Clean Energy Emission Reduction (CLEER) Protocol

Guidelines for Quantifying GHG Emission Reductions from Clean Energy Activities Conducted under the USAID Global Climate Change Initiative

May 2016

Resources to Advance LEDS Implementation (RALI)

This document was prepared for the United States Agency for International Development (USAID) by ICF International under Cooperative Agreement No. AID-OAA-LA-12-00002 and AID-OAA-L-11-00003-00.

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Developed by ICF International

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GHG PROTOCOL "BUILT ON" MARK

This Protocol includes the "Built on GHG Protocol" mark on the cover to indicate that it is based on and consistent with the Policy and Action Standard developed under the Greenhouse Gas Protocol. It includes the same basic concepts, steps, and principles as the Policy and Action Standard, but is tailored to the specific context of quantifying GHG reductions from clean energy activities conducted under the USAID Global Climate Change Initiative. The Policy and Action Standard can be found at http://www.ghgprotocol.org/policy-and-action-standard.

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1 INTRODUCTION

In January 2012, the United States Agency for International Development (USAID) released its vision for addressing climate change through international development and aid. USAID seeks to accelerate the transition of countries to low emission development through clean energy and sustainable landscapes for climate change mitigation; increase the resilience of people, places, and livelihoods through investments in climate change adaption; and strengthen development outcomes by integrating climate change in USAID programming, learning, policy dialogues, and operations (USAID, 2012).

The U.S. Global Climate Change Initiative (GCCI) is a U.S. Government commitment to work with global partners to address climate change by promoting low-carbon development, reducing greenhouse gas (GHG) emissions, and promoting sustainable, resilient societies.[1] Funding for the GCCI is divided into three pillars that address these challenges: Adaptation, Clean Energy, and Sustainable Landscapes. The Clean Energy Pillar supports activities that reduce GHG emissions by enabling the implementation of renewable energy and energy efficiency technologies. USAID captures GHG emission reductions achieved by these clean energy activities through a standard reporting indicator[2]:

"Greenhouse gas emissions, estimated in metric tons of CO_2 equivalent, reduced, sequestered, and/or avoided through clean energy activities supported by U.S. Government assistance."

This GHG Indicator was developed by USAID to enable the agency to assess the impact of GCCI mitigation activities on reducing GHG emissions, as well as the impacts of energy-related indirect allocation projects. At the program level, the indicator serves as a reporting metric to ensure accountability by in-country missions. At the agency level, this indicator captures the aggregate impact of USAID's GCCI mitigation portfolio for domestic and international audiences.

1.1 Purpose and Objectives

This document, the Clean Energy Emission Reduction (CLEER) Protocol, provides an overview of GHG accounting principles and practices, as well as standardized GHG estimation methodologies for common GCCI clean energy activities that have GHG reduction benefits.

By developing standardized methodologies for estimating emission reductions from clean energy activities, the Protocol will contribute to the following results for the GCCI:

- **Streamline reporting** to improve consistency, transparency, documentation, and accuracy across USAID operating units;
- **Identify high-impact activities** with cost-effective GHG reductions;
- **Monitor, evaluate, and verify** real GHG reduction impacts of clean energy programs;
- **Assess emission reduction potential** of planned activities or alternatives;
- **Reduce costs and staff resources** for estimating results of climate change activities;

[1] Available at: www.usaid.gov/climate/us-global-climate-change-initiative
[2] The standard GHG Indicator is known as Indicator EG.12-6 as of fiscal year 2016 reporting.

- **Improve communication** on the impacts of U.S. Government climate change assistance programs;
- **Help align programs** to the Global Climate Change and Development Strategy and GCCI; and
- **Measure benefits** from indirect clean energy activities.

1.2 Intended Use, Attribution, & Additionality

INTENDED USE

Users

The Protocol is intended for use by USAID operating units (OUs) to estimate, document, and report GHG emission reductions under the standard GHG Indicator, and to enable the aggregation and comparison of emission reduction impacts across the GCCI portfolio. Others may find this guidance helpful and applicable to their clean energy activities, but should consider additional data or documentation requirements that may be necessary for any alternative uses beyond the intended use by USAID.

Clean Energy Activities

The Protocol is intended to estimate GHG emissions reductions achieved by clean energy activities as defined by USAID GCCI clean energy funding requirements and may not be applicable to other energy-related projects that may lead to emission reductions, but are not considered clean energy under the GCCI—for example, improving coal power plant efficiency.

All USAID GCCI-funded mitigation programs are required to report under the GHG Indicator. USAID activities that do not receive direct GCCI funding may still result in quantifiable GHG emission reductions—therefore, reporting under the standard GHG indicator for these activities is optional, but encouraged.

Timeframe

The Protocol is intended to estimate GHG emissions reduced due to the implementation of the activity during a single reporting period *after* the implementation of the activity.[3] The reporting period required under the GHG Indicator is the previous fiscal year, from October 1 through September 30. Per the GHG Indicator requirements, OUs need to report emission reductions in each year in which the reported activity received USAID funding, and only those years. Other users may find this guidance helpful in estimating emission reductions before, during, or after the implementation of a clean energy activity, as well as reductions across several years.

Jurisdiction

The Protocol is intended to estimate GHG emissions reduced due to the implementation of the activity within a specified jurisdiction over which the USAID OU and Implementing Partners have authority, at

[3] GHG accounting frameworks commonly refer to this type of approach as *ex-post*, where emission reductions are assessed based on observed data after the implementation of an activity. Alternatively, an *ex-ante* approach forecasts future emission reductions from an activity.

least as it pertains to the implementation of the activity. A jurisdiction may constitute a geopolitical boundary such as a city or nation, or a specific project area. It is up to the OU to define a narrower or broader jurisdiction based on the specifics of the activity and the location of implementation, as well as determine whether emission reductions fall within or outside of the jurisdiction. The methods presented in this Protocol are intended to estimate in-jurisdiction emission reductions, but OUs and other user may find this guidance helpful in estimating out-jurisdiction effects as part of the assessment.

Finally, the CLEER Protocol does not make any claim to be fully complete in its coverage of clean energy activity types, emission sources, or estimation methodologies. The Protocol may undergo periodic revisions and improvements in order to serve the needs of USAID reporting.

The Protocol also does not assess or address program cost-effectiveness with regard to energy deployment or emission reductions.

ATTRIBUTION

The Protocol follows the USAID definition of attribution:

> *Ascribing a causal link between observed changes (results) and a specific intervention. A result is attributable to the USAID, or USAID can claim credit for a result, even when other partners are involved in achieving the result, if USAID can claim that without USAID intervention the outcome would not have taken place.*[4]

OUs are responsible for making this determination. The Protocol does not provide additional guidance on how to attribute emission reductions to USAID versus other donors based on funding or role.

ADDITIONALITY

Additionality is a criterion whereby GHG emission reductions are only recognized for activities that would not have occurred if not for USAID intervention. Hence, they are *additional* to what would have occurred.[5]

The Protocol provides OUs guidance on how to estimate GHG emissions reduced or avoided, and does not require OUs to prove 100 percent additionality, as would be required for marketable carbon credits or offsets. If an activity increases energy access by providing a new source of clean energy—e.g., solar photovoltaic power—the Protocol advises that OUs can assume that energy would have been provided by traditional or readily available sources in the absence of the activity, called the Baseline Energy Scenario (see *2.2.5:Stage 5: Define the Baseline Energy Scenario*). OUs should determine the most likely Baseline Energy Scenario and document all assumptions around this Scenario. Because the Protocol does not require OUs to prove 100 percent additionality, the results from using this Protocol are not sufficient to create marketable carbon credits or to adjust national GHG inventories to account for emission reductions due to mitigation efforts.

[4] USAID Operational Policy, Automated Directive System, Chapters 200-203

[5] For more information on additionality, see the GHG Protocol (WRI, 2005)

1.3 USAID Clean Energy Activities

The GCCI Clean Energy Pillar provides funding for programs that address climate change by promoting the sustainable use of renewable energy and energy efficient systems and technologies in developing countries. For example, GCCI supports a range of renewable energy activities and mechanisms that facilitate design and installation, feasibility studies, community training, and enabling markets. The GCCI also supports a range of cross-cutting activities, such as capacity building for GHG inventory development and Enhancing Capacity for Low Emission Development Strategies (EC-LEDS). GCCI activities typically focus on either the implementation of technologies and practices, or broader policy, assessment, and capacity building efforts. For the purposes of this Protocol, GCCI activities are categorized as either Technology Implementation and Practices activities, or Policy and Capacity Building activities.

The **Technology Implementation and Practices** category includes activities that lead to the installation of renewable energy generating units and efficiency improvements (both end-use and energy system efficiency). These activities may lead to outcomes such as:

- Installation of equipment or a system to generate renewable energy
- Infrastructure retrofit to reduce energy consumption
- Replacement of appliances with more efficient models
- Energy conservation and energy efficient practices
- Improvements in operations and maintenance practices that reduce building energy consumption

Alternatively, **Policy and Capacity Building** activities include clean energy-focused enabling environment activities—such as the development or support of policies that lead to the implementation of renewable and efficient energy; or legal, policy, and regulatory frameworks in the energy sector—as well as capacity building and research activities that prepare a country for participation in carbon markets—such as energy use assessments, feasibility studies, and national GHG inventories. Specific examples of policies may include feed-in tariffs, renewable portfolio standards, and energy efficiency codes. Policy and Capacity Building activities may lead to outcomes such as:

- Design or implementation of a policy
- Regulation or regulatory framework
- Feasibility assessment for renewable energy
- Utility incentive program
- A GHG emissions inventory

This categorization is helpful to distinguish activities that may result directly in GHG emission reductions—i.e., Technology Implementation and Practices—from activities that may lead indirectly to emission reduction benefits that may be more difficult to quantify or are delayed in time—i.e., Policy and Capacity Building. It may be the case that Policy and Capacity Building activities result in greater emission reductions over time given influence on governments and markets.

USAID OUs should follow the Protocol guidance to determine the potential results of clean energy activities from both categories, but the Protocol only includes methodologies for estimating emission reductions from the Technology Implementation and Practices category. The Protocol does not currently provide methodologies designed to estimate emission reductions from activities in the Policy and Capacity Building category, such as conducting a feasibility study for renewable energy or implementing a clean energy policy.

However, if an OU determines that technology implementation may result from a Policy or Capacity Building activity, then the Protocol may be helpful in estimating GHG emission reductions. Otherwise, further guidance and an accounting framework for USAID Policy and Capacity Building activities are under development.

1.4 Protocol Development and Organization

In coordination with USAID's Global Climate Change office and USAID OUs, the Protocol was developed based on various clean energy and GHG accounting protocols. *Table 1* summarizes the main source documents reviewed and organizations referenced during the development of the Protocol to ensure consistency with existing GHG accounting methodologies.

Table 1: Notable Source Documents Referenced During Protocol Development

Organization	Source Document	Uses in Protocol Development
World Resources Institute	GHG Protocol for Project Accounting (2005)	CLEER GHG Accounting Approach
World Resources Institute	Greenhouse Gas Protocol: Policy and Action Standard (2014)	CLEER GHG Accounting Approach
United Nations Framework Convention on Climate Change	Climate Development Mechanism Methodologies	CLEER Methodologies
Verified Carbon Standard	Methodologies: Energy	CLEER Methodologies
Intergovernmental Panel on Climate Change	Fourth Assessment Report: Climate Change 2007	Default data: Global Warming Potentials of Greenhouse Gases
Intergovernmental Panel on Climate Change	2006 Guidelines for National Greenhouse Gas Inventories	Uncertainty and default data: Stationary Fuel Emission Factors
International Energy Agency	CO_2 Emissions from Fuel Combustion – Highlights (2013)	Default data: Grid Emission Factors
National Institute of Standards and Technologies	The International System of Units – Conversion Factors for General Use	Default data: Unit Conversions and Standard Metrics

GHG ACCOUNTING ADVISORY GROUP

The Protocol underwent a review by an advisory group of international accounting experts from a variety of non-governmental organizations, government development agencies, and development banks. The reviewers assessed user-friendliness, robustness of the accounting approach, diversity of technology-specific clean energy projects, applicability of the data collection requirements, reasonableness of assumptions, and consistency with and conformity to international guidelines and standards. Feedback was documented, evaluated, and addressed according to priority and importance.

ORGANIZATION

The Protocol is organized into the following sections:

1. The **Introduction** provides a brief background on the GHG Indicator, key objectives of the Protocol, and an overview of the clean energy activities that may be reported under the GHG Indicator.

2. **CLEER GHG Accounting Approach** provides a background on the key concepts of GHG accounting, as well as an accounting framework for USAID clean energy activities.

3. **Estimating GHG Emissions from Clean Energy Results** provides calculation methodologies for estimating emission reductions from USAID clean energy activities, organized by Clean Energy Result.

4. **Reporting and Documentation** provides guidance on reporting under the GHG Indicator and documenting best practices for of all methodologies and assumptions.

5. **References and Appendices** provide sources references and data sources.

In addition to the Protocol, other supporting documents have been developed to enable OUs to estimate GHG emission reductions from clean energy activities. These include:

- CLEER Tool (web-based) at www.CLEERtool.org.
- CLEER Calculators (Excel-based) for the following methodologies:
  - Clean Energy GHG Calculator (Renewable Energy, Energy Efficiency, Fuel Switching)
  - Solar Photovoltaic Systems
  - Solar Thermal Systems
  - Wind Turbine Systems
  - Hydroelectric Systems
  - Geothermal Systems – Power Generation
  - Geothermal Systems – Direct Heat
  - Geothermal Systems – Heat Pumps
  - Biomass Energy – Select Fuels
  - Anaerobic Digesters for Manure Management
  - Building Energy Efficiency
  - Appliance & Equipment Efficiency
  - Stranded Natural Gas Capture Systems
  - Transmission and Distribution System Upgrades
- CLEER Calculator User Guide
  - Supplemental technology-specific information for each CLEER calculator
- CLEER Calculator Data Exercises
  - Step-by-step practice exercises for training purposes

2 CLEER GHG ACCOUNTING APPROACH

Contents of this section:

2.1 Introduction to GHG Project Accounting

This Protocol provides an overview of GHG accounting methods and standard guidelines for estimating carbon dioxide equivalent (CO_2e) emissions reduced, avoided, or sequestered, during the reporting year as a result of a USAID-funded activity.[6] This Protocol also provides guidance for identifying data sources, including default values and other variables, used to estimate emissions for a variety of clean energy activity types. These guidelines have been developed specifically for internal USAID reporting, and are therefore designed to complement and not replace other internationally-accepted standards.

ACCOUNTING FOR GHG EMISSION REDUCTIONS

Using proper GHG project accounting, OUs can estimate the GHG emissions reduced or avoided from the implementation of a specific activity, as well as comparing results across different project types. Project accounting also provides information that can be used to identify high-impact activities with cost-effective GHG reductions. This section provides an overview of the key elements and basic concepts of GHG project accounting.

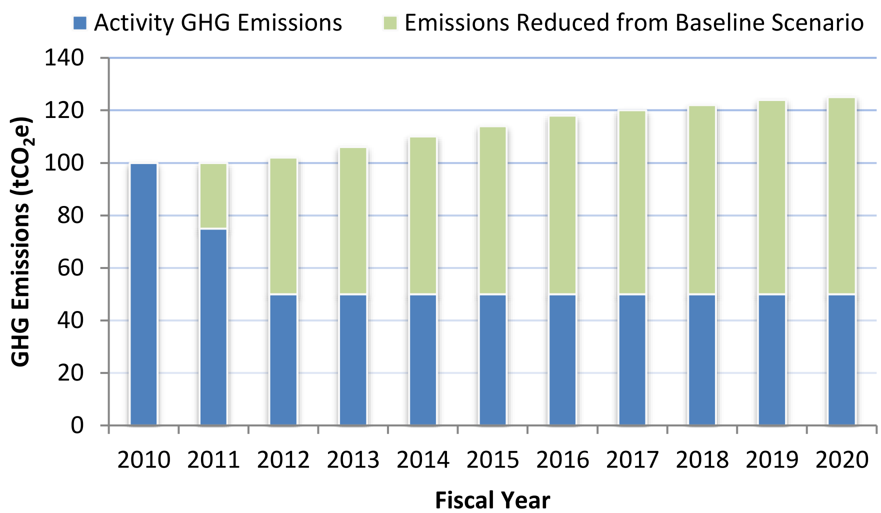
> The Intergovernmental Panel on Climate Change (IPCC) has identified seven categories of GHGs: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulfur hexafluoride (SF_6), and nitrogen trifluoride (NF_3).

GHG emission reductions refer to the amount of GHG emissions reduced, avoided, or sequestered as a result of a project. Emissions can be reduced in a variety of ways, such as decreasing the amount of energy used, using less carbon-intensive fuels, or displacing traditional fossil fuel energy with renewable energy. *Figure 1* illustrates GHG emission reductions due to a project compared to the

[6] USAID clean energy activities do not typically result in the sequestration of GHGs. Therefore, the Protocol does not include methods for estimating sequestered GHGs. The Biomass Energy – Select Fuels methodology does account for sustainability (i.e., the fraction of non-renewable biomass) with regard to the biogenic portion of the selected fuel, but does not estimate landscape sequestration directly.

relatively higher emissions that may have resulted without the implementation of the project (i.e., the business-as-usual scenario).

Figure 1. Example of GHG Emission Reductions



A project can result in both intended and unintended changes in GHG emissions—i.e., changes that are expected based on the design of a project, and changes that may arise from impacts for which the project did not originally plan. Intended changes may include the emission reductions anticipated from the project, accomplished by offsetting a traditional fuel, as well as emissions caused by the project if fuel is still consumed, often called the project footprint. Unintended changes may occur in emission sources not originally targeted by the project, or from market responses to increased or decreased energy supply, called leakage.[7] Emissions may also occur during the planning, construction, or decommissioning phases of a project, called lifecycle emissions.

The Protocol is designed to quantify the intended project emissions and emission reductions. It does not provide guidance for estimating absolute changes in emissions resulting from the entire lifecycle of a project.

GHG PROJECT ACCOUNTING PRINCIPLES

There are five standard principles that support the decision-making process for creating high-quality emission reduction estimates required for accurate GHG project accounting: Transparency, Accuracy, Consistency, Comparability, and Completeness. The application of these principles will help guide OU choices where the Protocol offers flexibility or appears ambiguous. These project accounting principles, defined below, have been adapted from the WRI *GHG Protocol for Project Accounting* and the *Policy and Action Standard* to relate specifically to USAID GCCI clean energy activities (WRI, 2005 and WRI, 2014).

[7] Leakage, as defined by IPCC, is a phenomenon "whereby the reduction in emissions (relative to a baseline) in a jurisdiction/sector associated with the implementation of mitigation policy is offset to some degree by an increase outside the jurisdiction/sector through induced changes in consumption, production, prices, land use and/or trade across the jurisdictions/sectors. Leakage can occur at a number of levels, be it a project, state, province, nation or world region."

It may be necessary for OUs to prioritize the application of these principles in order to fulfill the objectives of USAID reporting—for example, consistency in assumptions across OUs may be a higher priority than complete emission estimates. These five principles are defined below, along with questions to consider when applying each principle.

Box 1. Greenhouse Gas Project Accounting Principles

Transparency—Maintain transparency in calculations, particularly when flexibility or discretion is given to OUs. Clearly document all data sources, assumptions, references, activity information, inclusions, and exclusions so that the assessment can be understood and replicated.

- Are all exclusions, inclusions, and assumptions fully documented and explained?
- Are references provided for all data and assumptions?
- Is the data collection process documented?

Accuracy—Ensure accuracy of underlying data and calculations. Minimize uncertainty as much as is practical and avoid bias. Use transparent data and estimates.

- Are all data well documented?
- Is the method for estimating emissions transparent and relevant?
- Is there bias in the emission estimate?

Consistency—In order to ensure consistency within projects and across years, use consistent data, methods, and assumptions, following the guidelines in the Protocol.

- Are methods and procedures applied in the same manner?
- Do all the data, methods, and assumptions align with the Protocol?

Comparability—In order to promote credible and universal accounting, all USAID projects should use only appropriate Protocol methods so that reported estimates are comparable across USAID.

- Can estimates across projects be aggregated and compared?
- Do all the data, methods, and assumptions align with the Protocol?

Completeness—Consider all relevant effects of the activity and how data will be collected. Apart from areas where flexibility is provided, all steps of the Protocol must be accomplished to estimate and report emission reductions.

- Are all relevant emission reduction impacts included in the GHG reduction estimate?
- Is there a process in place for obtaining the data required to estimate emission reduction impacts?

Application of these principles will allow for meaningful comparison of emission reduction impacts across a broad range of activity types across the USAID GCCI portfolio, as well as the aggregation of GHG emissions reductions over time.

2.2 Stages of the CLEER GHG Accounting Approach

The CLEER GHG Accounting Approach follows a multiple stage approach for identifying and quantifying GHG emission reductions that result from the implementation of USAID clean energy activities categorized under Technology Implementation and Practices. This approach is designed to ensure greater consistency and transparency across USAID when assessing the impact of these activities. *Figure 2* provides an overview of each stage in the approach; these stages are discussed in detail in the following sections. This approach was adapted from the WRI *GHG Protocol for Project Accounting* (WRI, 2005) and WRI's *Policy and Action Standard* (WRI, 2014).

Figure 2. Stages in the CLEER GHG Accounting Approach

Stage 1: Define the Activity
Identify and describe the individual activities within a clean energy program to be assessed for GHG emissions reductions

↓

Stage 2: Identify the Clean Energy and GHG Results
Identify the Clean Energy Results that will lead to GHG emission reductions

↓

Stage 3: Define the Boundary
Identify which Clean Energy Results to include in the GHG emission reduction estimate

↓

Stage 4: Select a Methodology
Identify the methodology and data necessary to estimate emission reductions

↓

Stage 5: Define the Baseline Energy Scenario
Define the events or conditions, in terms of energy, that most likely would have occurred in the absence of the activity

↓

Stage 6: Gather Data
Gather necessary baseline and activity data

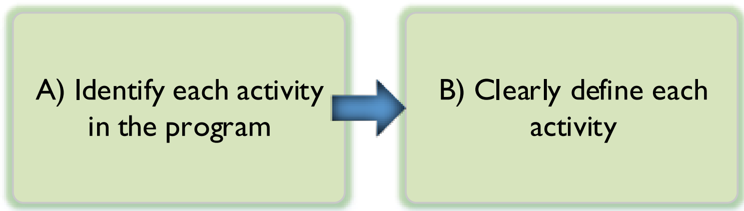
↓

Stage 7: Calculate GHG Reductions
Calculate GHG emission reductions

2.2.1 Stage 1: Define the Activity

The first stage in this approach is to identify and clearly define the activities within a program that may contribute to GHG emission reductions.

Figure 3. Steps in Stage 1: Define the Activity

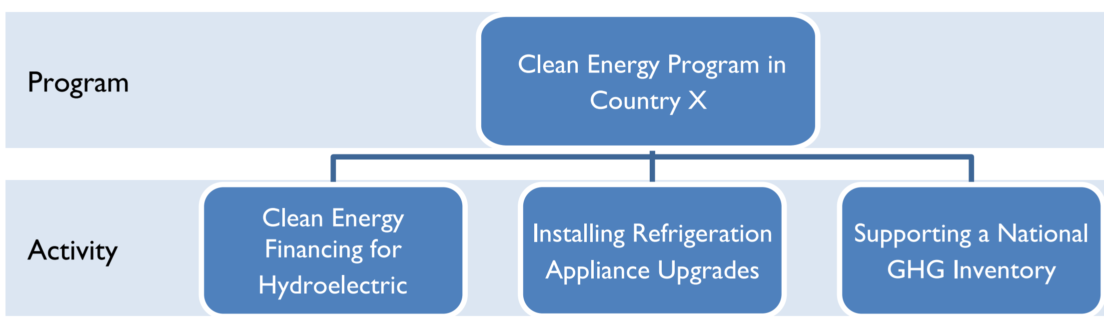


A) IDENTIFY EACH ACTIVITY IN THE PROGRAM

Each activity within a program that is anticipated to impact GHG emissions must first be identified.[8] Often, activities may be a part of a broader set of activities under a GCCI program; OUs should identify each activity that will be included in the GHG estimation, as they may impact emissions independently. Activities may increase energy efficiency, improve access to renewable energy, or build capacity in local institutions that support clean energy.

For example, a clean energy program may include many different activities, such as financing the construction or deployment of a renewable energy system, installing refrigeration appliance upgrades, or supporting the development of a national GHG inventory. *Figure 4* provides an example Clean Energy program that includes multiple clean energy activities.

Figure 4. Defining Components of an Example Clean Energy Program



Individual activities may be assessed separately as part of a comprehensive GHG reduction estimate of the entire program. Deciding on whether to assess activities individually or as a program is discussed in *Section 2.2.2: Stage 2: Identify the Clean Energy and GHG Result.*

[8] A "program" may constitute one or many awards, contracts, projects, or implementing mechanisms associated with a funding agency. OUs should avoid double counting results by clearly defining each program and activity.

B) CLEARLY DEFINE EACH ACTIVITY

Once each activity has been identified, the following information should be documented for each activity:

- General information about the activity, including the implementing mechanism name and number, parent program, start date, anticipated completion date, and location of the activity
- Roles and responsibilities in implementing the activity, including USAID's role, partner organizations, and implementing partners
- Sources of GHGs associated with the defined activity
- Sources of GHGs that will be mitigated due to the defined activity
- Intended Clean Energy Results (see *Section 2.2.2*)

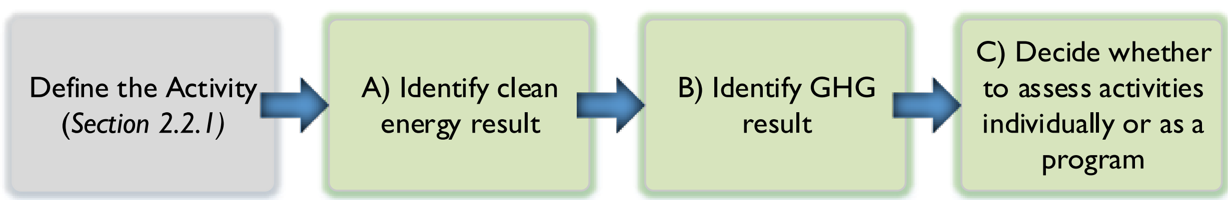
These details help to define the specific policies or actions taken under the activity and how they might lead to measurable GHG emission reductions. In addition, clearly identifying and defining each activity will avoid double-counting of GHG emission reductions, especially from activities that might be managed by multiple OUs, but should only be estimated and reported once.

Implementing partners should provide this information, if possible. This list is not intended to be exhaustive, and OUs should determine if there is additional relevant information to collect necessary to complete the assessment.

2.2.2 Stage 2: Identify the Clean Energy and GHG Results

The purpose of this stage is to identify the intended Clean Energy and GHG Results for each individual activity, their impact on GHG emissions, and whether and how to include those results in the overall activity GHG reduction estimate.

Figure 5. Steps in Stage 2: Identify the Clean Energy and GHG Results



A) IDENTIFY CLEAN ENERGY RESULTS

A **Clean Energy Result** is the intended result or targeted end goal of an activity in the context of clean energy, such as renewable energy generation or increasing energy efficiency. Identifying the Clean Energy Results of the activity will clarify which effects on GHG emissions (GHG Results) to include in the estimate, and which methodology should be used to estimate emissions and emission reductions.

A Clean Energy Result should be identified for each defined activity. If an OU determines that an activity may lead to multiple Clean Energy Results, then the OU should identify each action and associated Clean Energy Result to be assessed individually.

Note: The GCCI clean energy activities described in *Section 1.3* all seek to accelerate the transition of countries to low emission development through clean energy. Many of these activities will have quantifiable GHG reductions that can be estimated and reported using existing methodologies—for example, for technology-specific activities such as installing solar photovoltaic systems. However, some activities may have more complex components or multiple pathways that lead to emission reductions—e.g., an EC-LEDS program. Identifying Clean Energy Results for each component is a critical step in assessing a larger program. It is important to note that USAID activities can lead to multiple results in addition to clean energy, such as development and training results. The CLEER Protocol discusses only the Clean Energy Results of USAID activities.

Table 2 includes a list of Clean Energy Results likely to occur due to USAID clean energy activities.

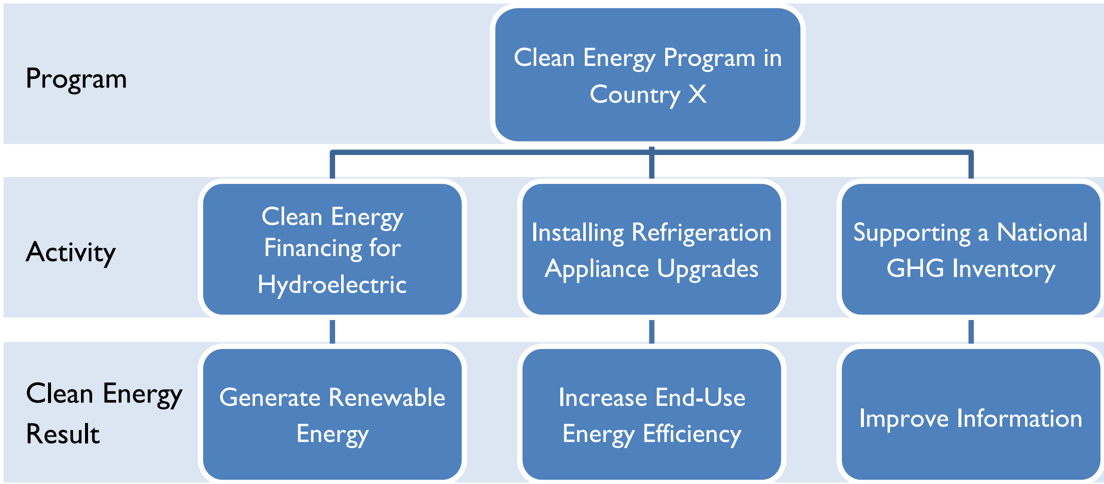
Table 2. Clean Energy Results

Clean Energy Result	Description	Methodologies included in Section 3.
Generate Renewable Energy	Implementation or installation of renewable energy technologies that produce energy from clean, renewable sources for on-site use or distribution to the grid.	Yes
Increase End-Use Energy Efficiency	Improved efficiency of end-use technologies through technology upgrades or replacements that reduce the amount of energy consumed by the end-user, as well as the implementation of practices that conserve energy.	Yes
Increase Energy System Efficiency	Improved efficiency of existing energy generation, transmission, and distribution systems by improving performance or reducing technical losses.	Yes
Fuel Switching	Substitution of traditional energy sources for less GHG-emissive types of fuel.	Yes
Market Development	Development of policies, regulations, and standards that further the implementation of clean technologies and practices through market forces.	No. Further guidance is under development.
Improve Information	Improved access to and/or the quality of information regarding clean energy deployment or management in order to build capacity.	No. Further guidance is under development.

If an OU identifies a Clean Energy Results not currently addressed by the Protocol—i.e., Market Readiness or Improve Information—the OU should still follow the Protocol guidance to determine if another Clean Energy Result is possible for each activity. For example, a policy may intend to increase renewable energy generation; OUs can use the Protocol to estimate changes in GHG emissions from the increased use of renewable generation. OUs can assess other indirect benefits from the policy upon release of the guidance for USAID Policy and Capacity Building activities.

Figure 6 provides an example of how to assign a Clean Energy Result to each of the activities under the example Clean Energy program, which includes financing the development of hydroelectric power, the installation of refrigeration appliance upgrades, and support for the development of a national GHG inventory.

Figure 6. Identifying Clean Energy Results of an Example Clean Energy Program



Identifying Clean Energy Results is an important step, because each result will involve different methodologies and required data for estimating emissions and emission reductions.

B) IDENTIFY GHG RESULTS

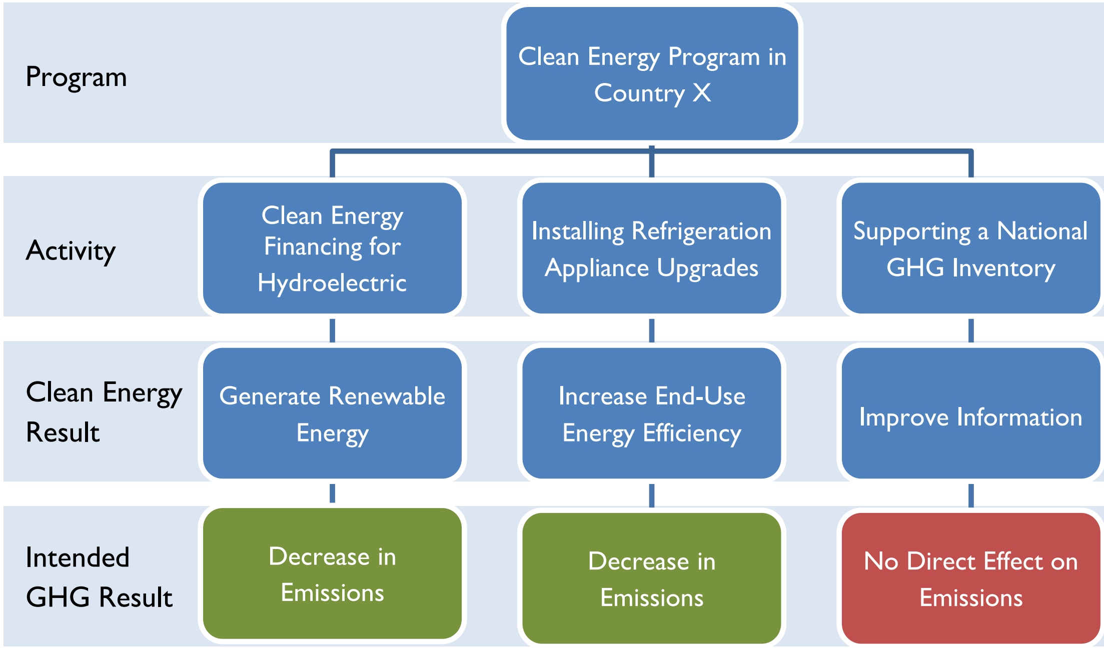
Once the Clean Energy Results from an activity have been determined, the intended GHG Results can also be identified. The **GHG Result** of an activity represents the positive or negative changes in GHG emissions (or removals) as a product of the Clean Energy Result. For example, replacing older appliances with more efficient appliances will decrease overall electricity consumption, leading to net emission reductions.

Activities do not always reduce GHG emissions directly, but instead often promote technical, environmental, economic, or social change that ultimately affect GHG emissions. GHG Results may be several steps removed from immediate outcomes of the activity. In addition, aspects of some activities may result in increased emissions. OUs should consider both increases and decreases in emissions that result from the activity.

Understanding the Clean Energy and GHG Results will inform which variables are likely to change due to implementation of the activity. This concept becomes more important when selecting a methodology in *Section2.2.4: Stage 4: Select a Methodology* and providing required data in *Section 2.2.6: Stage 6: Gather Data*.

Figure 7 illustrates the GHG Results associated with the example Clean Energy program. Only the first two activities are determined to have significant impacts on GHG emissions; thus, only these two should be assessed for GHG emission reductions.

Figure 7. Identifying GHG Results for an Example Clean Energy Program



Box 2: How to Identify Clean Energy and GHG Results

Various approaches and types of information can be used to identify Clean Energy and GHG Results and the relationship between them, such as:

- Previous policy assessments, evaluation studies, or other relevant literature for similar activities and circumstances to help identify various types of effects that are likely to be relevant;
- Professional judgment or expert opinion;
- Expert panels to facilitate exchange of information on different aspects of the impacts of an activity;
- Consultation with those with local knowledge in the countries;
- Surveys involving appropriate experts and local/regional/national/global entities;
- Consultation with statutory authorities, review of development plans, resource management plans and regulatory standards; and
- Complex computer models or geographic information systems (GIS).

Identifying various results within a broad program may be challenging. It is important to first identify all individual activities that may have discrete Clean Energy Results, for example by constructing flow charts for each activity. Mapping these results will provide a broad conceptual diagram of intended GHG Results for the program and will help aggregate the individual emission reductions across all activities.

C) DECIDE WHETHER TO ASSESS ACTIVITIES INDIVIDUALLY OR AS A PROGRAM

Activities within a program often interact, which makes it difficult to isolate results and aggregate GHG emission reductions for the program. For example, it may be difficult to separate results from a demand-side management initiative and energy efficiency financing that are implemented in the same geographic location. Combined, they result in measurable energy reductions, but the amount of GHG reductions attributable to each may be difficult to distinguish. In cases like this, activities may be assessed as a program, rather than individually.

The decision on whether to evaluate activities distinctly or as a package will be influenced by the resources available to conduct these assessments, and certain questions may help determine which approach to take:

- Do activities interact closely and/or do they lead to the same Clean Energy Result?
  - → If yes, the activities across a program can be packaged into a single Clean Energy and GHG Result. Collected data would be combined across the activities to estimate the overall reduction in emissions. For example, the total energy savings could be summed from multiple activities intended to increase energy use efficiency through appliance replacement and building envelope improvements in the same location.
  - → If no, consider assessing activities individually, assuming resources and data are available to do so. Then, sum the emission reductions across activities to estimate total reductions under the program. For example, emission reductions due to new solar panels that offset grid electricity should likely be assessed separately from reductions due to the installation of solar lanterns that replace kerosene use.

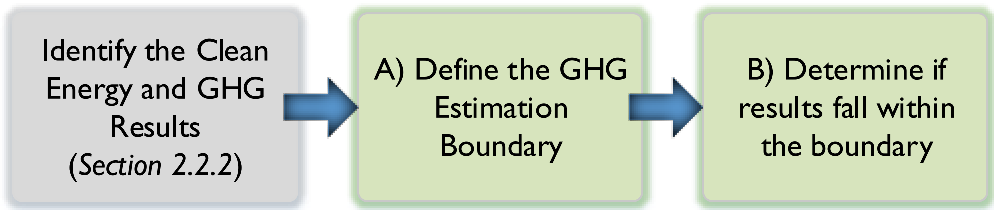
- Is it possible to disaggregate the observed Clean Energy Results and attribute them to separate individual activities—or, is separate data available for each activity?
  - → If yes, consider assessing activities individually. This may provide better resolution of the impact of individual activities, which otherwise could get lost when assessing the entire clean energy program.
  - → If no, consider assessing as a program. It is important to use the best information available to assess an activity's impact on emissions, even if it is aggregated with other activities.

OUs should avoid double-counting across overlapping Clean Energy or GHG results by assessing activities as a program, and estimating and reporting one net GHG reduction value.

2.2.3 Stage 3: Define the Boundary

This section provides guidance on clearly defining the GHG Estimation Boundary and determining which Clean Energy Results of the activity to include within that boundary.

Figure 8. Steps in Stage 3: Define the Boundary



A) DEFINE THE GHG ESTIMATION BOUNDARY

The **GHG Estimation Boundary** defines the scope of the estimate relative to the activity, including the types of gases, jurisdiction, and time period covered. This boundary affects which results are included in the GHG estimate. The Protocol clearly defines the following boundaries, which should be used by OUs in reporting under the GHG Indicator.

Activity Boundary

The Protocol is currently designed to assess only the GHG emissions and emission reductions, and associated changes in energy type and consumption, which occurred solely due to the implementation of the clean energy activity. Similarly, the Protocol only provides guidance for determining the energy use and emissions in the Baseline Energy Scenario with regard to the specific nature of the clean energy activity, call the Activity Boundary, as opposed to the geographic area. For example, the Activity Boundary for a solar photovoltaic system would likely consist of the amount of electricity generated by the system installed as well as the type and amount of grid electricity or traditional energy being replaced by the system.

The Protocol methods do not include other lifecycle activities within the Activity Boundary, such as production of materials, construction, or waste created during or after the implementation of the activity—often called upstream and downstream impacts. If OUs determine that these sources of emissions or emission reductions are significant enough to include in the Activity Boundary, they should document all data and assumptions.

Covered Gases

The Protocol focuses on clean energy activities, which typically lead to emission reductions of three primary GHGs: CO_2, CH_4, and N_2O. It is possible for USAID activities to result in the reductions of other greenhouse gases, such as HFCs, PFCs, SF_6, and NF_3. However, reduction of these gases is significantly less likely from USAID clean energy activities, and therefore this guidance addresses impacts on only CO_2, CH_4, and N_2O.

Non-CO_2 GHGs covered in the Protocol have a corresponding global warming potential (GWP) to allow for direct comparison, expressed in units of CO_2 equivalent (CO_2e). For example, methane (CH_4) is 25 times more effective at trapping heat in the atmosphere than CO_2 (IPCC, 2007b). See *Section 3.1.1:*

GHG Accounting Basics for additional information on GWPs and a list of the most common GHGs and their corresponding GWP values.

Jurisdictional Boundary

A jurisdiction may constitute a geopolitical boundary such as a city or nation, or a specific project area, over which the USAID OU and Implementing Partners have authority, at least as it pertains to the implementation of the activity. Results that occur within the defined jurisdictional boundary are considered "in-jurisdiction," as opposed to "out-of-jurisdiction" results that occur outside of the boundary. Defining the jurisdiction helps to determine which results should be included in the emission reduction estimate. It is also helpful for identifying default data, such as emission factors (EF) used in estimating emission reductions—for example, a grid electricity emission factor for a particular region.

For example, a building efficiency policy may affect buildings within a municipal area, but may also lead to GHG reductions in near-by jurisdictions due to a market response for improved building efficiency. The latter is an out-of-jurisdiction result called spillover. Leakage is an out-of-jurisdiction result that increases emissions due to the activity.

It is up to the OU to define a narrower or broader jurisdiction based on the specifics of the activity and the location of implementation, as well as determine whether emission reductions fall within or outside of the jurisdiction.

The methods presented in this Protocol are intended to estimate in-jurisdiction emissions and emission reductions, but OUs should determine if out-of-jurisdiction effects are significant enough to include in the assessment, being sure to document all data and assumptions. [9]

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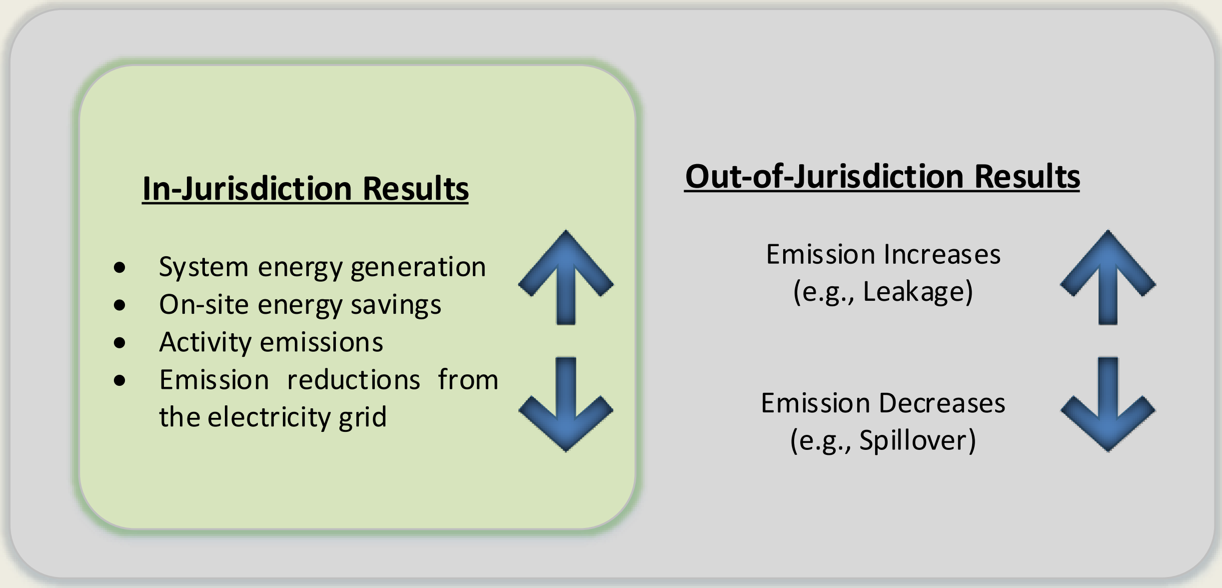
[9] Certain activities (e.g., biomass energy) can result in unanticipated decreases (or increases) in GHG benefits outside of the Activity Boundary. For example, an increase in demand for renewable biomass from a particular project may induce shifts in the types and amounts of fuel used within the same or adjacent jurisdictions, or lead to changes in land use in other locations. In these cases, inclusion of these potentially significant secondary effects is important, though OUs may likely have to estimate data of secondary effects.

Box 3: Screening In-Jurisdiction and Out-of-Jurisdiction Results



OUs should determine if out-of-jurisdiction results, such as spillover and leakage, are significant enough to include in the assessment, and if measurements of such are feasible and sufficiently accurate. OUs can employ an approach provided within the GHG Protocol Policy and Action Standard (WRI, 2014) for assessing significance by considering both likelihood and relative magnitude of each GHG Result.[10] If OUs exclude significant out-of-jurisdiction results for practical reasons, exclusions should be disclosed.

Temporal Boundary

The reporting period for the GHG Indicator is the most recently completed fiscal year for Clean Energy Pillar activities. OUs should only assess the portion of the activity's impact—e.g., energy savings—that occurs within the single reporting year, rather than the entire lifetime of the activity, as the GHG Indicator is not a reflection of the cumulative emission reductions of an activity reported in previous years. Each reporting year should be assessed individually

B) DETERMINE IF RESULTS FALL WITHIN THE GHG ESTIMATION BOUNDARY

If a Clean Energy Result or GHG Result falls outside any of the boundaries specified in the previous section, they are considered outside of the GHG Estimation Boundary and may be excluded from the emission estimation for reporting under the GHG Indicator. Any determinations of the Activity Boundary that deviate from what is defined above should be clearly documented with the justification for doing so.

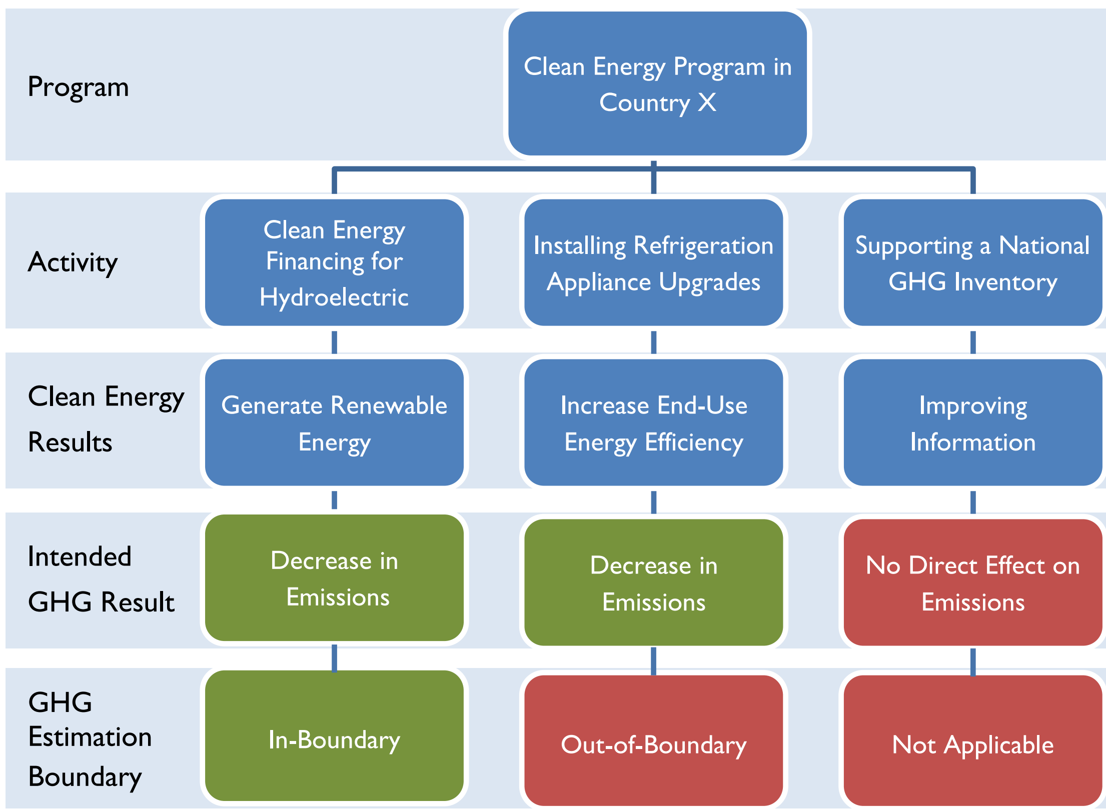
The diagram in *Figure 9* defines the GHG boundary for the Clean Energy program example. The jurisdictional boundary can be defined as the country in which the activities occurred. In this example,

[10] Chapter 7 of the Policy and Action Standard.

each activity took place in the same country, and therefore are within the jurisdictional boundary of the GHG Estimation Boundary.

In this example, the hydroelectric activity occurred during the reporting year, leading to measureable and in-boundary emission reductions. However, the refrigeration appliance upgrades did not begin until after the reporting year and are therefore out-of-boundary for the GHG Indicator. The OU in this example should only estimate emission reductions from the hydroelectric financing activity.

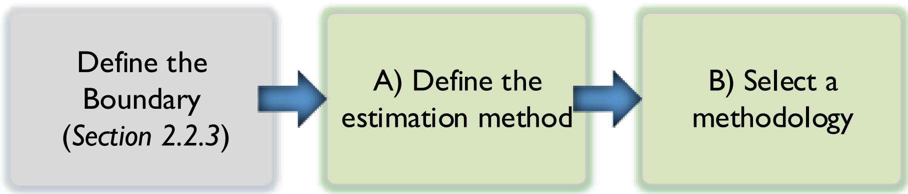
Figure 9. Determining the GHG Estimation Boundary for an Example Clean Energy Program



2.2.4 Stage 4: Select a Methodology

This section provides guidance for selecting which methodology to use to estimate emissions reduced from the Clean Energy Results included within the GHG Estimation Boundary.

Figure 10. Steps in Stage 4: Select a Methodology



A) DEFINE THE ESTIMATION METHOD

The CLEER Accounting Approach estimates GHG emissions reduced *after* the implementation of the activity. This requires comparing the energy and emissions due to the activity to what most likely would have occurred in the absence of the activity. Further detail on establishing what would have occurred in the absence of the activity is discussed in *Section 2.2.5: Stage 5: Define the Baseline Energy Scenario.*

The Protocol provides methods that use simple, standardized equations for estimating emission reductions. These methods do not require complex models or simulations in order to estimate emissions.

The Protocol provides methods that rely on "bottom-up" data, which are measured or collected at the activity level, such as technology specifications or energy consumption. This is opposed to "top-down" data, which are macro-level measurements collected at the jurisdiction or sector level, such as total energy consumption within a country or economic output data. Both top-down and bottom-up data may be used in some methodologies—for example, the Protocol includes country- or region-specific default data, such as marginal emission factors for grid electricity. However, changes in top-down data are not typically used to assess emission reductions due to the activity.

Directly measured energy generation or consumption data is preferred for all methodologies.

In order to ensure consistency, OUs should rely upon methods that utilize observed or known data about the activity and simple equations that require bottom-up data about the activity. OUs should document when a different method is used.

B) SELECT A METHODOLOGY

Section 3: Estimating GHG Reductions from Clean Energy Results provides standard methodologies for estimating GHG emission reductions from a variety of activity types based on their intended Clean Energy Result (see *Table 2. Clean Energy Results*) and available data. Included are two types of methodologies for estimating emissions:

- **Clean Energy GHG Methodology** – Under this methodology, it is assumed that OUs know and can provide the amount of electricity or fuel generated, consumed, or conserved due to the activity during the reporting year. This value is used to estimate emission reductions based on the type of energy that would have been used if the activity had not occurred.

  If an OU has measured or estimated the amount of electricity or fuel generated, consumed, or conserved in the activity, they can use the section of the Clean Energy GHG Methodology specific to their Clean Energy Result—either renewable energy generation, energy efficiency, or fuel switching—regardless of what technology is implemented. This method allows OUs to estimate emission reductions using this energy data and a fuel- or country grid-specific emission factor.

- **Technology-Specific Methodology** – When the amount of electricity or fuel generated, consumed, or conserved due to the activity is unknown, the Protocol provides alternative methods that allow OUs to estimate this amount. These methods require activity-specific data that are unique to the technology being implementing, such as number of units, unit efficiency, capacity of the system, etc.

Table 3 lists the methodologies currently provided in this Protocol by their associated Clean Energy Result. For each Clean Energy Result, this table presents the most relevant method for estimating the amount of energy or fuel generated, consumed, or conserved, and associated GHG emission reductions.

Table 3. Available Methodologies in the Protocol[11]

Clean Energy Result	CLEER Methodology
Generate Renewable Energy, Increase Energy Efficiency, and Fuel-Switching	Clean Energy GHG Methodology (when energy data has already been measured or estimated)
Generate Renewable Energy	Solar Photovoltaic Systems Solar Thermal Systems Wind Turbine Systems Hydroelectric Systems Geothermal Systems – Power Generation Geothermal Systems – Direct Heat Geothermal Systems – Heat Pumps Biomass Energy – Select Fuels Anaerobic Digesters for Manure Management
Increase End-Use Energy Efficiency	Building Energy Efficiency Appliance & Equipment Efficiency
Increase Energy System Efficiency	Transmission and Distribution System Upgrades Stranded Natural Gas Stranded Systems

[11] As defined in *Section 2.2.2 Stage 2: Identify the Clean Energy and GHG Result, Table 2. Clean Energy Results*, this table lists the Clean Energy Result methodologies available in v1.3 of the Protocol.

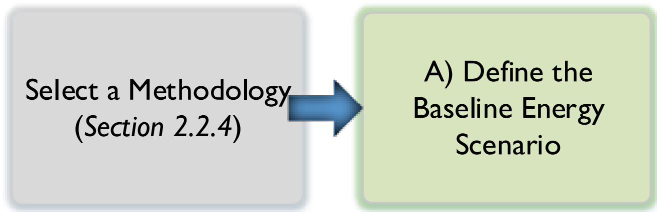
These technology-specific methods were designed to cover many USAID clean energy activities, but there may be unique activity types for which a methodology has not yet been developed. In these cases, it may be necessary to use the Clean Energy GHG Methodology. Alternatively, a methodology may not be required if the activity does not lead to direct emission reductions. OUs should follow the stepwise CLEER GHG Accounting Approach to make this determination.

Sections 2.2.5:Stage 5: Define the Baseline Energy Scenario and *2.2.6: Stage 6: Gather Data* present an introduction to the detailed methods presented in *Section 3*, including how to determine the type and amount of energy that mostly would have been in place in the absence of an activity, and how to estimate emission reductions given available data. These sections present fundamental concepts that are applied more specifically within the technology-specific methods in *Section 3*.

2.2.5 Stage 5: Define the Baseline Energy Scenario

This section provides guidance on how to define a Baseline Energy Scenario, and the role it plays in estimating GHG reductions.

Figure 11: Steps in Stage 5: Define the Baseline Energy Scenario



For any method included in the Protocol, OUs must define the **Baseline Energy Scenario**, which represents the events and conditions—in terms of energy—that most likely would have occurred within the Activity Boundary during the reporting year in the absence of the activity. For example, this may be the amount and type of fossil fuel or electricity that would have been consumed, or type of energy technology in place, in the absence of the clean energy alternative energy type or technology. **Baseline Emissions** are an estimate of the amount of GHG emissions associated with the Baseline Energy Scenario that would have been emitted during the reporting year in the absence of the activity.

Example Baseline Energy Scenarios

Each method in *Section 3* provides guidance on how to establish a specific Baseline Energy Scenario for an activity. Example scenarios include:

- For renewable energy generation, the Baseline Energy Scenario may be the amount of grid electricity that would have been consumed in the absence of renewable generation.
- For energy efficiency, the Baseline Energy Scenario is likely the amount of electricity or fuel that would have been consumed without the implementation of energy efficiency measures.
- For fuel switching, the Baseline Energy Scenario would include the amount and type of traditional fuel that would have been used in the absence of the activity.

The following questions may help determine the type of energy that would have been used under the Baseline Energy Scenario and how to account for energy savings and emission reductions from the activity:

- In the case of Renewable Energy Generation, does the new clean energy source replace non-electric thermal or lighting (for example, lanterns), or does it replace electricity?
  - → If it replaces non-electric thermal or lighting, what type of fuel was consumed to provide that energy?
  - → If it replaces electricity, did the electricity come from a central utility system, a distributed or microgrid system, or an on-site source such as diesel generators?

- In the case of Fuel Switching, what type of fuel would have been used in the absence of the clean energy alternative?

- In the case of Energy Efficiency, is energy provided by fuel or electricity? What is the expected energy savings or percent change in energy efficiency due to the activity?

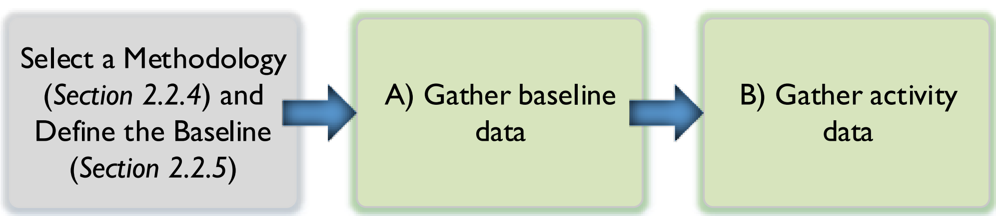
Once an OU determines a Baseline Energy Scenario, the OU should retain that Baseline Energy Scenario in terms of baseline energy type or efficiency for the entirety of reporting on the implementation of the activity. When reporting on each subsequent reporting year, OUs should calculate the Baseline Emissions for each year based on assumed energy consumed in the absence of the activity and should not include assumed changes in the Baseline Energy Scenario resulting from the implementation of the activity.

All methods within the Protocol assume that the Baseline Energy Scenario remains static across all reporting years. This may mean, in practice, that the energy type under the Baseline Energy Scenario remains the same throughout the implementation of the activity, while the energy demand associated with the Baseline Energy Scenario continues to depend on the amount of energy generated or consumed within the Activity Boundary. The Protocol does not provide guidance for redefining or recalculating the Baseline Energy Scenario across multiple years.

2.2.6 Stage 6: Gather Data

This section provides guidance on how to gather data using the method and Baseline Energy Scenario defined in *Stage 4: Select a Methodology* and *Stage 5: Define the Baseline Energy Scenario*.

Figure 12. Steps in Stage 6: Calculate GHG Reductions



A) GATHER BASELINE DATA

Estimating baseline emissions typically requires data on the type and amount of fuel that would have been consumed, the GHG emission factor for that fuel type for a specific gas—e.g., CO_2, N_2O, or CH_4—and the global warming potential (GWP) of each gas emitted. Total GHG emissions equals the sum of emissions for each gas.

A basic example equation for estimating baseline emissions is:

Equation 1

$$\text{Baseline GHG Emissions} = \text{Amount of Fuel Consumed} \times \text{Fuel Specific GHG Emission Factor} \times \text{GHG Specific GWP}$$

The type of energy that most likely would have been used in the absence of the activity must be identified as part of defining the Baseline Energy Scenario (see *Section 2.2.5*). The amount of fuel that would have been consumed, or other related baseline data, can be obtained in one of three ways:

1) **Directly-measured energy use under the activity** – For renewable energy and fuel switching, if energy or fuel use or generation was measured as part of the implementation of the activity, OUs may assume that same amount of energy would have been consumed or generated using the baseline type of energy. For energy efficiency activities, the amount of energy generated or consumed under the Baseline Energy Scenario can be estimated by assessing the energy generated or consumed under the activity, plus energy saved through the implementation of the activity. Directly-measured data is preferred.
2) **Historical energy use** – If direct measurements are not available, OUs can estimate baseline energy use based on historical fuel use or generation.
3) **Estimated energy use under the activity** – If direct measurements are unavailable and historical energy use is unknown, OUs can estimate baseline energy use using data related to the clean energy technology installed (e.g., number of units, capacity installed). The Protocol's technology-specific methods are designed to help OUs estimate the energy or fuel generated, consumed, or conserved under various activity types.

