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CO_2-emissions associated with different electricity mixes

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Contents

Summary

Agder Energi Produksjon AS want to document the CO_2- equivalents associated with their electricity production, and relate the data to emission properties of various national and regional electricity mixes. Emissions related to the consumption of electricity may be calculated in a number of ways. There are a variety of databases to choose from and a variety of system approaches that can be used.

This project collects the best available data for greenhouse gas emissions associated with different electricity production mixes and indicates the potential range of emissions that can be used and some of the areas where more research is needed.

The data presented will be used by Agder Energi Production AS for illustrating the benefits of purchasing Guarantees of Origin for electricity. The Guarantees of Origin enable use of emissions associated with Norwegian Hydropower in documenting properties of renewable power products and is a disclosure of energy sources for electricity supply.

The results obtained for greenhouse gas emissions associated with different electricity production mixes are shown in the table below.

		Electricity Mix (2007)					
	g CO2-equivalents/ kWh	Norwegian Hydroelectricity	Nuclear	Coal	Other fossil fuels	Other renewable fuels	Waste
Norwegian Hydro Electricity	1.99	100					
Norwegian Residual Mix	63.80	89.85	4.07	1.73	2.36	1.78	0.21
Swedish electricity	55.90	49.72	43.86	2.16	1.94	2.15	0.15
Swiss electricity	30.47	54.01	41.06	0.00	0.00	0.4	2.93
German electricity	741.71	4.33	22.08	48.86	1.42	10.2	3.2
UCTE electricity	629.75	11.28	29.10	39.44	14.86	4.7	0.62

This report documents the data used for calculating greenhouse gas emission properties related to different electricity production mixes. Data for electricity mixes, electricity production from different energy carriers and grid losses are documented. The software SimaPro 7.1.8 was used for the calculations performed.

1 Introduction

The Nordic electricity system consists mainly of hydroelectricity and nuclear power; these two sources make out the base of the electrical flow, and are produced steadily. Oil, coal and gas ensure the top load and production of electricity from these energy carriers is flexible enough that production can be easily adjusted up, or down (although the grid capacity and the price of energy carriers can complicate the picture somewhat). In reality, this means that the average electricity in the Nordic region has a large proportion of hydropower and nuclear power, but the marginal electricity (or an extra kWh consumed in addition to the normal consumption) comes mainly from coal, or gas power. One could say that continuous hourly measurement is required, in order to find the exact source of the electricity used.

What sort of electricity is used for a given purpose and which emissions are associated with this is no simple issue. The choice of energy carrier is both a technical and political question. Different political targets and different systems approaches can be used to calculate what is actually transported through the power lines.

This small project gives the status for the best available data that Ostfold Research has access to today. The sources of these data are given in detail and the greenhouse gas emissions (g CO_2-equivalents/kWh) are given for the different electricity production mixes analysed. This information is the basis for a summary sheet Agder Energy Production AS will use for their customers and as the background for future research work.

2 Energy Mix Data

Data Used

We have compared 6 different electricity production mixes in the LCA software SimaPro 7.1.8. The greenhouse gas emissions (g CO_2-equivalents) for these mixes were compared. The greenhouse gas emissions were calculated for the following electricity production mixes:

- Norwegian hydroelectricity.
- Residual mix, Norway 2007
- Sweden 2007
- Switzerland 2007
- Germany 2007
- UCTE 2007

For each mix, data for that specific country has been chosen, if available. Where specific country data were not available, the data which we considered the closest was chosen. An explanation of the data chosen, and the reasons for its choice, is given below. In general, the latest edition of the EcoInvent database (EcoInvent 2008) has been used, except for cases where Ostfold Research has more specific data from previous research projects (e.g. Norwegian hydropower). The data for the given mixes has been copied from the database and given under the headings for each mix. The text is mostly copied directly from the given database. The grid losses are also explained for each mix. If data is used in more than one mix, the information is not repeated.

2.1 Mix data

The mixes used are specified in the table below, data given are in % of the total mix:

Energy source	Norwegian Hydroelectricity	Residual mix 2007	Sweden 2007	Switzerland 2007	Germany 2007	UCTE 2007
Nuclear		4,07	43,86	41,06	22,08	29,10
Hydro	100	89,85	49,72	54,01	4,33	11,28
Solar/wind		1,02	0,29	0,06	6,76	3,46
Hard coal		1,73	1,22	0,00	22,78	27,11
Brown coal (lignite)			0,00	0,00	24,51	12,33
Peat		0,19	0,04	0,00	0,00	
Coal gasses			0,94	0,00	1,57	
Oil		0,09	1,70	0,26	1,50	1,79
Natural gas		2,08	0,20	1,16	11,70	13,07
Solid biomass		0,76	1,83	0,10	1,55	0,62
Industrial waste			0,05	0,43	0,02	
Minicipal waste		0,21	0,12	2,69	1,31	0,62
Biomass gasses			0,03	0,24	1,89	
Liquid biomass						0,62
Total	100	100	100	100	100	100

It should be noted that both industrial and municipal waste are treated as the same and that the data in these electricity production scenarios is allocated to waste management, so in this case, the emissions associated with this activity are zero. This is an assumption that should be examined in greater detail in the future.

