GLOBAL GREENHOUSE GAS EMISSIONS FROM ENERGY SYSTEMS

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ABSTRACT

In this paper we are presenting energy system of global greenhouse gases, Gases present in the atmosphere helps to control earth temperature. According to the IPCC, the anthropogenic greenhouse gas (GHG) emissions contributing most evidently to Global Warming in terms of relative radiative forcing are CO_2 , CH_4 , halocarbons and N2O. CO2 emissions originate mainly from combustion of fossil fuels, and are quite well-known. However, total emission rates of CH4 and N2O are much more uncertain. The most straightforward accounting of GHG emissions is based on emission factor associated with combustion of the various fossil fuels. This approach can also be used for estimating the overall national emission inventories, but is not practical when trying to fully account for emissions associated with the use of specific technologies. Energy systems, transport systems, material manufacturing, production of chemicals, waste treatment and disposal, as well as agricultural products, have all been assessed using detailed process analysis developed under common and consistently defined rules.

Keyword: - *CO_2, CH_4, Environment, Energy, Global Warming etc.*

1. INTRODUCTION

According to the IPCC, the anthropogenic greenhouse gas (GHG) emissions contributing most evidently to Global Warming in terms of relative radiative forcing are CO2 , CH4 , halocarbons and N2O [3]. Radiative forcing is the change in the net vertical irradiance (in Wm-2) at the boundary between the troposphere and the stratosphere. Compared to the pre-industrial era (250 years ago) additional radiative forcing due to increases of GHGs is estimated to be 2.43 Wm-2 , of which CO contributes most (1.46 Wm-2 2), followed by CH (0.48 Wm-2), halocarbons (0.34 Wm-2 4), and N2O (0.15 Wm-2). Other possible factors influencing the global climate are less well-understood, and so quantitatively more uncertain. Among them are: stratospheric ozone (cooling); tropospheric ozone (warming); sulphate (cooling); black carbon and organic carbon (warming or cooling); biomass burning (cooling); mineral dust (warming or cooling); aerosol indirect effects (cooling); land-usage (change of albedo, i.e. share of reflected sun light); and solar variation (minimal). Table 1.1 gives the global emissions of the major GHGs and the contribution of anthropogenic sources in the late 1990s. CO2 emissions originate mainly from combustion of fossil fuels, and are quite well-known. However, total emission rates of CH4 and N2O are much more uncertain. Halocarbons are molecules containing carbon, and either chlorine, fluorine, bromine or iodine. Among the halocarbons are several refrigerants, used as working fluids for cooling or heating. Many refrigerants of use in the industry sector (in refrigerators, heat pumps, air conditioners, etc.) have very high Global Warming Potential (GWP) on a per-kg-emitted basis. Energy scenarios for the reduction of CO2 emissions often include increased use of heat pumps, which substitute for fossil-fuel heating systems, and for which refrigerant emissions caused by leakages counteract (to a certain extent) the total GHG balance. In contrast, halocarbon emissions are almost completely man-made. Table 6.1 does not include refrigerants such as CFC-11 or CFC-12, which have been banned because of their high ozone-depleting potential; they currently have low emission rates, but are still abundant in the atmosphere because of past emissions.

	Annual Emissions [Mt/year]	Life time [years]	GWP 100-yr	CO_2-equiv. 100-yr [Mt/year]
CO_2:	29000		1	29000
- Fossil fuels	*22400*			*22400*
- Cement production	*700*			*700*
- Land use, etc.	*6000 (3000-9000)*			*6000*
CH_4:	600	8.4-12	23	13800
- Energy	*100 (89-110)*			*2300*
- Biomass burning	*40 (23-55)*			*900*
- Other anthropogenic sources	*230*			*5300*
- Natural sources	*230*			*5300*
N_2O:	26	120	296	7700
- Automobiles	*0.3 (0.2-0.4)*			*90*
- Industry, incl. Energy	*2.0 (1.1-2.8)*			*600*
- Other anthropogenic sources	*8.5 (7.6-9.6)*			*2500*
- Natural sources	*15*			*4500*
HFC refrigerants:				
HFC-23	0.007	260	12000	84
HFC-134a	0.025	13.8	1300	33
HFC-152a	0.004	1.4	120	0.5
Other halocarbons:				
Perfluoromethane (CF_4)	0.015	>50000	5700	86
Perfluoroethane (C_2F_6)	0.002	10000	11900	24
Sulphur hexafluoride (SF6)	0.006	3200	22200	133

