Methodological and Practical Considerations for Developing Multiproject Baselines for Electric Power and Cement Industry Projects in Central America

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Keywords: baselines, baseline emission rates, carbon intensity, cement industry, Central America, electric power, mitigation projects, multiproject baselines

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1. Introduction

1.1. GHG MITIGATION ACTIVITY

Projects to reduce greenhouse gas (GHG) emissions below business as usual conditions are being advanced and considered under various national and international schemes. In the absence of emissions caps, hypothetical baselines must be calculated, against which to compare these projects' emissions. For example, the U.S. Department of Energy (DOE) is in the process of revisiting its reporting guidelines for the Voluntary Greenhouse Gas Reporting Program in an effort to improve its capacity to estimate avoided GHG emissions for use in potential tradable credit schemes (DOE 2004). The U.S. Environmental Protection Agency (EPA) is looking at adopting guidelines for its Climate Leaders program for organizations that agree to meet GHG reduction targets. The World Resources Institute and the World Business Council for Sustainable Development have been working together to develop the GHG Protocol for estimating project-level GHG savings that could serve as an internationally accepted protocol. In addition, bilateral and international programs such as the Clean Development Mechanism (CDM), the Dutch government's Certified Emission Reduction Unit Procurement Tender, the Prototype Carbon Fund, and other preliminary carbon trading programs have provided guidelines for calculating avoided greenhouse gas emissions from mitigation projects.

1.2. GHG MITIGATION PROJECT CAPACITY BUILDING IN CENTRAL AMERICA

Staff from the Lawrence Berkeley National Lab (Berkeley Lab) have been working with the Center for Sustainable Development in the Americas (CSDA) and the U.S. Agency for International Development (USAID) to develop capacity in Central America to evaluate GHG mitigation projects in this region. As part of this work, Berkeley Lab, CSDA, and USAID organized two workshops in Central America to introduce stakeholders to a variety of publications and tools by the Berkeley Lab to assist project developers and program administrators with the implementation of GHG mitigation projects. The first workshop was held in Antigua, Guatemala in April 2003 and brought together more than thirty governmental, non-profit, private sector, and academic participants representing every Central American country to discuss various approaches to setting multiproject GHG baselines. The workshop introduced the MBase[1] spreadsheet tools (Sathaye et al. 2003; Murtishaw et al. 2003) for calculating multiproject baselines in the electric power and cement industries. This workshop also covered the use of ProForm, a GHG mitigation project feasibility evaluation tool, which allows project developers, financial institutions, and other parties to investigate how changes in basic assumptions affect key parameters of a project (Golove et al. 2004).[2] In addition to the presentations on these tools given by Berkeley Lab staff, participants were guided through practicums, during which preliminary baselines were created for several Central American countries and participants' own projects were evaluated using ProForm.

The second workshop took place in San Salvador, El Salvador in May 2003 and focused on monitoring, evaluation, reporting, verification, and certification (MERVC) guidelines developed by Berkeley Lab for GHG mitigation projects (Vine et al. 1999). This workshop involved approximately fifteen participants from throughout Latin America, most of them from the private sector. The workshop covered all aspects of MERVC, and participants worked together to prepare and present several case studies.

This report focuses on findings of the Berkeley Lab baseline studies of the electrical grid in Guatemala and the cement sector in Central America. For the electricity sector, plant-specific operations data were collected in order to calculate various baselines that represent the average emissions of plants that may be expected to come online in the absence of mitigation projects. For the cement sector, issues of confidentiality impeded data collection for most plants in the region. In lieu of actual data, estimates were used for some plants to derive the baseline. Two hypothetical projects were fabricated to demonstrate the use of the MBase tool for the cement industry.

1.3. PREVIOUS MULTIPROJECT BASELINE STUDIES

In previous studies (Sathaye et al. 2001, 2004), Berkeley Lab applied its baseline methodology to data for the power sectors of India and South Africa as well as the cement industries of China and Brazil. In the course of these studies, Berkeley Lab staff found that obtaining detailed plant operations data was not always possible. Some data had to be estimated on the basis of what was known about plant technologies and fuel choices. Once the necessary data were estimated, applying the methodology was straightforward and yielded interesting results. One challenge encountered in conducting the South Africa study was that the methodology is difficult to apply in cases where little recent construction has occurred (see also Bosi et al. 2002). For the purposes of the study on the South African electricity sector, assumptions were made about the likely options for capacity expansion. These studies showed that, often, the most challenging aspect of calculating baselines is collecting the plant-specific data necessary to evaluate recent trends in technology and fuel choice. Presumably, programs instituted by host country governments would have greater authority to obtain the necessary data.

2. Methodology

The basic methodological approach underlying MBase and similar multiproject methods is to calculate multiproject baseline emission rates (BERs) based on the ratios of carbon dioxide emissions to product output from existing plants.[3] These BERs serve as approximations of the emission rate of supplying the same output from sources displaced by GHG mitigation projects. Multiplying the activity (e.g., kilowatt-hours) and emission rate (kg CO_2/kWh) yields an emissions baseline (kg CO_2).[4] The reduction due to the project is simply the difference between the project's emissions and the emissions that would have occurred to produce the same amount of output in the reference case. Since grid operation and capacity planning are extremely complex, determining the precise sources of electricity offset by a given project poses a major challenge. There are several rationales for exploring the use of these multiproject approaches as an alternative to project-specific baselines. One advantage to developing BERs for a given grid or industry sector and region is that they can be used for any project on that grid or in that sector and region. Most importantly, these approaches offer consistency across projects; once set, all projects will receive credit based on the same BER. Moreover, BERs rely on a transparent methodology open to all stakeholders. Another benefit is that developing BERs helps to minimize transaction costs. The higher transaction costs of setting project-specific baselines are likely to reduce the number of projects that attract investment, particularly for smaller renewable energy and energy efficiency projects. Experience with other project evaluations has shown that construction of project-specific baselines is time-consuming and costly, and can be highly uncertain.[5]

