4 Greenhouse Gases calculation

In this section it will be described the main sources of emissions, emission factors, assumptions and references. This includes also the numerical model in *pseudo code* (i.e. an outline of the computer program, written in a shorthand language giving an abstract view of the steps that have to be implemented when writing the actual program's code).

4.1 Emissions from electricity generation

In mobGAS, the mix of fuels to produce electricity will determine the calculation of emissions of two greenhouse gases: carbon dioxide and methane. You are asked to choose the relevant fuels for production of electricity in your country (or in the region if you think it is substantially different from those of the country), as well as their percentage in the mix. mobGAS has **default values for the 27 countries of the European Union based on the literature**. To consult or change this values, you should access from the main menu of mobGAS application 'my world > country options > power production'. If you don't have further information about these figures, do not alter the figures in the fields. The figures are percentages, hence the total fuel mix must sum to 100%.

Possible sources of electricity are divided into those that because of their manipulation do produce greenhouse gases and those that do not. Only emissions from the phase of production of electricity are considered. Transport of materials or other phases of operation are not considered.

To know more about electricity sources see section '2.8.2.2. Power production'.

CO_2 emissions from electricity generation

CO_2 emissions derived from electricity consumption were calculated taking in consideration conversion factors from the literature and the shares on power production.

$$CO_2\_emissions\_power = \sum (TOTAL\_PC \times \%_{[fuel]} \times CO_2\_conv\_factor_{[fuel]})$$

Where:

[fuel] – can be oil, coal or natural gas

CO_2_conv_factor$_{[fuel]}$ – conversion factor for the fuel

TOTAL_PC = total power consumption in kWh

$\%_{[fuel]}$ – share of electricity generation due to oil, coal or natural gas

CO_2_emissions_power – emissions of CO_2 due to the production of electricity (kg)

Assumptions

It is assumed the following conversion factors in kg of CO_2 per kwh of electricity produced (based on IPCC guidelines 2006)

CO_2_conv_factor_oil = 0.259

CO_2_conv_factor_coal = 0.334

CO_2_conv_factor_natural_gas = 0.198

4.1.1 CH_4 emissions from electricity generation

CH_4 emissions derived from electricity consumption were calculated taking on consideration conversion factors from the literature and the shares on power production.

$$CH_4\_emissions\_power = \sum (TOTAL\_PC \times \%_{coal} \times CH_4\_conv\_factor_{coal})$$

Where:

CH_4_conv_factor$_{coal}$ – conversion factor for coal

TOTAL_PC - total power consumption in kWh

$\%_{coal}$ – share of electricity generation due coal

CH_4_emissions_power – emissions of CH_4 due to the production of electricity in kg

Assumptions

It is assumed the following conversion factors in kg of CH_4 per kwh of electricity produced (due to coal mining operations) (based on IPCC guidelines 2006).

CH_4_conv_factor$_{coal}$ = 0.00186

Further reading

HYDRO:

DOE - http://hydropower.inl.gov/

EPA - http://yosemite.epa.gov/oar/globalwarming.nsf/content/ImpactsWaterResourcesHydropower.html

NREL- http://www.nrel.gov/learning/re_hydropower.html.

N.B. All links are US links.

SOLAR:

NREL- http://www.nrel.gov/learning/re_photovoltaics.html

WIND:

EWEA - http://www.ewea.org/

EERE - http://www.eere.energy.gov/RE/wind.html

NUCLEAR:

NEA - http://www.nea.fr/

NEI - http://www.nei.org/

DOE - http://www.ne.doe.gov/

LBL - http://www.lbl.gov/abc/

France - http://www.ecolo.org/

Greenpeace - http://www.greenpeace.org/international/campaigns/nuclear

International Atomic Energy Agency - http://www.iaea.org/

EPA - http://es.epa.gov/oeca/sector/#fossil

TRANS-CANADA - http://www.transcanada.com/

A book reference for this issue is: *Standard Handbook of Power Plant Engineering* by Elliot, Thomas C.Published by McGrawHill, Inc. New York, 1989.

On mobGAS it was considered the following shares of production of energy for the year 2004 (Eurostat, 2006) – Table 44.

