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Calculating, Monitoring, and Evaluating Greenhouse Gas Benefits from Solar Home Systems in Developing Countries

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List of Abbreviations

AIJ = Activities Implemented Jointly

CDM = Clean Development Mechanism

ESCo = Energy Service Company

GEF = Global Environment Facility

GHG = Greenhouse Gas

IPCC = Intergovernmental Panel on Climate Change

PV = Photovoltaic

Q,M,&E = Quantification, Monitoring, and Evaluation

REPP = Renewable Energy Policy Project

SHS = Solar Home System

UNFCCC = United Nations Framework Convention on Climate Change

USIJI = United States Initiative on Joint Implementation

Background

This draft working paper was prepared as part of the Renewable Energy Policy Project's (REPP's) assessment of solar home system (SHS) dissemination as an activity for mitigating climate change. The Joyce Mertz-Gilmore Foundation provided funding for the assessment.

1. Introduction

Experience has proven that SHSs can supply electricity to rural areas of developing countries while directly displacing greenhouse gas (GHG) emissions. Several SHS projects have been explicitly linked with international climate change mitigation efforts. As of April 1999, the Global Environment Facility (GEF) had over 15 SHS projects at various stages of development in its Climate Change portfolio; while most of were still being prepared, at least three were being implemented – in India, Indonesia, and Sri Lanka – and one had been completed in Zimbabwe. Also at that time, five SHS projects – in Bolivia, Burkina Faso, Honduras, Indonesia, and Sri Lanka – had been officially recognized in the Pilot Phase of Activities Implemented Jointly (AIJ) under the United Nations Framework Convention on Climate Change. In the future, qualifying SHS projects will also be able to participate in the Clean Development Mechanism (CDM) under the Kyoto Protocol.

SHS projects participating in GEF and AIJ programs have used a variety of approaches to the tasks of GHG benefit quantification, monitoring, and evaluation (Q,M,&E). Since the GEF and AIJ programs have different goals and expectations of their respective participants, variation in their approach to Q,M,&E is to be expected. Furthermore, guidelines for quantifying, monitoring, and evaluating GHG benefit in GEF and AIJ projects provide substantial latitude with regard to methodology, so individual projects within the AIJ and GEF programs have sometimes approached these tasks differently from one another. There is, however, significant commonality among the approaches to Q,M,&E used in various GEF and AIJ projects. Though limited in actual implementation, the GEF and AIJ SHS projects provide an experience base that can help to illuminate relevant Q,M,&E issues and begin to indicate the merits of different approaches to these tasks in future SHS projects structured for climate change mitigation.

This paper reviews approaches to GHG benefit Q,M,&E used to date in GEF and AIJ projects involving SHS dissemination. It also briefly reviews existing guidance regarding Q,M,&E for the AIJ and GEF programs and summarizes emerging trends that may affect these tasks for SHS projects intending to participate in the CDM. Based on the review of experience and trends, the paper presents some suggestions regarding what might constitute good practices for Q,M,&E, particularly in the context of the CDM.

2.0 Quantifying, Monitoring, and Evaluating GHG Benefits for SHS Projects

The tasks of GHG benefit quantification, monitoring, and evaluation are used to first estimate and then confirm the GHG benefits associated with specific climate change mitigation projects. In the context of this discussion, quantification refers to calculations of GHG reductions expected from an SHS project that are made prior to the project's implementation. Monitoring and evaluation are used to determine the extent to which the anticipated GHG benefits are actually realized once the project is implemented. Monitoring involves the periodic measurement of a project's actual GHG reductions based on specific indicators. Evaluation entails a comparison between anticipated reductions and monitored results.

In the GEF, quantification is used to identify a project's global environmental benefits for purposes of incremental cost calculation. GEF projects are primarily intended to demonstrate new technologies or approaches to a given problem, build national capacity, and generally assist developing countries in advancing their sustainable development objectives in specific areas of international environmental priority, including climate change. Funding is limited to supporting the "incremental costs" associated with the global environmental benefits of a given project. With an emphasis on technology and process catalyzation, GEF projects have often sought to estimate both their direct and indirect climate change benefits, including the long-term and downstream impacts of successfully demonstrating a new technology, or increasing a country's institutional capacity to develop and implement similar projects and policies. GEF projects generally place greater emphasis on monitoring and evaluating broader-based outcomes than on confirming GHG displacement and do not require verification of GHG benefits.

