for the next update of the TWG common dataset. Likewise, where an IFI has conducted a country or project-related emission factor study, the results of this study can be submitted to the TWG and UNFCCC for consideration of inclusion in the joint dataset in future updates.

Calculating the OM:

- The IEA database specifies the country's generation mix and related emissions for the following fuel types: gas, oil, coal and other (mainly hydro, renewables and nuclear). The common dataset uses a 3 year rolling average of the IEA data.
- It is assumed that hydropower, other renewables and nuclear are likely to be must-run⁸ resources in most countries, while gas, oil and coal are considered most likely to be on the margin.

⁷ IEA. 2015. *CO₂ Emissions from Fuel Combustion Highlights 2015*. Paris.

⁸ Must-run resources are defined by the UNFCCC as "power plants with low marginal generation costs or dispatched independently of the daily or seasonal load of the grid. They include hydro, geothermal, wind, low-cost biomass, nuclear and solar generation. Source: UNFCCC. 2013. *Tool to calculate the emission factor for an electricity system*. <https://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-07-v4.0.pdf>

- Oil and gas-based generation are assumed to be highest on the fossil merit order and most likely to be replaced on the margin by any incoming new renewable generation. The bottom 50% of the merit order is assumed to be unaffected by any new generation and is not considered for the OM calculation.
- In countries where RE accounts for a significant share of the energy mix (>50%), an adjustment factor (λ) is introduced as a proxy for the share of low cost and must-run generation output that is potentially not dispatched and can be displaced by new generation. This adjustment will bring the OM calculation in line with the Simple Adjusted OM method covered under the CDM Grid Tool.

Calculating the BM:

- The BM is based on the future developments of the country's likely generation mix over a time horizon of 5–10 years. The development of some new renewable energy generation is assumed for all countries.
- Until the development of an agreed BM dataset, an interim BM will be calculated as a weighted average of the generating mix in the country based on the fuels used (IEA data). For each type of generation (gas, oil, coal, other) a GHG emission factor is applied taking into account the impact of Best Available Technology data based on a common agreed list of applicable BAT (e.g. as defined by the UNFCCC in the CDM Grid Tool).
- As better country information becomes available on expected future developments in new generation capacity, the database will be updated. The BM may be characterised by a limited set of generic emissions profiles, each corresponding to a range of generation mixes that result in similar GHG emissions.⁹
- The TWG will periodically review the initial set of country profiles on the basis of available information and cross checks as these BMs are piloted going forward.

Combining the OM and BM to construct the CM BEF:

The common dataset will initially consist of a CM arrived at by combining the OM and BM, using the following weighting:

- For variable generation (e.g. most wind and solar PV), the weighting is 75% OM: 25% BM.
- For firm generation (e.g. hydropower, geothermal and biomass), the weighting is 50% OM: 50% BM.

Over time, the TWG in coordination with the UNFCCC, will consider future modifications of the weights applied between OM and BM to account for additional factors, such as countries with high or low demand growth.¹⁰

Calculating Baseline Emissions:

In the calculation, the energy production of the project is multiplied by the CM emission factor in tCO₂e/MWh.

⁹ The first version of the BEF common database based on the existing generation mix (IEA data) within 2015. An updated version may include BMs based on mapping against generation profiles.

¹⁰ Until more definitive guidance is available, the IFI should transparently document and share with the TWG any alternative weighting proposal for a specific country.

Guidelines for Estimating Greenhouse Gas Emissions of Asian Development Bank Projects

Additional Guidance for Clean Energy Projects

Developing Asia has the world's fastest-growing rate of greenhouse gas emissions, with the leading driver being emissions from power generation. Reducing these emissions is paramount to ensuring a sustainable future while responding to the threat of climate change. This publication provides Asian Development Bank energy sector staff, consultants, and other interested readers with an understanding of key concepts and principles for estimating and reporting on the climate change impacts of energy projects. These guidelines provide more detail on estimating the emissions reductions attributable to energy efficiency and renewable energy projects.

About the Asian Development Bank

ADB's vision is an Asia and Pacific region free of poverty. Its mission is to help its developing member countries reduce poverty and improve the quality of life of their people. Despite the region's many successes, it remains home to a large share of the world's poor. ADB is committed to reducing poverty through inclusive economic growth, environmentally sustainable growth, and regional integration.

Based in Manila, ADB is owned by 67 members, including 48 from the region. Its main instruments for helping its developing member countries are policy dialogue, loans, equity investments, guarantees, grants, and technical assistance.