The BER values ultimately obtained depend heavily on which reference plants a project is compared to. There are four types of decisions that must be made to select the reference plants: geographic scope, plant vintage, fuel specificity, and stringency. Below we briefly describe the guidelines that were used for this analysis. A detailed explanation of the Berkeley Lab methodology used for determining BERs for the electricity sector may be found in Sathaye et al. (2004).

The first decision that needs to be made is the geographic scope of plants to be included in the benchmark set. For the electricity sector, the scope should be determined by the extent of the grid since the indirect emission rates of electricity may differ substantially from one grid to another, and a new power plant is physically constrained to displacing power from other plants on the same grid. For Guatemala this is relatively straightforward, since there is relatively little trade in electricity with neighboring countries (Fundaci´on Solar 2002). Therefore, the Guatemala grid constitutes the grid in question. For the cement industry, the geographic scope is determined by the number of plants in a given region and the size and integration of the market served. One country in Central America would not have contained enough plants for a baseline, and the cement used for construction in these countries is likely to come from any of the plants in the region. Therefore, the entire Central American region was chosen as the baseline for this study.

The second decision concerns the vintage of reference plants to use when constructing the BER. When recently built plants are used, a cut-off year must be chosen for plants to qualify as recently built. The cut-off year is somewhat arbitrary and may vary according to country-specific conditions. A tradeoff must be made between an overly restrictive cut-off year that leaves too few plants to yield a representative sample and an overly inclusive cut-off that includes plants whose efficiencies or fuel sources are no longer indicative of plants being built today.

The third issue for determining the baseline is the fuel specificity of the plants to be used for comparison to the proposed project – plants of the same fuel type only, plants of another specific fuel type, or an average of all plants.

The fourth decision to make when estimating BERs for projects is the stringency of the benchmarks. MBase generates four levels of stringency: weighted average, top 25th percentile, top 10th percentile, and best plant.[6] The weighted average is simply the reference plants' total sum of emissions divided by their total sum of output. The percentiles are calculated by ranking the plants within each fuel type from lowest emission rate to highest, and using the emission rate of the plant where 25% or 10% of the total generation or output occurs. The fuel-specific 25th and 10th percentile stringencies are weighted by generation from each fuel type to produce sector-wide 25th and 10th percentile BERs that reflect efficiency within fuel types rather than BERs dominated by low-or zero-emitting sources.

3. Power Sector Results

3.1. METHODOLOGY SPECIFIC TO THE POWER SECTOR

There is some question as to whether to differentiate BERs based on differences in project generation profiles. For example, some projects provide intermittent power and may not always be able to generate power when needed. These types of projects are referred to as nonfirm power projects and may include sources such as wind power or energy efficiency projects whose impact on demand are not predictable. Since nonfirm generators cannot provide power on demand, they have less effect on planning for future capacity. Thus, an argument can be made that their main impact is to reduce the need for energy from existing load-following sources and future sources that must be built anyway to maintain an adequate reserve.

In contrast, firm power generating sources are able to reliably produce power on demand. Thus, projects providing firm power are likely to offset the need for future capacity. This distinction between the impact of new projects on the operations of plants and the impact on the construction of new plants has been referred to as the operating margin and build margin effects (Kartha et al. 2002).

Firm power technologies consist of two distinct types on the basis of their load profile: baseload plants that operate at very high capacity factors (i.e., plants that usually generate 70% or more of their potential capacity over the course of the year) and load-following plants whose output fluctuates according to demand. Baseload plants tend to be large plants with low operating costs, such as coal or nuclear plants. Load-following generators are generally smaller plants – often gas-fired turbines, reciprocating engines, or smaller hydro stations. Because of the differences in their emission rates, we believe that baseload and load-following projects need to be evaluated separately, using reference plants of the same type. Alternatively, it has been argued that creating different baselines according to load profile will not be worth the effort due to the difficulty of obtaining the necessary data to classify the plants and the low number of load-following projects expected to apply for credits from GHG mitigation programs (Lazarus et al. 2000; Kartha et al. 2002, 2004). This total build margin is the approach used by the CDM's consolidated methodology (UNFCCC 2004a).

The Berkeley Lab and CDM consolidated methodologies differ on two other counts. First, the consolidated methodology recommends using the five most recently constructed plants or the most recently constructed plants that comprise 20% of the system generation, whichever represents the larger share of generation. We have suggested using the most recent plants to have gone online during a certain time period, generally five years (Murtishaw et al. 2004). Second, we have advocated using predominately build margins for projects providing relatively reliable or dispatchable power. For nonfirm projects such as wind farms, we have suggested using predominately operation margins with a share of output receiving credit at the build margin emission rate depending on whatever capacity credit the project may have received. In contrast, the consolidated methodology assumes all projects affect future emissions in the same manner, initially affecting the operations of plants at the margin and subsequently affecting capacity expansion. To model this impact, a combined margin is used in the first CDM crediting period (by default a simple average of the operating and total build margins although other weightings of the operating and total build margins are permitted), and the build margin is used in subsequent periods.

