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Chemical Plant GHG Emissions

Reconciling the Financing of Chemical Plants with Climate Change Objectives

Paul Suding

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Janine Ferretti Supervisor and Chief (VPS/ESG)

Implemented by:

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I. Introduction and Applicability

1.1 The Inter-American Development Bank (IDB) is developing guidelines and technical notes for particular sectors and sub-sectors planned for future investment that potentially contribute significantly to greenhouse gas (GHG) emissions. This is one of the strategic items of the Bank's Integrated Strategy for Climate Change Adaptation and Mitigation, and Sustainable and Renewable Energy (ISCC).[1]

1.2 Sector-specific guidelines for high-emissions projects are one of the instruments by which the IDB mainstreams climate change mitigation in Bank-funded operations. In IDB's terminology, guidelines provide technical or methodological advice to assist project teams in either applying specific policy mandates or other norms required for Bank operations[2]. In case of the GHG emission guidelines, which IDB has already approved for coal power plants[3], oil and gas power plants[4], land fill gas plants[5] and cement plants[6], specific binding Minimum Performance Criteria (MPC) are adopted and in force.

1.3 The chemical industry is another high GHG emission intensive sector. GHG emission intensity per U.S. dollar of investment is high in key chemical plants. The IDB is and will be involved in financing such plants, since the chemical industry constitutes an important step in the national value chain, particularly in countries with both a resource base and a significant product market.

1.4 However, it is not efficient to design specific binding Minimum Performance Criteria (MPC) for the great variety of chemical plants like those adopted for the much more homogeneous cement plants. Chemical plants, the production steps and the many diverse processes and products that determine GHG emissions are diverse and complex. Moreover, future investment in given regions and the participation of the IDB are not always certain, less so for a particular type of plants. In view of the uncertain use of an overall guideline, dedicating extensive Bank resources to develop it seems not efficient. Therefore, this technical note is prepared as a best practice paper. In case IDB's

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[1] According to paragraph C.4.4 of this ISCC (IDB, 2011a), "the Bank will promote sector-specific principles to meet climate mitigation objectives. In the case of the *industrial sector,* several options for mitigating industry-generated GHG emissions will be analyzed when selecting a project for Bank financing. These include: adequate consideration of sector-wide options for GHG emission reductions, industrial process-specific options for GHG emission reductions, and operating procedures applied at the industrial plant level."According to paragraph C.4.5, The Bank "will develop sectoral technical notes containing orientation and best practices for the development of activities in GHG-intensive industries, where the Bank anticipates substantial work. It will also screen the projects it supports for energy efficiency opportunities early in the project cycle and offer assistance for energy audits, pilots and scale-ups, and energy management training."

[2] Given their nature, Guidelines are approved by Management and sent to the Board for Information. Strategies; IDB, Policies, Sector Frameworks and Guidelines at the IDB. Revised Version, IDB 2012

[3] IDB 2009; see link in references section

[4] IDB 2012; see link in references section

[5] IDB 2010 a; see link in references section

[6] IDB 2010 b; see link in references section

engagement for specific chemical plants becomes more intense, a guideline could become indicated for these types of plants.

1.5 This technical note nevertheless presents orientation for project teams and clients on best practice how to reconcile the financing of chemical plants with climate change objectives. In lieu of MPC, it provides quantitative benchmarks by which to prioritize levels of attention. It also provides guidance on assessing and encouraging the reduction of projects' GHG emissions in accordance with the best available appropriate technologies. The present document in form of a technical note, therefore, conveys an approach to financing chemical plants in a manner consistent with the IDB's commitment to protecting the environment and reducing adverse impacts on the global climate, as established in its Environment and Safeguards Compliance Policy.[7]

1.6 This technical note addresses only new plants or new core process units within existing plants presented to the IDB for potential financing prior to initiation of operations. This technical note does not cover the rehabilitation of existing operational plants, which are addressed in the IDB Sustainable Energy Sector Guidelines.[8]

1.7 This note helps implement the IDB's climate change strategy and focus on GHG emissions. Other air emissions, liquid effluents and solid waste, hazardous materials and noise, as well as health and safety issues, are dealt with in the environmental and social impact analysis (EIA), based on the Environment and Safeguards Compliance Policy Directive B.11.