2.1.1 Residual mix for Norway 2007

Løseth, M., 2008: A model for estimating the Global Warming Potential of the Norwegian Electricity Supply in a Life Cycle Perspective, Master thesis, Industrial Ecology Programme Faculty of Engineering Science and Technology, Dept. of Hydraulic and Environmental Engineering, Waste Engineering and Industrial Ecology. (n.b. NVE, The Norwegian Water Resources and Energy Directorate, is the source of the basis data for the Rest Mix).
Import mixes from specific Nordic countries are assumed to be the same as those given in NordEl Statistics for 2007 (n.b. Iceland is not included in the NordEl mix, as there is no physical connection between Iceland's grid and the rest of NordEl).
The unspecified import to Norway is assumed to be the same as the NordEl mix.

2.1.2 Sweden 2007

NordEl Statistics for 2007: http://www.nordel.org/content/Default.asp?PageID=213

n.b. Iceland is not included in the NordPool mix, as there is no physical connection between Iceland's grid and the rest of NordPool (this is the same simplification that was used in Version 1 of the Energy Tracer).

2.1.3 Switzerland 2007

IEA Statistics, *Electricity Information 2008 (with 2007 data)*, OECD/IEA, 2008.

Data for electricity mix are actually from 2007 estimates, as the 2007 data available in this reference is preliminary data (based on monthly reported data).

2.1.4 Germany 2007

IEA Statistics, *Electricity Information 2008 (with 2007 data)*, OECD/IEA, 2008.

Data for electricity mix are actually from 2007 estimates, as the 2007 data available in this reference is preliminary data (based on monthly reported data).

2.1.5 UCTE 2007

UCTE production data 2007, www.ucte.org.

Data for electricity mix are calculated from detailed monthly production data in GWh downloaded from the UCTE website (se references, UCTE production data 2007).

2.2 Norwegian Hydroelectricity

Data from Vold et al. 1998 for Average Norwegian Hydropower distributed to “other users” (low voltage):

Time period: 1998
Geography: Norwegian
Technology: Average installed technology.

Data from STØ report OR 58.98 (Vold et al. 1998) for Average Norwegian Hydropower distributed to other users (as opposed to High Voltage users). Reference: OR 58.98. Infrastructure is included. Representative for Norway. Distribution grid is included in this data set. Grid losses used in this study were 2% in the main grid and 2% in each of the other three parts of the grid (regional, high voltage local and low voltage local).

2.3 Residual mix, Norway 2007

The mix data used was calculated from NVEs residual mix, see over (2.1.1.)

2.3.1 **Hydro electricity, other users** (Ostfold Research database)

Data as for Norwegian Hydroelectricity (2.2).

2.3.2 **Electricity, hard coal, at power plant/kWh/NORDEL** (Ecoinvent database)

Time period: 1993- 2000
Geography: Country-specific data
Technology: Average installed technology.

Detailed data on electricity production from coal in Scandinavia (NordEl), data is based on a collection of information about single plants. Base data on all major UCTE power plants in 1993 have been integrated, to the extent possible, with updated information for year 2000. The size distribution of particles has been derived from German data.

2.3.3 **Electricity, industrial gas, at power plant/kWh/NORDEL** (Ecoinvent database)

Time period: Unspecified
Geography: Country-specific data
Technology: Average of installed power plants
Energy values Undefined
System boundary: Unspecified
Translated name: Strom, ab Industriegas-Kraftwerk

Included processes: The module includes coke oven gas and blast furnace gas. The module uses the average net efficiency of industrial gas power plants in NORDEL countries (estimated from IEA 2001, including countries FI, NO, SE).

2.3.4 **Electricity, at wind power plant/kWh/RER** (Ecoinvent database)

Time period:	Unspecified
Geography:	European average data.
Technology:	Average technology
Energy values	Undefined
System boundary:	Unspecified

Translated name: Strom, ab Windkraftanlage
Included processes: Included are the modules for the wind power plant 800kW (RER) and the wind power plant 2MW, offshore.
Remark: The share of the used modules is based on the installed capacity in 2002 and the average capacity factors assumed (20% onshore, 30% offshore).