Table 44 Shares of production of energy

Power generation	Hydric	Coal	Nuclear	Oil	Wind	Natural Gas	Solar
EU 25 *	11	32	31	4	2	20	0
Belgium	2	13	55	2	0	28	0
Bulgaria	8	46	40	2	0	4	0
Czech Republic	5	50	27	2	4	12	0
Denmark	2	13	55	2	0	28	0
Germany	11	28	32	5	2	21	0
Estonia	3	60	31	0	0	6	0
Ireland	0	93	0	0	0	7	0
Greece	0	55	0	4	16	25	0
Spain	13	29	23	9	6	20	0
France	12	5	78	1	0	4	0
Italy	17	17	0	20	1	45	0
Cyprus	9	60	0	14	2	15	0
Latvia	66	1	0	1	1	31	0
Lithuania	5	0	79	2	0	14	0
Luxembourg	21	2	0	0	1	76	0
Hungary	1	27	35	2	0	35	0
Malta	0	0	0	100	0	0	0
Netherlands	0	28	4	3	2	63	0
Austria	61	16	0	3	1	19	0
Poland	2	93	0	2	0	3	0
Portugal	22	37	0	13	2	26	0
Romania	29	38	10	4	0	19	0
Slovenia	27	35	36	0	0	2	0
Slovakia	14	19	56	2	0	9	0
Finland	40	6	51	1	1	1	0
Sweden	40	6	51	1	1	1	0
United Kingdom	2	36	20	1	1	40	0

Note: the values extracted from Eurostat were in *GWh* (Gigawatt hour) of Gross electricity generation. On mobGAS the share of coal aggregates the shares on electricity generation from coal, lignite and biomass fired power stations. The share on natural gas aggregates the share on electricity generation from natural gas and derived gas fired power stations.

* EU 25 average not including Bulgaria and Romania

4.2 CO_2 calculations

The carbon dioxide (CO_2) emissions model consists of an account of the daily CO_2 emissions derived from personal consumption of electricity, fuel for transportation, heating, cooking and waste incineration. In the case of electricity, only CO_2 emissions from the operation of apparatus are considered, i.e. no industrial processes are considered. The same applies to fuel consumption; mobGAS does not consider emissions from the phase of vehicle construction or from fugitive emissions from liquid fuels or refining processes.
The rationale of this model is to assess the quantity of CO_2 produced in activities that involve COMBUSTION processes, such as of fossil fuels, waste, etc. yet related to ordinary human activities.

To calculate the CO_2 emissions two different main types of calculations were made: one regarding the direct emissions from the combustion of fossil fuels or other fuels in different activities such as transport or cooking (natural gas; butane gas; LPG; biodiesel; petrol; diesel; airplane fuel; wood; charcoal; pellet and incineration of waste) and other regarding the production of energy.
In this section of the help we will only focus on the emissions due to the production of energy. To have more information about CO_2 emissions other than due to electricity production, please consult the apposite appliance or activity section.

The final value of CO_2 emissions is the sum of CO_2 emissions due to electricity generation and due to the combustion of fossil fuels and waste.

4.2.1 Total CO_2 emissions

CO_2_EMISSIONS = CO_2_emissions_power + CO_2_emissions_butane_gas + CO_2_emissions_natural_gas + CO_2_emissions_wood + CO_2_emissions_wood_stove + CO_2_emissions_charcoal + CO_2_emissions_pellet + CO_2_emissions_biodiesel + CO_2_emissions_petrol + CO_2_emissions_petrol_motorcycle + CO_2_emissions_LPG + CO_2_emissions_LPG_boiler + CO_2_emissions_kerosene + CO_2_emissions_waste

Where:

CO_2_emissions_biodiesel - emissions of CO_2 due to the burning of biodiesel on public transports

CO_2_emissions_butane_gas - emissions of CO2 due to the burning of butane gas (e.g. cooking, heating)

CO_2_emissions_charcoal - emissions of CO2 due to the burning of charcoal for barbecue

CO_2_emissions_kerosene - emissions of CO2 due to the burning of kerosene for airplane travels

CO_2_emissions_LPG - emissions of CO2 due to the burning of LPG on transports

CO_2_emissions_LPG_boiler - emissions of CO_2 due to the burning of LPG in boilers

