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Development Bank

VPS/ESG

TECHNICAL NOTE

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Greenhouse Gas Assessment Emissions Methodology

Milena Breisinger

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This Technical Note was prepared under the direction of the Environmental and Social Safeguards Unit (VPS/ESG) of the Inter-American Development Bank (IDB). This document provides the methodology prepared and used by IDB to assess the impact of its direct investments loans on greenhouse gas (GHG) emissions since 2009.

This document was prepared under the supervision of Janine Ferretti, Chief of the Environmental and Social Safeguards Unit (VPS/ESG) by Milena Breisinger. GHG emission calculation tools presented within were developed by SAIC® under the guidance of Emmanuel Boulet and Milena Breisinger (VPS/ESG). Insightful contributions were provided by Amarilis Netwall (VPS/ESG). IDB appreciates the support from Deutsche Gesellschaft fuer Internationale Zusammenarbeit (GIZ) GmbH with funds from Bundesministerium fuer Wirtschaftliche Zusammenarbeit und Entwicklung (BMZ).

August 2012

Contents

Acronyms

ADB	Asian Development Bank
CDM	Clean Development Mechanism
CO_2	Carbon Dioxide
DOC	Degradable Organic Carbon
DOE	Department of Energy
EE	Energy Efficiency
EF	Emission Factor
EPA	Environmental Protection Agency
FGD	Flue Gas Desulfurization
GHG	Greenhouse Gases
GJ	Gigajoules
GWP	Global Warming Potential
ha	Hectares
HHV	High Heating Value
IDB	Inter-American Development Bank
IEA	International Energy Agency
IFI	International Finance Institutions
IPCC	Intergovernmental Panel on Climate Change
km	Kilometer
kWh	Kilowatt Hour
LHV	Low Heating Value
LTO	Landing and Takeoff
MWh	Megawatt Hour
RE	Renewable Energy
ROW	Right-of-Way

sqf	Square feet
sqm	Square meter
t	Tons
T&D	Transmission and Distribution
UNFCCC	United Nations Framework Convention on Climate Change
VKT	Vehicle Kilometers Travelled
WBCSD	World Business Council for Sustainable Development
WRI	World Resources Institute
WWTP	Wastewater Treatment Plant

1. INTRODUCTION

IDB has assessed the impact on greenhouse gas (GHG) emissions of its direct investments (investment loans) since 2009. Summaries of these impacts were published for the first time in the Bank's *Sustainability Report 2011*.

All direct investment projects with emissions, or emissions savings, exceeding 25 kilotons CO_2-equivalents (CO_2e) per annum have been assessed, with a focus on projects in the seven sectors—energy, industry, agriculture, water and sanitation, transport, urban development, and tourism—that dominate the portfolio GHG emissions footprint. Other sectors are considered to have low or no GHG emissions impact. To avoid double counting, supplementary loans are not included. In the cases of financial intermediaries, policy-based loans, financial emergencies, and the trade finance facilitation program, adequate methodologies have not yet been developed.

Since 2006, Directive B.11 of the Bank's Environment and Safeguards Compliance Policy (OP-703) mandates calculation and reporting of GHG emissions for operations that are expected to produce significant amounts of them.

2. CARBON FOOTPRINT

The carbon footprint is expressed in CO_2e and consists of the GHGs and their global warming potential (GWP), as shown in Table 1. GHG emissions are determined by multiplying GHG activity data (e.g., gigajoules (GJ) electricity consumption for a furnace) with emission factors (EF) (e.g., CO_2–emissions per GJ/natural gas). The unit of measurement is metric tons, and all GHG emissions are converted to tons of CO_2e, using the 100-year GWP factors as published in the *Fourth Assessment Report* of the Intergovernmental Panel on Climate Change (IPCC) in 2007. This allows for the aggregation of all GHG emissions in one single indicator, expressed as the carbon footprint.

TABLE 1: GREENHOUSE GASES AND GLOBAL WARMING POTENTIALS

Emission	Chemical formula	GWP (over 100 years)	Sources
Carbon dioxide	CO_2	1	Combustion processes
Methane	CH_4	25	Landfills, coal mining, wastewater treatment, biomass combustion
Nitrous oxide	N_2O	298	Agricultural soils and nitric acid production
Hydrofluorocarbons	—	124-14800	Substitutes for ozone-depleting substance, semiconductor manufacturing
Sulfur hexafluoride	SF_6	22800	Electrical transmission and distribution
Perfluorocarbons	—	7390-12200	Substitutes for ozone-depleting substance, semiconductor manufacturing

3. REPORTING GROSS AND NET FIGURES

IDB reports separate numbers for a positive (+) gross and a negative (–) net.

> *Positive (+) gross GHG emissions are significant scope 1 (direct) and scope 2 (associated with the offsite generation of electricity, heat, and steam used by the project and, if calculable, scope 3 (indirect emissions)) CO_2e emissions in the geographic boundaries[1] of the financed project that are generated during the first year of full operation/production and may include construction emissions averaged over the project lifetime (WRI/ international financial institutions (IFIs) common elements).*
>
> *Negative (–) net GHG reductions of the financed project are quantified relative to a baseline.*

Direct emissions from within the project boundary together with the estimated emissions associated with the generation of grid electricity used by the project are included in the

[1] The project boundary may need to include associated facilities where these exist solely to serve the project. European Investment Bank reports the emissions for the whole project whether it is rehabilitation or capacity increase, resulting sometimes in wider boundaries than the project itself.

assessment. Other upstream emissions associated with the provision of materials used by the project or downstream emissions from the use of the goods and services generated by the project are not included.[2]

Presenting gross positive emissions and net savings numbers alongside each other allows for a holistic view of the carbon footprint of the activity of an institution. The institution is able to draw attention not only to increases in avoided emissions but also to improvements made on projects with significant emissions. It is important to highlight positive (+) gross GHG emissions figures in order to be transparent and credible and to create an awareness of high-emission projects.

4. METHODOLOGY

The methodology used to analyze these investments is based on established international GHG accounting standards developed by the IPCC, the World Resources Institute (WRI), and the World Business Council for Sustainable Development (WBCSD).

The tools provide a way to consistently monitor projects approved by the Bank. Sixteen sectoral GHG accounting tools allow the calculation of emissions with varying levels of required data and at various project stages. The "initial review" enables quick estimates of construction and operations emissions during project preparation. This simplified approach is designed to estimate the bulk of emissions from a project using data generally available at the early stages of project development. Data-intensive methods provide more detailed methodologies for estimating construction and operational emissions once the project has been implemented and detailed data are available. For renewable energy, bioenergy, and energy efficiency projects, the tools calculate the emissions that have been avoided. The project GHG emissions are taken as the annual emissions occurring once the project has been fully implemented. Construction emissions are included by averaging them over the lifetime of the project. A detailed table with all the methodologies used appears at the end of this document.

[2] Using the definitions adopted by the GHG Protocol of the WBCSD/WRI, direct emissions are termed Scope 1, emissions from grid electricity used are Scope 2, and other upstream and downstream emissions are Scope 3.

5. BASELINE FOR RENEWABLE ENERGY PROJECTS

Renewable energy (RE) and energy efficiency (EE) are becoming increasingly important in Latin America to help meet the growing demand for energy brought on by rapid economic growth. IDB has estimated that the region could reduce energy consumption by 10 percent over the next 10 years by increasing efficiency using existing technologies.[3]

For renewable energy and energy efficiency projects, IDB uses a static baseline. Static baseline emission rates such as factor for the country energy mix (national grid factor) do not change over time, while dynamic baseline emission rates modify over time to reflect relevant changes such as in the country grid, economy, etc. Due to many uncertainties about the design phase of a project as well as about the future in general, IDB chose to go with the static approach to ensure consistency in the calculations as well as transparency and traceability.

Calculations for RE projects for the IDB are usually done for new plants called Greenfield, such as new plants in the wind, solar, small hydro, or geothermal sector. The renewable energy calculation modules estimate reduced emissions by comparing the generated energy with the national grid default factor as static baseline. The national grid default factors are based on the newest International Energy Agency (IEA) data sheets. This methodology is in line with the approaches taken by the other IFIs.

Projects seeking to benefit from the Kyoto Protocol flexibility mechanisms (e.g., the Clean Development Mechanism (CDM)) project and baseline emission assessments have to run a separate, more-detailed calculation based on methodologies approved under the United Nations Framework Convention on Climate Change (UNFCCC).

6. BASELINE FOR ENERGY EFFICIENCY PROJECTS

Compared with the Greenfield approach for RE projects, only EE is applicable for already existing plants /projects, called Brownfield.

[3] Inter-American Development Bank, Energy Efficiency. IDB Website. http://www.iadb.org/en/topics/energy/energy-efficiency,2654.html

IDB added modules to an initial set of GHG tools that calculate the avoided emissions associated with energy efficiency improvements to help quantify avoided emissions of investment projects. EE modules had been added to the cement production, power plant, steel production, wastewater, solid waste, urban development, and tourism tools. The EE calculation approach varies slightly by sector to accommodate each tool's individual methodologies and data requirements. Generally, the EE calculation modules estimate avoided emissions by comparing the pre-upgrade project configuration with the current, or post-upgrade, configuration. The calculations have two main steps. First, emission intensity is calculated for the project before and after the upgrade. The emission intensity indicates the emissions per unit of output, where output is defined as the physical output of the project, such as tons of steel or cement produced, or another indicator, such as the amount of organic waste treated by a wastewater treatment plant. The emission intensity is calculated by dividing the total emissions by the total output of a project, as illustrated in the following equation:

Emission Intensity = (Total Emissions)/(Total Output)

Next, the avoided emissions are calculated. Avoided emissions are emissions that would have occurred without the energy efficiency upgrades but that were avoided as a result of the upgrades. They are calculated by multiplying the change in emission intensity by the current output, as illustrated in the following equation:

Avoided Emissions = (Intensity Before Upgrade – Intensity After Upgrade) x Output After Upgrade

The change in emission intensity and current output are used to calculate avoided emissions in order to show the benefit of the energy efficiency upgrades, regardless of whether overall emissions from a project increase as a result of an increase in total output. For example, EE upgrades at a cement plant lead to increased output and the overall emissions from the plant increase. Since the cement is now produced with fewer emissions per unit (emission intensity), the emissions that would have occurred from producing the same amount of cement at the higher emission intensity constitute the baseline.

7. CONTENTS OF THIS GUIDANCE

This document contains guidance for IDB-appointed consultants or in-house practitioners on applying the IDB GHG Assessment Methodology.

The methodology outlined seeks to ensure that greenhouse gas emission assessments are carried out in a systematic manner, using data whose sources are documented and recording all assumptions and methods of calculation. However, no generalized methodology can hope to meet the needs of every project; inevitably, users will find occasion where they need to use their own professional judgment. In such instances, any assumptions made and any departures taken from the recommended methods should be recorded. As a general guide, procedures and assumptions that are accepted in the preparation of projects for CDM support will be acceptable for the assessment of IDB projects.