2.3.5 **Electricity, peat, at power plant/kWh/NORDEL** (Ecoinvent database)

Time period:	Unspecified
Geography:	Country-specific data.
Technology:	Average technology
Energy values	Undefined
System boundary:	Unspecified

Included processes: Electricity output at busbar. The module uses the average net efficiency of peat power plants in NORDEL countries.
Remark: Due to lack of specific information, the emission data were assumed to be same as for German average lignite plants, whose fuel has a similar heating value. The following information refers to this German lignite plant. The module describes the electricity production of an average plant for the country.

2.3.6 **Electricity from waste, at municipal waste incineration plant/kWh/CH** (Ecoinvent database)

Time period:	Waste composition as given in literature reference, theoretical data or other source. Transfer coefficients for modern Swiss MSWI. Emission speciation based on early 90ies data.
Geography:	Specific to the technology mix encountered in Switzerland in 2000
Technology:	Average Swiss MSWI plants in 2000 with electrostatic precipitator for fly ash (ESP), wet flue gas scrubber and 29.4%, SNCR 32.2%, SCR-high dust 24.6%, SCR-low dust DeNOx facilities and 13.8% without Denox (by burnt waste, according to Swiss average). Share of waste incinerated in plants with magnetic scrap separation from slag: 50%. Gross electric efficiency technology mix 12.997% and Gross thermal efficiency technology mix 25.57%

Energy values	Undefined
System boundary:	Unspecified

Translated name: Strom aus Kehricht, ab Kehrichtverbrennungsanlage
Included processes: waste-specific air and water emissions from incineration, auxiliary material consumption for flue gas cleaning. Short-term emissions to river water and long-term emissions to ground water from slag compartment (from bottom slag) and residual material landfill (from solidified fly ashes and scrubber sludge). Process energy demands for MSWI.
Remark: The multioutput-process 'municipal solid waste to municipal incineration' delivers the co-products 'disposal, municipal solid waste, 22.9% water, to municipal incineration' and 'electricity from waste, at municipal waste incineration plant' and 'heat from waste, at municipal waste incineration plant '. Default allocation 100% to disposal function, 0% to energy production. These allocation factors also apply to emissions of waste heat: i.e. neither electricity nor heat from waste at MSWI does contain any waste heat emissions. Net energy produced in MSWI: 1.01MJ/kg waste electric energy and 2.16MJ/kg waste electric energy
Allocation of energy production: no substitution or expansion. Total burden allocated to waste disposal function of MSWI.

Ostfold Research comment: this means in reality that waste incineration for energy production has 0 emissions allocated, as the entire emissions burden is assumed to apply to the waste disposal function and not the energy production function of the waste incineration plants. This is the approach decided upon by the EcoInvent database. However, this is an area for further research, where it is important to consider the developments in the standards for environmental product declarations for energy production, where allocation guidelines are given (www.environdec.com). These are not in agreement with the EcoInvent approach. The PCR reference describes the relevant allocation being a split between the items of equipment that are needed for destruction of the waste (should be allocated to the waste treatment service) and the items of equipment needed for the production of heat and electricity should be allocated to these functions. This PCR guideline also gives guidelines that specify the allocation appropriate for co-generation facilities, where this is also relevant for MSW incineration. It should be noted that waste incineration is most dominant in the Swiss electricity production mix and only amounts to a total of 3% of this mix.

2.3.7 **Electricity, nuclear, at power plant/kWh/DE** (Ecoinvent database)

Time period:	None
Geography:	Swiss data of one specific PWR and one specific BWR for requirements and German PWRs and BWRs for emissions.
Technology:	Standard technology for commercial operation.
Energy values	Undefined
System boundary:	Unspecified

Translated name: Strom, ab Kernkraftwerk
The module represents the German nuclear mix (electricity delivered in the period 1995 - 1999) of 72% PWR and 28% BWR.
Remark: Details on the two components average PWR and average BWR can be found in the respective modules.

2.3.8 **Heat, at cogen 6400kWth, wood, allocation exergy/MJ/CH** (Ecoinvent database)

Time period:	None
Geography:	Could be used for central European conditions.
Technology:	Specific cogeneration unit installed in Switzerland.
Energy values	Undefined
System boundary:	Unspecified

Translated name: Nutzwärme, ab Holz-WKK 6400kWth, Allokation Exergie
Included processes: This module describes the combustion of natural wood chips. Included are the infrastructure, the wood input, the emissions to air, the transport of the fuel, and the disposal of the ashes. Also included are substances needed for operation: lubricating oil, urea, organic chemicals, sodium chloride, chlorine and decarbonizes water.
Remark: The multioutput-prozess "wood chips, burned in cogen 6400kWth, allocation exergy" delivers the co products "heat, at cogen 6400kWth, wood, allocation exergy" and "electricity, at cogen 6400kWth, wood, allocation exergy".