1.8 This note consists merely of recommendations; however, it will be used as guidance in the Environment and Safeguards Compliance process, since GHG emissions are to be addressed according to Directive B.11.

1.9 The remainder of the document is divided into four chapters. Section 2 gives a brief overview of types of chemical plants that may be financed in Latin America and the Caribbean (LAC). Section 3 shows typical GHG emissions associated with such plants. Section 4 presents approaches of other multilateral development banks (MDBs). Section 5 presents IDB's proposed approach to financing fossil fuel power plants. This document was developed using publicly available data and background papers developed in part by external consultants.[9] A technical review was undertaken, which included distributing technical papers, draft notes and notes from internal meetings, as well as communicating with other multilateral development institutions, specialized consulting firms and experts. Feedback and comments were taken into account and were essential to improving these notes in form and content.

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[7] Directive B.11 of IDB's Environment and Safeguards Compliance Policy states that "[t]he Bank encourages the reduction and control of greenhouse gas emissions in a manner appropriate to the nature and scale of operations."

[8] IDB, 2011b, paragraph 3.13: "The objective of many EEC [end uses energy efficiency] projects is to overcome information, regulatory, and financing barriers" and achieve "direct financing of efficient technologies in energy-intensive industries."

[9] Benchaita, 2012; IHS, 2012; IHS, 2013. See links in references section.

II. Potential Projects in the Chemical Sector[10]

2.1 The chemical industry is a vast realm of often-interrelated production chains, consisting of numerous steps, a wide array of basic, intermediate and final products. These products may be produced from various feedstock and use various kinds of energy. They may also entail different processes and technologies and emit GHGs in varying intensity and quantities. Only some of these merit specific GHG emission attention as a result of notably high intensity or quantities of GHG emissions and opportunities to mitigate them.

2.2 However, only a limited number of chemical plants come into consideration for IDB financing, namely those anticipated to be built in the region. Private clients may solicit IDB to participate in the financing of projects, new or extended chemical plants in LAC, although state-owned enterprises may also be involved.

2.3 According to market-observing consulting companies[11], more than 30 chemical plants (new or additions) may be expected in LAC in the medium-term future (i.e., they are currently under construction or will be before 2015). New plants or plant extensions will be mainly located in Brazil, Mexico, Peru and Venezuela, and to a lesser extent in Colombia and Trinidad and Tobago.

2.4 Most of the anticipated chemical plants within LAC fall into a few major value chains, defined by their base commodities: olefins, aromatics, methanol, ammonia, carbon black and chlorine. The first five value chains are part of the petrochemical industry, since the feedstock for each is a hydrocarbon.

2.5 The following graph (Figure 1) shows the principal value chains of potential new chemical plants in LAC, all of which involve high energy and emission intensity in at least one production step. Depending on the value chain, this step may be using various kinds of feedstock and energy, producing base commodities, producing intermediates or turning out semifinal or final products. The commodities and products set in bold italics indicate plants under planning or construction in LAC as of 2013.

2.6 A project proposed to be financed by IDB may consist of several production steps — for example, an ethylene plant may contain an HDPE or LDPE plant. Some production steps may also be attached to or included in a refinery, as in propylene production. Often, these production steps are integrated in petrochemicals or refinery complexes. Despite these levels of

[10] Information in this section based mostly on background study and presentations by IHS for IDB and GIZ. See links in references section.
[11] IHS, 2012; IHS, 2013.

interconnectedness and complexity, it is possible to specify the characteristics of the separate steps in most cases.

Figure 1 Chemical Value Chains

III. GHG Emission Intensity and Volumes of Chemical Plants[12]

3.1 GHG intensity and quantity is defined by the quantity and kind of energy that is used in the respective production step, as well as the efficiency of the respective use of energy.

3.2 The production of the base commodities from feedstock often involves high quantities of energy for processing. The possible processes are steam cracking, steam-supported separation, oxidation involving combustion, synthetic gas production, reforming, refrigeration, compression and an electrochemical process. For these processes, steam, heat and/or electricity are required. Generating them from fuels is the source of GHG (CO_2) emissions into the atmosphere. This is why the basic chemicals are in focus when GHG emissions are concerned.

3.3 By contrast, the use of fuels as feedstock is not GHG emission-intensive, since the carbon of the feedstock is maintained almost entirely in the product and methane is recovered and recycled as much as possible, or flared.