The Activities Implemented Jointly Pilot Phase was created at the First Conference of the Parties to the Framework Convention on Climate Change in 1995 as an interim activity intended to encourage cooperative climate change mitigation projects between participants in different countries. While projects in the AIJ pilot phase accrue no emission reduction credits, the AIJ pilot activity has been widely viewed as a precursor to international project-based emissions trading. The AIJ pilot phase began to focus on the project-level specification of GHG benefits associated with a given set of project-level interventions. For AIJ projects, monitoring and evaluation are oriented toward confirming actual GHG results. While not required of all projects in the AIJ pilot phase, verification – which involves an independent audit to establish the validity of GHG benefit performance claims – is required of all projects participating in the United States' AIJ program (the "USIJI").

2.1 Quantification Issues

SHSs directly displace GHG emissions by substituting solar powered electric lights for the kerosene, other hydrocarbon lamp fuels, and candles commonly used in unelectrified homes. Often, SHSs also displace GHG emissions associated with the charging of automotive batteries using electricity from a nearby grid connection or generator. Alternatively, SHSs sometimes substitute directly for small gasoline generators used to supply electricity in some off-grid households. In addition to these direct GHG displacement benefits, SHSs may also help to avoid growth in mini-grid and grid-based GHG emissions by supplying electricity to rural households that might otherwise be added to a grid or mini-grid system. Finally, SHSs sales may play a substantial market transformation role by helping photovoltaics manufacturers scale-up their production and cut costs. As prices for photovoltaic (PV) technology fall, larger markets should open up, resulting in GHG displacement from a broader range of PV applications.[1]

Key GHG benefit quantification issues for SHS projects include project boundary setting, determination of project baselines (i.e., the energy situation expected in the absence of the SHS project), and determination of the emissions displacement expected to result from SHS use.

2.2 Project Boundary

The "project boundary" defines the extent of impact that can be attributed to a given project over a specified time and geographic area. For purposes of GHG benefit calculation in SHS projects, the boundary issue primarily relates to the overall number of SHS installations that can be attributed to the project plus any "upstream" GHG impacts from SHSs themselves.

Since energy is used to produce and transport PV modules and other system components, SHSs will generate some "upstream" GHG emissions to the extent that fossil fuels are used for these activities. A World Bank study that examined these upstream emissions found that they are small and that in solar lanterns (which are smaller than, but substantially similar to, SHSs) they are offset by comparable upstream emissions savings associated with displaced kerosene refining and transportation.[2] It is therefore assumed here that GHG emissions with and without a SHS can be compared at the point of end-use; i.e., zero emission SHS operations can be compared with the emissions from fossil fuel burned for lighting and to generate electricity. All AIJ and GEF SHS projects to date appear to have made a similar assumption.

The number of SHS installations attributable to a project is a function of the project's design and intended scope of impact. Most GEF and AIJ SHS projects are designed to remove one or more of the barriers to SHS dissemination, which typically include lack of knowledge about the technology, high up-front system cost, lack of trained technicians, lack of capital for SHS businesses, and the need for greater business skills.

Many GEF projects are structured as market development initiatives and expect substantial indirect benefits; some such projects set their boundary to include SHS installations catalyzed by, though not directly resulting from, the project inputs (SHSs financed by a project would be one example of a direct input). A paper by deLucia and Associates prepared for a GEF SHS project in Indonesia proposes a specific calculation methodology using a multiplier to account for market acceleration benefits.[3] For proposed GEF projects in Bolivia and Peru, GEF Scientific and

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[1] In a forthcoming Energy Journal article, Richard Duke and Daniel Kammen suggest a methodology for estimating the indirect demand effect in global photovoltaics markets due to the price reductions induced by SHSs sales. In sum, SHS sales help reduce the international price of photovoltaics, thereby increasing demand for the technology in all applications.

[2] Alternative Energy Development, Inc. *India Non-Conventional Energy Projects for Global Environment Facility Funding Volume I: Main Report*, prepared for the World Bank (Washington DC: December, 1991).

[3] To account for installations "triggered" by the project, the proposed methodology applies a multiplier of 200% for a duration of six years to the number of SHS installations directly resulting from the project.

Technical Advisory Panel reviewers suggested other ways to view and account for the GHG benefits expected from the indirect market catalytic impacts.