CO_2_emissions_natural_gas - emissions of CO_2 due to the burning of natural gas (e.g. cooking, heating)

CO_2_emissions_pellet - emissions of CO_2 due to the burning of pellet for heating

CO_2_emissions_petrol - emissions of CO_2 due to the burning of petrol (e.g. transports, outdoor activities)

CO_2_emissions_petrol_motorcycle - emissions of CO_2 due to the burning of petrol on motorcycles with mix fuel (< EURO 1)

CO_2_emissions_power – emissions of CO_2 due to the production of electricity

CO_2_emissions_waste - emissions of CO_2 due to waste incineration

CO_2_emissions_wood - emissions of CO_2 due to the burning of wood (e.g. cooking, fireplace)

CO_2_emissions_wood_stove - emissions of CO_2 due to the burning of wood on stoves

CO_2_EMISSIONS – total emissions of CO_2

To have an overview of how the emissions from CO_2 were calculated, please consult the 'emissions from electricity generation' section on this chapter and 'groups description' chapter.

4.2.2 Facts about CO2

1. Of the three greenhouse gases CO_2 is the most studied and for which more reliable information exists
2. It remains in the atmosphere for a long time (for many decades to centuries), so affecting radiative forcing on long time scales.
3. CO_2 emissions from industrial processes in 1991 (1000 metric tons) (UNEP/IUP, 1997):

World	22 339 408
Africa	715 773
Europe	6 866 494
North/central America	5 715 466
South America	605 029
Asia	7 118 317
Oceania	297 246

4.3 CH_4 calculations

The methane (CH_4) emissions model consists of an account of the daily methane emissions derived from personal consumption of meat, dairy products, rice, eggs and household waste management. Also methane emissions from coal mining operations are taken in consideration for the production of electricity.

Formation of methane is related to anaerobic decomposition processes of organic material (i.e. the breakdown of molecules into simpler molecules or atoms by microorganisms that can survive in the partial or complete absence of oxygen) and enteric fermentation. Therefore some processes related to everyday activity, implying the emission of CH_4 are considered here, such as disposal and treatment of organic waste, rice cultivation, raising of cattle and poultry, etc.

CH_4 is the second most important greenhouse gas. Its main sources in EU are agriculture (48%) followed by waste treatment and disposal and also leakage from natural gas distribution networks (European Commission, 1999). According to the EEA (2005), EU methane emissions fell by 25% between 1990 and 2003. Fugitive emissions of CH_4 decreased due mainly to the decline of coal mining, followed by the waste sector, due mainly to reducing the amount of biodegradable waste in landfills and installing landfill gas recovery.

4.3.1 Total CH_4 emissions

CH_4_EMISSIONS = CH_4_emissions_power + CH_4_emissions_natural_gas + CH_4_emissions_wood + CH_4_emissions_wood_stove + CH_4_emissions_charcoal + CH_4_emissions_biodiesel + CH_4_emissions_petrol + CH_4_emissions_petrol_motorcycle + CH_4_emissions_LPG + CH_4_emissions_LPG_boiler + CH_4_emissions_kerosene + CH_4_emissions_meat + CH_4_emissions_rice + CH_4_emissions_dairy + CH_4_emissions_eggs + CH_4_emissions_waste

Where:

CH_4_emissions_biodiesel - emissions of CH_4 due to the burning of biodiesel on public transports

CH_4_emissions_charcoal - emissions of CH_4 due to the burning of charcoal for barbecue

CH_4_emissions_dairy - emissions of CH_4 due to breeding of cows

CH_4_emissions_eggs - emissions of CH_4 due to breeding of poultry

CH_4_emissions_kerosene - emissions of CH_4 due to the burning of kerosene for airplane travels

CH_4_emissions_LPG - emissions of CH_4 due to the burning of LPG on transports

CH_4_emissions_LPG_boiler - emissions of CH_4 due to the burning of LPG in boilers

CH_4_emissions_meat - emissions of CH_4 due to breeding of animals (pork, poultry, cow and lamb)

CH_4_emissions_natural_gas - emissions of CH_4 due to the burning of natural gas (e.g. cooking, heating)