3.4 With regard to GHG emissions, chemical plants release mainly carbon dioxide (CO_2). Other green house gases such as fugitive methane (CH_4), sulfur hexafluoride (SF_6), hydro fluorocarbons (HFCs) or nitrous oxide (N_2O), all with higher global warming potential (GWP), may be emitted in very small quantities from petrochemical plants, including auxiliaries. This document deals only with CO_2 emissions.[13]

3.5 Table 1 summarizes quantitative information on GHG emissions as a basis for project team orientation. This list includes all chemical products that produce noteworthy GHG emissions for processes that generate these products as their principal outputs (main product only).[14] For example, it gives the specific GHG emission per ton of High Density Polyethylene in an HDPE plant, not including the GHG emissions of the ethylene production step that precedes the production of HDPE. Table 1 also shows the typical plant size of such steps and gives ranges of their typical total GHG emissions.

[12] Information in this section based mostly on background study and presentations by IHS (access for IDB and GIZ only), as well as background study by Ty Benchaita.

[13] All other GHG emissions are not reflected in GHG statistics for energy, but rather in other subsectors. Nonetheless, the document uses carbon dioxide equivalents (CO_2e) as a common unit. See the delineation of GHG emissions applied by the International Energy Agency (IEA) regarding the energy sector. These are based on conventions from IPCC and in IEA 2010.

[14] In some cases (in particular, for ethylene production from naphta), output includes various byproducts and high-value chemicals, such as propylene and butadiene, as well as aromatics.

3.6 The left columns of Table 1 present the specific GHG emissions per ton of product, based on expert information from a leading chemical consultancy.[15] The direct GHG emissions include the combined (process and fuel) GHG emission intensities per ton of product. Coefficients are given for two alternatives of fuel, namely natural gas and fuel oil. Other potential fuels, such as coal, are not likely to be used in Latin America and the Caribbean.

3.7 The indirect emission figures are typical values seen when a plant is situated in the United States and the U.S. grid emission factor therefore applies. These specific GHG emission coefficients are the basis for the benchmarking proposed in Section 5 below.

3.8 The typical plant size figures in the middle column of Table 1 are taken from statistics of recent plant projects and from background studies. The typical total GHG emissions ranges given are a result of the multiplication of specific emissions by typical plant capacities. These typical plant sizes are useful in determining whether a project proposed to be financed by the bank is likely to be a significant emitter and thus needs to be scrutinized more closely under the Environment and Safeguards Compliance Policy Directive B.11.

3.9 As a result of the analysis, chemical plants considered for the LAC region can be classified according to their typical GHG emission volume:

Very significant emitters (indicated in Table 1 by red text)
Produce GHG emissions in the high 6-digit tons, or even over 1 million tons, CO_2 equivalent per year, as a result of high intensity and high volume.
Examples: Plants producing basic chemicals Ammonia and Olefins (Ethylene, Propylene and Butadiene as byproducts)

Significant emitters (indicated in Table 1 by orange text)
Produce GHG emissions in the low 6-digit tons CO_2 equivalent per year: large plants with lower emission intensity or lower-capacity plants with high emission intensity.
Examples: Plants producing basic chemicals Methanol, Propylene[10], Butadiene[11], Aromatics[12], Carbon black and Chlorine, but also intermediates Ammonium Nitrate, HDPE, LDPE, Para-xylene, Terephthalic acid and Adipic acid.

Substantial (moderate) emitters
Produce fewer than 100,000 tons CO_2 equivalent per year

[15] It is highly recommended that project teams consult the IHS presentation and study when working on a project. See references section for links.
[10] Mostly produced as byproducts of ethylene or in refineries.
[11] Mostly produced as byproducts of ethylene or in refineries.
[12] Mostly produced as byproducts of ethylene or in refineries.

Examples: Plants producing intermediate products including Ethylene oxide, Acrylic acid, ABS resin, VCM and PVC.

Special cases

High-volume urea plants use very significant energy but capture GHGs in the process.

3.10 Furthermore, the reduction potentials of the particular production steps are an important information for the discussion with borrower. These are indicated the extreme right column of the table, on the basis of expert information. Moderate and small reductions potentials are to be considered if the specific GHG emission values in the left part of the table are attained. In cases when projects indicate higher GHG emission values, a higher reduction potential may be assumed.