2.3.9 **Electricity, oil, at power plant/kWh/DK** (Ecoinvent database)

Time period:	No new data for today situation thus assessment with older data and data for Europe.
Geography:	Estimation for the country (Denmark)
Technology:	Estimation for average technology
Energy values	Undefined
Production volume	0.07 TWh from power plants and 4.8 TWh from combined cycle plants
System boundary:	Unspecified

Translated name: Strom, ab Ölkraftwerk
Included processes: Country specific efficiency of transformation
Remark: Calculation for electricity production in oil power plants with efficiency and oil input.

2.3.10 **Grid losses**

Grid losses calculated in this study for low voltage users were assumed to be the same as for Norwegian electricity in the EcoInvent database. These losses are 13.4% in total (production→high: 1.02%; high→medium: 1.08%; medium→low: 11.09%).

2.4 Sweden 2007

2.4.1 **Electricity, hydropower, at power plant/kWh/SE** (Ecoinvent database)

Time period:	Unspecified
Geography:	Valid for this single country (Sweden)
Technology:	Not applicable because the dataset just describes shares.
Energy values	Undefined

System boundary: Undefined

Translated name: Strom, Wasserkraft, ab Kraftwerk
Included processes: Includes shares of electricity produced by of run-of-river and reservoir hydropower plants.
Remark: Electricity production shares are determined on annual average and on the level of net production.

2.4.2 **Electricity, hard coal, at power plant/ kWh/Nordel** (Ecoinvent database)

Described in point 2.3.2 above.

2.4.3 **Electricity, oil, at power plant/kWh/SE** (Ecoinvent database)

Time period:	Emission factors provided by an authority for 2000, other data for Europe. Version: 2.0
Geography:	Estimation for the country. (Sweden)
Technology:	Estimation for average technology.
Energy values	Undefined
Production volume	0.03 TWh from power plants and 2.9 TWh from combined cycle plants
System boundary:	Undefined

Translated name: Strom, ab Ölkraftwerk
Included processes: Country specific efficiency of transformation
Remark: Calculation for electricity production in oil power plants with efficiency and oil input.

2.4.4 **Electricity, natural gas, at power plant/kWh/NORDEL:**

Time period:	Unspecified
Geography:	The module uses the average net efficiency of natural gas power plants in NORDEL (estimated from IEA 2001, including countries DK, FI, NO, SE).
Technology:	Average of installed power plants.
Energy values	Undefined
System boundary:	Undefined

Translated name: Strom, ab Erdgas-Kraftwerk
Included processes: The module calls the module 'natural gas, burned in power plant', NORDEL, which in turn includes fuel input from high pressure (DK, FI, SE) network, infrastructure, emissions, and substances needed for operation.

2.4.5 **Electricity, industrial gas, at power plant/kWh/**NORDEL (Ecoinvent database)

Described in point 2.3.3 above.

2.4.6 **Electricity, at wind power plant/kWh/RER** (Ecoinvent database)

Described in point 2.3.4 above.

2.4.7 **Heat, at cogen 6400kWth, wood, allocation exergy/MJ/CH** (Ecoinvent database)

Described in point 2.3.8 above.

2.4.8 **Electricity from waste, at municipal waste incineration plant/kWh/CH** (Ecoinvent database)

Described in point 2.3.6 above.

2.4.9 **Electricity, at cogen, biogas agricultural mix, allocation exergy/kWh/CH:**

Time period:	Unspecified
Geography:	For this process 20 plants in Switzerland producing about 50% of electricity from biogas have been evaluated.
Technology:	Mix of biogas engines and ignition gas engine
Energy values	Undefined
Production volume:	25 GWh electricity, 12 mio. m3 Biogas
System boundary:	Undefined

Translated name: Strom, ab BHKW, Biogas Landwirtschaft Mix, Allokation Exergie
Included processes: This process connects the different productions for electricity from agricultural biogas plants.
Remark: This process gives the mix of electricity production from biogas from agricultural plants in Switzerland in the year 2006.