Relating Activity and Baseline Energy Use

The Protocol is intended to estimate the amount of energy and associated GHG emissions that would have occurred if not for the implementation of the activity after implementation of the activity occurred. In addition, the Protocol is intended to determine only the emissions reduced or avoided within the Activity Boundary.

Given these two conditions, it is assumed that for renewable energy and fuel switching activities, the amount of energy generated or consumed by the activity in the reporting year would have been met by the Baseline Energy Scenario energy type in the absence of the activity. For energy efficiency activities, the amount of energy generated or consumed under the Baseline Energy Scenario (if baseline data is not available) can be estimated by assessing the energy generated or consumed under the activity, plus energy saved through the implementation of the activity—i.e., the efficiency. This amount of activity energy helps determine Baseline Emissions, and therefore, it is assumed that the estimated emissions reduced from the Baseline Energy Scenario are due to the implementation of the clean energy activity.

B) GATHER DATA FOR THE ACTIVITY

The implementation of the activity can result in conditions that differ from the Baseline Energy Scenario, which can result in changes in the value of data variables used to estimate GHG emissions. For example, the reduction in electricity generated or fuel consumed, as well as changes in other factors, can result in GHG emission reductions. The data for the activity can be obtained in one of two ways:

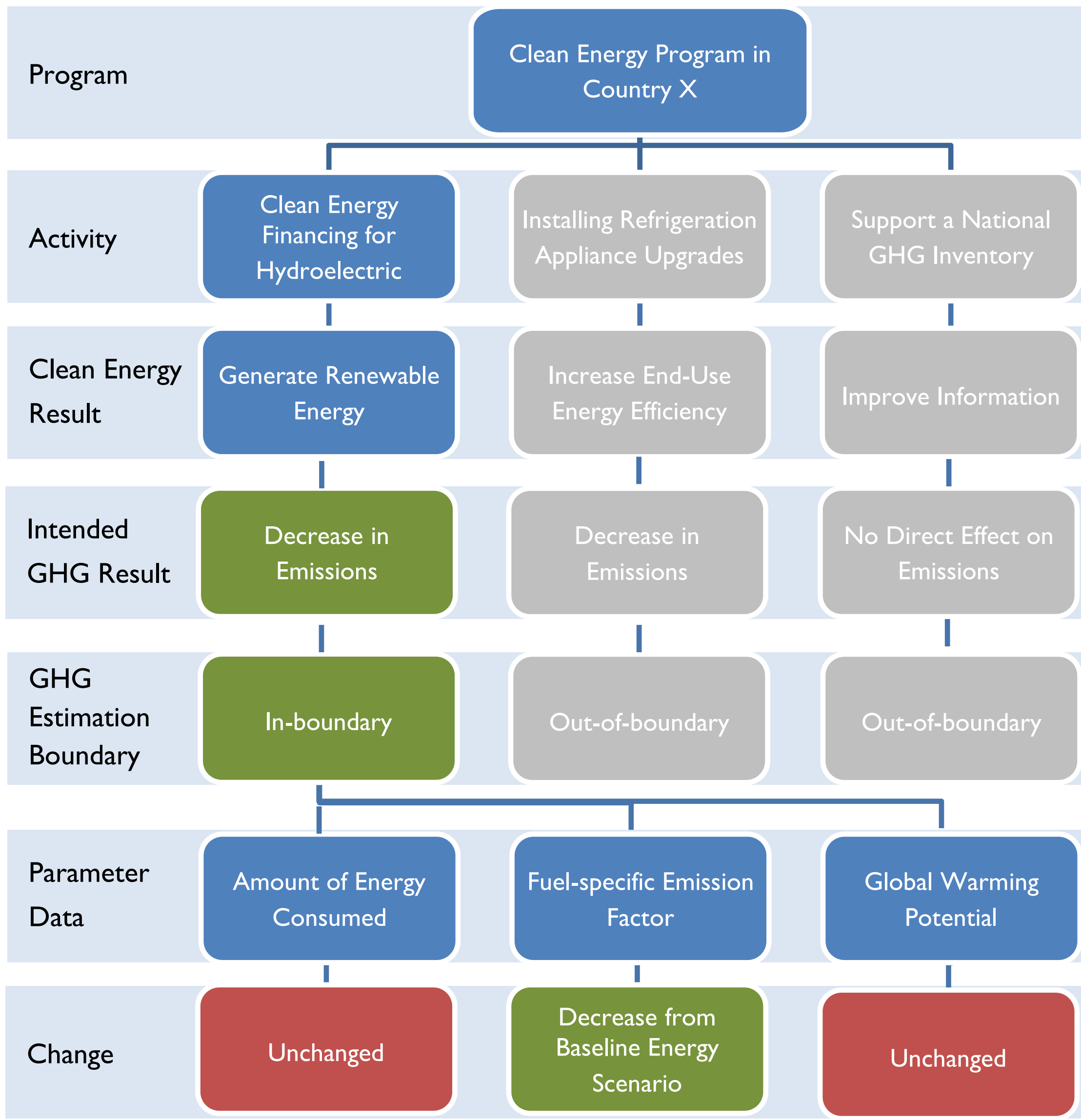
1) **Directly-measured energy use** – If the absolute amount of energy generated, consumed, or conserved was measured or estimated as part of the implementation of the activity, it can be used in the activity and baseline emission calculations. Directly-measured data is preferred.
2) **Estimated energy use** – If the amount of energy or fuel generated, consumed, or conserved is unknown, the Protocol's technology-specific methods are designed to help OUs estimate that data for various activity types.

This Protocol provides default values for several parameters, including electricity and fuel GHG emission factors, GWPs, and capacity factors. This data can be found in the appendices starting in *Section 6*. OUs should use the most recent and relevant site-specific emission factors for each reporting year, if they are available. Otherwise, regional or international default values can be used, as provided in the Protocol. Default values can also be used for other variables within the technology-specific methods, such as renewable energy generation capacity factors, energy conversion factors, and technical specifications. OUs should document the source for each data element used in the calculation—whether it is directly measured, estimated by other means, or is a default value from a another source.

All methods within the Protocol prioritize the use of data that are considered static over the reporting year, as opposed to dynamic over time. For example, the grid electricity emission factor is assumed to remain constant over the reporting year for the purpose of calculating grid electricity emissions. More complicated analyses such as modeling may be required to understand how an activity can influence such variables over time, especially when such changes are non-linear. OUs should document if they include any dynamic data parameters in the estimation that change over time.

Figure 13 illustrates how variables may change from the Baseline Energy Scenario due to the activity; in this example, the emission factor changes due to the installation of hydroelectric power to replace traditional fuel use.

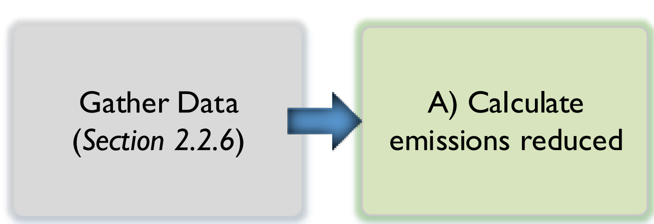
Figure 13. Changes in Parameter Data for Example Clean Energy Program



2.2.7 Stage 7: Calculate GHG Reductions

This section provides guidance on how to estimate emission reductions using the data gather in *Stage 6: Gather Data.*

Figure 14. Steps in Stage 7: Calculate GHG Reductions



A) CALCULATE EMISSIONS REDUCED

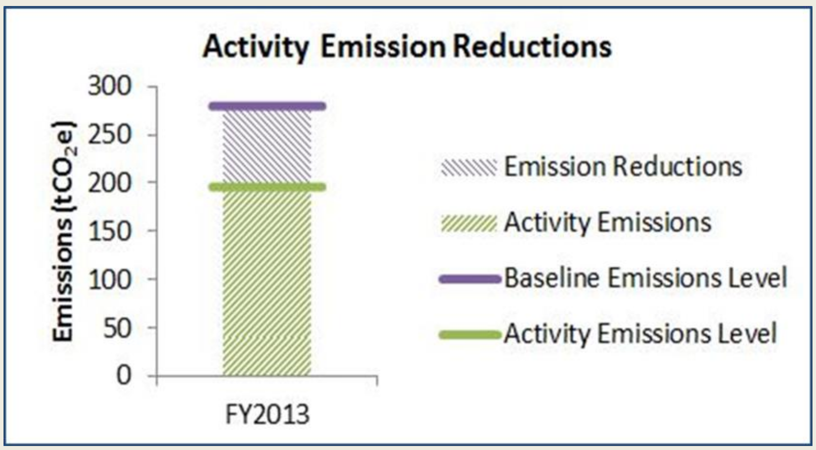
Data for the baseline and the activity gathered in the previous two stages are used to estimate emissions reduced using either the Clean Energy GHG Methodology or Technology-specific Methodologies in the Protocol. *Section 3: Estimating GHG Reductions from Clean Energy Results* provides methods for a number of USAID activity types and Clean Energy Results, and includes calculations for estimating emission reductions by activity type. The basic equation for estimating emissions reduced is:

Equation 2

$$\text{GHG Emissions Reduced} = \text{Baseline GHG Emissions} - \text{Activity GHG Emissions}$$

<u>Visualizing Emission Reductions</u>

GHG emissions reduced are the difference between the Baseline Emissions that would have been emitted in the absence of the activity and the Activity Emissions that occurred due to the activity during the reporting year.



For programs with multiple activities, and for which multiple, unique Clean Energy Results were identified and assessed, emissions reduced from each calculation should be aggregated to reflect the overall emissions reduced due to the clean energy program within the reporting year. For example:

Equation 3

$$\begin{aligned}\text{Total Program Emissions Reduced} \\ &= \text{Emissions Reduced from Activity A} + \text{Emissions Reduced from Activity B} \\ &+ \text{Emissions Reduced from Activity C}\end{aligned}$$

Emission reductions should only be aggregated for the purpose of reporting under the GHG Indicator for activities that occurred within the same reporting year. OUs should ensure there was no double-counting across multiple estimations for which there may have been overlapping Clean Energy or GHG results.

OUs are also encouraged to assess the estimate's uncertainty and conduct a sensitivity analysis to understand the impact of the key data assumptions taken into consideration with in the estimate. More information on uncertainty is provided in *Section 4.2 Uncertainty of Clean Energy Methodologies*. Guidance for conducting a sensitivity analysis can be found in section 12.4 in the GHG Protocol Policy and Action Standard.[12]

2.3 Case Study: Applying the GHG Accounting Approach

This section illustrates the steps an OU would take to estimate emission reductions using the CLEER GHG Accounting Approach. USAID supports a wide range of clean energy activities and thus the application of this GHG Accounting Approach may vary across activities, and this section may not address every possible circumstance.

This case study example involves a USAID program implemented in the Philippines between 2002 and 2005. The Alliance for Mindanao Off-Grid Renewable Energy (AMORE) Program[13] expanded renewable energy-focused rural electrification and economic development. The goal of the activity was to electrify at least 160 off-grid rural communities in the Autonomous Region in Muslim Mindanao and Western, Central, and Southern Mindanao with renewable energy systems, mainly solar photovoltaic (PV) and hydroelectric systems. This program electrified 200 rural communities.

The remainder of this section describes how each stage of the CLEER GHG Accounting Approach may apply to the AMORE Program example.

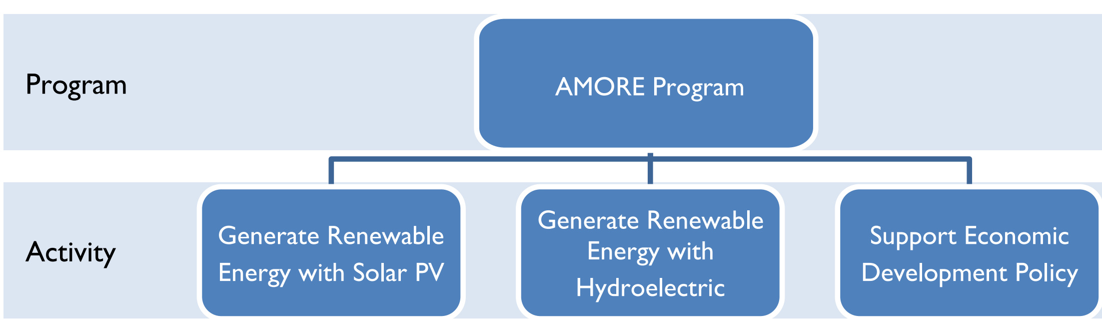
STAGE 1: DEFINE THE ACTIVITY

The first stage is to clearly define the activity that will be assessed for emission reductions.

A) IDENTIFY EACH ACTIVITY IN THE PROGRAM

Each activity within the AMORE Program is listed in *Figure 15*.

Figure 15. AMORE Program Components



[12] http://www.ghgprotocol.org/policy-and-action-standard.

[13] The information regarding the AMORE Program included in the Protocol were gathered from publicly available resources and do not necessarily reflect information provided by AMORE Program. Some assumptions were made regarding data from individual activities only to illustrate specific components of the Protocol.

B) CLEARLY DEFINE EACH ACTIVITY

After identifying the activities within the program, collect general information on each activity in the program. *Table 4* provides an example of the information collected for the solar PV activity within the AMORE Program.

Table 4. General Information about the AMORE Program

Information	Description
Parent Program	The Alliance for Mindanao Off-Grid Renewable Energy (AMORE)
Implementing mechanism number	USAID-Winrock Associate Cooperative Agreement No. 492-A-00-02-00006-00
Implementing mechanism name	Electrification of rural communities
Name of the Activity	Generate renewable energy with solar photovoltaic systems.
Operating Unit	USAID/Philippines' Office of Environmental Management, later renamed the Office of Energy and Environment
Partner organizations / Implementing Partners	Winrock International
Location of Activity	Autonomous Region in Muslim Mindanao and Western, Central and Southern Mindanao in Philippines
USAID role	Primary funder
Fiscal year reported	2004 (assume reporting in year 3)
Activity start date	2002
Date of completion	2005

For more information on defining the activities within a program that contribute to GHG emission reductions, see *Section 2.2.1: Stage 1: Define the Activity*.

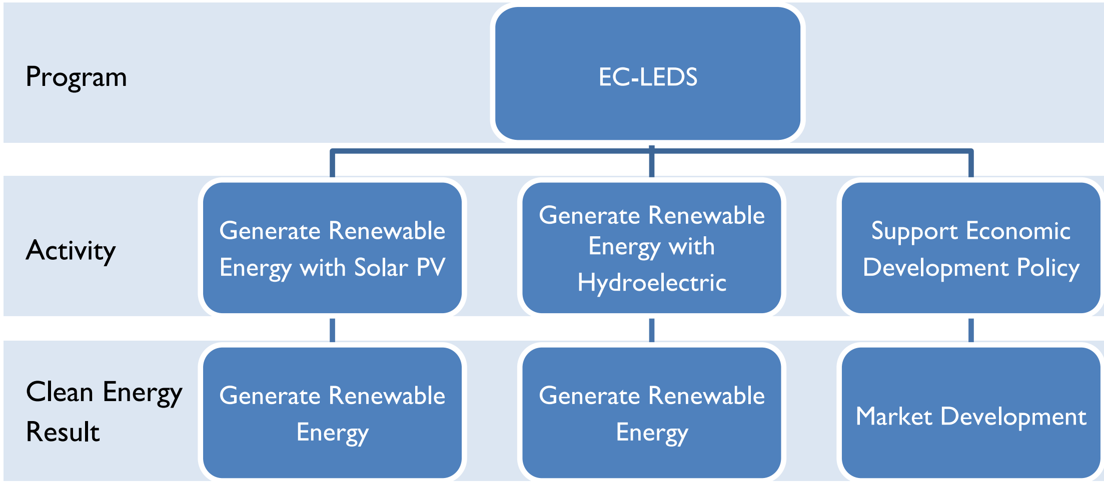
STAGE 2: IDENTIFY THE CLEAN ENERGY AND GHG RESULTS

The second stage identifies the intended **Clean Energy Results** and **GHG Result** for each activity.

A) IDENTIFY CLEAN ENERGY RESULTS

Based on the descriptions listed in *Table 2. Clean Energy Results*, each AMORE Program activity can be assigned a **Clean Energy Result**, as illustrated below in *Figure 16*.

Figure 16. AMORE Program Clean Energy Results



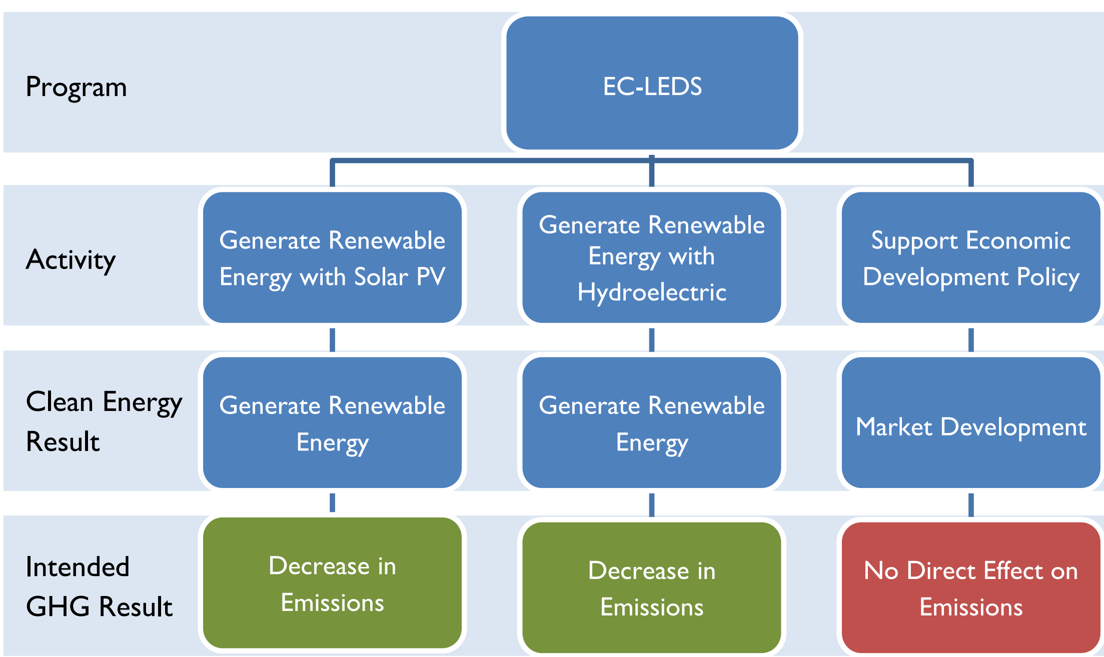
For more information on how to identify a Clean Energy Result, see *Section 2.2.2: Stage 2: Identify the Clean Energy and GHG Result.*

B) IDENTIFY GHG RESULTS

Once the Clean Energy Result has been identified, the **GHG Result** should be identified for each activity, which represents the intended change in GHG emissions from the Clean Energy Result. However, activities do not always reduce GHG emissions directly, but instead often promote technical, environmental, economic, or social change that ultimately affect GHG emissions.

Figure 17 illustrates the GHG Results from the AMORE Program. Only the first two activities have measureable impacts on GHG emissions.

Figure 17. Identifying GHG Results for the AMORE Program



C) DECIDE WHETHER TO ASSESS ACTIVITIES INDIVIDUALLY OR AS A PROGRAM

Since the AMORE Program includes three discrete activities, it is necessary to consider whether to assess these activities together or separately. As determined in the previous step, only the first two activities—the renewable energy generation from solar PV and hydroelectric—could result in GHG emission reductions. Since the AMORE Program collected activity-specific data for both renewable energy activities, it is possible to separate the emission impacts and assess the two activities separately.

STAGE 3: DEFINE THE BOUNDARY

The **GHG Estimation Boundary** defines the scope of the estimate in terms of the types of gases, activity, jurisdiction, and time period covered. This information should be clear and precise as it is essential to the GHG estimate.

A) DEFINE THE GHG ESTIMATION BOUNDARY

Table 5 outlines the gases covered, jurisdiction, and time period for the AMORE Program.

Table 5. GHG Estimation Boundary for the AMORE Program

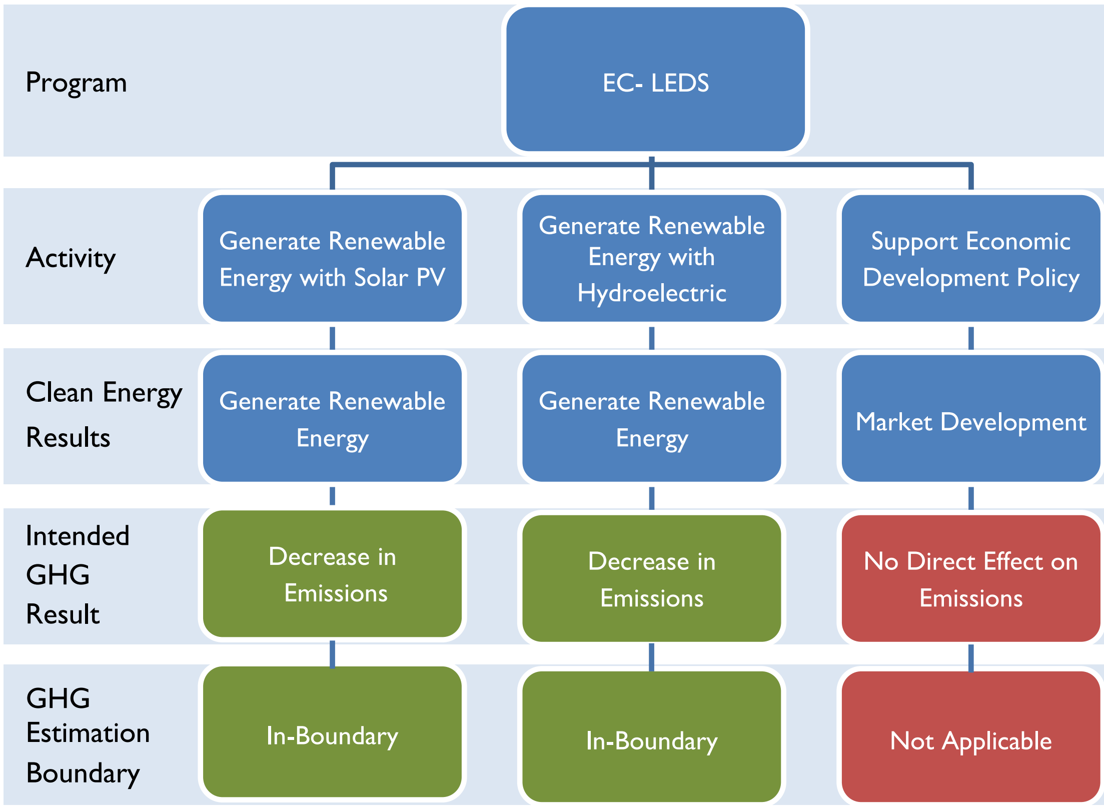
Data Collection Needs	Activity-Specific Data
Covered Gases	CO_2, CH_4, N_2O
Activity Boundary	AMORE Solar Photovoltaic Energy Implementation
Jurisdiction Boundary	Philippines
Temporal Boundary	FY 2004

B) DETERMINE IF RESULTS FALL WITHIN THE GHG BOUNDARY

This step identifies any Clean Energy and intended GHG Results that fall within the boundaries established in the previous step (see *Section 2.2.3:Stage 3: Define the Boundary* for more information). If identified as outside the GHG boundary, then those activities should be excluded from the emission estimate reported under the GHG Indicator.

Figure 18 defines the GHG boundary for the AMORE Program. The solar PV and hydroelectric activities occurred during the reporting year, leading to measureable and in-boundary emission reductions. However, supporting economic policy development did not lead to direct results within the reporting year. Therefore, this activity within the AMORE Program does not fall within the GHG boundary. The OU in this example should estimate emission reductions from the solar PV and hydroelectric activities.

Figure 18. GHG Estimation Boundary for AMORE Program



STAGE 4: SELECT A METHODOLOGY

Next, the OU should determine the appropriate methodologies to estimate emission reductions from the solar PV and hydroelectric activities. This section outlines how the OU selects a methodology to estimate emissions reduced from the Clean Energy Results included within the GHG Estimation Boundary.

A) DEFINE THE ESTIMATION METHOD

Emission reductions are estimated after the implementation of the solar PV and hydroelectric systems. Therefore, the OU should identify a method involving simple equations and bottom-up data, which are measured or collected at the activity level. In the case of the solar PV system, the program manager has activity-level data, including the number of systems installed and total capacity of each system.

B) SELECT A METHODOLOGY

The Protocol provides two types of methodologies for estimating GHG emission reductions: the Clean Energy GHG Methodology and Technology-Specific Methodologies (see *Section 2.2.4: Stage 4: Select a Methodology*) Between the two types of methods available for estimating emission reductions, the OU would use the **Solar PV Technology-specific Methodology**, because the amount of electricity generated from the solar PV system is unknown. The amount of electricity generated can be estimated from the total capacity of the solar PV system for the entire program, as well as the number of systems installed. Energy generation can be derived from the total installed capacity, a geographically-specific capacity factor, and other specifics about the technology installed, such as tracking capabilities of the solar PV systems. Once the amount of electricity generated from the solar PV in 2004 is estimated, GHG emission reductions can be estimated.

STAGE 5: DEFINE THE BASELINE ENERGY SCENARIO

Defining the Baseline Energy Scenario requires an assumption of what most likely would have happened in the absence of the activity. Although the communities were not connected to the electric grid prior to the AMORE activities, the user assumes that the energy demand would have been provided by regional grid electricity if not for the renewable energy.

STAGE 6: GATHER DATA

The next step is to gather data. The steps in this stage will depend on the methodology chosen and available data. In the case of the AMORE Program, because directly-measured activity energy generation is not available, it is assumed the amount of energy generated by the renewable energy under the activity in the reporting year would have been met by the energy type under the Baseline Energy Scenario—i.e., grid electricity.

STAGE 7: CALCULATE GHG REDUCTIONS

Finally, the GHG emission reductions due to the activity are calculated using the gathered data and the selected methodology. For the AMORE Program, the amount of activity energy is used to determine Baseline Emissions, and it is assumed that the estimated emissions reduced from the Baseline Energy Scenario are due to the implementation of this activity.

This AMORE case study illustrates one possible application of the CLEER GHG Accounting Approach used to assist OUs in the estimation of emission reductions. The application of the CLEER GHG Accounting Approach may vary due to the variety of clean energy activities supported by USAID supports.

3 ESTIMATING GHG REDUCTIONS FROM CLEAN ENERGY RESULTS

Contents of this section:

As discussed in *Sections 1.3: USAID Clean Energy Activities* and *2: CLEER GHG Accounting Approach*, all USAID clean energy activities intended to accomplish at least one Clean Energy Result. *Section 3: Estimating GHG Reductions from Clean Energy Results* provides methodologies for OUs to estimate emissions reduced from clean energy activities, and includes discussions on data needs, emission factors, equations, and other considerations for each Clean Energy Result. This section includes the following:

Section 3.1: CLEER Methodology Overview and Assumptions – An overview of the CLEER methodology framework and cross-cutting assumptions.

Section 3.2: Clean Energy GHG Methodology - A generalized methodology that can be used when the amount of energy or fuel generated or consumed are known.

Sections 3.3: Clean Energy Result: Generate Renewable Energy through *3.8: Clean Energy Result: Improve Information*. More specific methodologies for estimating emission reductions by Clean Energy Result and technology.

Increasing Access to Energy

USAID funds a number of activities that provide GHG-free or low GHG-emitting energy sources to communities that did not previously have access to energy. By providing new energy capacity through renewable energy sources, USAID contributes to the sustainable development of low-emission energy in partner countries.

Two types of methodologies are provided in this section:

1) **The Clean Energy GHG Methodology** can be used when the amount of energy generated, consumed, or conserved under the activity and the Baseline Energy Scenario are known, likely through existing measuring or estimation.
2) **The Technology-Specific Methodologies** can be used when the amount of energy generated, consumed, or conserved under the activity is unknown. These methodologies range in complexity and involve collecting activity and technology-specific information. Some of these variables can be populated using standard default values, which are provided in this Protocol. See *Section 2.2.4: Stage 4: Select a Methodology* for additional information on how to select an appropriate method based on available data.[14]

The CLEER GHG Accounting Approach and estimation methodologies presented in this document are adapted from existing accounting protocols and guidance documents widely in use to estimate GHG emissions from projects (see *Table 1: Notable Source Documents Referenced During Protocol Development*). The information from these protocols and guidance documents has been adapted to the circumstances, needs, and data availability of OUs and USAID activities.

For simplicity, the Protocol utilizes simple equations to estimate emission reductions, rather than a complex modeling of conditions. This allows for a consistent calculation of emission reductions across a broad portfolio of activities, but may result in increased uncertainty (see *Section 4.2: Uncertainty*).

[14] The Protocol also does not currently address GHG mitigation from low-emissions transportation—e.g., biofuel use, bus rapid transit, vehicle efficiency, and fuel standards. However, the Clean Energy GHG Methodology could be used if energy savings data are known.

3.1 CLEER Methodology Overview and Assumptions

This section summarizes the basic GHG accounting framework and data assumptions included in the Protocol methodologies.

3.1.1 GHG Accounting Basics

The Protocol applies a basic accounting framework for estimating emission reductions that includes three main components:

- **Activity data** are the project-specific input data needed to calculate emission estimates. These data can be directly measured or can be approximated through various methods. Examples of activity data include kilowatt-hours (kWh) of electricity generated or liters of fuel consumed.
- **Emission factors** are standard values that relate the quantity of GHGs emitted per unit of activity data—for example, kilograms of carbon dioxide (CO_2) per kWh of electricity generated. Activity data can be multiplied by the emission factor to generate an emission estimate.
- **Global Warming Potentials** (GWPs) are relative measures of the radiative forcing impact (or energy-trapping in the atmosphere) of each GHG as compared to CO_2 (WRI, 2014). Converting emissions to CO_2 equivalent (CO_2e) emissions using GWPs enables comparisons and aggregations of the impacts of reduced emissions of different gases in similar terms.

In general, GHG emission calculations take the following simplified form:

Equation 4

$$\text{Activity GHG Emissions} = \text{Activity Data} \times \text{GHG Emission Factor} \times \text{GHG Specific GWP}$$

Emissions reduced from the implementation of clean energy activities are estimated by:

Equation 5

$$\text{GHG Emissions Reduced} = \text{Baseline GHG Emissions} - \text{Activity GHG Emissions}$$

DEFAULT EMISSION FACTORS

Emission factors (e.g., GHG emissions per unit of energy) are needed to estimate GHG emissions reduced from clean energy activities. Where site-specific or activity-specific emission factors are not available, OUs can refer to outside sources for emission factors for certain variables by country, including:

- National grid electricity marginal emission factors, by country $\left(\frac{\mathrm{tCO_2e}}{\mathrm{kWh}}\right)$
- Fuel combustion emission factors, by fuel type $\left(\frac{\mathrm{tCO_2e}}{\mathrm{GJ}}\right)$
- Transmission and distribution line loss rates, by country (%)

Fuel combustion factors for coal, natural gas, oil, biomass fuels, and other fuel types (e.g., diesel) are available from the *IPCC Guidelines for National Greenhouse Gas Inventories* (IPCC, 2006).

Marginal CO_2 emission factors for grid electricity use by country have been compiled by the Institute for Global Environmental Strategies (IGES, 2015) using Clean Development Mechanism (CDM) data. These marginal grid factors include a combination of both operating margin and build margin, and can be found in *Appendix P: IGES Combined Marginal Emission Factors for Grid Electricity*. Where marginal emission factors are not available from IGES, grid average emission factors can be found in the International Energy Agency (IEA) *CO_2 Emissions from Fuel Combustion* statistics (IEA, 2015).[15] If available, it is preferable to use marginal grid emission factors rather than average grid factors for activities that displace grid electricity.

Electricity grid loss factors by country can be found in IEA's public web-based query tool (IEA, 2013). These values, however, contain both losses attributed to transmission and distribution (technical) and losses attributed to theft (non-technical). For the purpose of calculating GHG emission reductions from clean energy activities, OUs should consider only technical line loss.

In cases where a default emission factor is not available for a particular country, regional averages can be used.

GLOBAL WARMING POTENTIALS

Global Warming Potentials (GWPs) are relative measures of the radiative forcing impact (or energy-trapping ability) of each GHG as compared to CO_2 (WRI, 2014). GWP values enable comparisons and aggregations of the impacts of reduced emissions of different gases in similar terms—i.e., CO_2 equivalent (CO_2e). It is best practice, per UNFCCC reporting guidelines, to use the 100-year GWPs from the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (AR4) in order to maintain international consistency and comparability. *Table 6* lists the most common GHGs and their corresponding GWP values (IPCC, 2007b). For example, methane is 25 times more effective at trapping heat than CO_2.

Global Warming Potentials

GWPs allows for comparison of the relative energy-trapping impacts of different gases.

Table 6: Global Warming Potentials for Key GHGs (IPCC, 2007b)

Greenhouse Gas	Chemical Formula	100-year GWP (AR4)
Carbon Dioxide	CO_2	1
Methane	CH_4	25
Nitrous Oxide	N_2O	298
Perfluorocarbons (PFCs)	varies	7,390-22,800
Hydrofluorocarbons (HFCs)	varies	124-14,800
Sulfur Hexafluoride	SF_6	22,800
Nitrogen Trifluoride	NF_3	17,200

[15] Accessing the IEA data is a paid service, so these data are not provided within the Protocol.

3.1.2 Baseline Energy Scenarios

As described in *Section 2.2.5:Stage 5: Define the Baseline Energy Scenario,* a Baseline Energy Scenario[16] represents the set of events and conditions that most likely would have occurred in the absence of the activity, based on available information. OUs should identify the Baseline Energy Scenario for each clean energy activity. Options for the Baseline Energy Scenario vary according to the Clean Energy Result and include, but are not limited to:

- Electricity from the national grid would have been used
- Electricity from on-site diesel generators would have been used
- Energy from direct combustion of fuel would have been used

HELPFUL TIPS FOR ENERGY CONVERSIONS

Box 4: How to Obtain the Energy Content of Fuel

The equations presented in this section for on-site energy combustion require the amount of energy consumed from fuel in terms of gigajoules (GJ), which may require a conversion from the volume or mass of fuel consumed based on its energy content. Conversion values can vary. International default values for heat content by fuel type can be used if local or national values are not available.

The net energy content (GJ) will equal the amount of fuel consumed (in kilograms or liters, as examples) multiplied by a conversion factor of GJ/kilogram or GJ/liter.

Box 5: How to Obtain Electricity Generation from Capacity

Equations that involve grid electricity require the amount of electricity generated or consumed in terms of kilowatt-hours (kWh) or megawatt-hours (MWh).

Electricity generation from an activity will not always equal the installed capacity of an electricity generation technology, which is measured in kilowatts (kW) or megawatts (MW). This is because the generating equipment will not operate at full performance all the time. For example, the actual generation of a solar photovoltaic array will depend not only on the system's capacity, but also on the number of daylight hours, the solar insolation, and the weather conditions in that location.

In order to account for these factors, a location-specific parameter called the capacity factor is introduced to represent all natural and technical impacts on generation. The electricity generation (kWh) from a generation technology will therefore equal the installed capacity (kW) multiplied by a capacity factor.

[16] Shortened to "baseline" or "baseline scenario" within the methodologies.

3.1.3 Technology Lifetimes and Degradation Rates

The GHG Indicator captures emissions reduced during a single reporting year, but GCC and program officers may be interested in evaluating potential impacts of an activity on GHG emissions over the course of the activity lifetime. While the Protocol provides guidance for quantifying emissions reduced in a single reporting year, it may be used to estimate potential lifetime reductions.

When estimating emissions reduced over the lifetime of an activity, it may be necessary to account for the lifetime and degradation of installed equipment. Several factors can impact the useful lifetime or performance rate of a technology, including type of equipment, maintenance, operation, and weather. Equipment performance and efficiency will decrease over time, which can affect amount of energy generated by the system and associated emission reductions. For example, the efficiency of a solar PV array decreases over time due to weather damage and age. The annual degradation value represent the percent reduction in total potential output of a system in a single year due to natural deterioration.

Default values for technology lifetimes and degradation rates can be found in *Appendix O: Equipment Lifetimes and Degradation Rates.*

3.1.4 Universal Assumptions

This section summarizes universal assumptions regarding several key components of the CLEER GHG Accounting Approach.

BASELINE ENERGY SCENARIO

When measured Baseline data is unavailable, the Protocol methodologies assume that the amount of energy generated or consumed by the activity in the reporting year would have been met by the Baseline Energy Scenario energy type in the absence of the activity. For energy efficiency activities, the amount of energy generated or consumed under the Baseline Energy Scenario (if baseline data is not available) can be estimated by assessing the energy generated or consumed under the activity, plus energy saved through the implementation of the activity. This amount of activity energy is used to determine Baseline Emissions, and it is assumed that the estimated emission reduced from the Baseline Energy Scenario are due to the implementation of the clean energy activity.

DATA VARIABLES

The following are standard assumptions about variables used in the CLEER methodologies.

- Global Warming Potentials (GWPs) used in the CLEER methodologies are the 100-year GWPs from the IPCC *Fourth Assessment Report (AR4),* which is consistent with international GHG accounting standards.
- Marginal emission factors for grid electricity are preferable. If this factor is not available for a particular country, a regional marginal factor or a national average grid factor can be used.
- For grid-connected activities that involve a central utility generation system (e.g., a power plant), it is assumed that the baseline electricity generation source is no closer or farther on the

transmission and distribution system than the renewable energy system under the activity. Therefore, no technical line loss savings are assumed to occur.

- For electricity grid-connected activities that involve distributed or microgrid-connected electricity generation or efficiency systems, it is assumed that energy savings due to the implementation of the activity also result in avoided technical losses from the transmission and distribution of electricity from central utility generation systems. Therefore, technical line loss savings are assumed to occur.
- Data parameters are considered static over time for all methodologies within the Protocol. For example, the value of a grid electricity emission factor is assumed to remain constant over the reporting year.
- The Protocol provides default values for emission factors, system efficiencies, energy content of fuels, and other standard variables.
- Renewable forms of electricity generation are assumed to have an emission factor of zero. The Protocol does not provide guidance for to calculating lifecycle emissions from activities, due to estimation boundary constraints, increased methodological complexity, and increased uncertainty. As such, emission factors in the Protocol do not account for lifecycle GHG emissions, which is consistent with many GHG accounting protocols.
- The Protocol typically requires the use of "bottom-up" data, which are measured or collected at the activity level, as opposed to "top-down," which are macro-level statistics collected at the jurisdiction or sector level. There may be a mix of both where appropriate, as methodologies included in the Protocol offer country- or region-specific default data to support OUs in accomplishing the calculations.

BOUNDARIES

As described in *Section 2.2* of the GHG Accounting Approach, the following defined boundaries should be determined when using in the CLEER methodologies:

- **Activity Boundary.** The Protocol methods assess GHG emissions and emission reductions, and associated changes in energy type and consumption that occurred solely due to the implementation of the clean energy activity. Similarly, the Protocol only provides guidance for determining the baseline energy use and emissions that would have occurred with regard to the Activity Boundary, as opposed to the larger geographic area.[17] Lifecycle emissions such as those from the production of materials, construction, or waste created during or after the implementation of the activity, are not typically included in the Activity Boundary. If OUs determine that these sources of emissions or emission reductions are significant enough to include in the Activity Boundary, they should document all data and assumptions.
- **Temporal Boundary.** Consistent with the definition of the GHG Indicator, the Protocol methods provide guidance for calculating emissions and emission reductions for a single reporting period. The reporting period for an activity is constrained to the most recently completed fiscal year, from October 1 through September 30.

[17] In other words, the methodologies in this Protocol enable estimation of *emissions and emission reductions* from an activity, rather than a complete GHG inventory or footprint of all activities within an activity boundary.

- **Jurisdictional Boundary.** The Protocol methods are intended to estimate emissions and emission reductions that occur within the jurisdictional boundary, which may constitute a geopolitical boundary such as a city or nation, or a specific project area, over which the USAID OU and Implementing Partners have authority, at least as it pertains to the implementation of the activity. OUs should determine if out-of-jurisdiction effects are significant enough to include in the assessment, being sure to document all data and assumptions.
- **Covered Gases.** The Protocol methods focus on clean energy activities, which typically lead to reductions of three GHGs: CO_2, CH_4, and N_2O emissions. Therefore, this guidance covers GHGs impacts of these three gases.

3.2 Clean Energy GHG Methodology

This methodology is used to estimate emission reductions when the amount of energy or fuel generated or consumed are known both under the Baseline Energy Scenario and due to the implementation of the clean energy activity. This methodology is applicable to the following Clean Energy Results: Renewable Energy Generation; Fuel Switching; and Energy Efficiency (End-Use and System).

Photo: Asian Development Bank / CC BY-NC-ND 3.0

ACTIVITY DATA REQUIREMENTS

Emission reductions are estimated using the energy data from the Baseline Energy Scenario and implementation of the activity, in kilowatt-hours (kWh) or gigajoules (GJ), along with location- and fuel-specific emission factors. USAID Operating Units (OUs) will need to provide:

1) The country in which implementation of the activity occurs
2) The types of energy used in the Baseline Energy Scenario[18] and under the activity (grid electricity, on-site electricity generation, or other fuel type for on-site combustion)
3) The amount of energy (electricity or fuel) generated or consumed under the Baseline Energy Scenario and under the activity in the reporting year

Renewable energy generation and fuel switching activities assume the same amount of energy consumed under the baseline and the activity in the reporting year. The amount of energy consumed in the reporting year under an energy efficiency activity equal the amount of energy consumed under the Baseline Energy Scenario, plus the percent or absolute efficiency savings due to the activity.

Additional data elements are required for each equation included in this methodology, and default values are provided for OUs to utilize if the OU does not have site-specific data.

The remainder of this section describes five steps to calculate GHG emission reductions from clean energy activities, as follows:

- Step 1: Define the Activity
- Step 2: Define the Baseline Energy Scenario
- Step 3: Estimate Baseline GHG Emissions
- Step 4: Estimate Activity GHG Emissions
- Step 5: Estimate Emissions Reduced

[18] The baseline scenario is a description of what would have most likely occurred in the absence of the activity. See *Section 2* for a discussion about determining baseline scenarios.

METHODOLOGY

STEP 1: DEFINE THE ACTIVITY

In order to estimate GHG emissions reduced, OUs should first define activity and identify the Clean Energy Result of the activity. Options for the activity for each Clean Energy Result include:

a) ***Renewable Electricity Generation***

1) Use of electricity from the renewable energy sources

b) ***Fuel Switching***

1) Use of energy produced from on-site combustion of fuel

c) ***Energy Efficiency***

1) Use of electricity from national grid
2) Use of energy produced from on-site combustion of fuel

Depending on the result, baseline and activity emissions are estimated using various inputs detailed below.

STEP 2: DEFINE THE BASELINE ENERGY SCENARIO

In order to estimate GHG emissions reduced, OUs should estimate GHG emissions for the Baseline Energy Scenario. Options for the Baseline Energy Scenario vary according to the activity and Clean Energy Result, and include:

a) ***Renewable Electricity Generation in the Baseline***

1) Use of electricity from the national grid
2) Use of electricity produced from on-site diesel generators
3) Use of energy produced from on-site combustion of fuel

If the Baseline Energy Scenario involves no electricity consumption, OUs should determine whether the demand would have been met in the future by grid electricity or diesel generators and select option 1) or 2) as the Baseline Energy Scenario.[19] If the consumption of traditional fuel was replaced by renewable electricity, OUs should select option 3) as the Baseline Energy Scenario.

b) ***Fuel Switching in the Baseline***

1) Use of electricity from the national grid
2) Use of energy produced from on-site combustion of fuel

c) ***Energy Efficiency in the Baseline***

1) Use of electricity from the national grid without energy efficient technologies or conservation practices in place

[19] The Protocol assumes that activities that generate or consume energy are displacing energy that would have been provided by conventional sources.

2) Use of electricity produced from on-site diesel generators without energy efficient technologies or conservation practices in place
3) Use of energy produced from on-site combustion of fuel without energy efficient technologies or conservation practices in place

STEP 3: ESTIMATE BASELINE GHG EMISSIONS

Depending on the Baseline Energy Scenario chosen in Step 2, OUs should use the approach for *Grid-Connected Renewable Energy Activities, Grid-Connected Energy Efficiency Activities, On-Site Electricity Generation*, or *On-Site Combustion* equations below to estimate baseline GHG emissions.

Grid-Connected Renewable Energy Activities

Emissions from grid electricity consumed in the Baseline Energy Scenario can be estimated using Equation 6:

Equation 6

$$\text{Baseline Emissions} = \text{Electricity Generated} \times \left(\frac{1}{1 - \text{Line Loss Rate}}\right) \times \text{EF}_{\text{Grid}}$$

The line loss rate is applicable only for distributed or microgrid-connected activities (e.g., rooftop units). For central utility generation activities (e.g., power plant), the line loss rate is 0 percent.[20]

Table 7: Data Requirements for Equation 6

Data Element	Definition	Data Type	Data Source
Baseline Emissions	The amount, in metric tons of carbon dioxide equivalent, of GHG emissions in the Baseline Energy Scenario, associated with the baseline fuel type, that would have occurred in the reporting year (tCO_2e)	Calculated	Equation 6
Electricity Generated	The quantity of electricity generated by the system in the reporting year (kWh)	User-Provided	N/A
Line Loss Rate	Average annual technical grid line loss due to transmission and distribution, by country (%)	Default	Expert Judgement based on IEA, 2013
EF_{Grid}	The average combined marginal GHG emission factor for grid electricity, by country $\left(\frac{\text{tCO}_2\text{e}}{\text{kWh}}\right)$	Default	IGES, 2015 IEA, 2013

[20] For grid-connected activities, it is assumed that the baseline generation source is no closer or farther on the transmission and distribution system than the renewable energy system under the activity.

Note: Default values can be overridden by the user if site-specific information is available.

Grid-Connected Energy Efficiency Activities

Emissions from grid electricity consumed in the Baseline Energy Scenario can be estimated using Equation 7:

Equation 7

$$\text{Baseline Emissions} = \text{Baseline Electricity Consumed} \times \left(\frac{1}{1 - \text{Line Loss Rate}}\right) \times \text{EF}_{\text{Grid}}$$

If the baseline electricity consumption is not known, OUs can use Equation 8 to estimate the electricity consumed in the baseline scenario using the electricity consumed under the action in the reporting year.

Equation 8

$$\text{Baseline Electricity Consumed} = \frac{\text{Activity Electricity Consumed}}{(1 - \text{Activity Percent Savings})}$$

Table 8 describes these data elements, whether data are default or user-provided, and suggested data sources.

Table 8: Data Requirements for Equation 7 and Equation 8

Data Element	Definition	Data Type	Data Source
Baseline Emissions	The amount, in metric tons of carbon dioxide equivalent, of GHG emissions in the Baseline Energy Scenario, associated with the baseline fuel type, that would have occurred in the reporting year (tCO_2e)	Calculated	Equation 7
Baseline Electricity Consumed	The quantity of electricity that would have been consumed in the reporting year in the absence of the activity (kWh)	User-Provided or Calculated	N/A or Equation 8
Line Loss Rate	Average annual technical grid line loss due to transmission and distribution, by country (%)	Default	Expert Judgement based on IEA, 2013
EF_{Grid}	The average combined marginal GHG emission factor for grid electricity, by country $\left(\frac{tCO_2e}{kWh}\right)$	Default	IGES, 2015 IEA, 2013
Activity Electricity Consumed	The quantity of electricity consumed by the activity in the reporting year (kWh)	User-Provided	N/A
Activity Percentage Savings	Actual or expected percent energy savings achieved by the activity in the reporting year (%)	User-Provided	N/A

On-Site Electricity Generation

Emissions from on-site electricity generation from diesel generators in the Baseline Energy Scenario can be estimated using Equation 9:

Equation 9

$$\text{Baseline Emissions } = \text{Electricity Generated } \times \left(\frac{0.0036 \text{ GJ}}{1 \text{ kWh}}\right) \times \left(\frac{1}{\text{Generator Efficiency}}\right) \times \text{ EF}_{\text{Diesel}}$$

Table 9: Data Requirements for Equation 9

Data Element	Definition	Data Type	Data Source
Baseline Emissions	The amount, in metric tons of carbon dioxide equivalent, of GHG emissions in the Baseline Energy Scenario, associated with the baseline fuel type, that would have occurred in the reporting year (tCO_2e)	Calculated	Equation 9
Electricity Generated	The quantity of electricity generated by the system in the reporting year (kWh)	User-Provided	N/A
$\frac{0.0036 \text{ GJ}}{1 \text{ kWh}}$	Kilowatt-hours to gigajoule conversion factor $\left(\frac{\text{GJ}}{\text{kWh}}\right)$	Conversion Factor	NIST, 2006
Generator Efficiency	The efficiency of the on-site generator that consumes diesel to generate electricity. Default value is 35%.	Default	Expert Judgment
$\text{EF}_{\text{Diesel}}$	GHG emission factor for stationary combustion of diesel. Default value is 0.074354 $\frac{tCO_2e}{GJ}$.	Default	IPCC, 2006

Note: Default values can be overridden by the user if site-specific information is available.

On-Site Combustion

Emissions from on-site combustion of fuel in the Baseline Energy Scenario can be estimated using Equation 10:

Equation 10

$$\text{Baseline Emissions } = \text{Fuel Consumed } \times \text{Fuel Energy Content} \times \text{EF}_{\text{Fuel Specific}} \times \left(\frac{1 \text{ t}}{1{,}000{,}000 \text{ g}}\right)$$

Table 10: Data Requirements for Equation 10

Data Element	Definition	Data Type	Data Source
Baseline Emissions	The amount, in metric tons of carbon dioxide equivalent, of GHG emissions in the Baseline Energy Scenario, associated with the baseline fuel type, that would have occurred in the reporting year (tCO_2e)	Calculated	Equation 10

Data Element	Definition	Data Type	Data Source
Fuel Consumed	The quantity of baseline fuel that would have been consumed in the reporting year. Applicable units by fuel type and unit conversions found in Appendix L: Fuel Consumption Units.	User-Provided	N/A
Fuel Energy Content	The energy content of the selected fuel, in GJ per selected units $\left(\frac{\mathrm{GJ}}{\mathrm{units}}\right)$. Default values and applicable units found in Appendix L: Fuel Consumption Units.	Default	Various, see Appendix L: Fuel Consumption Units
$\mathrm{EF}_{\mathrm{Fuel\ Specific}}$	GHG emission factor for stationary combustion of specific fuel type $\left(\frac{\mathrm{gCO_2e}}{\mathrm{GJ}}\right)$. Default values found in Appendix D: Fuel Emission Factors.	Default	IPCC, 2006
$\frac{1\ \mathrm{t}}{1{,}000{,}000\ \mathrm{g}}$	Gram to ton conversion factor $\left(\frac{\mathrm{t}}{\mathrm{g}}\right)$	Conversion Factor	NIST, 2006

Note: Default values can be overridden by the user if site-specific information is available.

STEP 4: ESTIMATE ACTIVITY GHG EMISSIONS

Depending on the activity, OUs should use the approach for *Grid-Connected Activities* and *On-Site Combustion* equations below to estimate activity GHG emissions.

Grid-Connected Renewable Energy Activities

Renewable electricity activities are assumed to emit zero GHGs per kilowatt-hour (kWh) generated; thus, activity emissions for renewable energy are equal to zero.

Grid-Connected Energy Efficiency Activities

For energy efficiency activities, emissions from grid electricity consumed in the reporting year can be estimated using Equation 11:

Equation 11

$$\text{Activity Emissions} = \text{Activity Electricity Consumed} \times \left(\frac{1}{1 - \text{Line Loss Rate}}\right) \times \mathrm{EF}_{\mathrm{Grid}}$$

The line loss rate is applicable only for distributed or microgrid-connected activities (e.g., rooftop units). For central utility generation activities (e.g., power plant), the line loss rate is 0 percent.[21]

Table 11: Data Requirements for Equation 11

Data Element	Definition	Data Type	Data Source
Activity Emissions	The amount, in metric tons of carbon dioxide equivalent, of GHG emissions that	Calculated	Equation 11

[21] For grid-connected activities, it is assumed that the baseline generation source is no closer or farther on the transmission and distribution system than the renewable energy system under the activity.

Data Element	Definition	Data Type	Data Source
	occurred due to the activity in the reporting year (tCO_2e)		
Activity Electricity Consumed	The quantity of electricity consumed in the reporting year (kWh)	User-Provided	N/A
Line Loss Rate	Average annual technical grid line loss due to transmission and distribution, by country (%)	Default	Expert Judgement based on IEA, 2013
EF_{Grid}	The average combined marginal GHG emission factor for grid electricity, by country $\left(\frac{tCO_2e}{kWh}\right)$	Default	IGES, 2015 IEA, 2013

Note: Default values can be overridden by the user if site-specific information is available.

On-Site Combustion

Emissions from on-site combustion in the reporting year can be estimated using Equation 12:

Equation 12

$$\text{Activity Emissions} = \text{Fuel Consumed} \times \text{Fuel Energy Content} \times EF_{\text{Fuel Specific}} \times \left(\frac{1\ \text{t}}{1{,}000{,}000\ \text{g}}\right)$$

Table 12: Data Requirements for Equation 12

Data Element	Definition	Data Type	Data Source
Activity Emissions	The amount, in metric tons of carbon dioxide equivalent, of GHG emissions that occurred due to the activity in the reporting year (tCO_2e)	Calculated	Equation 12
Fuel Consumed	The quantity of fuel consumed in the reporting year. Applicable units by fuel type and unit conversions found in Appendix L: Fuel Consumption Units.	User-Provided	N/A
Fuel Energy Content	The energy content of the selected fuel, in GJ per selected units $\left(\frac{GJ}{units}\right)$. Default values and applicable units found in Appendix L: Fuel Consumption Units.	Default	Various, see Appendix L: Fuel Consumption Units
$EF_{\text{Fuel Specific}}$	GHG emission factor for stationary combustion of specific fuel type $\left(\frac{gCO_2e}{GJ}\right)$. Default values found in Appendix D: Fuel Emission Factors.	Default	IPCC, 2006
$\frac{1\ \text{t}}{1{,}000{,}000\ \text{g}}$	Gram to ton conversion factor $\left(\frac{t}{g}\right)$	Conversion Factor	NIST, 2006

Note: Default values can be overridden by the user if site-specific information is available.

STEP 5. ESTIMATE EMISSIONS REDUCED

GHG emissions reduced are equal to the difference in GHG emissions from the conventional energy source (baseline emissions) and GHG emissions resulting from the activity (activity emissions) in the reporting year:

Equation 13

$$\text{Emissions Reduced} = \text{Baseline Emissions} - \text{Activity Emissions}$$

Table 13: Data Requirements for Equation 13

Data Element	Definition	Data Type	Data Source
Emissions Reduced	The amount, in metric tons of carbon dioxide equivalent, of GHG emissions reduced in the reporting year (tCO_2e)	Calculated	Equation 13
Baseline Emissions	The amount, in metric tons of carbon dioxide equivalent, of GHG emissions in the Baseline Energy Scenario, associated with the baseline fuel type, that would have occurred in the reporting year (tCO_2e)	Calculated	Equation 6, or Equation 7, or Equation 9, or Equation 10
Activity Emissions	The amount, in metric tons of carbon dioxide equivalent, of GHG emissions that occurred due to the activity in the reporting year (tCO_2e)	Calculated	Equation 11, or Equation 12

3.3 Clean Energy Result: Generate Renewable Energy

"Generate Renewable Energy" includes the implementation or installation of renewable energy technologies that produce energy from clean, renewable sources. Renewable technologies offset the generation of energy from traditional fossil sources, which results in a net decrease in GHG emissions. This includes enabling activities that lead to the installation of renewable energy or the actual installation itself. *Box 6* lists some of the USAID activities that achieve this Clean Energy Result.

Box 6: GCC Activities that Generate Renewable Energy

Key Characteristics:

- Increased or new capacity to generate energy from renewable sources
- Displacement of conventional fuel types with renewable energy sources

Example Activities:

- Installation of renewable energy technologies, including solar photovoltaic systems, solar thermal power, wind energy, and geothermal systems
- Development or retrofits to hydroelectric systems
- Conversion of biomass, municipal solid waste, or anaerobic digestion to power, liquid fuels, gas, or bio-products

This section includes methodologies for activities relating to the implementation or installation of renewable energy technologies that produce energy from clean, renewable sources. The methodologies included in this section are:

- Solar Photovoltaic Systems
- Solar Thermal Systems
- Wind Turbine Systems
- Hydroelectric Systems
- Geothermal Systems – Power generation
- Geothermal Systems – Direct Heat
- Geothermal Systems – Heat Pumps
- Biomass Energy – Select Fuels
- Anaerobic Digesters for Manure Management

3.3.1 Solar Photovoltaic Systems

CLEAN ENERGY RESULT:
GENERATE RENEWABLE ENERGY

Photo: Asian Development Bank / CC BY-NC-ND 3.0

This section applies to the following activities:

- The installation of photovoltaic (PV) systems to generate electricity for on-site consumption,
- The installation of PV arrays to generate electricity to supply to the grid, or
- Enabling activities that directly lead to increased implementation of or access to solar PV generation in the reporting year.

Solar PV systems convert sunlight into electricity for use on-site or dispatch to the electricity grid. Converting sunlight into electricity through PV technology is a greenhouse gas (GHG) emission-free process resulting in a reduction of GHG emissions compared to consuming grid electricity or on-site combustion of fossil fuels under the Baseline Energy Scenario. Solar PV systems reduce GHG emissions by decreasing consumption of grid electricity or on-site combustion.

The remainder of this section describes five steps to calculate GHG emission reductions from activities involving Solar PV technology, as follows:

- Step 1: Define the Baseline Energy Scenario
- Step 2: Estimate electricity generated from the activity
- Step 3: Estimate baseline GHG emissions
- Step 4: Estimate activity GHG emissions
- Step 5: Estimate emissions reduced

STEP 1. DEFINE THE BASELINE ENERGY SCENARIO

In order to estimate GHG emissions reduced by an installed solar PV system, OUs should define the Baseline Energy Scenario, or what would have occurred in the absence of the activity (e.g., the energy source used prior to the installation of the solar PV system). Options for the Baseline Energy Scenario are:

4) Use of electricity from the national grid,
5) Use of electricity produced from on-site diesel generators, or
6) Use of energy produced from on-site combustion of fuel.

If the Baseline Energy Scenario involves no electricity consumption, OUs should determine whether the demand would have been met in the future by grid electricity or diesel generators and select option 1) or 2) as the Baseline Energy Scenario.[22] If the consumption of traditional fuel was replaced by renewable electricity, OUs should select option 3) as the Baseline Energy Scenario.

If the activity is replacing fuels for cooking, heating or lighting—i.e., not power generation—then OUs should collect the amount of fuel used along with the type of fuel and proceed to Step 3, On-Site Combustion.

STEP 2. ESTIMATE ELECTRICITY GENERATED FROM THE ACTIVITY

If the electricity generated in kilowatt-hours (kWh) by the solar PV system is known, then users should proceed directly to Step 3. If electricity generation from the solar PV system is not known, OUs can estimate annual electricity generated using the approach as defined below.

Annual electricity generation can be calculated as a function of the direct current (DC) rating of the PV array, the efficiency of the system, the average-day insolation, and a premium assigned to systems that track the sun angle. To estimate solar PV system electricity generation, OUs will need to know:

1) The country in which implementation occurs, and
2) The DC rating of the photovoltaic array.