Emissions are given in real mass per year and CO_2-equivalent mass per year.GWP=Global Warming Potential; HFC=Hydrofluorocarbon. All figures have been rounded.

Table 1. 1: Annual emissions of important greenhouse gases in the late 1990s.

2. THE MOST STRAIGHTFORWARD ACCOUNTING OF GHG EMISSIONS IS BASED ON EMISSION FACTORS

The most straightforward accounting of GHG emissions is based on emission factors associated with combustion of the various fossil fuels. This approach can also be used for estimating the overall national emission inventories, but is not practical when trying to fully account for emissions associated with the use of specific technologies. While uses of nuclear and renewable energy sources exhibit practically negligible emission levels for GHGs at the stage of power generation, the same is not necessarily true for other stages of the corresponding energy chains. In addition, emissions may arise when manufacturing the components for the plants, transporting fuels and other materials, or at the decommissioning stage. LCA, an approach utilizing process-chain analysis specific to the types of fuels used in each process, allows for the full accounting of all such emissions, even when they take place outside the national boundaries. Thus, LCA considers not only emissions from power plant construction, operation and decommissioning, but also the environmental burdens associated with the entire lifetime of all the relevant upstream and downstream processes within the energy chain. These processes include exploration, extraction, processing and transport of the energy carrier, as well as waste treatment and disposal. The direct emissions include releases from the operation of power plants, mines, processing factories and transport systems. In addition, indirect emissions are also covered, originating from manufacturing and transport of materials from energy inputs to all steps in the chain, as well as those from the infrastructure. An alternative, non-process-oriented approach is the Input/Output (I/O) method, which divides the economy into distinct sectors, and is based on the input and output between the sectors to generate the energy flows and associated emissions. A hybrid approach is also frequently employed, combining LCA and I/O methods; the I/O method is then used exclusively for assessing the processes of secondary importance.

3. ENERGY CHAIN SPECIFIC GREENHOUSE GAS EMISSIONS

Some basic features of the LCA methodology, as applied to the Swiss applications, are summarized below; most of these principles also apply to other state-of-the-art studies which, however, may differ in terms of scope, level of detail, specific assumptions, and methodology applied (some results are based on hybrid approaches). The most important features are listed here. Energy systems, transport systems, material manufacturing, production of chemicals, waste treatment and disposal, as well as agricultural products, have all been assessed using detailed process analysis developed under common and consistently defined rules. Electricity inputs have been modeled using production technology or supply mix as close as possible to the actual situation. In the case of lack of specification, the UCTE (Union for the Co-ordination of Transmission of Electricity, mainly continental Western Europe) mix was used as an approximation. Allocation criteria were developed for multi-purpose processes. The results provided in this section focus on electricity supply, but selected results are also given for heat generation and cogeneration systems. All GHG emissions are given using GWP for the 100 years time horizon [3].

4. FOSSIL ENERGY CHAINS

Hard Coal

In the Swiss study [1], European, country-specific, average power plants were analysed, operating around year 2000. For the estimation of the infrastructure of the plants, two rated power levels of 100 MW and 500 MW were considered; a mix with a share of 10% and 90%, respectively, was defined for the reference plant.

Lignite

The reference plant used for lignite in the Swiss LCA study [1] has similar characteristics to those for hard coal, but a larger share of plants of low-rated power has been used. The reference unit is assumed to be used for a base load of 6000 hours of operation per year, at full capacity, and for a total of 200 000 hours during its lifetime.