This methodology is intended for use on all projects for the purposes of estimating the impact of project implementation on overall GHG emissions and identifying opportunities for GHG reduction during project appraisal. For projects seeking CDM accreditation under the Kyoto Protocol mechanisms, an analysis will be required following protocols approved by the UNFCCC for such projects. These requirements are not covered by this guidance.

Recurrent methodologies such as energy consumption during construction or operation are presented only once.

8. GHG EMISSIONS FROM CONSTRUCTION

Construction Emissions	Description / Input Data Requirements	Calculation Method	Methodology Source
Land Use Change Right-of-Way (ROW) Area	This method provides a simplified default approach for estimating emissions based on the area of land cleared and IPCC default values for the amount of above and below ground carbon stocks in various types of vegetation. Note: The Land Use Change section includes a methodology to estimate the area of the ROW cleared for the transmission line. This methodology estimates the area of ROW required for a transmission line using the length and nominal voltage of the line. Since ROW clearing does not affect below ground carbon stocks, these will not be included in land areas for ROWs. Land Cover Type (Above biomass carbon (tC/ha) / Below biomass carbon (tC/ha)): 1. Natural Forest - Tropical rainforest (141.0/52.2) 2. Natural Forest - Tropical moist deciduous (84.6/18.6) 3. Natural Forest - Tropical dry (61.1/25.7) 4. Natural Forest - Tropical scrubland (32.9/13.2) 5. Natural Forest - Tropical mountain systems (65.8/17.8) 6. Natural Forest - Subtropical humid (103.4/22.7) 7. Natural Forest - Subtropical dry (61.1/25.7) 8. Natural Forest - Subtropical steppe (32.9/10.5) 9. Natural Forest - Subtropical mountain systems (65.8/0.0) 10. Natural Forest - Temperate oceanic (84.6/18.6) 11. Natural Forest - Temperate continental (56.4/14.7) 12. Natural Forest - Temperate mountain systems (47.0/12.2) 13. Natural Forest - Boreal coniferous (23.5/9.2) 14. Natural Forest - Boreal tundra woodland (7.1/2.7) 15. Natural Forest - Boreal mountain systems (14.1/5.5) 16. Plantation Forest - Tropical rain forest (70.5/26.1) 17. Plantation Forest - Tropical moist deciduous forest (56.4/12.4) 18. Plantation Forest - Tropical dry forest (28.2/11.8) 19. Plantation Forest - Tropical scrubland (14.1/5.6) 20. Plantation Forest - Tropical mountain systems (42.3/11.4) 21. Plantation Forest - Subtropical humid forest (65.8/14.5) 22. Plantation Forest - Subtropical dry forest (28.2/11.8) 23. Plantation Forest - Subtropical steppe (14.1/ 4.5) 24. Plantation Forest - Subtropical mountain systems (42.3/0.0) 25. Plantation Forest - Temperate oceanic forest (75.2/16.5) 26. Plantation Forest - Temperate continental forest (47.0/12.2) 27. Plantation Forest - Temperate mountain systems (47.0/12.2)	CO_2 (t) = $\sum_i [Area\ of\ land\ cover\ type\ cleared\ (ha)$ $\times\ (EF\ Above\ Ground\ Biomass\ Carbon\ \ (tC/ha_i)$ $+\ EF\ Above\ Ground\ Biomass\ Carbon\ \ (tC/ha_i))]\ x\ {}^{44}/_{12}$ In case of transmission lines or other activity that do not disturb the below ground carbon stock. CO_2 (t) = $\sum_i Area\ of\ land\ cover\ type\ cleared\ (ha)$ $\times$ EF Above Ground Biomass Carbon $(\mathrm{tC/ha}_i) \times {}^{44}/_{12}$	2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 4, Table 4.12 (Natural Forest and Plantation Forest), Table 5.1 (Cropland), and Table 6.4 (Grassland). Degraded and managed pastureland factor from Brazilian Sugarcane Industry Association, Second Letter to California Air Resources Board, 04/17/2009 USDA, Rural Utilities Service, RUS BULLETIN 1724E-203, pg 6. http://www.rurdev.usda.gov/SupportDocuments/UEP_Bulletin_1724E-203.pdf 44/12 to convert from C to CO_2

<table>
<tr><th>Construction Emissions</th><th>Description / Input Data Requirements</th><th>Calculation Method</th><th>Methodology Source</th></tr>
<tr><td></td><td>28. Plantation Forest - Boreal coniferous forest (18.8/7.3)
29. Plantation Forest - Boreal tundra woodland (7.1/2.7)
30. Plantation Forest - Boreal mountain systems (14.1/5.5)
31. Cropland - Temperate (all regions), woody biomass (63/0)
32. Cropland - Tropical dry, perennial woody biomass (9/0)
33. Cropland - Tropical moist, perennial woody biomass (21/0)
34. Cropland - Tropical wet, perennial woody biomass (50/0)
35. Cropland - Annual crops (all) (4.7/0)
36. Grassland - Boreal (dry & wet) (0.68/1.6)
37. Grassland - Cold Temperate (dry) (0.68/1.1)
38. Grassland - Cold Temperate (wet) (0.96/1.9)
39. Grassland - Warm Temperate (dry) (0.64/1.1)
40. Grassland - Warm Temperate (wet) (1.08/1.6)
41. Grassland - Tropical (dry) (0.92/1.1)
42. Grassland - Tropical (moist & wet) (2.48/0.6)
43. Settlement – Construction (0/0)
44. Managed Pasture (6.5/0)
45. Degraded Pastureland (1.3/0)
Area Cleared (Hectares)</td><td></td><td></td></tr>
<tr><td>Building Construction</td><td>Provides an integrated approach for estimating emissions from building construction activities based on the total area of the buildings or the type and number of buildings being constructed. This method accounts for the embodied GHG emissions that are created through the extraction, processing, transportation, construction, and disposal of building materials as well as emissions created through landscape disturbance (by both soil disturbance and changes in above ground biomass).

<table>
<tr><th>Surface area of building components</th><th>Average EF (lbs CO_2e/sq ft)</th></tr>
<tr><td>Columns and Beams</td><td>5.298593639</td></tr>
<tr><td>Intermediate Floors</td><td>7.758435526</td></tr>
<tr><td>Exterior Walls</td><td>19.1154907</td></tr>
<tr><td>Windows</td><td>51.15692823</td></tr>
<tr><td>Interior Walls</td><td>5.689792474</td></tr>
<tr><td>Roofs</td><td>21.29063814</td></tr>
</table>

<table>
<tr><th>Building Type</th><th>Average EF CO_2 per Sq Ft</th></tr>
<tr><td>Residential Housing</td><td>2,272.0</td></tr>
<tr><td>Education</td><td>25,580.3</td></tr>
<tr><td>Food Sales</td><td>5,553.1</td></tr>
</table></td><td>CO_2 (t) =

$\sum_i Surface\ area\ of\ buidings\ component_i \times Surface\ area\ EF_i$

CO_2 (t) =

$\sum_i Building\ type_i \times EF_i$</td><td>King County Department of Development and Environmental Services in Washington State.
- Average Materials Used per Square Foot Building Space - Buildings Energy Data Book: 7.3 Typical/Average Household Materials Used in the Construction of a 2,272-Square-Foot Single-Family Home, 2000. http://buildingsdatabook.eren.doe.gov/?id=view_book_table&TableID=2036&t=xls . See also: NAHB, 2004 Housing Facts, Figures and Trends, Feb. 2004, p. 7 .
- CO_2 e Emission Factors - Athena EcoCalculator, Athena Assembly Evaluation Tool v2.3- Vancouver Low Rise Building Assembly, Average Emissions (kg) per square meter. http://www.athenasmi.ca/tools/ecoCalculator/index.html
- Residential Floor Space per Unit - 2001 Residential Energy Consumption Survey (National Average, 2001), Square footage measurements and comparisons. http://www.eia.doe.gov/emeu/recs/sqft-measure.html
- Commercial Floor Space per Unit - EIA, 2003 Commercial Buildings Energy Consumption Survey</td></tr>
</table>

<table>
<tr><th>Construction Emissions</th><th>Description / Input Data Requirements</th><th>Calculation Method</th><th>Methodology Source</th></tr>
<tr><td></td><td>

Food Service	5,569.0
Health Care	24,519.4
Lodging	35,887.3
Mercantile	17,035.0
Retail (Other Than Mall)	9,744.9
Enclosed and Strip Malls	32,277.0
Office	14,815.5
Public Assembly	14,220.2
Public Order and Safety	15,352.1
Religious Worship	10,145.9
Service	6,511.3
Warehouse and Storage	16,881.1
Other	22,000.0

Special Case for renewable energy projects To calculate emissions related to the construction of the renewable energy project, select the renewable energy project type and enter the average amount of electricity generated by this project on an annual basis.

Default Emission Factors for Construction of Renewable Energy Projects (g- CO_2/kWh)	
Solar	41.1
Wind	21.2
Hydroelectric	9.3
Geothermal	5.3

</td><td>

CO_2 (t) =

$Annual\ amount\ of\ electricity\ generated\ (kWh/yr) \times EF_i\ RE\ construction\ \div 1000000$

</td><td>

(National Average, 2003). Table C3. Consumption and Gross Energy Intensity for Sum of Major Fuels for Non-Mall Buildings, 2003. http://www.eia.doe.gov/emeu/cbecs/cbecs2003/detailed_tables_2003/2003set9/2003excel/c3.xls

Average Window Size - Energy Information Administration/Housing Characteristics 1993. Appendix B, Quality of the Data. Pg. 5. ftp://ftp.eia.doe.gov/pub/consumption/residential/rx93hcf.pdf

For renewable energy projects, life cycle GHG emission analysis of power generation systems: Japanese case, Hiroki Hondo 2005

http://campus.udayton.edu/~physics/rjb/PHY399Winter2007/Hondo%20-%20GHG%20LCA%20for%20power%20generation.pdf

</td></tr>
<tr><td>Road Pavement</td><td>

New Road: The Road Pavement methodology provides an integrated method for estimating emissions from the construction of roadways. Four recent life cycle assessments of the environmental impacts of roads form the basis for the per unit embodied emissions of pavement. Each study is constructed in slightly different ways; however, the aggregate results of the reports represent a reasonable estimate of the GHG emissions that are created from the manufacture of paving materials, construction-related emissions, and maintenance of the pavement over its expected life cycle.

EF per square meter (sqm) = 182.99

Road Rehabilitation: This method is adopted from the King County (Washington State) Department of Development and Environmental Services: SEPA GHG Emissions Worksheet, Version 1.7 12/26/07. This method calculates the emissions from downstream maintenance and repair of the highway. For the King County project, 33 $MTCO_2e$/1000 square feet of pavement was used to compute emissions from road maintenance activities over the 40-year life of the road. This method

</td><td>

CO_2 (t) =

Road constructed (sqm) **x** EF (182.99 per sqm)

OR

Road rehabilitated (sqm) **x** EF (8.88 for sqm)

</td><td>

King County Department of Development and Environmental Services in Washington State. The methodology is based on four studies:

Meil, J. A Life Cycle Perspective on Concrete and Asphalt Roadways: Embodied Primary Energy and Global Warming Potential. 2006.