AIJ-participating SHS projects have defined fairly narrow project boundaries, limiting the claim of impacts attributable to a given project to the SHSs directly installed by its participants. Even where activities by project participants are expected to lead to installations by others – as stated in the Honduras and Sri Lanka projects' AIJ application documents – these indirect installations and their associated GHG benefits are considered outside the project boundary.

With regard to temporal boundaries, nearly all AIJ and GEF projects reportedly anticipate that GHG benefits will accrue from SHS use over a period of either 15 or 20 years.

2.3 Baseline Determination

Generally, GEF SHS projects have specified kerosene lighting, or kerosene lighting plus automotive battery charging, as their project baseline for GHG benefit calculations. At least one GEF SHS project, in Ghana, assumes grid-based power supply as its baseline; even though the target participants have no electricity, this baseline is used since Ghana's government has a goal of 100% electrification. For GHG benefit quantification, most AIJ projects have included only kerosene lighting in their baseline. Though some AIJ projects identify and even quantify GHG benefits from reduced battery charging, most have not included this among the benefits claimed for AIJ-recognition.[4] The E7's AIJ project in Indonesia is an exception, having included calculations for avoided battery charging in its estimate of CO_2 offsets attributed to the project.

Kerosene Lighting

Since displacing kerosene lamps represents the most significant direct carbon benefit from SHS dissemination projects in developing countries, GEF and AIJ SHS projects almost always include kerosene consumption figures as the principal component of their calculated baseline emissions. Table I shows the amount of kerosene fuel for lighting reported in the baseline for a geographically diverse sampling of GEF-supported and AIJ-participating SHS projects that are currently planned or being implemented.

Table I. Baseline kerosene lighting figures for various SHS projects.

PROJECT TITLE & LOCATION	*KEROSENE for LIGHTING (liters/month)*
Argentina GEF	15.2 to 21.3
Benin GEF	3.0 to 11.7

The authors say the figure is intended to indicate the order of magnitude of the market catalytic effect and suggest further study to develop a more refined methodology. deLucia and Associates, Inc. *Indonesia Renewable Energy Development Project: A Note on the Global Environmental Calculus,* prepared for the World Bank East Asia & Pacific - Country Department III, Industry & Energy Operations Division (Cambridge, MA: October 14, 1994).

[4] In the Honduras AIJ project, this was done to be conservative, to simplify M&E, and because emissions related to battery charging were calculated to be much lower than those from kerosene lighting.

Bolivia AIJ (1)	5.0
Burkina Faso AIJ	12.0
Honduras AIJ	7.6
Indonesia AIJ	16.4
Indonesia GEF	15.0
Peru GEF	7.5
Sri Lanka AIJ	10.0 to 13.4
Zimbabwe GEF	2.8
Togo GEF	3.0 to 11.7

(1) Figure is for diesel fuel.

In some cases the figures reported for kerosene consumption in baseline calculations represent national averages for kerosene lighting in unelectrified households, while in other cases they indicate kerosene consumption specifically for the population targeted to participate in the SHS project. The participant-specific figures are based on survey data and/or calculated from assumptions about lamp usage patterns and combustion characteristics. Since the amount of kerosene used for lighting in unelectrified households can vary significantly depending on household income – with higher income families burning substantially more lighting fuel than lower income ones – participant-specific consumption figures have the potential to be more accurate than population averages.

Most GEF and AIJ SHS projects expect that all or nearly all kerosene lighting will stop after SHSs are installed. For example: AIJ projects in Bolivia and Honduras and GEF projects in Benin and Peru make calculations based on 100% kerosene lighting displacement; an AIJ project in Sri Lanka assumes 2 percent continued kerosene use post-SHS for outdoor and supplemental lighting; and a GEF project in Argentina makes calculations based on 96% displacement. While anecdotal evidence supports the assumption of high levels of kerosene displacement,[5] some studies have found significant continued kerosene lighting after SHS installations. One study of an SHS project in India, for example, found about 45% continued kerosene lighting after SHS installations.[6] The high level of continued kerosene use may be due to the specific characteristics of that project (e.g., about 50% subsidies for SHS purchases, just two electric lamps installed per SHS), but further study will be needed to better understand how such factors as system design, maintenance, and subsidies affect the persistence of kerosene lighting after SHS installations.