Equation 14

$$\begin{aligned}&\text{Electricity Generated}\\&\quad = \text{Generation Capacity} \times \text{Capacity Factor} \times \text{Tracker Premium}\\&\quad \times \text{Operating Days} \times \frac{24 \text{ hours}}{1 \text{ day}}\end{aligned}$$

Table 14 describes the data elements, whether they are default or user-provided, and suggested data sources.

Table 14: Data Requirements for Equation 14

Data Element	Definition	Data Type	Data Source
Electricity Generated	The quantity of electricity generated in the reporting year (kWh)	Calculated	Equation 14
Generation Capacity	The rated generation capacity of the solar photovoltaic system installed and/or operational within the reporting year (kW)	User-Provided	N/A
Capacity Factor	Calculated as the product of the efficiency of the system and average-day insolation incident on a tilted surface at specific coordinates (%). Default values	Default	NASA, 2012

[22] The baseline scenario is a description of what would have most likely occurred in the absence of the activity. See *Section 2* for a discussion about determining baseline scenarios.

Data Element	Definition	Data Type	Data Source
	found in Appendix I: Capacity Factors and Solar Insolation by Country.		
Tracker Premium	Improved performance factor resulting from systems that track the sun angle. The default value is 1.27 (Unitless).	Default	Expert Judgment[23]
Operating Days	The number of days that the system is operational in the reporting year. The default value is 365 days.	Default	N/A
$\frac{24 \text{ hours}}{1 \text{ day}}$	Days to hours conversion factor $\left(\frac{\text{hours}}{\text{day}}\right)$	Conversion Factor	N/A

Note: Default values can be overridden by the user if site-specific information is available.

STEP 3. ESTIMATE BASELINE GHG EMISSIONS

Depending on the baseline option chosen in Step 1, users should use either the *Grid-Connected Activities* approach or the *On-Site Combustion* approach equations below to estimate baseline GHG emissions.

Grid-Connected Activities

Emissions from grid-connected activities can be estimated using the electricity generated (kWh) from the solar PV system during the reporting year, along with location-specific emission factors. OUs will need to know:

1) The quantity of electricity generated from the solar PV system in the reporting year, and
2) The country in which implementation occurs.

Emissions from grid electricity consumed in the baseline can be estimated using Equation 15:

Equation 15

$$\text{Baseline Emissions} = \text{Electricity Generated} \times \left(\frac{1}{1 - \text{Line Loss Rate}}\right) \times \text{EF}_{\text{Grid}}$$

The line loss rate is applicable only for distributed or microgrid-connected activities (e.g., rooftop units). For central utility generation activities (e.g., power plant), the line loss rate is 0 percent.[24] *Table 15* describes the data elements of Equation 15, whether they are default or user-provided, and suggested data sources.

Table 15: Data Requirements for Equation 15

Data Element	Definition	Data Type	Data Source
Baseline Emissions	The amount, in metric tons of carbon dioxide equivalent, of GHG emissions in the Baseline Energy Scenario, associated	Calculated	Equation 15

[23] For the purposes of the Protocol, some default values were determined based on expert judgment.
[24] For grid-connected activities, it is assumed that the baseline generation source is no closer or farther on the transmission and distribution system than the renewable energy system under the activity.

Data Element	Definition	Data Type	Data Source
	with the baseline fuel type, that would have occurred in the reporting year (tCO_2e)		
Electricity Generated	The quantity of electricity generated in the reporting year (kWh)	Calculated	Equation 14
Line Loss Rate	Average annual technical grid line loss due to transmission and distribution, by country (%)	Default	Expert Judgement based on IEA, 2013
EF_{Grid}	The average combined marginal GHG emission factor for grid electricity, by country $\left(\frac{tCO_2e}{kWh}\right)$	Default	IGES, 2015 IEA, 2013

Note: Default values can be overridden by the user if site-specific information is available.

On-Site Electricity Generation

Emissions from on-site electricity generation from diesel generators can be estimated using the electricity generated (kWh) from the solar PV system during the reporting year, along with fuel-specific emission factors. OUs will need to know:

1) The quantity of electricity generated from the solar PV system in the reporting year.

Emissions from on-site electricity generation in the Baseline Energy Scenario can be estimated using *Equation 16*:

Equation 16

$$\text{Baseline Emissions} = \text{Electricity Generated} \times \left(\frac{0.0036\ \text{GJ}}{1\ \text{kWh}}\right) \times \left(\frac{1}{\text{Generator Efficiency}}\right) \times EF_{\text{Diesel}}$$

Table 16 describes the data elements of *Equation 16*, whether they are default or user-provided, and suggested data sources.

Table 16: Data Requirements for Equation 16

Data Element	Definition	Data Type	Data Source
Baseline Emissions	The amount, in metric tons of carbon dioxide equivalent, of GHG emissions in the Baseline Energy Scenario, associated with the baseline fuel type, that would have occurred in the reporting year (tCO_2e)	Calculated	Equation 16
Electricity Generated	The quantity of electricity generated in the reporting year (kWh)	Calculated	Equation 12
$\frac{0.0036\ \text{GJ}}{1\ \text{kWh}}$	Kilowatt-hours to gigajoule conversion factor $\left(\frac{GJ}{kWh}\right)$	Conversion Factor	NIST, 2006

Data Element	Definition	Data Type	Data Source
Generator Efficiency	The efficiency of the on-site generator that consumes diesel to generate electricity. Default value is 35%.	Default	Expert Judgment[25]
EF_{Diesel}	GHG emission factor for stationary combustion of diesel. Default value is $0.074354 \frac{tCO_2e}{GJ}$.	Default	IPCC, 2006

Note: Default values can be overridden by the user if site-specific information is available.

On-Site Combustion

If the activity is replacing fuels for cooking, heating or lighting—i.e., not power generation—then emissions from on-site combustion can be estimated using the amount and type of fuel consumed in the Baseline Energy Scenario. OUs will need to know:

1) The amount of fuel consumed in the Baseline Energy Scenario during the reporting year, and
2) The type of fuel that was replaced by the activity.

Emissions from on-site combustion in the Baseline Energy Scenario can be estimated using *Equation 17*:

Equation 17

$$\text{Baseline Emissions} = \text{Fuel Consumed } \times \text{Fuel Energy Content} \times EF_{\text{Fuel Specific}} \times \left(\frac{1\text{ t}}{1{,}000{,}000\text{ g}}\right)$$

Table 17 describes the data elements of *Equation 17*, whether they are default or user-provided, and suggested data sources.

Table 17: Data Requirements for Equation 17

Data Element	Definition	Data Type	Data Source
Baseline Emissions	The amount, in metric tons of carbon dioxide equivalent, of GHG emissions in the Baseline Energy Scenario, associated with the baseline fuel type, that would have occurred in the reporting year (tCO_2e)	Calculated	Equation 17
Fuel Consumed	The quantity of fuel consumed in the reporting year. Applicable units by fuel type and unit conversions found in Appendix L: Fuel Consumption Units.	User-Provided	N/A
Fuel Energy Content	The energy content of the selected fuel, in GJ per selected units $\left(\frac{GJ}{units}\right)$. Default values and applicable units found in Appendix L: Fuel Consumption Units.	Default	Various, see Appendix L: Fuel Consumption Units

[25] For the purposes of the Protocol, some default values were determined based on expert judgment.

$EF_{Fuel\ Specific}$	GHG emission factor for stationary combustion of specific fuel type $\left(\frac{gCO_2e}{GJ}\right)$. Default values found in Appendix D: Fuel Emission Factors.	Default	IPCC, 2006
$\frac{1\ t}{1{,}000{,}000\ g}$	Gram to ton conversion factor $\left(\frac{t}{g}\right)$	Conversion Factor	NIST, 2006

Note: Default values can be overridden by the user if site-specific information is available.

STEP 4. ESTIMATE ACTIVITY GHG EMISSIONS

Solar PV systems are assumed to emit zero GHGs per kWh generated; thus, activity emissions are equal to zero.

Equation 18

$$\text{Activity Emissions} = \text{Electricity Generated} \times EF_{Solar\ PV}$$

Table 18 describes the data elements of *Equation 18*, whether they are default or user-provided, and suggested data sources.

Table 18: Data Requirements for Equation 18

Data Element	Definition	Data Type	Data Source
Activity Emissions	The amount, in metric tons of carbon dioxide equivalent, of GHG emissions that occurred due to the activity in the reporting year (tCO_2e)	Calculated	Equation 18
Electricity Generated	The quantity of electricity generated in the reporting year (kWh)	Calculated	Equation 14
$EF_{Solar\ PV}$	GHG emission factor for the solar photovoltaic system. The default value is $0\ \frac{tCO_2e}{kWh}$.	Default	Protocol Assumption

Note: Default values can be overridden by the user if site-specific information is available.

STEP 5. ESTIMATE EMISSIONS REDUCED

GHG emissions reduced from the solar PV activity are equal to the difference in GHG emissions from the conventional energy source (baseline emissions) and GHG emissions resulting from the activity (activity emissions) in the reporting year:

Equation 19

$$\text{Emissions Reduced} = \text{Baseline Emissions} - \text{Activity Emissions}$$

Table 19 describes the data elements of *Equation 19*, whether they are default or user-provided, and suggested data sources.

Table 19: Data Requirements for Equation 19

Data Element	Definition	Data Type	Data Source
Emissions Reduced	The amount, in metric tons of carbon dioxide equivalent, of GHG emissions reduced in the reporting year (tCO_2e)	Calculated	Equation 19
Baseline Emissions	The amount, in metric tons of carbon dioxide equivalent, of GHG emissions in the Baseline Energy Scenario, associated with the baseline fuel type, that would have occurred in the reporting year (tCO_2e)	Calculated	Equation 15, or Equation 16, or Equation 17
Activity Emissions	The amount, in metric tons of carbon dioxide equivalent, of GHG emissions that occurred due to the activity in the reporting year (tCO_2e)	Calculated	Equation 18

Based on the assumptions described above, emission reductions from the Baseline Energy Scenario will equal the emissions from the clean energy activity, as the baseline emissions are equal to zero.

3.3.2 Solar Thermal Systems

CLEAN ENERGY RESULT:
GENERATE RENEWABLE ENERGY

Photo by Jiri Rezac, The Climate Group / CC BY-NC-SA 2.0

This section covers activities that include the installation of solar thermal systems to generate space heating or hot water for on-site consumption, or enabling activities that directly lead to increased implementation of or access to solar thermal applications in the reporting year. Specifically, this section includes calculations for the following types of solar thermal systems:[26]

- Unglazed flat plate collector systems,
- Glazed domestic hot water systems (DHW) in one- and multi-family houses or businesses,
- Evacuated tube collectors, and
- Combined domestic hot water and space heating systems in one- and multi-family houses

In a solar thermal system, sunlight strikes and heats a solar thermal collector, which transfers the sun's heat energy to a heat-conveying medium, such as water or glycol. Building space heating or water heating systems can use this heated fluid to reduce energy required from sources such as grid electricity or conventional fuel types. Solar thermal energy systems are designed to produce different fluid temperatures—low, medium, or high—which dictate system application: space or water heating, solar cooling, or process heating. The calculations herein apply to only water and space heating applications, and exclude the following applications: district heating, cooling / AC, solar thermal electricity, or process heat for industrial applications.

Converting sunlight into energy through solar thermal technology is a GHG emission-free process resulting in a reduction of GHG emissions compared to the baseline, whether the baseline is grid electricity or on-site combustion.[27] The use of solar thermal systems reduces GHG emissions by displacing the consumption of grid electricity or on-site combustion, which emit GHGs. The remainder

[26]Unglazed flat plate collectors are usually made of a black polymer, without a frame, with a glass cover and insulation on the backside. These collectors are low cost but have high thermal losses.

Glazed flat plate collectors are flat plate absorbers fixed in a frame, with a single and double layer of glass on the top and an insulation panel at the backside. These are the most popular type of solar thermal collectors and are used in hot water, space heating and process heating applications.

Evacuated Tube Collectors are collectors with the absorbers enclosed in a sealed vacuum tube. These are relatively expensive but have a high efficiency. These collectors are used in high temperature applications such as hot water, space heating, and process heating applications. Source: UNFCCC (2006)

[27] The baseline scenario is a description of what would have most likely occurred in the absence of the activity.

of this section describes five steps to calculate GHG emissions reduced from activities utilizing solar thermal technology, which are:

- Step 1: Estimate energy generated from the activity
- Step 2: Estimate activity GHG emissions
- Step 3: Define the Baseline Energy Scenario
- Step 4: Estimate baseline GHG emissions
- Step 5: Estimate emissions reduced

STEP 1. ESTIMATE ENERGY GENERATED FROM THE ACTIVITY

The energy generated from a solar collector (annual solar collector output), measured in gigajoules (GJ) can be calculated as a function of the area of the solar collector.[28] To estimate energy generation, OUs will need to know:

1) The country in which implementation occurs,
2) The type of solar thermal system (unglazed flat plate collector systems, glazed domestic hot water systems (DHW), evacuated tube collectors, or combined domestic hot water and space heating systems),
3) The size of the collector aperture, or the area of the system collecting solar energy, and
4) The number of days per year the system is operational.

Use *Equation 20* below to estimate the annual energy generated from the activity.

Equation 20

$$\text{Energy Generated} = \text{Efficiency Coefficent} \times \text{Solar Irradiation} \times \text{Aperture Area} \times \text{Operating Days} \times \left(\frac{0.0036\ \text{GJ}}{1\ \text{kWh}}\right)$$

Table 20 below describes the data elements, type of data, and sources for the variables in *Equation 20*.

Table 20: Data Requirements for Equation 20

Data Element	Definition	Data Type	Data Source
Energy Generated	The quantity of energy generated in the reporting year (GJ)	Calculated	Equation 20
Efficiency Coefficient	Coefficient of conversion, based on the solar thermal system type (Unitless). Default values found in Table 21.	Default	Table 21

[28] A relationship exists between the solar collector area and the installed solar thermal capacity in terms of kW_{th} (IEA 2011). The relationship is 0.7 kW_{th}/m^2 and OUs can use this to convert nominal power to area if desired. The relationship between GJ and kWh_{th} is 0.0036 GJ/kWh_{th}.

Data Element	Definition	Data Type	Data Source
Solar Irradiation	Annual global solar irradiation on a horizontal surface at the given location, by country $\left(\frac{\text{kWh}}{\text{m}^2\cdot\text{day}}\right)$. Default values found in Appendix I: Capacity Factors and Solar Insolation by Country.	Default	NASA, 2012
Aperture Area	Area of the collector aperture (m^2)	User-Provided	N/A
Operating Days	The number of days that the system is operational in the reporting year. The default value is 365 days.	User-Provided	N/A
$\frac{0.0036\ \text{GJ}}{1\ \text{kWh}}$	Kilowatt-hours to gigajoule conversion factor $\left(\frac{\text{GJ}}{\text{kWh}}\right)$	Conversion Factor	NIST, 2006

Note: Default values can be overridden by the user if site-specific information is available.

Table 21: Efficiencies of Types of Solar Thermal Systems

System	Coefficient of conversion (IEA, 2011)
Un-glazed collector	0.29
Glazed collectors DHW systems	0.44
Evacuated tube collectors[29]	0.47
Glazed collector combi-systems	0.33

STEP 2. ESTIMATE ACTIVITY GHG EMISSIONS

Solar thermal systems are assumed to emit zero GHGs per GJ energy generated; thus, activity emissions are equal to zero.

Equation 21

$$\text{Activity Emissions} = \text{Energy Generated} \times \text{EF}_{\text{Solar Thermal}}$$

Table 22 describes the data elements, whether they are default or user-provided, and suggested data sources.

Table 22: Data Requirements for Equation 21

Data Element	Definition	Data Type	Data Source
Activity Emissions	The amount, in metric tons of carbon dioxide equivalent, of GHG emissions that occurred due to the activity in the reporting year (tCO_2e)	Calculated	Equation 21

[29] Utilizing existing conversion factors (671 W_{th}/m^2 of aperture area for glazed flat plate collectors, and 717 W_{th}/m^2 of aperture area for evacuated tubular plate collectors) evacuated tubes are 6% more efficient than glazed collectors per m^2 of aperture area of the collector (UNFCCC 2006).

Data Element	Definition	Data Type	Data Source
Energy Generated	The quantity of energy generated in the reporting year (GJ)	Calculated	Equation 20
$\mathrm{EF}_{\mathrm{Solar\ Thermal}}$	GHG emission factor for the solar thermal system. The default value is 0 $\frac{\mathrm{tCO_2e}}{\mathrm{GJ}}$.	Default	Protocol Assumption

Note: Default values can be overridden by the user if site-specific information is available.

STEP 3. DEFINE THE BASELINE ENERGY SCENARIO

To estimate GHG emissions reduced by the solar thermal system, OUs should define the Baseline Energy Scenario, or what would have occurred in the absence of the activity (e.g., the energy source used prior to the installation of the solar thermal system). Options for the Baseline Energy Scenario are:

a) Use of electricity from the regional grid.
b) Use of energy produced from on-site combustion of fuel.

If the Baseline Energy Scenario involves no electricity consumption, OUs should determine whether the demand would have been met in the future by grid electricity or on-site combustion of fuel and select option a) or b) as the Baseline Energy Scenario.[30]

STEP 4. ESTIMATE BASELINE GHG EMISSIONS

Depending on the baseline option chosen in Step 3, users should use either the *Grid-Connected Activities* approach or the *On-Site Combustion* approach equations below to estimate baseline GHG emissions.

Grid-Connected Activities

Emissions from grid-connected activities can be estimated using the energy generated (GJ) from the solar thermal system during the reporting year, along with location-specific emission factors. USAID OUs will need to know:

1) The quantity of energy generated from the solar collector in the reporting year (annual solar collector output), and
2) The country in which implementation occurs.

Emissions from grid electricity consumed under the Baseline Energy Scenario can be estimated using *Equation 22*:

[30] The Protocol assumes that activities that generate or consume energy are displacing energy that would have been provided by conventional sources.

Equation 22

$$\text{Baseline Emissions} = \text{Energy Generated} \times \left(\frac{1}{1-\text{Line Loss Rate}}\right) \times \frac{1\ \text{kWh}}{0.0036\ \text{GJ}} \times \text{EF}_{\text{Grid}}$$

The line loss rate is applicable only for distributed or microgrid-connected activities (e.g., rooftop units). For central utility generation activities (e.g., power plant), the line loss rate is 0 percent.[31] *Table 23* describes the data elements of *Equation 22*, whether they are default or user-provided, and suggested data sources.

Table 23: Data Requirements for Equation 22

Data Element	Definition	Data Type	Data Source
Baseline Emissions	The amount, in metric tons of carbon dioxide equivalent, of GHG emissions in the Baseline Energy Scenario, associated with the baseline fuel type, that would have occurred in the reporting year (tCO_2e)	Calculated	Equation 22
Energy Generated	The quantity of energy generated in the reporting year (GJ)	Calculated	Equation 20
Line Loss Rate	Average annual technical grid line loss due to transmission and distribution, by country (%)	Default	Expert Judgement based on IEA, 2013
$\frac{1\ \text{kWh}}{0.0036\ \text{GJ}}$	Gigajoule to kilowatt-hours conversion factor $\left(\frac{\text{kWh}}{\text{GJ}}\right)$	Conversion Factor	NIST, 2006
EF_{Grid}	The average combined marginal GHG emission factor for grid electricity, by country $\left(\frac{tCO_2e}{\text{kWh}}\right)$	Default	IGES, 2015 IEA, 2013

Note: Default values can be overridden by the user if site-specific information is available.

On-Site Combustion

Emissions from on-site combustion can be estimated using the energy generated (GJ) from the solar thermal system during the reporting year, along with fuel-specific emission factors for the baseline fuel that would have been used to fill that need. OUs will need to know:

1) The quantity of energy generated from the solar collector in the reporting year, and
2) The type of fuel that would have been used in the Baseline Energy Scenario.

Baseline emissions from on-site combustion can be estimated using *Equation 23*:

[31] For grid-connected activities, it is assumed that the baseline generation source is no closer or farther on the transmission and distribution system than the renewable energy system under the activity.

Equation 23

$$\text{Baseline Emissions} = \text{Fuel Consumed} \times \text{Fuel Energy Content} \times \text{EF}_{\text{Fuel Specific}} \times \left(\frac{1\ \text{t}}{1{,}000{,}000\ \text{g}}\right)$$

Table 24 below describes these data elements, whether data are default or user-provided, and suggested data sources.

Table 24: Data Requirements for Equation 23

Data Element	Definition	Data Type	Data Source
Baseline Emissions	The amount, in metric tons of carbon dioxide equivalent, of GHG emissions in the Baseline Energy Scenario, associated with the baseline fuel type, that would have occurred in the reporting year (tCO_2e)	Calculated	Equation 23
Fuel Consumed	The quantity of fuel consumed in the reporting year. Applicable units by fuel type and unit conversions found in Appendix L: Fuel Consumption Units.	User-Provided	N/A
Fuel Energy Content	The energy content of the selected fuel, in GJ per selected units $\left(\frac{\text{GJ}}{\text{units}}\right)$. Default values and applicable units found in Appendix L: Fuel Consumption Units.	Default	Various, see Appendix L: Fuel Consumption Units
$\text{EF}_{\text{Fuel Specific}}$	GHG emission factor for stationary combustion of specific fuel type $\left(\frac{\text{gCO}_2\text{e}}{\text{GJ}}\right)$. Default values found in Appendix D: Fuel Emission Factors.	Default	IPCC, 2006
$\frac{1\ \text{t}}{1{,}000{,}000\ \text{g}}$	Gram to ton conversion factor $\left(\frac{\text{t}}{\text{g}}\right)$	Conversion Factor	NIST, 2006

Note: Default values can be overridden by the user if site-specific information is available.

STEP 5. ESTIMATE EMISSIONS REDUCED

GHG emissions reduced from the solar thermal activity are equal to the difference in GHG emissions from the conventional energy source (baseline emissions) and GHG emissions resulting from the activity (activity emissions) in the reporting year:

Equation 24

$$\text{Emissions Reduced} = \text{Baseline Emissions} - \text{Activity Emissions}$$

Table 25 below describes these data elements, whether data are default or user-provided, and suggested data sources.

Table 25: Data Requirements for Equation 24

Data Element	Definition	Data Type	Data Source
Emissions Reduced	The amount, in metric tons of carbon dioxide equivalent, of GHG emissions reduced in the reporting year (tCO_2e)	Calculated	Equation 24
Baseline Emissions	The amount, in metric tons of carbon dioxide equivalent, of GHG emissions in the Baseline Energy Scenario, associated with the baseline fuel type, that would have occurred in the reporting year (tCO_2e)	Calculated	Equation 22, or Equation 23
Activity Emissions	The amount, in metric tons of carbon dioxide equivalent, of GHG emissions that occurred due to the activity in the reporting year (tCO_2e)	Calculated	Equation 21

Based on the assumptions described above, emission reductions will equal the emissions under the Baseline Energy Scenario as the activity emissions are equal to zero.

3.3.3 Wind Turbine Systems

CLEAN ENERGY RESULT:
GENERATE RENEWABLE ENERGY

This section applies to the following activities:

- The installation of wind turbines to generate electricity for on-site consumption,
- The installation of wind turbines to generate electricity to supply to the grid.

Photo: Yahoo Inc., courtesy of Vestas / CC BY 2.0

Wind turbines convert wind into electricity for use on-site or for dispatch to the electricity grid. Converting wind power into electricity through wind turbine technology is a greenhouse gas (GHG) emission-free process resulting in a reduction of GHG emissions compared to the baseline, whether the baseline is grid electricity or on-site combustion.[32]

The installation of wind turbines reduces GHG emissions by decreasing the amount of grid electricity consumed or fossil fuels combusted on-site.

The remainder of this section describes five steps to calculate GHG emission reductions from activities utilizing wind turbine technology:

- Step 1: Define the Baseline Energy Scenario
- Step 2: Estimate electricity generated from the activity
- Step 3: Estimate baseline GHG emissions
- Step 4: Estimate activity GHG emissions
- Step 5: Estimate emissions reduced

STEP 1. DEFINE THE BASELINE ENERGY SCENARIO

In order to estimate GHG emissions reduced by the wind turbine system, OUs should define the Baseline Energy Scenario, or what would have occurred in the absence of the activity (e.g., the type of energy used prior to the installation of the wind turbine system). Options for the Baseline Energy Scenario are:

1) Use of electricity from the national grid,
2) Use of from electricity produced from on-site diesel generators, or
3) Use of energy produced from on-site combustion of fuel.

[32] The baseline scenario is a description of what would have most likely occurred in the absence of the activity. See *Section 2* for a discussion about determining baseline scenarios.

If the Baseline Energy Scenario involves no electricity consumption, OUs should determine whether the demand would have been met in the future by grid electricity or diesel generators and select option 1) or 2) as the Baseline Energy Scenario[33]. If the consumption of traditional fuel was replaced by renewable electricity, OUs should select option 3) as the Baseline Energy Scenario.

If the activity is replacing fuels for cooking, heating or lighting—i.e., not power generation—then OUs should collect the amount and type of fuel used and proceed to Step 3.

STEP 2. ESTIMATE ELECTRICITY GENERATED FROM THE ACTIVITY

If the electricity generated in kilowatt-hours (kWh) by the wind turbine is known, then users should proceed directly to Step 3. If electricity generation from the wind turbine is not known, OUs can estimate annual electricity generated using either Approach 1 or 2 as defined below.

Approach 1

The annual electricity generation (kWh) can be calculated as a function of the nameplate capacity of the turbine and the total operating hours. To estimate wind turbine electricity generation, OUs will need to know:

1) The nameplate capacity of the wind turbine system, and
2) The number of days per year the system is operational.

Equation 25

$$\text{Electricity Generated} = \text{Nameplate Capacity} \times \text{Operating Hours}$$

Table 26 describes the data elements, whether they are default or user-provided, and suggested data sources.

Table 26: Data Requirements for Equation 25

Data Element	Definition	Data Type	Data Source
Electricity Generated	The quantity of electricity generated in the reporting year (kWh)	Calculated	Equation 25
Nameplate Capacity	Nameplate rating of wind turbine (kW)	User-Provided	N/A
Operating Hours	The average number of hours that the system is operational in the reporting year. The default value is 8,760 hours.	Default	N/A

Note: Default values can be overridden by the user if site-specific information is available.

Approach 2

OUs can use this approach if the total operational hours of the wind turbine are not known, but the nameplate capacity is known. This approach estimates electricity generated using default country-specific

[33] The Protocol assumes that activities that generate or consume energy are displacing energy that would have been provided by conventional sources.

capacity factors for wind generation along with the nameplate capacity of the turbine. To use this approach, OUs will need to know:

1) The country where the implementation occurs,
2) The nameplate capacity of the wind turbine system.

Equation 26

$$\text{Electricity Generated} = \text{Generation Capacity} \times \text{Capacity Factor} \times \text{Operating Hours}$$

Table 27 describes the data elements, whether they are default or user-provided, and suggested data sources for *Equation 26*.

Table 27: Data Requirements for Equation 26

Data Element	Definition	Data Type	Data Source
Electricity Generated	The quantity of electricity generated in the reporting year (kWh).	Calculated	Equation 26
Generation Capacity	The rated capacity of the wind turbine installed and/or operational within the reporting year (kW)	User-Provided	N/A
Capacity Factor	Country specific wind capacity factor (%). Default values found in Appendix I: Capacity Factors and Solar Insolation by Country.	Default	IEA, 2011
Operating Hours	The average number of hours that the system is operational in the reporting year. The default value is 8,760 hours.	Default	N/A

Note: Default values can be overridden by the user if site-specific information is available.

STEP 3. ESTIMATE BASELINE GHG EMISSIONS

Depending on the baseline option chosen in Step 1, users should use either the *Grid-Connected Activities* approach or the *On-Site Combustion* approach equations below to estimate baseline GHG emissions.

Grid-Connected Activities

Emissions from grid-connected activities can be estimated using the electricity generated, in kilowatt-hours (kWh), from the wind turbine system during the reporting year, along with location-specific emission factors. OUs will need to know:

1) The quantity of electricity generated from the wind turbine in the reporting year, and
2) The country in which implementation occurs.

Emissions from grid electricity consumed in the baseline can be estimated using *Equation 27*:

Equation 27

$$\text{Baseline Emissions} = \text{Electricity Generated} \times \left(\frac{1}{1-\text{Line Loss Rate}}\right) \times \text{EF}_{\text{Grid}}$$

The line loss rate is applicable only for distributed or microgrid-connected activities (e.g., rooftop units). For central utility generation activities (e.g., power plant), the line loss rate is 0 percent.[34] *Table 28* describes the data elements, whether they are default or user-provided, and suggested data sources.

Table 28: Data Requirements for Equation 27

Data Element	Definition	Data Type	Data Source
Baseline Emissions	The amount, in metric tons of carbon dioxide equivalent, of GHG emissions in the Baseline Energy Scenario, associated with the baseline fuel type, that would have occurred in the reporting year (tCO_2e)	Calculated	Equation 27
Electricity Generated	The quantity of electricity generated in the reporting year (kWh)	Calculated	Equation 25, or Equation 26
Line Loss Rate	Average annual technical grid line loss due to transmission and distribution, by country (%)	Default	Expert Judgement based on IEA, 2013
EF_{Grid}	The average combined marginal GHG emission factor for grid electricity, by country $\left(\frac{tCO_2e}{kWh}\right)$	Default	IGES, 2015 IEA, 2013

Note: Default values can be overridden by the user if site-specific information is available.

On-Site Electricity Generation

Emissions from on-site electricity generation from diesel generators can be estimated using the electricity generated (kWh) from the wind turbine system during the reporting year, along with fuel-specific emission factors. OUs will need to know:

1) The quantity of electricity generated from the wind turbine in the reporting year

Emissions from on-site electricity generation in the Baseline Energy Scenario can be estimated using *Equation 28*:

Equation 28

$$\text{Baseline Emissions} = \text{Electricity Generated} \times \left(\frac{0.0036\ \text{GJ}}{1\ \text{kWh}}\right) \times \left(\frac{1}{\text{Generator Efficiency}}\right) \times \text{EF}_{\text{Diesel}}$$

Table 29 describes the data elements, types, and suggested data sources for *Equation 28*.

[34] For grid-connected activities, it is assumed that the baseline generation source is no closer or farther on the transmission and distribution system than the renewable energy system under the activity.

Table 29: Data Requirements for Equation 28

Data Element	Definition	Data Type	Data Source
Baseline Emissions	The amount, in metric tons of carbon dioxide equivalent, of GHG emissions in the Baseline Energy Scenario, associated with the baseline fuel type, that would have occurred in the reporting year (tCO_2e)	Calculated	Equation 28
Electricity Generated	The quantity of electricity generated in the reporting year (kWh)	Calculated	Equation 25, or Equation 26
$\frac{0.0036\ \mathrm{GJ}}{1\ \mathrm{kWh}}$	Kilowatt-hours to gigajoule conversion factor $\left(\frac{\mathrm{GJ}}{\mathrm{kWh}}\right)$	Conversion Factor	NIST, 2006
Generator Efficiency	The efficiency of the on-site generator that consumes diesel to generate electricity. Default value is 35%.	Default	Expert Judgment
$\mathrm{EF_{Diesel}}$	GHG emission factor for stationary combustion of diesel. Default value is 0.074354 $\frac{\mathrm{tCO_2e}}{\mathrm{GJ}}$.	Default	IPCC, 2006

Note: Default values can be overridden by the user if site-specific information is available.

On-Site Combustion

If the activity is replacing fuels for cooking, heating or lighting—i.e., not power generation—then emissions from on-site combustion can be estimated using the amount and type of fuel consumed in the Baseline Energy Scenario. OUs will need to know:

1) The amount of fuel consumed in the Baseline Energy Scenario during the reporting year, and
2) The type of fuel that was replaced by the activity.

Emissions from on-site combustion in the Baseline Energy Scenario can be estimated using *Equation 29*:

Equation 29

$$\mathrm{Baseline\ Emissions} = \mathrm{Fuel\ Consumed} \times \mathrm{Fuel\ Energy\ Content} \times \mathrm{EF_{Fuel\ Specific}} \times \left(\frac{1\ \mathrm{t}}{1{,}000{,}000\ \mathrm{g}}\right)$$

Table 30 below describes these data elements, whether data are default or user-provided, and suggested data sources.

Table 30: Data Requirements for Equation 29

Data Element	Definition	Data Type	Data Source
Baseline Emissions	The amount, in metric tons of carbon dioxide equivalent, of GHG emissions in the Baseline Energy Scenario, associated with the baseline fuel type,	Calculated	Equation 29

Data Element	Definition	Data Type	Data Source
	that would have occurred in the reporting year (tCO_2e)		
Fuel Consumed	The quantity of fuel consumed in the reporting year. Applicable units by fuel type and unit conversions found in Appendix L: Fuel Consumption Units.	User-Provided	N/A
Fuel Energy Content	The energy content of the selected fuel, in GJ per selected units $\left(\frac{\mathrm{GJ}}{\mathrm{units}}\right)$. Default values and applicable units found in Appendix L: Fuel Consumption Units.	Default	Various, see Appendix L: Fuel Consumption Units
$\mathrm{EF}_{\text{Fuel Specific}}$	GHG emission factor for stationary combustion of specific fuel type $\left(\frac{\mathrm{gCO_2e}}{\mathrm{GJ}}\right)$. Default values found in Appendix D: Fuel Emission Factors.	Default	IPCC, 2006
$\frac{1\ \mathrm{t}}{1{,}000{,}000\ \mathrm{g}}$	Gram to ton conversion factor $\left(\frac{\mathrm{t}}{\mathrm{g}}\right)$	Conversion Factor	NIST, 2006

Note: Default values can be overridden by the user if site-specific information is available.

STEP 4. ESTIMATE ACTIVITY GHG EMISSIONS

Wind turbine systems are assumed to emit zero GHGs per kWh generated; thus, activity emissions are equal to zero.

Equation 30

$$\text{Activity Emissions} = \text{Electricity Generated} \times \mathrm{EF}_{\text{Wind Turbine}}$$

Table 31 describes these data elements, whether they are default or user-provided, and suggested data sources.

Table 31: Data Requirements for Equation 30

Data Element	Definition	Data Type	Data Source
Activity Emissions	The amount, in metric tons of carbon dioxide equivalent, of GHG emissions that occurred due to the activity in the reporting year (tCO_2e)	Calculated	Equation 30
Electricity Generated	The quantity of electricity generated in the reporting year (kWh)	Calculated	Equation 25, or Equation 26
$\mathrm{EF}_{\text{Wind Turbine}}$	GHG emission factor for the wind turbine system. The default value is 0 $\frac{\mathrm{tCO_2e}}{\mathrm{kWh}}$.	Default	Protocol Assumption

Note: Default values can be overridden by the user if site-specific information is available.

STEP 5. ESTIMATE EMISSIONS REDUCED

GHG emissions reduced are equal to the difference in GHG emissions from the conventional energy source (baseline emissions) and GHG emissions resulting from the activity (activity emissions) in the reporting year:

Equation 31

$$\text{Emissions Reduced} = \text{Baseline Emissions} - \text{Activity Emissions}$$

Table 32 below describes these data elements, whether data are default or user-provided, and suggested data sources.

Table 32: Data Requirements for Equation 31

Data Element	Definition	Data Type	Data Source
Emissions Reduced	The amount, in metric tons of carbon dioxide equivalent, of GHG emissions reduced in the reporting year (tCO_2e)	Calculated	Equation 31
Baseline Emissions	The amount, in metric tons of carbon dioxide equivalent, of GHG emissions in the Baseline Energy Scenario, associated with the baseline fuel type, that would have occurred in the reporting year (tCO_2e)	Calculated	Equation 27, or Equation 28, or Equation 29
Activity Emissions	The amount, in metric tons of carbon dioxide equivalent, of GHG emissions that occurred due to the activity in the reporting year (tCO_2e)	Calculated	Equation 30

Based on the assumptions described above, emission reductions will equal the emissions under the Baseline Energy Scenario as the activity emissions are equal to zero.

3.3.4 Hydroelectric Systems

CLEAN ENERGY RESULT:
GENERATE RENEWABLE ENERGY

Photo by Alex Turdziladze, UNDP Georgia / CC BY-NC-SA 2.0

This section applies to the following activities:

- The installation of conventional hydroelectric dam systems to generate electricity for on-site consumption,
- The installation of hydroelectric systems to generate electricity to supply to the grid, or
- Enabling activities that directly lead to increased implementation of or access to hydroelectric generation in the reporting year.

Hydroelectric systems make use of the potential and kinetic energy of water to generate electricity for use on-site or dispatch to the electricity grid. Using hydroelectric technology to create electricity is a greenhouse gas (GHG) emission-free process, resulting in a reduction of GHG emissions compared to the baseline, whether the baseline is grid electricity or on-site combustion.

The remainder of this section describes five steps to calculate GHG emission reductions from activities involving hydroelectric technology, as follows:

- Step 1: Define the Baseline Energy Scenario
- Step 2: Estimate electricity generated from the activity
- Step 3: Estimate baseline GHG emissions
- Step 4: Estimate activity GHG emissions
- Step 5: Estimate emissions reduced

STEP 1. DEFINE THE BASELINE ENERGY SCENARIO

In order to estimate GHG emissions reduced by an installed hydroelectric system, OUs should define the Baseline Energy Scenario, or what would have occurred in the absence of the activity (e.g., the energy source used prior to the installation of the hydroelectric system). Options for the Baseline Energy Scenario are:

1) Use of electricity from the national grid,
2) Use of electricity produced from on-site diesel generators, or
3) Use of energy produced from on-site combustion of fuel.

If the Baseline Energy Scenario involves no electricity consumption, OUs should determine whether the demand would have been met in the future by grid electricity or diesel generators and select option 1) or 2) as the Baseline Energy Scenario.[35] If the consumption of traditional fuel was replaced by renewable electricity, OUs should select option 3) as the Baseline Energy Scenario.

If the activity is replacing fuels for cooking, heating or lighting—i.e., not power generation—then OUs should collect the amount of fuel used along with the type of fuel and proceed to Step 3.

STEP 2. ESTIMATE ELECTRICITY GENERATED FROM THE ACTIVITY

If the electricity generated in kilowatt-hours (kWh) by the hydroelectric system is known, then users should proceed directly to Step 3. If electricity generation from the hydroelectric system is not known, OUs can estimate annual electricity generated using either Approach 1 or Approach 2 as defined below.

If OU's know the hydroelectric turbine rating they should proceed to Approach 1 below. If turbine rating is not known OU's should proceed to Approach 2 and enter the head and flowrate of the hydroelectric system.

Approach 1

Annual electricity generation (kWh) can be calculated as a function of the hydroelectric system turbine rating, in kilowatts (kW), and a turbine capacity factor. To estimate hydroelectric system electricity generation, OUs will need to know:

1) The country in which implementation occurs, and
2) The turbine capacity of the hydroelectric system.

Equation 32

$$\text{Electricity Generated } = \text{Turbine Capacity} \times \text{Capacity Factor } \times \text{ Operating Hours}$$

Table 33 describes the data elements, whether they are default or user-provided, and suggested data sources.

Table 33: Data Requirements for Equation 32

Data Element	Definition	Data Type	Data Source
Electricity Generated	The quantity of electricity generated in the reporting year (kWh)	Calculated	Equation 32
Turbine Capacity	The rated generation capacity of the hydroelectric system installed and/or operational within the reporting year (kW)	User-Provided	N/A
Capacity Factor	The capacity factor of the hydroelectric system (%). Default values found in Appendix I: Capacity Factors and Solar Insolation by Country.	Default	Intpow, 2013

[35] The Protocol assumes that activities that generate or consume energy are displacing energy that would have been provided by conventional sources.

Data Element	Definition	Data Type	Data Source
Operating Hours	The average number of hours per year that the system is operational in the reporting year. The default value is 8,760 hours.	Default	N/A

Note: Default values can be overridden by the user if site-specific information is available.

Approach 2

If OUs do not know the turbine capacity rating of the Hydroelectric system, in kW, the nominal power of the system can be calculated as function of the efficiency of the turbine, the nominal flow rate of water through the turbines, the head (or height of water) of the system, density of water, the acceleration due to gravity, and the number of turbines in the system. Annual electricity generation (kWh) can be calculated as a function of the hydroelectric system turbine rating and a turbine capacity factor. To estimate hydroelectric system electricity generation, OUs will need to know:

1) The country in which implementation occurs,
2) The flow rate of the turbine,
3) The head, or height of water falling into the turbine, and
4) The number of turbines in the system.

Equation 33

$$\text{Total System Power} = \text{Turbine Efficiency} \times \text{Flow Rate} \times \text{Head} \times \text{Density}_{\text{Water}} \times \text{Acceleration}_{\text{Gravity}} \times \text{Number of Turbines}$$

Equation 34

$$\text{Electricity Generated} = \text{Total System Power} \times \left(\frac{1\ \text{kW}}{1000\ \text{W}}\right) \times \text{Capacity Factor} \times \text{Operating Hours}$$

Table 34 describes the data elements, whether they are default or user-provided, and suggested data sources.

Table 34: Data Requirements for Equation 33 and Equation 34

Data Element	Definition	Data Type	Data Source
Total System Power	The power per hydroelectric system turbine (W)	Calculated	Equation 33
Turbine Efficiency	The operational efficiency of the turbine in converting the energy of water to rotational energy. The default value is 80%.	Default	Kaltschmitt, 2007
Flow Rate	Nominal water flow rate through the turbine $\left(\frac{\text{m}^3}{\text{s}}\right)$	User-Provided	N/A
Head	The nominal head, which is the height of the water falling into the turbine (m)	User-Provided	N/A
$\text{Density}_{\text{Water}}$	The weight of water per cubic meter. The default value is 1,000 $\frac{\text{kg}}{\text{m}^3}$ (at 4 degrees Centigrade).	Constant	NIST, 2013a

Data Element	Definition	Data Type	Data Source
$\text{Acceleration}_{\text{Gravity}}$	The average acceleration of an object due to Earth's gravity. The default value is 9.81 $\frac{\text{m}}{\text{s}^2}$.	Constant	NIST, 2013b
Number of Turbines	The number of hydroelectric turbines in the system (Unitless)	User-Provided	N/A
Electricity Generated	The quantity of electricity generated from the turbine in the reporting year (kWh).	Calculated	Equation 34
$\frac{1\ \text{kW}}{1000\ \text{W}}$	Watt to kilowatt conversion factor $\left(\frac{\text{kW}}{\text{W}}\right)$	Conversion Factor	NIST, 2006
Capacity Factor	The capacity factor of the hydroelectric system (%). Default values found in Appendix I: Capacity Factors and Solar Insolation by Country.	Default	Intpow, 2013
Operating Hours	The average number of hours that the system is operational in the reporting year. The default value is 8,760 hours.	Default	N/A

Note: Default values can be overridden by the user if site-specific information is available.

STEP 3. ESTIMATE BASELINE GHG EMISSIONS

Depending on the baseline option chosen in Step 1, users should use either the *Grid-Connected Activities* approach or the *On-Site Combustion* approach equations below to estimate baseline GHG emissions.

Grid-Connected Activities

Emissions from grid-connected activities can be estimated using the electricity generated (kWh) from the hydroelectric system during the reporting year, along with location-specific emission factors. OUs will need to know:

1) The quantity of electricity generated from the hydroelectric system in the reporting year, and
2) The country in which implementation occurs.

Emissions from grid electricity consumed in the baseline can be estimated using *Equation 35*:

Equation 35

$$\text{Baseline Emissions} = \text{Electricity Generated} \times \left(\frac{1}{1 - \text{Line Loss Rate}}\right) \times \text{EF}_{\text{Grid}}$$

The line loss rate is applicable only for distributed or microgrid-connected activities (e.g., rooftop units). For central utility generation activities (e.g., power plant), the line loss rate is 0 percent.[36] *Table 35*

[36] For grid-connected activities, it is assumed that the baseline generation source is no closer or farther on the transmission and distribution system than the renewable energy system under the activity.

describes the data elements of *Equation 35*, whether they are default or user-provided, and suggested data sources.

Table 35: Data Requirements for Equation 35

Data Element	Definition	Data Type	Data Source
Baseline Emissions	The amount, in metric tons of carbon dioxide equivalent, of GHG emissions in the Baseline Energy Scenario, associated with the baseline fuel type, that would have occurred in the reporting year (tCO_2e)	Calculated	Equation 35
Electricity Generated	The quantity of electricity generated in the reporting year (kWh)	Calculated	Equation 32, or Equation 34
Line Loss Rate	Average annual technical grid line loss due to transmission and distribution, by country (%)	Default	Expert Judgement based on IEA, 2013
EF_{Grid}	The average combined marginal GHG emission factor for grid electricity, by country $\left(\frac{tCO_2e}{kWh}\right)$	Default	IGES, 2015 IEA, 2013

Note: Default values can be overridden by the user if site-specific information is available.

On-Site Electricity Generation

Emissions from on-site electricity generation from diesel generators can be estimated using the electricity generated (kWh) from the hydroelectric system during the reporting year, along with fuel-specific emission factors. OUs will need to know:

1) The quantity of electricity generated from the hydroelectric system in the reporting year (annual electric output)

Emissions from on-site electricity generation in the Baseline Energy Scenario can be estimated using *Equation 36*:

Equation 36

$$\text{Baseline Emissions} = \text{Electricity Generated} \times \left(\frac{0.0036\ \text{GJ}}{1\ \text{kWh}}\right) \times \left(\frac{1}{\text{Generator Efficiency}}\right) \times \text{EF}_{\text{Diesel}}$$

Table 36 describes the data elements of *Equation 36* whether they are default or user-provided, and suggested data sources.

Table 36: Data Requirements for Equation 36

Data Element	Definition	Data Type	Data Source
Baseline Emissions	The amount, in metric tons of carbon dioxide equivalent, of GHG emissions in the Baseline Energy Scenario, associated with the baseline fuel type,	Calculated	Equation 36

Data Element	Definition	Data Type	Data Source
	that would have occurred in the reporting year (tCO_2e)		
Electricity Generated	The quantity of electricity generated in the reporting year (kWh)	Calculated	Equation 32, or Equation 34
$\frac{0.0036\ \mathrm{GJ}}{1\ \mathrm{kWh}}$	Kilowatt-hours to gigajoule conversion factor $\left(\frac{\mathrm{GJ}}{\mathrm{kWh}}\right)$	Conversion Factor	NIST, 2006
Generator Efficiency	The efficiency of the on-site generator that consumes diesel to generate electricity. Default value is 35%.	Default	Expert Judgment[37]
$\mathrm{EF_{Diesel}}$	GHG emission factor for stationary combustion of diesel. Default value is $0.074354 \frac{tCO_2e}{GJ}$.	Default	IPCC, 2006

Note: Default values can be overridden by the user if site-specific information is available.

On-Site Combustion

If the activity is replacing fuels for cooking, heating or lighting—i.e., not power generation—then emissions from on-site combustion can be estimated using the amount and type of fuel consumed in the Baseline Energy Scenario. OUs will need to know:

1) The amount of fuel consumed in the Baseline Energy Scenario during the reporting year, and
2) The type of fuel that was replaced by the activity.

Emissions from on-site combustion in the baseline can be estimated using *Equation 37*:

Equation 37

$$\text{Baseline Emissions} = \text{Fuel Consumed} \times \text{Fuel Energy Content} \times \mathrm{EF_{Fuel\ Specific}} \times \left(\frac{1\ \mathrm{t}}{1{,}000{,}000\ \mathrm{g}}\right)$$

Table 37 describes the data elements of *Equation 37*, whether they are default or user-provided, and suggested data sources.

Table 37: Data Requirements for Equation 37

Data Element	Definition	Data Type	Data Source
Baseline Emissions	The amount, in metric tons of carbon dioxide equivalent, of GHG emissions in the Baseline Energy Scenario, associated with the baseline fuel type, that would have occurred in the reporting year (tCO_2e)	Calculated	Equation 37
Fuel Consumed	The quantity of fuel consumed in the reporting year. Applicable units by fuel type and unit conversions found in Appendix L: Fuel Consumption Units.	User-Provided	N/A

[37] For the purposes of the Protocol, some default values were determined based on expert judgment.

Data Element	Definition	Data Type	Data Source
Fuel Energy Content	The energy content of the selected fuel, in GJ per selected units $\left(\frac{\text{GJ}}{\text{units}}\right)$. Default values and applicable units found in Appendix L: Fuel Consumption Units.	Default	Various, see Appendix L: Fuel Consumption Units
$\text{EF}_{\text{Fuel Specific}}$	GHG emission factor for stationary combustion of specific fuel type $\left(\frac{\text{gCO}_2\text{e}}{\text{GJ}}\right)$. Default values found in Appendix D: Fuel Emission Factors.	Default	IPCC, 2006
$\frac{1\ \text{t}}{1{,}000{,}000\ \text{g}}$	Gram to ton conversion factor $\left(\frac{\text{t}}{\text{g}}\right)$	Conversion Factor	NIST, 2006

Note: Default values can be overridden by the user if site-specific information is available.

STEP 4. ESTIMATE ACTIVITY GHG EMISSIONS

Hydroelectric systems are assumed to emit zero GHGs per kWh generated; thus, activity emissions are equal to zero.

Equation 38

$$\text{Activity Emissions} = \text{Electricity Generated} \times \text{EF}_{\text{Hydroelectric}}$$

Table 38 describes the data elements of *Equation 38*, whether they are default or user-provided, and suggested data sources.

Table 38: Data Requirements for Equation 38

Data Element	Definition	Data Type	Data Source
Activity Emissions	The amount, in metric tons of carbon dioxide equivalent, of GHG emissions that occurred due to the activity in the reporting year (tCO_2e)	Calculated	Equation 38
Electricity Generated	The quantity of electricity generated in the reporting year (kWh)	Calculated	Equation 32, or Equation 34
$\text{EF}_{\text{Hydroelectric}}$	GHG emission factor for the hydroelectric system. The default value is 0 $\frac{\text{tCO}_2\text{e}}{\text{kWh}}$.	Default	Protocol Assumption

Note: Default values can be overridden by the user if site-specific information is available.

STEP 5. ESTIMATE EMISSIONS REDUCED

GHG emissions reduced from the hydroelectric activity are equal to the difference in GHG emissions from the conventional energy source (baseline emissions) and GHG emissions resulting from the activity (activity emissions) in the reporting year:

Equation 39

$$\text{Emissions Reduced} = \text{Baseline Emissions} - \text{Activity Emissions}$$

Table 39 describes the data elements of *Equation 39*, whether they are default or user-provided, and suggested data sources.

Table 39: Data Requirements for Equation 39

Data Element	Definition	Data Type	Data Source
Emissions Reduced	The amount, in metric tons of carbon dioxide equivalent, of GHG emissions reduced in the reporting year (tCO_2e)	Calculated	Equation 39
Baseline Emissions	The amount, in metric tons of carbon dioxide equivalent, of GHG emissions in the Baseline Energy Scenario, associated with the baseline fuel type, that would have occurred in the reporting year (tCO_2e)	Calculated	Equation 35, or Equation 36, or Equation 37
Activity Emissions	The amount, in metric tons of carbon dioxide equivalent, of GHG emissions that occurred due to the activity in the reporting year (tCO_2e)	Calculated	Equation 38

The emissions reduced from the hydroelectric system will equal the emissions under the Baseline Energy Scenario, as the activity emissions equal zero.

3.3.5 Geothermal Systems – Power Generation

CLEAN ENERGY RESULT:
GENERATE RENEWABLE ENERGY

Photo: Asian Development Bank / CC BY-NC-ND 2.0

This section applies to the following activities:

- The installation of geothermal systems to generate electricity for on-site consumption,
- The installation of geothermal systems to generate electricity to supply to the grid,
- Enabling activities that directly lead to increased implementation of or access to geothermal generation in the reporting year.

Geothermal systems make use of high temperatures inside the earth to create steam and generate electricity for use on-site or dispatch to the electricity grid. Using geothermal technology to create electricity is a largely GHG emission-free process, resulting in a reduction of GHG emissions compared to the baseline, whether the baseline is grid electricity or on-site combustion.[38] Geothermal systems are not completely emission-free, as the activity results in fugitive emissions due to the release of non-condensable gases. However, this protocol does not account for the use of non-condensable GHGs for simplicity.

The installation of a geothermal system reduces GHG emissions by decreasing the amount of grid electricity consumed or fossil fuels combusted on-site.

The remainder of this section describes five steps to calculate GHG emission reductions from activities utilizing geothermal system technology:

- Step 1: Define the Baseline Energy Scenario
- Step 2: Estimate electricity generated from the activity
- Step 3: Estimate baseline GHG emissions
- Step 4: Estimate activity GHG emissions
- Step 5: Estimate emissions reduced

[38] The baseline scenario is a description of what would have most likely occurred in the absence of the activity. See *Section 2* for a discussion about determining baseline scenarios.

STEP 1. DEFINE THE BASELINE ENERGY SCENARIO

In order to estimate GHG emissions reduced by the geothermal system, OUs should define the Baseline Energy Scenario, or what would have occurred in the absence of the activity (e.g., the type of energy used prior to the installation of the geothermal system). Options for the Baseline Energy Scenario are:

1) Use of electricity from the national grid,
2) Use of electricity produced from on-site diesel generators, or
3) Use of energy produced from on-site combustion of fuel.

If the Baseline Energy Scenario involves no electricity consumption, OUs should determine whether the demand would have been met in the future by grid electricity or diesel generators and select option 1) or 2) as the Baseline Energy Scenario.[39] If the consumption of traditional fuel was replaced by renewable electricity, OUs should select option 3) as the Baseline Energy Scenario.

If the activity is replacing fuels for cooking, heating or lighting—i.e., not power generation—then OUs should collect the amount and type of fuel used and proceed to Step 3.

STEP 2. ESTIMATE ELECTRICITY GENERATED FROM THE ACTIVITY

If the electricity generated in kilowatt-hours (kWh) by the geothermal system is known, then users should proceed directly to Step 3. If electricity generation from the geothermal system is not known, OUs can estimate annual electricity generated using the approach defined below.

The annual electricity generation (kWh) can be calculated as a function of the nameplate capacity of the generator and the capacity factor. This approach estimates electricity generated using either user-provided or default country-specific capacity factors for geothermal system generation along with the nameplate capacity of the system. In the case where default country-specific capacity factors are not known, regional or global average capacity factors are used. To use this approach, OUs will need to know:

1) The country where the implementation occurs,
2) The nameplate capacity of the geothermal system,
3) Optionally, the capacity factor of the plant.

Equation 40

$$\text{Electricity Generated} = \text{Generation Capacity} \times \text{Capacity Factor} \times \text{Operating Hours}$$

Table 40 describes the data elements, whether they are default or user-provided, and suggested data sources for *Equation 40*.

Table 40: Data Requirements for Equation 40

Data Element	Definition	Data Type	Data Source
Electricity Generated	The quantity of electricity generated in the reporting year (kWh)	Calculated	Equation 40

[39] The Protocol assumes that activities that generate or consume energy are displacing energy that would have been provided by conventional sources.

Data Element	Definition	Data Type	Data Source
Generation Capacity	The rated capacity of the geothermal power unit installed and/or operational within the reporting year (kW)	User-Provided	N/A
Capacity Factor	The capacity factor of the geothermal system (%). Default values found in Appendix I: Capacity Factors and Solar Insolation by Country.	Default	Bertani, 2012
Operating Hours	The average number of hours that the system is operational in the reporting year. The default value is 8,760 hours.	Default	N/A

Note: Default values can be overridden by the user if site-specific information is available.

STEP 3. ESTIMATE BASELINE GHG EMISSIONS

Depending on the baseline option chosen in Step 1, users should use either the *Grid-Connected Activities* approach or the *On-Site Combustion* approach equations below to estimate baseline GHG emissions.

Grid-Connected Activities

Emissions from grid-connected activities can be estimated using the electricity generated (kWh) from the geothermal system during the reporting year, along with location-specific emission factors. OUs will need to know:

1) The quantity of electricity generated from the geothermal system in the reporting year, and
2) The country in which implementation occurs.

Emissions from grid electricity consumed in the baseline can be estimated using Equation 41:

Equation 41

$$\text{Baseline Emissions} = \text{Electricity Generated} \times \left(\frac{1}{1 - \text{Line Loss Rate}}\right) \times \text{EF}_{\text{Grid}}$$

The line loss rate is applicable only for distributed or microgrid-connected activities (e.g., rooftop units). For central utility generation activities (e.g., power plant), the line loss rate is 0 percent.[40] *Table 41* describes the data elements, whether they are default or user-provided, and suggested data sources.

Table 41: Data Requirements for Equation 41

Data Element	Definition	Data Type	Data Source
Baseline Emissions	The amount, in metric tons of carbon dioxide equivalent, of GHG emissions in the Baseline Energy Scenario, associated with the baseline fuel type, that would have occurred in the reporting year (tCO_2e)	Calculated	Equation 41
Electricity Generated	The quantity of electricity generated in the reporting year (kWh)	Calculated	Equation 40

[40] For grid-connected activities, it is assumed that the baseline generation source is no closer or farther on the transmission and distribution system than the renewable energy system under the activity.

Data Element	Definition	Data Type	Data Source
Line Loss Rate	Average annual technical grid line loss due to transmission and distribution, by country (%)	Default	Expert Judgement based on IEA, 2013
EF_{Grid}	The average combined marginal GHG emission factor for grid electricity, by country $\left(\frac{tCO_2e}{kWh}\right)$	Default	IGES, 2015 IEA, 2013

Note: Default values can be overridden by the user if site-specific information is available.

On-Site Electricity Generation

Emissions from on-site electricity generation from diesel generators can be estimated using the electricity generated (kWh) from the geothermal system during the reporting year, along with fuel-specific emission factors. OUs will need to know:

1) The quantity of electricity generated from the geothermal system in the reporting year.

Emissions from on-site electricity generation in the Baseline Energy Scenario can be estimated using *Equation 42*:

Equation 42

$$\text{Baseline Emissions} = \text{Electricity Generated} \times \left(\frac{0.0036\ \text{GJ}}{1\ \text{kWh}}\right) \times \left(\frac{1}{\text{Generator Efficiency}}\right) \times EF_{\text{Diesel}}$$

Table 42 describes the data elements, types, and suggested data sources for *Equation 42*.

Table 42: Data Requirements for Equation 42

Data Element	Definition	Data Type	Data Source
Baseline Emissions	The amount, in metric tons of carbon dioxide equivalent, of GHG emissions in the Baseline Energy Scenario, associated with the baseline fuel type, that would have occurred in the reporting year (tCO_2e)	Calculated	Equation 42
Electricity Generated	The quantity of electricity generated in the reporting year (kWh)	Calculated	Equation 40
$\frac{0.0036\ \text{GJ}}{1\ \text{kWh}}$	Kilowatt-hours to gigajoule conversion factor $\left(\frac{GJ}{kWh}\right)$	Conversion Factor	NIST, 2006
Generator Efficiency	The efficiency of the on-site generator that consumes diesel to generate electricity. Default value is 35%.	Default	Expert Judgment[41]
EF_{Diesel}	GHG emission factor for stationary combustion of diesel. Default value is 0.074354 $\frac{tCO_2e}{GJ}$.	Default	IPCC, 2006

[41] For the purposes of the Protocol, some default values were determined based on expert judgment.

Note: Default values can be overridden by the user if site-specific information is available.

On-Site Combustion

If the activity is replacing fuels for cooking, heating or lighting—i.e., not power generation—then emissions from on-site combustion can be estimated using the amount and type of fuel consumed in the Baseline Energy Scenario. OUs will need to know:

1) The amount of fuel consumed in the Baseline Energy Scenario during the reporting year, and
2) The type of fuel that was replaced by the activity.