Park, K, Hwang, Y., Seo, S., M.ASCE, and Seo, H. , “Quantitative Assessment of Environmental Impacts on Life Cycle of Highways,” Journal of Construction Engineering and Management , Vol 129, January/February 2003, pp 25-31, (DOI: 10.1061/(ASCE)0733-9364(2003)129:1(25)).

Stripple, H. Life Cycle Assessment of Road. A Pilot Study for Inventory Analysis. Second Revised Edition. IVL Swedish Environmental Research Institute Ltd. 2001.

Treloar, G., Love, P.E.D., and Crawford, R.H. Hybrid Life-Cycle Inventory for Road Construction

</td></tr>
</table>

<table>
<tr><th>Construction Emissions</th><th>Description / Input Data Requirements</th><th>Calculation Method</th><th>Methodology Source</th></tr>
<tr><td></td><td>utilizes an equivalent annual emissions factor of 0.825MTCO_2e/1000 square feet/year. The square feet numbers were converted into square meters.
EF per square meter (sqm) = 8.88</td><td></td><td>and Use. Journal of Construction Engineering and Management. P. 43-49. January/February 2004.</td></tr>
<tr><td>Purchased Energy Consumption

(Electricity Use and Fuel Consumption)</td><td>Estimates emissions of CO_2, CH_4, and N_2O from electricity and fuel use purchased for use in project construction or activities based on default emission factors. Custom emission factors can be used if available. Specific heating values for fuels may also be used to provide a more accurate estimate. The emission factors for electricity are country-dependent.
<table>
<tr><th>Fossil Fuel Type</th><th>Units</th><th>CO_2 EF KgCO_2/MMBtu</th><th>CH_4 EF gCH_4/MMBtu</th><th>N_2O EF gN_2O/MMBtu</th></tr>
<tr><td>Natural Gas</td><td>MMBtu</td><td>53.28</td><td>0.01236</td><td>0.0093441</td></tr>
<tr><td>Diesel</td><td>MMBtu</td><td>74.25</td><td>1.00</td><td>0.10</td></tr>
<tr><td>Heavy Fuel Oil</td><td>MMBtu</td><td>77.56</td><td>3.00</td><td>0.60</td></tr>
<tr><td>LPG/Pro-pane</td><td>MMBtu</td><td>59.89</td><td>3.00</td><td>0.60</td></tr>
</table></td><td>CO_2 (t) =
Annual amount of electricity used (MWh/year) **x** EF *country or regional electricity grid* (based on latest IEA statistics)
OR
$\sum_i[(fossil\ fuel\ type\ in\ MMBtu/yr) \ \times fuel\ kg\ CO2/MMBtu\ EF_{\ i}] \div 1000 + \ [Fossil\ fuel\ type\ in\ (MMBtu/yr) \times \ g\ CH4\ EF_i \ \ \times 25 \ + Fossilfuel\ type\ in\ (MMBtu/yr) \ \times g\ N2O\ EF_i \ \ \times 298\ ] \div 1000000$</td><td>Electricity Consumption - IEA CO_2 Emissions from Fossil Fuel Combustion - 2011 Edition

Fuel Use - US EPA, Climate Leaders, Greenhouse Gas Inventory Protocol Core Module Guidance, 2008. http://www.epa.gov/stateply/

2006 IPCC Guidelines for National Greenhouse Gas Inventories. The IPCC values were originally on a NCV (LHV) basis and have been converted to a GCV (HHV) basis using rule of thumb. Gross calorific (higher heating) values are preferred because they are more closely related to the carbon content of fuels than net calorific (lower heating) values.</td></tr>
<tr><td>Emissions from vehicles and equipment used during construction

Same method applies to vehicles and equipment used during operation

Fuel consumption method (stationary combustion)</td><td>Estimates CO_2, CH_4, and N_2O emissions from construction vehicles and equipment. This method is used for any construction equipment or vehicles that are not associated with the construction of buildings since these emissions are captured in the Integrated Building Construction methodology described above. This method estimates fuel use emissions from mobile sources based on the type and amount of fuel use or by type of vehicle and total miles traveled if fuel use data are not available. Default CO_2, CH_4, and N_2O emission factors are provided and custom emission factors may be used if available.

Type of fuel used:
<table>
<tr><th>kg GHG/Liter</th><th>CO_2 EF kg CO_2/l</th></tr>
<tr><td>Aviation Gasoline</td><td>2.17</td></tr>
<tr><td>Biodiesel/Biodiesel Blend</td><td></td></tr>
<tr><td>B 100</td><td>0.00</td></tr>
<tr><td>B 20</td><td>2.12</td></tr>
<tr><td>B 10</td><td>2.39</td></tr>
<tr><td>B 5</td><td>2.52</td></tr>
</table></td><td>CO_2 (t) =
$\sum_i Annual\ fuel\ energy\ input\ (l/yr)_i \ \times \ \ fuel\ Co2\ EF_i$</td><td>Fuel Consumption Emission Factors - Source: Energy Information Administration, Documentation for Emissions of Greenhouse Gases in the United States 2003, (May 2005), p.189, web site: www.eia.doe.gov/oiaf/1605/ggrpt/documentation/pdf/0638(2003).pdf.

- Emission factors for biodiesel blends were calculated using the net (lower) heating value for biodiesel from National Biodiesel Board web site: www.biodiesel.org/pdf_files/fuelfactsheets/BTU_Content_Final_Oct2005.pdf. The gross (higher) heating value was assumed to be 5% higher than the net heating value (see Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories: Reference Manual, p. 1.5, web site: www.ipcc-</td></tr>
</table>

<table>
<tr><th>Construction Emissions</th><th>Description / Input Data Requirements</th><th>Calculation Method</th><th>Methodology Source</th></tr>
<tr>
<td>OR

Vehicle Miles Traveled Data</td>
<td>
<table>
<tr><td>B 2</td><td>2.60</td></tr>
<tr><td>Diesel Fuel (No. 1, 2)</td><td>2.65</td></tr>
<tr><td>Ethanol/Ethanol Blends</td><td></td></tr>
<tr><td>E 100</td><td>0.00</td></tr>
<tr><td>E 85</td><td>0.35</td></tr>
<tr><td>E 10</td><td>2.09</td></tr>
<tr><td>Motor Gasoline</td><td>2.32</td></tr>
<tr><td>Jet Fuel, Kerosene</td><td>2.50</td></tr>
<tr><td>Propane</td><td>1.51</td></tr>
<tr><td>Residual Fuel (No. 5, 6)</td><td>3.09</td></tr>
<tr><td>LNG</td><td>1.17</td></tr>
<tr><td>LPG</td><td>1.51</td></tr>
<tr><td>Methanol</td><td>1.07</td></tr>
<tr><td>CNG</td><td>53.73</td></tr>
</table>
Type of vehicle and total miles traveled:
<table>
<tr><th colspan="4">Default EF per vehicle type</th></tr>
<tr><td>CO_2 Emissions</td><td>g CO_2/mile</td><td>gCH_4/mile</td><td>g N_2O/mile</td></tr>
<tr><td>Motorcycle</td><td>57.7875208</td><td>0.0672</td><td>0.0069</td></tr>
<tr><td>New small gas/electric hybrid</td><td>62.1992563</td><td>N/A</td><td>N/A</td></tr>
<tr><td>Gasoline light duty automobile</td><td>144.088212</td><td>0.0704</td><td>0.0647</td></tr>
<tr><td>LPG light duty automobile</td><td>165.284737</td><td>0.037</td><td>0.067</td></tr>
<tr><td>Diesel light duty automobile</td><td>144.779487</td><td>0.0005</td><td>0.001</td></tr>
<tr><td>Gasoline vans & pick-up truck</td><td>196.151351</td><td>0.0813</td><td>0.1035</td></tr>
<tr><td>Gasoline light truck</td><td>248.548476</td><td>N/A</td><td>N/A</td></tr>
<tr><td>Diesel light truck</td><td>232.392825</td><td>0.0011</td><td>0.0017</td></tr>
<tr><td>Gasoline heavy truck</td><td>574.146981</td><td>0.3246</td><td>0.1142</td></tr>
<tr><td>Diesel heavy truck</td><td>540.592937</td><td>0.0051</td><td>0.0048</td></tr>
<tr><td>Diesel bus</td><td>642.877670</td><td>N/A</td><td>N/A</td></tr>
</table>
</td>
<td>OR

Vehicle Miles Traveled Data

CO_2 (t) =

$\sum_i$ [$Total\ distance\ traveled\ by\ verhicle\ type\ (km/yr) \times gCo2\ vehicle\ type\ EF_i$ ++ $(Total\ distance\ traveld\ by\ vehicle\ type\ (km/yr) \times gCH4\ vehicle\ type\ EF_i \times 25)$ + $(Total\ distance\ traveled\ by\ vehicle\ type(km/yr) \times gN2O\ vehicle\ type\ EF_i \times 298)] \div 1000000$</td>
<td>nggip.iges.or.jp/public/gl/invs6.htm)

Emission factors for ethanol blends were calculated using the higher heating value for ethanol from U.S. Department of Energy, Alternative Transportation Fuel Data Center, web site: www.eere.energy.gov/afdc/pdfs/fueltable.pdf

Fraction combusted is assumed to be 99 percent.