Together, the Berkeley Lab and CDM consolidated methodologies yield five different types of BERs: operating margin; load-following build margin; baseload build margin; total build margin (which aggregates the load-following and baseload plants); and a combined margin that averages the operating and total build margins. The results of these various BERs are compared below in Section 3.3.

When determining the reference plant vintage for an electricity project, all units are included – regardless of age – for calculating the operating margin, since power may be displaced from any existing load-following unit.[7] For build margins, the more recent baseload and load-following plants added to the grid are examined to give an indication of expected trends in the technologies and fuel sources that will be used in the near future. For some grids, the plants that will be built over the next several years may be significantly different from those recently constructed. This may be the case if a new technology has been introduced or if a new fuel source, such as natural gas, will become available. In this case, it may be preferable to use estimated data on planned capacity additions to produce a more accurate BER.

On grids for which no single fuel is dominant, large fluctuations in the build margin from year to year are likely. Guatemala's grid provides a good example, as shown in Table I. There is a large variability from year to year in the average emission rates of new baseload plants going on line. Average annual build margin rates from 1996 to 2000 ranged from zero emissions in one year to a maximum of

1.039 kg CO_2/kWh. Berkeley Lab has conducted an analysis of plant construction trends on several grids, including Guatemala's, to compare time series of build margins based on various ranges of plant construction (Murtishaw et al. 2004). Including plants built in additional numbers of prior years makes the average more stable and more representative of the range of resource options available to the grid. When there is a high degree of scatter in the data, it is important to use a large enough time period to yield a representative mean. Using multiple years offers a way to smooth over annual fluctuations in the type and sizes of power plants that might be built in a given year. We also found that a time series of build margins based on multiple years' worth of plants produces smaller prediction intervals around the BERs due to a lower degree of scatter.

TABLE I Number and capacity of new baseload plants in guatemala, and one-year, three-year, five-year, and seven-year GHG emissions build margins (BM) in kg CO_2/kWh

Data	1994	1995	1996	1997	1998	1999	2000
New capacity,	66	34	0	64	87	19	150
MW Number of	2	1	0	3	3	1	2
plants One-yr BM	0.753	0.681	N/A	0.464	0.477	0.000	1.039
Three-Yr BM			0.735	0.530	0.474	0.383	0.744
Five-Yr BM					0.553	0.407	0.715
Seven-Yr BM						0.475	0.718

Circumstances that significantly affect the average emission rate of plants built on a given grid may suggest a bound on the number of years' worth of plants to include in the reference set. There are four basic types of breakpoint events that may induce long-term changes in emissions characteristics of the plants built on a given grid: government policies, technological advances, changes in fuel supply, and market integration. See Murtishaw et al. (2004) for a fuller discussion of the causes and implications of breakpoints.

Given the complexity of decisions regarding investments in new generation capacity, it is very difficult to demonstrate that a project displaces generation from any particular source. Thus, fuel specific BERs would rarely be appropriate for the power sector. We suggest calculating two generation-weighted average emission rates of all recently built units, one rate for baseload and one for load-following units, and using these rates as benchmarks for estimating baselines for all firm capacity power projects.

3.2. HISTORY OF GUATEMALA'S POWER SECTOR

The past two decades have been a tumultuous period for Guatemala's power sector. In the 1980s, the publicly owned electricity sector in Guatemala became unable to finance the capital expenditures required for the sector's sustainable growth and development. From 1959 to 1986, the power sector in Guatemala was completely state run (Fundaci´on Solar 2002). During this time INDE, the state power company, focused on developing Guatemala's indigenous power supply, which consists chiefly of hydropower. In 1986, INDE froze its investments due to a lack of outside financing. The Guatemala Congress attempted to promote private investment through the Renewable Energy Law of 1986. This law granted tax-exempt status for renewable energy projects. Several bagasse cogeneration and hydro projects, and some geothermal projects, were registered under the Renewable Energy Law, but it proved to be ineffective in attracting large-scale private investment. By 1990, 92% of electricity was still generated by state-owned facilities.

In the early 1990s, the system had reached its generation limits and daily blackouts were common. International agencies joined in support of a new electricity regulatory framework. As consultations on developing a new structure dragged on, the energy crisis deepened. INDE began to offer extremely generous purchasing conditions to private sector companies willing to invest immediately in electricity generation. Between 1993 and 1996 private generators entered into power purchase agreements (PPAs) with INDE, opening electricity generation to private investment. Thirteen generation contracts were signed, including 178 MW of renewable energy projects (small hydro and bagasse co-generators) and 201 MW of fossil fuel projects. Due to the energy crisis and the high risks for investment in Guatemala, INDE was allowed to enter into long-term (15-year) PPAs without meeting requirements for competitive pricing (Fundaci´on Solar 2002).

In October 1996, the Guatemala Congress passed the General Electricity Law. The law defined a new structure for the country's energy sector and further reformed the electric power market, allowing the private sector to participate in all sectors of the energy market. The law gave private companies unrestricted direct access to the power grid, distributors, and wholesale customers, and provided for a general unbundling of generation, transmission, and distribution. It created the new regulatory commission and defined the wholesale power market. Privatization of state-owned electric companies began with the selling off of INDE and the state distribution company, EEGSA. The state, however, retained ownership of the transmission company.