Battery Charging

[5] Enersol's experience in Honduras and NRECA's in Bolivia were cited to support assumptions about kerosene displacement in the USIJI applications for SHS projects in those countries. Published survey data for households who purchased SHSs in Kenya (without subsidies) indicate high levels of displaced kerosene lighting. While the surveys did not explicitly ask about continued kerosene use post-SHS, one of the publication's authors, Robert van der Plas, said he expected that continued kerosene lighting in Kenya post-SHS would be quite limited, perhaps for outdoor use or when the SHSs were not operating. Personnel communication 1/26/99.

[6] Tata Energy Research Institute (TERI), Evaluation of SPV Systems Installed Under INDO-US Collaboration Programme, Sundarbans, West Bengal (draft) (Arlington, VA: 1998).

Off-grid households often use automotive batteries to power small appliances, commonly including black and white televisions. The batteries are usually charged with power from a local electric grid or from stand-alone diesel or gasoline generators. Several GEF projects and a couple of AIJ projects have estimated emissions associated with battery charging based on a calculated amount of electricity per battery charge, the estimated number of charges per time interval, and the emissions characteristics of the electricity source(s) used for charging. Electricity per charge depends on the size of the battery, depth of discharge, and efficiency of the charger.[7] Information on emissions factors for battery charging is included in Appendix A.

Standard Factors

The carbon content of kerosene is relatively uniform throughout the world. Thus, with the exception of some variation in lamp combustion characteristics, there seems little reason to expect much variation in CO_2 emissions from kerosene lighting. GEF and AIJ projects have generally assumed kerosene lamp emissions factors in the range of 2.4 to 2.5 kilograms CO_2 per liter of kerosene burned (see Appendix A). In contrast, with battery charging, CO_2 emissions per kWh can and reportedly do vary widely (again, see Appendix A). Emissions per kWh for grid-based battery charging depend on the mix of fuels and technologies used to generate electricity. In stand-alone generators, emissions vary depending on generator type, size, and load factors.

Some GEF projects have used a type of standard overall emission displacement factor, specified as CO_2 per kWh, to calculate emissions from activities in different countries. The factor, developed by deLucia and Associates to calculate global environmental benefits for a GEF project in Indonesia, is based on an assumed ratio between displaced kerosene lighting and diesel-powered battery charging expected from a typical 53Wp SHS in Indonesia. It is not clear to what extent this factor is applicable outside Indonesia. Since kerosene lighting displacement generally has a much greater CO_2 impact per kWh than displaced battery charging (even assuming inefficient diesel or gasoline generators), the application of a single factor may also be problematic if the ratio of lighting to appliance use does not remain linear as SHSs increase or decrease in size.

2.4 Monitoring & Evaluation

For many GEF projects, planning documents use a logical framework approach, identifying key project inputs, anticipated outputs, and specific performance indicators that will be used to track progress. This approach facilitates project monitoring and evaluation. Most GEF SHS projects reported that they intend to track the number of SHS installations directly resulting from project interventions. Many projects also plan to track several additional indicators of market development to determine how effectively the project removes market barriers. GEF is working to promote uniformity in M&E standards and procedures for future project evaluations.

Since most AIJ SHS projects to-date count only kerosene displacement and claim (for GHG benefit attribution) only those systems directly installed by participants, planned monitoring and

[7] Charging a 50 to 100 amp-hour 12 volt battery could require, roughly, in the range of 350 watt-hours to about 1 kWh.

evaluation tasks are generally straightforward. In most cases, principal monitoring activities reportedly will involve tracking the number and status of SHSs installed by project participants. In the case of the Honduras AIJ project, the US participant Enersol Associates, in collaboration with the US EPA, developed a plan that will also confirm baseline assumptions and track a sampling of SHS users over time to confirm continued system functioning and determine whether and to what extent kerosene lighting persists after the SHS installations.

Actual results from monitoring and evaluation of SHS projects to date have been very limited. For the GEF, some SHS projects have been reviewed in a programmatic evaluation and report on lessons learned.[8] That document includes information on SHS projects in Zimbabwe and India and provides useful programmatic insights but it does not specifically address GHG ramifications. Likewise, the final evaluation of the Zimbabwe GEF project does not directly address the extent to which GHG benefits were achieved.[9] For the AIJ pilot phase, monitoring and evaluation results for implemented projects have not yet been reported.