Vehicle Miles Traveled Default Factors

Ø CO_2 Factors - WRI/ WBCSD Greenhouse Gas Protocol Initiative. Average HWY/CITY and small/medium/large vehicle sizes- http://www.ghgprotocol.org/calculation-tools (mobile)

Ø CH_4 and N_2O Factors - EPA Climate Leaders: http://www.epa.gov/stateply/documents/resources/mobilesource_guidance.pdf</td>
</tr>
<tr>
<td>SF6 emissions from installed electrical</td>
<td>Estimates SF_6 emissions from leaks and other fugitive sources during the installation of electrical equipment.</td>
<td>SF_6 (kg/yr) =

SF_6 nameplate capacity for equipment installed during</td>
<td>The Climate Registry: 2009 Electric Power Sector Protocol v1.0</td>
</tr>
</table>

Construction Emissions	Description / Input Data Requirements	Calculation Method	Methodology Source
equipment	EF for equipment installed during project construction = 0.15	construction (kg) **x** EF *SF6 equipment installment* (0.15)	http://www.theclimateregistry.org/

9. GHG EMISSIONS FROM ONE FULL YEAR OF OPERATION

Agricultural Sector: Livestock			
Operational Emissions	**Description / Input Data Requirements**	**Calculation Method**	**Methodology Source**
Nitrous Oxide (N_2O) Emissions from Fertilizer Use	Estimates emissions occurring from the use of nitrogen-based fertilizer based on the amount of fertilizer used and emission factors for the amount of N_2O per unit of nitrogen. N_2O (kg) = direct N_2O emissions + volatization emissions + runoff emissions	N_2O (kg) = Percent nitrogen (N) in amount of fertilizer (kg/yr) **x** EF *direct* (0.9) x kg N_2O / kg N (0.02) + Percent nitrogen (N) in amount of fertilizer (kg/yr) **x** EF *volatization* (0.1) **x** kg N_2O / kg N (0.016) + Percent nitrogen (N) in amount of fertilizer (t/yr) **x** EF *runoffs* (0.3) **x** kg N_2O / kg N (0.008)	Environmental Protection Agency. 2009. Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2007. Chapter 6. http://www.epa.gov/climatechange/emissions/usinventoryreport.html
Emissions from lime and dolomite application	Limestone and dolomite are sometimes added by land managers to ameliorate acidification. When these compounds come in contact with acid soils, they degrade, thereby generating CO_2. The methodology estimates emissions from lime application based on the amount of limestone or dolomite applied and a default emission factor. Custom emission factors may be entered if available. **Default Factors for Limestone and Dolomite**	CO_2 (t) = Amount of limestone applied (t/yr)) **x** EF *limestone carbon fraction* (0.12) **x** 44/12 CO_2 (t) =	2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 4, Section 11.3.1 (based on equation 11.12) 44/12 (to convert CO_2 –C emissions into CO_2)

<table>
<tr><th colspan="4">Agricultural Sector: Livestock</th></tr>
<tr><th>Operational Emissions</th><th>Description / Input Data Requirements</th><th>Calculation Method</th><th>Methodology Source</th></tr>
<tr><td></td><td><table><tr><th colspan="2">Applications (fraction carbon)</th></tr><tr><td>Limestone</td><td>0.12</td></tr><tr><td>Dolomite</td><td>0.13</td></tr></table></td><td>Amount of dolomite applied (t/yr) x EF dolomite carbon fraction (0.13) x 44/12</td><td></td></tr>
<tr><td>Nitrous oxide and methane emissions from burning sugarcane crops</td><td>Estimates emissions from the burning of crop residues based on the amount of crop produced and fraction burned.
<table><tr><th colspan="2">Default Factors for Sugarcane Burning</th></tr><tr><td>Dry mass burned per unit moist harvested</td><td>0.20863</td></tr><tr><td>Combustion Factor (fraction)</td><td>0.8</td></tr><tr><td>CH_4 Emission Factor (g/kg burned)</td><td>2.7</td></tr><tr><td>N_2O Emission Factor (g/kg burned)</td><td>0.07</td></tr></table></td><td>CH_4 (t) =
Annual crop production (t/yr) x fraction burned annually x amount of dry mass burned per unit sugar cane moist harvested (0.20863) x EF gCH_4/kg burned (2.7) ÷1000
+
N_2O (t) =
Annual Crop Production (t/yr) x fraction burned annually x amount of dry mass burned per unit sugar cane moist harvested (0.20863) x EF gN_2O /kg burned (0.07) ÷ 1000</td><td>2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 4, Tables 2.5 (CH_4 and N_2O from "Agricultural Residues") and Table 2.6

Dry mass burned per unit moist harvested from RSB GHG Calculation Methodology, RSB-STD-01-003-01 (Version 2.0), pg. 73</td></tr>
<tr><td>Emissions from livestock</td><td>Estimates CH_4 emissions from enteric fermentation and both CH_4 and nitrous oxide N_2O emissions from livestock manure management systems based on animal type, using default emission factors. Site-specific factors may be used if available.
<table><tr><th>Type of Livestock</th><th>kg CH_4/head</th><th>Animal Mass (kg)</th><th>Annual kg N per animal</th><th>t N_2O/t N</th></tr><tr><td>Dairy cattle</td><td>63</td><td>400</td><td>70.08</td><td>0.02</td></tr><tr><td>Other cattle</td><td>56</td><td>305</td><td>40.08</td><td>0.02</td></tr><tr><td>Sheep</td><td>6.5</td><td>38.25</td><td>16.33</td><td>0.01</td></tr><tr><td>Goats</td><td>5</td><td>34.25</td><td>17.13</td><td>0.01</td></tr><tr><td>Swine</td><td>1.25</td><td>28</td><td>16.76</td><td>0.02</td></tr><tr><td>Poultry</td><td></td><td>2.8</td><td>0.84</td><td>0.02</td></tr><tr><td>Camels</td><td>46</td><td>217</td><td>33.27</td><td>0.01</td></tr><tr><td>Horses</td><td>18</td><td>307.5</td><td>42.09</td><td>0.01</td></tr></table></td><td>CH_4 (t) =
$$\sum_i Number\ of\ heads\ of\ lifestock_i \times EF_i animal\ mass \times EF_i\ kg\ CH4\ per\ head\ per\ year \div 1000$$
+
N_2O (t) =
$$\sum_i Number\ of\ heads\ of\ lifestock_i \times EF_i\ annual\ kgN\ per\ animal \times tN2O/tN \div 1000$$</td><td>2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 4, Chapter 10.

http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_10_Ch10_Livestock.pdf</td></tr>
</table>

Agricultural Sector: Livestock			
Operational Emissions	**Description / Input Data Requirements**	**Calculation Method**	**Methodology Source**
	Mules and Asses | 10 | 130 | 17.79 | 0.01		

Energy Sector: Fossil Fuel Power Plants			
Operational Emissions	**Description / Input Data Requirements**	**Calculation Method**	**Methodology Source**
Stationary Combustion	Estimates emissions from the burning of fossil fuels based on the quantity and type of fuel used, heat content, carbon content, and oxidation fraction. Default values are provided for heat content, carbon content, and oxidation fraction based on fuel type. Custom values may be entered for these inputs. If quantity of fuel used is not known, use heat rate equation.	CO_2 (t) = Annual amount of electricity produced (MWh/yr) **x** Plant Heat Rate (MMBtu/MWh) **x** EF *CO_2 content coefficient* (kg CO_2 /MMBtu) **x** EF *fraction oxidized* ÷1000 + CH_4 (t) = Annual amount of electricity produced (MWh/yr) **x** Plant Heat Rate (MMBtu/MWh) **x** EF *CH_4 g/MMBtu*) ÷1000000 + N_2O (t) = Annual amount of electricity produced (MWh/yr) **x** Plant Heat Rate (MMBtu/MWh) **x** EF *N_2O g/MMBtu* ÷1000000 Plant Heat Rate MMBtu/MWh:	US EPA, Climate Leaders, Greenhouse Gas Inventory Protocol Core Module Guidance, 2008 http://epa.gov/climateleaders/ Note the ration of the molecular weights of CO_2 and C (44/12 or 3.664) have been already factored in the CO_2 coefficient

CO_2 Emission Factors (mass CO_2 /fuel energy) for Fossil Fuel Combustion

Fossil Fuel	Heat Content (HHV)	CO_2 Content Coefficient	Fraction Oxidized
Coal and Coke	(MMBtu/short ton)	(kg CO_2/MMBtu)	
Anthracite	25.09	103.62	1.0
Bituminous	24.93	93.46	1.0
Sub-Bituminous	17.25	97.09	1.0
Lignite	14.21	96.43	1.0
Unspecified (industrial coking)	26.27	93.72	1.0
Unspecified (industrial other)	22.05	93.98	1.0
Unspecified (electric utility)	19.95	94.45	1.0

<table>
<tr><th colspan="4">Energy Sector: Fossil Fuel Power Plants</th></tr>
<tr><th>Operational Emissions</th><th>Description / Input Data Requirements</th><th>Calculation Method</th><th>Methodology Source</th></tr>
<tr><td></td><td>
<table>
<tr><td>Unspecified (residential/commercial)</td><td>22.05</td><td>95.33</td><td>1.0</td></tr>
<tr><td>Coke</td><td>24.80</td><td>113.67</td><td>1.0</td></tr>
<tr><td>Natural Gas_</td><td>(Btu/scf)</td><td>(kg CO_2/MMBtu)</td><td></td></tr>
<tr><td>Natural Gas</td><td>1029.00</td><td>53.06</td><td>1.0</td></tr>
<tr><td>Petroleum</td><td>(MMBtu/Barrel)</td><td>(kg CO_2/MMBtu)</td><td></td></tr>
<tr><td>Distillate Fuel Oil (#1, 2, & 4)</td><td>5.825</td><td>73.15</td><td>1.0</td></tr>
<tr><td>Residual Fuel Oil (#5 & 6)</td><td>6.287</td><td>78.8</td><td>1.0</td></tr>
<tr><td>Kerosene</td><td>5.67</td><td>72.31</td><td>1.0</td></tr>
<tr><td>Petroleum Coke</td><td>6.024</td><td>102.12</td><td>1.0</td></tr>
<tr><td>LPG (average for fuel use)</td><td>3.8492</td><td>63.16</td><td>1.0</td></tr>
</table>
<table>
<tr><th></th><th>CH_4</th><th>N_2O</th></tr>
<tr><td>Coal and Coke</td><td>1</td><td>1.6</td></tr>
<tr><td>Petroleum</td><td>3</td><td>0.6</td></tr>
<tr><td>Natural gas</td><td>1</td><td>0.1</td></tr>
</table>
</td><td>CO_2 (t) =

$Annual\ amount\ of\ fuel\ used\ (t/yr)$
$\div\ 0.907\ to\ convert\ to\ short\ tons$
$\times\ heat\ content\ (HHV)\ factor\ _i\ (MMBtu/\ unit\ fuel)$
$\div\ amount\ of\ electricity\ produced\ (MWh/yr)$</td><td></td></tr>
<tr><td>Flue Gas Desulfurization (FGD) Sorbent Emissions</td><td>Estimates emissions that occur from the use of limestone and/or soda ash in FGD systems if they are installed at the plant. Emissions are calculated based on the amount of limestone and/or soda ash used.</td><td>CO_2 (t) =

Quantity limestone consumption (t/yr) x (44/100) + quantity soda ash consumption (t/yr) x (44/106)</td><td>US EIA, Technical Guidelines Voluntary Reporting of Greenhouse Gases (1605(b)) Program.

http://www.eia.doe.gov/oiaf/1605/gdlins.html</td></tr>
<tr><td>Methane and Nitrous Oxide Emissions</td><td>Estimates emissions of methane and nitrous oxide emitting during fuel combustion based on the energy content of the fuel used and default emissions factors. Custom emission factors may be entered. Emissions of methane and nitrous oxide from combustion are difficult to measure accurately, but fortunately they are relatively small.</td><td>CH_4 (t) =

Annual amount of electricity produced (MWh/yr) x plant heat rate (MMBtU/MWh) or (GJ/MWh) x EF g CH_4/(MMBtu/MWh) or (GJ/MWh) / 10000</td><td>US EIA, Technical Guidelines Voluntary Reporting of Greenhouse Gases (1605(b)) Program.