3.11 The negative values in some cases (methanol and carbon black) indicate that the process is at this stage exothermic, i.e. releases energy from the feedstock. In the case of methanol, the energy released from the feedstock in the production process is recovered for providing steam or heat later in the process, reducing the fuel input to zero energy in an integrated plant. In case of carbon black, GHG and energy are released from the feedstock in the production process. Surplus energy can be provided to other processes in an integrated chemical plant.

Table 1 GHG Emission Intensity and Plant GHG Emissions for Selective Production Steps in the Chemical Industry

	Typical GHG emission intensity (CO_2e/t of product) Location USA			Typical plant size	GHG emission of plant (Tt CO_2e /a)			Reduction potential
Products	**Direct if natural gas (ng)**	**Direct if fuel oil (fo)**	**Indirect (grid electricity)**	**Capacity (Tt/a product)**	**Typical direct**	**Typical indirect**	**Total typical**	
Ammonia	1.592	1.670	0.077	> 500	>800 ng > 850 fo	>~40	>850 >900	moderate
Ammonium Nitrate	0.26	0.35	0.25	>200	~50/~70		~100/1 20	small
Urea	-0.54	-0.466	0.013	>750	minus 300 to 400	~10	(Capture)	small
Ethylene (from ethane)	0.887	1.213	0.017	>1000	>900 ng >1200 fo	>~10	>900 ng >1200 fo	moderate
Ethylene (from naphtha)*	1.304	1.789	0.033	>500 (>800 total HVC)	> 650 ng > 800 fo	>~20	> 650 ng > 800 fo	moderate
Propylene† (in refinery)	No data; TBD							
Butadiene‡ (from ethanol)	No data; TBD							
Ethylene oxide	0.370	0.359	0.296	>50			>30	moderate
Styrene	0.375	0.517	0.062	>250	~80 ~130	~20	100 150	small
HDPE (gas phase reactor)	0.048	0.048	0.233	>750	~35	~160	~200	small
LDPE Tubular reactor	0.101	0.128	0.443	>300	~35	~135	~170	small
Acrylic acid	0.395	0.426	0.189	>50			~30	moderate
ABS resin	0.044	0.002	0.182	>50			10	small
PTA Terephthalic acid via Para-xylene from Xylene	0.949 1.118	1.201 1.374	0.231 0.047	>150			>200 >180	small
Methanol	0.282	0.282	0	> 700	>~200	0	>200	moderate

* Ethylene production from naphtha yields several high value byproducts (HVCs), including propylene, aromatics and hydrogen. The specific GHG emission intensity is calculated per t ethylene. When all HVCs are included, the GHG emission intensity of the naphtha-based ethylene drops to similar levels or even below the intensity of the ethane-based plants.

† Apart from the abovementioned propylene yield from ethylene production via "steam cracking," the main manufacturing process of propylene is with gasoline production via "fluid catalytic cracking" (FCC) in refineries.

‡ Butadiene can be produced as a byproduct of the steam cracking process used to produce ethylene and other olefins. In smaller plants, it is also produced directly from ethanol.

Carbon black (using oxygen)	1.808	1.758	0.25	> 100	>~ 180	25	>200	small
Chlorine	0.652	0.895	1.7	> 50	>35 ng > 45 fo	85	>110	small

Table 1 Continued

	Typical GHG emission intensity (CO_2e/t of product) Location USA			Typical plant size	GHG emission of plant (Tt CO_2e /a)			Reduction potential
Products	**Direct if natural gas**	**Direct if oil fuel**	**Indirect (grid electricity)**	**Capacity (Tt/a product)**	**Typical direct**	**Typical indirect**	**Total typical**	
VCM Vinyl Cloride Monomer	0.292	0.378	0.04	>50			~10	small
PVC (Suspension polymertaisation)	0.129	0.172	0.246	>50			~30	small
Adipic acid	2.993	3.964	0.086	>50			>150/200	moderate

Source: IHS consulting, author calculations

IV. Approaches of Other Development-Focused Multilateral Financing Institutions (MFIs)

4.1 Among Multilateral Financing Institutions (MFIs), the International Finance Corporation (IFC) has the largest chemical industry sector portfolio, and is responsible for most of the chemical sector financing within the World Bank Group. Chemical industry investment is done principally by the private sector. Most other MFIs also provide financing for the chemical industry, sometimes jointly with IFC.