Between 1997 and 2002, 569 MW were added to the national grid (AMM 2003a). Only 80 MW of this additional capacity were from renewable energy projects. The privatization of power supply in Guatemala resulted in a sharp increase in the use of large reciprocating engines burning heavy fuel oil, whereas prior to that, the bulk of the power serving the Guatemalan main grid was from hydro stations. This is a common phenomenon when private entities begin to invest in generation, since private investors will seek to minimize their risk by constructing plants with low capital costs and short construction lead times. In addition, existing cogeneration facilities in the sugar industry began to generate excess electricity for sale to the grid. These facilities burn bagasse when it is available and heavy fuel oil for supplying power to the grid when bagasse stocks are exhausted. Figure 1 depicts how rapidly capacity was installed after the introduction of the PPAs and, again, with the 1996 power sector restructuring. It also makes clear the dramatic fuel shifts that occurred with the influx of new investments.

Data on the net generation and fuel consumption for all plants that were operational for the full year during 2001 were used to construct BERs for the Guatemala grid. The plant-specific fuel consumption data were confidential data provided by the Guatemala Ministry of Energy and Mines (MEM). Data for the fuel oil consumed for electricity delivered to the grid by cogeneration facilities were provided by the Guatemala Cogenerators' Association. The final data set consists of 37 plants. These plants were separated into baseload and load following units based on their capacity utilization factors, supplemented with detailed dispatch information from Guatemala's Major Market Administrator (AMM 2003b).

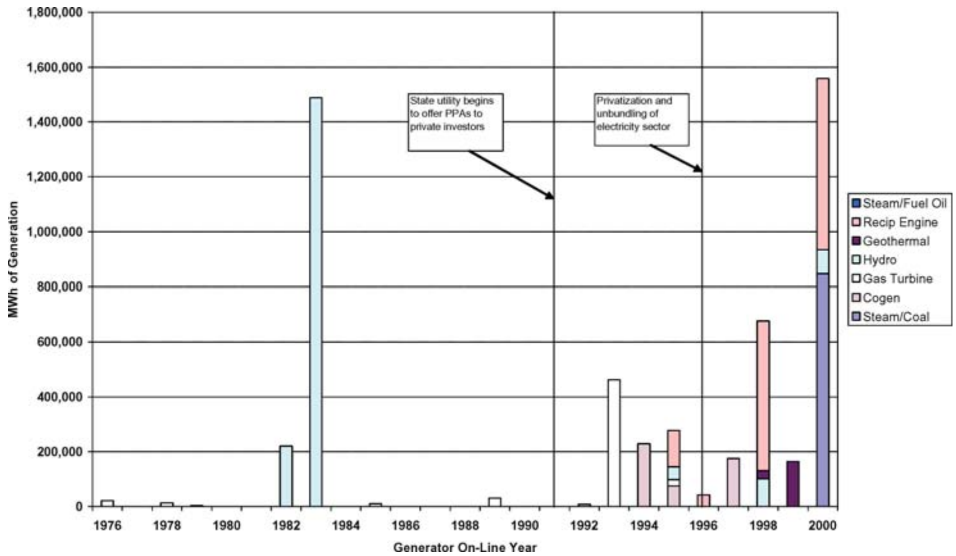

Figure 1. Generation in Guatemala in 2001, by Generation Type and On-line Year.

3.3. MBASE RESULTS FOR THE GUATEMALA GRID

The Electricity Law of 1996 constitutes a clear breakpoint for Guatemala's grid, since it has had such a profound impact on the recent and continuing development of capacity additions. Of the 37 plants operational in 2001, 13 went online between 1996 and 2000. We used these plants to calculate the baseload, load-following, and total build margins. Another version of the total build margin was calculated from the five most recently built plants, in accordance with the consolidated methodology (UNFCCC 2004a). For the hydro plants, detailed daily dispatch curves were examined in addition to capacity utilization to see how the plants were actually dispatched throughout the day. Based on the criteria established to classify the plants, only three plants (one hydro and two reciprocating engine plants) were designated as load-following plants. The ten plants constituting the baseload reference set are a diverse mix of coal, hydro, geothermal, cogeneration (bagasse and heavy fuel oil), and reciprocating engines burning heavy fuel oil.

Table II lists all of the sector-wide BERs generated by MBase. The large drop from the 25th to the 10th percentile for the baseload build margin is due to the performance of the best cogenerating stations, which burned bagasse as well as fuel oil. Since only three load-following plants were constructed during this period, there were not enough reference points to calculate meaningful percentiles for load-following BERs. The weighted average of the load-following plants is much lower than the average for the baseload plants, due to the presence of the coal plant and the more carbon-intensive cogenerating stations that burned mostly fuel oil for grid-delivered power in the baseload. The closeness of the total build margin BERs to the baseload build margins shows that the baseload units contribute much more to the total generation from the recently built plants.

TABLE II Multiproject baseline emission rates (kgCO_2/kWh) for the main guatemala grid using a five-year build margin

Type of baseline emission rate	Weighted average	Top 25th percentile	Top 10th percentile
Baseload Build Margin	.702	.643	.507
Load-Following Build Margin	.567	N/A	N/A
Total Build Margin, Berkeley Lab	.689	.633	.510
Total Build Margin, CDM[a]	.771	N/A	N/A
Operating Margin	.735	N/A	N/A
Operating Margin, w/Coal	.901	N/A	N/A
Combined Margin, excl Coal from OM[a]	.753	N/A	N/A
Combined Margin, w/Coal in OM[a]	.836	N/A	N/A

[a]Calculated using the five most recently built plants for the build margin following the CDM consolidated methodology (UNFCCC 2004a).