CH_4_emissions_petrol - emissions of CH_4 due to the burning of petrol (e.g. transports, outdoor activities)
CH_4_emissions_petrol_motorcycle - emissions of CH_4 due to the burning of petrol on motorcycles with mix fuel (< EURO 1)
CH_4_emissions_power – emissions of CH_4 due to the production of electricity
CH_4_emissions_rice - emissions of CH_4 due to production of rice (enteric fermentation)
CH_4_emissions_waste - emissions of CH_4 due to waste management (dump, landfill, incineration and composting)
CH_4_emissions_wood - emissions of CH_4 due to the burning of wood (e.g. cooking, fireplace)
CH_4_emissions_wood_stove - emissions of CH_4 due to the burning of wood on stoves
CH_4_EMISSIONS – total emissions of CH_4

To have an overview of how the emissions from CH_4 were calculated, please consult the 'emissions from electricity generation' section on this chapter and 'groups description' chapter.

4.3.2 Facts about CH_4

1. Wetland or 'paddy' rice farming produces roughly 1/5 or 1/4 of global methane emissions from human activities. This emission is due to bacteria and other micro-organisms in the soil of the flooded rice paddy that decompose organic matter producing methane (UNEP/IUC, 1997).
2. Livestock account for about 1/4 of the CH_4 emissions from human activities.
3 There is a great deal of UNCERTAINTY on the emission estimates of CH_4 because the emissions from agricultural and waste management sources are not well quantified.
4. The greenhouse effect of CH_4 is estimated to be 72 times that of carbon dioxide over a 20-year period and 21 times over a 100-year period (IPCC, 2007).
5. Methane is estimated to be the cause of 14% of the global greenhouse effect (IPCC 2007) methane from landfills has been estimated to make up 28% of total methane emissions from EU in 1995 (EEA-ETC/W, 1999).
6. Methane emissions from the waste management sector fell by 38 % between 1990 and 2005 (EEA, 2007).

4.4 N_2O calculations

The nitrous oxide (N_2O) model consists of an account of the yearly nitrous oxide emissions derived from personal consumption of vegetables produced with fertilisers, raising of cattle, burn of fossil fuels and waste management (incineration and composting).
Indeed, fertiliser use increases nitrous oxide emissions, because the nitrogen contained on nitrogenous fertilisers enhances the processes of nitrification and denitrification performed by microorganisms in the soil - those processes lead to the emission of nitrous oxide.
There is, however, a great deal of uncertainty in the measurement of how much quantity of N_2O is emitted per unit of fertiliser applied. This is because dependent upon the soil conditions and also local climate, as well as on the type and quantity of fertiliser applied.

4.4.1 Total N_2O emissions

N_2O_EMISSIONS = N_2O_emissions_natural_gas + N_2O_emissions_wood + N_2O_emissions_wood_stove + N_2O_emissions_charcoal + N_2O_emissions_biodiesel + N_2O_emissions_petrol + N_2O_emissions_petrol_motorcycle + N_2O_emissions_kerosene + N_2O_emissions_meat + N_2O_emissions_rice + N_2O_emissions_dairy + N_2O_emissions_eggs + N_2O_emissions_vagetables + N_2O_emissions_waste

Where:

N_2O_emissions_biodiesel - emissions of N_2O due to the burning of biodiesel on public transports

N_2O_emissions_charcoal - emissions of N_2O due to the burning of charcoal for barbecue

N_2O_emissions_dairy - emissions of N_2O due to breeding of cows

N_2O_emissions_eggs - emissions of N_2O due to breeding of poultry

N_2O_emissions_kerosene - emissions of N_2O due to the burning of kerosene for airplane travels

N_2O_emissions_meat - emissions of N_2O due to breeding of animals (pork, poultry, cow and lamb)

N_2O_emissions_natural_gas - emissions of N_2O due to the burning of natural gas (e.g. cooking, heating)

N_2O_emissions_petrol - emissions of N_2O due to the burning of petrol (e.g. transports, outdoor activities)

N_2O_emissions_petrol_motorcycle - emissions of N_2O due to the burning of petrol on motorcycles with mix fuel (< EURO 1)

N_2O_emissions_rice - emissions of N_2O due to production of rice

N_2O_emissions_vagetables - emissions of N_2O due to fertilizers used on agriculture

N_2O_emissions_waste - emissions of N_2O due to waste management (incineration and composting)

N_2O_emissions_wood - emissions of N_2O due to the burning of wood (e.g. cooking, fireplace)

N_2O_emissions_wood_stove - emissions of N_2O due to the burning of wood on stoves

N_2O_EMISSIONS – total emissions of N_2O

To have an overview of how the emissions from N_2O were calculated, please consult the groups section.