4.2 Like IDB, most MFIs include chemical sector projects in their respective GHG accounting and reporting. They base their calculations on the absolute significance of the GHG emissions of the various plants. Thresholds for accounting can be as low as 20,000 or 25,000 tons of CO_2e per year.

4.3 None of the MFIs, however, has yet adopted minimum criteria or quantified Emission Performance Standards (EPS) for chemical plants. These would be decision-relevant, in the sense that plants not compliant with the criteria would not be financed. However, the MFIs are increasingly exhorting their clients to address concerns over resources and energy efficiency, including GHG emissions reductions, apart from the other air emissions for which quantitative standards are defined.

4.4 An explicit wording of such a request for efficiency is provided by IFC in IFC Performance Standard 3[13]: “the client will consider alternatives and implement technically and financially feasible and cost-effective options to reduce project-related GHG emissions during the design and operation of the project.” EBRD, EIB, ADB, AfDB will ask for similar efforts, in particular where they co-finance projects with IFC.

V. Addressing Chemical Plants’ GHG Emissions in IDB Project Cycle

5.1 IDB will support the development of chemical plants that adhere to the principles of sustainable development and reduced impact on climate change. Both principles are essential for an industry that already emits high levels of CO_2 and has a growing market outlook.

5.2 In order to promote industrial development in the region without undermining support for climate change mitigation efforts or a commitment to environmental protection, in the case significant emitters, IDB will put a particular focus on GHG emissions during project preparation and the due diligence process. IDB will also

[13] International Financed Corporation, Performance Standards on Environmental and Social Sustainability (IFC 2012)

ask the borrower to maintain energy efficiency and GHG emissions according to benchmarks, as well as explore options to further reduce expected GHG emissions and implement them if they are cost-effective. Annex 1 to this technical note provides benchmarks (which leave sufficient scope for applying prevalent and advanced technologies) for plants engaging in certain high-emissions processes.

5.3 To put this into practice, the IDB project team asks the respective borrower to present assessments of both the expected annual GHG emissions and the expected GHG emission per ton of product generated (i.e., GHG emission intensity) in a specific plant that produces basic chemicals and intermediates. This assessment must not use typical data for such type of plants but be tailored to the specific design data of the plant to be financed by IDB and updated as planning becomes more detailed. Ideally, the assessment should be available during project preparation, so it can be reviewed as part of the due diligence process. Annex 2 presents a tutorial on how to determine a project's GHG emission characteristics and calculate the key coefficients for comparison with benchmarks.

5.4 The assessment of annual GHG emissions will lead to impact classification according to OP 703, B.3. If the expected annual GHG emissions of a proposed plant or the composite of plants

a) exceed 100,000 tCO_2e/year, this requires marking "Significant Greenhouse Gas Emissions are predicted" in the Safeguard Classification Filter under "Air Pollution." Such action will suggest a project be classified as Category A; or

b) exceed 25,000 tCO_2e/year but remain below 100,000 tCO_2e/year, this requires marking "Substantial Greenhouse Gas Emissions are predicted " in the Safeguard Classification Filter under "Air Pollution. "Such action will suggest a project be classified a Category B project.

5.5 The assessment of GHG emissions per ton of product will allow the project team to compare the plant's characteristics to current IDB benchmarks. It will also stimulate and inform a discussion about possibilities to avoid unnecessary GHG emissions. This is particularly important in the case of high and significant emitters among the chemical production steps, for which benchmarks are given in Annex I.

5.6 Varying benchmarks are given for the cases of natural gas or fuel oil as feedstock, in order to accommodate specific local situations. In the unlikely case that a borrower in the region proposes a chemical plant on coal as a feedstock, the fuel oil numbers could serve as a benchmark.

5.7 The main focus is on direct GHG emissions. This is because of their higher GHG emission intensity (except in the case of chlorine) and because indirect emission intensity depends on the grid emission factor, which is external to the project.

5.8 IDB will work with borrowers to improve GHG emission performance for high and significant emitters, though it will also be sure not to omit lower emitters from consideration.[15] Most of the chemical industry process technology represented in Table 1 is mature. Thus, reduction potential for specific energy input and feedstock input is limited when the benchmark intensity levels (Table 2) are attained.[15] If, however, the GHG emission intensity of a specific plant is significantly higher than the benchmarks, IDB will have to closely scrutinize the planning of the proposed plant for reduction options as part of its engineering review.