http://www.eia.doe.gov/oiaf/1605/gdlins.html</td></tr>
</table>

<table>
<tr><th colspan="4">Energy Sector: Fossil Fuel Power Plants</th></tr>
<tr><th>Operational Emissions</th><th>Description / Input Data Requirements</th><th>Calculation Method</th><th>Methodology Source</th></tr>
<tr><td></td><td>

EF	g CH_4/MMBtu	g N_2O /MMBtu
Coal and Coke	1	1.6
Petroleum	3	0.6
Natural gas	1	0.1

</td><td>+

N_2O (t) =

Annual amount of electricity produced (MWh/yr) **x** Plant Heat Rate (MMBtU/MWh) or (GJ/MWh) **x** EF *g N_2O (MMBtu/MWh) or (GJ/MWh)* / 10000</td><td></td></tr>
</table>

<table>
<tr><th colspan="4">Energy Sector: Renewable Energy (Solar, Wind, Hydro, Geothermal)</th></tr>
<tr><th>Operational Emissions</th><th>Description / Input Data Requirements</th><th>Calculation Method</th><th>Methodology Source</th></tr>
<tr><td>Avoided Electricity Use

(for all types of RE)</td><td>Estimates emissions avoided from electricity generation during operation of each renewable project type.</td><td>Net (-) CO_2 (t) =
Annual amount of electricity generated (kWh/yr) **x** expected losses/station use (fraction) **x** EF *country electricity grid* (based on latest IEA statistics)</td><td>Electricity Emission Factor Source: IEA CO_2 Emissions from Fossil Fuel Combustion - 2011 Edition

http://www.iea.org/publications/</td></tr>
<tr><td>Maintenance Emission Factors (for all types of RE)</td><td>Provides emission factors to calculate emissions associated with the maintenance of renewable energy projects.

Default Emission Factors for Maintenance of Renewable Energy Projects (g- CO_2/kWh)	
Solar	12.3
Wind	8.3

</td><td>CO_2 (t) =

Annual amount of electricity generated (kWh/yr) **x** EF *maintenance of RE projects* / 1000000</td><td>Life cycle GHG emission analysis of power generation systems: Japanese case, Hiroki Hondo 2005

http://campus.udayton.edu/~physics/rjb/PHY399Winter2007/Hondo%20-%20GHG%20LCA%20for%20power%20generation.pdf</td></tr>
</table>

Energy Sector: Renewable Energy (Solar, Wind, Hydro, Geothermal)			
Operational Emissions	**Description / Input Data Requirements**	**Calculation Method**	**Methodology Source**
	Hydroelectric: 1.9 Geothermal: 9.7		
Transmission and Distribution (T&D) of Electricity - Line Losses short version (for all types of RE)	For RE projects that include transmission with/without distribution, a default T&D loss factor is provided and is currently set to the U.S. average. **Default Transmission/Distribution Line Loss Factor** Default Transmission Factor: 2.0% Default Transmission and Distribution Factor: 5.6%	With distribution CO_2 (t) = Electricity transmitted through system annually (MWh/yr) **x** EF *country electricity grid* **x** loss factor (0.056) Without distribution CO_2 (t) = Electricity transmitted through system annually (MWh/yr) **x** EF *country electricity grid* **x** loss factor (0.02)	Default loss factor: The Climate Registry: 2009 Electric Power Sector Protocol v1.0 http://www.theclimateregistry.org/
Fugitive Sulfur Hexafluoride (SF_6) Losses from Transmission Equipment (for all types of RE) Method 3	Fugitive Emissions of SF_6: Method 3, EIA SF_6 Fugitive Emissions Calculation Method. Estimates fugitive SF_6 emissions based on total length of transmission lines and a default fugitive emission factor. **Default Fugitive SF_6 Emissions Factor (kg-SF_6/km)** Small Utilities (less than 16,093 transmission kilometers): 1.001 Large Utilities (more than 16,093 transmission kilometers): 0.58	SF_6 (kg) = Length of Transmission Lines (km) **x** EF *fugitive SF6*	The Climate Registry: 2009 Electric Power Sector Protocol v1.0 http://www.theclimateregistry.org/
Fugitive CO_2 and CH_4 (Geothermal Only)	Default mass fraction of non-condensable gases (CO_2 and CH_4) from steam produced in geothermal plants. Average Mass Fraction of CO_2 in produced steam: 97.8 % Average Mass Fraction of CH_4 in produced steam: 0.18 %	CO_2 (t) = Annual quantity of steam produced (t/yr) **x** EF *fraction of non-condensable gases* (97.8) **+** CH_4 (t) = Annual quantity of steam produced (t/yr) **x** EF *fraction of non-condensable gases* (0.18)	INEEL, http://www.osti.gov/bridge/servlets/purl/10996-pK1dMM/10996.pdf

Energy Sector: Transmission Line

<table>
<tr><th>Operational Emissions</th><th>Description / Input Data Requirements</th><th>Calculation Method</th><th>Methodology Source</th></tr>
<tr>
<td>Transmission Line Losses</td>
<td>Estimates emissions from electricity consumption from line losses based on the amount of energy flowing into the transmission line, the country and fuel type of the generation source, and a default line loss factor of 2 percent. If the amount of energy into AND out of the line is known, that can be used to calculate a more accurate value. A custom loss factor may be entered if available.

<table>
<tr><th colspan="2">Default Transmission/Distribution Line Loss Factor</th></tr>
<tr><td>Default Transmission Factor</td><td>2.0 %</td></tr>
<tr><td>Default Transmission and Distribution Factor</td><td>5.6 %</td></tr>
</table>
</td>
<td>CO_2 (t) =

Electricity transmitted through system annually (MWh/yr) x EF country electricity grid x difference of energy flow IN and OUT of system in %

OR

With distribution CO_2 (t) =

Electricity transmitted through system annually (MWh/yr) x EF country electricity grid x loss factor (0.056)

Without distribution CO_2 (t) =

Electricity transmitted through system annually (MWh/yr) x EF country electricity grid x loss factor (0.02)</td>
<td>Country-specific electricity emission factors: IEA CO_2 Emissions from Fossil Fuel Combustion - 2011 Edition

http://www.iea.org/publications/

Default loss factor: The Climate Registry: 2009 Electric Power Sector Protocol v1.0

http://www.theclimateregistry.org/</td>
</tr>
<tr>
<td>Fugitive Emissions of SF_6: <u>Method 1</u>, EPA Emissions Quantification Method</td>
<td>Estimates fugitive emissions of SF_6 from electrical equipment during operation of transmission and distribution systems based on inventory, acquisition, disbursement, and equipment capacity. This is the most accurate method of calculating SF_6 emissions but requires the most data inputs.</td>
<td>SF_6 (kg) =

Decrease in inventory (SF_6 contained in cylinders, NOT electrical equipment) (kg SF_6/yr) within one year

+

Purchases/Acquisitions of SF_6

-

Sales/Disbursements of SF_6

-

Increase in Nameplate Capacity</td>
<td>The Climate Registry: 2009 Electric Power Sector Protocol v1.0

http://www.theclimateregistry.org/</td>
</tr>
<tr>
<td>Fugitive Emissions of SF_6: <u>Method 2</u>, IPCC Good Practice Guidance 2000 Default Factors</td>
<td>Estimates fugitive SF_6 emissions based on nameplate capacity of SF_6 by equipment type and default emission factors. Custom emission factors may be entered if available.

<table>
<tr><th>Equipment Type per SF_6 capacity (kg SF_6)</th><th>Default EF
%</th></tr>
<tr><td>Existing equipment</td><td>2.0%</td></tr>
</table>
</td>
<td>SF_6 (kg) =

New nameplate capacity for SF_6 by equipment type x EF Sf6 existing equipment (0.02)

+

Retiring nameplate capacity for SF_6 by equipment type x EF SF6 retiring equipment (0.95)</td>
<td>IPCC Good Practice Guidance 2000

http://www.ipcc-nggip.iges.or.jp/public/gp/english/</td>
</tr>
</table>

Energy Sector: Transmission Line			
Operational Emissions	**Description / Input Data Requirements**	**Calculation Method**	**Methodology Source**
	Retiring equipment: 95.0%		
Fugitive Emissions of SF_6: Method 3, EIA SF_6 Fugitive Emissions Calculation Method	Estimates fugitive SF_6 emissions based on total length of transmission lines and a default fugitive emission factor. **Default Fugitive SF_6 Emissions Factor (kg-SF_6/km)** Small Utilities (less than 16,093 transmission kilometers): 1.001 Large Utilities (more than 16,093 transmission kilometers): 0.58	SF_6 (kg) = Length of Transmission Lines (km) **x** EF *fugitive SF6*	The Climate Registry: 2009 Electric Power Sector Protocol v1.0 http://www.theclimateregistry.org/

Energy Sector: Bioenergy Plants			
Operational Emissions	**Description / Input Data Requirements**	**Calculation Method**	**Methodology Source**
Co-Product: Glycerin produced during biodiesel conversion process	This method is based on the US EPA's treatment of glycerin in the Renewable Fuels Standard. The US EPA uses an energy equivalent amount of residual oil as a simplifying assumption to reflect the mid-range of possible glycerin uses in terms of GHG credits. EPA believes that this is an appropriate representation of GHG reduction credit across the possible range of uses without necessarily biasing the results toward high or low GHG impact. This method uses an emission factor for residual oil from the US DOE. **Default Factors for Glycerin (Co-product credit emission factor) kg CO_2/ liters** Glycerin: 3115	CO_2 (t) = Annual liters of Glycerin produced (l/yr) x EF *Glycerin / 1000*	US EPA, Renewable Fuels Standard (RFS) http://www.epa.gov/otaq/fuels/renewablefuels/index.htm Emission Factor: US DOE, Energy Information Administration (EIA). http://205.254.135.7/oiaf/1605/coefficients.html
Co-Product: Surplus Electricity Production	Estimates avoided emissions resulting from surplus biofuel produced electricity delivered to the grid. This electricity displaces grid-produced electricity that would otherwise be purchased to meet energy needs.	CO_2 (t) =	Electricity Emission Factor Source: IEA CO_2 Emissions from Fossil Fuel Combustion - 2011 Edition