Emissions from on-site combustion in the baseline can be estimated using *Equation 43*:

Equation 43

$$\text{Baseline Emissions} = \text{Fuel Consumed} \times \text{Fuel Energy Content} \times \text{EF}_{\text{Fuel Specific}} \times \left(\frac{1\ \text{t}}{1{,}000{,}000\ \text{g}}\right)$$

Table 43 below describes these data elements, whether data are default or user-provided, and suggested data sources.

Table 43: Data Requirements for Equation 43

Data Element	Definition	Data Type	Data Source
Baseline Emissions	The amount, in metric tons of carbon dioxide equivalent, of GHG emissions in the Baseline Energy Scenario, associated with the baseline fuel type, that would have occurred in the reporting year (tCO_2e)	Calculated	Equation 43
Fuel Consumed	The quantity of fuel consumed in the reporting year. Applicable units by fuel type and unit conversions found in Appendix L: Fuel Consumption Units.	User-Provided	N/A
Fuel Energy Content	The energy content of the selected fuel, in GJ per selected units $\left(\frac{\text{GJ}}{\text{units}}\right)$. Default values and applicable units found in Appendix L: Fuel Consumption Units.	Default	Various, see Appendix L: Fuel Consumption Units
$\text{EF}_{\text{Fuel Specific}}$	GHG emission factor for stationary combustion of specific fuel type $\left(\frac{\text{gCO}_2\text{e}}{\text{GJ}}\right)$. Default values found in Appendix D: Fuel Emission Factors.	Default	IPCC, 2006
$\frac{1\ \text{t}}{1{,}000{,}000\ \text{g}}$	Gram to ton conversion factor $\left(\frac{\text{t}}{\text{g}}\right)$	Conversion Factor	NIST, 2006

Note: Default values can be overridden by the user if site-specific information is available.

STEP 4. ESTIMATE ACTIVITY GHG EMISSIONS

Geothermal systems are assumed to emit zero GHGs per kWh generated; thus, activity emissions are equal to zero.

Equation 44

$$\text{Activity Emissions} = \text{Electricity Generated} \times EF_{\text{Geothermal System}}$$

Table 44 describes these data elements, whether they are default or user-provided, and suggested data sources.

Table 44: Data Requirements for Equation 44

Data Element	Definition	Data Type	Data Source
Activity Emissions	The amount, in metric tons of carbon dioxide equivalent, of GHG emissions that occurred due to the activity in the reporting year (tCO_2e)	Calculated	Equation 44
Electricity Generated	The quantity of electricity generated in the reporting year (kWh)	Calculated	Equation 40
$EF_{\text{Geothermal System}}$	GHG emission factor for the geothermal power generation system. The default value is 0 $\frac{tCO_2e}{kWh}$.	Default	Protocol Assumption

Note: Default values can be overridden by the user if site-specific information is available.

STEP 5. ESTIMATE EMISSIONS REDUCED

GHG emissions reduced are equal to the difference in GHG emissions from the conventional energy source (baseline emissions) and GHG emissions resulting from the activity (activity emissions) in the reporting year:

Equation 45

$$\text{Emissions Reduced} = \text{Baseline Emissions} - \text{Activity Emissions}$$

Table 45 below describes these data elements, whether data are default or user-provided, and suggested data sources.

Table 45: Data Requirements for Equation 45

Data Element	Definition	Data Type	Data Source
Emissions Reduced	The amount, in metric tons of carbon dioxide equivalent, of GHG emissions reduced in the reporting year (tCO_2e)	Calculated	Equation 45
Baseline Emissions	The amount, in metric tons of carbon dioxide equivalent, of GHG emissions in the Baseline Energy Scenario, associated with the baseline fuel type, that would have occurred in the reporting year (tCO_2e)	Calculated	Equation 47, or Equation 48, or Equation 49
Activity Emissions	The amount, in metric tons of carbon dioxide equivalent, of GHG emissions	Calculated	Equation 50

Data Element	Definition	Data Type	Data Source
	that occurred due to the activity in the reporting year (tCO_2e)		

Total emission reductions will equal the emissions under the Baseline Energy Scenario as the activity emissions equal zero.

3.3.6 Geothermal Systems – Direct Heat

CLEAN ENERGY RESULT:
GENERATE RENEWABLE HEAT

This section applies to the following activities:

- The installation of geothermal systems for direct heating for on-site consumption,
- Enabling activities that directly lead to increased implementation of or access to geothermal heat generation in the reporting year.

Geothermal systems for direct heating utilize hot water inside the earth to deliver heat to activity implementers. Using geothermal technology to provide heat is a greenhouse gas (GHG) emission-free process, resulting in a reduction of GHG emissions compared to the baseline, whether the baseline is grid electricity or on-site combustion.

The remainder of this section describes five steps to calculate GHG emission reductions from activities involving geothermal technology, as follows:

- Step 1: Define the Baseline Energy Scenario
- Step 2: Estimate heat generated from the activity
- Step 3: Estimate baseline GHG emissions
- Step 4: Estimate activity GHG emissions
- Step 5: Estimate emissions reduced

STEP 1. DEFINE THE BASELINE ENERGY SCENARIO

In order to estimate GHG emissions reduced by an installed geothermal system, OUs should define the Baseline Energy Scenario[42], or what would have occurred in the absence of the activity (e.g., the energy source used prior to the installation of the geothermal system). Options for the Baseline Energy Scenario are:

1) Use of electricity from the regional grid, or
2) Use of heat produced from on-site combustion.

STEP 2. ESTIMATE HEAT GENERATED FROM THE ACTIVITY

If the heat generated by the Geothermal Direct Heat system is known, then users should proceed directly to Step 3. If heat generation from the Geothermal Direct Heat system is not known, OUs can estimate annual heat generated using either Approach 1 or Approach 2 as defined below.

If OU's know the geothermal system rating they should proceed to Approach 1 below. If system rating is not known OU's should proceed to Approach 2 and enter the mass flow rate and the temperature of the inlet and outlet.

[42] The Protocol assumes that activities that generate or consume energy are displacing energy that would have been provided by conventional sources.

Approach 1

Annual heat generation, in gigajoules (GJ), can be calculated as a function of the nameplate capacity of the geothermal system and the capacity factor. To estimate geothermal system heat generation, OUs will need to know:

1) The country in which implementation occurs, and
2) The nameplate capacity of the geothermal system.

Equation 46

$$\text{Heat Generated} = \text{Nameplate Capacity} \times \text{Capacity Factor} \times \text{Operating Hours} \times \left(\frac{0.0036\ \text{GJ}}{1\ \text{kWh}}\right)$$

Table 46 describes the data elements, whether they are default or user-provided, and suggested data sources.

Table 46: Data Requirements for Equation 46

Data Element	Definition	Data Type	Data Source
Heat Generated	The quantity of heat generated in the reporting year (GJ).	Calculated	Equation 46
Nameplate Capacity	Nameplate capacity of geothermal system (kW)	User-Provided	N/A
Capacity Factor	The ratio of total heat delivered to the total potential heat generation capacity. (%). Default values found in Appendix I: Capacity Factors and Solar Insolation by Country.	Default	Lund, 2010
Operating Hours	The average number of hours that the system is operational in the reporting year. The default value is 8,760 hours.	Default	N/A
$\frac{0.0036\ \text{GJ}}{1\ \text{kWh}}$	Kilowatt-hours to gigajoule conversion factor $\left(\frac{\text{GJ}}{\text{kWh}}\right)$	Conversion Factor	NIST, 2006

Note: Default values can be overridden by the user if site-specific information is available.

Approach 2

If OUs do not know the nameplate capacity of the Geothermal Direct Heat system, the mass flow rate and the temperature of operating fluid (water) at the inlet and outlet can be used to calculate the amount of heat generated.

Annual heat generation, in GJ, can be calculated as a function of the mass flow rate, the change in enthalpy between the inlet and the outlet, and the system runtime. To estimate geothermal system heat generation, OUs will need to know:

1) The mass flow rate of the system, and
2) The temperature of the Inlet and Outlet.

Enthalpy is defined as the measure of total energy in a thermodynamic system. It is calculated as a function of the internal energy, pressure, and volume of a system. Given default assumptions on the thermodynamic properties of water and the temperature entered by the user, enthalpy can be calculated. An embedded calculation estimates the change in enthalpy by taking the difference for the temperatures of the inlet and outlet.

Equation 47

$$\text{Change in Enthalpy} = \text{Enthalpy}_{\text{Inlet}} - \text{Enthalpy}_{\text{Outlet}}$$

Equation 48

$$\text{Heat Generated} = \text{Mass Flow Rate} \times \text{Change in Enthalpy} \times \text{Operating Hours} \times \left(\frac{1\ \text{GJ}}{1{,}000{,}000\ \text{kJ}}\right)$$

Table 47 describes the data elements, whether they are default or user-provided, and suggested data sources.

Table 47: Data Requirements for Equation 47 and Equation 48

Data Element	Definition	Data Type	Data Source
Change in Enthalpy	The loss of energy of the operating fluid between the inlet and the outlet of the system in the reporting year. Enthalpy values at the inlet and outlet are calculated based on the temperatures $\left(\frac{\text{kJ}}{\text{kg}}\right)$.	User-Provided	Equation 47
$\text{Enthalpy}_{\text{Inlet}}$	Enthalpy of the operating fluid at the inlet. Calculated as a function of temperature $\left(\frac{\text{kJ}}{\text{kg}}\right)$. Default values found in Appendix M: Water Enthalpy.	Calculated	NIST, 2011
$\text{Enthalpy}_{\text{Outlet}}$	Enthalpy of the operating fluid at the outlet. Calculated as a function of temperature $\left(\frac{\text{kJ}}{\text{kg}}\right)$. Default values found in Appendix M: Water Enthalpy.	Calculated	NIST, 2011
Heat Generated	The quantity of heat generated from the geothermal system in the reporting year (GJ).	Calculated	Equation 48
Mass Flow Rate	The mass of water that flows through the system per hour in the reporting year (kg/h).	User-Provided	N/A
Operating Hours	The average number of hours that the system is operational in the reporting year. The default value is 8,760 hours.	Default	N/A
$\frac{1\ \text{GJ}}{1{,}000{,}000\ \text{kJ}}$	Kilojoule to gigajoule conversion factor $\left(\frac{\text{GJ}}{\text{kJ}}\right)$	Conversion Factor	NIST, 2006

Note: Default values can be overridden by the user if site-specific information is available.

STEP 3. ESTIMATE BASELINE GHG EMISSIONS

Depending on the baseline option chosen in Step 1, users should use either the *Grid-Connected Activities* approach or the *On-Site Combustion* approach equations below to estimate baseline GHG emissions.

Grid-Connected Activities

Emissions from grid-connected activities can be estimated using the equivalent electricity generated (kWh) from the geothermal system during the reporting year, along with location-specific emission factors. OUs will need to know:

1) The quantity of heat generated from the geothermal system in the reporting year (GJ), and
2) The country in which implementation occurs.

Emissions from grid electricity consumed in the baseline can be estimated using *Equation 49*:

Equation 49

$$\text{Baseline Emissions} = \text{Heat Generated} \times \left(\frac{1\ \text{kWh}}{0.0036\ \text{GJ}}\right) \times \left(\frac{1}{1 - \text{Line Loss Rate}}\right) \times \text{EF}_{\text{Grid}}$$

The line loss rate is applicable only for distributed or microgrid-connected activities (e.g., rooftop units). For central utility generation activities (e.g., power plant), the line loss rate is 0 percent.[43] *Table 48* describes the data elements of *Equation 49*, whether they are default or user-provided, and suggested data sources.

Table 48: Data Requirements for Equation 49

Data Element	Definition	Data Type	Data Source
Baseline Emissions	The amount, in metric tons of carbon dioxide equivalent, of GHG emissions in the Baseline Energy Scenario, associated with the baseline fuel type, that would have occurred in the reporting year (tCO_2e)	Calculated	Equation 49
Heat Generated	The quantity of heat generated in the reporting year (GJ)	Calculated	Equation 46, or Equation 48
$\frac{1\ \text{kWh}}{0.0036\ \text{GJ}}$	Gigajoule to kilowatt-hours conversion factor $\left(\frac{\text{kWh}}{\text{GJ}}\right)$	Conversion Factor	NIST, 2006
Line Loss Rate	Average annual technical grid line loss due to transmission and distribution, by country (%)	Default	Expert Judgement based on IEA, 2013

[43] For grid-connected activities, it is assumed that the baseline generation source is no closer or farther on the transmission and distribution system than the renewable energy system under the activity.

Data Element	Definition	Data Type	Data Source
EF_{Grid}	The average combined marginal GHG emission factor for grid electricity, by country $\left(\frac{tCO_2e}{kWh}\right)$	Default	IGES, 2015 IEA, 2013

Note: Default values can be overridden by the user if site-specific information is available.

On-Site Combustion

If the activity is replacing fuels for heating—i.e., not power generation—then emissions from on-site combustion can be estimated using the amount and type of fuel consumed in the Baseline Energy Scenario. OUs will need to know:

1) The amount of fuel consumed in the Baseline Energy Scenario during the reporting year, and
2) The type of fuel that was replaced by the activity.

Emissions from on-site combustion in the baseline can be estimated using *Equation 50*:

Equation 50

$$\text{Baseline Emissions} = \text{Fuel Consumed} \times \text{Fuel Energy Content} \times EF_{\text{Fuel Specific}} \times \left(\frac{1\text{ t}}{1{,}000{,}000\text{ g}}\right)$$

Table 49 describes the data elements of Equation 50, whether they are default or user-provided, and suggested data sources.

Table 49: Data Requirements for Equation 50

Data Element	Definition	Data Type	Data Source
Baseline Emissions	The amount, in metric tons of carbon dioxide equivalent, of GHG emissions in the Baseline Energy Scenario, associated with the baseline fuel type, that would have occurred in the reporting year (tCO_2e)	Calculated	Equation 50
Fuel Consumed	The quantity of fuel consumed in the reporting year. Applicable units by fuel type and unit conversions found in Appendix L: Fuel Consumption Units.	User-Provided	N/A
Fuel Energy Content	The energy content of the selected fuel, in GJ per selected units $\left(\frac{GJ}{units}\right)$. Default values and applicable units found in Appendix L: Fuel Consumption Units.	Default	Various, see Appendix L: Fuel Consumption Units
$EF_{\text{Fuel Specific}}$	GHG emission factor for stationary combustion of specific fuel type $\left(\frac{gCO_2e}{GJ}\right)$. Default values found in Appendix D: Fuel Emission Factors.	Default	IPCC, 2006

Data Element	Definition	Data Type	Data Source
$\frac{1\ \text{t}}{1{,}000{,}000\ \text{g}}$	Gram to ton conversion factor $\left(\frac{\text{t}}{\text{g}}\right)$	Conversion Factor	NIST, 2006

Note: Default values can be overridden by the user if site-specific information is available.

STEP 4. ESTIMATE ACTIVITY GHG EMISSIONS

Geothermal systems are assumed to emit zero GHGs per kWh generated; thus, activity emissions are equal to zero.

Equation 51

$$\text{Activity Emissions} = \text{Heat Generated} \times \text{EF}_{\text{Geothermal Direct}}$$

Table 50 describes the data elements of *Equation 51*, whether they are default or user-provided, and suggested data sources.

Table 50: Data Requirements for Equation 51

Data Element	Definition	Data Type	Data Source
Activity Emissions	The amount, in metric tons of carbon dioxide, of GHG emissions that occurred due to the activity in the reporting year (tCO_2e)	Calculated	Equation 51
Heat Generated	The quantity of heat generated in the reporting year (GJ)	Calculated	Equation 46, or Equation 48
$\text{EF}_{\text{Geothermal Direct}}$	GHG emission factor for the geothermal direct heat system. The default value is 0 $\frac{tCO_2e}{GJ}$.	Default	Protocol Assumption

Note: Default values can be overridden by the user if site-specific information is available.

STEP 5. ESTIMATE EMISSIONS REDUCED

GHG emissions reduced from the geothermal activity are equal to the difference in GHG emissions from the conventional energy source (baseline emissions) and GHG emissions resulting from the activity (activity emissions) in the reporting year:

Equation 52

$$\text{Emissions Reduced} = \text{Baseline Emissions} - \text{Activity Emissions}$$

Table 51 describes the data elements of *Equation 52*, whether they are default or user-provided, and suggested data sources.

Table 51: Data Requirements for Equation 52

Data Element	Definition	Data Type	Data Source
Emissions Reduced	The amount, in metric tons of carbon dioxide equivalent, of GHG emissions reduced in the reporting year (tCO_2e)	Calculated	Equation 52

Data Element	Definition	Data Type	Data Source
Baseline Emissions	The amount, in metric tons of carbon dioxide equivalent, of GHG emissions in the Baseline Energy Scenario, associated with the baseline fuel type, that would have occurred in the reporting year (tCO_2e)	Calculated	Equation 49, or Equation 50
Activity Emissions	The amount, in metric tons of carbon dioxide equivalent, of GHG emissions that occurred due to the activity in the reporting year (tCO_2e).	Calculated	Equation 51

The emissions reduced from the geothermal system will equal the emissions under the Baseline Energy Scenario, as the activity emissions equal zero.

3.3.7 Geothermal Systems – Heat Pumps

CLEAN ENERGY RESULT:
GENERATE RENEWABLE ENERGY

This section applies to the following activities:

- The installation of geothermal heat pumps for space heating and/or cooling,
- Enabling activities that directly lead to increased implementation of or access to geothermal heat pumps in the reporting year.

Geothermal heat pumps (or ground source heat pumps) for heating and cooling utilize constant ground temperature for space heating and cooling. Using geothermal heat pumps results in a reduction of GHG emissions compared to the baseline, whether the baseline is grid electricity or on-site combustion.[44] Unlike other renewable sources, geothermal heat pumps are not completely emission-free as the pumps consume electricity to operate. The installation of ground source heat pumps reduces GHG emissions by decreasing the amount of grid electricity consumed or fossil fuels combusted on-site. The methodology addresses both heating and cooling provided by the ground source heat pumps. If a system is used for both heating and cooling, the methodology should be performed separately for heating and cooling as the baseline conditions or coefficients of performance (COPs) of the system may vary depending on the usage conditions.

The remainder of this section describes the six steps to calculate GHG emission reductions from activities utilizing ground source heat pumps technology:

- Step 1: Define the Baseline Energy Scenario,
- Step 2: Estimate energy transferred from/to the ground due to the activity,
- Step 3: Estimate baseline GHG emissions,
- Step 4: Estimate activity electricity consumed,
- Step 5: Estimate activity GHG emissions, and
- Step 6: Estimate emissions reduced.

STEP 1. DEFINE THE BASELINE ENERGY SCENARIO

In order to estimate GHG emissions reduced by the geothermal heat pumps, OUs should first define the Baseline Energy Scenario, or what would have occurred in the absence of the activity (e.g., the type of energy used prior to the installation of the geothermal heat pump). Options for the Baseline Energy Scenario are:

1) Use of electricity from the national grid,
2) Use of energy produced from on-site combustion of fuel.

[44] The baseline scenario is a description of what would have most likely occurred in the absence of the project. See *Section 2* for a discussion about determining baseline scenarios.

If the Baseline Energy Scenario involves no electricity consumption, OUs should determine whether the demand would have been met in the future by grid electricity or on-site combustion and select option 1) or 2) as the Baseline Energy Scenario.[45]

STEP 2. ESTIMATE ENERGY TRANSFERRED FROM/TO THE GROUND DUE TO THE ACTIVITY

OUs should first determine the heating or cooling load of the facility. This amount is then assumed to be the total energy transferred due to the ground as a result of the heat pump system. If the energy transferred by the geothermal heat pump is known, users can skip to Step 3. In addition to the energy transferred, users should have the COP of the system to estimate the activity emissions, described in Step 4. In the case where OUs know the total electricity consumed by the heat pump system, the same method described in Step 4 can be used to estimate the total energy transferred using the electricity consumed and the COP. If neither the electricity consumed nor the energy transferred are known, the total energy transferred can be estimated using one of the approaches below given available data.

Approach 1

OUs can utilize this approach if neither the annual heating or cooling load of a facility nor the electricity consumed by the heat pump system are not known, but the nameplate capacity of the heat pump is known. This approach assumes the heat pumps' energy consumption is a function of the total operational hours, which depends on the weather conditions of a country. Detailed descriptions are provided in sections below. To use this approach, OUs will need to know:

1) The nameplate capacity of the heat pump, and
2) The location of the activity.

The electricity consumed by the heat pump system is calculated based on the nameplate capacity and the weather corrected heating or cooling energy per kW. The electricity consumed is estimated separately for heating and cooling. The equation used is shown in below:

Equation 53

$$\text{Electricity Consumed} = \text{Nameplate Capacity} \times \frac{\text{Weather Corrected Heating or Cooling Energy}}{\text{kW}}$$

Table 52 describes the data elements, whether they are default or user-provided, and suggested data sources.

Table 52: Data Elements Used in Equation 53

Data Element	Definition	Data Type	Data Source
Electricity Consumed	The quantity of electricity consumed by the heat pump system in the reporting year (kWh)	Calculated	Equation 53
Nameplate Capacity	Nameplate capacity of the Heat Pump system (kW)	User-Provided	N/A

[45] The Protocol assumes that activities that generate or consume energy are displacing energy that would have been provided by conventional sources.

Data Element	Definition	Data Type	Data Source
Weather Corrected Heating or Cooling Energy per kW	The total estimated heating or cooling energy consumption per kW in the reporting year, specific to the selected location $\left(\frac{\text{kWh}}{\text{kW}}\right)$	Calculated	Equation 54

In the equation above, to account for the differences in the cooling or heating needs of varying countries, weather-corrected electricity consumption is used. For the purpose, a correction factor is applied to an estimate of the unadjusted estimate of electricity consumed of a base city, Chicago, IL, USA. To this value, a correction factor is applied which scales the energy required to run the heat pump for the selected city with reference to a base city. To determine the correction factor, a sample modeling was done to estimate the electricity required to cool and heat a typical office building for randomly selected cities and a curve fit was determined. This curve fit provides the cooling and heating electricity needs as a function of the cooling degree days and heating degree days respectively. Using the fit, the electricity needed for a small office building in the selected city and the reference city is found using the cooling and heating degree days. The ratio of the two was applied to the electricity consumed determined from *Equation 54* to estimate the weather corrected electricity consumed. The weather corrected electricity consumed is calculated as:

Equation 54

$$\frac{\text{Weather Corrected Electricity Consumed}_{\text{H,C}}}{\text{kW}} = \frac{\text{Electricity Consumed}_{\text{H,C}}}{\text{kW}} \times \frac{\text{Selected City Office Electricity Consumed}_{\text{H,C}}}{\text{Reference City (Chicago, IL) Office Electricity Consumed}_{\text{H,C}}}$$

Table 53 describes the data elements, whether they are default or user-provided, and suggested data sources.

Table 53: Data Elements Used in Equation 54

Data Element	Definition	Data Type	Data Source
Weather Corrected Electricity Consumed per kW	The total estimated heating or cooling energy consumption per kW in the reporting year, specific to the selected location $\left(\frac{\text{kWh}}{\text{kW}}\right)$	Calculated	Equation 54
Electricity Consumed per kW	The quantity of electricity consumed by the heat pump system per kW and COP in the reporting year $\left(\frac{\text{kWh}}{\text{kW}}\right)$	Calculated	Equation 55
Selected City Office Electricity Consumed	The quantity of electricity required to cool and heat an office in the selected city (kWh)	Calculated	Equation 56, and Equation 57

Data Element	Definition	Data Type	Data Source
Reference City Office Electricity Consumed	The quantity of electricity required to cool and heat an office in the reference city (Chicago, IL) (kWh).	Calculated	Equation 56, and Equation 57
H, C	Subscripts signifying heating and cooling respectively. Equation 54 needs to be used twice to estimate electricity consumed - once for heating and again for cooling purposes.	N/A	N/A

The estimated heating and cooling energies per kW for the base city, Chicago, IL, USA, are estimated using the full heating and cooling load hours of the base city and the COP of the system. The full load hours of the base city are assumed to be 819 hours for cooling and 1,069 hours for heating. (IEESAG, 2012) Using these values and the COP, an unadjusted cooling and heating electricity consumption (kWh) is calculated by the following equation:

Equation 55

$$\frac{\text{Electricity Consumed}_{\text{H,C}}}{\text{kW}} = \frac{\text{Full Load Hours}_{\text{ H,C}}}{\text{Coefficient of Performance}_{\text{H,C}}}$$

Table 54 describes the data elements, whether they are default or user-provided, and suggested data sources.

Table 54: Data Elements Used in Equation 55

Data Element	Definition	Data Type	Data Source
Electricity Consumed per kW	The quantity of electricity consumed by the heat pump system per kW and COP in the reporting year $\left(\frac{\text{kWh}}{\text{kW}}\right)$	Calculated	Equation 55
Full Load Hours	The number of hours that the heat pump system is assumed to run at full load in the reporting year. The default value is 819 hours for cooling and 1,069 hours for heating.	Default	IEESAG, 2012
H, C	Subscripts signifying heating and cooling respectively. Equation 55 needs to be used twice to estimate electricity consumed for both heating and cooling purposes.	User-Provided	N/A
Coefficient of Performance (COP)	The amount of heat transferred to (cooling) or from (heating) the ground by the heat pump per unit electricity consumed by the system in the reporting year (Unitless)	User-Provided	N/A

Note: Default values can be overridden by the user if site-specific information is available.

The sample modeling done to determine a curve fit to estimate the electricity required to cool and heat a typical office building are shown in *Equation 56* and *Equation 57* below.

Equation 56

$$\text{Office Cooling Electricity} = 4.3874 \times \text{CDD} + 1148.2$$

Table 55 describes the data elements, whether they are default or user-provided, and suggested data sources.

Table 55: Data Elements Used in Equation 56

Data Element	Definition	Data Type	Data Source
Office Cooling Electricity	The quantity of electricity required to cool an office in the selected city in the reporting year (kWh)	Calculated	Equation 56
4.3874	Constants are determined after a curve fit of office cooling electricity as a function of CDD$\left(\frac{\text{kWh}}{°\text{C}\cdot\text{Day}}\right)$.	Default	Based on Confidential Data
Cooling Degree Days (CDD)	The number of cooling degree days of the selected city relative to a baseline of 18.3°C ($°\text{C} \cdot \text{Day}$). Default value found in source material.	Default	DOE, 2013
1148.2	Constants are determined after a curve fit of office cooling electricity as a function of CDD (kWh).	Default	Based on Confidential Data

Note: Default values can be overridden by the user if site-specific information is available.

Equation 57

$$\text{Office Heating Electricity} = 0.1938 \times \text{HDD} - 77.346$$

Table 56 describes the data elements, whether they are default or user-provided, and suggested data sources.

Table 56: Data Elements Used in Equation 57

Data Element	Definition	Data Type	Data Source
Office Heating Electricity	The quantity of electricity required to heat an office in the selected city in the reporting year (GJ)	Calculated	Equation 57
0.1938	Constants are determined after a curve fit of office cooling electricity as a function of HDD$\left(\frac{\text{GJ}}{°\text{C}\cdot\text{Day}}\right)$.	Default	Based on Confidential Data
Heating Degree Days (HDD)	The number of heating degree days of the selected city relative to a baseline of 18.3°C ($°\text{C} \cdot \text{Day}$). Default value found in source material.	Default	DOE, 2013
77.346	Constants are determined after a curve fit of office cooling electricity as a function of HDD (GJ).	Default	Based on Confidential Data

Note: Default values can be overridden by the user if site-specific information is available.

Approach 2

OUs can utilize this approach to estimate the total energy transferred from the heat pump system if the nameplate capacity is not known. This approach is used in conjunction with Approach 1 to estimate the total energy transferred from the heat pump system once the capacity of the system is determined. This approach estimates the capacity of the heat pump system based on the type of system, and the length of the pipe installed in closed type systems and flow rate in open type systems. To use this approach, OUs will need to know:

1) The length of piping used for closed loop type heat pumps, or
2) The flow rate of the system for open loop type heat pumps, and
3) The location of the activity.

In addition, users should have the COP of the system to estimate the activity emissions, described in Step 4. OUs can estimate the energy transferred by the activity using *Equation 58*:

Equation 58

$$\text{Nameplate Capacity} = \frac{\text{Length of Piping or Flow Rate}}{\text{Length of Piping or Flow Rate per Ton Heating or Cooling}} \times \left(\frac{3.52\ \text{kW}}{1\ \text{t}}\right)$$

Table 57 describes the data elements, whether they are default or user-provided, and suggested data sources.

Table 57: Data Requirements for Equation 58

Data Element	Definition	Data Type	Data Source
Nameplate Capacity	Nameplate capacity of the Heat Pump System (kW)	Calculated	Equation 58
Length of Piping or Flow Rate	The length of the pipe used (ft) or the flow rate (gallons per minute, GPM) of the geothermal heat pump in the reporting year.	User-Provided	N/A
Length of Piping or Flow Rate per Ton Heating or Cooling	The average length of piping or flow rate that provides one ton of heating $\left(\frac{\text{ft}}{\text{t}}\right)$ or $\left(\frac{\text{GPM}}{\text{t}}\right)$	Default	Table 58, IEC, 2009
$\frac{3.52\ \text{kW}}{1\ \text{t}}$	Ton to kW conversion factor $\left(\frac{\text{kW}}{\text{t}}\right)$	Conversion Factor	NIST, 2008

Note: Default values can be overridden by the user if site-specific information is available.

The values for the length of piping or flow rate per ton of heating or cooling are obtained from Iowa Energy Center (IEC, 2009) and are shown in *Table 58* below:

Table 58: Length of piping or flow rate per ton heating or cooling (IEC, 2009)

Type of Heat Pump	Value
Horizontal Trench Loop	600 ft/t
Slinky Loop	700 ft/t

Type of Heat Pump	Value
Vertical Bore Loop	200 ft/t
Horizontal Boring	200 ft/t
Pond Loop	300 ft/t
Open Loop	2 GPM/t

Once the capacity is determined, Approach 1 needs to be used to estimate the total annual energy transferred by the system to estimate activity and baseline emissions.

STEP 3. ESTIMATE BASELINE GHG EMISSIONS

Depending on the baseline option chosen in Step 1, users should use the approach for either *Grid-Connected Activities* approach or the *On-Site Combustion* approach equations below to estimate baseline GHG emissions.

Grid-Connected Activities

Emissions from grid-connected activities can be estimated using the total annual electricity consumed as a result of geothermal activity (kWh) from the geothermal heat pump during the reporting year, along with location-specific emission factors. OUs will need to know:

1) The amount of electricity consumed from the activity due to the installation of the geothermal heat pump in the reporting year, and
2) The country in which implementation occurs.

Emissions from grid electricity consumed in the baseline can be estimated using *Equation 59*:

Equation 59

$$\text{Baseline Emissions} = \text{Electricity Consumed} \times \left(\frac{1}{1 - \text{Line Loss Rate}}\right) \times EF_{\text{Grid}}$$

The line loss rate is applicable only for distributed or microgrid-connected activities (e.g., rooftop units). For central utility generation activities (e.g., power plant), the line loss rate is 0 percent.[46] *Table 59* describes the data elements, whether they are default or user-provided, and suggested data sources.

Table 59: Data Requirements for Equation 59

Data Element	Definition	Data Type	Data Source
Baseline Emissions	The amount, in metric tons of carbon dioxide equivalent, of GHG emissions in the Baseline Energy Scenario, associated with the baseline fuel type, that would have occurred in the reporting year (tCO_2e)	Calculated	Equation 59

[46] For grid-connected activities, it is assumed that the baseline generation source is no closer or farther on the transmission and distribution system than the renewable energy system under the activity.

Data Element	Definition	Data Type	Data Source
Electricity Consumed	The quantity of annual electricity consumed from the geothermal heat pump in the reporting year (kWh)	Calculated	Equation 53
Line Loss Rate	Average annual technical grid line loss due to transmission and distribution, by country (%)	Default	Expert Judgement based on IEA, 2013
EF_{Grid}	The average combined marginal GHG emission factor for grid electricity, by country $\left(\frac{tCO_2e}{kWh}\right)$	Default	IGES, 2015 IEA, 2013

Note: Default values can be overridden by the user if site-specific information is available.

On-Site Combustion

If the activity is replacing fuels for heating—i.e., not power generation—then emissions from on-site combustion can be estimated using the amount and type of fuel consumed in the Baseline Energy Scenario. OUs will need to know:

1) The amount of fuel consumed in the Baseline Energy Scenario during the reporting year, and
2) The type of fuel that was replaced by the activity.

Emissions from on-site combustion in the baseline can be estimated using *Equation 60*:

Equation 60

$$\text{Baseline Emissions} = \text{Fuel Consumed} \times \text{Fuel Energy Content} \times EF_{\text{Fuel Specific}} \times \left(\frac{1\ \text{t}}{1{,}000{,}000\ \text{g}}\right)$$

Table 60 describes these data elements, whether data are default or user-provided, and suggested data sources.

Table 60: Data Requirements for Equation 60

Data Element	Definition	Data Type	Data Source
Baseline Emissions	The amount, in metric tons of carbon dioxide equivalent, of GHG emissions in the Baseline Energy Scenario, associated with the baseline fuel type, that would have occurred in the reporting year (tCO_2e)	Calculated	Equation 60
Fuel Consumed	The quantity of fuel consumed in the reporting year. Applicable units by fuel type and unit conversions found in Appendix L: Fuel Consumption Units.	User-Provided	N/A

Fuel Energy Content	The energy content of the selected fuel, in GJ per selected units $\left(\frac{\text{GJ}}{\text{units}}\right)$. Default values and applicable units found in Appendix L: Fuel Consumption Units.	Default	Various, see Appendix L: Fuel Consumption Units
$\text{EF}_{\text{Fuel Specific}}$	GHG emission factor for stationary combustion of specific fuel type $\left(\frac{\text{gCO}_2\text{e}}{\text{GJ}}\right)$. Default values found in Appendix D: Fuel Emission Factors.	Default	IPCC, 2006
$\frac{1\text{ t}}{1{,}000{,}000\text{ g}}$	Gram to ton conversion factor $\left(\frac{\text{t}}{\text{g}}\right)$	Conversion Factor	NIST, 2006

Note: Default values can be overridden by the user if site-specific information is available.

STEP 4. ESTIMATE ACTIVITY ELECTRICITY CONSUMED

Geothermal heat pumps make use of electricity to drive the pumps. Hence, the activity emissions arise from using the grid electricity that is used to run the system. To estimate the emissions, first the amount of electricity used by the geothermal system should be estimated. The electricity consumed can be estimated using the annual energy transferred and the Coefficient of Performance (COP). OUs will need to know:

1) The quantity of energy transferred from the activity due to the installation of the geothermal heat pump in the reporting year, and
2) The coefficient of performance (COP) of the installed heat pump.

OUs can estimate the annual electricity consumed by the activity using *Equation 61*.

Equation 61

$$\text{Electricity Consumed}_{\text{H,C}} = \frac{\text{Energy Transferred}_{\text{ H,C}}}{\text{Coefficient of Performance}_{\text{H,C}}}$$

Table 61 below describes these data elements, whether data are default or user-provided, and suggested data sources.

Table 61: Data Requirements for Equation 61

Data Element	Definition	Data Type	Data Source
Electricity Consumed	The quantity of electricity consumed by the operation of the heat pump used for cooling or heating during the activity, in the reporting year (kWh)	Calculated	Equation 61
Energy Transferred	The quantity of energy transferred by the geothermal heat pump in the reporting year (kWh)	Calculated	Equation 53
Coefficient of Performance (COP)	The amount of heat transferred to (cooling) or from (heating) the ground by the heat pump per unit electricity	User-Provided	N/A

Data Element	Definition	Data Type	Data Source
	consumed by the system in the reporting year (Unitless)		
H, C	Subscripts signifying heating and cooling respectively. Equation 61 needs to be used twice to estimate electricity consumed for both heating and cooling purposes.	User-Provided	N/A

STEP 5. ESTIMATE ACTIVITY GHG EMISSIONS

The emissions from the geothermal heat pumps can be estimated using the amount of electricity used by the geothermal heat pumps and location-specific electricity emission factors. USAID OUs will need to know:

1) The total annual electricity consumed, and
2) The country in which the implementation occurs.

Emissions from grid electricity consumed by the activity can be estimated using *Equation 62*.

Equation 62

$$\text{Activity Emissions} = \text{Electricity Consumed} \times \left(\frac{1}{1 - \text{Line Loss Rate}}\right) \times \text{EF}_{\text{Grid}}$$

Table 62 describes the data elements, whether they are default or user-provided, and suggested data sources.

Table 62: Data Requirements for Equation 62

Data Element	Definition	Data Type	Data Source
Activity Emissions	The amount, in metric tons of carbon dioxide equivalent, of GHG emissions that occurred due to the activity in the reporting year (tCO_2e)	Calculated	Equation 62
Electricity Consumed	The quantity of electricity consumed under the baseline and activity in the reporting year (kWh)	Calculated	Equation 61
Line Loss Rate	Average annual technical grid line loss due to transmission and distribution, by country (%)	Default	Expert Judgement based on IEA, 2013
EF_{Grid}	The average combined marginal GHG emission factor for grid electricity, by country $\left(\frac{tCO_2e}{kWh}\right)$	Default	IGES, 2015 IEA, 2013

Note: Default values can be overridden by the user if site-specific information is available.

STEP 6. ESTIMATE EMISSIONS REDUCED

GHG emissions reduced are equal to the difference in GHG emissions from the conventional energy source (baseline emissions) and GHG emissions resulting from the activity (activity emissions) in the reporting year:

Equation 63

$$\text{Emissions Reduced} = \text{Baseline Emissions} - \text{Activity Emissions}$$

Table 63 describes these data elements, whether data are default or user-provided, and suggested data sources.

Table 63: Data Requirements for Equation 63

Data Element	Definition	Data Type	Data Source
Emissions Reduced	The amount, in metric tons of carbon dioxide equivalent, of GHG emissions reduced in the reporting year (tCO_2e).	Calculated	Equation 63
Baseline Emissions	The amount, in metric tons of carbon dioxide equivalent, of GHG emissions in the Baseline Energy Scenario, associated with the baseline fuel type, that would have occurred in the reporting year (tCO_2e)	Calculated	Equation 59, or Equation 60
Activity Emissions	The amount, in metric tons of carbon dioxide equivalent, of GHG emissions that occurred due to the activity in the reporting year (tCO_2e)	Calculated	Equation 62

3.3.8 Biomass Energy – Select Fuels

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GENERATE RENEWABLE ENERGY

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This methodology applies to the following activities:

- Direct combustion of biomass (e.g., agricultural and forest residues, wood chips, briquettes, pellets, etc.) for the production of thermal energy (heat or steam) or electricity.
- Enabling activities that directly lead to increased use of biomass resources for direct combustion at the residential and commercial scale.

Direct combustion of biomass reduces the consumption of fossil fuels in the production of thermal energy or electricity at the residential or commercial scale. While biogenic emissions of carbon dioxide do occur in the direct combustion of biomass, emissions can be reduced to the extent that non-renewable fossil fuels are replaced by renewable biomass fuel types.

The displacement of fossil fuels with biomass feedstocks can occur either through the retrofit or replacement of existing thermal or electricity generation equipment that burns fossil fuels or through the installation of new thermal or electricity generating equipment.

For the purposes of this methodology, biomass is defined as non-fossilized and biodegradable organic material originating primarily from plants, including products, by-products, and residues from agriculture- and forestry-related activities. This methodology does not cover biomass from the biogenic portions of industrial and municipal wastes, nor does it cover the production of gases or liquid fuels from biomass.

Emissions reduced from the direct combustion of biomass can be estimated using electricity generated in kilowatt-hours (kWh) or thermal energy generated in gigajoules (GJ) from the biomass combustion facility, along with the location and fuel-specific emission factors of the electricity grid or on-site thermal generation facility. Net emissions reduced are calculated based on the quantity of fossil fuel consumption displaced by the use of biomass, adjusted for non-combustion emissions related to biomass including emissions associated with leakage,[47] cultivation including biomass production site effects (e.g., fertilizer application), and biomass processing (e.g., pelletizing, baling, drying).

The remainder of this section describes four steps to calculate GHG emission reductions from activities involving combustion of biomass, as follows:

- Step 1: Define the Baseline Energy Scenario
- Step 2: Estimate baseline GHG emissions
- Step 3: Estimate activity GHG emissions
- Step 4: Estimate emissions reduced

STEP 1. DEFINE THE BASELINE ENERGY SCENARIO

In order to calculate GHG emissions reduced by a biomass activity, OUs should first define the Baseline Energy Scenario[48] (see *Section 2* of the Protocol for a discussion of baselines). Options for the Baseline Energy Scenario are:

1) Use of electricity from the national grid
2) Use of electricity produced from on-site diesel generators
3) Use of energy produced from on-site combustion of fuel

If under the Baseline Energy Scenario no energy was produced or consumed prior to the biomass activity, OUs should determine whether the demand would have been met in the future by grid electricity, diesel generators, or the combustion of another fuel, and select option 1), 2), or 3) as the Baseline Energy Scenario.

STEP 2. ESTIMATE BASELINE GHG EMISSIONS

Depending on the baseline option chosen in Step 1, users should use the approach for either *Grid-Connected Activities*, *On-Site Electricity Generation,* or *On-Site Combustion* equations below to estimate baseline GHG emissions.

[47] Leakage is broadly defined as the unanticipated decrease (or increase) in GHG benefits outside of the project's accounting boundary (the boundary defined for the purposes of estimating the project's net GHG impact) as a result of project activities. For example, conserving forests that otherwise would have been deforested for agricultural land may displace farmers to an area outside of the project's boundaries. There, the displaced farmers may engage in deforestation (e.g., indirect land-use change) and the resulting carbon emissions are referred to as leakage.
Projects may also yield greater GHG benefits than anticipated—positive leakage or "spillover." For example, if a project introduced a new land management approach or technology—such as increased use of agroforestry or cover crops or increased saw mill efficiency—and this technology was more widely adopted outside the project's boundaries, the net GHG benefits would be larger than initially estimated.

[48] The baseline scenario is a description of what would have most likely occurred in the absence of the activity. See *Section 2* for a discussion about determining baseline scenarios. The Protocol assumes that activities that generate or consume energy are displacing energy that would have been provided by conventional sources.

Grid-Connected Activities

Emissions from grid-connected activities can be estimated using the electricity consumed (kWh) under the Baseline Scenario in the reporting year, along with location-specific emission factors. OUs will need to know:

1) The quantity of electricity consumed under the Baseline Scenario in the reporting year, and
2) The country in which implementation occurs.

Emissions from grid electricity consumed in the baseline can be estimated using *Equation 64*:

Equation 64

$$\text{Baseline Emissions} = \text{Electricity Consumed} \times \frac{1}{(1 - \text{Line Loss Rate})} \times \text{EF}_{\text{Grid}}$$

The line loss rate is applicable only for distributed or microgrid-connected activities (e.g., rooftop units). For central utility generation activities (e.g., power plant), the line loss rate is 0 percent.[49] *Table 64* describes the data elements of *Equation 64*, whether they are default or user-provided, and suggested data sources.

Table 64: Data Requirements for Equation 64

Data Element	Definition	Data Type	Data Source
Baseline Emissions	The amount, in metric tons of carbon dioxide equivalent, of GHG emissions in the Baseline Energy Scenario, associated with the baseline fuel type, that would have occurred in the reporting year (tCO_2e)	Calculated	Equation 64
Electricity Consumed	The quantity of electricity consumed in the reporting year (kWh)	User-Provided	N/A
Line Loss Rate	Average annual technical grid line loss due to transmission and distribution, by country (%)	Default	Expert Judgement based on IEA, 2013
EF_{Grid}	The average combined marginal GHG emission factor for grid electricity, by country $\left(\frac{tCO_2e}{kWh}\right)$	Default	IGES, 2015 IEA, 2013

Note: Default values can be overridden by the user if site-specific information is available.

On-Site Electricity Generation

Emissions from on-site electricity generation from diesel generators can be estimated using the electricity generated (kWh) from the combustion of biomass during the reporting year, along with fuel-specific emission factors. OUs will need to know:

[49] For grid-connected activities, it is assumed that the baseline generation source is no closer or farther on the transmission and distribution system than the renewable energy system under the activity.

1) The quantity of electricity generated from the combustion of biomass in the reporting year (annual electric output)

Emissions from on-site electricity generation in the Baseline Energy Scenario can be estimated using *Equation 65*:

Equation 65

$$\text{Baseline Emissions } = \text{Electricity Generated} \times \left(\frac{0.0036 \text{ GJ}}{1 \text{ kWh}}\right) \times \left(\frac{1}{\text{Generator Efficiency}}\right) \times \text{EF}_{\text{Diesel}}$$

Table 65 describes the data elements of *Equation 65*, whether they are default or user-provided, and suggested data sources.

Table 65: Data Requirements for Equation 65

Data Element	Definition	Data Type	Data Source
Baseline Emissions	The amount, in metric tons of carbon dioxide equivalent, of GHG emissions in the Baseline Energy Scenario, associated with the baseline fuel type, that would have occurred in the reporting year (tCO_2e)	Calculated	Equation 65
Electricity Generated	The quantity of electricity generated in the reporting year (kWh)	User-Provided	N/A
$\frac{0.0036 \text{ GJ}}{1 \text{ kWh}}$	Kilowatt-hours to gigajoule conversion factor $\left(\frac{\text{GJ}}{\text{kWh}}\right)$	Conversion Factor	NIST, 2006
Generator Efficiency	The efficiency of the on-site generator that consumes diesel to generate electricity. Default value is 35%.	Default	Expert Judgment[50]
$\text{EF}_{\text{Diesel}}$	GHG emission factor for stationary combustion of diesel. Default value is 0.074354 $\frac{tCO_2e}{GJ}$.	Default	IPCC, 2006

Note: Default values can be overridden by the user if site-specific information is available.

On-Site Combustion

If the activity is replacing fuels for cooking, heating or lighting—i.e., not power generation—then emissions from on-site combustion can be estimated using the amount and type of fuel consumed in the Baseline Energy Scenario. OUs will need to know:

1) The amount of fuel consumed in the Baseline Energy Scenario during the reporting year, and
2) The type of fuel that was replaced by the activity.

Emissions from on-site combustion for thermal energy in the baseline can be estimated using *Equation 66*:

[50] For the purposes of the Protocol, some default values were determined based on expert judgment.

Equation 66

$$\text{Baseline Emissions} = \text{Fuel Consumed} \times \text{Fuel Energy Content} \times \text{EF}_{\text{Fuel Specific}} \times \left(\frac{1\ \text{t}}{1{,}000{,}000\ \text{g}}\right)$$

Table 66 describes the data elements of *Equation 66*, whether they are default or user-provided, and suggested data sources.

Table 66: Data Requirements for Equation 66

Data Element	Definition	Data Type	Data Source
Baseline Emissions	The amount, in metric tons of carbon dioxide equivalent, of GHG emissions in the Baseline Energy Scenario, associated with the baseline fuel type, that would have occurred in the reporting year (tCO_2e)	Calculated	Equation 66
Fuel Consumed	The quantity of fuel consumed in the reporting year. Applicable units by fuel type and unit conversions found in Appendix L: Fuel Consumption Units.	User-Provided	N/A
Fuel Energy Content	The energy content of the selected fuel, in GJ per selected units $\left(\frac{\text{GJ}}{\text{units}}\right)$. Default values and applicable units found in Appendix L: Fuel Consumption Units.	Default	Various, see Appendix L: Fuel Consumption Units
$\text{EF}_{\text{Fuel Specific}}$	GHG emission factor for stationary combustion of specific fuel type $\left(\frac{\text{gCO}_2\text{e}}{\text{GJ}}\right)$. Default values found in Appendix D: Fuel Emission Factors.	Default	IPCC, 2006
$\frac{1\ \text{t}}{1{,}000{,}000\ \text{g}}$	Gram to ton conversion factor $\left(\frac{\text{t}}{\text{g}}\right)$	Conversion Factor	NIST, 2006

Note: Default values can be overridden by the user if site-specific information is available.

STEP 3. ESTIMATE ACTIVITY GHG EMISSIONS

The activity emissions calculation applies an adjustment factor to account for the amount of biomass that is sourced sustainably and therefore does not contribute to activity emissions. The remaining portion is counted as activity emissions, and additional emission factors are applied to account for non-combustion related emission sources related to biomass cultivation and processing, as well as a leakage adjustment factor to account for emission associated with leakage.

Equation 67

$$\begin{aligned}\text{Activity Emissions}\\ &= \big((\text{Biomass Consumed} \times \text{EF}_{\text{Combustion}}) \times \text{fNRB}\big) \times (1 - \text{Leakage})\\ &+ (\text{Biomass Consumed} \times \text{EF}_{\text{Cultivation}}) + \big(\text{Biomass Consumed} \times \text{EF}_{\text{Processing}}\big)\end{aligned}$$

Table 67 describes the data elements of *Equation 67*, whether they are default or user-provided, and suggested data sources.

Table 67: Data Requirements for Equation 67

Data Element	Definition	Data Type	Data Source
Activity Emissions	The amount, in metric tons of carbon dioxide equivalent, of GHG emissions that occurred due to the activity in the reporting year (tCO_2e)	Calculated	Equation 67
Biomass Consumed	The quantity of biomass consumed by the activity in the reporting year (GJ)	User-Provided	N/A
$\text{EF}_{\text{Combustion}}$	GHG emission factor for the combustion of specific biomass fuel types $\left(\frac{tCO_2e}{GJ}\right)$.	Default	IPCC, 2006
$\text{EF}_{\text{Cultivation}}$	GHG emission factor for the cultivation of specific biomass fuel types $\left(\frac{tCO_2e}{GJ}\right)$. Default values found in Appendix F: Calorific Values and Emission Factors of Various Types of Biomass.	Default	EU, 2010a
$\text{EF}_{\text{Processing}}$	GHG emission factor for the processing of specific biomass fuel types $\left(\frac{tCO_2e}{GJ}\right)$. Default values found in Appendix F: Calorific Values and Emission Factors of Various Types of Biomass.	Default	EU, 2010a
fNRB	The fraction of the biomass fuel that originates from non-renewable sources (%)	Default	Expert Judgement[51]
Leakage	Leakage emissions, calculated as 5% of total project emissions from combustion. (%)	User-Provided / Default	UNFCCC CDM, 2013a, 2013b, 2013c

Note: Default values can be overridden by the user if site-specific information is available.

The fraction of non-renewable biomass (fNRB) variable is the portion of the biomass used that can be established as being renewable based on a variety of factors, including population density, forest productivity, and fuel demand. Default values for fNRB are country- and fuel-specific, and range from 0% (e.g., the use of entirely renewable biomass) to 100% (e.g., the use of entirely non-renewable biomass).

[51] For the purposes of the Protocol, some default values were determined based on expert judgment.

Non-combustion sources of biogenic emissions related to the cultivation and processing of biomass are calculated by multiplying fuel consumption by cultivation- and processing-specific emission factors.

Non-combustion biogenic emission factors include:

1) *Cultivation* Emissions related to off-site application of fertilizer and other emission positive soil amendments resulting from the production/removal of primary biomass and residues
2) *Processing* Emissions related to the processing of biomass feedstock.
3) *Leakage* The primary source of leakage emissions in the biomass combustion project activity is an increase in emissions from fossil fuel combustion or other sources due to diversion of biomass residues from other uses to the project. Market-induced changes in carbon stocks (i.e., indirect land-use change) are expected to be insignificant for biomass residues, and are not included in the leakage term applied in Equation 67.

Transportation related emissions (e.g., transportation fuel use, biomass losses during transportation/storage) are not included due to an incompatibility between the project boundary in the accounting of emissions of fossil fuels and biomass. Since the emissions from transportation for fossil fuels (and other upstream emissions) are not accounted for, biomass transportation related emissions are also excluded.

STEP 4. ESTIMATE EMISSIONS REDUCED

GHG emissions reduced are equal to the difference in GHG emissions from the selected Baseline Energy Scenario (baseline emissions) and GHG emissions resulting from the project activity (activity emissions) in the reporting year:

Equation 68

$$\text{Emissions Reduced} = \text{Baseline Emissions} - \text{Activity Emissions}$$

Table 68 describes the data elements of *Equation 68*, whether they are default or user-provided, and suggested data sources.

Table 68: Data Requirements for Equation 68

Data Element	Definition	Data Type	Data Source
Emissions Reduced	The amount, in metric tons of carbon dioxide equivalent, of GHG emissions reduced in the reporting year (tCO_2e)	Calculated	Equation 68
Baseline Emissions	The amount, in metric tons of carbon dioxide equivalent, of GHG emissions in the Baseline Energy Scenario, associated with the baseline fuel type, that would have occurred in the reporting year (tCO_2e)	Calculated	Equation 64, or Equation 65, or Equation 66
Activity Emissions	The amount, in metric tons of carbon dioxide equivalent, of GHG emissions	Calculated	Equation 67

Data Element	Definition	Data Type	Data Source
	that occurred due to the activity in the reporting year (tCO_2e)		

3.3.9 Anaerobic Digesters for Manure Management

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GENERATE RENEWABLE ENERGY

Photo: Sustainable Sanitation Alliance / CC BY 2.0

This section applies to the use of anaerobic digesters at farms to recover and use bio-gas (methane) by adapting manure management practices. Several manure management strategies, including anaerobic digesters, reduce the emission of greenhouse gases (GHGs) relative to other management strategies. In breaking down animal waste, anaerobic digesters break down (digest) animal waste to generate biogas. The biogas is 60 to 80 percent methane and is considered a renewable energy resource (EPA, 2004). Anaerobic digesters capture methane generated from anaerobic treatment of animal waste and reduce GHG emissions by:

- Flaring the resultant biogas,
- Combusting the resultant biogas to provide on- or off-site heat, and
- Collecting the resultant biogas to generate electricity at an on- or off-site power generation facility.

On farms, anaerobic digesters are implemented for the purpose of managing animal waste and its odor as an alternative to current manure management practices, such as open pits, lagoons, composting, or spreading manure. USAID has supported projects developing digesters in many developing countries, including Brazil, Dominican Republic, Haiti, Honduras, Indonesia, Jordan, Kenya, and South Africa. In addition to facilitating the management of large amounts of waste, digesters can significantly reduce emissions of methane (CH_4), a potent greenhouse gas and, in cases for which the CH_4 is collected as biogas for fuel, can also offset emissions from other fuels used to supply energy during normal operations.

Anaerobic digesters work by allowing certain bacteria, in an oxygen-deprived environment, to convert volatile solids from waste into CH_4 and more stable organic compounds. The emissions of nitrous oxides from anaerobic digesters are negligible (IPCC 2006b). Although the methodology included here covers only animal manure, digesters can also be used to process wastewater, food waste, human waste, and other organic materials.

The remainder of this section describes five steps to calculate GHG emission reductions from activities involving anaerobic digesters, as follows:

- Step 1: Define the baseline scenario

- Step 2: Estimate methane collected from the activity
- Step 3: Estimate fugitive GHG emissions[52] from the activity
- Step 4: Estimate energy generated from the activity
- Step 5: Estimate fugitive GHG emissions from baseline Manure Management Practices
- Step 6: Estimate baseline GHG emissions from energy consumption
- Step 7: Estimate emissions reduced

STEP 1. DEFINE THE BASELINE SCENARIO

In order to calculate GHG emissions reduced by implementation of the anaerobic digester, OUs should first define the baseline scenario[53] (see *Section 2* of the Protocol for a discussion of baseline energy and fuel consumption).[54] It is important to consider both the baseline manure management practice and baseline source for energy production in order to fully capture the entire scope of emissions impacts. Components and options for determining the baseline scenario are:

1) The CH_4 and N_2O generated by baseline manure management practice[55], and
2) The baseline energy production. The options for the baseline energy production are:
   a. Use of electricity from the national grid, or
   b. Use of electricity produced from on-site diesel generators, or
   c. Use of energy produced from on-site or off-site combustion of fuel.

STEP 2. ESTIMATE METHANE COLLECTED FROM THE ACTIVITY

Methane collected by the activity should be measured by flow meters. If directly measuring the volume of CH_4 produced by the digester with a meter (*Approach 1*) is not possible, estimates can be made using basic information about the animals that produced the manure, the local climate (warm, temperate, cool), and the depth of digesters (*Approach 2*). The basic information about animals, local climate and depth of digesters is also required for calculating the fugitive N_2O emissions from the baseline Manure Management Practice. Hence, the OUs should collect this information whether they use *Approach 1* or *Approach 2*. The two approaches are presented below.

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[52] Only fugitive GHG emissions are considered under the Activity. Combustion emissions are not counted towards activity emissions because they are considered biogenic.
[53] The Protocol assumes that activities that generate or consume energy are displacing energy that would have been provided by conventional sources.
[54] OUs can also assume that the electricity generated is not offsetting energy that would have been produced in the absence of this activity. In this case, OUs should report zero emission reductions. However, as discussed in *Section 1.2*, USAID is assuming that activities that generate additional energy are displacing energy that would have been provided by conventional sources.
[55] The baseline practice has major impact on the emission reductions. Practices such as daily spread, drylots, and pastures generate significantly less methane than anaerobic digesters, and the methane emission could be less than the fugitive emissions from the installation of anaerobic digesters, resulting in negative emission reductions.

Approach 1: Use of Flow Meter

If the biogas produced by the anaerobic digester is measured with a flow meter, OUs can calculate the CH_4 by assuming 60%[56] of the biogas is CH_4 (unless this value has been determined by other means)[57] and converting that value from a volume to mass units (tCH_4).[58] The conversion from volume to mass units depends on the density of methane and a range of default values are provided for various temperature ranges. To estimate total methane collected, OUs will need to know:

1) Total biogas produced,
2) Methane fraction of the biogas, and
3) Density of methane at a given temperature.

The methane collected using flow meters can be estimated using *Equation 69*:

Equation 69

$$\text{CH}_4\text{ Collected} = \text{Biogas Produced} \times \text{CH}_4\text{ Fraction} \times \text{Density}_{\text{CH}_4} \times \left(\frac{1\text{ t}}{1{,}000\text{ kg}}\right)$$

Table 69 describes the data elements, whether they are default or user-provided, and suggested data sources for *Equation 69*.

Table 69: Data Requirements for Equation 69

Data Element	Definition	Data Type	Data Source
CH_4 Collected	The amount of methane, in metrics tons of methane gas, collected in the reporting year (tCH_4)	Calculated	Equation 69
Biogas Produced	The volume of biogas produced, including both CH_4 and CO_2, measured with a flow meter, in the reporting year (m3)	User-Provided	N/A
CH_4 Fraction	The portion of biogas that is CH_4. The default value is 0.60 (Unitless)	Default	EPA, 2004 EPA, 2011
$\text{Density}_{\text{CH}_4}$	The density of methane gas, which varies according to the average ambient temperature $\left(\frac{\text{kg}}{\text{m}^3}\right)$. Default values found in Table 70.	Default	Wischnewski, 2013

[56] EPA's Manual for Developing Biogas Systems at Commercial Farms in the United States (EPA, 2004) estimates the methane content in biogas to be between 60 percent and 80 percent. EPA's more recent document, Market Opportunities for Biogas Recovery Systems at U.S. Livestock Facilities (EPA. 2011) estimates the methane content in biogas to be between 60 and 70 percent. For conservative estimates, in this methodology the biogas content of methane is assumed to be 60%.
[57] New meters are available to measure CH_4 and CO_2 separately. In cases for which such meters are used, no modifier is required in this equation. The measured amount of CH_4 directly from the meter can be converted to tCO_2e by utilizing a 1 for the Methane Fraction in Biogas parameter.
[58] Anaerobic digesters are conservatively assumed to have fugitive emissions of 15% of CH_4 produced (UNFCCC 2005); this is the entirety of project emissions. This is accounted for in Equation 70 but is unnecessary in Equation 69as the metering is used after fugitive emissions would have occurred.