4.4.2 Facts about N_2O

1. N_2O is removed from the atmosphere by photolysis (breakdown by sunlight) in the stratosphere.
2. The greenhouse effect of N_2O is estimated to be 289 times that of carbon dioxide over a 20-year period and 310 times over a 100-year period (IPCC, 2007).
3. The increase in N_2O concentration is primarily due to agriculture.
4. Current estimates are that about 40% of total N_2O emissions are anthropogenic but individual source estimates remain subject to significant uncertainties (IPCC, 2007).
5. Agriculture is the source of 52% of N_2O emissions in the EU (European Commission, 1999).

4.5 GHG calculations

mobGAS provides an indication of the total emissions of Greenhouse Gases (GHG) in equivalent carbon dioxide emissions for the three GHG considered (Carbon dioxide, methane and Nitrous oxide).

Equivalent carbon dioxide is the amount of carbon dioxide emission that would cause the same integrated radiative forcing, over a given time horizon, as an emitted amount of a well mixed greenhouse gas or a mixture of well mixed greenhouse gases. The equivalent carbon dioxide emission is obtained by multiplying the emission of a well mixed greenhouse gas by its Global Warming Potential for the given time horizon. For a mix of greenhouse gases it is obtained by summing the equivalent carbon dioxide emissions of each gas. Equivalent carbon dioxide emission is a standard and useful metric for comparing emissions of different greenhouse gases but does not imply exact equivalence of the corresponding climate change responses (IPCC, 2007).

In mobGAS, when an indication of total GHG emission is provided (e.g. users ranking, emissions log, etc.) it is only referring to the aggregate emissions of CO_2, CH_4 and N_2O. Even though these are the most important GHG, there are other important GHG (see Climate Change & Greenhouse Gases section).

For each GHG it is considered a global warming potential (GWP). The GWP represents the combined effect of the differing times these gases remain in the atmosphere and their relative effectiveness in absorbing outgoing thermal infrared radiation (IPCC, 2007).

The equivalent carbon dioxide emission is obtained by multiplying the emission of the GHG by the global warming potential.

On mobGAS we used the GWP for a 100-year time frame (the same GWP of the Kyoto Protocol). The GWP for a 100-year time frame is 21 for CH_4 and 310 for N_2O (Forster *et al.*, 2007).

$$GHG\_emissions = CO_2\_emissions + 21 \times CH_4\_emissions + 310 \times N_2O\_emissions$$

Where:

CO_2_emissions – Total amount of CO_2 emissions calculated by mobGAS in kg

CH_4_emissions – Total amount of CH_4 emissions calculated by mobGAS in kg

N_2O_emissions – Total amount of N_2O emissions calculated by mobGAS in kg

GHG_emissions – total amount of GHG's emissions in kg calculated by mobGAS taken in consideration CO_2, CH_4 and N_2O in equivalent of CO_2

Assumptions

For the calculation of Total GHG it was considered the following Global Warming Potentials for a 100-year time frame:

CH_4 – 21 CO_2 eq.
N_2O – 310 CO_2 eq.

4.5.1 Facts about GHG

1 - Greenhouse gas emissions in the EU-27 decreased by 7.9 % between 1990 and 2005. (EEA, 2007)
2 – EU-27 greenhouse gas emissions are projected to remain approximately at 2005 levels by 2010, but with planned additional policies, EU-27 greenhouse gas emissions could decrease from 2005 levels down to 11 % below their 1990 levels by 2010. (EEA, 2007)
3- Under the Kyoto Protocol, the EU-15 must reach an average annual level of greenhouse gas emissions 8 % lower than in the base year (close to 1990), during the whole period 2008–2012.
4 - In 2005, a 2 % reduction of EU-15 greenhouse gas emissions compared to base-year levels had been achieved. (EEA, 2007)