Energy Sector: Bioenergy Plants			
Operational Emissions	**Description / Input Data Requirements**	**Calculation Method**	**Methodology Source**
Delivered to the Grid	The methodology uses default country-specific IEA grid electricity factors.	$Annual\ surplus\ electricity\ delivered\ to\ the\ grid\ (kWh/yr) \times EF_i\ country\ electricity\ grid$	http://www.iea.org/publications/free_new_Desc.asp?PUBS_ID=2143
Annual Emissions Reductions Carbon Debt Payoff Time	Carbon debt is calculated by dividing the annual savings in emissions from biofuel use by the amount of carbon released during the production of the biofuel crop. Carbon Debt Payoff Time=(Carbon Released During Conversion)/(Annual Biofuel Carbon Savings) The annual emissions savings used for the calculation are based on the operational emissions because that is what is paying off the construction emissions. For example, if ethanol from a sugarcane project reduces CO_2 emissions by 300,000 tons each year, but the initial production of the biofuel releases 3 million tons of CO_2, that project's carbon debt would be 10 years. **REFERENCE FUEL EMISSION FACTORS (kg CO_2/liter)** Reference Fuel / Emission Factor: Gasoline: 3.12 Diesel: 3.53 Kerosene: 3.29	CO_2 (t) annual emissions reductions = (Annual amount of biofuel produced $(l/yr) \times$ EF_i $reference\ fuel\ \div$ $1000) - (construction\ emissions \div$ $lifetime\ of\ plant\ (default\ 20\ years))$ – operational emissions + co-product credits CO_2 (t) carbon payoff time = $Construction\ emissions\ \div$ [$EF_i\ reference\ fuel\ -$ (Annual operational emissions $\div$ annual biofuel produced $(l/yr) \times 1000) \times$ $(annual\ biofuel\ produced \div 1000) + co-product\ credits$]	Adapted from Land Clearing and the Biofuel Carbon Debt, Joseph Fargione, et al., Science 319, 1235 (2008) http://www.atmos.washington.edu/2009Q1/111/Readings/Fargione2008_biofuel_land-clearing.pdf

Industry Sector: Cement Plants			
Operational Emissions	**Description / Input Data Requirements**	**Calculation Method**	**Methodology Source**

<table>
<tr><th colspan="4">Industry Sector: Cement Plants</th></tr>
<tr><th>Operational Emissions</th><th>Description / Input Data Requirements</th><th>Calculation Method</th><th>Methodology Source</th></tr>
<tr><td>Stationary Combustion Fuel Use</td><td>Estimates emissions from the burning of fossil fuels at stationary combustion equipment located at the project site based on the type and quantity of fuel used. Custom emissions factors for each fuel may be entered if available.</td><td>CO_2 (t) =

Annual amount clinker used (t/yr) x plant efficiency (unit energy / unit clinker produced MJ or MMBtu) x EF fuel type used in clinker production / 1000</td><td>Source: 2006 IPCC Guidelines for National Greenhouse Gas Inventories. The IPCC values were originally on a NCV (LHV) basis and have been converted to a GCV (HHV) basis using rule of thumb. Gross calorific (higher heating) values are preferred because they are more closely related to the carbon content of fuels than net calorific (lower heating) values.

http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.html</td></tr>
<tr><td>Process Emissions from the Production of Clinker: Cement Method, User-Specific Production Data</td><td>Estimates process emissions based on the quantity of cement produced, clinker content of the cement, raw material to clinker ratio, and lime content (CaO). Default values for clinker content are provided or a custom value can be entered.

<table><tr><th colspan="3">Clinker Composition Default Values</th></tr><tr><th>Component</th><th>Content</th><th>Ratio to CO_2</th></tr><tr><td>Calcium Oxide (CaO) Content of Clinker</td><td>0.650</td><td>0.785</td></tr><tr><td>Magnesium Oxide (MgO) Content of Clinker</td><td>0.015</td><td>1.092</td></tr></table></td><td>CO_2 (t) =

Annual amount cement produced (t/yr) x percentage of clinker ratio/100 x EF calcium oxide (CaO – lime) content of clinker (0.65) x 44/56

+

Annual amount cement produced (t/yr) x percentage of clinker ratio/100 x EF Magnesium Oxide (MgO)content of clinker (0.015) x Molecular ratio of CO_2 to MgO (1.092)</td><td>These method derives from the following sources:

Intergovernmental Panel on Climate Change, Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories (1997), web site: www.ipcc-nggip.iges.or.jp/public/gl/invs1.htm

World Resources Institute/World Business Council for Sustainable Development, Greenhouse Gas Protocol Initiative (2001), web site: www.ghgprotocol.org

44/56 (Molecular ratio of CO_2 to CaO (0.785)</td></tr>
</table>

Industry Sector: Iron and Steel Plants			
Operational Emissions	**Description / Input Data Requirements**	**Calculation Method**	**Methodology Source**
Emissions from Steel Production: Integrated Steel Mill Approach	Estimates total emissions from all aspects of iron and steel production at an integrated facility using a single emission factor. A default factor is provided, but a custom factor may be entered if available.	CO_2 (t) = Annual steel produced (t/yr) **x** EF *steel and iron making methods*	IPCC, Guidelines for National Greenhouse Gas Inventories, 2006, pp. 4.27, 4.25. http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.html
Emissions from Steel Production: Process-Based Approach	Estimates emissions from iron and steel production by using amounts of reducing agents, flux, and other materials and it uses material-specific emission factors.	CO_2 (t) = Annual amount of limestone used (t/yr) **x** EF *limestone* (0.12) **x** 3.664 (44/12) + Annual amount of dolomite used (t/yr) **x** EF *dolomite* (0.13) **x** 3.664 (44/12) + $\sum_i Annual\ mass\ reducing\ agents\ used\ (t/yr) \times EF_i\ \ process\ materials\ \times {}^{44}/_{12}$ - Annual amount of steel produced (t/yr) **x** EF *steel production* (0.1) **x** 3.664 (44/12) - Annual amount of iron production not converted to steel	IPCC, Guidelines for National Greenhouse Gas Inventories, 2006, Volume 3, Chapter 4. http://www.ipcc-nggip.iges.or.jp/public/2006gl/vol3.html

CO_2 EMISSION FACTORS FOR IRON & STEEL PRODUCTION MT CO_2/t of steel

Steel and iron making method	Emission Factor
Basic Oxygen Furnace (BOF)	1.46
Electric Arc Furnace (EAF)	0.08
Open Hearth Furnace (OHF)	1.72
Global Average Factor (65% BOF, 30% EAF, 5% OHF)*	1.06

MATERIAL-SPECIFIC CARBON CONTENTS FOR IRON & STEEL AND COKE PRODUCTION

Process Materials	Carbon Content (kg C/kg)
Coke	0.83
Coal	0.67
Petroleum Coke	0.87
Charcoal	0.00
Coal Tar	0.62
Coking Coal	0.73
Fuel Oil	0.86
Gas Coke	0.83
Natural Gas	0.73
Oxygen Steel Furnace Gas	0.35
Blast Furnace Gas	0.17
Coke Oven Gas	0.47
Limestone	0.12
Dolomite	0.13
EAF Carbon Electrodes	0.82
EAF Charge Carbon	0.83

Industry Sector: Iron and Steel Plants			
Operational Emissions	**Description / Input Data Requirements**	**Calculation Method**	**Methodology Source**
	Direct Reduced Iron (DRI) 0.02 Hot Briquetted Iron 0.02 Purchased Pig Iron 0.04 Scrap Iron 0.04 Steel 0.01	(t/yr) **x** EF *direct reduced iron* (0.02) x 3.664 (44/12)	

Industry Sector: Oil and Gas Systems			
Operational Emissions	**Description / Input Data Requirements**	**Calculation Method**	**Methodology Source**
Fugitive Emissions from Oil and Gas Operations	Calculates the amount of fugitive emissions from oil and gas operations using the volume of product. It includes CO_2, CH_4, and N_2O emissions. It covers a wide range of oil and gas processes including production, processing, and transportation. Emission factors for fugitive emissions from oil and gas include venting and flaring. Table was too large to include here.	CO_2 (t) = Annual Volume (m3/yr) from oil and gas process **x** EF *CO_2 (kg/m3)*/1000 + CH_4 (t) = Annual Volume (m3/yr) from oil and gas process **x** EF *CH_4 (kg/m3)*/1000 + N_2O (t) = Annual Volume (m3/yr) from oil and gas process **x** EF *N_2O (kg/m3)*/1000	IPCC 2006 Guidelines, Volume 2, Chapter 4, Table 4.2.5. http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_4_Ch4_Fugitive_Emissions.pdf

Transport Sector: Airports

Operational Emissions	Description / Default emission factors	Calculation Method	Methodology Source
Emissions from Pavement Maintenance Activities	Roads require periodic maintenance to repair potholes, cracks, and other deformations and keep them in safe working order. These maintenance activities generate emissions primarily through fuel consumption of maintenance vehicles and equipment and use of concrete or asphalt for resurfacing. This method calculates the emissions from downstream maintenance and repair of the highway.	See calculation in construction section.	This method is adopted from the King County (Washington State) Department of Development and Environmental Services: SEPA GHG Emissions Worksheet, Version 1.7 12/26/07.
Emissions from Vehicle Traffic	Estimates CO_2, CH_4, and N_2O emissions from vehicle traffic on the new roadway. This method estimates fuel use emissions from mobile sources based on the type and amount of fuel use or by type of vehicle and total miles traveled if fuel use data are not available.	See calculations in construction section.	See methodology in construction section.
Emissions from Electricity Consumption of Airport Lighting and Beacons	Electricity consumption of road lighting and traffic signals generates indirect emissions. This method estimates these indirect emissions based on annual electricity consumption.	CO_2 (t) = Total annual electricity used by airport lighting and beacons (kWh/yr) **x** EF *country electricity grid* (based on latest IEA statistics)	
Emissions from Aircraft Landing and Takeoff (LTO) Cycles	Domestic flights: **GHG** | **Default EF** kg/LTO CO_2 | 2,680 CH_4 | 0.3 N_2O | 0.1 International flights: **GHG** | **Default EF** kg/LTO CO_2 | 7,900 CH_4 | 1.5 N_2O | 0.2	CO_2 (t) = $\sum_i [Number\ of\ flights\ that\ depart\ annually \times (EF_{i}CO2 + (EF_i\ CH4 \times 25) + (EF_i\ N2O \times 298))_i] \div 1000$	

Transport Sector: Canals and Ports

Operational Emissions	Description / Input Data Requirements	Calculation Method	Methodology Source
Emissions from Fuel Consumption by Tugboat Fleet	Estimates emissions from fuel use by tugboats based on type and amount of fuel used.	CO_2 (t) = Annual fuel used by tugboat fleet during operation of lock system (gallons or liters/yr) **X** EF	Mobile Sources: CO_2 Factors - WRI/ WBCSD Greenhouse Gas Protocol Initiative. Average HWY/CITY and small/medium/large vehicle sizes- http://www.ghgprotocol.org/calculation-tools (mobile) CH_4 and N_2O Factors - EPA Climate Leaders: http://www.epa.gov/stateply
Emissions from Increased Canal Traffic	Estimates emissions from increased canal traffic based on fuel consumption by ships. This is considered a Scope 3 emission source, however, it is included here since it represents a significant source of ongoing operational emissions from a project of this type.	CO_2 (t) = Annual fuel used from shipping activity (l/yr) **X** associated emission factor **+** CH_4 (t) = specific fuel consumption factor (efficiency factor) **X** activity **X** associated emission factor CH_4 **+** N_2O (t) = Specific fuel consumption factor (efficiency factor) **X** activity **X** associated emission factor N_2O	US EPA Climate Leaders, Mobile Combustion Sources - Guidance, May 2008. Table A-6. http://epa.gov/climateleaders/