$\frac{1\ \mathrm{t}}{1{,}000\ \mathrm{kg}}$	Kilograms to ton conversion factor $\left(\frac{\mathrm{t}}{\mathrm{kg}}\right)$	Conversion Factor	NIST, 2006

Note: Default values can be overridden by the user if site-specific information is available.

Table 70 describes the density of methane at different ambient temperatures.

Table 70: Density of Methane at Varying Ambient Temperatures (Wischnewski, 2013)

Average Ambient Temperature (°C)	Density of Methane (kg/m3)
<7°C	0.72
8°C to 17°C	0.68
18°C to 22°C	0.67
>23°C	0.66

Approach 2: Estimate Based on Animal Population

If the biogas production from the anaerobic digester is not monitored with a flow meter, OUs can use this approach to estimate CH_4 collected from the manure management practice. This approach makes use of the amount of volatile solids (VS) i.e., the organic material in the livestock manure that consist of both biodegradable and non-biodegradable fractions, and the maximum amount of methane able to be produced from that manure (B_o). For anaerobic digesters, the methane conversion factor is assumed to be 1. This approach considers that some of the CH_4 will be lost in the anaerobic digester via fugitive emissions.

To estimate the annual methane collected, OUs will need to know:

1) The number of livestock, by animal type.

The methane collected using the animal population can be estimated using *Equation 70*:

Equation 70

$$\begin{aligned}\mathrm{CH_4\ Collected} &= \mathrm{Livestock\ \ Population} \times \mathrm{Volatile\ Solids} \times \mathrm{Operating\ Days} \\ &\times \mathrm{Production\ Capacity_{CH_4}} \times \mathrm{Density_{CH_4}} \times \mathrm{Methane\ Conversion\ Factor} \\ &\times (1 - \mathrm{Fugitive\ Emissions\ Rate}) \times \left(\frac{1\ \mathrm{t}}{1{,}000\ \mathrm{kg}}\right)\end{aligned}$$

Table 71 describes the data elements, whether they are default or user-provided, and suggested data sources for *Equation 70*.

Table 71: Data Requirements for Equation 70

Data Element	Definition	Data Type	Data Source
CH_4 Collected	The amount of methane, in metrics tons of methane gas, collected in the reporting year (tCH_4)	Calculated	Equation 70

Livestock Population	The number of livestock, per animal type and climate in the reporting year (head)	User-Provided	N/A
Volatile Solids	The amount of volatile solids produced per day, per livestock type, in the reporting year $\left(\frac{\text{kg}}{\text{head}\cdot\text{day}}\right)$. Default values found in Appendix K: Anaerobic Digesters Emission Factors.	Default	IPCC, 2006b
Operating Days	The number of days that the system is operational in the reporting year. The default value is 365 days.	Default	N/A
$\text{Production Capacity}_{\text{CH}_4}$	Maximum methane producing capacity, per livestock type, in the reporting year $\left(\frac{\text{m}^3 CH_4}{\text{kg VS}}\right)$. Default values found in Appendix K: Anaerobic Digesters Emission Factors.	Default	IPCC, 2006b
$\text{Density}_{\text{CH}_4}$	The density of methane gas, which varies according to the average ambient temperature. Default values found in Table 70.	Default	Wischnewski, 2013
Methane Conversion Factor	Methane Conversion Factor (MCF) for manure management system, by temperature (percent). MCFs reflect the portion of methane production capacity that is achieved. Default value for Anaerobic Digesters is assumed to be 100%.	Default	IPCC, 2006b
Fugitive Emission Rate	The percent of fugitive emissions in the reporting year. The default value is 15%.	Default	UNFCCC, 2005
$\frac{1\text{ t}}{1{,}000\text{ kg}}$	Kilograms to ton conversion factor $\left(\frac{\text{t}}{\text{kg}}\right)$	Conversion Factor	NIST, 2006

Note: Default values can be overridden by the user if site-specific information is available.

STEP 3. ESTIMATE ACTIVITY FUGITIVE GHG EMISSIONS FROM ANAEROBIC DIGESTERS

Anaerobic digesters and the biogas collection system are assumed to have fugitive emissions of 15% of the CH_4 produced, but OUs can provide their own values if they have such information for their digesters. Methane collected in the reporting year in Step 2, whether it is measured using flow meters or based on animal population, can be used to estimate the fugitive emissions. To estimate the total fugitive emissions, the first step is to estimate the total methane produced in the digesters. OUs will need to know:

1) The amount of methane collected under the activity, and
2) The fugitive emissions rate.

Amount of methane produced can be estimated using *Equation 71*:

Equation 71

$$CH_4 \text{ Produced} = CH_4 \text{ Collected} \times \frac{1}{1 - \text{Fugitive Emissions Rate}}$$

The activity emissions can then be estimated using the methane produced and the fugitive emissions rate using *Equation 72*:

Equation 72

$$\text{Activity Emissions}_{\text{Fugitive}} = CH_4 \text{ Produced } \times \text{Fugitive Emissions Rate} \times GWP_{CH_4}$$

Table 72 describes the data elements, whether they are default or user-provided, and suggested data sources for *Equation 71* and *Equation 72*.

Table 72: Data Requirements for Equation 71 and Equation 72

Data Element	Definition	Data Type	Data Source
CH_4 Produced	The volume of CH_4 produced, measured with a flow meter, in the reporting year (tCH_4)	Calculated	Equation 71
CH_4 Collected	The amount of methane, in metrics tons of carbon dioxide equivalent, collected in the reporting year (tCH_4)	Calculated	Equation 69 or Equation 70
Fugitive Emissions Rate	The percent of fugitive emissions in the reporting year. The default value is 15%.	Default	IPCC, 2006b
Activity $\text{Emissions}_{\text{Fugitive}}$	The amount of methane, in metrics tons of carbon dioxide equivalent, emitted from the anaerobic digester in the reporting year (tCO_2e)	Calculated	Equation 72
GWP_{CH_4}	The 100-year global warming potential of methane gas (CH_4) in CO_2 equivalence. Constant value of 25 CO_2e.	Default	IPCC, 2007b

Note: Default values can be overridden by the user if site-specific information is available.

STEP 4. ESTIMATE ENERGY GENERATED FROM THE ACTIVITY

Methane collected from Anaerobic Digesters, once captured, can be combusted to produce electricity or combusted to generate heat. The electricity generation and/or heat generation can take place either on-site or transported to an off-site location[59]. Depending on the baseline energy production scenario

[59] Transportation losses are not taken into account in the methodology.

chosen in Step 1, OUs should select either Electricity Generation or Heat Generation and proceed to Step 5.

Electricity Generation

To estimate electricity generated from methane collected from anaerobic digesters, OUs will need to know:

1) The amount of methane collected
2) Heat rate of the internal combustion engine

The amount of electricity generated can be estimated using *Equation 73*:

Equation 73

$$\text{Electricity Generated} = \text{CH}_4\ \text{Collected} \times \left(\frac{1{,}000\ \text{kg}}{1\ \text{t}}\right) \times \left(\frac{1}{\text{Density}_{\text{CH}_4}}\right) \times \left(\frac{35.3\ \text{ft}^3}{1\ \text{m}^3}\right) \times \text{Energy Content}_{\text{CH}_4} \times \frac{1}{\text{Heat Rate}_{\text{ICE}}}$$

Table 73 describes the data elements, whether they are default or user-provided, and suggested data sources for *Equation 73*.

Table 73: Data Requirements for Equation 73

Data Element	Description	Data Type	Data Source
Electricity Generated	The quantity of electricity generated in the reporting year (kWh)	Calculated	Equation 73
CH_4 Collected	The amount of methane, in metrics tons of carbon dioxide equivalent, collected in the reporting year (tCH_4)	Calculated	Equation 69 or Equation 70
$\frac{1{,}000\ \text{kg}}{1\ \text{t}}$	Tons to kilogram conversion factor $\left(\frac{\text{kg}}{\text{t}}\right)$	Conversion Factor	NIST, 2006
$\text{Density}_{\text{CH}_4}$	The density of methane gas, which varies according to the average ambient temperature$\left(\frac{\text{kg}}{\text{m}^3}\right)$. Default values found in Table 70.	Default	Wischnewski, 2013
$\frac{35.3\ \text{ft}^3}{1\ \text{m}^3}$	Cubic meters to cubic feet conversion factor $\left(\frac{\text{ft}^3}{\text{m}^3}\right)$	Conversion Factor	NIST, 2006
$\text{Energy Content}_{\text{CH}_4}$	The energy content of methane gas. Default value is $1000\frac{\text{Btu}}{\text{ft}^3}$.	Default	Bracmort, 2010 and EPA, 2004.
$\text{Heat Rate}_{\text{ICE}}$	The average heat rate of an internal combustion engine$\left(\frac{\text{Btu}}{\text{kWh}}\right)$. It is assumed that a typical farm will	Default	EPA, 2015

	have 65kW generator and thus a Default Heat Rate of 14,393 is used. Other Heat rates, by nominal capacities, are provided in Table 74.

Note: Default values can be overridden by the user if site-specific information is available.

Users can overwrite the default heat rate of the generator used (if known). If the heat rate is not known, but the nominal capacity of the generator is known, users can use the values in *Table 74* to estimate the heat rate of the turbine used by linearly interpolating between the ranges of capacities. If the nominal capacity is not known, a ratio of 5-8 cows per kW is a reasonable range to use in sizing a generator system (MN Project, 2005).

Table 74 provides the typical heat rates of gas turbines, by nominal capacity.

Table 74: Gas Turbines Typical Heat Rates

Nominal Capacity (kW)	Heat Rate (Btu/kWh)
30	15,535
65	14,393
200	12,824
250	13,110
333	12,198
1000	12,824

Source: EPA, 2015. Table 5-2.

Heat Generation

To estimate the amount of heat generated from methane collected from anaerobic digesters, OUs will need to know:

1) The amount of methane collected

The amount of heat generated using methane collected can be estimated using *Equation 74*:

Equation 74

$$\text{Heat Generated} = \text{CH}_4\text{ Collected} \times \left(\frac{1{,}000\text{ kg}}{1\text{ t}}\right) \times \left(\frac{1}{\text{Density}_{\text{CH}_4}}\right) \times \left(\frac{35.3\text{ ft}^3}{1\text{ m}^3}\right) \times \text{Energy Content}_{\text{CH}_4} \times \left(\frac{1.055 \times 10^{-6}\text{GJ}}{\text{Btu}}\right)$$

Table 75 describes the data elements, whether they are default or user-provided, and suggested data sources for *Equation 74*.

Table 75: Data Requirements for Equation 74

Data Element	Description	Data Type	Data Source
Heat Generated	The quantity of heat generated in the reporting year (GJ).	Calculated	Equation 74

CH_4 Collected	The amount of methane, in metrics tons of carbon dioxide equivalent, collected in the reporting year (tCH_4)	Calculated	Equation 69 or Equation 70
$\frac{1{,}000\ \mathrm{kg}}{1\ \mathrm{t}}$	Tons to kilogram conversion factor $\left(\frac{\mathrm{kg}}{\mathrm{t}}\right)$	Conversion Factor	NIST, 2006
$\mathrm{Density}_{\mathrm{CH_4}}$	The density of methane gas, which varies according to the average ambient temperature$\left(\frac{\mathrm{kg}}{\mathrm{m^3}}\right)$. Default values found in Table 70.	Default	Wischnewski, 2013
$\frac{35.3\ \mathrm{ft^3}}{1\ \mathrm{m^3}}$	Cubic meters to cubic feet conversion factor $\left(\frac{\mathrm{ft^3}}{\mathrm{m^3}}\right)$	Conversion Factor	NIST, 2006
$\mathrm{Energy\ Content}_{\mathrm{CH_4}}$	The energy content of methane gas. Default value is $1000\frac{\mathrm{Btu}}{\mathrm{ft^3}}$.	Default	Bracmort, 2010 and EPA, 2004
$\frac{1.055 \times 10^{-6}\mathrm{GJ}}{\mathrm{Btu}}$	Btu to GJ conversion factor $\left(\frac{\mathrm{GJ}}{\mathrm{Btu}}\right)$	Conversion Factor	NIST, 2006

Note: Default values can be overridden by the user if site-specific information is available.

STEP 5. ESTIMATE BASELINE GHG EMISSIONS FROM PREVIOUS MANURE MANAGEMENT PRACTICES

There are two elements of the baseline emissions: the emissions resulting from the previous livestock manure management practice (before the installation of the digester) and the emissions from energy use prior to using methane from the digester (see Step 6). Baseline emissions from previous manure management practice consists of methane as well as nitrous oxide emissions. *Equation 75* and *Equation 76* below can be used to estimate baseline CH_4 and N_2O emissions.

CH_4 Emissions from Baseline Manure Management Practice

The baseline emissions are the total CH_4 produced by the manure management practice used before the installation of the digester. In some management situations (e.g., dry lots, pasture, daily spread), the manure is kept in aerobic conditions and there is low CH_4 production relative to other systems (e.g., relative to lagoons, deep pits, liquid/slurry systems). In these cases, the baseline CH_4 emissions from manure management may be lower than the fugitive CH_4 emissions resulting from anaerobic digesters, leading to negative emission savings.

CH_4 emissions can be calculated using *Equation 75* below. In the equation, the Manure Conversion Factor (MCF) should be used for the previous manure management practice, which can be obtained from Table A-3. To estimate the baseline CH_4 emissions, OUs will need to know:

1) The number of livestock, by animal type
2) Manure management system

The baseline methane emissions from previous manure management practices can be estimated using *Equation 75*:

Equation 75

$$\text{Baseline } CH_4 \text{ Emissions} = \text{Livestock Population} \times \text{Volatile Solids} \times \left(\frac{365 \text{ days}}{1 \text{ year}}\right) \times \text{Production Capacity}_{CH_4} \times \text{Density}_{CH_4} \times \text{Methane Conversion Factor} \times \left(\frac{1 \text{ t}}{1{,}000 \text{ kg}}\right) \times GWP_{CH_4}$$

Table 76 describes the data elements, whether they are default or user-provided, and suggested data sources for *Equation 75*.

Table 76: Data Requirements for Equation 75

Data Element	Definition	Data Type	Data Source
Baseline CH_4 Emissions	The amount, in metric tons of carbon dioxide equivalent, of fugitive methane emissions in the baseline scenario that would have occurred in the reporting year (tCO_2e)	Calculated	Equation 75
Livestock Population	The number of livestock, per animal type and climate in the reporting year (head).	User-Provided	N/A
Volatile Solids	The amount of volatile solids produced per day, per livestock type, in the reporting year $\left(\frac{\text{kg VS}}{\text{head·day}}\right)$. Default values found in Appendix K: Anaerobic Digesters Emission Factors.	Default	IPCC, 2006b
Operating Days	The number of days that the system is operational in the reporting year. The default value is 365 days.	Default	N/A
$\text{Production Capacity}_{CH_4}$	Maximum methane producing capacity, per livestock type, in the reporting year $\left(\frac{m^3 CH_4}{\text{kg VS}}\right)$. Default values found in Appendix K: Anaerobic Digesters Emission Factors.	Default	IPCC, 2006b
Density_{CH_4}	The density of methane gas, which varies according to the average ambient temperature. Default values found in Table 70.	Default	N/A
Methane Conversion Factor	Methane Conversion Factor (MCF) for manure management system, by temperature (percent). MCFs reflect the portion of methane production capacity that is achieved.	Default	IPCC, 2006b
$\frac{1 \text{ t}}{1{,}000 \text{ kg}}$	Kilograms to ton conversion factor $\left(\frac{\text{t}}{\text{kg}}\right)$	Conversion Factor	NIST, 2006

GWP_{CH_4}	The 100-year global warming potential of methane gas (CH_4) in CO_2 equivalence. Constant value of 25 CO_2e.	Default	IPCC, 2007b

Note: Default values can be overridden by the user if site-specific information is available.

N_2O Emissions from Baseline Manure Management Practice

N_2O emissions are produced as part of the nitrogen cycle through the nitrification and denitrification of organic nitrogen in livestock dung and urine. Emissions are most likely to occur in dry manure handling systems that have aerobic conditions but also contain pockets of anaerobic conditions due to saturation (e.g., a dry lot system where feces and urine are deposited and mixed by animal hoof action).

Fugitive N_2O emissions from baseline manure management practice can be estimated using *Equation 76*. To estimate N_2O emissions, OUs will need to know:

1) The number of livestock, by animal type.

The baseline nitrous oxide emissions from previous manure management practices can be estimated using *Equation 76*:

Equation 76

$$\begin{aligned}&\text{Baseline N}_2\text{O Emissions}\\&\quad= \text{Livestock Population} \times \text{Nitrogen Excretion} \times EF_{N_2O} \times \left(\frac{1\ \text{t}}{1{,}000\ \text{kg}}\right)\\&\quad\times \left(\frac{44\ \text{N}_2\text{O}}{28\ \text{N}_2\text{O} - \text{N}}\right) \times GWP_{N_2O}\end{aligned}$$

Table 77 describes the data elements, whether they are default or user-provided, and suggested data sources for *Equation 76*.

Table 77: Data Requirements for Equation 76

Data Element	Definition	Data Type	Data Source
Baseline N_2O Emissions	The amount, in metric tons of carbon dioxide equivalent, of fugitive nitrous oxide emissions in the baseline scenario that would have occurred in the reporting year (tCO_2e).	Calculated	Equation 76
Livestock Population	The number of livestock, per animal type and climate in the reporting year (head).	User Provided	N/A
Nitrogen Excretion	The amount of nitrogen excreted per animal head by region in the reporting year (kg Nitrogen Excreted). Default values found in Appendix K: Anaerobic Digesters Emission Factors.	Default	IPCC, 2006c

EF_{N_2O}	Emission factor for N_2O-N for each manure management system type$\left(\frac{\text{kg } N_2O-N}{\text{kg Nitrogen Excreted}}\right)$. Default values found in Appendix K: Anaerobic Digesters Emission Factors.	Default	IPCC, 2006c
$\frac{1 \text{ t}}{1{,}000 \text{ kg}}$	Kilograms to ton conversion factor $\left(\frac{\text{t}}{\text{kg}}\right)$	Conversion Factor	NIST, 2006
$\frac{44 \text{ } N_2O}{28 \text{ } N_2O - N}$	Conversion factor to convert N_2O-N emissions to N_2O emissions (Unitless)	Conversion Factor	IPCC, 2006c
GWP_{N_2O}	The 100-year global warming potential of nitrous oxide gas (N_2O) in CO_2 equivalence. Constant value of 298 CO_2e.	Default	IPCC, 2007b

Note: Default values can be overridden by the user if site-specific information is available.

Total Baseline Fugitive Emissions from Manure Management Practices

The CH_4 and N_2O fugitive emissions are aggregated to calculate the total baseline fugitive emissions from manure management practices.

Equation 77

$$\text{Baseline Emissions}_{\text{Fugitive}} = \text{Baseline } CH_4 \text{ Emissions} + \text{Baseline } N_2O \text{ Emissions}$$

Table 78 describes the data elements, whether they are default or user-provided, and suggested data sources for *Equation 77*.

Table 78: Data Requirements for Equation 77

Data Element	Definition	Data Type	Data Source
$\text{Baseline Emissions}_{\text{Fugitive}}$	The amount, in metric tons of carbon dioxide equivalent, of fugitive GHG emissions from baseline manure management that would have occurred in the reporting year (tCO_2e).	Calculated	Equation 77
Baseline CH_4 Emissions	The amount, in metric tons of carbon dioxide equivalent, of fugitive methane emissions in the baseline scenario that would have occurred in the reporting year (tCO_2e).	Calculated	Equation 75
Baseline N_2O Emissions	The amount, in metric tons of carbon dioxide equivalent, of fugitive nitrous oxide emissions in the baseline scenario that	Calculated	Equation 76

	would have occurred in the reporting year (tCO_2e).

STEP 6. ESTIMATE GHG EMISSIONS FROM BASELINE ENERGY CONSUMPTION

Depending on the baseline option chosen in step 1, OUs should select either the *Grid-Connected Activities* approach or the *On-Site Combustion* approach equations below to estimate baseline GHG emissions. To estimate the energy consumption in the baseline scenario, it is assumed that all collected biogas from the activity is used and is representative of the energy consumption in the baseline scenario for all activities below.

Grid-Connected Projects

Emissions from grid-connected activities can be estimated using the electricity generated (kWh) from the CH_4 collected from anaerobic digesters during the reporting year, along with location-specific emission factors. OUs will need to know:

1) The quantity of electricity generated from the methane collected from anaerobic digesters in the reporting year, and
2) The country in which the implementation occurs.

Emissions from grid electricity consumed in the baseline can be estimated using *Equation 78*:

Equation 78

$$\text{Baseline Emissions}_{\text{Energy}} = \text{Electricity Generated} \times \left(\frac{1}{1 - \text{Line Loss Rate}}\right) \times \text{EF}_{\text{Grid}}$$

The line loss rate is applicable only for distributed or microgrid-connected activities (e.g., rooftop units). For central utility generation activities (e.g., power plant), the line loss rate is 0 percent.[60] *Table 79* describes the data elements, whether they are default or user-provided, and suggested data sources for *Equation 78*.

Table 79: Data Requirements for Equation 78

Data Element	Definition	Data Type	Data Source
Baseline $\text{Emissions}_{\text{Energy}}$	The amount, in metric tons of carbon dioxide equivalent, of GHG emissions emitted in the baseline scenario in the reporting year (tCO_2e)	Calculated	Equation 78
Electricity Generated	The quantity of electricity generated in the reporting year (kWh)	Calculated	Equation 73

[60] For grid-connected activities, it is assumed that the baseline generation source is no closer or farther on the transmission and distribution system than the renewable energy system under the activity.

Line Loss Rate	Average annual technical grid line loss due to transmission and distribution, by country (%)	Default	Expert Judgement based on IEA, 2013
EF_{Grid}	The average combined marginal GHG emission factor for grid electricity, by country $\left(\frac{tCO_2e}{kWh}\right)$	Default	IGES, 2015 IEA, 2013

Note: Default values can be overridden by the user if site-specific information is available.

On-Site Electricity Generation

If the anaerobic digester is displacing on-site electricity generation from diesel generators, emissions from on-site electricity generation from diesel generators can be estimated using the electricity generated (kWh), the CH_4 collected from anaerobic digesters during the reporting year, along with fuel-specific emission factors. OUs will need to know:

1) The quantity of electricity generated from the methane collected from anaerobic digesters in the reporting year.

Emissions from on-site electricity generation in the baseline scenario can be estimated using *Equation* 79:

Equation 79

$$\text{Baseline Emissions}_{\text{Energy}} = \text{Electricity Generated} \times \left(\frac{0.0036\ \text{GJ}}{1\ \text{kWh}}\right) \times EF_{\text{Diesel}} \times \frac{1}{\text{Generator Efficiency}}$$

Table 80 describes the data elements, whether they are default or user-provided, and suggested data sources for *Equation 79*.

Table 80: Data Requirements for Equation 79

Data Element	Definition	Data Type	Data Source
$\text{Baseline Emissions}_{\text{Energ}}$	The amount, in metric tons of carbon dioxide equivalent, of GHG emissions in the baseline scenario, associated with the baseline fuel type, that would have occurred in the reporting year (tCO_2e)	Calculated	Equation 79
Electricity Generated	The quantity of electricity generated in the reporting year (kWh).	Calculated	Equation 73
$\frac{0.0036\ \text{GJ}}{1\ \text{kWh}}$	Kilowatt-hours to gigajoule conversion factor $\left(\frac{GJ}{kWh}\right)$	Conversion Factor	NIST, 2006
EF_{Diesel}	GHG emission factor of diesel. Default value is 0.074354 $\frac{tCO_2e}{GJ}$.	Default	IPCC, 2006
Generator Efficiency	The efficiency of the on-site generator that consumes diesel to	Default	Expert Judgment[61]

[61] For the purposes of the Protocol, some default values were determined based on expert judgment.

	generate electricity. Default value is 35%.

Note: Default values can be overridden by the user if site-specific information is available.

On- or Off-Site Combustion

If the anaerobic digester is displacing combustion from other fuels for cooking, heating, or lighting –i.e., not power generation—then emissions from on- or off-site combustion can be estimated using the amount and type of fuel consumed in the baseline scenario. OUs will need to know:

1) The amount of fuel consumed in the baseline scenario during the reporting year, and
2) The type of fuel that was replaced by the activity.

Emissions from on-site combustion in the baseline scenario can be estimated using *Equation 80*:

Equation 80

$$\text{Baseline Emissions}_{\text{Energy}} = \text{Fuel Consumed } \times \text{Fuel Energy Content} \times \text{EF}_{\text{Fuel Specific}} \times \left(\frac{1\text{ t}}{1{,}000{,}000\text{ g}}\right)$$

Table 81 describes the data elements, whether they are default or user-provided, and suggested data sources for *Equation 80*.

Table 81: Data Requirements for Equation 80

Data Element	Definition	Data Type	Data Source
$\text{Baseline Emissions}_{\text{Energy}}$	The amount, in metric tons of carbon dioxide equivalent, of GHG emissions in the baseline scenario, associated with the baseline fuel type that would have occurred in the reporting year (tCO_2e)	Calculated	Equation 80
Fuel Consumed	The quantity of fuel consumed in the reporting year. Applicable units by fuel type and unit conversions found in Appendix L: Fuel Consumption Units.	User-Provided	N/A
Fuel Energy Content	The energy content of the selected fuel, in GJ per selected units $\left(\frac{\text{GJ}}{\text{units}}\right)$. Default values and applicable units found in Appendix L: Fuel Consumption Units.	Default	Various, see Appendix L: Fuel Consumption Units
$\text{EF}_{\text{Fuel Specific}}$	GHG emission factor for stationary combustion of specific fuel type $\left(\frac{\text{gCO}_2\text{e}}{\text{GJ}}\right)$. Default values found in Appendix D: Fuel Emission Factors.	Default	IPCC, 2006
$\frac{1\text{ t}}{1{,}000{,}000\text{ g}}$	Gram to ton conversion factor $\left(\frac{\text{t}}{\text{g}}\right)$	Conversion Factor	NIST, 2006

Note: Default values can be overridden by the user if site-specific information is available.

STEP 7. ESTIMATE EMISSIONS REDUCED

GHG emission reductions are equal to the difference in GHG emissions from the conventional energy source (baseline emissions) and GHG emissions resulting from the activity (project emissions) in the reporting year:

Equation 81

$$\begin{aligned}&\text{Emissions Reduced}\\&\quad = \left(\text{Baseline Emissions}_{\text{Fugitive}} + \text{Baseline Emissions}_{\text{Energy}}\right)\\&\quad - \left(\text{Activity Emissions}_{\text{Fugitive}}\right)\end{aligned}$$

Table 82 describes the data elements, whether they are default or user-provided, and suggested data sources for *Equation 81*.

Table 82: Data Requirements for Equation 81

Data Element	Definition	Data Type	Data Source
Emissions Reduced	The amount, in metric tons of carbon dioxide equivalent, of GHG emissions reduced in the reporting year (tCO_2e).	Calculated	Equation 81
$\text{Baseline Emissions}_{\text{Fugitive}}$	The amount, in metric tons of carbon dioxide equivalent, of GHG emissions from baseline manure management practice that would have occurred in the reporting year (tCO_2e).	Calculated	Equation 77
$\text{Baseline Emissions}_{\text{Energy}}$	The amount, in metric tons of carbon dioxide equivalent, of GHG emissions from baseline energy consumption that would have occurred in the reporting year (tCO_2e).	Calculated	Equation 78, Equation 79, or Equation 80
$\text{Activity Emissions}_{\text{Fugitive}}$	The amount, in metric tons of carbon dioxide equivalent, of GHG emissions that occurred due to the activity in the reporting year (tCO_2e).	Calculated	Equation 72

3.4 Clean Energy Result: Increase End-Use Energy Efficiency

"Increase End-Use Energy Efficiency" activities increase the efficiency of end-use technologies through technology upgrades or replacements that reduce the amount of energy consumed by the end-user, as well as the implementation of more energy efficient practices that reduce the amount of energy consumed for a given operation (i.e., conserve energy). Implementing more energy efficient practices leads to energy conservation by requiring less energy use to accomplish the same end result. Requiring energy efficient building standards, for example, encourages an implementer to install more efficient appliances and equipment. Once installed or applied, energy consumption decreases, resulting in a reduction in GHG emissions from energy saved. Box 7 lists some of the activities that achieve this Clean Energy Result.

Box 7: GCC Activities that Increase End-Use Energy Efficiency

Key Characteristics:

- Reduce end-use energy consumption
- Reduce energy demand

Example Activities:

- Building efficiency measures
- Installation of high efficiency appliances
- Development of appliance efficiency standards
- Development of building code standards
- Demand-side management (DSM) programs

The methodologies included in this section are:

- Building Energy Efficiency
- Appliance & Equipment Efficiency

3.4.1 Building Energy Efficiency

CLEAN ENERGY RESULT:
INCREASE END-USE ENERGY
EFFICIENCY

Photo: Natural Resources Defense Council (NRDC) / CC BY-ND 2.0

This section applies to the following activities:

- Improving building efficiency using various measures that lead to reduced energy consumption compared to the Baseline Energy Scenario, or
- Replacing less efficient baseline technologies with more energy efficient ones, or
- Enabling activities that directly lead to increased implementation of or access to building energy efficiency measures in the reporting year.

Building efficiency measures facilitate the consumption of less electricity or fuel to either achieve same output as less efficient technologies, introduce setbacks, or prevent energy loss. Examples include replacing incandescent light bulbs with compact fluorescent lamps (CFLs) that provide the same level of light, setting water temperature at a lower degree, inserting strip curtains on commercial refrigerator, etc. Utilizing less energy compared to the baseline leads to reduction of GHG emissions, whether the baseline technologies use grid electricity or fossil fuels.[62]

The remainder of this section describes the four steps to calculate GHG emissions reduced from building energy efficiency activities:

- Step 1: Define the efficiency measures
- Step 2: Estimate energy consumed in the baseline and activity scenario
- Step 3: Estimate baseline and activity GHG emissions
- Step 4: Estimate emissions reduced

STEP 1. DEFINE THE EFFICIENCY MEASURES

OUs should first define the various efficiency measures in order to estimate GHG emissions reduced by building efficiency measures. The various efficiency measures are category-specific, which in turn, are sector-specific. The categories are laid out for two sectors – residential and commercial.

For the residential sector, the options for the category are:

[62] The baseline scenario is a description of what would have most likely occurred in the absence of the activity. See *Section 2* for a discussion about determining baseline scenarios.

1) Heating ventilation and air conditioning (HVAC) – this category includes upgrade in residential HVAC systems with options to choose central air conditioning (AC) efficiency improvements or room AC efficiency improvements.

2) Lighting Upgrade – this category includes upgrade in lighting systems with options to choose replacement of incandescent type lights with CFL type. Typical replacement measures that provide equivalent light output are included.

3) Water Heating – this category includes upgrades in heater type (heat pumps), water flow controls (low flow aerators and shower heads) and temperature setbacks. Implementation of various measures within the Water Heating category results in energy savings due to less energy spent on either heating less amount of water or heating to a lower temperature.

For the commercial sector, the options for the category are:

1) HVAC – this category includes upgrade in commercial HVAC systems with options to choose room, unitary, or chiller AC efficiency improvements.

2) Lighting Upgrade – this category includes upgrade in lighting systems with options to choose replacement of incandescent type lights with CFL type, and upgrading from high bay, linear fluorescent and T8 types to high performance T8 type. Typical replacement measures that provide equivalent light output are included. Installation of occupancy sensors is also included in lighting upgrade measures.

3) Refrigeration – this category includes refrigeration related upgrades such as installation of automatic door closers, door heater controls, electronically commutated motors, evaporator fan controls, and strip curtains. Energy efficient refrigerated vending machines are also included in refrigeration upgrades.

Implementation of various measures within the various categories lead to reduction in electricity or fossil fuel consumption, which offsets electricity from the regional grid or heating from a thermal fuel source.

STEP 2. ESTIMATE ENERGY CONSUMED IN THE BASELINE AND ACTIVITY SCENARIO

The energy consumed before and after implementation of energy efficient measures are calculated based on various assumptions. The methodologies used for energy estimations for measures within various categories are described below. OUs will need to know:

1) The type of sector and category specific efficiency measures reflecting the baseline and activity scenario,
2) The number of units of the efficiency measures implemented in the reporting year.

The various efficiency measures save either electricity or thermal energy. The electricity and thermal energy savings are specific to the measure selected from a pre-populated database. *Table 83* describes the data requirements for defining the efficiency measures which will lead to estimating the energy consumed in the baseline[63] and activity scenario.

Table 83: Data Requirements for Defining Efficiency Measures

Data Element	Definition	Data Type	Data Source
Sector	The sector in which the energy efficiency measure was implemented in the reporting year	User-Provided	Default options: Residential or Commercial
Category	The category of the energy efficiency measures	User-Provided	Default options: Sector-specific
Measure	The energy efficiency measures which are specific to the category chosen	User-Provided	Default options: Category-specific
Number of Units	The total number of units of efficiency installed under the measure in the reporting year	User-Provided	Default options: Measure-specific

For the residential sector, the categories are differentiated into three types: HVAC, Lighting Upgrade, and Water Heating. For the commercial sector, the categories are differentiated into three types: HVAC, Lighting Upgrade, and Refrigeration. Various measures fall under each category and the energy consumption are pre-calculated for each measure using the following methodologies for respective categories.

Equation 82 through *Equation 85* describe the methods used to calculate the energy consumed in the baseline and activity scenarios for each of the measures available in the calculator. OUs are not required to actively apply these equations; the equations and data elements are presented below for reference purposes only.

The lighting upgrade category takes into account the nameplate power of the installed equipment and the replaced equipment. The equation used to estimate the electricity consumed is shown below:

Equation 82

$$\text{Electricity Consumed } = \text{Nameplate Capacity } \times \text{Operational Hours}$$

Table 84 describes the data elements, whether they are default or user-provided, and suggested data sources.

Table 84: Data Requirements for Equation 82

Data Element	Definition	Data Type	Data Source
Electricity Consumed	The quantity of electricity consumed in the reporting year (kWh)	Calculated	Equation 82
Nameplate Capacity	Nameplate Capacity rating of the equipment (kW)	User-Provided	N/A

[63] The Protocol assumes that activities that generate or consume energy are displacing energy that would have been provided by conventional sources.

Data Element	Definition	Data Type	Data Source
Operational Hours	The average number of hours that the system is operational in the reporting year (hours). The default value varies according to the type of lighting equipment installed during the activity.	Default	IEESAG, 2012

Note: Default values can be overridden by the user if site-specific information is available.

In the residential sector, it is assumed that the lighting equipment is operated for 2.57 hours per day for 365 days in a year. In the commercial sector, it is assumed that the CFLs are operated for 3,198 hours per year and the other lighting equipment are operated for 4,576 hours per year. These assumptions are taken from the Illinois Energy Efficiency Stakeholder Advisory Group's Technical Resource Manual (IEESAG, 2012]).

The water heating upgrade category in the residential sector and the refrigeration upgrade category in the commercial sector use savings estimated from the Illinois Energy Efficiency Stakeholder Advisory Group's Technical Resource Manual (IEESAG, 2012).

The HVAC upgrade category calculates the annual electricity consumed based on the Coefficient of Performance, Capacity, and Full Load Hours. The equation used is shown in Equation 83 below:

Equation 83

$$\text{Electricity Consumed} = \frac{\text{Full Load Hours} \times \text{Nameplate Capacity}}{\text{Coefficient of Performance}}$$

Table 85 describes the data elements, whether they are default or user-provided, and suggested data sources.

Table 85: Data Requirements for Equation 83

Data Element	Definition	Data Type	Data Source
Electricity Consumed	The amount of electricity consumed for a HVAC system with a given capacity and COP in the reporting year (kWh)	Calculated	Equation 83
Full Load Hours	The total number of hours that the HVAC equipment is assumed to run at full load in the reporting year (hours). The default value varies according to the user-specified location.	Default	IEESAG, 2012
Nameplate Capacity	Nameplate capacity of the HVAC equipment (kW)	User-Provided	N/A
Coefficient of Performance	The amount of energy transferred per unit electricity consumed by the HVAC system in the reporting year (Unitless)	User-Provided	N/A

Note: Default values can be overridden by the user if site-specific information is available.

For weather sensitive measures, the full load hours vary depending on location. For the purposes of this methodology, a reference city is chosen - Chicago, Illinois, USA and the full load hours of that city are assumed. In addition to the full load hours, the cooling needs will vary as well. To account for the differences in cooling needs of varying cities, a correction factor is applied to estimate the electricity consumed. For the purpose, a sample modeling was done to estimate the electricity required for a typical office building for randomly selected cities and a simple curve fit was determined which is a function of the cooling degree days. Using the fit, the electricity needed for a small office building in the selected city and the reference city is found using the cooling degree days. The ratio of the two was applied to the electricity consumed determined from *Equation 83* to estimate the weather corrected electricity consumed. The weather corrected electricity consumed is then calculated as:

Equation 84

$$\text{Weather Corrected Electricity Consumed} = \text{Electricity Consumed} \times \frac{\text{Selected City Office Cooling Electricity}}{\text{Reference City Office Cooling Electricity}}$$

Table 86 describes the data elements, whether they are default or user-provided, and suggested data sources.

Table 86: Data Requirements for Equation 84

Data Element	Definition	Data Type	Data Source
Weather Corrected Electricity Consumed	The quantity of electricity consumed by the HVAC system after adjusting for location in the reporting year (kWh)	Calculated	Equation 84
Electricity Consumed	The quantity of electricity consumed by the HVAC system in the reporting year (kWh)	Calculated	Equation 83
Selected City Office Cooling Electricity	The quantity of electricity required to cool an office in the selected city (kWh)	Calculated	Equation 85
Reference City Office Cooling Electricity	The electricity required to cool an office in the reference city (Chicago, IL)	Calculated	Equation 85

Equation 85

$$\text{Office Cooling Electricity} = 4.3874 \times \text{CDD} + 1148.2$$

Table 87 describes the data elements, whether they are default or user-provided, and suggested data sources.

Table 87: Data Requirements for Equation 85

Data Element	Definition	Data Type	Data Source
Office Cooling Electricity	The quantity of electricity required to cool an office in the selected city (kWh)	Calculated	Equation 85
4.3874	Constants are determined after a curve fit of office cooling electricity as a function of CDD $\left(\frac{\text{kWh}}{℃\cdot\text{Day}}\right)$.	Default	Based on Confidential Data
Cooling Degree Days (CDD)	The number of cooling degree days of the selected city relative to a baseline of	Default	DOE, 2013

Data Element	Definition	Data Type	Data Source
	18.3°C (°C · Day). Default value found in source material.		
1148.2	Constants are determined after a curve fit of office cooling electricity as a function of CDD (kWh).	Default	Based on Confidential Data

Note: Default values can be overridden by the user if site-specific information is available.

STEP 3. ESTIMATE BASELINE AND ACTIVITY GHG EMISSIONS

Depending on the energy efficiency measure chosen in Step 1, the calculations use the approach for either *Grid-Connected Activities* to estimate GHG emissions from activities that consume electricity or *On-Site Combustion* to estimate GHG emissions from activities that consume fossil fuel.

Grid-Connected Activities

Emissions from grid connected activities in the baseline and activity scenarios can be estimated using the electricity consumed (kWh) during the reporting year, along with location-specific emission factors. USAID OUs will need to know:

3) The total annual electricity consumed, and
4) The country in which the implementation occurs.

Emissions from grid electricity consumed by the baseline and the activity can be estimated using *Equation 86*:

Equation 86

$$\text{Emissions} = \text{Electricity Consumed} \times \left(\frac{1}{1 - \text{Line Loss Rate}}\right) \times \text{EF}_{\text{Grid}}$$

The data elements are described, and their type and sources are given in Table 88 below.

Table 88: Data Requirements for Equation 86

Data Element	Definition	Data Type	Data Source
Emissions	The amount, in metric tons of carbon dioxide equivalent, of GHG emissions in the baseline or activity scenario, that would have occurred in the reporting year (tCO_2e)	Calculated	Equation 86
Electricity Consumed	The quantity of electricity consumed under the baseline or activity in the reporting year (kWh)	Calculated	Equation 82, or Equation 84
Line Loss Rate	Average annual technical grid line loss due to transmission and distribution, by country (%)	Default	Expert Judgement based on IEA, 2013

Data Element	Definition	Data Type	Data Source
EF_{Grid}	The average combined marginal GHG emission factor for grid electricity, by country $\left(\frac{tCO_2e}{kWh}\right)$	Default	IGES, 2015 IEA, 2013

Note: Default values can be overridden by the user if site-specific information is available.

On-Site Combustion

If the activity is replacing fuels for cooking, heating or lighting—i.e., not power generation—then emissions from on-site combustion can be estimated using the amount and type of fuel consumed in the Baseline Energy Scenario. OUs will need to know:

1) The amount of fuel consumed in the Baseline Energy Scenario during the reporting year, and
2) The type of fuel that was replaced by the activity.

Emissions from fuels consumed on-site in the baseline and the activity scenarios can be estimated using *Equation 87*:

Equation 87

$$\text{Emissions} = \text{Fuel Consumed} \times \text{Fuel Energy Content} \times EF_{\text{Fuel Specific}} \times \left(\frac{1\text{ t}}{1{,}000{,}000\text{ g}}\right)$$

Table 89 describes the data elements, whether they are default or user-provided, and suggested data sources.

Table 89: Data Requirements for Equation 87

Data Element	Definition	Data Type	Data Source
Emissions	The amount, in metric tons of carbon dioxide equivalent, of GHG emissions in the baseline or activity scenario, that would have occurred in the reporting year (tCO_2e)	Calculated	Equation 87
Fuel Consumed	The quantity of fuel consumed in the reporting year. Applicable units by fuel type and unit conversions found in Appendix L: Fuel Consumption Units.	User-Provided	N/A
Fuel Energy Content	The energy content of the selected fuel, in GJ per selected units $\left(\frac{GJ}{units}\right)$. Default values and applicable units found in Appendix L: Fuel Consumption Units.	Default	Various, see Appendix L: Fuel Consumption Units
$EF_{\text{Fuel Specific}}$	GHG emission factor for stationary combustion of specific fuel type $\left(\frac{gCO_2e}{GJ}\right)$. Default values found in Appendix D: Fuel Emission Factors.	Default	IPCC, 2006
$\frac{1\text{ t}}{1{,}000{,}000\text{ g}}$	Gram to ton conversion factor $\left(\frac{t}{g}\right)$	Conversion Factor	NIST, 2006

Note: Default values can be overridden by the user if site-specific information is available.

STEP 4. ESTIMATE EMISSIONS REDUCED

GHG emissions reduced are equal to the difference in GHG emissions before the implementation of the energy efficient measure (baseline emissions) and GHG emissions resulting from the implementation of the measure (activity emissions) in the reporting year:

Equation 88

$$\text{Emission Reduced} = \text{Baseline Emissions} - \text{Activity Emissions}$$

Table 90 below describes these data elements, whether data are default or user-provided, and suggested data sources.

Table 90: Data Requirements for Equation 88

Data Element	Definition	Data Type	Data Source
Emissions Reduced	The amount, in metric tons of carbon dioxide equivalent, of GHG emissions reduced in the reporting year (tCO_2e)	Calculated	Equation 88
Baseline Emissions	The amount, in metric tons of carbon dioxide equivalent, of GHG emissions in the Baseline Energy Scenario, associated with the baseline fuel type, that would have occurred in the reporting year (tCO_2e)	Calculated	Equation 86, or Equation 87
Activity Emissions	The amount, in metric tons of carbon dioxide equivalent, of GHG emissions that occurred due to the activity in the reporting year (tCO_2e)	Calculated	Equation 86, or Equation 87

The emissions reduced will equal to the emissions under the Baseline Energy Scenario as the activity emissions in the above will be equal to zero.

3.4.2 Appliance & Equipment Efficiency

CLEAN ENERGY RESULT: INCREASE END-USE ENERGY EFFICIENCY

Photo by Jiri Rezac, The Climate Group / CC BY-NC-SA 2.0

This section applies to the following activities:

- Improving appliance and equipment energy efficiency that leads to reduced energy consumption compared to the Baseline Energy Scenario, or
- Replacing less efficient baseline appliances or equipment with more energy efficient appliances, or
- Enabling activities that directly lead to increased implementation of or access to energy efficient appliances and equipment in the reporting year.

Energy efficient appliances and equipment consume less electricity or fuel to achieve the same output as less efficient appliances. Using less energy results in reduction of GHG emissions compared to the baseline, whether the baseline appliance utilizes grid electricity or on-site combustion.[64]

The remainder of this section describes the four steps to calculate GHG emissions reduced from appliance and equipment energy efficiency activities:

- Step 1: Estimate energy consumption under the activity and the baseline
- Step 2: Define the baseline and activity energy source
- Step 3: Estimate baseline and activity GHG emissions
- Step 4: Estimate emissions reduced

STEP 1. ESTIMATE ENERGY CONSUMPTION UNDER THE ACTIVITY AND THE BASELINE

OUs should first determine the amount of energy consumed under the activity and the baseline[65]. If energy consumed by the baseline and the activity appliances and equipment are known, users can skip to Step 2. If energy consumed under either the baseline or activity scenarios are not known, they can be estimated using one of the approaches below given available data.

[64] The baseline scenario is a description of what would have most likely occurred in the absence of the activity. See *Section 2* for a discussion about determining baseline scenarios.
[65] The Protocol assumes that activities that generate or consume energy are displacing energy that would have been provided by conventional sources.

Approach 1

OUs can utilize this approach if electricity consumed under the baseline is not known, but the energy savings percentage of the equipment installed along with the activity electricity consumption are known. This approach assumes the baseline activity can be estimated using the estimated energy savings percentage of the equipment installed. To use this approach, OUs will need to know:

1) The electricity consumed by the activity, and
2) The energy savings percentage of the installed equipment.

OUs can estimate baseline energy consumption using *Equation 89*:

Equation 89

$$\text{Baseline Electricity Consumed} = \frac{\text{Activity Electricity Consumed}}{(1 - \text{Activity Appliance Percentage Savings})}$$

Table 91 describes these data elements, whether data are default or user-provided, and suggested data sources.

Table 91: Data Requirements for Equation 89

Data Element	Definition	Data Type	Data Source
Baseline Electricity Consumed	The quantity of electricity consumed by the baseline appliances in the reporting year (kWh)	Calculated	Equation 89
Activity Electricity Consumed	The quantity of electricity consumed by the appliances installed in the activity in the reporting year (kWh)	User-Provided	N/A
Activity Appliance Percentage Savings	Percentage savings offered by the appliances installed by the activity as established by the manufacturer (%)	User-Provided	N/A

Approach 2

OUs can utilize this approach if electricity consumed under both the baseline and activity scenarios are not known, but the power ratings of both the activity and baseline equipment, along with their weekly operating hours are known. This approach estimates the electricity consumed using the power rating and the hours of operation per equipment, along with the total number of equipment replaced. To use this approach, OUs will need to know:

1) The power rating of activity and baseline appliance,
2) The hours of operation per week of activity and baseline appliance, and
3) The total number of appliances.

OUs can estimate energy consumed for both the baseline and activity appliances using *Equation 90*:

Equation 90

$$\text{Electricity Consumed} = \text{Number of Appliances} \times \text{Power Rating of Appliance} \times \frac{\text{Operating Hours}}{\text{Week}} \times \frac{\text{52 Weeks}}{\text{1 Year}}$$

Table 92 describes these data elements, whether data are default or user-provided, and suggested data sources.

Table 92: Data Requirements for Equation 90

Data Element	Definition	Data Type	Data Source
Electricity Consumed	The quantity of electricity consumed by the baseline or activity appliances, in the reporting year (kWh)	Calculated	Equation 90
Number of Appliances	The number of appliances replaced in the baseline (i.e., installed under the activity) in the reporting year (Units)	User-Provided	N/A
Power Rating of Appliance	The rated power rating of the baseline and the activity appliances (kW)	User-Provided	N/A
Operating Hours per Week	The average number of hours per week that the system is operational in the reporting year $\left(\frac{\text{hours}}{\text{week}}\right)$.	User-Provided	N/A
$\frac{\text{52 Weeks}}{\text{1 Year}}$	Total number of weeks in a year (weeks)	Conversion Factor	N/A

Note: Default values can be overridden by the user if site-specific information is available.

Detailed Refrigerator-Specific Approach

OUs can utilize this approach to estimate the energy savings from refrigerators, including compact refrigerators and freezers of various style types and varying storage volume. The methodology estimates the energy consumption of refrigerators in the baseline and activity scenario based on the style type and the net freezer and fresh volumes. This approach assumes that the activity refrigerators replace the same kind of baseline refrigerators and the energy savings come from assumed constant factors that estimate energy consumption. To use this approach, OUs will need to know:

1) The total number and style type of the refrigerators, compact refrigerators, and freezers. The various style types are listed in *Table 121* in *Appendix* G: Tables for Appliance & Equipment Efficiency along with the constant factors used,
2) The estimated energy savings from energy efficient activity equipment. Default energy savings percentages for various types are provided, and
3) The net fresh and freezer volumes of each style type of refrigerators, compact refrigerators, and freezers.

The total annual energy consumed by the baseline and activity refrigerators can be estimated using *Equation 91*:

Equation 91

$$\text{Electricity Consumed} = \text{Number of Units} \times \frac{\text{Electricity Consumed}}{\text{Unit}}$$

And,

$$\frac{\text{Electricity Consumed}}{\text{Unit}} = (\text{Constant}_1 \times \text{Adjusted Volume}) + \text{Constant}_2$$

$$\text{Adjusted Volume} = \begin{array}{c}\text{Fresh Volume} + (1.63 \times \text{Freezer Volume}) \text{ for Refrigerators and Compacts, OR} \\ (1.73 \times \text{Freezer Volume}) \text{ for Freezers}\end{array}$$

Table 93 describes these data elements, whether data are default or user-provided, and suggested data sources.

Table 93: Data Requirements for Equation 91

Data Element	Definition	Data Type	Data Source
Electricity Consumed	The quantity of annual electricity consumed by the baseline or activity equipment in the reporting year (kWh)	Calculated	Equation 91
Number of Refrigerator Units	The total number of units replaced in the Baseline Energy Scenario (i.e., installed in the activity) for specific styles, in the reporting year (Units)	User-Provided	N/A
Electricity Consumed per Unit	The quantity of annual electricity consumed by one unit of the baseline or activity equipment in the reporting year $\left(\frac{\text{kWh}}{\text{unit}}\right)$	Calculated	Equation 91
Constant_1	Constants used to determine energy consumed by specific style refrigerators, compacts, and freezers, as presented in Energy Star Program Requirements. $\left(\frac{\text{kWh}}{\text{ft}^3}\right)$ Default values found in Appendix G: Tables for Appliance & Equipment Efficiency.	Default	US EPA Energy Star, 2007
Adjusted Volume	The adjusted volume of specific type of refrigerators as defined by the equations above (ft^3)	Calculated	Equation 91
Constant_2	Constants used to determine energy consumed by specific style refrigerators, compacts, and freezers, as presented in Energy Star Program Requirements. (kWh) Default values found in Appendix G: Tables for Appliance & Equipment Efficiency.	Default	US EPA Energy Star, 2007
Fresh Volume	Net volume of the fresh food compartment of the refrigerator (ft^3)	User-Provided	N/A

Data Element	Definition	Data Type	Data Source
Freezer Volume	Net volume of the freezer compartment of the refrigerator or the entire volume of the freezer (ft^3)	User-Provided	N/A
1.63	Volume adjustment for refrigerators and compacts (Unitless)	Constant	US EPA Energy Star, 2007
1.73	Volume adjustment for freezers (Unitless)	Constant	US EPA Energy Star, 2007

Note: Default values can be overridden by the user if site-specific information is available.

Simple Refrigerator-Specific Approach

OUs can utilize this approach to estimate the energy savings from refrigerators, compact refrigerators, and freezers without knowing the various style types and varying storage volume. The methodology estimates the energy consumption of refrigerators in the baseline and activity scenario based on the market data that takes the weighted average of the storage volumes of various types of refrigerators and market share of each type of refrigerators to estimate annual energy consumption of a sample refrigerator type. This approach also assumes that the activity refrigerators replace the same kind of baseline refrigerators and the energy savings come from assumed constant factors that estimate energy consumption. To use this approach, OUs will need to know:

1) Number of refrigerators, compact refrigerators and freezers, and
2) Estimated energy savings from energy efficient refrigerators, compacts, and freezers.

The total annual energy consumed by the baseline and activity refrigerators can be estimated using *Equation 92*:

Equation 92

$$\text{Electricity Consumed} = \text{Number of Units} \times \frac{\text{Electricity Consumed}}{\text{Unit}}$$

Table 94 describes these data elements, whether data are default or user-provided, and suggested data sources.

Table 94: Data Requirements for Equation 92

Data Element	Definition	Data Type	Data Source
Electricity Consumed	The quantity of electricity consumed by the baseline or activity equipment in the reporting year (kWh)	Calculated	Equation 92
Number of Refrigerator Units	The total number of units replaced in the Baseline Energy Scenario (i.e., installed under the activity) for specific style types, in the reporting year (Units)	User-Provided	N/A
Electricity Consumed per Unit	The quantity of energy consumed by a sample refrigerator type in the Baseline Energy Scenario and activity in the reporting year. This estimate is based on assumed energy efficiency $\left(\frac{\text{kWh}}{\text{unit}}\right)$. Default	Default	Based on Confidential Data

Data Element	Definition	Data Type	Data Source
	values found in Appendix G: Tables for Appliance & Equipment Efficiency.		

Note: Default values can be overridden by the user if site-specific information is available.

STEP 2. DEFINE THE BASELINE AND ACTIVITY ENERGY SOURCE

In order to estimate GHG emissions reduced due to appliance efficiency projects, OUs should then define the source of energy in the baseline and activity scenario. Options for the energy options are:

1) The baseline and activity appliances consume electricity from the regional grid.
2) The baseline and activity appliances combust fuels on-site.

Activities that make use of estimate electricity consumption, in kilowatt-hours (kWh) (Approach 2 and refrigerator-specific approaches) should not use baseline and activity scenarios which combust fuels on-site.

STEP 3. ESTIMATE BASELINE AND ACTIVITY GHG EMISSIONS

Depending on the baseline and activity energy scenario chosen in Step 2, users should use the approach for either *Grid-Connected Activities* or *On-Site Combustion* equations below to estimate baseline and activity GHG emissions.

Grid-Connected Activities

Emissions from grid connected activities in the baseline and activity scenarios can be estimated using the electricity consumed (kWh) from the appliances during the reporting year, along with location-specific emission factors. USAID OUs will need to know:

1) The total annual electricity consumed, and
2) The country in which the implementation occurs.

Emissions from grid electricity consumed by the baseline and the activity appliances can be estimated using Equation 93:

Equation 93

$$\text{Baseline Emissions} = \text{Electricity Consumed} \times \left(\frac{1}{1 - \text{Line Loss Rate}}\right) \times \text{EF}_{\text{Grid}}$$

The data elements are described, and their type and sources are given in *Table 95* below.

Table 95: Data Requirements for Equation 93

Data Element	Definition	Data Type	Data Source
Baseline Emissions	The amount, in metric tons of carbon dioxide equivalent, of GHG emissions in the baseline or activity scenario, in the reporting year (tCO_2e)	Calculated	Equation 93

Data Element	Definition	Data Type	Data Source
Electricity Consumed	The quantity of electricity consumed under the baseline or during the activity in the reporting year (kWh)	Calculated	Equation 89, or Equation 90, or Equation 91, or Equation 92
Line Loss Rate	Average annual technical grid line loss due to transmission and distribution, by country (%)	Default	Expert Judgement based on IEA, 2013
EF_{Grid}	The average combined marginal GHG emission factor for grid electricity, by country $\left(\frac{tCO_2e}{kWh}\right)$	Default	IGES, 2015 IEA, 2013

Note: Default values can be overridden by the user if site-specific information is available.

On-Site Combustion

If the activity is replacing fuels for cooking, heating or lighting—i.e., not power generation—then emissions from on-site combustion can be estimated using the amount and type of fuel consumed in the Baseline Energy Scenario. OUs will need to know:

1) The amount of fuel consumed in the Baseline Energy Scenario during the reporting year, and
2) The type of fuel that was replaced by the activity.

Emissions from fuels consumed on-site in the baseline and the activity scenarios can be estimated using *Equation 94*:

Equation 94

$$\text{Baseline Emissions} = \text{Fuel Consumed} \times \text{Fuel Energy Content} \times EF_{\text{Fuel Specific}} \times \left(\frac{1\ \text{t}}{1{,}000{,}000\ \text{g}}\right)$$

Table 96 describes these data elements, whether data are default or user-provided, and suggested data sources.

Table 96: Data Requirements for Equation 94

Data Element	Definition	Data Type	Data Source
Baseline Emissions	The amount, in metric tons of carbon dioxide equivalent, of GHG emissions in the baseline or activity scenario, in the reporting year (tCO_2e)	Calculated	Equation 94
Fuel Consumed	The quantity of fuel consumed in the reporting year. Applicable units by fuel type and unit conversions found in Appendix L: Fuel Consumption Units.	User-Provided	N/A
Fuel Energy Content	The energy content of the selected fuel, in GJ per selected units $\left(\frac{GJ}{units}\right)$. Default values and applicable units found in Appendix L: Fuel Consumption Units.	Default	Various, see Appendix L: Fuel Consumption Units

Data Element	Definition	Data Type	Data Source
$EF_{\text{Fuel Specific}}$	GHG emission factor for stationary combustion of specific fuel type $\left(\frac{gCO_2e}{GJ}\right)$. Default values found in Appendix D: Fuel Emission Factors.	Default	IPCC, 2006
$\frac{1\ t}{1{,}000{,}000\ g}$	Gram to ton conversion factor $\left(\frac{t}{g}\right)$	Conversion Factor	NIST, 2006

Note: Default values can be overridden by the user if site-specific information is available.

STEP 4. ESTIMATE EMISSIONS REDUCED

GHG emissions reduced are equal to the difference in GHG emissions from the emissions from the appliance usage in the Baseline Energy Scenario and GHG emissions resulting from the appliance usage in the activity scenario during the reporting year:

Equation 95

$$\text{Emissions Reduced} = \text{Baseline Emissions} - \text{Activity Emissions}$$

Table 97 describes these data elements, whether data are default or user-provided, and suggested data sources.

Table 97: Data Requirements for Equation 95

Data Element	Definition	Data Type	Data Source
Emissions Reduced	The amount, in metric tons of carbon dioxide equivalent, of GHG emissions reduced in the reporting year (tCO_2e)	Calculated	Equation 95
Baseline Emissions	The amount, in metric tons of carbon dioxide equivalent, of GHG emissions in the Baseline Energy Scenario, associated with the baseline fuel type, that would have occurred in the reporting year (tCO_2e)	Calculated	Equation 93, or Equation 94
Activity Emissions	The amount, in metric tons of carbon dioxide equivalent, of GHG emissions that occurred due to the activity in the reporting year (tCO_2e)	Calculated	Equation 93, or Equation 94

The emissions reduced will equal to the emissions under the Baseline Energy Scenario as the activity emissions in the above will be equal to zero.

3.5 Clean Energy Result: Increase Energy System Efficiency

This section includes methodologies regarding updating existing systems that produce energy for end users, or installing more efficient energy generation technologies. Improvements to performance, or a reduction in losses from electricity and gas distribution systems, result in a net gain to the grid that would have otherwise been lost. GHG emissions are decreased by the reduction in fossil fuels combusted to meet the same amount of end-use energy demand. For example, combined heat and power production activities are typically more efficient than separate power and heat generation. Box 8 lists some of the activities that achieve this Clean Energy Result.