3.0 Existing Guidance for Quantification, Monitoring, & Evaluation

In 1994 the World Bank published guidelines for monitoring and evaluating GEF climate change projects. The guidelines suggest alternative approaches and appropriate levels of expenditure for monitoring and evaluating projects within different sectors, including fuel substitution projects in the energy sector.[10] As of March 1999, these guidelines were in the process of being substantially revised. A recent draft World Bank report on monitoring and evaluation of market development in World Bank-GEF climate change projects includes examples of performance indicators as well as suggestions for measuring indirect benefits.[11]

For the AIJ pilot phase, individual countries' AIJ programs encourage transparent documentation of the approaches used for Q,M,&E and provide some general guidance. Regarding quantification, the USIJI guidelines, for example, request information on methodologies, data, assumptions, and calculations used to estimate emissions for the baseline case and the project. They say "established principles and methodologies are preferred, but new methodologies will be considered if accompanied by adequate documentation." For M&E, USIJI guidelines request information about the party(ies) responsible for monitoring, data to be used, procedures, and implementation schedule. Most countries' national AIJ guidelines are structured to facilitate compliance with the uniform project reporting format developed by the Framework Convention on Climate Change's Subsidiary Body for Science and Technological Advice.

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[8] Resource Futures International, *Lessons Learned During the GEF Pilot Phase*, Prepared for the Global Environment Facility, Revised April 1998.
[9] Majero, Stanley and Steve Chetse, *Report on the Termination Evaluation of the UNDP Global Environment Facility Photovoltaic Project for Household and Community Use in Zimbabwe*, Submitted to the Dept. of Energy, Ministry of Transportation and Energy, Government of Zimbabwe, Oct. 1997.
[10] The World Bank, Global Environment Coordination Division, Environment Department, *Greenhouse Gas Abatement Investment Project Monitoring & Evaluation Guidelines*, Washington, DC. 1994.
[11] Martinot, Eric., *Monitoring and Evaluation of Market Development in World Bank-GEF Climate Change Projects, Framework and Guidelines*, World Bank, Environment Department Papers, Climate Change Series, Pre-Publication Draft, September 1998.

In addition to GEF guidance material and AIJ program guidelines, several other documents provide suggestions and technical reference information relevant to Q,M,&E in climate change projects. Appendix B briefly summarizes some of the most prominent and useful documents that are currently available.

4.0 Quantification, Monitoring, & Evaluation in the CDM

The Clean Development Mechanism, created under Article 12 of the Kyoto Protocol, in effect intends to make the AIJ pilot phase operational (with emissions crediting) in developing countries. The CDM is intended to help industrialized countries achieve their emissions reduction targets while helping developing countries achieve their sustainable development goals. Under the CDM, "certified emissions reductions" (CERs) resulting from CDM projects within developing countries will be available – at least partially – to the project funders. The CERs will be transferable to industrialized countries, allowing them to raise their domestic emissions caps without violating the Kyoto Protocol. As such, CDM projects will almost certainly be characterized by a much higher level of accountability with regard to their GHG benefits than either GEF or AIJ projects.

Article 12 of the Kyoto Protocol stipulates that CERs must be "additional to any that would occur in the absence of the certified project activity." How this and perhaps other "additionality" requirements will be applied in the CDM's operational criteria is not yet clear. Two types of additionality are commonly discussed: emissions (or environmental) additionality, which refers to whether some or all of the CO_2 benefits would occur in the absence of the project; and financial additionality, which refers to whether the project's financing is in some way supplemental to "business as usual" financial and capital flows.

Two possible approaches to addressing additionality under the CDM are widely discussed:

1. Conducting project-specific reviews of additionality; and
2. Developing technology performance standards or benchmarks.

The project-specific approach has prevailed under the AIJ pilot phase to date, including for the SHS projects already underway. This approach involves the construction of "best guess" reference cases at the project level. The difficulty is that "best guesses" can vary widely, allowing analysts in good faith to come to different conclusions with respect to both the financial and emissions additionality of a given project. It also creates an incentive for project developers to overstate project benefits.

Based on some projection of business-as-usual performance at the sectoral or country level, the benchmarking approach would establish the "standard-to-beat" for projects seeking CO_2 credits. Once established, projects going beyond the benchmarks would receive CO_2 credits. Although less case-specific than a project-level additionality review, the benchmarking approach is less susceptible to gaming and more useful for guiding mitigation activities in particular policy and project directions.

If the CDM requires additionality determinations on a project-by-project basis, baseline setting for GHG quantification would likely also be project specific. If a benchmarking approach is used, it is possible that national or even broader default baselines might apply. In either case, the CDM will require the development and application of quantification criteria and rules that are much more standardized and likely much stricter than those for the GEF or AIJ.