Oil

Since the role of oil in electricity generation is decreasing, only a few key factors are provided in the Swiss study [1]. The average GHG emissions of oil chains from the European countries range from 519 g CO2-equiv./kWh to 1200 g CO2-equiv./kWh, depending on the respective use of power plants for base or peak load.

Gas

Natural Gas Chain For natural gas, as for the other fossil-fuel electricity or heating systems, the dominant contributor to GHG emissions is CO2 from the power plant or boiler. Natural gas is transported in pipelines over long distances. Since natural gas consists mainly of methane (i.e. natural gas itself is a greenhouse gas!), leakages in the pipelines can contribute significantly to the total GHG emissions. For European countries, the CO4 emissions can make up to about 10% of the total GHG emissions in the full chain, depending on the location of the natural gas power plant or boiler.

Industrial Gas

Industrial gas covers blast furnace gas from pig iron production and coke-oven gas. The results cited here are based on the mix used for electricity production in the UCTE countries for the year 2000. Due to its high CO2 content, blast furnace gas has high CO2 emission factors of 90 g/MJ to 260 g/MJ of burned gas, while emission factors of coke-oven gas range from 40 g/MJ to 90 g/MJ of the gas burned.

Heating and Cogeneration

Heating

Two hard-coal heating systems were modelled in the Swiss LCA study [1]: an industrial furnace with thermal capacity in the range 1 MW to 10 MW, and a stove of about 5 kW to 15 kW. The thermal efficiency of the furnace is 80%, while that of the stove is 70%. The industrial furnace is assumed to be fuelled with the average Western European hard-coal supply mix, the stove either with coke or briquettes. Assuming that all the CO is oxidised to CO2 , it contributes about 10% to the total GHG emissions associated with the stove. Direct CH4 emissions from burning briquettes are 20 times higher than from burning coke, and direct methane emissions are about50% of the total methane emissions calculated for the chain.

5. NUCLEAR ENERGY CHAIN

The amount of GHG emissions from the nuclear chain associated with Light Water Reactors (LWRs) is controlled by several parameters: the nuclear cycle considered, the average enrichment and burn-up at discharge of the fuel, the lifetime of the plant, especially of the power plant, and, most important, the enrichment process used, together with the electricity supply to the enrichment diffusion plant Average U-235 enrichment ranges between to 3%, while the hydrofluoro- and hydrochloro-carbon 3.8% for French PWRs and Swiss BWRs, to 4.2% for emissions from the enrichment stage are below 5%. The GHG associated with the power plant ranges from (approximately) 1.0 to 1.3 g CO2-equiv./kWh, while that from waste management (back-end or downstream) is between (approximately) 0.6 and 1.0 g CO2-equiv./kWh. The upstream chain makes up the rest, though this may change substantially according to the main assumptions made for the cycle. In comparison, the total GHG emissions for the Chinese reference (once-through) nuclear cycle were estimated at 9 g CO2-equiv./kWh, assuming centrifuge technology for all enrichment services [6]. Conversely, taking the extreme assumption of only diffusion enrichment, powered by coal plants, the highest GHG emission was calculated at nearly 80 g CO2-equiv./kWh. If electricity mixes and mixed fuels (also including gas and nuclear) would be used together, this amount could be almost halved, i.e. to about 45 g CO2-equiv./kWh. The maximum was calculated for The study [1] assumes partial or total reprocessing of Germany, under the assumption of about 13% MOX, the fuel, according to the current conditions in West and a mix of enrichment services, including 10% of European countries. In particular, 40% of the total the USEC diffusion plant, which is assumed to be spent fuel produced at Swiss and German plants supplied by coal power plants. Nearly 70% of the during their lifetime was assumed to be reprocessed. enrichment services are assumed to be supplied by For France, this is most likely to be 100%, whereas for URENCO facilities (one is located in Northern the UCTE countries, a weighted average of 80% was Germany), and are based on centrifugal technology, assumed.