Box 8: GCC Activities that Increase Energy System Efficiency

Key Characteristics:

- Energy generation and supply
- Increased efficiency and reduced line losses

Example Activities:

- Combined heat and power production (cogeneration)
- Improve performance and reduce losses of electricity and gas distribution utilities, if integral to GHG reduction plan
- Electricity generation transmission infrastructure projects
- Gas transmission infrastructure projects using gas that would otherwise be flared or vented
- Policies providing incentives for energy sector utilities to improve efficiency of operations and quality of service, leading to attractive climate for investment capital
- Electricity distribution reform–e.g., reforms of electricity and gas distribution systems and utilities that reduce losses and increase revenues

The methodologies included in this section are:

- Transmission and Distribution System Upgrades: Technical Loss Reductions
- Stranded Natural Gas Capture Systems

3.5.1 Transmission and Distribution System Upgrades: Technical Loss Reductions

CLEAN ENERGY RESULT: INCREASE ENERGY SYSTEM EFFICIENCY

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The Transmission and Distribution Systems Upgrade – Technical Loss Reductions methodology presents multiple methods for calculating the greenhouse gas emissions reductions associated with the reduction of technical electricity losses in the transmission and distribution systems. These technical transmission and distribution losses include electrical and thermal losses that occur as electrical power is delivered through transmission and distribution infrastructure, which includes power lines, transformers, and other system equipment.

The remainder of this section describes the steps to calculate GHG emission reductions from activities involving transmission and distribution systems upgrades. These steps include:

- Step 1: Define the Baseline Energy Scenario
- Step 2: Estimate the baseline technical loss rate
- Step 3: Estimate the activity technical loss rate
- Step 4: Estimate GHG emissions from the baseline practice
- Step 5: Estimate GHG emissions from the activity practice
- Step 6: Estimate GHG emissions reduced

STEP 1. DEFINE THE BASELINE ENERGY SCENARIO

In order to estimate GHG emissions reduced by the implementation of transmission and distribution systems upgrade activities, OUs should define the baseline scenario[66] (see Section 2 of the Protocol for a discussion of baseline energy and fuel consumption). In the case of transmission and distribution systems upgrade activities, energy in the baseline and the activity is assumed to come from electricity from the national grid.

[66] The Protocol assumes that activities that generate or consume energy are displacing energy that would have been provided by conventional sources.

OUs need to know the technical loss percentage before and after the implementation of the activity. If the OUs know the technical loss rate before the project was implemented and after the project, they should proceed to Step 4.

STEP 2. ESTIMATE THE BASELINE TECHNICAL LOSS RATE

If the OUs do not know the technical loss rate, they should use the approach presented below.

The calculation is based on the system-wide impact of the upgraded network configuration. For the customers that are served by the upgraded network configuration, OUs will need to know:

1) The amount of net electricity that was generated before the system upgrades (annual average or for previous year)
2) The amount of delivered before the system upgrades (annual average or for previous year)

The baseline technical loss rate can be estimated using Equation 96:

Equation 96

$$\text{Baseline Technical Loss Rate} = \frac{(\text{Electricity Delivered Before System Upgrades} - \text{Net Electricity Generated Before System Upgrades})}{\text{Net Electricity Generated Before System Upgrades}}$$

Table 98 describes the data elements of Equation 96, whether they are default or user-provided, and suggested data sources.

Table 98: Data Requirements for Equation 96

Data Element	Description	Data Type	Data Source
Baseline Technical Loss Rate	The technical transmission and distribution loss rate prior to the system upgrades (%)	Calculated	Equation 96
Electricity Delivered Before System Upgrades	The amount of electricity delivered to the customers served by the upgraded network configuration for either the previous year or an annual average (kWh)	User-Provided	N/A
Net Electricity Generated Before System Upgrades	The amount of electricity generated for the customers served by the upgraded network configuration for either the previous year or an annual average (kWh)	User-Provided	N/A

STEP 3. ESTIMATE THE ACTIVITY TECHNICAL LOSS RATE

Once OUs have calculated the baseline technical loss rate, the OU will need to calculate the activity technical loss rate. OUs will need to know:

1) The amount of net electricity generated in the reporting year
2) The amount of electricity delivered in the reporting year

Emissions from the activity can be estimated using Equation 97:

Equation 97

$$\text{Activity Technical Loss Rate} = \frac{(\text{Electricity Delivered After System Upgrades} - \text{Net Electricity Generated After System Upgrades})}{\text{Net Electricity Generated After System Upgrades}}$$

Table 99 includes the data elements of Equation 97, whether they are default or user-provided, and suggested data sources.

Table 99: Data Requirements for Equation 97

Data Element	Description	Data Type	Data Source
Activity Technical Loss Rate	The technical transmission and distribution loss rate in the reporting year after the system upgrades (%)	Calculated	Equation 97
Electricity Delivered After System Upgrades	The amount of electricity delivered to the customers served by the upgraded network configuration in the reporting year (kWh)	User-Provided	N/A
Net Electricity Generated After System Upgrades	The amount of electricity generated for the customers served by the upgraded network configuration in the reporting year (kWh)	User-Provided	N/A

STEP 4. ESTIMATE THE GHG EMISSIONS FROM THE BASELINE PRACTICE

In order to estimate GHG emissions reduced, OUs should estimate GHG emissions for the baseline scenario. OUs will need to know:

1) The amount of net electricity generated in the reporting year
2) Baseline technical loss rate

Emissions associated with the baseline practice can be estimated using Equation 98:

Equation 98

$$\text{Baseline Emissions} = \text{Net Electricity Delivered After System Upgrades} \times \frac{1}{(1 - \text{Baseline Technical Loss Rate})} \times EF_{Grid}$$

Table 100 includes the data elements of Equation 98, whether they are default or user-provided, and suggested data sources.

Table 100: Data Requirements for Equation 98

Data Element	Description	Data Type	Data Source
Baseline Emissions	The amount, in metric tons of carbon dioxide equivalent, of GHG emissions in the Baseline Energy Scenario, associated with the baseline fuel type, that would have occurred in the reporting year (tCO_2e)	Calculated	Equation 98

Net Electricity Delivered After System Upgrades	The amount of electricity delivered to the customers served by the upgraded network configuration in the reporting year (kWh)	User-Provided	N/A
Baseline Technical Loss Rate	Technical Transmission and Distribution Loss Rate in the reporting year (%)	User-Provided	User-Provided, or Equation 96
EF_{Grid}	The average combined marginal GHG emission factor for grid electricity, by country $\left(\frac{tCO_2e}{kWh}\right)$	Default	IGES, 2015 IEA, 2013

*Note: Default values can be overridden by the user if site-specific information is available.

STEP 5. ESTIMATE THE GHG EMISSIONS FROM THE ACTIVITY PRACTICE

In order to estimate GHG emissions reduced, OUs should estimate GHG emissions for the activity scenario. OUs will need to know:

1) The amount of net electricity generated in the reporting year
2) Activity technical loss rate

Emissions associated with the baseline practice can be estimated using Equation 99:

Equation 99

$$\text{Activity Emissions} = \text{Net Electricity Delivered After System Upgrades} \times \frac{1}{(1 - \text{Activity Technical Loss Rate})} \times EF_{Grid}$$

Table 101 includes the data elements of Equation 99, whether they are default or user-provided, and suggested data sources.

Table 101: Data Requirements for Equation 99

Data Element	Description	Data Type	Data Source
Activity Emissions	The amount, in metric tons of carbon dioxide equivalent, of GHG emissions that occurred due to the activity in the reporting year (tCO_2e)	Calculated	Equation 99
Net Electricity Delivered After System Upgrades	The amount of net electricity delivered to the customers served by the upgraded network configuration in the reporting year (kWh)	User-Provided	N/A
Activity Technical Loss Rate	Technical Transmission and Distribution Loss Rate in the reporting year (%)	User-Provided	User-Provided, or Equation 97
EF_{Grid}	The average combined marginal GHG emission factor for grid electricity, by country $\left(\frac{tCO_2e}{kWh}\right)$	Default	IGES, 2015 IEA, 2013

*Note: Default values can be overridden by the user if site-specific information is available.

STEP 6. ESTIMATE GHG EMISSIONS REDUCED

GHG emission reductions from technical upgrades to the transmission and distribution lines are equal to the difference in GHG emissions from baseline technical loss rate and the activity technical loss rate in the reporting year:

Equation 100

$$\text{Emissions Reduced} = \text{Baseline Emissions} - \text{Activity Emissions}$$

Table 102 describes the data elements of *Equation 100*, whether they are default or user-provided, and suggested data sources.

Table 102: Data Requirements for Equation 100

Data Element	Description	Data Type	Data Source
Emissions Reduced	The amount, in metric tons of carbon dioxide equivalent, of GHG emissions reduced in the reporting year (tCO_2e)	Calculated	Equation 100
Baseline Emissions	The amount, in metric tons of carbon dioxide equivalent, of GHG emissions in the Baseline Energy Scenario, associated with the baseline fuel type, that would have occurred in the reporting year (tCO_2e)	Calculated	Equation 98
Activity Emissions	The amount, in metric tons of carbon dioxide equivalent, of GHG emissions that occurred due to the activity in the reporting year (tCO_2e)	Calculated	Equation 99

3.5.2 Stranded Natural Gas Capture Systems

CLEAN ENERGY RESULT:
INCREASE ENERGY SYSTEM
EFFICIENCY

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This section applies to the following activities:

- The capture of stranded natural gas that would have been either vented or flared, and conversion to compressed natural gas (CNG), liquefied natural gas (LNG), or electricity via a gas turbine or microturbine;
- Enabling activities that directly lead to increased implementation of or access to capturing stranded gas in the reporting year.

Stranded gas is natural gas that is produced as part of petroleum (crude oil and gas) production that is not sent to the market due to lack of transportation infrastructure. Thus, stranded gas is often flared or vented. Diverting stranded gas to a beneficial use, such as electricity production and CNG, provides an approach to use a waste stream to offset current sources of energy.

The remainder of this section describes the steps to calculate GHG emission reductions from activities involving capturing stranded natural gas that would have otherwise been flared or vented[67]. The baseline gas and emissions are estimated based on the activity captured gas data. These steps include:

- Step 1: Define the activity
- Step 2: Estimate the captured natural gas during the activity
- Step 3: Estimate activity GHG emissions
- Step 4: Define the Baseline Energy Scenario
- Step 5: Estimate GHG emissions from baseline natural gas production practices
- Step 6: Estimate baseline GHG emissions from energy production
- Step 7: Estimate total baseline GHG emissions
- Step 8: Estimate GHG emissions reduced

[67] Due to the complexity of this methodology, and in order to provide the simplest mathematical procedure, the order of these steps is presented slightly differently than the approach described in the GHG Accounting Approach and steps presented in other CLEER methodologies. This should not affect the estimated emission reductions.

STEP 1. DEFINE THE ACTIVITY

In order to estimate GHG emissions reduced, OUs should define the activity, which describes the ultimate end product or use of the captured stranded gas. The methodology provides common end-uses of the captured natural gas.

OUs should know the volume of captured natural gas corresponding to any of the activities below. If OUs do not know the volume of captured natural gas, Step 2 provides four approaches to estimate the volume of natural gas captured corresponding to one of four activities:

1) Stranded gas is captured and converted to CNG (proceed to *Approach 1*)
2) Stranded gas is captured and converted to LNG (proceed to *Approach 2*)
3) Stranded gas is captured and generates electricity using a gas turbine (proceed to *Approach 3*)
4) Stranded gas is captured and generates electricity using a microturbine (proceed to *Approach 4).*

If the amount of natural gas captured during the activity is known, proceed to Step 3.

STEP 2. ESTIMATE CAPTURED NATURAL GAS DURING THE ACTIVITY

Approach 1: Based on the Amount of Compressed Natural Gas Product

If OUs do not have the volume of captured gas but do know the mass of the CNG product produced, the following equation should be used. OUs will need to know:

1) The total mass of the CNG product
2) The temperature of the CNG product
3) The pressure of the CNG product
4) The mole fraction of methane in the CNG product
5) The mole fraction of methane in the captured natural gas
6) The process efficiency of converting stranded natural gas to CNG
7) The amount of electricity used in the CNG conversion that was generated using the captured stranded gas

Recovered natural gas from the activity can be estimated using *Equation 101, Equation 102*, and *Equation 103*.

Equation 101

$$\text{Volume of Captured Natural Gas} = \text{Natural Gas in CNG Product} + \text{Natural Gas used for Electricity in CNG Conversion}$$

Equation 102

$$\begin{aligned}&\text{Natural Gas in CNG Product}\\ &= \frac{\text{Amount of CNG Product} \times \text{Standard Temperature} \times \text{Actual Pressure} \times \text{Mole Fraction of Methane}_{\text{CNG}}}{\text{Density of Methane}_{\text{CNG Product}} \times \text{Actual Temperature} \times \text{Standard Pressure} \times \text{Mole Fraction of Methane}_{\text{Captured NG}}}\\ &\times \frac{1}{\text{Process Efficiency}}\end{aligned}$$

Equation 103

$$\begin{aligned}&\text{Natural Gas used for Electricity in CNG Conversion}\\ &= \text{Amount of Electricity Used in CNG Conversion} \times \frac{\text{Net Electricity Generation Heat Rate}}{\text{Fuel Gas Net Heat Content}}\\ &\times \frac{0.02832\ \text{m}^3}{1\ \text{ft}^3}\end{aligned}$$

Table 103 describes the data elements of *Equation 101*, *Equation 102*, and *Equation 103*, whether they are default or user-provided, and suggested data sources.

Table 103: Data Requirements for Equation 101, Equation 102, and Equation 103

Data Element	Description	Data Type	Data Source
Volume of Captured Natural Gas	Volume of stranded natural gas that was captured (m^3)	Calculated	Equation 101
Natural Gas in CNG Product	Volume of natural gas within the generated CNG product (m^3)	Calculated	Equation 102
Natural Gas used for Electricity in CNG Conversion	Volume of natural gas used for electricity generation when producing CNG (m^3)	Calculated	Equation 103
Amount of CNG Product	The amount of CNG product produced by the captured natural gas (kg)	User-Provided	N/A
Actual Temperature	The temperature of the CNG product (K)	User-Provided	N/A
Standard Pressure[68]	The standard pressure conditions when determining the density of a gas. Default value is 101,325 Pa.	Default	ISO,1994
Mole Fraction of $\text{Methane}_{\text{CNG}}$	Mole fraction of CH_4 in CNG (unitless)	User-Provided	N/A
Density of $\text{Methane}_{\text{CNGProduct}}$	Density of methane at operating conditions of the CNG Product.	Calculated using User-Provided values	N/A

[68] Standard Temperature and Pressure (STP) are standard reference conditions for gases when calculating gaseous properties such as density. The standard temperature is 273 Kelvin and standard pressure is 101,325 pascals. At STP, one mole of gas occupies 22.4 liters of volume.

Standard Temperature	The standard temperature conditions when determining the density of a gas. Default value is 273.15 K.	Default	ISO, 1994
Actual Pressure	The pressure of the CNG product (Pa)	User-Provided	N/A
$\text{Mole Fraction of Methane}_{\text{Captured NG}}$	Mole fraction of CH_4 in captured natural gas (unitless)	User-Provided	N/A
Process Efficiency	The efficiency of the conversion process from stranded natural gas to CNG (%). Default value is 97.5%.	Default	ICF Expert Judgement
Amount of Electricity Used in CNG Conversion	The amount of electricity that was used in the CNG process that was generated using the captured natural gas (kWh)	User-Provided	N/A
Net Electricity Generation Heat Rate	The heat rate for net electricity generation for a natural gas power plant, by country $\left(\frac{\text{Btu}}{\text{kWh}}\right)$	Default	IEA, 2008
Fuel Gas Net Heat Content	The heat content of natural gas, by country $\left(\frac{\text{Btu}}{\text{ft}^3}\right)$	Default	EIA, 2014
$\frac{0.02832\ \text{m}^3}{1\ \text{ft}^3}$	Cubed feet to cubed meters conversion factor $\left(\frac{\text{m}^3}{\text{ft}^3}\right)$	Conversion Factor	NIST, 2006

Note: Default values can be overridden by the user if site-specific information is available.

Approach 2: Based on the Amount of Liquefied Natural Gas Product

If OUs do not have the volume of captured gas but do know the mass of the LNG product produced, the following equation should be used. OUs will need to know:

1) The total mass of the LNG product
2) The boiling temperature of the LNG product.
3) The mole fraction of methane in the LNG product
4) The mole fraction of methane in the captured natural gas
5) The process efficiency of converting stranded natural gas to CNG
6) The amount of electricity used in the CNG conversion that was generated using the captured stranded gas

Captured natural gas from the activity can be estimated using *Equation 104, Equation 105*, and *Equation 106*:

Equation 104

$$\text{Volume of Captured Natural Gas} = \text{Natural Gas in LNG Product} + \text{Natural Gas used for Electricity in LNG Conversion}$$

Equation 105

$$\text{Natural Gas in LNG Product} = \frac{\text{Amount of LNG Product} \times \text{Mole Fraction of Methane}_{\text{LNG}}}{\text{Density of LNG} \times \text{Mole Fraction of Methane}_{\text{Captured NG}}} \times \frac{600\ \text{m}^3 \text{of Natural Gas}}{\text{m}^3 \text{of LNG}} \times \frac{1}{\text{Process Efficiency}}$$

Equation 106

$$\text{Natural Gas used for Electricity in LNG Conversion} = \text{Amount of Electricity Used in LNG Conversion} \times \frac{\text{Net Electricity Generation Heat Rate}}{\text{Fuel Gas Net Heat Content}} \times \frac{0.02832\ \text{m}^3}{1\ \text{ft}^3}$$

Table 104 includes the data elements of *Equation 104, Equation 105*, and *Equation 106*, whether they are default or user-provided, and suggested data sources.

Table 104: Data Requirements for Equation 104, Equation 105, and Equation 106

Data Element	Description	Data Type	Data Source
Volume of Captured Natural Gas	Volume of stranded natural gas that was captured (m^3)	Calculated	Equation 104
Natural Gas in LNG Product	Volume of natural gas within the generated LNG product (m^3)	Calculated	Equation 105
Natural Gas used for Electricity in LNG Conversion	Volume of natural gas used for electricity generation when producing LNG (m^3)	Calculated	Equation 106
Amount of LNG Product	The amount of LNG product produced by the captured natural gas (kg)	User-Provided	N/A
$\frac{600\ \text{m}^3 \text{of Natural Gas}}{\text{m}^3 \text{of LNG}}$	Conversion factor of 1 volumetric unit of LNG to Natural Gas	Default	DOE, 2013
$\text{Mole Fraction of Methane}_{\text{LNG}}$	Mole fraction of CH_4 in LNG (unitless)	User-Provided	N/A
Density of LNG	Density of LNG at boiling point. Default value is 425.61 $\frac{\text{kg}}{\text{m}^3}$.	Default	Engineering Toolbox
$\text{Mole Fraction of Methane}_{\text{Captured NG}}$	Mole fraction of CH_4 in captured natural gas (unitless)	User-Provided	N/A
Process Efficiency	The efficiency of the conversion process from stranded natural gas to LNG (%). Default value is 97.5%.	Default	ICF Expert Judgement
Amount of Electricity Used in LNG Conversion	The amount of electricity that was used in the LNG conversion by the captured natural gas to produce the LNG (kWh)	User-Provided	N/A

Net Electricity Generation Heat Rate	The heat rate for net electricity generation for a natural gas power plant, by country $\left(\frac{\mathrm{Btu}}{\mathrm{kWh}}\right)$	Default	IEA, 2008
Fuel Gas Net Heat Content	The heat content of natural gas, by country $\left(\frac{\mathrm{Btu}}{\mathrm{ft}^3}\right)$	Default	EIA, 2014
$\frac{0.02832\ \mathrm{m}^3}{1\ \mathrm{ft}^3}$	Cubed feet to cubed meters conversion factor $\left(\frac{\mathrm{m}^3}{\mathrm{ft}^3}\right)$	Conversion Factor	NIST, 2006

Note: Default values can be overridden by the user if site-specific information is available

Approach 3: Based on the Amount of Electricity Generated from Gas Turbines

If OUs do not have the volume of captured gas but do know the amount of electricity produced using a gas turbine, the following equation should be used. OUs will need to know:

1) The amount of electricity generated by the gas turbine
2) The pressure and temperature of the captured natural gas
3) The mole fraction of CO_2 in the captured gas
4) The compressibility factor of the captured gas
5) Mole fraction of hydrocarbon constituents *i* (methane, ethane, propane, butane, and pentane-plus) in the captured gas
6) The turbine efficiency

Captured natural gas from the activity can be estimated using *Equation 107* and *Equation 108*:

Equation 107

$$\begin{aligned}\text{Volume of Captured Natural Gas}\\ &= \text{Electricity Generated} \times \mathrm{EF_{gas}} \times \text{Actual Temperature} \times \text{Standard Pressure} \times \text{Compressibility Factor}\\ &\times \frac{1}{\text{Total Carbon Mole Fraction}} \times \frac{1}{\text{Density of } \mathrm{CO_2}} \times \frac{1}{\text{Standard Temperature}} \times \frac{1}{\text{Actual Pressure}}\end{aligned}$$

Equation 108

$$\begin{aligned}\text{Total Carbon Mole Fraction}\\ &= \text{Mole Fraction of } \mathrm{CO_2} + \text{Turbine Efficiency}\\ &\times \sum_{i=1}^{5}(\text{Mole fraction of each Hydrocarbon Constituent}_i \times \text{Number of Carbon Atoms in Hydrocarbon}_i)\end{aligned}$$

Table 105 includes the data elements of *Equation 107* and *Equation 108*, whether they are default or user-provided, and suggested data sources.

Table 105: Data Requirements for Equation 107 and Equation 108

Data Element	Description	Data Type	Data Source
Volume of Captured Natural Gas	Volume of stranded natural gas that was captured (m^3)	Calculated	Equation 107

Electricity Generated	The quantity of electricity generated in the reporting year by the gas turbine (kWh)	User-Provided	N/A
EF_{gas}	CO_2 emissions per kWh from electricity generation using gas turbine $\left(\frac{kgCO_2}{kWh}\right)$	Default	IEA, 2014
Actual Temperature	The temperature of captured natural gas (K)	User-Provided	N/A
Standard Pressure	The standard pressure conditions when determining the density of a gas. Default Value is 101,325 Pa.	Default	ISO, 1994
Compressibility Factor	Compressibility factor at actual conditions for natural gas. You may use either a default compressibility factor of 1, or a site-specific compressibility factor based on actual temperature and pressure conditions. (unitless)	User-Provided	ICF Expert Judgement
Total Carbon Mole Fraction	The sum total of the fraction of carbon contributed by each constituent hydrocarbon *i* (methane, ethane, propane, butane, and pentane-plus) in combusted gas (unitless)	Calculated	Equation 108
Density of CO_2	Density of CO_2 at standard conditions. Default value is 1.8576 $\frac{kg}{m^3}$.	Default	Engineering Toolbox
Standard Temperature	The standard temperature conditions when determining the density of a gas. Default value is 273.15 K.	Default	ISO, 1994
Actual Pressure	Actual pressure of captured natural gas (Pa)	User-Provided	N/A
Mole Fraction of CO_2	Mole fraction of CO_2 in captured gas (unitless)	User-Provided	N/A
Turbine Efficiency	Gas combustion efficiency (unitless)	User-Provided	N/A
Mole Fraction of the Hydrocarbon Constituents	Mole fraction of hydrocarbon constituents *i* (methane, ethane, propane, butane, and pentane-plus) in captured gas (unitless)	User-Provided	N/A
Number of Carbon Atoms in $\mathrm{Hydrocarbon}_i$	Number of carbon atoms in the hydrocarbon constituents *i* in the captured gas (1 for methane, 2 for ethane, 3 for propane, 4 for butane, and 5 for pentanes-plus) (unitless)	Default	UK Chemguide, 2012

Note: Default values can be overridden by the user if site-specific information is available.

Approach 4: Based on the Amount of Electricity Generated from Microturbines

If OUs do not have the volume of captured gas but do know the rate of natural gas input into a microturbine, the following equation should be used. This approach assumes all natural gas from the flare is used in power generation by the microturbine. OUs will need to know:

1) The fuel input rate for the microturbine
2) The operational run time of the microturbine

Captured natural gas from the activity can be estimated using *Equation 109*:

Equation 109

$$\text{Volume of Captured Natural Gas} = \frac{\text{Fuel Input Rate}}{\text{Natural Gas Higher Heating Value}} \times \text{Operational Run Time}$$

Table 106 includes the data elements of *Equation 109*, whether they are default or user-provided, and suggested data sources.

Table 106: Data Requirements for Equation 109

Data Element	Description	Data Type	Data Source
Volume of Captured Natural Gas	Volume of stranded natural gas that was captured (m^3)	Calculated	Equation 109
Fuel Input Rate	Fuel input rate for microturbine $\left(\frac{\text{Btu}}{\text{h}}\right)$	User-Provided	N/A
Natural Gas Higher Heating Value	Higher heating value of Natural Gas, by country $\left(\frac{\text{Btu}}{\text{m}^3}\right)$	Default	EIA, 2014
Operational Run Time	The operational run time of the microturbine (hours)	User-Provided	N/A

Note: Default values can be overridden by the user if site-specific information is available.

STEP 3. ESTIMATE ACTIVITY EMISSIONS

Once OUs have calculated the volume of captured natural gas, they must calculate the GHG emissions associated with the combustion of natural gas under the activity. It is assumed that all captured gas is eventually combusted for useful energy. For off-site activities, no transportation emissions or losses are accounted for. OUs will need to know:

1) The total volume of captured natural gas (if not estimated under Step 2)
2) The net calorific value of the natural gas

Emissions from the activity can be estimated using *Equation 110*:

Equation 110

$$\begin{aligned}\text{Activity Emissions} \\ &= \text{Total Volume of Captured Natural Gas} \times \text{Net Calorific Value of Gas} \\ &\times \text{EF}_{\text{Natural Gas}} \times \left(\frac{1\ \text{t}}{1{,}000\ \text{kg}}\right)\end{aligned}$$

Table 107 includes the data elements of *Equation 110*, whether they are default or user-provided, and suggested data sources.

Table 107: Data Requirements for Equation 110

Data Element	Description	Data Type	Data Source
Activity Emissions	The amount, in metric tons of carbon dioxide equivalent, of GHG emissions that occurred due to the activity in the reporting year (tCO_2e)	Calculated	Equation 110
Total Volume of Captured Gas	The volume of natural gas that was flared or vented after accounting for natural gas that was used on-site (m^3)	User-Provided or Calculated	User Input or Equation 101, Equation 104, Equation 107, Equation 109
Net Calorific Value of Gas	The amount of energy released for a specific composition and volume of natural gas, by country $\left(\frac{\mathrm{GJ}}{\mathrm{m}^3}\right)$. Default values found in Appendix Q: Net Calorific Value of Natural Gas.	Default	EIA, 2014
$\mathrm{EF}_{\mathrm{Natural\ Gas}}$	The amount of GHGs, in $kgCO_2e$, released when burning natural gas. Default value is 56.155 $\frac{\mathrm{kgCO_2e}}{\mathrm{GJ}}$.	Default	IPCC, 2006
$\frac{1\ \mathrm{t}}{1{,}000\ \mathrm{kg}}$	Kilogram to ton conversion factor $\left(\frac{\mathrm{t}}{\mathrm{kg}}\right)$	Conversion Factor	NIST, 2006

Note: Default values can be overridden by the user if site-specific information is available.

STEP 4. DEFINE THE BASELINE ENERGY SCENARIO

OUs should define the Baseline Energy Scenario[69] in order to estimate GHG emissions from that scenario. It is important to consider both the baseline stranded natural gas practice, and baseline source of energy production to recover fully the entire scope of emissions impacts. The baseline natural gas practice represents the emissions that would have occurred if the stranded gas had not been flared or vented. The baseline energy production scenario represents the emissions that would have occurred if the stranded gas has not been diverted into usable forms. Components and options for the Baseline Energy Scenario are:

1) The natural gas practice. Options are:

    a) Natural gas captured by the activity would be flared and combustion byproduct is released into the atmosphere (proceed to Step 5 *Approach 1*)
    b) Natural gas captured by the activity would be vented and released into the atmosphere without combustion (proceed to Step 5 *Approach 2*)

2) The source of energy production. The only option for the Baseline Energy Scenario is that energy would have come from on-site or off-site combustion of natural gas. This method assumes that the captured natural gas, and associated natural gas products, would replace

[69] The baseline scenario is a description of what would have most likely occurred in the absence of the activity. See *Section 2* for a discussion about determining baseline scenarios.

natural gas, and associated natural gas products, mined and sold for the purpose of energy production. For example, LNG from captured natural gas replaces LNG in the market.

STEP 5. ESTIMATE BASELINE GHG EMISSIONS FROM NATURAL GAS PRACTICE

Approach 1: Flared Natural Gas

To quantify the emissions associated with natural gas that was flared in the baseline scenario, users should use the equations below to estimate baseline GHG emissions associated with the release of natural gas.

OUs will need to know:

1) The total volume of captured natural gas (Step 1 or Step 2), and
2) The average net calorific value of captured gas for the facility.

Baseline GHG emissions from the flared natural gas can be estimated using *Equation 111*:

Equation 111

$$\text{Baseline Emissions}_{\text{Natural Gas Practice}} = \text{Volume of Total Captured Natural Gas} \times \text{Net Calorific Value of Natural Gas} \times \text{EF}_{\text{Natural Gas}} \times \left(\frac{1\text{ t}}{1{,}000\text{ kg}}\right)$$

Table 108 includes the data elements of *Equation 111*, whether they are default or user-provided, and suggested data sources.

Table 108: Data Requirements for Equation 111

Data Element	Description	Data Type	Data Source
Baseline Emissions$_{\text{Natural Gas Practice}}$	GHG emissions in the baseline of the reporting year (tCO_2e)	Calculated	Equation 111
Total Volume of Captured Gas	The volume of natural gas that was flared or vented after accounting for natural gas that was used on-site (m^3)	User-Provided	User Input or Equation 101, Equation 104, Equation 107, Equation 109
Net Calorific Value of Gas	The amount of energy released for a specific composition and volume of natural gas, by country $\left(\frac{\text{GJ}}{\text{m}^3}\right)$. Default values found in Appendix Q: Net Calorific Value of Natural Gas.	Default	EIA, 2014
$\text{EF}_{\text{Natural Gas}}$	The amount of GHGs, in $kgCO_2e$, released when burning natural gas. Default value is 56.155 $\frac{\text{kgCO}_2\text{e}}{\text{GJ}}$.	Default	IPCC, 2006
$\frac{1\text{ t}}{1{,}000\text{ kg}}$	Kilogram to metric ton conversion factor $\left(\frac{\text{t}}{\text{kg}}\right)$	Conversion Factor	NIST, 2006

Note: Default values can be overridden by the user if site-specific information is available.

Approach 2: Vented Natural Gas

To quantify the emissions associated with natural gas that are stranded vented gases in the baseline scenario, users should use the equation below.

OUs will need to know:

1) Volume of total captured gas measured after on-site use summed over one year, and
2) The mass fraction of methane in the captured natural gas

Baseline GHG emissions from the vented natural gas can be estimated using *Equation 112*:

Equation 112

$$\text{Baseline Emissions}_{\text{Natural Gas Practice}} = \text{Volume of Natural Gas Vented} \times \text{Mass Fraction of Methane} \times \text{Density of Methane} \times \text{GWP}_{\text{CH}_4} \times \left(\frac{1\ \text{t}}{1{,}000\ \text{kg}}\right)$$

Table 109 describes the data elements of *Equation 112*, whether they are default or user-provided, and suggested data sources.

Table 109: Data Requirements for Equation 112

Data Element	Description	Data Type	Data Source
Baseline Emissions$_{\text{Natural Gas Practice}}$	GHG emissions of the activity during the reporting year (tCO_2e)	Calculated	Equation 112
Volume of Total Natural Gas Vented	The volume of natural gas that was vented after accounting for natural gas that was used on-site (m^3)	User-Provided	N/A
Mass Fraction of Methane in Captured Gas[1]	Mass fraction of CH_4 in captured natural gas (unitless)	User-Provided	N/A
Density of Methane	Density of methane at standard conditions. Default value is 0.717 $\frac{\text{kg}}{\text{m}^3}$.	Default	Engineering Toolbox
GWP_{CH_4}	The 100-year global warming potential of methane gas (CH_4) in CO_2 equivalence. Constant value of 25 CO_2e.	Default	IPCC, 2006
$\frac{1\ \text{t}}{1{,}000\ \text{kg}}$	Kilogram to ton conversion factor $\left(\frac{\text{t}}{\text{kg}}\right)$	Conversion Factor	NIST, 2006

[1]OUs can use volume fraction to estimate the volume of methane in the captured gas and convert to mass units using a default Density

Note: Default values can be overridden by the user if site-specific information is available.

STEP 6. ESTIMATE BASELINE GHG EMISSIONS FROM ENERGY PRODUCTION

This method assumes that the Baseline Energy Scenario includes the combustion of natural gas for cooking, heating, or electricity generation. The emissions from on-site or off-site combustion can be estimated using the amount and type of fuel (natural gas) consumed in the baseline scenario. OUs will need to know:

1) The amount of natural gas that would have been consumed in the baseline scenario for the reporting year, and
2) The type of fuel that was replaced by the activity.

Baseline GHG emissions from on-site or off-site combustion of fuel can be estimated using *Equation 113:*

Equation 113

$$\text{Baseline Emissions}_{\text{Energy}} = \text{Total Volume of Captured Gas} \times \text{Net Calorific Value of Gas} \times \text{EF}_{\text{Natural Gas}} \times \left(\frac{1\text{ t}}{1{,}000{,}000\text{ g}}\right)$$

Table 110 describes the data elements of *Equation 113*, whether they are default or user-provided, and suggested data sources.

Table 110: Data Requirements for Equation 113

Data Element	Definition	Data Type	Data Source
$\text{Baseline Emissions}_{\text{Energy}}$	The amount, in metric tons of carbon dioxide equivalent, of GHG emissions in the baseline scenario, associated with the baseline fuel type, that would have occurred in the reporting year (tCO_2e)	Calculated	Equation 113
Total Volume of Captured Gas	The volume of natural gas that was flared or vented after accounting for natural gas that was used on-site (m^3)	User-Provided,	User Input or Equation 101, Equation 104, Equation 107, Equation 109
Net Calorific Value of Gas	The amount of energy released for a specific composition and volume of natural gas, by country $\left(\frac{\text{GJ}}{\text{m}^3}\right)$. Default values found in Appendix Q: Net Calorific Value of Natural Gas.	Default	EIA, 2014
$\text{EF}_{\text{Natural Gas}}$	The amount of GHGs, in $kgCO_2e$, released when burning natural gas. Default value is 56.155 $\frac{\text{kgCO}_2\text{e}}{\text{GJ}}$.	Default	IPCC, 2006
$\frac{1\text{ t}}{1{,}000{,}000\text{ g}}$	Gram to ton conversion factor $\left(\frac{\text{t}}{\text{g}}\right)$	Conversion Factor	NIST, 2006

Note: Default values can be overridden by the user if site-specific information is available.

STEP 7. ESTIMATE GHG EMISSIONS REDUCED

GHG emission reductions from the captured natural gas activity are equal to the difference in baseline GHG emissions from the natural gas practice and energy production and the activity GHG emissions resulting from the activity in the reporting year.

Equation 114

$$\text{Emissions Reduced} = \left(\text{Baseline Emissions}_{\text{Natural Gas Practice}} + \text{Baseline Emissions}_{\text{Energy}}\right) - \text{Activity Emissions}$$

Table 111 describes the data elements of *Equation 114*, whether they are default or user-provided, and suggested data sources.

Table 111: Data Requirements for Equation 114

Data Element	Description	Data Type	Data Source
Emissions Reduced	The amount, in metric tons of carbon dioxide equivalent, of GHG emissions reduced in the reporting year (tCO_2e).	Calculated	Equation 114
Baseline $\text{Emissions}_{\text{Natural Gas Practice}}$	The amount, in metric tons of carbon dioxide equivalent, of GHG emissions from baseline natural gas practice that would have occurred in the reporting year (tCO_2e).	Calculated	Equation 111, or Equation 112
Baseline $\text{Emissions}_{\text{Energy}}$	The amount, in metric tons of carbon dioxide equivalent, of GHG emissions from baseline energy consumption that would have occurred in the reporting year (tCO_2e).	Calculated	Equation 113
Activity Emissions	The amount, in metric tons of carbon dioxide equivalent, of GHG emissions that occurred due to the activity in the reporting year (tCO_2e).	Calculated	Equation 110

3.6 Clean Energy Result: Fuel Switching

"Fuel Switching" involves replacing traditional fossil fuel sources with cleaner, more sustainable fuels that that emit fewer GHGs per unit of energy generated. GHG emissions are reduced by replacing the need for traditional fuels, switching to fuels that are more efficient (i.e., achieve the same energy output with less material input), or utilizing power systems from sources that are underutilized. *Box 9* lists some of the activities that achieve this Clean Energy Result.

Box 9: GCC Activities that Involve Fuel Switching

Key Characteristics:

- Conventional energy sources (e.g., fossil fuels)
- Switch to less emissive traditional or alternative energy sources

Example Activities:

- Alternative fuel vehicles (e.g., compressed natural gas, ethanol, or electric)
- Agricultural, landfill, and wastewater biogas capture and use
- Power plant retrofits (e.g., oil or coal to natural gas or biomass)

The methodology for calculating emissions reduced from fuel switching activities is covered under *Section 3.2 Clean Energy GHG Methodology*.

3.7 Clean Energy Result: Market Development

"Market Development" includes activities such as reforming regulatory environments to promote development of energy efficiency, assessing private and public sector abilities and interests, and developing strategies for effective participation in carbon markets. These activities may lead indirectly to GHG emission reductions by supporting or developing a market for renewable and efficient energy sources. Policies that lead to the gradual adoption of less GHG-intensive power systems, or increase capacity and efficiency in systems already in place also result in a net decrease in GHG emissions. *Box 10* lists some of the activities that achieve this Clean Energy Result.

Box 10: GCC Activities that Develop a Market for Clean Energy

Key Characteristics:

- Enhance capacity for clean energy development
- Create an enabling environment for clean energy policies

Example Activities:

- Projects designed for the evacuation, transportation, and trade in renewable energy
- Improve access to clean energy through regional electricity trade exchange, regional power pools, feed-in tariffs and renewable portfolio standards
- Builds a regulatory environment increasing transparency, accountability, and predictability
- Policies protecting interests of consumers and investors
- Market development and promotion, including monitoring, reporting, and verification (MRV) systems
- Strategies for effective participation in carbon markets, given current international climate policies and ensuring that national sustainable development needs are addressed
- Policies providing incentives for energy sector utilities to improve efficiency of operations and quality of service, leading to attractive climate for investment capital
- Development of EC-LEDS program

This section includes activities that lead to indirect reduction of GHGs by supporting or developing a market for renewable and efficient energy sources. Policies that lead to the gradual adoption of less GHG-intensive power systems, as well as increased capacity and efficiency in systems already in place also result in a net decrease in GHG emissions. Many activities that develop a market or enabling environment for clean and efficient energy will not result in quantifiable emission reductions for reporting. Activities that result in quantifiable emission reductions have methodologies below, or are mapped to methodologies in other sections.

3.8 Clean Energy Result: Improve Information

"Improve Information" includes activities that improve access to and/or the quality of information regarding clean energy deployment or management in order to build capacity, such as the assessment of energy use patterns, identification of gaps in knowledge and enhancing capacity to develop LEDS , and development of greenhouse gas inventories. These activities may contribute indirectly to GHG emission reductions by gathering the information necessary to implement clean and renewable energy strategies. However, they may not result in measurable GHG reductions directly. *Box 11* lists some of the activities that achieve this Clean Energy Result.

Box 11: GCC Activities that Improve Information

Key Characteristics:

- Gather information to assist in development of clean energy strategies
- Assess energy use

Example Activities:

- Assessment of energy use patterns
- Identification of gaps in knowledge and enhancing capacity to develop LEDS
- Support for GHG inventory development
- Assessment of private and public sector capacities, interests, and gaps in carbon market participation
- Education and engagement on climate change

Activities that are designed to improve information do not result in quantifiable emission reductions in the reporting year.

Activities that improve information but do not lead to direct GHG emission reductions should report zero emission reductions under the GHG indicator.

Activities covered under the "improving information" result include:

- Projects designed for the evacuation, transportation, and trade in renewable energy
- Improve access to clean energy through regional electricity trade exchange, regional power pools, feed-in tariffs and renewable portfolio standards
- Builds a regulatory environment increasing transparency, accountability, and predictability
- Policies protecting interests of consumers and investors
- Market development and promotion, including monitoring, reporting, and verification (MRV) systems
- Strategies for effective participation in carbon markets, given current international climate policies and ensuring that national sustainable development needs are addressed
- Policies providing incentives for energy sector utilities to improve efficiency of operations and quality of service, leading to attractive climate for investment capital
- Development of EC-LEDS program

4 REPORTING AND DOCUMENTATION

In general, reporting is a basic concept that ensures the results generated through GHG project accounting are structured for the intended audience. When reporting GHG emission reduction results from the Protocol, OUs should be aware of the required information to report on the standard GHG indicator. In general, data, methods, criteria, and assumptions that are misleading or inconsequential for reporting on the standard indicator should not be included in the report.

4.1 Guidelines for Internal Reporting

All activities that receive direct GCCI clean energy funding are required to report the GHG emissions benefit of their programs under the GHG Indicator, and should follow the guidance contained in this Protocol to estimate emission reductions. Programs that do not receive direct GCCI clean energy funding but that result in GHG emission reductions—e.g., fuel switching to less GHG-intensive fuels, such as from coal to natural gas—are encouraged to estimate the GHG benefits of their activities and report emission reductions through the GHG Indicator using this Protocol.

Table 112 lists information that should be documented for each clean energy activity as part of the GHG estimation.[70] These particular details help to describe the activity, how it may lead to emission reductions, and whether these results should be included in the emission estimate for reporting.

OUs should strive to provide information for each field in the table. However, the list is not intended to be exhaustive, and there may be additional information that may be relevant and therefore included.

Table 112: List of Information for Reporting on Clean Energy Activities

Information	Explanation/Example
Implementing mechanism number	The assigned identification number for the implementing mechanism of the parent program
Implementing mechanism name	Name of the implementing mechanism under which the activity falls (e.g., LEAD, Afghanistan Clean Energy Program)
Operating Unit	Field office implementing the activity
Partner organizations / Implementing Partners	Other governmental or non-governmental organizations directly involved with the planning and/or implementation of the activity
USAID role	USAID's specific role in the activity (e.g., co-funder, funder, Technical Assistance).
Implementation status	The current status of the activity at the time of the GHG estimate (e.g., ongoing, completed, or postponed.)
Name of the Activity	The title of the activity (e.g., Installation of Solar Home Systems)
Type of activity	The type of technological, policy, or capacity building activity.

[70] Adapted from (WRI, 2012).

Information	**Explanation/Example**
Description of the Activity	The individual clean energy actions or interventions, or program of activities, that occurred during the reporting year.
Location of Activity	The jurisdiction where the activity is implemented where GHG emission reductions are anticipated to occur. This includes the country and sub-region, state or province in which the activity occurs (e.g., province with access to a new solar installation or a village receiving more efficient appliances). OUs may also provide geographic coordinates for the location, if available.
Reporting year	Year for which emission reductions are being estimated for reporting under the GHG Indicator. The reporting year is the fiscal year for USAID OUs.
Activity start date	The date that USAID involvement in the activity began.
Date of completion	The planned date the activity ceases (or ceased), or when USAID completes its involvement in the activity.
Intended Clean Energy and GHG Results of the activity	The anticipated purpose or result(s) of the activity.
Description of GHG Estimation Boundaries	The GHG gases, activity boundary, temporal boundary, and jurisdiction included in the estimation, including aspect of the activity not included within the activity or estimation boundaries.
Description of Baseline Energy Scenario	The events and conditions—in terms of energy—that most likely would have occurred within the Activity Boundary during the reporting year in the absence of the activity.
Energy Capacity Installed or Operational	The amount of clean capacity installed or operational, in mega-Watts, during the reporting year under the activity.
Net GHG Emission Reductions	Greenhouse gas emissions, estimated in metric tons of CO_2 equivalent, reduced, sequestered, and/or avoided as a result of U.S. Government assistance within the reporting period. Separated by baseline and activity emissions, as well as by in-jurisdiction, and out-of-jurisdiction, if possible.
Methodology and Assumptions	The CLEER methodology, or other, and assumptions used to estimate baseline and activity emissions, including relevant data sources.
Uncertainty	Any methods or approaches used to assess uncertainty, the results of any sensitivity analysis of key parameters, and a qualitative description of the uncertainty.

4.2 Uncertainty of Clean Energy Methodologies

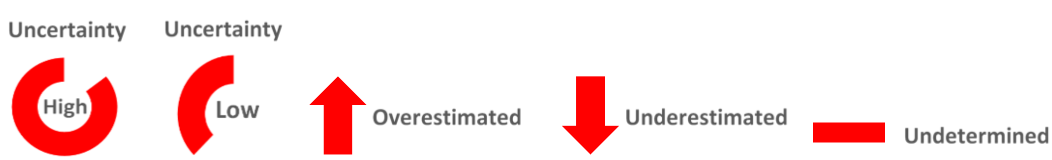
OUs are not required to conduct an uncertainty assessment when using the Protocol, however they should consider and attempt to minimize sources of uncertainty in their assessments by user higher quality site-specific data and fewer international defaults.

Uncertainty is a fundamental property of any calculated result. Uncertainty can propagate with the lack of a complete data set as well as an incomplete understanding of how emissions are generated. Uncertainty is being assessed qualitatively at the parameter level of each emissions equation used in the development of emission estimations for the CLEER calculation methodologies. Assessing the uncertainty associated with each parameter helps prioritize future efforts to improve accuracy and data limitations. These can guide future decisions on methodological choices or improve data quality and provides a way of qualifying confidence in a calculated result.

This section describes the key factors influencing uncertainty in the clean energy methodologies presented in the Protocol, including a classification of their relative contribution to uncertainty. This qualitative uncertainty assessment documents the limitations of some default values and methodologies.

Overall uncertainty is **HIGH** given the use of default factors, proxy data, and simplified emission calculation methods. A classification of HIGH is considered when data needs cannot be met and relative or proxy data point must be used. In cases where default factors and simplified emission equations are utilized contribution to uncertainty is high. A classification of LOW is considered when local data can be utilized and calculation equations cover parameters that are well understood.

The following key is used to indicate the classification of uncertainty, and whether emissions are likely to be overestimated, underestimated, or affected in an undetermined way as a result of the uncertainty:



4.2.1 Global Variables

TECHNICAL GRID LINE LOSS RATES

Rates are based on electricity generation and consumption data from IEA, which are not available for all countries. For countries where technical grid loss rates are not available, rates are approximated from a regional average. Given the differences between infrastructures a regional average may not apply as well for certain countries that operate with higher or lower infrastructure standards. Line loss rates include only technical losses and do not include losses from theft. Loss from theft by country can vary widely from regional assumptions.

An uncertainty estimate for this parameter is classified as **HIGH.** Considering that loss from theft is not accounted, emissions due to grid losses are likely underestimated.

DEFAULT EMISSIONS FACTORS FOR STATIONARY COMBUSTION (IPCC INVENTORY GUIDANCE, 2006B)

The default emissions factors for Stationary Combustion are references from the IPCC guidelines and were established by a large group of inventory experts and are still considered valid. The IPCC guidelines specifically set each an uncertainty range of plus/minus a factor of three for each variable.

An uncertainty estimate for this parameter is classified as **LOW**. It cannot be determined whether individual factors contribute to an overestimate or an underestimate given each factor is not assessed its own level of uncertainty. Most factors are likely a conservative number but this likely varies through the more than 50 fuels estimated.

DEFAULT EMISSIONS FACTORS FOR ELECTRICITY BY FUEL

IEA does not assess uncertainty information on implied emissions factors used by fuel. The values provided are an approximation and are estimated only from OECD countries. Additionally, these values represent the average grams of CO_2 per kWh of electricity produced in the OECD member countries between 2008 and 2010.

An uncertainty estimate for this parameter is classified as **HIGH**. Use of these factors outside the OECD membership is likely to result in an underestimation of emissions given the efficiency of fuel use is generally high in OECD countries.

DEFAULT EMISSIONS FACTORS FOR ELECTRICITY

IEA did not consider or assess uncertainty for the electricity factors. The calculation methodology has a number of drawbacks including the allocation of Combined Heat and Power plants into an electricity-only factor. As the efficiency of heat generation is almost always higher than electricity generation, countries with large amounts of district heating will see a higher efficiency (therefore lower CO_2 intensity) than warmer countries with less district heating.

An uncertainty estimate for this parameter is classified as **LOW**. In colder countries that utilized more district heating this parameter is likely to be overestimated.

4.2.2 Methodology Specific Variables

SOLAR INSOLATION

Data is only available by a regional grid average rather than point-by-point observations. Data from remote sensing satellite produces moderate bias at 60-degrees poleward. Methodology of data analysis and currency of data contribute to the overall uncertainty of the system.

Considering the 60-degree poleward bias horizontal insolation is likely underestimated at high latitudes. An uncertainty estimate for this parameter is classified as **LOW.**

LENGTH OF PIPE FOR HEAT PUMPS

Pipe length is one of the more important parameters in the heat generation from heat pumps. Longer length systems provide more surface area for ground/heat exchange. Although some styles of systems can be a general length most systems are typically built to suit. Depending on the location, system style, demand, and climate the pipe length can vary extensively.

An uncertainty estimate for this parameter is classified as **HIGH**. Not enough information was provided on specific of pipe measurements to conclude whether this parameter was under or overestimated.

BIOMASS FUEL TYPE EMISSION

High levels of uncertainty exist around the development of emission factors per each use of Biomass which include charcoal, sulphite lye, and wood/wood waste. The impact biomass has on the carbon cycle is still not well understood.

An uncertainty estimate for this parameter is classified as **HIGH**. Emission factors tend to overestimate the carbon content in biomass due the heterogeneous nature of biomass which leads to an overestimate in emissions.

FUGITIVE BIOGAS EMISSIONS

The largest sources of uncertainty surrounding biogas emissions are associated with the estimated methane emissions calculations related to animal population data, manure management systems, VS excretion rates, and methane conversion factors.

An uncertainty estimate for this parameter is classified as **LOW**. In emission equations methane tends to be overestimated leading to a potential overestimation of emissions.

METHANE GENERATING CAPACITY FOR LIVESTOCK

Methane generating capacity by livestock (dairy cows, other cattle, swine, buffalo, sheep, goats, camels, mules, poultry, turkeys, and ducks) are pulled directly from Appendix B of the IPCC 2006 report. Uncertainty exists around the limited number of diets used to estimate each emission factor. Accurate estimates of feed digestibility (DE %) are also critical to decreasing uncertainty.

An uncertainty estimate for this parameter is classified as **LOW**. Not enough data was present to determine whether emissions were over or underestimated.

4.3 Quality Assurance and Quality Control

When reporting and documenting results, OUs should also discuss general quality assurance and quality control (QA/QC) procedures and to ensure the integrity of estimation and reporting procedures. OUs can refer to QA/QC steps established by IPCC for reporting emission inventories in the *IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories* (IPCC, 2000).

One IPCC step in particular outlines a procedure for assessing quality of emission estimates. Since many calculations conducted through the use of the CLEER Protocol are based on *estimated* rather than *measured* data, they may be susceptible to inaccuracy to varying degrees. The accuracy of an emission estimate is determined by the quality of the data used to produce it. Therefore, it is necessary to implement QA/QC procedures as integral steps of an emission estimate. This underscores that OUs should collect the most accurate activity data as possible, use the best available methodologies to estimate GHGs, keep a careful record of the data and methods used to produce the emission estimate, consider sources of uncertainty within the methods and assumptions, and continually strive to improve the quality of GHG emission reduction estimates.

A basic QA/QC system should provide consistent checks to ensure data integrity, correctness, and completeness, as well as identify and address errors and omissions. It should also provide procedures for documenting and archiving inventory material and recording all QA/QC activities.

The following procedures should be discussed following emission estimates to ensure that the estimates receive a thorough review and that it adheres to the GHG accounting principles of relevance, completeness, consistency, transparency, and accuracy.

Table 113: Recommended Quality Control Procedures (IPCC, 2000)

Quality Control Activity	Procedures
Check the accuracy of data input from the original reference source	Confirm all data provided by the User is accurate based on original reference sources (i.e., manufacturer's equipment label).
Check emissions calculations	Ensure all calculations made outside of the Excel-based calculators are complete and accurate.
Check emission units and corresponding unit conversions	1) Check that all units are correctly applied to the specific activities (i.e., energy savings are reported in kWh instead of kW). 2) Check all unit conversions, either from inputted data or in the Excel-based calculator, for accuracy.
Check for consistency in scope of data	Check any data and emission estimates used to quantify emission reductions have consistent temporal and sectoral constraints (i.e., the same reporting year).
Check that emission estimates are realistic	Compare current emission estimates with relevant benchmarks (i.e., emission estimates from previous years, similar programs in the area, or regional averages).
Check for accurate documentation of data assumptions and procedures	Check that appropriate documentation and transparency is carried out to ensure quality and completeness of estimates.

5 REFERENCES

1 INTRODUCTION

IEA (International Energy Agency). (2013). CO_2 Emissions from Fuel Combustion – Highlights 2013. GHG Emission Factors. Accessed December, 2015: http://www.iea.org/bookshop/669-CO2_Emissions_from_Fuel_Combustion.

IPCC (Intergovernmental Panel on Climate Change). (2006). 2006 IPCC Guidelines for National Greenhouse Gas Inventories. The National Greenhouse Gas Inventories Programme, The Intergovernmental Panel on Climate Change, H.S. Eggleston, L. Buendia, K. Miwa, T. Ngara, and K. Tanabe (eds.). Hayama, Kanagawa, Japan. Default Emission Factors retrieved from Volume 2. Energy, Chapter 2 Stationary Combustion. Accessed October, 2013: http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_2_Ch2_Stationary_Combustion.pdf.

IPCC. (2007a). Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. Accessed January, 2015.

NIST (National Institute of Standards and Technology). (2006). The International System of Units (SI) – Conversion Factors for General Use. Accessed October, 2013: http://www.nist.gov/pml/wmd/metric/upload/SP1038.pdf

UNFCCC CDM (United Nations Framework Convention on Climate Change Clean Development Mechanism). Accessed October, 2012: http://cdm.unfccc.int/methodologies/index.html.

USAID (United States Agency for International Development). (2012). USAID Climate Change and Development Strategy: Clean Resilient Growth. Accessed October, 2015: http://pdf.usaid.gov/pdf_docs/PDACS780.pdf.

VCS (Verified Carbon Standard). Methodologies: Energy (renewable/non-renewable), Distribution, Demand. Accessed October, 2012: http://v-c-s.org/methodologies/find.

WRI (World Resources Institute). (2005). The Greenhouse Gas Protocol: The GHG Protocol for Project Accounting. Accessed October, 2012: http://www.ghgprotocol.org/standards/project-protocol.

WRI. (2014). Greenhouse Gas Protocol Policy and Action Standard. Accessed February, 2015: http://www.ghgprotocol.org/policy-and-action-standard.

2 CLEER GHG ACCOUNTING APPROACH

IPCC (Intergovernmental Panel on Climate Change). (2007b). GHG Lifetimes and GWPs. IPCC, Fourth Assessment Report (AR4), Working Group 1, Chapter 2, Changes in Atmospheric Constituents and in Radiative Forcing, Table 2.10.2. Accessed February, 2015: http://www.ipcc.ch/publications_and_data/ar4/wg1/en/ch2s2-10-2.html.

WRI (World Resources Institute). (2005). The Greenhouse Gas Protocol: The GHG Protocol for Project Accounting. Accessed October, 2012: http://www.ghgprotocol.org/standards/project-protocol.

WRI. (2014). Greenhouse Gas Protocol Policy and Action Standard. Accessed February, 2015: http://www.ghgprotocol.org/policy-and-action-standard.

3 ESTIMATING GHG REDUCTIONS FROM CLEAN ENERGY RESULTS

Climate Registry, The. (2008). General Reporting Protocol. Accessed December, 2015:http://www.theclimateregistry.org/wp-content/uploads/2014/11/TCR_GRP_Version_2.0-1.pdf.

UNFCCC CDM (United Nations Framework Convention on Climate Change Clean Development Mechanism). CDM Methodologies - Accessed October, 2012: http://cdm.unfccc.int/methodologies/index.html.

VCS (Verified Carbon Standard). Methodologies: Energy (renewable/non-renewable), Distribution, Demand. Accessed October, 2012: http://v-c-s.org/methodologies/find.

WRI (World Resources Institute). (2005). The Greenhouse Gas Protocol: The GHG Protocol for Project Accounting. Accessed October, 2012: http://www.ghgprotocol.org/standards/project-protocol.

WRI. (2014). Greenhouse Gas Protocol Policy and Action Standard. Accessed February, 2015: http://www.ghgprotocol.org/policy-and-action-standard.

3.1 CLEER METHODOLOGY OVERVIEW AND ASSUMPTIONS

CEC (California Energy Commission). (2010). Comparative Costs of California Central Station Electricity Generation. Accessed October, 2013: http://www.energy.ca.gov/2009publications/CEC-200-2009-017/CEC-200-2009-017-SF.PDF.

FERC (Federal Energy Regulatory Commission). (2011). Hydropower Licensing. Accessed October, 2013: http://www.ferc.gov/for-citizens/citizen-guides/hydro-guide.asp.

GEA (Geothermal Energy Association). (2013). Default Lifetime Value. Accessed October, 2013: http://geo-energy.org/reports.aspx.

IEA (International Energy Agency). (2009). International Energy Agency Electricity/Heat Statistics for 2009. Average Grid Line Loss Rate. Accessed October, 2013: http://www.iea.org/stats/prodresult.asp?PRODUCT=Electricity/Heat.

IEA. (2015). CO_2 Emissions from Fuel Combustion – Highlights 2015. GHG Emission Factors. Accessed December, 2015: http://www.iea.org/bookshop/669-CO2_Emissions_from_Fuel_Combustion.

IEESAG (Illinois Energy Efficiency Stakeholder Advisory Group). (2012). Energy Efficiency Technical Reference Manual Final Technical Version, August 20th, 2012. Accessed December, 2015: http://ilsagfiles.org/SAG_files/Subcommittees/IPA-TRC_Subcommittee/10-6-2015_Meeting/TRC_Subcommittee_Report_Final_Draft_9-28-15.pdf.

IGES (Institute for Global Environmental Strategies). (2015). List of Grid Emission Factors – Version 2015/10. A. Kuriyama (ed.). Accessed 15 March 2016: http://pub.iges.or.jp/modules/envirolib/view.php?docid=2136.

IPCC (Intergovernmental Panel on Climate Change). (2006). 2006 IPCC Guidelines for National Greenhouse Gas Inventories. The National Greenhouse Gas Inventories Programme, The Intergovernmental Panel on Climate Change, H.S. Eggleston, L. Buendia, K. Miwa, T. Ngara, and K. Tanabe (eds.). Hayama, Kanagawa, Japan. Default Emission Factors retrieved from Volume 2. Energy, Chapter 2 Stationary Combustion. Accessed October, 2013: http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_2_Ch2_Stationary_Combustion.pdf.

IPCC. (2007a). Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. Accessed January, 2015.

IPCC. (2007b). GHG Lifetimes and GWPs. IPCC, Fourth Assessment Report (AR4), Working Group 1, Chapter 2, Changes in Atmospheric Constituents and in Radiative Forcing, Table 2.10.2. Accessed February, 2015: http://www.ipcc.ch/publications_and_data/ar4/wg1/en/ch2s2-10-2.html.

NREL (National Renewable Energy Laboratory). (2012). Photovoltaic Degradation Rates. Accessed October, 2013: http://www.nrel.gov/docs/fy12osti/51664.pdf.