2.4.10 **Electricity, nuclear, at power plant/kWh/UCTE** (Ecoinvent database)

Time period:	Unspecified
Geography:	Swiss data of one specific PWR and one specific BWR for requirements and all UCTE (BE, CH, DE, ES, FR, NL) nuclear power plants for emissions
Technology:	Standard technology for commercial operation.
Energy values	Undefined
System boundary:	Undefined

Translated name: Strom, ab Kernkraftwerk
Included processes: The module represents the Swiss nuclear mix (electricity delivered in the period 1995 - 1999) of 90% PWR and 10% BWR. Remark: Details on the two components average PWR and average BWR can be found in the respective modules.

2.4.11 **Electricity, peat, at power plant/kWh/NORDEL** (Ecoinvent database)

Described in point 2.3.5 above.

2.4.12 **Grid losses**

For Sweden, EcoInvent assumes the following grid losses: 13.7% in total (production→high: 1%; high→medium: 1.1%; medium→low: 11.3%).

2.5 STØ electricity mix, Switzerland 2007

2.5.1 **Electricity, hydropower, at power plant/kWh/CH** (Ecoinvent database)

Time period:	Unspecified
Geography:	Valid for this single country (Switzerland)
Technology:	Not applicable because the dataset just describes shares.
Energy values	Undefined
System boundary:	Undefined

Translated name: Strom, Wasserkraft, ab Kraftwerk
Included processes: Includes shares of electricity produced by of run-of-river and reservoir hydropower plants.
Remark: Electricity production shares are determined on annual average and on the level of net production.

2.5.2 **Electricity, oil, at power plant/kWh/UCTE** (Ecoinvent database)

Time period:	Production mix for 2000
Geography:	Estimation for the mix of producing countries
Technology:	Estimation for average technology.
Energy values	Undefined
Production volume	121134 GWh in 2000
System boundary:	Undefined

Translated name: Strom, ab Ölkraftwerk
Included processes: UCTE specific efficiency of transformation
Remark: Calculation for electricity production in oil power plants with efficiency and oil input.

2.5.3 **Electricity, natural gas, at power plant/kWh/UCTE** (Ecoinvent database)

Time period:	Unspecified
Geography:	The module uses the average net efficiency of natural gas power plants in UCTE (estimated from IEA 2001, including countries AT, BE, DE, ES, FR, IT, LU, NL, GR, PT).
Technology:	Average of installed power plants.
Energy values	Undefined
System boundary:	Undefined

Translated name: Strom, ab Erdgas-Kraftwerk
Included processes: The module calls the module 'natural gas, burned in power plant', UCTE, which in turn includes fuel input from high pressure (RER) network, infrastructure, emissions, and substances needed for operation.

2.5.4 **Electricity, at wind power plant/kWh/RER** (Ecoinvent database)

Described in point 2.3.4 above.

2.5.5 **Electricity from waste, at municipal waste incineration plant/kWh/CH** (Ecoinvent database)

Described in point 2.3.6 above.

2.5.6 **Heat, at cogen 6400kWth, wood, allocation exergy/MJ/CH** (Ecoinvent database)

Described in point 2.3.8 above.

2.5.7 **Electricity, at cogen, biogas agricultural mix, allocation exergy/kWh/CH** (Ecoinvent database)

Described in point 2.4.9 above.

2.5.8 **Electricity, nuclear, at power plant/kWh/UCTE** (Ecoinvent database)

Described in point 2.3.10 above.

2.5.9 **Grid losses**

For Switzerland, EcoInvent assumes the following grid losses: 12.6% in total (production→high: 0.99%; high→medium: 1.02%; medium→low: 10.41%).

2.6 Germany 2007

2.6.1 **Electricity, hydropower, at power plant/kWh/DE** (Ecoinvent database)

Time period:	Unspecified
Geography:	Valid for this single country (Germany)
Technology:	Not applicable because the dataset just describes shares
Energy values	Undefined
System boundary:	Undefined

Translated name: Strom, Wasserkraft, ab Kraftwerk

Included processes: Includes shares of electricity produced by of run-of-river and reservoir hydropower plants.
Remark: Electricity production shares are determined on annual average and on the level of net production.

2.6.2 **Electricity, hard coal, at power plant/kWh/DE:**

Time period:	Unspecified
Geography:	Country-specific data. (Germany)
Technology:	Average installed technology
Energy values	Undefined
System boundary:	Undefined

Translated name: Strom, ab Steinkohlekraftwerk
Included processes: Electricity output at busbar. The module uses the average net efficiency of German hard coal power plants (35.9%).
Remark: The module describes the electricity production of an average plant for the country. The plant is used for middle load with 4000 hours of operation at full capacity per year. The plant is assumed to operate 150000 hours during its lifetime. For the assessment of main characteristics (LHV, sulphur and ash content of coal, efficiency of the plant) and criteria emissions (SOx, NOx, particles, and CO2) a bottom-up approach has been used. It consists on the collection of information about single plants. Base data on all major UCTE power plants in 1993 have been integrated, to the extent possible, with updated information for year 2000.