6. RENEWABLE ENERGY CHAINS

Biomass

For biomass-burning boilers and cogeneration systems modelled in the Swiss LCA study [1], only untreated wood was considered; i.e. no account was taken of waste-wood combustion. The emission of direct, biogenic CO_2 due to combustion was calculated assuming a carbon content of dry wood of 0.494% for all types of wood fuels. All carbon absorbed by the trees, and contained in the wood eventually burned, was assumed to be emitted during combustion, either as CO_2 or as CO. Furthermore, all CO was assumed to be fully oxidised to CO_2 in the atmosphere, and as such contributed to the total GHG level.

Hydro

Swiss and European Hydro Power Plants In order to reflect the situation in Switzerland and the rest of Europe, two types of hydro-power plant (storage and run-of-river), and one type of pumped-storage plant, were analyzed in the Swiss LCA study [1]. A representative sample was used, comprising four run-of-river power plants in Switzerland and one in Austria. Lifetime was assumed to be 80 years for the fixed structures, and 40 years for other parts.

Wind

The production of electricity from wind turbines generates no direct GHG emissions, though indirect emissions may be attributed to the construction and assembling of the wind power plant itself, the production and assembling of the materials from which it is composed, the transport of these materials to the site, and the waste disposal processes. The Swiss LCA study [1] analysed several such wind turbines, under both Swiss-specific and European-averaged conditions. Plants of 30 kW, 150 kW, 600 kW and 800 kW were modelled for on-shore conditions, and one unit (based on data from the wind park Middelgrunden, near Copenhagen) of 2 MW capacity for off-shore conditions. Actual capacity factors in Switzerland range from 8% to 14%. The average for Europe was assumed to be 20% for on-shore, and 30% for off-shore, units.

Solar

Mono (mc-Si) and poly-crystalline (pc-Si) silicon cell technologies, utilised in current photovoltaic (PV) panels, have been analysed [1] in a Swiss LCA study, and specifically for Swiss conditions (i.e. yield of 885 kWh kW^{-1} peak per annum for slanted-roof units). The plants considered were grid-connected 3 kW peak units, installed on buildings in two (integrated and non-integrated slanted-roof) configurations; both façade and flat-roof options were considered. For this study, the production chain has been decomposed into detailed steps, and the efficiency of the PV cells is assumed to be 16.5% for mc-Si, and 14.8% for pc-Si, respectively.

Heat Pumps

An attractive alternative to fossil fuel boilers is the use of heat pumps. Heat pumps can gain heat from ambient air, from the ground, or from groundwater. The seasonal performance factor (SPF) of an electrical heat pump is the ratio of the annual heat energy output to the annual electrical energy input. The SPF depends on the efficiency of the heat pump (COP, Coefficient of Performance), but also on the local climatic conditions and the actual integration of the heat pump into the building (e.g. low-temperature or high-temperature hydronic heat distribution system).

7. CONCLUSIONS

The production of electricity from wind turbines generates no direct GHG emissions, though indirect emissions may be attributed to the construction and assembling of the wind power plant itself, the production and assembling of the materials from which it is composed, the transport of these materials to the site, and the waste disposal processes. Some basic features of the LCA methodology, as applied to the Swiss applications, are summarized below; most of these principles also apply to other state-of-the-art studies which, however, may differ in terms of scope, level of detail, specific assumptions, and methodology applied (some results are based on hybrid approaches). The most important features are listed here. Energy systems, transport systems, material manufacturing, production of chemicals, waste treatment and disposal, as well as agricultural products, have all been assessed using detailed process analysis developed under common and consistently defined rules. There is growing interest and concerns regarding Green House Gas (GHG) emissions as these are a major contributor to global warning. Main GHGs from water bodies are carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). Holding capacity of heat by these gases is high which results in “greenhouse effect”. In current times, GHG concentrations in the atmosphere has been considerably increasing due to anthropogenic emissions from fossil fuel burning, creation of artificial wetlands, deforestation, etc. But recent research proved that natural water bodies also emits large amount of GHGs which are responsible for the climate change.

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