OR DOE (Oregon Department of Energy). (2013). Oregon Solar Electric Guide. Accessed December, 2015: http://energytrust.org/library/forms/sle_pg_pvguide_odoe.pdf.

UNFCCC CDM. (2013a). Tool to determine the remaining lifetime of equipment. Biomass Lifetimes. Accessed October, 2013: http://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-10-v1.pdf.

UNFCCC CDM. (2013b). Clean Development Mechanism Project Design Document Form. Accessed October, 2013: http://cdm.unfccc.int/filestorage/S/8/S/S8SF9ZW5RK08NFPWEK7PFHRS5JM7ZY/PDD.pdf?t=UER8bXI0NWdifDDaDuqec7D4_RxsGif-OADF.

US DOE (U.S. Department of Energy). (2012). Geothermal Heat Pumps Lifetime. Accessed October, 2013: http://energy.gov/energysaver/articles/geothermal-heat-pumps.

WRI (World Resources Institute). (2014). Greenhouse Gas Protocol Policy and Action Standard. Accessed February, 2015: http://www.ghgprotocol.org/policy-and-action-standard.

3.2 CLEAN ENERGY GHG

IEA (International Energy Agency). (2009). International Energy Agency Electricity/Heat Statistics for 2009. Average Grid Line Loss Rate. Accessed October, 2013: http://www.iea.org/stats/prodresult.asp?PRODUCT=Electricity/Heat.

IEA. (2013). CO_2 Emissions from Fuel Combustion – Highlights 2013. GHG Emission Factors. Accessed December, 2015: http://www.iea.org/bookshop/669-CO2_Emissions_from_Fuel_Combustion.

IGES (Institute for Global Environmental Strategies). (2015). List of Grid Emission Factors – Version 2015/10. A. Kuriyama (ed.). Accessed 15 March 2016: http://pub.iges.or.jp/modules/envirolib/view.php?docid=2136.

IPCC (Intergovernmental Panel on Climate Change). (2006). 2006 IPCC Guidelines for National Greenhouse Gas Inventories. The National Greenhouse Gas Inventories Programme, The Intergovernmental Panel on Climate Change, H.S. Eggleston, L. Buendia, K. Miwa, T. Ngara, and K. Tanabe (eds.). Hayama, Kanagawa, Japan. Default Emission Factors retrieved from Volume 2. Energy, Chapter 2 Stationary Combustion. Accessed October, 2013: http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_2_Ch2_Stationary_Combustion.pdf.

NIST (National Institute of Standards and Technology). (2006). The International System of Units (SI) – Conversion Factors for General Use. Accessed October, 2013: http://www.nist.gov/pml/wmd/metric/upload/SP1038.pdf.

3.3.1 SOLAR PHOTOVOLTAIC SYSTEMS

IEA (International Energy Agency). (2009). International Energy Agency Electricity/Heat Statistics for 2009. Average Grid Line Loss Rate. Accessed October, 2013: http://www.iea.org/stats/prodresult.asp?PRODUCT=Electricity/Heat.

IEA. (2013). CO_2 Emissions from Fuel Combustion – Highlights 2013. GHG Emission Factors. Accessed December, 2015: http://www.iea.org/bookshop/669-CO2_Emissions_from_Fuel_Combustion.

IGES (Institute for Global Environmental Strategies). (2015). List of Grid Emission Factors – Version 2015/10. A. Kuriyama (ed.). Accessed 15 March 2016: http://pub.iges.or.jp/modules/envirolib/view.php?docid=2136.

IPCC (Intergovernmental Panel on Climate Change). (2006). 2006 IPCC Guidelines for National Greenhouse Gas Inventories. The National Greenhouse Gas Inventories Programme, The Intergovernmental Panel on Climate Change, H.S. Eggleston, L. Buendia, K. Miwa, T. Ngara, and K. Tanabe (eds.). Hayama, Kanagawa, Japan. Default Emission Factors retrieved from Volume 2. Energy, Chapter 2 Stationary Combustion. Accessed October, 2013: http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_2_Ch2_Stationary_Combustion.pdf.

NASA (The National Aeronautics and Space Administration). (2012). Surface meteorology and Solar Energy (SSE) Release 6.0 Data Set (Jan 2008) 22-year Monthly & Annual Average (July 1983 - June 2005) Parameter: Insolation on a Tilted Surface. Accessed 20 October, 2012.

NIST (National Institute of Standards and Technology). (2006). The International System of Units (SI) – Conversion Factors for General Use. Conversion factors retrieved from http://www.nist.gov/pml/wmd/metric/upload/SP1038.pdf. Accessed October, 2013.

3.3.2 SOLAR THERMAL SYSTEMS

IEA (International Energy Agency). (2009). International Energy Agency Electricity/Heat Statistics for 2009. Average Grid Line Loss Rate. Accessed October, 2013: http://www.iea.org/stats/prodresult.asp?PRODUCT=Electricity/Heat.

IEA. (2011). Solar Heating and Cooling Programme. *Converting Installed Solar Collector Area & Power Capacity into Estimated Annual Solar Collector Energy Output.* Accessed December, 2015: http://www.iea-shc.org/Data/Sites/1/documents/statistics/Calculation_Method.pdf & http://www.estif.org/no_cache/news/single-news-item/archive/2011/march/article/common-calculation-method-of-the-solar-thermal-energy-produced-worldwide-now-available/?tx_ttnews.

IEA. (2013). CO_2 Emissions from Fuel Combustion – Highlights 2013. GHG Emission Factors. Accessed December, 2015: http://www.iea.org/bookshop/669-CO2_Emissions_from_Fuel_Combustion.

IGES (Institute for Global Environmental Strategies). (2015). List of Grid Emission Factors – Version 2015/10. A. Kuriyama (ed.). Accessed 15 March 2016: http://pub.iges.or.jp/modules/envirolib/view.php?docid=2136.

IPCC (Intergovernmental Panel on Climate Change). (2006). 2006 IPCC Guidelines for National Greenhouse Gas Inventories. The National Greenhouse Gas Inventories Programme, The Intergovernmental Panel on Climate Change, H.S. Eggleston, L. Buendia, K. Miwa, T. Ngara, and K. Tanabe (eds.). Hayama, Kanagawa, Japan. Default Emission Factors retrieved from Volume 2. Energy, Chapter 2 Stationary Combustion. Accessed October, 2013: http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_2_Ch2_Stationary_Combustion.pdf.

NASA (The National Aeronautics and Space Administration). (2012). Surface meteorology and Solar Energy (SSE) Release 6.0 Data Set (Jan 2008) 22-year Monthly & Annual Average (July 1983 - June 2005) Parameter: Insolation Incident on a Horizontal Surface. Accessed 20 October, 2012.

NIST (National Institute of Standards and Technology). (2006). The International System of Units (SI) – Conversion Factors for General Use. Accessed October, 2013: http://www.nist.gov/pml/wmd/metric/upload/SP1038.pdf.

UNFCCC CDM (United Nations Framework Convention on Climate Change Clean Development Mechanism). (2006). *Clean Development Mechanism (CDM) Small-Scale Working Group (SSC WG) Meeting 7. Annex 3: Analysis and Explanation of the Conversion factor for Solar Thermal Collectors*. Accessed October, 2013: https://cdm.unfccc.int/Panels/ssc_wg.

3.3.3 WIND TURBINE SYSTEMS

IEA (International Energy Agency). (2009). International Energy Agency Electricity/Heat Statistics for 2009. Average Grid Line Loss Rate. Accessed October, 2013: http://www.iea.org/stats/prodresult.asp?PRODUCT=Electricity/Heat.

IEA. (2011). World Statistics. Wind Power Generation Capacity and Total Energy Generated. Accessed October, 2013: http://www.iea.org/statistics/.

IEA. (2013). CO_2 Emissions from Fuel Combustion – Highlights 2013. GHG Emission Factors. Accessed December, 2015: http://www.iea.org/bookshop/669-CO2_Emissions_from_Fuel_Combustion.

IGES (Institute for Global Environmental Strategies). (2015). List of Grid Emission Factors – Version 2015/10. A. Kuriyama (ed.). Accessed 15 March 2016: http://pub.iges.or.jp/modules/envirolib/view.php?docid=2136.

IPCC (Intergovernmental Panel on Climate Change). (2006). 2006 IPCC Guidelines for National Greenhouse Gas Inventories. The National Greenhouse Gas Inventories Programme, The Intergovernmental Panel on Climate Change, H.S. Eggleston, L. Buendia, K. Miwa, T. Ngara, and K. Tanabe (eds.). Hayama, Kanagawa, Japan. Default Emission Factors retrieved from Volume 2. Energy, Chapter 2 Stationary Combustion. Accessed October, 2013: http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_2_Ch2_Stationary_Combustion.pdf.

NIST (National Institute of Standards and Technology). (2006). The International System of Units (SI) – Conversion Factors for General Use. Accessed October, 2013: http://www.nist.gov/pml/wmd/metric/upload/SP1038.pdf.

3.3.4 HYDROELECTRIC SYSTEMS

IEA (International Energy Agency). (2009). International Energy Agency Electricity/Heat Statistics for 2009. Average Grid Line Loss Rate. Accessed October, 2013: http://www.iea.org/stats/prodresult.asp?PRODUCT=Electricity/Heat.

IEA. (2013). CO_2 Emissions from Fuel Combustion – Highlights 2013. GHG Emission Factors. Accessed December, 2015: http://www.iea.org/bookshop/669-CO2_Emissions_from_Fuel_Combustion.

IGES (Institute for Global Environmental Strategies). (2015). List of Grid Emission Factors – Version 2015/10. A. Kuriyama (ed.). Accessed 15 March 2016: http://pub.iges.or.jp/modules/envirolib/view.php?docid=2136.

Intpow (2013). World Hydropower Potential. Hydroelectric Capacity Factors. Accessed October, 2013: http://www.intpow.com/index.php?id=487&download=1.

IPCC (Intergovernmental Panel on Climate Change). (2006). 2006 IPCC Guidelines for National Greenhouse Gas Inventories. The National Greenhouse Gas Inventories Programme, The Intergovernmental Panel on Climate Change, H.S. Eggleston, L. Buendia, K. Miwa, T. Ngara, and K. Tanabe (eds.). Hayama, Kanagawa, Japan. Default Emission Factors retrieved from Volume 2. Energy, Chapter 2 Stationary Combustion. Accessed October, 2013: http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_2_Ch2_Stationary_Combustion.pdf.

Kaltschmitt, Martin. (2007). Renewable Energy – Technology, Economics, and Environment. Hydroelectric Power Generation (8) 362-363.

NIST (National Institute of Standards and Technology). (2006). The International System of Units (SI) – Conversion Factors for General Use. Accessed October, 2013: http://www.nist.gov/pml/wmd/metric/upload/SP1038.pdf.

NIST. (2013a). Thermophysical Properties of Fluid Systems. Accessed October 2013: http://webbook.nist.gov/chemistry/fluid/.

NIST. (2013b). Reference on Constants, Units, and Uncertainty. Accessed October, 2013: http://physics.nist.gov/cgi-bin/cuu/Value?gn.

3.3.5 GEOTHERMAL SYSTEMS – POWER GENERATION

Bertani, Ruggero. (2012). Geothermal power generation in the world 2005–2010 update report. Geothermics (41), 1-29. Accessed October, 2015: http://www.sciencedirect.com/science/article/pii/S0375650511000526.

IEA (International Energy Agency). (2009). International Energy Agency Electricity/Heat Statistics for 2009. Average Grid Line Loss Rate. Accessed October, 2013: http://www.iea.org/stats/prodresult.asp?PRODUCT=Electricity/Heat.

IEA. (2013). CO_2 Emissions from Fuel Combustion – Highlights 2013. GHG Emission Factors. Accessed December, 2015: http://www.iea.org/bookshop/669-CO2_Emissions_from_Fuel_Combustion.

IGES (Institute for Global Environmental Strategies). (2015). List of Grid Emission Factors – Version 2015/10. A. Kuriyama (ed.). Accessed 15 March 2016: http://pub.iges.or.jp/modules/envirolib/view.php?docid=2136.

IPCC (Intergovernmental Panel on Climate Change). (2006). 2006 IPCC Guidelines for National Greenhouse Gas Inventories. The National Greenhouse Gas Inventories Programme, The Intergovernmental Panel on Climate Change, H.S. Eggleston, L. Buendia, K. Miwa, T. Ngara, and K. Tanabe (eds.). Hayama, Kanagawa, Japan. Default Emission Factors retrieved from Volume 2. Energy, Chapter 2 Stationary Combustion. Accessed October, 2013: http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_2_Ch2_Stationary_Combustion.pdf

NIST (National Institute of Standards and Technology). (2006). The International System of Units (SI) – Conversion Factors for General Use. Accessed October, 2013: http://www.nist.gov/pml/wmd/metric/upload/SP1038.pdf.

3.3.6 GEOTHERMAL SYSTEMS – DIRECT HEAT

IEA (International Energy Agency). (2009). International Energy Agency Electricity/Heat Statistics for 2009. Average Grid Line Loss Rate. Accessed October, 2013: http://www.iea.org/stats/prodresult.asp?PRODUCT=Electricity/Heat.

IEA. (2013). CO_2 Emissions from Fuel Combustion – Highlights 2013. GHG Emission Factors. Accessed December, 2015: http://www.iea.org/bookshop/669-CO2_Emissions_from_Fuel_Combustion.

IGES (Institute for Global Environmental Strategies). (2015). List of Grid Emission Factors – Version 2015/10. A. Kuriyama (ed.). Accessed 15 March 2016: http://pub.iges.or.jp/modules/envirolib/view.php?docid=2136.

IPCC (Intergovernmental Panel on Climate Change). (2006). 2006 IPCC Guidelines for National Greenhouse Gas Inventories. The National Greenhouse Gas Inventories Programme, The Intergovernmental Panel on Climate Change, H.S. Eggleston, L. Buendia, K. Miwa, T. Ngara, and K. Tanabe (eds.). Hayama, Kanagawa, Japan. Default Emission Factors retrieved from Volume 2. Energy, Chapter 2 Stationary Combustion. Accessed October, 2013: http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_2_Ch2_Stationary_Combustion.pdf.

Lund, J. W, Freeston, D. H., Boyd, T.L. (2010). Direct Utilization of Geothermal Energy 2010 Worldwide Review. Accessed December, 2015: http://www.sciencedirect.com/science/article/pii/S0375650511000344.

NIST (National Institute of Standards and Technology). (2006). The International System of Units (SI) – Conversion Factors for General Use. Accessed October, 2013: http://www.nist.gov/pml/wmd/metric/upload/SP1038.pdf.

NIST. (2011). Thermophysical Properties of Fluid Systems. Accessed October, 2013: http://webbook.nist.gov/chemistry/fluid/.

3.3.7 GEOTHERMAL SYSTEMS – HEAT PUMPS

DOE (Department of Energy). (2013). Weather Data for EnergyPlus Energy Simulation Software. Accessed October, 2013: http://apps1.eere.energy.gov/buildings/energyplus/weatherdata_about.cfm.

IEA (International Energy Agency). (2009). International Energy Agency Electricity/Heat Statistics for 2009. Average Grid Line Loss Rate. Accessed October, 2013: http://www.iea.org/stats/prodresult.asp?PRODUCT=Electricity/Heat.

IEA. (2013). CO_2 Emissions from Fuel Combustion – Highlights 2013. GHG Emission Factors. Accessed December, 2015: http://www.iea.org/bookshop/669-CO2_Emissions_from_Fuel_Combustion.

IEC (Iowa Energy Center). (2009). Introduction to Geothermal Heat Pump Systems. Accessed October, 2015: http://www.iowaenergycenter.org/wp-content/uploads/2012/03/IHPA2009Geo101A_Intro.pdf

IEESAG (Illinois Energy Efficiency Stakeholder Advisory Group). (2012). Energy Efficiency Technical Reference Manual. Final Technical Version, August 20th, 2012. Accessed December, 2015: http://ilsagfiles.org/SAG_files/Subcommittees/IPA-TRC_Subcommittee/10-6-2015_Meeting/TRC_Subcommittee_Report_Final_Draft_9-28-15.pdf

IGES (Institute for Global Environmental Strategies). (2015). List of Grid Emission Factors – Version 2015/10. A. Kuriyama (ed.). Accessed 15 March 2016: http://pub.iges.or.jp/modules/envirolib/view.php?docid=2136.

IPCC (Intergovernmental Panel on Climate Change). (2006). 2006 IPCC Guidelines for National Greenhouse Gas Inventories. The National Greenhouse Gas Inventories Programme, The Intergovernmental Panel on Climate Change, H.S. Eggleston, L. Buendia, K. Miwa, T. Ngara, and K. Tanabe (eds.). Hayama, Kanagawa, Japan. Default Emission Factors retrieved from Volume 2. Energy, Chapter 2 Stationary Combustion. Accessed October, 2013: http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_2_Ch2_Stationary_Combustion.pdf.

NIST (National Institute of Standards and Technology). (2006). The International System of Units (SI) – Conversion Factors for General Use. Accessed October, 2013: http://www.nist.gov/pml/wmd/metric/upload/SP1038.pdf.

NIST. (2008). Guide for the Use of the International System of Units (SI) – Conversion Factors. Accessed March, 2015: http://www.nist.gov/pml/pubs/sp811/index.cfm.

3.3.8 BIOMASS ENERGY – SELECT FUELS

EU (European Union). (2010a). "Commission Staff Working Document: Impact Assessment - Sustainability requirements for the use of solid and gaseous biomass sources in electricity, heating and cooling". COM (2010) 11 Final. SEC (2010) 65 Final.

EU. (2010b). "Report from the Commission to the Council and the European Parliament on Sustainability requirements for the use of solid and gaseous biomass sources in electricity, heating and cooling". SEC (2010) 65, 66 Final.

IEA (International Energy Agency). (2009). International Energy Agency Electricity/Heat Statistics for 2009. Average Grid Line Loss Rate. Accessed October, 2013: http://www.iea.org/stats/prodresult.asp?PRODUCT=Electricity/Heat.

IEA. (2013). CO_2 Emissions from Fuel Combustion – Highlights 2013. GHG Emission Factors. Accessed December, 2015: http://www.iea.org/bookshop/669-CO2_Emissions_from_Fuel_Combustion.

IGES (Institute for Global Environmental Strategies). (2015). List of Grid Emission Factors – Version 2015/10. A. Kuriyama (ed.). Accessed 15 March 2016: http://pub.iges.or.jp/modules/envirolib/view.php?docid=2136.

IPCC (Intergovernmental Panel on Climate Change). (2006). 2006 IPCC Guidelines for National Greenhouse Gas Inventories. The National Greenhouse Gas Inventories Programme, The Intergovernmental Panel on Climate Change, H.S. Eggleston, L. Buendia, K. Miwa, T. Ngara, and K. Tanabe (eds.). Hayama, Kanagawa, Japan. Default Emission Factors retrieved from Volume 2. Energy, Chapter 2 Stationary Combustion. Accessed October, 2013: http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_2_Ch2_Stationary_Combustion.pdf.

NIST (National Institute of Standards and Technology). (2006). The International System of Units (SI) – Conversion Factors for General Use. Accessed October, 2013: http://www.nist.gov/pml/wmd/metric/upload/SP1038.pdf.

UNFCCC CDM (United Nations Framework Convention on Climate Change Clean Development Mechanism). (2013a). ACM0006 "Consolidated methodology for electricity and heat generation from biomass". CDM Executive Board.

UNFCCC CDM. (2013b). ACM0020 "Co-firing of biomass residues for heat generation and/or electricity generation in grid connected power plants". CDM Executive Board.

UNFCCC CDM. (2013c). AM0036 "Fuel switch from fossil fuels to biomass residues in heat generation equipment" CDM Executive Board.

3.3.9 ANAEROBIC DIGESTERS FOR MANURE MANAGEMENT

Bracmort, Kelsi. (2010). Anaerobic Digestion: Greenhouse Gas Emission Reduction and Energy Generation. Accessed September 2015: http://nationalaglawcenter.org/wp-content/uploads/assets/crs/R40667.pdf

Engineering Toolbox. (2015). Chemical, Physical and Thermal Properties of Methane – CH_4. Accessed August 5, 2015: http://www.engineeringtoolbox.com/methane-d_1420.html.

EPA (Environmental Protection Agency). (2004). A Manual for Developing Biogas Systems at commercial Farms in the United States. Accessed August 5, 2015: http://www2.epa.gov/sites/production/files/2014-12/documents/agstar-handbook.pdf

EPA. (2011). Market Opportunities for Biogas Recovery Systems at U.S. Livestock Facilities. Accessed December, 2015: http://www.epa.gov/sites/production/files/2014-12/documents/biogas_recovery_systems_screenres.pdf.

EPA. (2015). Catalog of CHP Technologies. Section 5. Technology Characterization – Microturbines. Accessed December, 2015: http://www.epa.gov/sites/production/files/2015-07/documents/catalog_of_chp_technologies_section_5._characterization_-_microturbines.pdf

IEA (International Energy Agency). (2009). International Energy Agency Electricity/Heat Statistics for 2009. Average Grid Line Loss Rate. Accessed October, 2013: http://www.iea.org/stats/prodresult.asp?PRODUCT=Electricity/Heat.

IEA. (2013). CO_2 Emissions from Fuel Combustion – Highlights 2013. GHG Emission Factors. Accessed December, 2015: http://www.iea.org/bookshop/669-CO2_Emissions_from_Fuel_Combustion.

IGES (Institute for Global Environmental Strategies). (2015). List of Grid Emission Factors – Version 2015/10. A. Kuriyama (ed.). Accessed 15 March 2016: http://pub.iges.or.jp/modules/envirolib/view.php?docid=2136.

IPCC (Intergovernmental Panel on Climate Change). (2006). 2006 IPCC Guidelines for National Greenhouse Gas Inventories. The National Greenhouse Gas Inventories Programme, The Intergovernmental Panel on Climate Change, H.S. Eggleston, L. Buendia, K. Miwa, T. Ngara, and K. Tanabe (eds.). Hayama, Kanagawa, Japan. Default Emission Factors retrieved from Volume 2. Energy, Chapter 2 Stationary Combustion. Accessed October, 2013: http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_2_Ch2_Stationary_Combustion.pdf.

IPCC. (2006b). 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Prepared by the National Greenhouse Gas Inventories Programme. Japan: Intergovernmental Panel on Climate Change. Volume 4: Agriculture, Forestry and Other Land Use, Chapter 10. Emissions from Livestock and Manure Management. Accessed October, 2013: http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_10_Ch10_Livestock.pdf.

IPCC. (2006c). 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Prepared by the National Greenhouse Gas Inventories Programme. Japan: Intergovernmental Panel on Climate Change. Volume 4: Agriculture, Forestry and Other Land Use, Chapter 11. N_2O Emissions from Managed Soils, and CO2 Emissions from Lime and Urea Application. Accessed October, 2013: http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_11_Ch11_N2O&CO2.pdf.

IPCC. (2007a). Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. Accessed January, 2015.

IPCC. (2007b). GHG Lifetimes and GWPs. IPCC, Fourth Assessment Report (AR4), Working Group 1, Chapter 2, Changes in Atmospheric Constituents and in Radiative Forcing, Table 2.10.2. Accessed February, 2015: http://www.ipcc.ch/publications_and_data/ar4/wg1/en/ch2s2-10-2.html.

MN Project (The Minnesota Project). 2005. Anaerobic Digester Systems for Mid-Sized Dairy Farms. Accessed December, 2015. http://www.renewwisconsin.org/biogas/AD/Digesters%20for%20Mid-Size%20Farms.pdfNIST (National Institute of Standards and Technology). (2006). The International System of Units (SI) – Conversion Factors for General Use. Accessed October, 2013: http://www.nist.gov/pml/wmd/metric/upload/SP1038.pdf.

NIST (National Institute of Standards and Technology). (2011). Thermophysical Properties of Fluid Systems. Accessed October, 2013: http://webbook.nist.gov/chemistry/fluid/.

UNFCCC (United Nations Framework for Climate Change Convention). (2005). Draft revision to approved baseline methodology AM0013: Forced methane extraction from organic waste-water treatment plants for grid-connected electricity supply and/or heat production/ Version 02. Accessed October, 2013: http://cdm.unfccc.int/Panels/meth/meeting/05/Meth15_AM0013_revision.pdf.

USDA AgSTAR (United States Department of Agriculture). (2013). Anaerobic Digester Photo. Accessed April 10, 2013: http://www.ers.usda.gov/amber-waves/2012-december/alternative-policies-to-promote-anaerobic-digesters-produce-positive-net-benefits.aspx#.UWdLaalp-So.

Wischnewski, Berndt. (2013). Calculation of thermodynamic state variables of methane. Accessed August 8, 2013: http://www.peacesoftware.de/einigewerte/methan_e.html.

3.4.1 BUILDING ENERGY EFFICIENCY

DOE (Department of Energy). (2013). Weather Data for EnergyPlus Energy Simulation Software. Accessed October, 2013: http://apps1.eere.energy.gov/buildings/energyplus/weatherdata_about.cfm.

IEA (International Energy Agency). (2009). International Energy Agency Electricity/Heat Statistics for 2009. Average Grid Line Loss Rate. Accessed October, 2013: http://www.iea.org/stats/prodresult.asp?PRODUCT=Electricity/Heat.

IEA. (2013). CO_2 Emissions from Fuel Combustion – Highlights 2013. GHG Emission Factors. Accessed December, 2015: http://www.iea.org/bookshop/669-CO2_Emissions_from_Fuel_Combustion.

IEESAG (Illinois Energy Efficiency Stakeholder Advisory Group). (2012). Energy Efficiency Technical Reference Manual Final Technical Version, August 20th, 2012. Accessed December, 2015: http://ilsagfiles.org/SAG_files/Subcommittees/IPA-TRC_Subcommittee/10-6-2015_Meeting/TRC_Subcommittee_Report_Final_Draft_9-28-15.pdf

IGES (Institute for Global Environmental Strategies). (2015). List of Grid Emission Factors – Version 2015/10. A. Kuriyama (ed.). Accessed 15 March 2016: http://pub.iges.or.jp/modules/envirolib/view.php?docid=2136.

IPCC (Intergovernmental Panel on Climate Change). (2006). 2006 IPCC Guidelines for National Greenhouse Gas Inventories. The National Greenhouse Gas Inventories Programme, The Intergovernmental Panel on Climate Change, H.S. Eggleston, L. Buendia, K. Miwa, T. Ngara, and K. Tanabe (eds.). Hayama, Kanagawa, Japan. Default Emission Factors retrieved from Volume 2. Energy, Chapter 2 Stationary Combustion. Accessed October, 2013: http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_2_Ch2_Stationary_Combustion.pdf.

NIST (National Institute of Standards and Technology). (2006). the International System of Units (SI) – Conversion Factors for General Use. Accessed October, 2013: http://www.nist.gov/pml/wmd/metric/upload/SP1038.pdf.

3.4.2 APPLIANCE & EQUIPMENT EFFICIENCY

IEA (International Energy Agency). (2009). International Energy Agency Electricity/Heat Statistics for 2009. Average Grid Line Loss Rate. Accessed October, 2013: http://www.iea.org/stats/prodresult.asp?PRODUCT=Electricity/Heat.

IEA. (2013). CO_2 Emissions from Fuel Combustion – Highlights 2013. GHG Emission Factors. Accessed December, 2015: http://www.iea.org/bookshop/669-CO2_Emissions_from_Fuel_Combustion.

IGES. (2015). List of Grid Emission Factors – Version 2015/10. A. Kuriyama (ed.). Accessed 15 March 2016: http://pub.iges.or.jp/modules/envirolib/view.php?docid=2136.

IPCC (Intergovernmental Panel on Climate Change). (2006). 2006 IPCC Guidelines for National Greenhouse Gas Inventories. The National Greenhouse Gas Inventories Programme, The Intergovernmental Panel on Climate Change, H.S. Eggleston, L. Buendia, K. Miwa, T. Ngara, and K. Tanabe (eds.). Hayama, Kanagawa, Japan. Default Emission Factors retrieved from Volume 2.

Energy, Chapter 2 Stationary Combustion. Accessed October, 2013: http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_2_Ch2_Stationary_Combustion.pdf.

IPCC. (2011). IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation. Prepared by Working Group III of the Intergovernmental Panel on Climate Change [O. Edenhofer, R. Pichs-Madruga, Y. Sokona, K. Seyboth, P. Matschoss, S. Kadner, T. Zwickel, P. Eickemeier, G. Hansen, S. Schlömer, C. von Stechow (eds)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1075 pp

NIST (National Institute of Standards and Technology). (2006). The International System of Units (SI) – Conversion Factors for General Use. Accessed October, 2013: http://www.nist.gov/pml/wmd/metric/upload/SP1038.pdf.

US EPA Energy Star. (2007). Energy Star Program Requirements for Residential Refrigerators and/or Freezers. Partner Commitments. Accessed October, 2013: http://www.energystar.gov/ia/partners/product_specs/program_reqs/refrig_prog_req.pdf.

3.5.1 TRANSMISSION AND DISTRIBUTION SYSTEM UPGRADES: TECHNICAL LOSS REDUCTIONS

Climate Registry, The. (2009). "Electric Power Sector Protocol for the Voluntary Reporting Program: Annex I to the General Reporting Protocol". Ver 1.0: The Climate Registry.

EPA (Environmental Protection Agency). (2012). "How to use eGRID for Carbon Footprinting Electricity Purchases in Greenhouse Gas Emission Inventories". Retrieved December 12, 2014 from http://www.epa.gov/ttnchie1/conference/ei20/session3/adiem.pdf

EPA (2013). "Methodologies for U.S. Greenhouse Gas Emissions Projections: Non-CO_2 and Non-Energy CO_2 Sources". Retrieved December 12, 2014 from http://www.state.gov/documents/organization/219472.pdf

IEA (International Energy Agency). (2013). CO_2 Emissions from Fuel Combustion – Highlights 2013. GHG Emission Factors. Accessed December, 2015: http://www.iea.org/bookshop/669-CO2_Emissions_from_Fuel_Combustion.

IGES (Institute for Global Environmental Strategies). (2015). List of Grid Emission Factors – Version 2015/10. A. Kuriyama (ed.). Accessed 15 March 2016: http://pub.iges.or.jp/modules/envirolib/view.php?docid=2136.

Madrigal, Marcelino and Spalding-Fecher, Randall. (2010). "Review of Methodologies and a Proposed Approach in the Context of World Bank Lending Operations". Paper No. 21. The World Bank and The Energy and Mining Sector Board.

UNFCCC CDM (United Nations Framework Convention on Climate Change Clean Development Mechanism). (2009). "Supply-Side Energy Efficiency Improvements – Transmissions and Distribution". Version 10: Clean Development Mechanism.

UNFCCC CDM. (2012a). "Approved baseline and monitoring methodology AM0108: Interconnection between electricity systems for energy exchange". Ver 01.0.0: Clean Development Mechanism.

UNFCCC CDM. (2012b). "Clean Development Mechanism AM0035. Large-scale Methodology: SF6 emission reductions in electrical grids". Ver 02.0.0: Clean Development Mechanism.

3.5.2 STRANDED NATURAL GAS CAPTURE SYSTEMS

API (American Petroleum Institute). (2009). Compendium of Greenhouse Gas Emissions Methodologies for the Oil and Natural Gas Industry. Accessed March, 2016: http://www.api.org/~/media/Files/EHS/climate-change/2009_GHG_COMPENDIUM.pdf?la=en

CCEI (Canadian Centre for Energy Information). (2007). Flaring: Questions and Answers. Accessed January, 2015: http://siteresources.worldbank.org/EXTGGFR/Resources/578068-1258067586081/FlaringQA.pdf

Chemguide. (2012). Basics of Naming Conventions. Accessed April, 2015: http://www.chemguide.co.uk/basicorg/conventions/names.html

DOE (Department of Energy). (2013). Liquefied Natural Gas: Understanding the Basic Facts. Accessed 5/1/2016: http://energy.gov/sites/prod/files/2013/04/f0/LNG_primerupd.pdf

Engineering Toolbox. Densities of Gases. Accessed April, 2015: http://www.engineeringtoolbox.com/gas-density-d_158.html

EPA (Environmental Protection Agency). (2009). Greenhouse Gas Emissions Reporting from the Petroleum and Natural Gas Industry: Background Technical Support Document. Accessed December, 2014: http://www.epa.gov/ghgreporting/documents/pdf/2010/Subpart-W_TSD.pdf

IEA (International Energy Agency). 2009. International Energy Agency Electricity/Heat Statistics for 2009. Accessed October, 2013: http://www.iea.org/stats/prodresult.asp?PRODUCT=Electricity/Heat.

IEA. (2013). CO_2 Emissions from Fuel Combustion – Highlights 2013. GHG Emission Factors. Accessed December, 2015: http://www.iea.org/bookshop/669-CO2_Emissions_from_Fuel_Combustion.

IGES (Institute for Global Environmental Strategies). (2015). List of Grid Emission Factors – Version 2015/10. A. Kuriyama (ed.). Accessed March, 2016: http://pub.iges.or.jp/modules/envirolib/view.php?docid=2136.

ISO (International Organization for Standardization). (1994) ISO 10780:1994: Stationary Source Emissions – Measurement of Velocity and Volume Flowrate of Gas Streams in Ducts. Accessed April, 2015: http://www.iso.org/iso/iso_catalogue/catalogue_tc/catalogue_detail.htm?csnumber=18855

IPCC (Intergovernmental Panel on Climate Change). (2006). 2006 IPCC Guidelines for National Greenhouse Gas Inventories. The National Greenhouse Gas Inventories Programme, The Intergovernmental Panel on Climate Change, H.S. Eggleston, L. Buendia, K. Miwa, T. Ngara, and

K. Tanabe (eds.). Hayama, Kanagawa, Japan. Default Emission Factors retrieved from Volume 2. Energy, Chapter 2 Stationary Combustion. Accessed October, 2013: http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_2_Ch2_Stationary_Combustion.pdf.

IPCC. (2000). "Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories". IPCC

NIST (National Institute of Standards and Technology). (2006). The International System of Units (SI) – Conversion Factors for General Use. Accessed October, 2013: http://www.nist.gov/pml/wmd/metric/upload/SP1038.pdf.

IOGP (International Association of Oil and Gas Producers). (2000). "Flaring and Venting in the Oil and Gas Exploration and Production Industry: An Overview of Purpose, Quantities, Issues, Practices and Trends". Report No. 2.79/288.

ORNL (Oak Ridge National Laboratory). (2011). Biomass Energy Data Book Appendix A – Lower and Higher Heating Values of Gas, Liquid, and Solid Fuels. Accessed April 2015: http://cta.ornl.gov/bedb/appendix_a/Lower_and_Higher_Heating_Values_of_Gas_Liquid_and_Solid_Fuels.pdf

US GAO (United States Government Accountability Office). (2010). Federal Oil and Gas Leases: Opportunities Exist to Capture Vented and Flared Natural Gas, which would Increase Royalty Payments and Reduce Greenhouse Gases. Accessed January, 2015: http://www.gao.gov/new.items/d1134.pdf

UNFCCC (United Nations Framework Convention on Climate Change). (2013). Large-scale Methodology: Recovery and Utilization of Gas from Oil Fields that would Otherwise be Flared or Vented. AM0009 Version 7.0. Accessed March, 2016: https://cdm.unfccc.int/filestorage/K/P/9/KP9MVADO1RLGUJ34C5IZ8T7NYEB0W2/EB76_repan05_AM0009_ver07.0.pdf?t=bHV8bzRyYWJ4fDB3GZ6p5X9-myeN_zxtPM9h

USAID (United States Agency for International Development). (2010). USAID/Nigeria Strategy 2010-2013. Accessed December, 2014: http://pdf.usaid.gov/pdf_docs/PDACP977.pdf

USAID. (2011). Fulfilling our Commitment to Clean Energy: Promoting Clean and Efficient Energy Technology in Developing Countries. Accessed December, 2014: http://pdf.usaid.gov/pdf_docs/PDACW193.pdf

USAID. (2013). Africa Infrastructure Program: Gas-Flaring Reduction. Accessed December, 2014: http://www.aipproject.com/gcc/gas_flaring_reduction.php

4. REPORTING AND DOCUMENTATION

IEA (International Energy Agency). (2013). CO_2 Emissions from Fuel Combustion – Highlights 2013. GHG Emission Factors. Accessed December, 2015: http://www.iea.org/bookshop/669-CO2_Emissions_from_Fuel_Combustion.pdf

IGES (Institute for Global Environmental Strategies). (2015). List of Grid Emission Factors – Version 2015/10. A. Kuriyama (ed.). Accessed March, 2016: http://pub.iges.or.jp/modules/envirolib/view.php?docid=2136.

IPCC (International Panel on Climate Change). (2000). Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories, Chapter 8: Quality Assurance and Quality Control. Accessed June, 2015: http://www.ipcc-nggip.iges.or.jp/public/gp/english/8_QA-QC.pdf.

IPCC. (2006b). 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Prepared by the National Greenhouse Gas Inventories Programme. Japan: Intergovernmental Panel on Climate Change. Volume 4: Agriculture, Forestry and Other Land Use, Chapter 10. Emissions from Livestock and Manure Management. Accessed October, 2013: http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_10_Ch10_Livestock.pdf.

UNFCCC (United Nations Framework for Climate Change Convention). (2005). Draft revision to approved baseline methodology AM0013: Forced methane extraction from organic waste-water treatment plants for grid-connected electricity supply and/or heat production/ Version 02. Accessed October, 2013: http://cdm.unfccc.int/Panels/meth/meeting/05/Meth15_AM0013_revision.pdf.

WRI (World Resources Institute). (2014). Greenhouse Gas Protocol Policy and Action Standard. Accessed February, 2015: http://www.wri.org/sites/default/files/Policy_and_Action_Standard.pdf

6 APPENDIX A: CLEER PROTOCOL CLEAN ENERGY TYPOLOGY

This appendix provides a full list of the types of GCCI activities that have been considered as part of the development of this Protocol.

Table 114 includes a typology of USAID activities that was developed to categorize clean energy policies and actions for this Protocol, based on the sectors and categories defined above. This typology was developed based on a survey of GCCI activities, through interviews with GCCO staff, and a review of GCCI documentation such as *Fulfilling our Commitment to Clean Energy: 2008-2010*, *Consolidated State/USAID GCC Supplemental Guidance,* and *Meeting the Fast Start Commitment.* This Protocol provides methodologies for estimating GHG emission reductions resulting from activity types identified in *Table 114* that have anticipated measurable emission reductions attributable to the activity.

The GHG emission impacts of several activity types listed in the typology may be more difficult to assess than others, since GHG emission reductions may not result directly from the implementation of the activity or in the reporting year. Not all activities will result in GHG emission reductions that can be measured, nor result in GHG reductions during the reporting fiscal year. *Table 114* indicates which activity types are likely to lead to measurable emission reductions attributable to USAID and reportable under the GHG Indicator.

Table 114: CLEER Protocol Clean Energy Typology

Category and Sector	GCCI Activity Types	Anticipated measurable emission reductions
Renewable and Alternative Energy		
Technology Implementation	Installation of renewable energy systems, such as: • Solar photovoltaic systems • Solar thermal systems • Wind turbine systems • Geothermal systems • Hydroelectric systems	Yes
	Conversion of biomass, municipal solid waste, or anaerobic digestion to power, liquid fuels, gas or bio-products	Yes
Policy and Assessment	Policies designed for the evacuation, transportation, and trade in renewable energy	Potential
Energy Efficiency		
Technology Implementation	Implementation of energy efficient practices and technologies	Yes

	Combined heat and power production (cogeneration)	Yes
	Appliance efficiency improvement or replacement	Yes
Policy and Assessment	Assessment of energy use patterns	No
	Appliance efficiency standards	Potential
	Demand-side management (DSM) programs	Potential
	Building code standards	Potential
Energy Sector Reform and Enabling Environment		
Technology Implementation	Improving performance and reducing losses of electricity and gas distribution utilities, if integral to GHG reduction plan	Yes
	Electricity transmission infrastructure improvements (e.g., smart grid)	Yes
	Gas transmission infrastructure progress using gas that would otherwise be flared or vented	Yes
Policy and Assessment	Regional power pools–e.g., improve access to clean energy through regional electricity trade exchange	No
	Building a regulatory environment increasing transparency, accountability, and predictability of energy sector	No
	Policies protecting interests of consumers and investors	No
	Policies providing incentives for energy sector utilities to improve efficiency of operations and quality of service, leading to attractive climate for investment capital	No
	Electricity and gas distribution system/utilities reform that reduce losses and increase revenues	No
Carbon Market Readiness and Capacity Building		
Policy and Assessment	Market development and promotion, including monitoring, reporting, and verification (MRV) systems	No
	Assessment of private and public sector capacities, interests, and gaps in carbon market participation	No
	Strategies for effective participation in carbon markets, given current international climate policies and ensuring that national sustainable development needs are addressed	No
	Identification of gaps in knowledge and enhancing capacity to develop Low Emission Development Strategies (LEDS)	No

	Development of LEDS	Potential
	Support for GHG inventory development	No

7 APPENDIX B: ABBREVIATIONS

AC	Alternating current
AC	Air conditioning
AMORE	Alliance for Mindanao Off-Grid Renewable Energy
AR4	Intergovernmental Panel on Climate Change's Fourth Assessment Report
CDD	Cooling degree days
CDM	Clean Development Mechanisms
CFL	Compact fluorescent lamps
CH_4	Methane
CLEER	Clean Energy Emission Reduction
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent
COP	Coefficient of Performance
DC	Direct current
DE	Digestibility of energy
DHW	Domestic hot water systems
DSM	Demand-side management
EC-LEDS	Enhancing Capacity for Low Emission Development Strategies
EF	Emission factors
GCC	Global Climate Change
GCCI	Global Climate Change Initiative
GCCO	Global Climate Change Office
GHG	Greenhouse gas
GIS	Geographic Information Systems
GJ	Gigajoule
GPM	Gallons per minute

GWP	Global Warming Potentials
HDD	Heating degree days
HVAC	Heating ventilation and air conditioning
HFC	Hydrofluorocarbons
ICF	ICF International
IEA	International Energy Agency
IGES	Institutes for Global Environmental Strategies
IL	Illinois
IP	Implementing Partner
IPCC	Intergovernmental Panel on Climate Change
kW	kilowatt
kWh	kilowatt-hour
LEDS	Low Emission Development Strategies
MCF	Methane conversion factor
MJ	Megajoules
MRV	Monitoring, reporting and verification
MW	megawatt
MWh	megawatt-hour
N/A	Not applicable
NF_3	Nitrogen trifluoride
t	metric ton (tonne)
N_2O	Nitrous oxide
OECD	Organisation of Economic Co-operation and Development
OU	Operating unit
PFC	Perfluorocarbon
PMP	Performance Management Plan

PV	Photovoltaic
QA	Quality assurance
QC	Quality control
RE	Reduction efficiency
SCF	Standard cubic feet
SF_6	Sulfur hexafluoride
UNFCCC	United Nations Framework Convention on Climate Change
U.S.	United States
USAID	United States Agency for International Development
VCS	Verified carbon standard
VS	Volatile solids
WRI	World Resources Institute

8 APPENDIX C: GLOSSARY

Table 115: Definitions of GHG Accounting and other Terminology Used in this Protocol

GHG Accounting Term	Definition
Activity Emissions	Estimate of the GHG emissions, removals, or storage associated with the clean energy activity implementation in the reporting year.
Baseline Energy Scenario	Set of assumptions and data describing the most likely events or conditions, in terms of energy, that would have occurred in the absence of the activity in the reporting year (see *Stage 5: Define the Baseline Energy Scenario*).
Baseline Emissions	Estimate of the GHG emissions, removals, or storage associated with the Baseline Energy Scenario in the reporting year (see: *Stage 5: Define the Baseline Energy Scenario*).
Clean Energy Result	Result or targeted end goal of the activity in the context of clean energy, such as renewable energy generation, fuel switching, or increased energy efficiency (see *Stage 2: Identify the Clean Energy and GHG Result*).
Greenhouse gases (GHGs)	The earth absorbs heat energy from the sun and returns most of this heat to space as infrared radiation. Greenhouse gases (GHGs) trap heat in the lower atmosphere, absorb heat energy emitted by Earth's surface and lower atmosphere, and radiate much of it back to Earth's surface, thereby causing warming. This "greenhouse effect" is responsible for maintaining surface temperatures warm enough to sustain life.
GHG Estimation Boundary	Defines the scope of the estimate in terms of the types of gases, jurisdiction, sector, and time period (see: *Stage 3: Define the Boundary*).
Reporting Period	The time period over which an activity and the associated GHG Results are estimated. For the GHG Indicator, the reporting period is the fiscal year being reported (see: *Stage 3: Define the Boundary*).
GHG Result	The net change in GHG emissions (or removals) as a direct product of the result (see: *Stage 2: Identify the Clean Energy and GHG Result*).

9 APPENDIX D: FUEL EMISSION FACTORS

Table 116 includes data on emission factors for fuel types documented by the IPCC for CO_2, CH_4, and N_2O. The table includes default, lower, and upper emission factors for CO_2, CH_4, N_2O, and CO_2e emissions.

Table 116: Fuel Emission Factors on a Net Calorific Basis (g/GJ) (IPCC 2006)

	CO_2			CH_4			N_2O			CO_2e		
Fuel Type	**Default Emission Factor**	**Lower**	**Upper**	**Default Emission Factor**	**Lower**	**Upper**	**Default Emission Factor**	**Lower**	**Upper**	**Default Emission Factor**	**Lower**	**Upper**
Biofuel - Biodiesels	70,800	59,800	84,300	3	1	10	0.6	0.2	2	70,852	59,816	84,456
Biofuel - Biogasoline	70,800	59,800	84,300	3	1	10	0.6	0.2	2	71,049	59,883	85,130
Biofuel - Other Liquid Biofuels	79,600	67,100	95,300	3	1	10	0.6	0.2	2	80,086	67,261	96,913
Biogas - Landfill Gas	54,600	46,200	66,000	1	0.3	3	0.1	0.03	0.3	55,086	46,361	67,613
Biogas - Other Biogas	54,600	46,200	66,000	1	0.3	3	0.1	0.03	0.3	54,849	46,283	66,830
Biogas - Sludge Gas	54,600	46,200	66,000	1	0.3	3	0.1	0.03	0.3	54,849	46,283	66,830
Biomass - Charcoal	112,000	95,000	132,000	200	70	600	4	1.5	15	112,486	95,161	133,613
Biomass - Other Primary Solid	100,000	84,700	117,000	30	10	100	4	1.5	15	100,249	84,783	117,830
Biomass - Sulphite lyes (Black Liquor)[a]	95,300	80,700	110,000	3	1	18	2	1	21	95,549	80,783	110,830
Biomass - Wood / Wood Waste	112,000	95,000	132,000	30	10	100	4	1.5	15	112,249	95,125	133,250
Bitumen	80,700	73,000	89,900	3	1	10	0.6	0.2	2	81,186	73,161	91,513
Blast Furnace Gas	260,000	219,000	308,000	1	0.3	3	0.1	0.03	0.3	260,052	219,016	308,156
Brown Coal Briquettes	97,500	87,300	109,000	1	0.3	3	1.5	0.5	5	97,749	87,383	109,830
Coal - Anthracite	98,300	94,600	101,000	1	0.3	3	1.5	0.5	5	98,352	94,616	101,156
Coal - Bituminous	94,600	89,500	99,700	1	0.3	3	1.5	0.5	5	94,849	89,583	100,530
Coal - Coking Cole	94,600	87,300	101,000	1	0.3	3	1.5	0.5	5	94,652	87,316	101,156

Coal - Lignite	101,000	90,900	115,000	1	0.3	3	1.5	0.5	5	101,249	90,983	115,830
Coal - Sub-Bituminous	96,100	92,800	100,000	1	0.3	3	1.5	0.5	5	96,349	92,883	100,830
Coal Tar	80,700	68,200	95,300	1	0.3	3	1.5	0.5	5	82,570	68,419	102,050
Coke - Coke Oven and Lignite	107,000	95,700	119,000	1	0.3	3	1.5	0.5	4	107,052	95,716	119,156
Coke - Gas	107,000	95,700	119,000	1	0.3	3	0.1	0.03	0.3	107,249	95,783	119,830
Coke Oven Gas	44,400	37,300	54,100	1	0.3	3	0.1	0.03	0.3	44,649	37,383	54,930
Ethane	61,600	56,500	68,600	1	0.3	3	0.1	0.03	0.3	62,086	56,661	70,213
Gas Works Gas	44,400	37,300	54,100	1	0.3	3	0.1	0.03	0.3	46,270	37,975	60,850
Gasoline - Aviation	70,000	67,500	73,000	3	1	10	0.6	0.2	2	70,052	67,516	73,156
Gasoline - Jet	70,000	67,500	73,000	3	1	10	0.6	0.2	2	70,052	67,516	73,156
Gasoline - Motor	69,300	67,500	73,000	3	1	10	0.6	0.2	2	69,352	67,516	73,156
Industrial Wastes	143,000	110,000	183,000	30	10	100	4	1.5	15	143,249	110,083	183,830
Kerosene - Jet	71,500	69,700	74,400	3	1	10	0.6	0.2	2	76,940	71,635	91,650
Kerosene - Other	71,900	70,800	73,700	3	1	10	0.6	0.2	2	73,770	71,475	80,450
Liquefied Petroleum Gases	63,100	61,600	65,600	1	0.3	3	0.1	0.03	0.3	63,152	61,616	65,756
Lubricants	73,300	71,900	75,200	3	1	10	0.6	0.2	2	73,786	72,061	76,813
Municipal Wastes (biomass fraction)	100,000	84,700	117,000	30	10	100	4	0.03	15	101,870	85,375	123,750
Municipal Wastes (nonbiomass fraction)	91,700	73,300	121,000	30	10	100	4	1.5	15	91,949	73,383	121,830
Naphtha	73,300	69,300	76,300	3	1	10	0.6	0.2	2	73,786	69,461	77,913
Natural Gas	56,100	54,300	58,300	1	0.3	3	0.1	0.03	0.3	56,349	54,383	59,130
Natural Gas Liquids	64,200	58,300	70,400	3	1	10	0.6	0.2	2	64,449	58,383	71,230
Oil - Crude	73,300	71,100	75,500	3	1	10	0.6	0.2	2	73,549	71,183	76,330
Oil - Gas/Diesel	74,100	72,600	74,800	3	1	10	0.6	0.2	2	75,970	73,275	81,550
Oil - Other Petroleum	73,300	72,200	74,400	3	1	10	0.6	0.2	2	73,352	72,216	74,556
Oil - Paraffin Waxes	73,300	72,200	74,400	3	1	10	0.6	0.2	2	73,786	72,361	75,703
Oil - Refinery Gas	57,600	48,200	69,000	1	0.3	3	0.1	0.03	0.3	58,086	48,361	70,613
Oil - Residual Fuel	77,400	75,500	78,800	3	3	30	0.6	0.2	2	77,649	75,583	79,630
Oil - Shale	73,300	67,800	79,200	3	1	10	0.6	0.2	2	73,983	68,131	86,088
Oil - White Spirit and SBP	73,300	72,200	74,400	3	1	10	0.6	0.2	2	73,352	72,216	74,556

Oil Shale and Tar Sands	107,000	90,200	125,000	1	0.3	3	1.5	0.5	5	108,870	90,875	131,750
Orimulsion	77,000	69,300	85,400	3	1	10	0.6	0.2	2	77,249	69,383	86,230
Oxygen Steel Furnace Gas	182,000	145,000	202,000	1	0.3	3	0.1	0.03	0.3	182,249	145,083	202,830
Patent Fuel	97,500	87,300	109,000	1	0.3	3	1.5	0.5	5	97,749	87,383	109,830
Peat	106,000	100,000	108,000	1	0.3	3	1.5	0.5	5	106,052	100,016	108,156
Petroleum Coke	97,500	82,900	115,000	3	1	10	0.6	0.2	2	97,986	83,061	116,613
Refinery Feedstocks	73,300	68,900	76,600	3	1	10	0.6	0.2	2	73,786	69,061	78,213
Waste Oils	73,300	72,200	74,400	30	10	100	4	1.5	15	73,549	72,283	75,230

REFERENCES: FUEL EMISSION FACTORS

IPCC (Intergovernmental Panel on Climate Change). (2006). 2006 IPCC Guidelines for National Greenhouse Gas Inventories. The National Greenhouse Gas Inventories Programme, The Intergovernmental Panel on Climate Change, H.S. Eggleston, L. Buendia, K. Miwa, T. Ngara, and K. Tanabe (eds.). Hayama, Kanagawa, Japan. Default Emission Factors retrieved from Volume 2. Energy, Chapter 2 Stationary Combustion. Accessed October, 2013: http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_2_Ch2_Stationary_Combustion.pdf.

10 APPENDIX E: DEFAULT VALUES FOR OTHER VARIABLES

10.1 Efficiency of Diesel Generators

Table 117 includes data on efficiency of diesel generators based on load levels. Diesel generator efficiency was determined using approximate diesel consumption by various sized generators and operating at various load levels. The consumption data was obtained from a commercial company, Diesel Service and Supply and can be found online.

The analysis takes consumption data for each capacity size and load level to determine the efficiency, as seen in *Table 117: Efficiencies for Diesel Generators* below. The efficiencies of diesel generators increase as the operating load increases are the maximum when operating at a full load. In addition, the efficiencies also increase with the increase in capacity of the generator. Since there is no one load level or capacity can be a representative sample, the median value of all the efficiencies is used as the representative value for the efficiency. The median calculated is 34.9% which is the suggested default value for diesel generator efficiency used in the protocol.

Table 117: Efficiencies for Diesel Generators (gal/hr) (Diesel Service & Supply 2013)

Generator Size (kW)	1/4 Load (gal/hr)	1/2 Load (gal/hr)	3/4 Load (gal/hr)	Full Load (gal/hr)
20	21.9%	29.3%	30.4%	32.9%
30	15.2%	21.9%	24.7%	27.2%
40	16.5%	22.9%	24.7%	26.3%
60	21.9%	27.2%	31.2%	32.9%
75	20.6%	29.0%	32.2%	32.4%
100	25.3%	32.1%	34.0%	35.6%
125	26.5%	32.9%	34.8%	36.2%
135	26.9%	32.9%	35.1%	36.3%
150	27.4%	33.5%	35.3%	36.2%
175	28.1%	33.9%	35.6%	36.3%
200	28.0%	34.2%	35.9%	36.6%
230	28.6%	34.4%	36.3%	36.5%
250	28.9%	34.6%	36.3%	36.6%
300	29.0%	35.0%	36.8%	36.7%
350	29.2%	35.2%	37.0%	36.7%
400	29.6%	35.3%	37.1%	36.8%
500	29.9%	35.6%	37.4%	36.9%
600	29.9%	35.9%	37.6%	36.9%
750	30.3%	36.0%	37.7%	37.0%
1000	30.5%	36.2%	37.9%	37.0%
1250	30.6%	36.3%	38.0%	37.1%
1500	30.7%	36.4%	38.1%	37.1%
1750	30.7%	36.5%	38.1%	37.1%
2000	30.8%	36.5%	38.2%	37.1%
2250	30.8%	36.5%	38.2%	37.1%

REFERENCES: EFFICIENCY OF DIESEL GENERATORS

Diesel Service and Supply. 2013. "Approximate Diesel Fuel Consumption Chart". Fuel Consumption of Diesel Generators. Accessed February, 2015: http://www.dieselserviceandsupply.com/Diesel_Fuel_Consumption.aspx.

10.2 Default Tables for Manure Management

Table 118 includes manure management CH_4 emission factors for various livestock species and annual temperatures.

Table 118: Manure Management Methane Emission Factors by Temperature for Cattle, Swine, and Buffalo

Regional characteristics	Livestock species	CH_4 emission factors by average annual temperature (°C)[b]																		
		Cool					Temperate											Warm		
		≤ 10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	≥ 28
Africa: Most livestock manure is managed as a solid on pastures and ranges. A smaller, but significant fraction is burned as fuel.	Dairy Cows	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Other Cattle	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Swine	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2
Middle East: Over two-thirds of cattle manure is deposited on pastures and ranges. About one-third of swine manure is managed in liquid-based systems. Buffalo manure is burned for fuel or managed as a solid.	Dairy Cows	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	3
	Other Cattle	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Swine	1	1	1	2	2	2	2	2	3	3	3	3	4	4	4	5	5	5	6
	Buffalo	4	4	4	4	4	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Asia: About half of cattle manure is used for fuel with the remainder managed in dry systems. Almost 40% of swine manure is managed as a liquid. Buffalo manure is managed in drylots and deposited in pastures and ranges.	Dairy Cows	9	10	10	11	12	13	14	15	16	17	18	20	21	23	24	26	28	31	31
	Other Cattle	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Swine	2	2	2	2	2	3	3	3	3	4	4	4	5	5	5	6	6	7	7
	Buffalo	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Indian Subcontinent: About half of cattle and buffalo manure is used for fuel with the remainder managed in dry systems. About one-third of swine manure is managed as a liquid.	Dairy Cows	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	6	6
	Other Cattle	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
	Swine	2	2	3	3	3	3	3	3	4	4	4	4	4	5	5	5	6	6	6
	Buffalo	4	4	4	4	4	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Latin America: Almost all livestock manure is managed as a solid on pastures and ranges. Buffalo manure is deposited on pastures and ranges.	Dairy Cows	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2
	Other Cattle	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Swine	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2
	Buffalo	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2

Regional characteristics	Livestock species	CH_4 emission factors by average annual temperature (°C)[b]																		
		Cool					Temperate											Warm		
		≤ 10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	≥ 28
North America: Liquid-based systems are commonly used for dairy cows and swine manure. Other cattle manure is usually managed as a solid and deposited on pastures or ranges.	Dairy Cows	48	50	53	55	58	63	65	68	71	74	78	81	85	89	93	98	105	110	112
	Other Cattle	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2
	Market Swine	10	11	11	12	12	13	13	14	15	15	16	17	18	18	19	20	22	23	23
	Breeding Swine	19	20	21	22	23	24	26	27	28	29	31	32	34	35	37	39	41	44	45
Western Europe: Liquid/slurry and pit storage systems are commonly used for cattle and swine manure. Limited cropland is available for spreading manure.	Dairy Cows	21	23	25	27	29	34	37	40	43	47	51	55	59	64	70	75	83	90	92
	Other Cattle	6	7	7	8	8	10	11	12	13	14	15	16	17	18	20	21	24	25	26
	Market Swine	6	6	7	7	8	9	9	10	11	11	12	13	14	15	16	18	19	21	21
	Breeding Swine	9	10	10	11	12	13	14	15	16	17	19	20	22	23	25	27	29	32	33
	Buffalo	4	4	5	5	5	6	7	7	8	9	9	10	11	12	13	14	15	16	17
Eastern Europe: Solid based systems are used for the majority of manure. About one-third of livestock manure is managed in liquid-based systems.	Dairy Cows	11	12	13	14	15	20	21	22	23	25	27	28	30	33	35	37	42	45	46
	Other Cattle	6	6	7	7	8	9	10	11	11	12	13	14	15	16	18	19	21	23	23
	Market Swine	3	3	3	3	3	4	4	4	4	5	5	5	6	6	6	7	10	10	10
	Breeding Swine	4	5	5	5	5	6	7	7	7	8	8	9	9	10	11	12	16	17	17
	Buffalo	5	5	5	6	6	7	8	8	9	10	11	11	12	13	15	16	17	19	19
Oceania: Most cattle manure is managed as a solid on pastures and ranges, except dairy cows where there is some usage of lagoons. About half of the swine manure is managed in anaerobic lagoons.	Dairy Cows	23	24	25	26	26	27	28	28	28	29	29	29	29	29	30	30	31	31	31
	Other Cattle	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2
	Market Swine	11	11	12	12	12	13	13	13	13	13	13	13	13	13	13	13	13	13	13
	Breeding Swine	20	20	21	21	22	22	23	23	23	23	23	24	24	24	24	24	24	24	24

Table 119 includes manure manegement CH_4 emission factors for several livestock and annual temperature, differentiating by developed or developing countries.