2.6.3 **Electricity, lignite, at power plant/kWh/DE** (Ecoinvent database)

Time period:	Unspecified
Geography:	Country-specific data. (Germany)
Technology:	Average installed technology
Energy values	Undefined
System boundary:	Undefined

Translated name: Strom, ab Braunkohlekraftwerk
Included processes: Electricity output at busbar. The module uses the average net efficiency of German lignite power plants (33.1%).
Remark: The module describes the electricity production of an average plant for the country. The plant is used for middle load with 6000 hours of operation at full capacity per year. The plant is assumed to operate 200000 hours during its lifetime. For the assessment of main characteristics (LHV, sulphur and ash content of coal, efficiency of the plant) and criteria emissions (SOx, NOx, particles, and CO2) a bottom-up approach has been used. It consists on the collection of information about single plants. Base data on all major UCTE power plants in 1993 have been integrated, to the extent possible, with updated information for year 2000.

2.6.4 **Electricity, oil, at power plant/kWh/DE** (Ecoinvent database)

Time period:	No new data for today situation thus assessment with older data and data for Europe.
Geography:	Estimation for the country (Germany)

Technology: Estimation for average technology
Energy values Undefined
System boundary: Undefined

Translated name: Strom, ab Ölkraftwerk
Included processes: Country specific efficiency of transformation
Remark: Calculation for electricity production in oil power plants with efficiency and oil input.

2.6.5 **Electricity, natural gas, at power plant/kWh/DE** (Ecoinvent database)

Time period: No new data for today situation thus assessment with older data and data for Europe.
Geography: Estimation for the country (Germany)
Technology: Average of installed power plants
Energy values Undefined
System boundary: Undefined

Translated name: Strom, ab Erdgas-Kraftwerk
Included processes: The module calls the module 'natural gas, burned in power plant', DE, which in turn includes fuel input from high pressure (DE) network, infrastructure, emissions, and substances needed for operation. The module uses the average net efficiency of natural gas power plants in DE (estimated from IEA 2001).

2.6.6 **Electricity, industrial gas, at power plant/kWh/DE:**

Time period: No new data for today situation thus assessment with older data and data for Europe.
Geography: Estimation for the country (Germany)
Technology: Average of installed power plants
Energy values Undefined
System boundary: Undefined

Translated name: Strom, ab Industriegas-Kraftwerk
Included processes: The module includes coke oven gas and blast furnace gas. The module uses the average net efficiency of industrial gas power plants in DE (estimated from IEA 2001).

2.6.7 **Electricity, at wind power plant/kWh/RER** (Ecoinvent database)

Described in point 2.3.4 above.

2.6.8 **Heat, at cogen 6400kWth, wood, allocation exergy/MJ/CH** (Ecoinvent database)

Described in point 2.3.8 above.

2.6.9 **Electricity from waste, at municipal waste incineration plant/kWh/CH** (Ecoinvent database)

Described in point 2.3.6 above

2.6.10 **Electricity, at cogen, biogas agricultural mix, allocation exergy/kWh/CH** (Ecoinvent database)

Described in point 2.4.9 above.

2.6.11 **Grid losses**

For Germany, EcoInvent assumes the following grid losses: 11.1% in total (production→high: 0.93%; high→medium: 0.88%; medium→low: 8.98%).

2.7 STØ electricity, UCTE mix 2007

2.7.1 **Electricity, Hydropower at power plant/ kWh/DE** (Ecoinvent database)

Described in point 2.6.1 above.

2.7.2 **Electricity, hard coal, at power plant/kWh/DE** (Ecoinvent database)

Described in point 2.6.2 above.

2.7.3 **Electricity, lignite, at power plant/kWh/UCTE** (Ecoinvent database)

Time period:	UCTE in year 2000
Geography:	UCTE in year 2000.
Technology:	Undefined
Technology:	Average of installed power plants
Energy values	Undefined
System boundary:	Undefined

Translated name: Strom, ab Braunkohlekraftwerk
Included processes: The module represents the electricity output at busbar produced by the average lignite power plant in UCTE in year 2000.
Remark: The average for UCTE lignite power plant mix is calculated using country-specific average units weighted by the share of net electricity output. The countries are those composing, consistently with the UCTE electricity mix.