No standards yet exist for defining how the benefits of any given CDM project will need to be monitored, evaluated, and verified. The issue of CDM monitoring, reporting, and verification provisions is an important element of the CDM workplan approved by the Fourth Conference of the Parties in Buenos Aires. Extensive work on CDM processes and standards will be occurring prior to the Sixth Conference of the Parties, which will be held in the fall of the year 2000.

5.0 Possible Good Practices Suggestions

Following are observations drawn from GEF and AIJ experience with Q,M,&E in SHS projects and suggestions regarding what might constitute good practices for these tasks in the future, particularly in the context of the CDM.

Quantifying GHG Benefits

In establishing baselines, projects should try to use figures for kerosene lighting by the specific population of intended SHS project participants rather than national averages. For SHS dissemination projects that do not provide large end-user subsidies, national average figures will probably tend to underestimate actual kerosene consumption because the households that obtain SHSs will likely consume more kerosene than the national average.

Using a default emissions factor (e.g. kg of carbon-equivalent per liter) for kerosene burned in lamps seems perfectly reasonable since significant variation is not expected.

For displaced battery charging individualized calculations will provide much greater accuracy than default values because emissions rates can vary substantially depending on the characteristics of the generators and/or grid systems used. Since the amount of carbon emissions associated with battery charging is so small, however, the use of default values may have little adverse effect on the overall accuracy of direct GHG benefit estimates (kerosene displacement will typically account for the vast majority of direct GHG benefits).

In the future, a set of standardized factors for displaced emissions expected from SHSs could be useful; this would be consistent with and facilitate a benchmarking approach to baseline setting for SHS projects in the CDM. A single factor should be viewed with some caution as it may not be appropriate for systems of different sizes or in different locations. More research, as well as monitoring and evaluation of SHS project performance with regard to GHG displacement, will be needed to develop a good set of standardized baselines.

Monitoring and Evaluating GHG Benefits

Appropriate monitoring and evaluation procedures in the CDM will depend in part on how carbon benefits are calculated. If project-by-project baselines are used, monitoring and evaluation may be needed to confirm baseline assumptions. Monitoring may also be needed to determine the extent to which kerosene lighting persists after SHS installations, though further study may reveal consistent patterns based on identifiable variables. Monitoring to determine whether SHSs continue to function would also be valuable regardless of the approach to baseline setting. Certain types of projects will ease and facilitate the monitoring of continued system performance. An Energy Service Company (ESCo) approach, where an ESCo owns and maintains SHSs that households pay a periodic fee to use, would provide the greatest level of assurance that systems continue to function. Financed sales would provide some confidence in continued system functioning over the loan repayment period. Cash sales may be somewhat less reliable for carbon crediting without periodic monitoring to confirm continued system functioning. Observers report that SHS projects that heavily subsidize or simply give systems to end users have experienced the greatest problems with continued system functioning; any GHG benefit claims from such projects should be viewed as unreliable without periodic monitoring.

Appendix A Emissions Factors for Kerosene Lamps and Battery Charging

To calculate CO_2 emissions from kerosene burning, analysts apply an emissions factor that is usually based on the carbon content of kerosene by weight, kerosene's density, and the percentage of carbon converted to CO_2 through combustion. The carbon content of kerosene is generally reported to be about 87%;[12] kerosene's density is usually reported to be about 0.80 kilograms per liter. The IPCC recommends a default figure of 99% for converting carbon to CO_2 for combusted oil and oil by-products; but many types of kerosene lamps likely convert a somewhat smaller percentage of carbon to CO_2 as evidenced by visible emissions and deposits of carbon soot. A conversion factor of 95% has been roughly estimated by deLucia and Associates and is used in calculations for some GEF projects.[13] Multiplying by 44/12 (to covert from C to CO_2), the above parameters yield a typical kerosene CO_2 emission factor of roughly 2.4 to 2.5 kg/liter. With few exceptions, emissions factors used in GEF and AIJ SHS projects fall within about 10 percent of this range.

To calculate emissions associated with battery charging, it is necessary to have some knowledge about the grid system or generator being used, as these will greatly impact CO_2 emission per kWh. The rate of CO_2 emissions per kWh from electric grid systems will vary depending on the mix of fuels and technologies used to supply electricity to a given system. Once system supply characteristics are known, several sources indicate standard emissions factors by fuel type and power plant technology; the "existing guidance" summary in Appendix B of this paper briefly reviews some of the more prominent guidance documents that include such factors.