Transport Sector: Road Construction and Rehabilitation			
Operational Emissions	**Description / Input Data Requirements**	**Calculation Method**	**Methodology Source**

<table>
<tr><th colspan="4">Transport Sector: Road Construction and Rehabilitation</th></tr>
<tr><th>Operational Emissions</th><th>Description / Input Data Requirements</th><th>Calculation Method</th><th>Methodology Source</th></tr>
<tr><td>Emissions from Road Maintenance Activities</td><td>See calculation and methodology in the construction section.</td><td></td><td></td></tr>
<tr><td>Emissions from Electricity Consumption of Street Lighting</td><td>Estimates emissions from electricity use by street lighting and traffic signals. This is assumed to be a very small source of emissions.</td><td>CO_2 (t) =

Annual amount of electricity used (MWh/yr) x EF country electricity grid (based on latest IEA statistics)</td><td>IEA CO_2 Emissions from Fossil Fuel Combustion - 2011 Edition

http://www.iea.org/publications/</td></tr>
<tr><td>Emissions from Vehicle Traffic (Scope 3)

Specifically for rural roads

Differentiated between:

1. New rural roads
2. Rehabilitated rural roads</td><td>The methodology used to calculate Scope 3 emissions from vehicles using new or improved roads is adapted from a previously established transport emissions evaluation tool developed by the Asian Development Bank (ADB). Scope 3 estimates are based on three distinct categories of traffic that may exist on a new or improved road:
• Vehicles using the existing road before the improvement (existing)
• Vehicles that shifted to the new or improved road from other roads (existing)
• Vehicles that otherwise would not have made a trip at all without the new or improved road (induced)

Road elasticity rural road 0.25

Road elasticity for urban roads 0.8

<table>
<tr><th colspan="3">Road roughness fuel economy adjustment:</th></tr>
<tr><th>Road Roughness (m/km)</th><th>Factor</th><th>Description</th></tr>
<tr><td>2</td><td>1</td><td>• Airport Runways / Super Highways
• New Pavement with no imperfections</td></tr>
<tr><td>3</td><td>0.99</td><td>• New pavement with few surface imperfections
• Older Pavement with no imperfections</td></tr>
</table></td><td>CO_2 (t) =

[CO_2 emissions (t/yr) of existing traffic before the project (road itself (only in case of rehabilitation) +shifted VKT from alternate routes)]

-

[CO_2 emission (t/yr) of traffic from new/rehabilitated road (road itself + induced traffic)

To be able to calculate emissions from road and induced traffic you need to have data from shifted VKT, induced VKT, road roughness fuel economy adjustment etc.

Induced traffic (new road):</td><td>ADB Evaluation Study, Methodology for Transport Emissions, Evaluation Model for Projects, July 2010.

http://www.adb.org/Documents/Evaluation/Knowledge-Briefs/REG/EKB-REG-2010-16/methodology.pdf</td></tr>
</table>

<table>
<tr><th colspan="4">Transport Sector: Road Construction and Rehabilitation</th></tr>
<tr><th>Operational Emissions</th><th>Description / Input Data Requirements</th><th>Calculation Method</th><th>Methodology Source</th></tr>
<tr>
<td></td>
<td>
<table>
<tr><td>4</td><td>0.98</td><td>• Older Pavement with surface imperfections
• Well maintained unpaved road</td></tr>
<tr><td>5</td><td>0.98</td><td>• Older Pavement with frequent surface imperfections
• Maintained unpaved road</td></tr>
<tr><td>6</td><td>0.97</td><td>• Older Pavement with minor depressions
• Maintained unpaved road with frequent surface imperfections</td></tr>
<tr><td>7</td><td>0.96</td><td>• Older Pavement with minor depressions
• Maintained unpaved road with frequent minor depressions</td></tr>
<tr><td>8</td><td>0.95</td><td>• Maintained unpaved road with shallow depressions
• Damaged Pavements
• Rough unpaved roads</td></tr>
<tr><td>9</td><td>0.95</td><td>• Maintained unpaved road with frequent shallow depressions
• Damaged Pavements with frequent minor depressions
• Rough unpaved roads with frequent minor depressions</td></tr>
<tr><td>10</td><td>0.94</td><td>• Maintained unpaved road with frequent shallow depressions, some deep depressions
• Damaged Pavements with frequent minor and shallow depressions
• Rough unpaved roads with frequent minor and shallow depressions</td></tr>
<tr><td>11</td><td>0.93</td><td>• Damaged Pavements with frequent shallow depressions, some deep
• Rough unpaved roads with frequent shallow depressions</td></tr>
<tr><td>12</td><td>0.92</td><td>• Rough unpaved roads with frequent shallow depressions, some deep</td></tr>
<tr><td>13</td><td>0.92</td><td>• Rough unpaved roads with frequent shallow and deep depressions</td></tr>
</table>
</td>
<td>
$\sum_i Annual\ VKT\ on\ the\ road$
$\times\ percentage\ of\ vehicle\ type$
$\times\ road\ elasticity_i$
$\times\ 1/\ vehicle\ capacity\ by\ type_i$

Induced traffic (rehabilitated road):
$\sum_i Annual\ VKT\ after\ project\ implem.\ on\ the\ road$
$\times\ percentage\ of\ vehicle\ type\ _x$
$\times\ road\ elasticity_i$
$\times\ 1/\ vehicle\ capacity\ by\ type_x$

Shifted VKT From Alternate Routes (rehabilitated roads):

Annual VKT after project implementation - Annual VKT before project implementation – induced traffic

Shifted VKT From Alternate Routes (new roads):

Annual VKT after project implementation - induced traffic

CO_2 (t) Alternate Routes before the project for new or rehabilitated roads=

Shifted VKT x (1+percentage of VKT saved) x percentage of vehicle type x road roughness fuel economy adjustment / 1000000

CO_2 (t) of traffic on the road after project:

Shifted VKT after project (= total VKT after- induced traffic) x percentage of vehicle fleet type x road roughness fuel economy adjustment after project implementation/ 1000000

CO_2 induced traffic after project:
</td>
<td></td>
</tr>
</table>

Transport Sector: Road Construction and Rehabilitation

Operational Emissions	Description / Input Data Requirements	Calculation Method	Methodology Source

14	0.91	• Rough unpaved roads with frequent deep depressions
15	0.90	• Rough unpaved roads with erosion gullies and frequent deep depressions

Vehicle Capacity by Type	
Vehicle Type	**Avg Capacity**
2 wheeler	0.5
3 wheeler	1.0
Passenger cars	1.0
Light commercial vehicle	1.5
Buses	3.0
Heavy commercial vehicles	3.0

Vehicle Emission Factors by Type	
Vehicle Type	**kg/l**
2 wheeler	2.416
3 wheeler	2.416
Passenger cars	2.448
Light commercial vehicle	2.582
Buses	2.582
Heavy commercial vehicles	2.582

Induced traffic VKT x percentage of vehicle fleet type x road roughness fuel economy adjustment after project implementation / 1000000

CO_2 (t) traffic on the road before the project=

Annual VKT on the road before the project x percentage of vehicle flees type x road roughness fuel economy adjustment /1000000

Emission factor for Road roughness and speed adjustment :

1/ [1/emission factor of vehicle fleet type x (1+ average speed fuel economy adjustment) **x** road roughness fuel economy adjustment)]

Tourism Sector/ Urban Development and Housing

Operational Emissions	Description / Input Data Requirements	Calculation Method	Methodology Source
Emissions from Hotel/Resort Stays	Estimates emissions based on a default factor for electricity use from hotel rooms. A custom factor can be used if available. **Default Hotel Room Electricity Usage** Room Type / kWh Usage / Units Standard / 20 / kWh/room/night Upscale / 40 / kWh/room/night	CO_2 (t) = $\sum_i Annual\ room\ nights \times EF_i hotel\ room\ type \times EF_i\ country\ electricity\ grid$	Climate Neutral Network http://climateneutralnetwork.org/intro.php
Electricity Use from Streetlights only	Estimates emissions from electricity used by streetlights. This methodology should be used If street lighting is a major component of an urban development project. The general electricity use methodology may be used in conjunction to estimate emissions from other electricity use.	CO_2 (t) = Installed Watts (Number of Bulbs **X** Bulb wattage) **X** hours per day of usage **X** 365 **X** EF *country electricity grid* (based on latest IEA statistics)/1000	Electricity Emission Factor Source: IEA CO_2 Emissions from Fossil Fuel Combustion - 2011 Edition http://www.iea.org/publications/free_new_Desc.asp?PUBS_ID=2143

Water and Sanitation Sector: Wastewater			
Operational Emissions	**Description / Input Data Requirements**	**Calculation Method**	**Methodology Source**
Emissions from Wastewater Treatment Lagoons	Estimates fugitive methane emissions from the aerobic or anaerobic digestion of the organic matter during the wastewater treatment process. This method also estimates fugitive nitrous oxide emissions from the nitrogen content in the effluent. **ESTIMATED BOD5 VALUES IN DOMESTIC WASTEWATER FOR SELECTED REGIONS AND COUNTRIES** Country/Region / BOD(5) (g/person/day) Brazil / 50 Other Latin America / 40 Type of Waste discharge: Type of Treatment/Discharge / Methane Correction Factor / Maximum CH_4 Producing	CH_4 (t) = Population served by WWTP **X** EF BOD (kg BOD/person/day) **X** 365 (days)) **X** EF *methane correction factor* **X** maximum CH_4 producing capacity (kg CH_4/kg BOD) by type of treatment/discharge OR CH_4 (t) =	IPCC, Waste - available at http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.html

<table>
<tr><th colspan="4">Water and Sanitation Sector: Wastewater</th></tr>
<tr><th>Operational Emissions</th><th>Description / Input Data Requirements</th><th>Calculation Method</th><th>Methodology Source</th></tr>
<tr><td></td><td>
<table>
<tr><th></th><th></th><th>Capacity
kg CH_4/kg BOD</th></tr>
<tr><td>Untreated - Sea, river, and lake discharge</td><td>0.1</td><td>0.6</td></tr>
<tr><td>Untreated - Stagnant Sewer</td><td>0.5</td><td>0.6</td></tr>
<tr><td>Untreated - Flowing Sewer (open or closed)</td><td>0</td><td>0.6</td></tr>
<tr><td>Treated-Centralized, aerobic treatment plant (well-managed)</td><td>0</td><td>0.6</td></tr>
<tr><td>Treated-Centralized, aerobic treatment plant (overloaded)</td><td>0.3</td><td>0.6</td></tr>
<tr><td>Treated-Anaerobic digester for sludge (excludes CH_4 capture)</td><td>0.8</td><td>0.6</td></tr>
<tr><td>Treated-Anaerobic reactor (excludes CH_4 capture)</td><td>0.8</td><td>0.6</td></tr>
<tr><td>Treated-Anaerobic shallow lagoon (<2m)</td><td>0.2</td><td>0.6</td></tr>
<tr><td>Treated-Anaerobic deep lagoon (>2m)</td><td>0.8</td><td>0.6</td></tr>
<tr><td>Treated-Septic System</td><td>0.5</td><td>0.6</td></tr>
<tr><td>Treated-Latrine (3-5 users, dry climate, above water table)</td><td>0.1</td><td>0.6</td></tr>
<tr><td>Treated-Latrine (Many users, dry climate, above water table)</td><td>0.5</td><td>0.6</td></tr>
<tr><td>Treated-Latrine (Wet climate/flush water use, below ground water table)</td><td>0.7</td><td>0.6</td></tr>
<tr><td>Treated-Latrine (Regular sediment removal for fertilizer)</td><td>0.1</td><td>0.6</td></tr>
</table>
</td><td>Total annual BOD Load (BOD5 load (kg BOD5/day) X 365 (days)