2.7.4 **Electricity, oil, at power plant/kWh/UCTE** (Ecoinvent database)

Described in point 2.5.2 above.

2.7.5 **Electricity, natural gas, at power plant/kWh/UCTE** (Ecoinvent database)

Described in point 2.5.3 above.

2.7.6 **Electricity, at wind power plant/kWh/RER** (Ecoinvent database)

Described in point 2.3.4 above.

2.7.7 **Heat, at cogen 6400kWth, wood, allocation exergy/MJ/CH** (Ecoinvent database)

Described in point 2.3.8 above.

2.7.8 **Electricity from waste, at municipal waste incineration plant/kWh/CH** (Ecoinvent database)

Described in point 2.3.6 above

2.7.9 **Electricity, at cogen, biogas agricultural mix, allocation exergy/kWh/CH** (Ecoinvent database)

Described in point 2.4.9 above.

2.7.10 **Electricity, nuclear, at power plant/kWh/UCTE** (Ecoinvent database)

Described in point 2.4.10 above.

2.7.11 **Grid losses**

For the UCTE mix, EcoInvent assumes the following grid losses: 13.5% in total (production→high: 1.03%; high→medium: 1.09%; medium→low: 11.16%).

3 Results

The greenhouse gas emissions data for the different electricity mixes where calculated and compared using SimaPro 7.1.8. Table 1 and Figure 1 below show the results obtained.

	g CO2-equivalents/kWh
Norwegian Hydro Electricity	1,99
Norwegian Residual Mix	63,80
Swedish electricity	55,90
Swiss electricity	30,47
German electricity	741,71
UCTE electricity	629,75

Table 1: g CO2- equivalents/kWh for different electricity production mixes

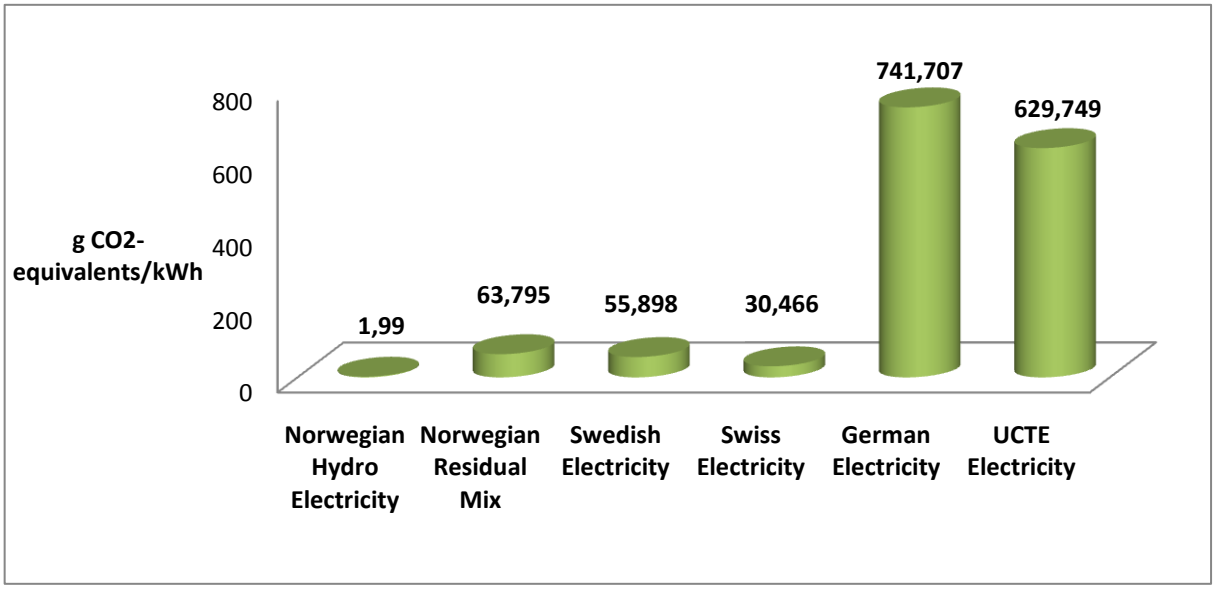

Figure 1: g CO2- equivalents/ kWh for different electricity mixes.

These results show clearly that the CO_2-equivalent emissions can be hugely different for different electricity production mixes. In order to see what this difference can mean for companies purchasing Guarantees of Origin (GoO), calculations where performed for a medium sized electricity consumer and a large consumer, using 50 and 400 GWh per year respectively. Figure 2 and Table 2 below show the results for these calculations, where the emissions savings are calculated for these customers if they change their purchase of electricity from a given general mix to GoO electricity from Norwegian hydropower. The emissions savings are shown in units of tonnes CO_2-equivalents saved annually.