Table 119: Manure Management Methane Emission Factors by Temperature for Sheep, Goats, Camels, Horses, Mules and Asses, and Poultry (kg CH_4/ Head/ Year) (IPCC 2006),

Livestock	CH_4 emission factor by average annual temperature (°C)		
	Cool (<15°C)	Temperate (15 to 25°C)	Warm (>25°C)
Sheep			
Developed countries	0.19	0.28	0.37
Developing countries	0.10	0.15	0.20
Goats			
Developed countries	0.13	0.20	0.26
Developing countries	0.11	0.17	0.22
Camels			
Developed countries	1.58	2.37	3.17
Developing countries	1.28	1.92	2.56
Horses			
Developed countries	1.56	2.34	3.13
Developing countries	1.09	1.64	2.19
Mules and Asses			
Developed countries	0.76	1.10	1.52
Developing countries	0.60	0.90	1.20
Poultry			
Developed countries			
Layers (dry)[b]	0.03	0.03	0.03
Layers (wet)[c]	1.2	1.4	1.4
Broilers	0.02	0.02	0.02
Turkeys	0.09	0.09	0.09
Ducks	0.02	0.03	0.03
Developing countries	0.01	0.02	0.02

REFERENCES: DEFAULT TABLES FOR MANURE MANAGEMENT

IPCC (International Government on Climate Change). (2006b). 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Prepared by the National Greenhouse Gas Inventories Programme. Japan: Intergovernmental Panel on Climate Change. Volume 4: Agriculture, Forestry and Other Land Use, Chapter 10. Emissions from Livestock and Manure Management. Accessed October, 2013: http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_10_Ch10_Livestock.pdf.

11 APPENDIX F: CALORIFIC VALUES AND EMISSION FACTORS OF VARIOUS TYPES OF BIOMASS

Table 120 includes biomass-related caloric values and emission factors.

Table 120: Caloric Values and Emission Factors for Biomass

Type	Calorific Value (MJ/kg)	Emission Factor (gCO_2e/MJ)	Source
Wood Chips	14	98.21	BEC, 2013
Wood Briquettes or Pellets	17	97.06	BEC, 2013
Charcoal	29.5	112	IPCC, 2006
Wheat Straw	14.5	96.09	BEC, 2013
Bagasse Briquettes	7.6	97.84	EPA, 1993
Palm Kernel	18.5	57.97	Ghani et al. , 2013
Rice Husk	13.5	111.59	Ghani et al., 2013
Miscanthus Bales	13.4	80.17	Jagustyn et al., 2013

REFERENCES: CALORIFIC VALUES AND EMISSION FACTORS OF VARIOUS TYPES OF BIOMASS

Biomass Energy Centre (BEC). 2013. "Carbon emissions of different fuels". Accessed October, 2013: http://www.biomassenergycentre.org.uk/portal/page?_pageid=75,163182&_dad=portal&_schema=PORTAL.

Environment Protection Agency (EPA) (1993). "Emission Factor Documentation for AP-42 Section 1.8 Bagasse Combustion in Sugar Mills". Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency, Research Triangle Park, NC.

Ghani, W. A. W, A. K., and Alias, A. B. (2013). Sustainable Power Generation through Co-Combustion of Agricultural Residues with Coal in Existing Coal Power Plant. Chapter 16 of New Developments in Renewable Energy. Accessed October, 2013: http://www.intechopen.com/books/new-developments-in-renewable-energy/sustainable-power-generation-through-co-combustion-of-agricultural-residues-with-coal-in-existing-co.

IPCC (Intergovernmental Panel on Climate Change). (2006). 2006 IPCC Guidelines for National Greenhouse Gas Inventories. The National Greenhouse Gas Inventories Programme, The Intergovernmental Panel on Climate Change, H.S. Eggleston, L. Buendia, K. Miwa, T. Ngara, and K. Tanabe (eds.). Hayama, Kanagawa, Japan. Default Emission Factors retrieved from Volume 2. Energy, Chapter 2 Stationary Combustion. Accessed October, 2013: http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_2_Ch2_Stationary_Combustion.pdf.Jagustyn, B., Patyna, I., and Skawinska, A. (2013). Evaluation of physicochemical properties of Palm Kernel Shell as agro biomass used in the energy industry. CHEMIK 2013, **67**, 6, 552-559. Accessed October, 2013: http://www.chemikinternational.com/year-2013/year-2013-issue-6/evaluation-of-physicochemical-properties-of-palm-kernel-shell-as-agro-biomass-used-in-the-energy-industry/.

12 APPENDIX G: TABLES FOR APPLIANCE & EQUIPMENT EFFICIENCY

Table 121 includes energy consumption constant factors for baseline and activity appliances.

Table 121: Energy Consumption Constant Factors (US EPA Energy Star 2007)

		Baseline Appliance		Activity Appliance	
		Const1	Const2	Const1	Const2
Refrigerators					
1	Refrigerator-only or Refrigerator-Freezer (manual or partial automatic-defrost)	8.82	248.4	7.056	198.72
2	Top-Mounted Freezer with through-the-door ice	10.2	356	8.16	284.8
3	Top-Mounted Freezer without through-the-door ice	9.8	276	7.84	220.8
4	Side-Mounted Freezer with through-the-door ice	10.1	406	8.08	324.8
5	Side-Mounted Freezer without through-the-door ice	4.91	507.5	3.928	406
6	Bottom-Mounted Freezer with through-the-door ice	5	539	4	431.2
7	Bottom-Mounted Freezer without through-the-door ice	4.6	459	3.68	367.2
Compact Refrigerators					
1	Compact Refrigerator only or Refrigerator-Freezer (manual defrost)	10.7	299	8.56	239.2
2	Compact Refrigerator only or Refrigerator-Freezer (partial automatic defrost)	7	398	5.6	318.4
3	Top-Mounted (automatic defrost)	12.7	355	10.16	284
4	Side-Mounted (automatic defrost)	7.6	501	6.08	400.8
5	Bottom-Mounted (automatic defrost)	12.1	367	9.68	293.6
Freezers (Including Compacts)					
1	Chest Freezer	9.88	143.7	8.892	129.33
2	Chest Freezer (automatic defrost)	14.76	211.5	13.284	190.35
3	Upright Freezer (manual defrost)	7.55	258.3	6.795	232.47
4	Upright Freezer (automatic defrost	12.43	326.1	11.187	293.49
5	Compact Chest Freezer	10.45	152	9.405	136.8
6	Compact Upright Freezer (manual defrost)	9.78	250.8	8.802	225.72
7	Compact upright Freezer (automatic defrost)	11.4	391	10.26	351.9

Table 122 includes annual electricity consumption for baseline and activity of several equipment types.

Table 122: Annual Electricity Consumption of various types of refrigerators

Type	Annual Electricity Consumption	
	Baseline Equipment	Activity Equipment
Refrigerators	565.5 kWh/yr	452.4 kWh/yr
Compact Refrigerators	351.8 kWh/yr	281.4 kWh/yr
Freezers	473.5 kWh/yr	426.1 kWh/yr

REFERENCES: TABLES FOR APPLIANCE & EQUIPMENT EFFICIENCY

US EPA Energy Star. 2007. Energy Star Program Requirements for Residential Refrigerators and/or Freezers. Partner Commitments. Accessed October, 2013: http://www.energystar.gov/ia/partners/product_specs/program_reqs/refrig_prog_req.pdf.

13 APPENDIX H: UNITS OF MEASUREMENT

13.1 Energy

Table 123 includes common energy unit conversion factors from the National Institute of Standards and Technology.

Table 123: Energy Unit Conversions (NIST 2006)

Energy Unit	Watt-hour	Joule	BTU	Therm
1 watt-hour	1	3600	3.412142	3.41E-05
1 kilowatt-hour	1000	3600000	3412.142	0.03412128
1 megawatt-hour	1000000	3.60E+09	3412142	34.12128
1 gigawatt-hour	1.00E+09	3.60E+12	3.41E+09	34121.28
1 joule	0.00028	1	0.00094782	9.48E-09
1 kilojoule	0.27778	1000	0.9478171	9.48E-06
1 megajoule	277.778	1000000	947.8171	0.009478134
1 gigajoule	277778	1E+09	947817.1	9.478134
1 BTU	0.29307	1055.056	1	1.00E-05
1 MMBtu	293071	1.06E+09	1000000	9.999961
1 therm	29307.2	1.06E+08	100000.4	1

13.2 Power

Table 124 includes common power unit conversion factors from the National Institute of Standards and Technology.

Table 124: Power Unit Conversions (NIST 2006)

Power Unit	watt	kilowatt	megawatt	BTU/hour
1 watt	1	0.001	1.00E-06	3.415179
1 kilowatt	1000	1	0.001	3415.179
1 megawatt	1000000	1000	1	3415179
1 BTU/hour	0.29281	0.00029281	2.93E-07	1

13.3 Mass

Table 125 includes common mass unit conversion factors from the National Institute of Standards and Technology.

Table 125: Mass Unit Conversions (NIST 2006)

Mass Unit	gram	pound	short ton
1 gram	1	0.0022	1.1023E-06
1 kilogram	1,000	2.2046	0.00110231
1 Megagram (ton)	1,000,000	2,205	1.10231131
1 Gigagram	1,000,000,000	2,204,623	1,102.3
1 Teragram (MMT)	1,000,000,000,000	2,204,622,622	1,102,311
1 pound	454	1	0.0005
1 short ton	907,185	2000	1

13.4 Volume

Table 126 includes common volume unit conversion factors from the National Institute of Standards and Technology.

Table 126: Volume Unit Conversions (NIST 2006)

Volume Unit	liter	gallon	quart	cubic inch	cubic foot	thousand cubic feet (MCF)	million cubic feet (MMCF)	cubic yard	cubic meter
1 liter	1	0.2641721	1.056688	61.02374	0.035315	3.53147E-05	3.5315E-08	0.00130795	0.001
1 gallon	3.785412	1	4	231	0.133681	0.000133681	1.3368E-07	0.00495113	0.00378541
1 quart	0.9463529	0.25	1	57.75	0.03342	3.34201E-05	3.342E-08	0.00123778	0.00094635
1 cubic inch	0.01638706	0.004329004	0.017316	1	0.000579	5.78704E-07	5.787E-10	2.14E-05	1.64E-05
1 cubic foot	28.31685	7.480519	29.92208	1728	1	0.001	0.000001	0.03703704	0.02831685
1 thousand cubic feet (MCF)	28316.85	7480.519	29922.08	1728000	1000	1	0.001	37.03704	28.31685
1 million cubic feet (MMCF)	28316850	7480519	29922080	1.73E+09	1000000	1000	1	37037.04	28316.85
1 cubic yard	764.5549	201.974	807.8961	46656	27	0.027	0.000027	1	0.7645549
1 cubic meter	1000	264.1721	1056.688	61023.74	35.31467	0.03531467	3.5315E-05	1.307951	1
1 petroleum barrel	158.99	42.00	168.00	9702.00	5.61	0.005614585	5.6146E-06	0.21	0.16

REFERENCES: UNITS OF MEASURE

NIST (National Institute of Standards and Technology). (2006). The International System of Units (SI) – Conversion Factors for General Use. Conversion factors. Accessed October, 2013: http://www.nist.gov/pml/wmd/metric/upload/SP1038.pdf.

14 APPENDIX I: CAPACITY FACTORS AND SOLAR INSOLATION BY COUNTRY

14.1 Solar Insolation and Capacity Factors

Table 127 includes country specific data on daily solar insolation and capacity factor values for several renewable energy systems.

Table 127: Country Capacity Factors (CFs) by Power Generation Source

Short-form name	Solar Insolation ($kWh/m^2/day$)[a]	Solar CF (%)[a]	Wind CF (%)[b]	Hydro CF (%)[c]	Geothermal Power CF (%)[d]	Geothermal Direct Heat CF (%)[e]
Afghanistan	5.30	18.6%	1%	29%	72%	34%
Albania	4.14	14.7%	22%*	42%	80%	11%
Algeria	5.61	19.2%	25%*	23%	94%	98%
Andorra	3.70	13.2%	22%*	36%	80%	29%
Angola	5.58	18.6%	25%*	45%	94%	60%
Antigua and Barbuda	6.16	20.7%	24%*	47%	67%	16%
Argentina	4.80	16.7%	30%	41%	72%	40%
Armenia	3.96	14.2%	18%	6%	72%	48%
Australia	5.90	20.1%	27%	25%	5%	22%
Austria	3.25	11.5%	20%	33%	31%	18%
Azerbaijan	3.48	12.3%	22%*	34%	72%	34%
Bahamas, The	5.74	19.2%	24%*	47%	67%	16%
Bahrain	6.01	20.2%	34%	42%	72%	34%
Bangladesh	4.65	16.0%	11%	60%	72%	34%
Barbados	6.10	20.1%	24%*	47%	67%	16%
Belarus	2.82	9.9%	36%	44%	80%	31%
Belgium	2.81	9.6%	23%	38%	80%	15%
Belize	4.85	16.0%	34%	57%	67%	16%
Benin	5.59	18.3%	25%*	52%	94%	60%
Bhutan	5.31	18.9%	19%*	55%	72%	34%
Bolivia	4.61	15.2%	24%*	50%	72%	50%
Bosnia and Herzegovina	3.43	12.2%	22%*	30%	80%	37%
Botswana	5.87	20.0%	25%*	52%	94%	60%

Brazil	4.87	15.9%	23%	50%	72%	58%
Brunei Darussalam	5.65	18.2%	19%*	42%	72%	34%
Bulgaria	3.78	13.4%	21%	37%	80%	44%
Burkina Faso	5.95	19.7%	25%*	40%	94%	60%
Burma	5.14	17.5%	19%*	42%	72%	34%
Burundi	5.05	16.2%	25%*	47%	94%	60%
Cambodia	5.27	17.4%	19%*	52%	72%	34%
Cameroon	5.65	18.3%	25%*	60%	94%	60%
Canada	2.87	10.8%	21%	58%	67%	25%
Cape Verde	5.90	19.7%	3%	52%	94%	60%
Central African Republic	5.69	18.5%	25%*	78%	94%	60%
Chad	6.64	22.2%	25%*	52%	94%	60%
Chile	5.59	19.2%	23%	52%	72%	46%
China	4.28	15.5%	18%	46%	71%	27%
Colombia	4.86	15.6%	32%	53%	72%	63%
Comoros	6.22	20.5%	25%*	23%	94%	60%
Congo	4.86	15.4%	25%*	52%	94%	60%
Congo, Democratic Republic	4.80	15.2%	25%*	52%	94%	60%
Costa Rica	4.15	13.4%	41%	55%	78%	67%
Côte d'Ivoire	5.10	16.6%	25%*	34%	94%	60%
Croatia	3.54	12.6%	21%	28%	80%	22%
Cuba	5.05	16.7%	17%	19%	67%	16%
Cyprus	5.19	17.9%	14%	23%	80%	29%
Czech Republic	2.84	9.8%	18%	23%	80%	19%
Denmark	2.91	10.3%	28%	27%	80%	40%
Djibouti	6.05	19.9%	25%*	52%	94%	60%
Dominica	5.97	19.8%	1%	34%	67%	16%
Dominican Republic	5.10	17.0%	35%	34%	67%	16%
Ecuador	3.75	11.9%	1%	51%	72%	63%
Egypt	6.05	20.3%	26%	62%	94%	48%
El Salvador	5.28	17.4%	24%*	50%	80%	63%
Equatorial Guinea	4.35	13.9%	25%*	23%	94%	60%

Eritrea	5.48	18.1%	25%*	52%	94%	60%
Estonia	2.82	10.0%	18%	68%	80%	18%
Ethiopia	5.81	19.0%	4%	46%	16%	60%
Fiji	5.47	18.2%	23%	57%	75%	73%
Finland	2.48	9.0%	20%	52%	80%	31%
France	3.34	11.4%	22%	31%	68%	30%
Gabon	4.55	14.5%	25%*	60%	94%	60%
Gambia, The	5.75	19.0%	25%*	52%	94%	60%
Georgia	3.77	13.8%	22%*	31%	72%	85%
Germany	2.70	9.2%	18%	45%	86%	16%
Ghana	5.28	17.2%	25%*	50%	94%	60%
Greece	4.16	14.3%	25%	8%	80%	22%
Grenada	6.21	20.4%	24%*	47%	67%	16%
Guatemala	4.87	16.0%	24%*	64%	63%	78%
Guinea	5.67	18.6%	25%*	48%	94%	60%
Guinea-Bissau	5.66	18.6%	25%*	52%*	94%	60%
Guyana	4.89	15.7%	24%*	11%	72%	50%
Haiti	5.47	18.3%	24%*	51%	67%	16%
Holy See	4.08	14.6%	22%*	36%	80%	29%
Honduras	5.05	16.5%	38%	50%	67%	74%
Hungary	3.42	11.9%	27%	45%	80%	47%
Iceland	2.00	6.9%	22%*	75%	91%	42%
India	5.23	17.8%	18%	35%	72%	30%
Indonesia	5.05	16.2%	41%	27%	92%	59%
Iran	5.34	18.8%	24%	27%	72%	81%
Iraq	5.02	17.4%	23%*	42%	72%	34%
Ireland	2.42	8.2%	26%	33%	80%	16%
Israel	5.19	17.5%	11%	49%	72%	84%
Italy	3.75	13.3%	19%	26%	75%	36%
Jamaica	5.60	18.7%	26%	37%	67%	16%
Japan	3.63	12.6%	21%	48%	65%	39%
Jordan	5.34	18.0%	23%	59%	72%	32%
Kazakhstan	3.83	13.6%	17%	38%	72%	34%
Kenya	6.08	19.3%	34%	46%	98%	25%
Kiribati	5.96	19.0%	19%*	35%	75%	73%
Korea, North	4.03	15.7%	19%*	31%	72%	34%
Korea, South	3.88	14.2%	22%*	25%	72%	27%
Kosovo	3.74	13.3%	22%*	36%	80%	29%
Kuwait	5.57	18.9%	23%*	42%	72%	34%

Kyrgyzstan	4.40	16.6%	22%*	42%	72%	34%
Laos	4.01	13.2%	19%*	64%	72%	34%
Latvia	2.91	10.4%	19%	20%	80%	62%
Lebanon	4.93	16.8%	23%*	31%	72%	34%
Lesotho	5.13	18.2%	25%*	30%	94%	60%
Liberia	4.99	16.1%	25%*	52%	94%	60%
Libya	5.89	19.6%	25%*	52%	94%	60%
Liechtenstein	3.34	11.9%	22%*	36%	80%	29%
Lithuania	2.87	10.2%	27%	43%	80%	27%
Luxembourg	2.81	9.6%	15%	32%	80%	29%
Macedonia, FYR	3.79	13.4%	22%*	36%	80%	40%
Madagascar	5.49	18.5%	25%*	64%	94%	60%
Malawi	5.22	17.2%	25%*	42%	94%	60%
Malaysia	5.05	16.1%	19%*	30%	72%	34%
Maldives	5.84	18.7%	19%*	42%	72%	34%
Mali	6.18	20.7%	25%*	37%	94%	60%
Malta	4.98	17.3%	22%*	36%	80%	29%
Marshall Islands	5.83	19.0%	19%*	35%	75%	73%
Mauritania	5.81	19.4%	25%*	46%	94%	60%
Mauritius	5.92	19.8%	42%	16%	94%	60%
Mexico	5.79	19.7%	27%	25%	84%	82%
Micronesia, Federated States of	5.55	17.9%	19%*	35%	75%	73%
Moldova	3.37	11.7%	22%*	57%	80%	29%
Monaco	3.67	13.3%	22%*	36%	80%	29%
Mongolia	4.20	15.5%	35%	42%	72%	99%
Montenegro	3.88	13.8%	22%*	35%	80%	29%
Morocco	5.18	18.1%	29%	12%	94%	50%
Mozambique	5.41	18.1%	25%*	77%	94%	60%
Namibia	6.20	21.2%	25%*	54%	94%	60%
Nauru	6.11	19.4%	19%*	35%	75%	73%
Nepal	5.06	17.7%	19%*	42%	72%	86%
Netherlands	2.87	9.8%	24%	33%	80%	24%
New Zealand	4.46	16.3%	38%	50%	74%	77%
Nicaragua	4.56	14.9%	26%	32%	40%	16%
Niger	6.67	22.4%	25%*	52%	94%	60%
Nigeria	5.69	18.7%	25%*	45%	94%	60%
Norway	2.43	8.7%	25%	36%	80%	24%
Oman	5.77	19.4%	23%*	42%	72%	34%
Pakistan	4.93	17.3%	4%	51%	72%	34%
Palau	5.52	17.9%	19%*	35%	75%	73%

Panama	4.86	15.8%	24%*	51%	67%	16%
Papua New Guinea	5.51	17.8%	19%*	26%	92%	32%
Paraguay	5.02	16.7%	24%*	71%	72%	50%
Peru	4.37	14.2%	16%	67%	72%	65%
Philippines	5.07	16.6%	26%	30%	62%	38%
Poland	2.85	9.9%	22%	28%	80%	17%
Portugal	4.32	15.3%	26%	28%	69%	44%
Qatar	6.01	20.2%	23%*	42%	72%	34%
Romania	3.33	11.7%	16%	30%	80%	26%
Russia	2.86	10.8%	3%	41%	61%	63%
Rwanda	4.88	15.6%	25%*	27%	94%	60%
Saint Kitts and Nevis	6.23	20.9%	24%*	47%	67%	16%
Saint Lucia	6.09	20.1%	24%*	47%	67%	16%
Saint Vincent and the Grenadines	6.08	20.1%	24%*	47%	67%	16%
Samoa	5.26	17.3%	19%*	49%	75%	73%
San Marino	3.94	14.1%	22%*	36%	80%	29%
Sao Tome and Principe	4.86	15.5%	25%*	19%	94%	60%
Saudi Arabia	5.73	18.9%	23%*	42%	72%	34%
Senegal	5.74	18.9%	25%*	51%	94%	60%
Serbia	3.59	12.8%	22%*	42%	80%	44%
Seychelles	5.88	18.9%	25%*	52%	94%	60%
Sierra Leone	5.34	17.4%	25%*	51%	94%	60%
Singapore	4.49	14.3%	19%*	42%	72%	34%
Slovakia	2.86	10.0%	23%	28%	80%	74%
Slovenia	3.40	12.0%	22%*	42%	80%	35%
Solomon Islands	5.27	17.1%	19%*	35%	75%	73%
Somalia	6.13	20.1%	25%*	52%	94%	60%
South Africa	5.77	20.2%	25%*	45%	94%	61%
Spain	4.40	15.6%	25%	14%	80%	15%
Sri Lanka	5.03	16.2%	27%	35%	72%	34%
Sudan	6.51	21.7%	25%*	86%	94%	60%
Suriname	5.28	16.9%	24%*	53%	72%	50%
Swaziland	4.81	16.5%	25%*	24%	94%	60%
Sweden	2.54	9.2%	22%	48%	80%	32%
Switzerland	3.37	11.8%	20%	32%	80%	23%
Syria	5.00	17.0%	23%*	61%	72%	34%

Tajikistan	4.13	14.8%	22%*	39%	72%	60%
Tanzania	6.03	19.5%	25%*	43%	94%	60%
Thailand	5.19	17.3%	14%	21%	76%	99%
Timor-Leste	5.64	18.4%	19%*	35%	75%	73%
Togo	5.30	17.3%	25%*	35%	94%	60%
Tonga	5.39	17.9%	19%*	35%	75%	73%
Trinidad and Tobago	6.10	20.0%	24%*	47%	67%	16%
Tunisia	4.84	16.4%	22%	26%	94%	26%
Turkey	4.45	15.7%	29%	40%	68%	56%
Turkmenistan	4.45	15.9%	22%*	34%	72%	34%
Tuvalu	5.31	17.2%	19%*	35%	75%	73%
Uganda	5.60	17.8%	25%*	40%	94%	60%
Ukraine	3.24	11.3%	12%	31%	80%	35%
United Arab Emirates	5.61	18.8%	23%*	42%	72%	34%
United Kingdom	2.61	9.0%	25%	30%	80%	14%
United States	4.30	15.3%	27%	39%	61%	14%
Uruguay	4.60	15.7%	23%	33%	72%	50%
Uzbekistan	4.32	15.7%	22%*	43%	72%	34%
Vanuatu	5.24	17.3%	19%*	57%	75%	73%
Venezuela	5.37	17.5%	24%*	68%	72%	63%
Vietnam	4.52	15.0%	32%	50%	72%	9%
Yemen	6.46	21.6%	23%*	42%	72%	48%
Zambia	5.69	19.0%	25%*	75%	94%	60%
Zimbabwe	5.71	19.3%	25%*	84%	94%	60%

a Nasa 2012
b IEA 2011
c Intpow 2013
d Bertani 2012
e Lund 2010

Table 128 includes region specific data for wind capacity factors.

Table 128: 2012 Regional Wind Capacity Factors by Power Generation Source (%)

Region	Wind CF (%)
North America	27%
Central & South America	24%
Europe	22%
Middle East	23%
Africa	25%

Asia & Oceania	19%

Table 129 includes region specific capacity factors by power generation source.

Table 129: Regional Capacity Factors by Power Generation Source (%)

Region	Hydro CF (%)	Geothermal Power CF (%)	Geothermal Direct Heat CF (%)
North America	47%	67%	16%
South America	53%	72%	50%
Europe	36%	80%	29%
Africa	52%	94%	60%
Asia	42%	72%	34%
Oceania	35%	75%	73%
World	43%	72%	27%

REFERENCES: SOLAR INSOLATION AND CAPACITY FACTORS BY POWER GENERATION SOURCE AND COUNTRY

NASA (The National Aeronautics and Space Administration). 2012. Surface meteorology and Solar Energy (SSE) Release 6.0 Data Set (Jan 2008) 22-year Monthly & Annual Average (July 1983 - June 2005) Parameter: Insolation on a Tilted Surface. Accessed 20 October, 2012.

IEA. 2011. World Statistics. Wind Power Generation Capacity and Total Energy Generated. Accessed October, 2013: http://www.iea.org/statistics/.

Intpow. 2013. World Hydropower Potential. Hydroelectric Capacity Factors. Accessed October, 2013: http://www.intpow.com/index.php?id=487&download=1.

Bertani, Ruggero. 2012. Geothermal power generation in the world 2005–2010 update report. Geothermics (41), 1-29. http://www.sciencedirect.com/science/article/pii/S0375650511000526.

Lund, J. W, Freeston, D. H., Boyd, T.L. 2010. Direct Utilization of Geothermal Energy 2010 Worldwide Review. http://www.sciencedirect.com/science/article/pii/S0375650511000344.

15 APPENDIX J: BUILDING ENERGY EFFICIENCY

Table 130 includes operational hours and full load hours for residential and commercial sector efficiency measures.

Table 130: Operational Hours per Year and Full Load Hours for Residential and Commercial Efficiency Measures

Sector	Category	Operational Hours per Year	Full Load Hours
Residential	Lighting Upgrade	938	N/A
Residential	Water Heating[a]	N/A	N/A
Residential	HVAC – Room AC	N/A	210
Residential	HVAC – Central AC	N/A	570
Commercial	Lighting Upgrade	4576	N/A
Commercial	Refrigeration[a]	N/A	N/A
Commercial	HVAC – Room AC	N/A	254
Commercial	HVAC – Unitary AC	N/A	819
Commercial	HVAC – Chiller AC	N/A	1343

[a] Energy savings are obtained on a per measure basis and operational hours per year or full load hours are not applicable.

REFERENCES: BUILDING ENERGY EFFICIENCY

IEESAG (Illinois Energy Efficiency Stakeholder Advisory Group). (2012). Energy Efficiency Technical Reference Manual Final Technical Version, August 20th, 2012. Accessed December, 2015: http://ilsagfiles.org/SAG_files/Subcommittees/IPA-TRC_Subcommittee/10-6-2015_Meeting/TRC_Subcommittee_Report_Final_Draft_9-28-15.pdf

16 APPENDIX K: ANAEROBIC DIGESTERS EMISSION FACTORS

Table 131 includes the amount of volatile solids produced per day by region and animal type.

Table 131: Daily Volatile Solids Production by Region and Animal Type (kg/head/day)

Region	Dairy Cows	Other Cattle	Market Swine	Buffalo	Breeding Swine
North America	5.4	2.4	0.27	N/A	0.5
Europe[71]	4.8	2.65	0.3	3.9	0.48
Oceania	3.5	3	0.28	N/A	0.5
South America	2.9	2.5	0.3	3.9	0.3
Africa	1.9	1.5	0.3	N/A	0.3
Asia[72]	2.43	1.73	0.3	3.63	0.3

Source: IPCC (2006b) Tables 10A-4 to 10A-8

[71] Average of Western Europe and Eastern Europe
[72] Average of Middle East, Asia, and Indian Subcontinent

Table *132* includes the amount of volatile solids produced per day by animal and country type.

Table 132: Daily Volatile Solids Production by Country and Animal Type (kg/head/day)

Animal Type	Country Type	
	Developed	Developing
Sheep	0.4	0.32
Goats	0.3	0.35
Camels	2.49	2.49
Horses	2.13	2.13
Mules and Asses	0.94	0.94
Poultry (General)	0.02	0.02
Layers (dry)	0.02	0.02
Layers (wet)	0.02	0.02
Broilers	0.01	0.02
Turkeys	0.07	0.02
Ducks	0.02	0.02

Source: IPCC (2006b) Table 10A-9

Table 133 includes the maximum amount of methane producing capacities by region and animal type.

Table 133: Maximum Methane Producing Capacity by Region and Animal Type (m^3 CH_4/kg VS)

Region	Animal Type				
	Dairy Cows	Other Cattle	Market Swine	Buffalo	Breeding Swine
North America	0.24	0.19	0.48	N/A	0.48
Europe[73]	0.24	0.18	0.45	0.10	0.45
Oceania	0.24	0.17	0.45	N/A	0.45
South America	0.13	0.10	0.29	0.10	0.29
Africa	0.13	0.10	0.29	N/A	0.29
Asia[74]	0.13	0.10	0.29	0.10	0.29

Source: IPCC (2006b) Tables 10A-4 to 10A-8

[73] Average of Western Europe and Eastern Europe
[74] Average of Middle East, Asia, and Indian Subcontinent

Table 134 includes the maximum amount of methane producing capacities by animal and country type.

Table 134: Maximum Methane Producing Capacity by Country and Animal Type (m^3 CH_4/kg VS)

Animal Type	Country Type	
	Developed	**Developing**
Sheep	0.19	0.13
Goats	0.18	0.13
Camels	0.26	0.21
Horses	0.30	0.26
Mules and Asses	0.33	0.26
Poultry (General)	0.24	0.24
Layers (dry)	0.39	0.24
Layers (wet)	0.39	0.24
Broilers	0.36	0.24
Turkeys	0.36	0.24
Ducks	0.36	0.24

Source: IPCC (2006b) Table 10A-9

Table 135 includes default methane conversion factors by temperature and manure management system.

Table 135: Default Methane Conversion Factors by Temperature and Manure Management System (%)

Management System	Climate Type		
	Cool	**Temperate**	**Warm**
Pasture/Range/Paddock	1.0%	1.5%	2.0%
Daily Spread	0.1%	0.5%	1.0%
Solid Storage	2.0%	4.0%	5.0%
Dry Lot	1.0%	1.5%	2.0%
Liquid Slurry w/ Natural Crust Cover	12.6%	27.2%	47.3%
Liquid Slurry w/out Natural Crust Cover	20.6%	43.6%	76.3%
Uncovered anaerobic lagoon	69.6%	77.3%	79.6%
Pit storage below confinement < 1 Month	3.0%	3.0%	30.0%
Pit storage below confinement > 1 Month	20.6%	43.6%	76.3%
Burned for Fuel	10.0%	10.0%	10.0%
Cattle and Swine Deep Bedding < 1 Month	3.0%	3.0%	30.0%
Cattle and Swine Deep Bedding > 1 Month	20.6%	43.6%	76.3%
Composting - In Vessel	0.5%	0.5%	0.5%
Composting - Static Pile	0.5%	0.5%	0.5%
Composting - Intensive Windrow	0.5%	1.0%	1.5%
Composting - Passive Windrow	0.5%	1.0%	1.5%
Poultry Manure w/ Litter	1.5%	1.5%	1.5%
Poultry Manure w/out Litter	1.5%	1.5%	1.5%
Aerobic Treatment	0.0%	0.0%	0.0%

Note: The default Methane Conversion Factor values for Cool, Temperate and Warm climate types are averaged if they are provided for individual temperature levels.

Source: IPCC (2006b), Table 10.17

Table 136 includes default emission factors for nitrogen dioxide emissions from a variety of manure management practices.

Table 136: Default Emission Factors for Direct N_2O Emissions from Manure Management (kg N_2O-N/ kg Nitrogen Excreted)

Manure Management System	EF (kg N2O-N/kg N) (IPCC 2006b unless otherwise noted)
Pasture/Range/Paddock (IPCC 2006c)	
Dairy Cattle, Non-Dairy Cattle and Buffalo	0.02
Poultry	0.02
Pigs	0.02
Sheep	1
Other animals	0.01
Daily Spread (IPCC 2006c)	0.01[75]
Solid Storage	0.005
Dry Lot	0.02
Liquid Slurry w/ Natural Crust Cover	0.005
Liquid Slurry w/out Natural Crust Cover	0
Uncovered anaerobic lagoon	0
Pit storage below confinement < 1 Month	0.002
Burned for Fuel	NA
Cattle and Swine Deep Bedding – No mixing	0.01
Cattle and Swine Deep Bedding – Active mixing	0.07
Composting - In Vessel	0.006
Composting - Static Pile	0.006
Composting - Intensive Windrow	0.1
Composting - Passive Windrow	0.01
Poultry Manure w/ Litter	0.001
Poultry Manure w/out Litter	0.001

Source: IPCC (2006b) Table 10.21, IPCC (2006c) Table 11.1

Table 137 includes nitrogen excretion values by region and animal type.

[75] The value is listed as 0 in IPCC 2006b. Since manure deposited on pasture results in N_2O emissions, an emission factor of 0.01 from IPCC 2006c is used.

Table 137: Nitrogen Excretion by Region and Animal Type (kg N/year)

Animal Type	Region					
	North America	Europe	Oceania	South America	Africa	Asia
Dairy Cows	97.0	87.1	80.3	70.1	60.2	47.2
Other Cattle	44.0	50.3	60.2	40.1	39.8	21.5
Market Swine	7.1	9.7	8.7	16.0	16.0	4.3
Breeding Swine	17.3	30.4	30.2	5.6	5.6	2.5
Buffalo	44.4	44.4	44.4	44.4	44.4	44.4
Sheep	7.4	15.0	20.0	12.0	12.0	12.0
Goats	6.3	18.0	20.0	15.0	15.0	15.0
Camels	30.1	30.1	30.1	36.4	36.4	36.4
Horses	41.3	35.8	41.3	40.0	40.0	40.0
Mules and Asses	14.2	12.3	14.2	21.8	21.8	21.8
Poultry (General)	0.5	0.6	0.5	0.5	0.5	0.5
Layers (Dry)	0.5	0.6	0.5	0.5	0.5	0.5
Layers (Wet)	0.5	0.6	0.5	0.5	0.5	0.5
Broilers	0.2	0.2	0.2	0.2	0.2	0.2
Turkeys	2.1	2.1	2.1	2.1	2.1	2.1
Ducks	0.8	0.8	0.8	0.8	0.8	0.8

Source: IPCC (2006b). Tables 10.19 and Tables 10A.2, 10A.4-10A.9

Nitrogen Excretion by Region and Animal Type are derived from two tables in IPCC 2006b. The first table, 10.19, provides the nitrogen excretion rates in kg N per 1000 kg Animal Mass per day. The table 10.19 values are then converted to kg N per day by multiplying them by the typical animal mass, in kg, provided in table 10A.2 and tables 10A-4 through 10A-9. Finally, the values are converted to annual excretion rates by multiplying by the number of days in a year.

REFERENCES: ANAEROBIC DIGESTERS EMISSION FACTORS

IPCC. (2006b). 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Prepared by the National Greenhouse Gas Inventories Programme. Japan: Intergovernmental Panel on Climate Change. Volume 4: Agriculture, Forestry and Other Land Use, Chapter 10. Emissions from Livestock and Manure Management. Accessed October, 2013: http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_10_Ch10_Livestock.pdf.

IPCC. (2006c). 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Prepared by the National Greenhouse Gas Inventories Programme. Japan: Intergovernmental Panel on Climate Change. Volume 4: Agriculture, Forestry and Other Land Use, Chapter 11. N_2O Emissions from Managed Soils, and CO_2 Emissions from Lime and Urea Application. Accessed October, 2013: http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_11_Ch11_N2O&CO2.pdf

NIST. (2011). Thermophysical Properties of Fluid Systems. Accessed October, 2013: http://webbook.nist.gov/chemistry/fluid/.

17 APPENDIX L: FUEL CONSUMPTION UNITS

Fuel consumption unit measurements include: gigajoules (GJ), tonnes (t), gallons (gal), litres (L), pounds (lbs.), kilograms (kg), million BTUs (MMBTU), therms, and 100 cubic feet (Ccf). Natural gas is the only fuel which may be measured through all fuel consumption units within this protocol. Liquids are measured in all fuel consumption units except Ccf. Solid and gas fuel consumption measurement units exclude gal, L, and Ccf. See *Table 138* below for visual explanation. An 'x' indicate units are relevant to the listed fuel type.

Table 138: Fuel Consumption Units

	Giga-joules (GJ)	Tonnes (t)	Gallons (gal)	Liters (L)	Pounds (lbs.)	Kilo-grams (kg)	Million BTUs (MM-BTU)	Therms	100 Cubic Feet (Ccf)
Natural gas	X	X	X	X	X	X	X	X	X
Liquid	X	X	X	X	X	X	X	X	
Solid & Gas	X	X			X	X	X	X	

Table 139 gives the fuel energy content data by specific fuel type.

Table 139: Fuel Energy Content Data

IPCC Name	Density (kg/L)	Tonnes (t)	Gallons (gal)	Liter (L)	Pounds (lbs.)	Kilograms (kg)	Million BTUs (MM-BTU)	Therms	100 Cubic Feet (Ccf)
		GJ/t	GJ/gal	GJ/L	GJ/lbs	GJ/kg	GJ/MM-BTU	GJ/ Therm	GJ/Ccf
Biodiesels		27.00			0.01	0.03	1.06	0.11	
Biogasoline		27.00			0.01	0.03	1.06	0.11	
Other Liquid Biofuels		27.40			0.01	0.03	1.06	0.11	
Landfill Gas		50.40			0.02	0.05	1.06	0.11	
Other Biogas		50.40			0.02	0.05	1.06	0.11	
Sludge Gas		50.40			0.02	0.05	1.06	0.11	
Charcoal		29.50			0.01	0.03	1.06	0.11	
Other Primary Solid Biomass		11.60			0.01	0.01	1.06	0.11	
Sulphite lyes (Black Liquor)[a]		11.80			0.01	0.01	1.06	0.11	
Wood/ Wood Waste		15.60			0.01	0.02	1.06	0.11	
Bitumen		40.20			0.02	0.04	1.06	0.11	
Blast Furnace Gas		2.47			0.00	0.00	1.06	0.11	

Brown Coal Briquettes		20.70			0.01	0.02	1.06	0.11	
Anthracite		26.70			0.01	0.03	1.06	0.11	
Other Bituminous Coal		25.80			0.01	0.03	1.06	0.11	
Coking Coal		28.20			0.01	0.03	1.06	0.11	
Lignite		11.90			0.01	0.01	1.06	0.11	
Sub-Bituminous Coal		18.90			0.01	0.02	1.06	0.11	
Coal Tar		28.00			0.01	0.03	1.06	0.11	
Coke Oven Coke and Lignite Coke		28.20			0.01	0.03	1.06	0.11	
Gas Coke		28.20			0.01	0.03	1.06	0.11	
Coke Oven Gas		38.70			0.02	0.04	1.06	0.11	
Ethane		46.40			0.02	0.05	1.06	0.11	
Gas Works Gas		38.70			0.02	0.04	1.06	0.11	
Aviation Gasoline	0.71	44.30	0.119	0.031	0.02	0.04	1.06	0.11	
Jet Gasoline		44.30			0.02	0.04	1.06	0.11	
Motor Gasoline	0.74	44.30	0.124	0.033	0.02	0.04	1.06	0.11	
Industrial Wastes		NA			NA	NA	1.06	0.11	
Jet Kerosene	0.79	44.10	0.132	0.035	0.02	0.04	1.06	0.11	
Other Kerosene	0.80	43.80	0.133	0.035	0.02	0.04	1.06	0.11	
Liquefied Petroleum Gases	0.54	47.30	0.097	0.026	0.02	0.05	1.06	0.11	
Lubricants	1.00	40.20	0.152	0.040	0.02	0.04	1.06	0.11	
Municipal Wastes (biomass fraction)		11.60			0.01	0.01	1.06	0.11	
Municipal Wastes (nonbiomass fraction)		10.00			0.00	0.01	1.06	0.11	
Naphtha	0.77	44.50	0.130	0.034	0.02	0.04	1.06	0.11	
Natural Gas		48.00			0.02	0.05	1.06	0.11	0.1079
Natural Gas Liquids	0.47	44.20	0.079	0.021	0.02	0.04	1.06	0.11	
Crude Oil	0.80	42.30	0.128	0.034	0.02	0.04	1.06	0.11	
Gas/Diesel Oil	0.84	43.00	0.137	0.036	0.02	0.04	1.06	0.11	

Other Petroleum Products		40.20			0.02	0.04	1.06	0.11
Paraffin Waxes		40.20			0.02	0.04	1.06	0.11
Refinery Gas		49.50			0.02	0.05	1.06	0.11
Residual Fuel Oil	0.94	40.40	0.144	0.038	0.02	0.04	1.06	0.11
Shale Oil	1.00	38.10	0.144	0.038	0.02	0.04	1.06	0.11
White Spirit and SBP		40.20			0.02	0.04	1.06	0.11
Oil Shale and Tar Sands		8.90			0.00	0.01	1.06	0.11
Orimulsion		27.50			0.01	0.03	1.06	0.11
Oxygen Steel Furnace Gas		7.06			0.00	0.01	1.06	0.11
Patent Fuel		20.70			0.01	0.02	1.06	0.11
Peat		9.76			0.00	0.01	1.06	0.11
Petroleum Coke		32.50			0.01	0.03	1.06	0.11
Refinery Feedstocks		43.00			0.02	0.04	1.06	0.11
Waste Oils		40.20			0.02	0.04	1.06	0.11

REFERENCES: FUEL CONSUMPTION UNITS

IPCC (Intergovernmental Panel on Climate Change). (2006). 2006 IPCC Guidelines for National Greenhouse Gas Inventories. The National Greenhouse Gas Inventories Programme, The Intergovernmental Panel on Climate Change, H.S. Eggleston, L. Buendia, K. Miwa, T. Ngara, and K. Tanabe (eds.). Hayama, Kanagawa, Japan. Default Emission Factors retrieved from Volume 2. Energy, Chapter 2 Stationary Combustion. Accessed October, 2013: http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_2_Ch2_Stationary_Combustion.pdf.

WRI (World Resources Institute). (2005). The Greenhouse Gas Protocol: The GHG Protocol for Project Accounting. Accessed October, 2012: http://www.ghgprotocol.org/standards/project-protocol.

18 APPENDIX M: WATER ENTHALPY

Table 140 includes water enthalpy values as a function of temperature.

Table 140: Water Enthalpy Values as a Function of Temperature (kJ/kg) (NIST 2011)

Temperature (Kelvin)	Enthalpy (kJ/kg)
270	1185.1
275	1210.7
280	1236.7
285	1263.1
290	1289.8
295	1317.1
300	1344.8
305	1373.1
310	1402.0
315	1431.6
320	1462.0
325	1493.4
330	1525.8
335	1559.4
340	1594.6
345	1631.7
350	1671.2
355	1714.0
360	1761.5
365	1817.2
370	1891.2
373.95	2084.3

REFERENCES: WATER ENTHALPY

NIST (National Institute of Standards and Technology). (2011). Thermophysical Properties of Fluid Systems. Accessed October 2013: http://webbook.nist.gov/chemistry/fluid/.

19 APPENDIX N: BIOMASS CULTIVATION AND PROCESSING EMISSION FACTORS

Table 141 includes the biomass cultivation and processing emission factors for various fuel types.

Table 141: Biomass Cultivation and Processing Emission Factors (EU 2010)

Fuel Types	Fuel Categories	Calorific Value (MJ/kg)	Combustion Emission Factor (gCO_2e/MJ)	Combustion Emission Factor (gCO_2e/kg)	Typical Cultivation EF ($g\ CO_2e/MJ$)	Typical Processing EF ($g\ CO_2e/MJ$)
Wood chips from forest residues (EU Forest)	Wood and Wood Residuals	14	98.21	1,375	0	0.4
Wood chips from forest residues (Brazilian)	Wood and Wood Residuals	14	98.21	1,375	0	0.4
Wood chips from short rotation forestry (EU Forest)	Wood and Wood Residuals	14	98.21	1,375	2	0.4
Wood chips short rotation forestry (eucalyptus)	Wood and Wood Residuals	14	98.21	1,375	2.9	0.4
Wood briquettes or pellets from forest residues (EU forest) - wood as process fuel	Wood and Wood Residuals	17	97.06	1,650	0	0.5
Wood briquettes or pellets from forest residues (EU forest) - NG as process fuel	Wood and Wood Residuals	17	97.06	1,650	0	15.4

Wood briquettes or pellets from forest residues (Brazilian forest) - wood as process fuel	Wood and Wood Residuals	17	97.06	1,650	0	0.5
Wood briquettes or pellets from forest residues (Brazilian forest) - NG as process fuel	Wood and Wood Residuals	17	97.06	1,650	0	15.4
Wood briquettes or pellets from short rotation forestry (EU forest) - wood as process fuel	Wood and Wood Residuals	17	97.06	1,650	2.1	0.5
Wood briquettes or pellets from short rotation forestry (EU forest) - NG as process fuel	Wood and Wood Residuals	17	97.06	1,650	2.1	15.4
Wood briquettes or pellets from short rotation forestry (eucalyptus) - wood as process fuel	Wood and Wood Residuals	17	97.06	1,650	3.6	0.5
Wood briquettes or pellets from short rotation forestry (eucalyptus) - NG as process fuel	Wood and Wood Residuals	17	97.06	1,650	3.6	15.4
Charcoal from forest residues (European temperate continental forest)	Wood and Wood Residuals	29.50	112	3,304	0	32.8

Charcoal from forest residues (tropical and sub-tropical forest)	Wood and Wood Residuals	29.50	112	3,304	0	32.9
Charcoal from short rotation forestry (European temperate continental forest)	Wood and Wood Residuals	29.50	112	3,304	4.1	32.9
Charcoal from short rotation forestry (tropical and sub-tropical e.g., eucalyptus)	Wood and Wood Residuals	29.50	112	3,304	5.9	33
wheat straw (EU)	Agricultural Byproducts	14.5	96.09	1,393	0	0.8
Bagasse briquettes - (Brazil) wood as process fuel	Agricultural Byproducts	7.61	97.84	745	0	0
Bagasse briquettes - (Brazil) NG as process fuel	Agricultural Byproducts	7.61	97.84	745	0	15
Bagasse bales (Brazil)	Agricultural Byproducts	7.61	97.84	745	0	0.8
Palm Kernel (Indonesia)	Agricultural Byproducts	18.53	57.97	1,074	0	0
Rice Husk briquettes (Thailand)	Agricultural Byproducts	13.5	111.59	1,506	0	0
Miscanthus bales (temperate continental climate)	Agricultural Byproducts	13.4	80.17	1,074	3.6	1.1

Note: some data are calculated, some are assumed

REFERENCES: BIOMASS CULTIVATION AND PROCESSING EMISSION FACTORS

EU (European Union). 2010. "Commission Staff Working Document: Impact Assessment - Sustainability requirements for the use of solid and gaseous biomass sources in electricity, heating and cooling". COM (2010) 11 Final. SEC (2010) 65 Final.

20 APPENDIX O: EQUIPMENT LIFETIMES AND DEGRADATION RATES

Table 142 provides average useful equipment lifetimes and annual degradation values for various equipment used in or as a result of USAID clean energy activities. Technical lifetime is defined by the UNFCCC as the total time for which the equipment is technically designed to operate from its first commissioning, and is expressed in hours or years of operation (UNFCCC CDM, 2009). These values should be applied with caution as these default values are derived from many variables such as equipment size, use patterns, and capacity.

Table 142: Typical Equipment Lifetimes and Degradation Rates

Equipment	Default Value for Lifetime of Technology	Annual Degradation Values
Solar Photovoltaic Systems	25 years	0.5%
Solar Thermal Systems	30 years	0.3%
Wind Turbine Systems	25 years	1.0%
Geothermal: Power generation	30 years	1.0%
Geothermal: Direct heat	30 years	0.5%
Geothermal: Heat pumps	20 years	0.4%
Hydroelectric Systems	40 years	0.3%
Biomass Energy	25 years	1.0%
Anaerobic Digesters for Manure Management	15 years	N/A
Appliance & Equipment Efficiency	15 years	0.5%
Building Energy Efficiency	Various	Various[76]

[76] Various building energy efficiency measures have default lifetimes associated with them. In the residential building energy efficiency side, compact fluorescent lamps (CFL) lights are assumed to have lifetime of 11 years and room air conditioning (AC) units are assumed to have lifetime of 12 years. Water heating measures vary anywhere between 2 years (low flow shower heads) to 13 years (heat pump water heaters). In the commercial building energy efficiency side, the high performance lamps are assumed to have lifetimes of 15 years and refrigerating measures are assumed to vary between 6 years (strip curtain for walk-in freezers) to 16 years (for evaporator fan control for walk-in coolers). Commercial room AC units are assumed to have lifetime of 9 years while the unitary AC units and chillers are assumed to have lifetimes of 15 years. All these lifetimes are derived from the Energy Efficiency Technical Reference Manual by the Illinois Energy Efficiency Stakeholder Advisory Group (IEESAG 2012).

For calculations in the Protocol, OUs should consider the date a technology is installed, the age of the system, and degradation of equipment over time when estimating emission reductions for a particular reporting year. For simplicity, the default degradation values assume a linear annual rate. Additionally, long term impacts on natural resource availability are not reflected in the default values for asset life or degradation values.

Due to the nature of the technologies involved, lifetime and annual degradation values are not estimated for the Transmission and Distribution Systems Upgrade – Technical Loss Reductions and the Stranded Natural Gas Recovery Systems methodologies.

REFERENCES: EQUIPMENT LIFETIMES AND DEGRADATION RATES

CEC (California Energy Commission). (2010). Comparative Costs of California Central Station Electricity Generation. Accessed October, 2013: http://www.energy.ca.gov/2009publications/CEC-200-2009-017/CEC-200-2009-017-SF.PDF

DOE (Department of Energy). (2013). Weather Data for EnergyPlus Energy Simulation Software. Accessed October, 2013.

FERC (Federal Energy Regulatory Commission). (2011). Hydropower Licensing. Accessed October, 2013: http://www.ferc.gov/for-citizens/citizen-guides/hydro-guide.asp.

IEESAG (Illinois Energy Efficiency Stakeholder Advisory Group). (2012). Energy Efficiency Technical Reference Manual Final Technical Version, August 20th, 2012. Accessed December, 2015: http://ilsagfiles.org/SAG_files/Subcommittees/IPA-TRC_Subcommittee/10-6-2015_Meeting/TRC_Subcommittee_Report_Final_Draft_9-28-15.pdf.

NREL (National Renewable Energy Laboratory). (2012). Photovoltaic Degradation Rates. Accessed October, 2013: http://www.nrel.gov/docs/fy12osti/51664.pdf.

UNFCCC CDM (United Nations Framework Convention on Climate Change Clean Development Mechanism). (2013a). ACM0006 "Consolidated methodology for electricity and heat generation from biomass". CDM Executive Board.

UNFCCC CDM. (2013b). ACM0020 "Co-firing of biomass residues for heat generation and/or electricity generation in grid connected power plants". CDM Executive Board.

UNFCCC CDM. (2009). Methodology: Tool to determine the remaining lifetime of equipment. Accessed March, 2015: https://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-10-v1.pdf/history_view.

US DOE (U.S. Department of Energy). (2012). Geothermal Heat Pumps Lifetime. Accessed October, 2013: http://energy.gov/energysaver/articles/geothermal-heat-pumps.

21 APPENDIX P: IGES COMBINED MARGINAL EMISSION FACTORS FOR GRID ELECTRICITY

Table 143 provides country-specific combined marginal emission factors for grid electricity, as provided by IGES.

Table 143: IGES Combined Marginal Emission Factors

Country	Combined Marginal EF (gCO2e/kWh)
Angola	841
Burkina Faso	368
Côte d'Ivoire	660
Egypt	539
Ghana	479
Iran	632
Israel	705
Jordan	584
Kenya	603
Kuwait	780
Lebanon	650
Libya	794
Madagascar	552
Mali	582
Mauritius	975
Morocco	661
Namibia	920
Nigeria	573
Rwanda	654
Saudi Arabia	654
Senegal	683
Sierra Leone	402
South Africa	955
Sudan	305
Tanzania	529
Tunisia	554
Uganda	529
United Arab Emirates	704
Africa/Middle and Near East Asia	**714**
Bangladesh	641

Bhutan	779
Burma	713
Cambodia	665
China	884
India	899
Indonesia	758
Korea, North	632
Korea, South	912
Laos	554
Malaysia	668
Mongolia	1061
Pakistan	540
Papua New Guinea	679
Philippines	511
Singapore	486
Sri Lanka	691
Thailand	547
Vietnam	564
Asia	**852**
Argentina	521
Bahamas, The	723
Belize	152
Bolivia	711
Brazil	299
Chile	600
Colombia	333
Costa Rica	281
Cuba	874
Dominican Republic	654
Ecuador	590
El Salvador	678
Guatemala	651
Guyana	948
Honduras	666
Jamaica	783
Mexico	529
Nicaragua	690
Panama	607
Peru	594
Uruguay	574
Latin America	**473**
Albania	393
Armenia	436

Azerbaijan	590
Bosnia and Herzegovina	973
Cyprus	798
Fiji	597
Georgia	402
Macedonia	861
Montenegro	984
Serbia	1099
Uzbekistan	593

REFERENCES: IGES COMBINED MARGINAL EMISSION FACTORS

IGES (Institute for Global Environmental Strategies). (2016). List of Grid Emission Factor. Accessed March, 2016: http://pub.iges.or.jp/modules/envirolib/view.php?docid=2136

22 APPENDIX Q: NET CALORIFIC VALUE OF NATURAL GAS

Table 144 provides country- and region-specific net weighted average heat content for stranded natural gas capture systems, as provided by EIA.

Table 144: EIA Net Weighted Average Heat Content

Country	Net Weighted average Heat Content (Btu/Feet^3)
Algeria	982.7
Angola	929.1
Benin	947.1
Botswana	947.1
Burkina Faso	947.1
Burundi	947.1
Cameroon	933.6
Cape Verde	947.1
Central African Republic	947.1
Chad	947.1
Comoros	947.1
Côte d'Ivoire	900.9
Djibouti	947.1
Egypt	930.7
Equatorial Guinea	942.3
Eritrea	947.1
Ethiopia	947.1
Gabon	937.2
Gambia, The	947.1
Ghana	447.7
Guinea	947.1
Guinea-Bissau	947.1
Kenya	947.1
Lesotho	947.1
Liberia	947.1
Libya	930.0
Madagascar	947.1
Malawi	947.1
Mali	947.1
Mauritania	947.1
Mauritius	947.1
Morocco	943.7

Mozambique	925.8
Namibia	947.1
Niger	947.1
Nigeria	936.0
Rwanda	947.1
Sao Tome and Principe	947.1
Senegal	805.9
Seychelles	947.1
Sierra Leone	947.1
Somalia	947.1
South Africa	931.0
Swaziland	947.1
Tanzania	931.4
Togo	947.1
Tunisia	1028.7
Uganda	947.1
Zambia	947.1
Zimbabwe	947.1
Africa	**947.1**
Afghanistan	942.5
Armenia	942.3
Azerbaijan	941.8
Bahrain	931.0
Bangladesh	934.3
Bhutan	938.7
Cambodia	938.7
China	941.7
Georgia	960.7
India	946.0
Indonesia	981.0
Iran	950.4
Iraq	929.1
Israel	918.3
Japan	948.9
Jordan	937.7
Kazakhstan	972.5
Korea, North	938.7
Korea, South	1007.7
Kuwait	930.4
Kyrgyzstan	942.2
Laos	938.7
Lebanon	939.5
Malaysia	947.7

Maldives	938.7
Mongolia	938.7
Nepal	938.7
Oman	931.6
Pakistan	780.3
Philippines	927.0
Qatar	967.2
Saudi Arabia	933.2
Singapore	930.9
Sri Lanka	938.7
Syria	923.4
Tajikistan	930.1
Thailand	879.3
Turkey	925.2
Turkmenistan	927.7
United Arab Emirates	942.3
Uzbekistan	915.3
Vietnam	932.4
Yemen	981.0
Asia	**938.7**
Albania	932.9
Austria	922.5
Belarus	933.3
Belgium	927.1
Bosnia and Herzegovina	914.4
Bulgaria	915.5
Croatia	912.5
Cyprus	924.9
Czech Republic	921.1
Denmark	1003.0
Estonia	911.0
Finland	916.1
France	993.7
Germany	927.1
Greece	926.7
Hungary	910.5
Iceland	924.9
Ireland	956.5
Italy	920.7
Kosovo	924.9
Latvia	900.9
Lithuania	899.1
Luxembourg	977.5

Malta	924.9
Moldova	859.3
Montenegro	924.9
Netherlands	805.5
Norway	953.7
Poland	847.5
Portugal	977.5
Romania	860.7
Russia	923.4
Serbia	901.6
Slovakia	926.2
Slovenia	914.0
Spain	977.6
Sweden	981.9
Switzerland	919.8
Ukraine	928.5
United Kingdom	954.9
Europe	**924.9**
Antigua and Barbuda	925.5
Bahamas, The	925.5
Barbados	942.9
Belize	925.5
Canada	934.1
Costa Rica	925.5
Cuba	917.7
Dominica	925.5
Dominican Republic	942.3
El Salvador	925.5
Grenada	925.5
Guatemala	925.5
Haiti	925.5
Honduras	925.5
Jamaica	925.5
Mexico	977.1
Nicaragua	925.5
Panama	925.5
Saint Kitts and Nevis	925.5
Saint Lucia	925.5
Trinidad and Tobago	940.5
United States	921.7
North America	**925.5**
Australia	965.5
Fiji	938.7

Kiribati	938.7
Nauru	938.7
New Zealand	924.6
Papua New Guinea	942.9
Samoa	938.7
Solomon Islands	938.7
Tonga	938.7
Vanuatu	938.7
Oceania	**938.7**
Argentina	940.5
Bolivia	940.5
Brazil	952.2
Chile	943.6
Colombia	836.1
Ecuador	1170.0
Guyana	964.1
Paraguay	964.1
Peru	1085.4
Suriname	964.1
Uruguay	942.9
Venezuela	1071.9
South America	**964.1**
World	**932.3**

REFERENCES: NET CALORIFIC VALUE OF NATURAL GAS

EIA (United States Energy Information Administration). (2010-2014). Gross Heat Content of Dry Natural Gas Production (Btu per Cubic Foot). Accessed September, 2015: http://www.eia.gov/cfapps/ipdbproject/IEDIndex3.cfm?tid=3&pid=52&aid=10