Since the CDM methodology does not differentiate between baseload and load-following projects, we also present the total build margin of the five most recent plants, as specified in the consolidated methodology. This BER is higher than that calculated using the Berkeley Lab reference plants since there are fewer plants to offset the higher emission rate of the coal plant. It is also weighted more heavily toward baseload units since there is only one load-following unit among the five most recently built in the reference set.

The operating margin consists of the average emission rate of all the thermal plants whose generation is relatively responsive to changes in the system load. These plants consist of the two fossil-fuel burning load-following plants that were recently built, as well as all of the diesel-burning gas turbines (which are all used at very low capacity factors), some of the older reciprocating engines, and a couple of older oil-burning steam turbines. The inefficiency of the older plants and the infrequency of their operation lead to very high emission rates, which explains the high figure for the operating margin.

A second operating margin is also shown, which includes the San Jose plant in the calculation. This BER is 23% higher than the operating margin with the San Jose plant excluded. This margin is included to show the importance of how coal plants are treated with respect to the assumptions about whether they respond to load like other fossil fuel powered plants. The CDM consolidated methodology states that the operating margin should exclude low-cost and must-run resources, which are defined basically as nuclear and renewable power sources. By default, coal stations would generally be included in the operating margin, although the document explains that coal plants should be excluded where they are obviously must-run. We believe that coal plants rarely operate as load-following resources except in countries that depend on coal for a large portion of their total generation. An uncritical application of the methodology might include the San Jose plant despite the fact that it has been operating at nearly 100% capacity factor except during outages. Over a one-year period from 2003 to 2004 its annual capacity factor was over 92% (AMM 2005). This plant is clearly not responding to changes in total system load.

The two consolidated methodology BERs differ based on whether the operating margin includes or excludes the San Jose plant. The second combined margin is 11% higher than the first one, indicating that the inappropriate inclusion of a coal plant in the operating margin can significantly bias the combined BER.

3.4. COMPARISON OF MBASE RESULTS TO TWO PREVIOUS STUDIES

Two previous studies have also provided estimates of avoided CO_2 emissions due to additional renewable energy projects in Guatemala (Friedman 2000; PCF 2003a). Data limitations hindered the calculation of baselines for the Friedman report cited above. Assumptions about operating efficiencies for some plants had to be made since the author of this report was not able to obtain actual fuel consumption data. This report also does not distinguish between baseload and load-following build margins. It found a total build margin of plants built over the same five-year period as our study (1996–2000) of 0.750 $kgCO_2$/kWh. This is about 10% higher than the total build margin we calculated, but given the limited data used for the EPA report, a difference of this magnitude could be expected. The EPA report also does not treat operating margins per se, but it does discuss some characteristics of the wet and dry season dispatch curves. As a rough approximation of the operating margin, an average emission rate of 0.900 $kgCO_2$/kWh is given based on the average efficiency of the oil-fired generators. This figure is significantly higher than our calculation, but the exact calculation for the EPA report is not given. Thus, this discrepancy cannot be explained.

A baseline study for a project seeking support from the Prototype Carbon Fund (PCF) in Guatemala for a small hydro project assumes that the station will only have an impact on the operating margin (PCF 2003a).[8] The baselines method assumes that power from the hydro plant is equally likely to have an impact on any of the plants that operate on the margin on the main Guatemala grid, which they define as all heavy and distillate fuel oil plants. Their method weights the existing plants by capacity, not actual generation, and thus overstates the role of some of the older turbines, which are run at very low capacity factors. The figure derived from this calculation is 0.810 $kgCO_2$/kWh, roughly 10% higher than the operating margin calculated by MBase. The MBase operating margin is weighted by the actual generation of the units, which should more closely approximate the impact of reduced demand for marginal generation throughout the year.

3.5. DISCUSSION

This case study of constructing BERs for Guatemala's power sector has illustrated four challenges for setting BERs that will be of interest to climate policy analysts and mitigation program administrators. First, the inclusion of reference plants for build margins should not be based on generic guidelines without considering market realities. The types of plants that will attract investment will change in response to the policy and market environments. As shown in Figure 1, the introduction of private investment to Guatemala's power sector had a profound impact on its total generating capacity as well as its fuel mix. This breakpoint event set a bound on the vintage of plants that one would include in the set of reference plants, since plants constructed before the breakpoint are no longer representative of the types of plants likely to be constructed in the near future. Two other events may constitute a breakpoint that will affect future baselines. One is the completion of the San Jose coal-fired power plant, the first in

Guatemala, in 2000. Since Guatemala has no indigenous coal supply, it must import the coal it uses for this station. In order to do so, special receiving facilities had to be constructed at Puerto Quetzal (TWG 2003). Presumably, now that facilities have been established to receive and process coal, it is more likely that other coal-fired power plants will be constructed in the future. This may represent a significant fuel mix breakpoint that leads to higher baselines from 2000 on. Similarly, a planned regional transmission line (known as SIEPAC) would constitute a market integration breakpoint since new power for distribution in Guatemala could come from any of the other five participating Central American countries, broadening the resource base for future power needs. However, it is uncertain when this project will be completed (PCF 2003b; Ringius et al. 2003).