		50 GWh	400 GWh
	t/GWh	tonnes CO_2-equivalents	tonnes CO_2-equivalents

		saved	saved
Norwegian Residual Mix	61,80	3 090,24	24 721,91
Swedish electricity	53,91	2 695,37	21 562,94
Swiss electricity	28,48	1 423,78	11 390,26
German electricity	739,72	36 985,83	295 886,63
UCTE electricity	565,95	28 297,72	226 381,76

Table 2: Savings in CO_2- equivalent emissions if Norwegian Hydroelectricity GoO are purchased instead of other production mixes.

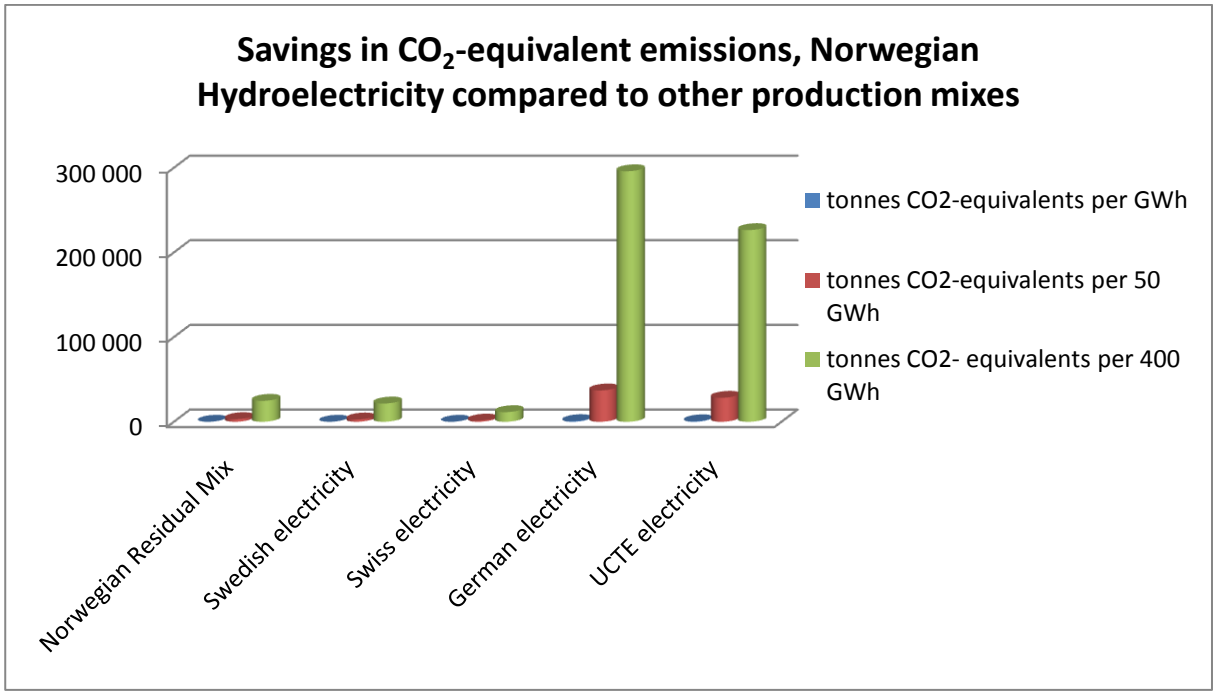

Figure 2: Savings in CO_2-equivalent emissions, Norwegian Hydroelectricity compared to other mixes.

4 Conclusions and Recommendations

Companies purchasing Guarantees of Origin (GoO), of electricity can use the emissions data associated with these GoO instead of a general or residual mix that would otherwise be relevant. It is clearly important to have good up to date data for emissions associated with the relevant electricity production mixes when performing environmental analyses, as the differences in data for given production mixes can be large. The data presented in this report gives greenhouse gas emissions ranging from 2-742 g CO_2-equivalents/kWh depending on the production mix chosen.

Agder Energy Production AS is part of a group of companies involved in the research project “Energihandel og miljø 2020” (translation: Energy trading and the environment 2020), which will explore the methodological aspects of the documentation of environmental impacts associated with electricity that is traded in greater detail. The work presented in this report will also contribute towards this research.

5 References

EcoInvent 2008: The SimaPro version of the updated EcoInvent database that was availbale in SimaPro software in 2008. The reference given in the database files is: “Converted Ecoinvent 2.0 data as unit processes with links to other processes, including uncertainty data.

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