The rate of CO_2 emissions per kWh from stand-alone diesel and gasoline generators used for battery charging can vary widely depending on generator type, size, and load factors. Smaller generators are often less efficient than larger ones and emit more CO_2 per kWh. Generators operating at a lower fraction of their potential capacity also emit CO_2 at a higher rate. Selected CO_2 emissions factors for diesel generators range from US EPA's AP-42[14] factors of 0.7 kg/kWh for industrial diesel engines to other reported figures of 1.25kg/kWh and 2.5 kg/kWh for small diesel generators.[15] Selected data for gasoline generators also indicate wide variation.

[12] Using IPCC's National GHG Emissions Inventory Guidelines, kerosene's carbon content calculates to 87.7% by weight; a GTZ Environmental Manual reports kerosene's carbon content as 86.5% by weight.

[13] deLucia and Associates, Inc., 1994 Op. Cit.

[14] US EPA *Compilation of Air Pollutant Emission Factors AP-42, Fifth Edition, Volume I: Stationary Point and Area Sources.* This document can be downloaded from http://www.epa.gov/ttn/chief/.

[15] Fuel consumption figures of 0.5 to 0.6 liters per kWh for small diesel generators were reported in Gerald Foley, *Photovoltaic Applications in Rural Areas of the Developing World*, World Bank Technical Paper No. 304. (Washington, DC: World Bank, 1995. P. 25); this translates to about 1.3 to 1.6 kgCO2/kWh. Annex IV of the Project Brief of a proposed GEF project in Ghana reports that a "load-following free-standing" diesel genset has fuel consumption of about 1-1.5 kWh/liter; CO2 emissions would be about 2.5 kg/kWh at 1 kWh/liter. EPA provided Steven Kaufman with a diesel generator CO_2 emission factor of 1.25 kg/kWh for calculations made for the Honduras SHS AIJ project in 1994.

Appendix B Brief Summary of Guidance Documents

Following is a brief summary of the more prominent guidance documents addressing Q,M,&E issues relevant to climate change projects.

IPCC's Guidelines for National Greenhouse Gas Inventories. [16] The IPCC prepare detailed guidance to help countries develop national GHG emissions inventories. This three volume set is comprised of a reference manual, a workbook, and reporting instructions. These guidelines contains much information regarding GHG emissions quantification and include default emission factors for various fuels.

US Department of Energy Guidelines for the Voluntary Reporting of Greenhouse Gases.[17] The US DOE has produced a three volume set of guidelines to facilitate the reporting of the GHG emissions impacts of voluntary projects wishing to be recorded in DOE's national registry. These documents suggest some methodologies for estimating GHG emission reductions and include as appendices emission factors associated with electric power generation by fuel type and technology.

Lawrence Berkeley National Laboratory has produced a detailed report on monitoring, evaluation, reporting, and verification in climate change mitigation projects. The report thoroughly reviews existing guidance and suggests principles to be applied in developing more comprehensive, detailed guidance for these tasks in the future.[18]

Various World Bank publications provide useful insights regarding GHG emissions quantification, including a recent publication titled Greenhouse Gas Assessment Handbook: A Practical Guidance Document for the Assessment of Project-level Greenhouse Gas Emissions.[19]

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[16] Intergovernmental Panel on Climate Change, *IPCC Guidelines for National Greenhouse Inventories; Reference Manual, Workbook, and Reporting Instructions*; 1994, and Revised 1996.
[17] U.S. Department of Energy, *General Guidelines and Sector-Specific Issues and Reporting Methodologies Supporting the General Guidelines for the Voluntary Reporting of Greenhouse Gases Under Section 1605(b) of the Energy Policy Act of 1992. DOE/PO-0028*, Volume 1, 2, and 3. 1994.
[18] Vine, Edward and Jayant Sathaye, *The Monitoring, Evaluation, Reporting, and Verification of Climate Change Mitigation Projects: Discussion of Issues and Methodologies and Review of Existing Protocols and Guidelines*, Lawrence Berkeley Laboratory, 1997.
[19] World Bank, *Greenhouse Gas Assessment Handbook: A Practical Guidance Document for the Assessment of Project-level Greenhouse Gas Emissions, Environment Department Paper No. 64*, (World Bank, Washington, DC), September, 1998.