A second factor to be considered is the classification of plants and projects into baseload and load following cohorts. Where data availability permits, this classification should not be conducted solely on the basis of annual capacity factors or simplified guidelines based on generator or fuel type. Adjustments should be made for seasonal differences in output or for prolonged outages. Some of Guatemala's hydro plants with relatively low annual capacity factors were found to operate as baseload plants in the wet season and load following plants in the dry season when dispatch data were analyzed. Similarly, the cogeneration units at the sugar mills have low annual capacity factors but only supply electricity to the grid during the dry season when they run as baseload plants. As Table II showed, classifying all fossil fuel powered plants into the load-following cohort would result in the coal plant's inclusion in the operating margin. This yields a much higher operating margin BER than projects should receive based on observed dispatch data.

A third consideration that may affect the calculation of operating margin BERs is the possibility that a plant may be load-following but benefit from a take-orpay clause in its power purchase agreement. While the plant may serve to follow load, in practice its output will almost never be curtailed during expected operating hours. Thus, these must-run plants should be excluded from the operating margin calculation. It is known that some plants built between 1993 and 1996 received generous power purchase agreements, but information was insufficient to allow an additional classification of these load-following plants into a "must-run" category. Contractual obligations should be taken into account when deciding whether plants will be included in the operation margin, but obtaining access to this information may be difficult without legal authority to examine power purchase contracts.

Finally, assumptions regarding how a project will affect future emissions can have a considerable effect on the estimation of marginal emission rates used for BERs. If one assumes that the distinction between baseload and load following generators is justified, then load-following projects (e.g. a solar photovoltaic unit that only produces power during daytime peak loads) would receive a BER almost 20% lower than the BER for baseload projects using the Berkeley Lab build margins or 26% lower than the CDM combined margin (see Table II).

4. Cement Sector Results

4.1. CENTRAL AMERICA'S CEMENT SECTOR

The cement industry contributes about 5% of annual CO_2 emissions from fossil fuel combustion and industrial processes, making it an important industry for CO_2 mitigation projects (Worrell et al. 2001). In addition to its large contribution to global CO_2 emissions, the cement industry has many opportunities for efficiency improvements (Worrell et al. 2001; Worrell et al.

2004a, b). Like many developing regions, Central America has seen growth in the cement industry in the last decade. Thus, mitigation projects are likely to emerge in Central America in the near future. Only one cement plant is currently operated in Guatemala. This fact, combined with the presence of regional trade in cement, implies the need to use a broader geographic region. For these reasons, all plants in Central America were used to set the BERs.

The cement sector has been changing rapidly over the past decade in Central America, with three major foreign companies – Holcim Ltd, CEMEX S.A. and Lafarge S.A. – now owning most of the plants in the region. This has changed since 1996, when these three companies owned only 6 of the 12 plants in operation at that time. Table III shows the current distribution of plants and their ownership as well as ownership circa 1996 (when the last complete set of data from Cembureau was published). Today, there are ten cement plants in Central America and one grinding plant (Cembureau 1996; Guti´errez 2003; Holcim 2004). One of the plants operational in 1996 has been shut down.

TABLE III Cement industry overview

Country	Company	Plant	Owner/s	Previous Owner/s
Costa Rica	Industria Nacional de Cemento SA (INCSA)	Aguacaliente	Holcim	Holcim
	Cementos del Pacifico SA	Colorado	CEMEX, 80%	CEMEX, 80%
	Cementos del Pacifico SA	Patarrá	CEMEX	CEMEX
El Savador	Cemento Maya SA	Cantón Tecomapa	Holcim	CESSA
	Cementos de El Salvador SA (CESSA)	El Ronco	Holcim	Partly by 450 El Salvadorans, partly by Holcim
Guatemala	Cementos Progreso, SA	San Miguel	Holcim	Family owned
	Cementos Progreso, SA	La Pedrera	N/A[a]	Family owned
Honduras	Cementos del Norte SA de C.V.	Rio Bijao	Holcim	Holcim
	Industria Cementera Hondureña SA (INCEHSA)	Pedras Azules	Lafarge	Lafarge
Nicaragua	Compania Nacional Productora de Cemento SA (CANAL)	San Rafael Del Sur	State owned, CEMEX operated	State owned, CEMEX operated
Panama	Cemento Panama SA	Quebrancha	Holcim	Corporación Incem
	Cemento Bayano	Calzada Larga	CEMEX	CEMEX (95%), employees (5%)

Source: Cembureau 1996; Gutiérrez 2003; Holcim 2004.
[a]No longer in operation.

Figure 2 shows the production of cement in Central America from 1993 to 2001. Because data sources were incomplete for later years, some individual plant production data were approximated based on previous years to obtain a total for 2001. Through our contacts with the industry, we were able to obtain more accurate and up-to-date data for the Holcim plants in Central America. These data are shown in Figure 3. Both Figures 2 and 3 show that production of cement has increased in the last decade. Holcim has shown an 80% increase from 1993 to 2002 for four plants in the region.

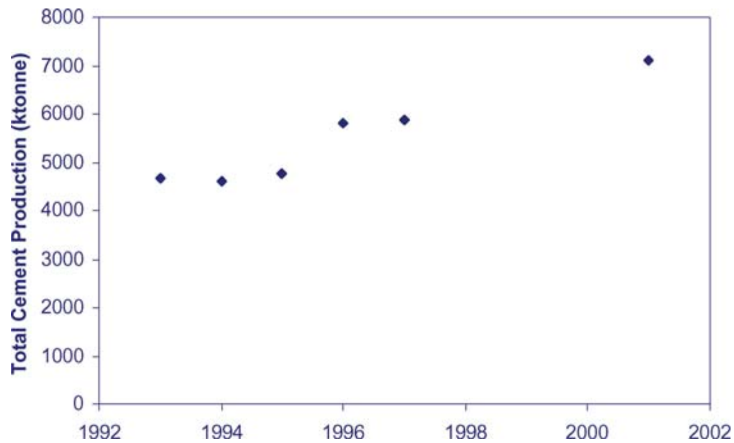

Figure 2. Total production of cement in Central America from 1993 to 2001.