5.9 In the spirit of sustainable development, and to reduce the demands for new plants, IDB will urge borrowers to commit to participation in national programs of material efficiency or set up company specific plastics recycling programs, among other initiatives.

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[14] IPCC provides default values for specific GHG emissions intensities, including for chemical plants (see IPCC 2006). These are not relevant for this comparison to benchmarks, since they are typical default values and may not correspond to plants' specificities.

[15] Detailed analysis by the International Energy Agency has shown that there are still reduction potentials when comparing Best Practice Technology (BPT) with current practices in existing plants. These potentials are reduced when a new plant is engineered by leading global engineering firms on the basis of leading patented technologies. Nonetheless, small improvements are possible within the processes (direct emissions), as well as in the generation of heat and power, which can be combined to reduce indirect emissions. Also, chemical industry GHG emissions may be mitigated by using biological feedstock and energy input instead of using fuel as feedstock (see Saygin, 2009).

Annex 1 Typical (Benchmark) GHG Emission Intensity of High and Substantial Emitters (CO_2e/t of Principal Product) as of 2013

	Direct if natural gas fuel	**Direct if oil fuel**
	Typical/ Benchmark	Typical/ Benchmark
Ammonia	**1.592**	**1.670**
Ethylene (from ethane)	**0.887**	**1.213**
Ethylene (from naphtha)	**1.304**	**1.789**
Methanol	**0.282**	**0.282**
Carbon black (using oxygen)	**1.808**	**1.758**
Chlorine	**0.652**	**0.895**
Ammonium Nitrate	0.26	0.35
HDPE	0.048	0.048
LDPE	0.101	0.128
Terephthalic Acid/ via Para-xylene from Xylene	***0.949/ 1.118***	***1.201/ 1.374***
Adipic acid	2.993	3.964

Source: Author calculations

Annex 2 Tutorial: How to Determine a Project's GHG Emission Characteristics and Calculate the Key Coefficients for Comparison with Benchmarks.

The IDB project team will request from the borrower the coefficients of (direct and indirect) specific GHG emissions per ton of product, as seen in the production steps to be financed. For the purpose of this technical note, it is not sufficient to base calculations on default numbers like those provided by IPCC. It is instead appropriate to use the design data for the plant project to be financed.

If these coefficients are not readily available, the borrower should provide the data for overall GHG emissions of the plant, as well as for each production step if it is a multiple step plant (see steps in chemical value chains in Figure 1). The borrower should also provide information on feedstock input, fuel input and electricity input, indicating the nature of feedstock and fuel. Then the project team may perform the following procedure:

1. Identify the production steps in the project. If it is a multiple-step project, separate the steps.
2. Identify and quantify feedstock, fuel and electricity consumption (gigacalories, tons of oil equivalents, MBTU, gigawatt hours, terajoules; see conversion factors at http://www.iea.org/interenerstat_v2/energy_unit.asp) of the particular production step, or for each step separately if it is a multiple-step plant project.
3. Determine the direct and indirect GHG emissions released by the plant in the process from the consumption or loss of energy inputs (for conversion factors, see, for example, http://www.carbontrust.com/media/18223/ctl153_conversion_factors.pdf). In particular, these include:
    a. emissions from the loss of feedstock (not incorporated into the project), multiplied by the respective carbon factor;
    b. emissions from fuel consumption, multiplied by the respective carbon factor (direct emissions); and
    c. emissions from the electricity consumed in and delivered to the process, and the GHG emission factor applicable to that electricity (may be auto-produced or acquired from the power grid; for the latter, the grid emission factor must be applied).

4. Identify the output quantity of the principal product (weight in tons) of the production step, or the quantities for each step separately if it is a multiple-step plant project. For multiple products, identify the principal product and determine the output quantity.
5. Divide the various GHG emission quantities (direct, indirect, total) by the output quantity (Gt) of the principal product.
6. Compare the result to the respective benchmark value in Annex I. Discuss the comparison with the borrower, with the participation of engineering and environmental experts. Deviation between benchmarks and specifically calculated coefficients for a particular plant may indicate reduction potential worth pursuing.

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