X

EF methane correction factor X maximum CH_4 producing capacity (kg CH_4/kg BOD) by type of treatment/discharge</td><td></td></tr>
<tr><td>Emissions from Digester Gas</td><td>Estimates emissions from digester gas combustion by either using the daily average output of gas from the plant or, if this is unavailable, the population served by the water treatment facility. This estimate incorporates default factors or user-defined project-specific factors for percent methane in the digester gas, combustion efficiency, heat content, and CO_2 and N_2O emission factors.</td><td>From incomplete combustion CH_4 (t) =

Percentage of captured/flared digester gas (kg) of total emissions from wastewater treatment lagoons (m3/year) X EF CH_4 combustion efficiency (0.99)</td><td>IPCC, Waste - available at http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.html

Local Government Operations Protocol For the quantification and reporting of greenhouse gas emissions inventories. Version 1.0, September 2008. These</td></tr>
</table>

Water and Sanitation Sector: Wastewater			
Operational Emissions	**Description / Input Data Requirements**	**Calculation Method**	**Methodology Source**
		+ N_2O (t) = Percentage of captured/flared digester gas (kg) of total generation digester gas (m3/year) (WWTP x EF *biogas generation* (1 ft3/person/day) **X** 0.0283 (conversion from ft3 to m3)) **x** 365 (days) **X** EF *heat content of biogas* (Btu /m3) /1000000 **X** EF N_2O (0.1)/1000	methodologies are adapted for use by local governments from Section 6.2.2 of the 1996 IPCC Guidelines and Section 8.2 of the US EPA Inventory of U.S. Greenhouse Gas Emissions and Sinks (1990-2006). http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.html
N_2O emissions	Estimates emissions from advanced centralized wastewater treatment plants (WWTPs) with controlled nitrification and denitrification and emissions from wastewater effluent discharged to aquatic environments (rivers, streams, lakes)	Direct Emissions from advanced centralized WWTPs with controlled nitrification and denitrification N_2O (t) = Total population served by advanced centralized WWTP **X** EF (g N_2O /person/yr) 3.2 Indirect Emissions from wastewater effluent discharged to aquatic environments (rivers, streams, lakes) N_2O (t) = Default total nitrogen in effluent (kg N/yr)**X** EF (kg N_2O -N/kg N) 0.005	IPCC 2006, Volume 5, Chapter 6. http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_6_Ch6_Wastewater.pdf
Purchased Electricity	Estimates emissions from electricity use during wastewater treatment plant operations.	See calculation in construction section.	Electricity Emission Factor Source: IEA CO_2 Emissions from Fossil Fuel Combustion - 2011 Edition http://www.iea.org/publications/

Water and Sanitation Sector: Wastewater			
Operational Emissions	**Description / Input Data Requirements**	**Calculation Method**	**Methodology Source**
Water Supply: Emissions from Purchased Electricity	Estimates emissions generated from the supply of water as a result of the project **Default Electricity Factor**: 0.404752997 kWh/m3	CO_2 (t) = Annual volume of water supplied (m^3/yr) x EF_i *electricity for* water supplied per m^3 x EF_i *country electricity grid*	Electricity Factor: Average of factors from several different sources, including: The Alliance to Save Energy, Water Program (Mexico's Monclova water project, http://esmap.org/esmap/sites/esmap.org/files/Mexico_Monclova_Water_071010%20final%20edited.pdf ; Veracruz, Mexico project , http://watergy.org/resources/casestudies/veracruz_mexico.pdf ; Pune, India: http://watergy.org/resources/casestudies/pune_india.pdf) Managing Wet Weather with Green Infrastructure, Municipal Handbook: Rainwater Harvesting Policies. Prepared by the Low Impact Development Center (EPA-833-F-08-010) http://beta.asoundstrategy.com/sitemaster/userUploads/site300/Municipal%20rainwater%20harvesting.pdf U.S. Water Supply and Distribution, University of Michigan Center for Sustainable Systems, http://css.snre.umich.edu/css_doc/CSS05-17.pdf

Water and Sanitation Sector: Solid Waste			
Operational Emissions	**Description / Input Data Requirements**	**Calculation Method**	**Methodology Source**
CH_4 Emissions from Landfill Operations	This method is based on a mass of waste disposed, the estimated amount of degradable organic carbon (DOC) content of the waste based on waste type, and the oxidation rate. It does not incorporate any time factors into the methodology. Rather, this methodology assumes that all potential	CH_4 (t) = Percentage of waste type by weight **X** EF *DOC*	2006 IPCC Guidelines for National Greenhouse Gas Inventories. Volume 5.

<table>
<tr><th colspan="4">Water and Sanitation Sector: Solid Waste</th></tr>
<tr><th>Operational Emissions</th><th>Description / Input Data Requirements</th><th>Calculation Method</th><th>Methodology Source</th></tr>
<tr><td></td><td>

CH_4 is released from waste in the year that the waste is disposed of. Although this is not what actually occurs, it gives a reasonable estimate of the current year's emissions if the amount and composition of the waste disposed of has been relatively constant over the previous several years. If, however, there have been significant changes in the rate of waste disposal, a more detailed method of estimating emissions is recommended, such as the Tier 2 or Tier 3 method in the 2006 IPCC Guidelines.

Waste types:

<table>
<tr><th>IPCC Default DOC Fractions by Waste Type</th><th></th><th></th></tr>
<tr><th>Waste Type</th><th>DOC Content (fraction)</th><th>Fossil Carbon (fraction)</th></tr>
<tr><td>Food waste</td><td>0.15</td><td>0</td></tr>
<tr><td>Garden</td><td>0.2</td><td>0</td></tr>
<tr><td>Paper</td><td>0.4</td><td>0.01</td></tr>
<tr><td>Wood and straw</td><td>0.43</td><td>0</td></tr>
<tr><td>Textiles</td><td>0.24</td><td>0.2</td></tr>
<tr><td>Disposable nappies</td><td>0.24</td><td>0.1</td></tr>
<tr><td>Sewage sludge</td><td>0.05</td><td>0</td></tr>
<tr><td>Rubber</td><td>0.39</td><td>0.2</td></tr>
<tr><td>Bulk MSW waste</td><td>0.18</td><td></td></tr>
<tr><td>Industrial waste</td><td>0.15</td><td></td></tr>
</table>

Type of solid waste disposal site

<table>
<tr><th colspan="2">Waste Disposal Classification and Methane Correction Factors DefaultValues</th></tr>
<tr><td></td><td></td></tr>
<tr><td>Managed – anaerobic</td><td>1.0</td></tr>
<tr><td>Managed – semi-aerobic</td><td>0.5</td></tr>
<tr><td>Unmanaged – deep (>5 m waste)</td><td>0.8</td></tr>
<tr><td>Unmanaged – shallow (<5 m waste)</td><td>0.4</td></tr>
<tr><td>Uncategorized SWDS</td><td>0.6</td></tr>
</table>

</td><td>

content (fraction) **X** total mass of waste disposed annually (t/yr) **X** EF *CH_4 fraction value for Degradable Organic Carbon that Decomposes* (DOCf) (0.5)

X

methane correction factor associated with type of solid waste disposal **X** EF *CH_4 fraction value for Fraction of CH_4 in Generated Landfill Gas (F)* (0.5)

-

Amount of CH_4 captured (t/yr)

</td><td>http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.html</td></tr>
<tr><td>Incineration of Waste</td><td>This method estimates the CH_4 and N_2O emissions associated with the incineration of municipal solid waste from a combination of up to four</td><td>

CH_4 (t) =

Annual amount of waste incinerated (t/yr) **X** EF

</td><td>2006 IPCC Guidelines for National Greenhouse Gas Inventories. Volume 5.</td></tr>
</table>

<table>
<tr><th colspan="4">Water and Sanitation Sector: Solid Waste</th></tr>
<tr><th>Operational Emissions</th><th>Description / Input Data Requirements</th><th>Calculation Method</th><th>Methodology Source</th></tr>
<tr><td></td><td>different incineration technologies, including continuous incineration, semi-continuous incineration, batch type incineration, and open burning of waste. The methodology uses the amount of waste incinerated and default CH_4 and N_2O emission factors.

Types of incineration:

<table>
<tr><th colspan="3">IPCC Default CH_4 and N_2O Factors for Incineration of Municipal Solid Waste</th></tr>
<tr><th>Type of Incineration technology</th><th>CH_4 EF (kg/ton waste)</th><th>N_2O EF (kg/ton waste)</th></tr>
<tr><td>Continuous incineration - Stoker</td><td>0.0002</td><td>0.050</td></tr>
<tr><td>Continuous incineration - Fluidized Bed</td><td>0</td><td>0.050</td></tr>
<tr><td>Semi-continuous incineration - Stoker</td><td>0.006</td><td>0.050</td></tr>
<tr><td>Semi-continuous incineration - Fluidized Bed</td><td>0.188</td><td>0.050</td></tr>
<tr><td>Batch type incineration - Stoker</td><td>0.060</td><td>0.060</td></tr>
<tr><td>Batch type incineration - Fluidized Bed</td><td>0.237</td><td>0.060</td></tr>
<tr><td>Open Burning of Waste</td><td>6.50</td><td>0.150</td></tr>
</table></td><td>incineration technology

+

N_2O (t) =

Annual amount of waste incinerated (t/yr) X EF $_i$ incineration technology</td><td>Chapter 5.

http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.html</td></tr>
<tr><td>Fuel Use from Transportation of Waste</td><td>Estimates CO_2, CH_4, and N_2O emissions associated with the transportation of waste to landfills. This method estimates fuel use emissions from mobile sources based on the type and amount of fuel use or by type of vehicle and total miles traveled if fuel use data are not available. Default CO_2, CH_4, and N_2O emission factors are provided, and custom emission factors may be used if available.</td><td>See calculation for fuel use in construction section.</td><td>CO_2 Factors - WRI/ WBCSD Greenhouse Gas Protocol Initiative. Average HWY/CITY and small/medium/large vehicle sizes- http://www.ghgprotocol.org/calculation-tools (mobile)

CH_4 and N_2O Factors - EPA Climate Leaders: http://www.epa.gov/stateply</td></tr>
</table>