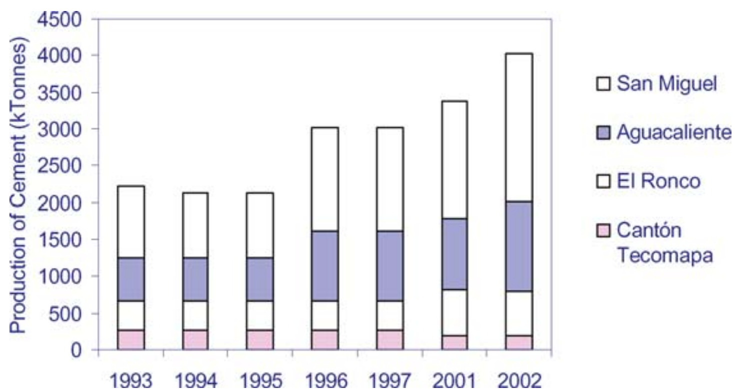

Figure 3. Production of cement by Holcim Plants in Central America from 1993 to 2002.

Clean Development Mechanism and Activities Implemented Jointly (AIJ) projects have already been proposed for this region. For example, Cemento de El Salvador, S.A. (CESSA) participated in an AIJ CO_2 reduction project that resulted in replacement of its wet kiln with a new, larger dry kiln, eliminating about

0.19 tonne of CO_2 per tonne of clinker (UNFCCC 2004b). Since this project was a retrofit, the current plant was used as the baseline.

4.2. METHODOLOGY FOR THE CEMENT SECTOR

In addition to the questions posed above in Section 2, in the development of any industrial sector BERs, it also is necessary to determine which process steps are to be included, and whether or not to include process emissions in the calculations of total carbon emission reductions, where applicable.[9] For industrial processes, BERs should be calculated from the bottom up by process step since not all facilities perform all processes involved in producing the final output. For example, some cement plants only produce clinker, with the final grinding done at a separate site. In order for BERs to be appropriately tailored to any given project, they should be adjusted to cover only the process steps that are performed by the project facility.

The first version of MBase Cement was developed for a study of projects based in China and Brazil (Sathaye et al. 2002). In this version, three stages of production were included in the model: grinding and homogenizing raw materials, kiln operation for clinker production (or pyro-processing), and finish grinding of the final cement product. Process-based emissions from the calcination of limestone were not included in this first model.

Blended cements are cements that use a higher ratio of blended materials than the 5% used in the most common type of cement, known as Portland cement. By reducing the clinker to cement ratio – increasing the amount of additives used in cement – the CO_2 intensity (CO_2 per tonne of cement) is also reduced, not only by decreasing energy requirements, but also by reducing process-based emissions.

In the current version of MBase, two sets of emission reductions are calculated: emission reductions based solely on energy efficiency upgrades (as in the original version of MBase Cement), and emission reductions that include process-based emission reductions from increasing the amount of blended components used. Process-based emission reductions are calculated based on the average clinker to cement ratio of the reference set compared to the ratio used by the project plant.

Two process steps have been added to MBase Cement. The first step was added to account for the fuels required for drying any additives used in blended cements. This seemed a necessary addition once process-based emissions were included (see above). This step is only applicable to some cement production because not all additives are dried.[10] The second addition was made to the clinker production stage. In the first version of MBase, this stage included the fuels required to heat the kiln, but it did not include any electricity requirements for kiln operation. In the current version of MBase, both fuel and electricity requirements are included in the model for this step.

4.3. CENTRAL AMERICA CEMENT CASE STUDY

Similar to the electricity sector, one goal for the cement industry project was to create a baseline, given appropriate data for plants in the Central American region. From industry contacts, we were able to collect data on four plants in the region – all owned by Holcim. Unfortunately, due to the lack of plant data for the remaining six plants in the region, we were unable to construct rigorous BERs for Central America.

In order to create a baseline for the region, we estimated production and energy consumption data for the remaining plants based on known characteristics of their ages and kiln designs. Baseline plants were ‘chosen’ based on vintage (1971– 2001), geographical scope (Central America), and fuel specificity (all fuels). Two hypothetical projects were also created. The first project (project #1) was a retrofit of a kiln to a new highly efficient one. The second project (project #2) implemented the same energy-efficient kiln but also incorporated blended cements at the plant (at a clinker to cement ratio of 80%, versus 95% for project #1). Total carbon emissions for the two projects as well as the baseline plants were calculated (at varying levels of stringency), taking into account process emissions from the calcination process. These results are shown in Figure 4. The BERs ranged from 496 kg CO_2/metric ton of cement to 425 kg CO_2/metric ton of cement.

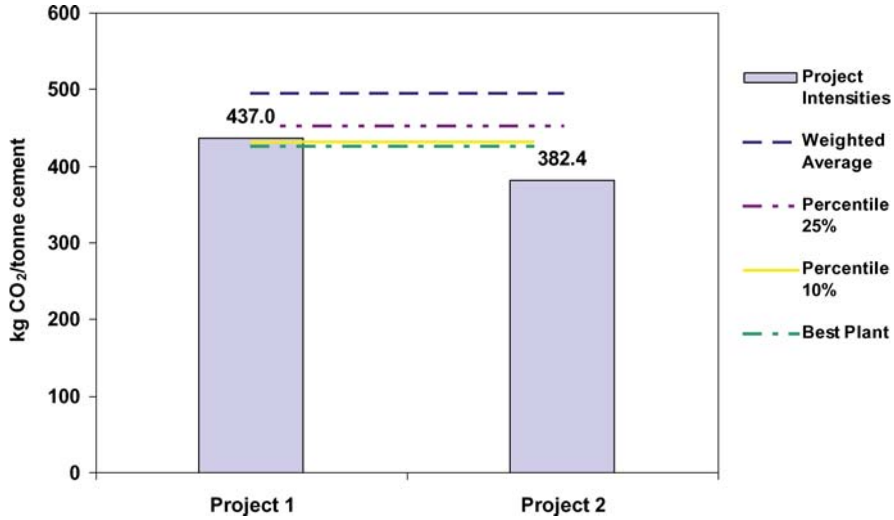

Figure 4. Carbon Intensities for two hypothetical plants compared to estimated baselines for the Central American region.

Both projects reduce emissions when compared to the least stringent baseline (a weighted average). However, because process emissions are included in the calculations for carbon emissions, project #2, which benefits from a substantial reduction due to its greater reliance on blending components, shows a reduction in carbon emissions at each stringency level, whereas project #1 only reduces emissions at the weighted-average stringency.

4.4. DISCUSSION

Due to the lack of plant data, we were unable to create a true set of BERs for the Central American region. In order to have successful data collection efforts in the future, it will be vital to involve companies from the start of a project and engage them on the development of the model. Working with the cement industry attendees at the Guatemala workshop allowed us to explain and verify the manner of calculating carbon emission reductions and energy efficiency in the model, as well as to make the tool more useful for their companies by presenting the data in a manner that was consistent with industry norms.

This case study also demonstrated that for capital-intensive industries like cement, baselines probably need to be regional for small countries where few plants exist and for which large shares of demand are likely to be imported from nearby countries.

5. Conclusions

This study has shown that using MBase, or a similar multiproject method, is a viable approach for calculating baselines for the Guatemala power sector. Using BERs may facilitate the evaluation of GHG mitigation projects in Central America, where projects under consideration have tended to be smaller renewable energy projects. In recent years, there has been sufficient electricity capacity expansion to produce meaningful results for build margins. The results of this study were found to agree, approximately, with those of two previous studies (Friedman 2000; PCF 2003a). However, the current study used a more complete data set to derive its marginal emission rates. There were not enough load-following plants constructed during the period examined to yield results for various stringencies other than the weighted average. For the baseload margin, the higher stringencies had a marked effect on lowering the BERs. The level of stringency a program administrator ultimately chooses may depend on local circumstances that are likely to affect the carbon intensity of future sources of generation.

Two different methodologies were examined for determining power sector BERs, the CDM consolidated and the Berkeley Lab approaches. In the Guatemala example, these BERs were found to be within 10 percent of each other with the exception of the CDM BERs where coal is assumed to operate in the margin, which are much higher.

For the cement industry, it was not possible to collect data for a sufficient number of plants in the Central America region to create a rigorous baseline. Access to more data would enable the creation of a more credible baseline and would provide a relatively inexpensive, transparent, and consistent alternative for evaluating GHG mitigation projects in the Central American cement industry. For the cement industry, as for other manufacturing industries, BERs need to be calculated from the bottom up by process step to the extent possible. This helps to ensure that projects do not fall below the BER simply due to the performance of some process steps elsewhere.

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Notes

1. MBase was developed with the financial support of the U.S. Environmental Protection Agency.
2. Both MBase and ProForm are available free of charge from Berkeley Lab servers (see references for Golove et al. 2004; Murtishaw et al. 2003; and Sathaye et al. 2003 at the end of this paper).
3. Planned units may also be included in the reference set of plants, but this introduces uncertainty with regard to actual plant completion, capacity utilization factors, and operating efficiencies.
4. In this paper, we account only for emissions of CO_2 and not any of the other GHG emissions that may arise in the process of generating electricity.
5. An evaluation of a number of World Bank-managed Prototype Carbon Fund projects found that the costs associated with preparing a project-specific baseline study and presenting a case for environmental additionality are about US$ 20,000 per project (PCF 2000). Uncertainty

related to calculation of emissions reductions using project-specific baselines has been estimated to range from ± 35% to ±60% for demand-side, heat supply, cogeneration, and electricity supply projects (Parkinson et al. 2001).

6. The 'best plant' stringency is only calculated for fuel-specific comparisons since, in the power sector, the best plant often will have zero emissions.
7. Additionally, neither the fuel specificity nor the stringency decisions affect estimation of the operating margin for the electricity sector, since this emission rate reflects the actual emissions displaced from existing stations.
8. It is interesting to note that the final Project Description Document (PCF 2003b) for the project baseline study cited in PCF 2003a asserts the project's additionality on the basis of coal-fired generation being the least-cost alternative for capacity expansion but uses the operating margin from the baseline study to estimate emissions reductions. Thus, the argument for additionality rests on the assumption of a build margin effect, whereas the estimated emissions reductions are based on an operating margin effect. This contradiction is not explained in the project proposal.
9. In cement production, the calcination of lime produces CO_2 as a byproduct. However, most industries do not produce process-based emissions.
10. Portland cements, e.g., generally only use pozzolans as additives, which do not need to be dried. Only blast-furnace slag generally needs to be dried prior to use in cement making.

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