Update of LCI Background Data Exemplified for the German Steam Coal Supply Chain

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ABSTRACT

The quality of Life Cycle Assessment (LCA) studies substantially depends on the quality of the data used. Apart from the general availability of data it is of high importance to rely the process chain analysis on up-to-date data. This also refers to the background LCI data, which in this context are Life Cycle Inventory (LCI) data on the supply chain of materials, energy carriers or basic services as for example heat and electricity generation.

This paper presents an approach for a standardised update of LCI background data based on the methodology of a parametrised Life Cycle Assessment. With parameters and fundamental coherences on material flows integrated in the process chain analysis, this methodology allows an easy and standardised revision of the central processes in the background supply chain by parameter variation. The update of LCI data by means of the methodology of parametrised LCA is shown as example for the German steam coal supply chain. This chain describes the energy consumption, material flows and emissions release starting from hard coal mining, along processing to steam coal until its transportation to a typical German power plant site. The data for the German steam coal supply chain have been compiled according to the guidance on generating LCI data for the German electricity mix, which had been worked out by the German network on Life Cycle Inventory Data. Results are shown for an annual time series of hard coal supply chains during the years 1990 to 2005.

Introduction

The availability of up-to-date data is a prerequisite for high quality LCA studies. This need for accurate data also refers to the background LCI data, which represent LCI data on the supply chain of materials, energy carriers or basic services as for example heat and electricity generation.

For these supply chains data had firstly been surveyed ten to fifteen years ago, when LCA methodology became a frequently used methodology within several scientific fields. Since then most of this background data have been updated in order to take major changes into account. Such a detailed and thorough revision of the background data, however, is time intensive and involves high effort.

This paper outlines a methodology for an update of LCI background data with less low time effort and work load, but still high accuracy. This LCI data update is shown at the example of the German steam coal supply chain. Steam coal besides coke, anthracite and coking coal, is one of the main products made from hard coal. In this study the steam coal supply chain for electricity generation in German power plants is investigated, comprising the energy consumption, material flows and emissions release along hard coal mining, processing to steam coal and its transportation to a typical German power plant site.

Background

Triggered by the idea of having standardised LCI background data for material and energy provision in Germany, the German Network on Life Cycle Inventory Data performed a pilot study on generating LCI data on the generation of electricity in Germany. This constitutes the LCI background data for the so called German electricity mix. In order to achieve high data quality, only data sources from scientific approved institutions and experts have been used for the data survey. The possibility for updates of this LCI data on the German electricity mix was guaranteed by using predominantly data sources, which are published at regular intervals and with revised figures.

An important pillar of the German electricity mix is the hard coal based electricity generation, for which an investigation of the steam coal supply chain was required. This contribution was performed by IER (Institute of Energy Economics and the Rational Use of Energy of the University of Stuttgart). The outcome of the entire pilot study is published in [1], which constitutes a guidance on the generation and the update of life cycle inventory data on the German electricity mix.

Starting from this project of the German Network on Life Cycle Inventory Data sensitivity analyses on the results for the LCI data on the German steam coal supply were performed. Using the outlined update methodology for this LCI data, which originally was intended to picture future time horizons, a retrospective investigation for the years 1990 to 2005 was performed.

Methodology

This paper applies the methodology of parametrised LCA, allowing a standardised update of LCI background data. With parameters and fundamental coherences on material flows integrated into the process chain analysis, this methodology allows a revision of the central processes in the background supply chain by automated calculation of the implemented algorithms. The numerical values standing behind the parameters can be varied and enable an immediate recalculation of the revised process chain analyses.

For the evaluation of the time series on the hard coal supply LCI data, those parameters have been fitted so as to coherently represent the amount of domestic hard coal and the amount of hard coal imported from different countries. In other words, the import mix of the steam coal has been varied using parameters. The necessary figures for this parameter adjustment originate from the German Coal Importer Federation, which publishes this information in an annual report [2]. An overview of this data is summarized in table 1.

in 1000 tons of steam coal	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
Domestic steam coal	44280	45560	44860	44430	46160	44340	41340	39110	35500	34060	30360	25870	23530	23720	24420	24500
Hard coal import																
European Union	788	953	842	674	1.613	1.162	791	1.000	1.154						7.554	7.397
Poland	2.699	3.924	3.285	3.246	3.732	3.263	3.312	3.886	4.657	5.413	6.742	7.374	6.727	6.780	EU	EU
Czech Republic	276	771	751	534	771	923	771	945	976	1.044	1.061	908	905	865	EU	EU
Russia and CIS	334	169	249	241	224	212	70	86	90	184	779	2.066	1.906	2.526	5.288	5.855
Norway	122	120	102	77	116	70	38	53	72	170	347	687	215	644	1.387	905
USA	716	1.414	1.275	893	576	2.679	2.354	1.116	451	334	424	782	321	381	778	198
Canada	70	406	201	34	12	102	73	474	1	-	-	-	-	-	73	-
Columbia	128	446	622	748	1.187	996	2.266	3.709	4.291	4.468	4.603	5.754	5.823	5.900	4.719	4.750
South Africa	4.512	5.496	5.974	4.624	5.197	4.228	6.003	7.230	8.679	8.753	8.072	9.000	9.871	8.950	9.860	8.230
Australia	1.151	1.284	1.399	1.532	1.592	939	1.189	809	840	561	302	294	805	1.934	440	434
China	8	281	213	7	13	85	20	30	20	196	29	48	251	178	239	160
Indonesia	38	120	441	253	268	193	247	105	38	134	149	405	381	405	814	206
Venezuela	-	-	58	180	177	193	30	539	337	451	341	462	62	131	16	1
Other countries	14	16	16	9	5	7	26	49	27	3	27	239	167	719	336	623
Sum hard coal import	10.856	15.400	15.428	13.052	15.483	15.052	17.190	20.031	21.633	21.711	22.876	28.019	27.434	29.413	31.504	28.759
Thereof steam coal import	6.117	8.474	8.831	6.948	9.171	10.457	12.660	16.184	20.464	20.458	21.544	26.647	26.100	27.900	30.900	28.600
Sum domestic and imported steam coal supply	50.397	54.034	53.691	51.378	55.331	54.797	54.000	55.294	55.964	54.518	51.904	52.517	49.630	51.620	55.320	53.100

Table 1: Origin and composition of the German steam coal supply. Source: [2], [3]

Study

The process chain of the German steam coal supply is oriented at a very accurate process structure of the hard coal supply chain in the ecoinvent database, which is described in [4]. Infrastructure data, information on operating supplies and values of direct emissions during mining and transportation have been assumed from ecoinvent data. The deviant and newly balanced part of the process chain of the steam coal supply represents the variable import mix of the steam coal, newly balanced transportation from the hard coal mine to a typical German power plant site and the modelling of the energy expenditures along the supply chain. A simplified picture of the modelled hard coal process chain is given in figure 1.

The electricity need for mining was assumed to be generated by a country-specific hard coal power plant close to the mine. According to ecoinvent database an industrial furnace in the power range of 1-10 MW was assumed to provide the heat for the mining.

After processing to steam coal at the mine site, the steam coal is transported to a country-specific regional storage. From this regional storage the transportation to a typical German power plant site follows. From [2] and [6] as well as based on maps and public available distance calculators, for each steam coal exporting country distances and transport means for transportation to Germany was surveyed (table 2).

Transoceanic freight ships were used for offshore transportation, onshore transportation was carried out by freight train. For transportation within Germany average distances of 120 km train transport and 140 km for barge transport have been assumed. According to [5] a heating value of 30,121 MJ/ kg was used for German steam coal in this study.

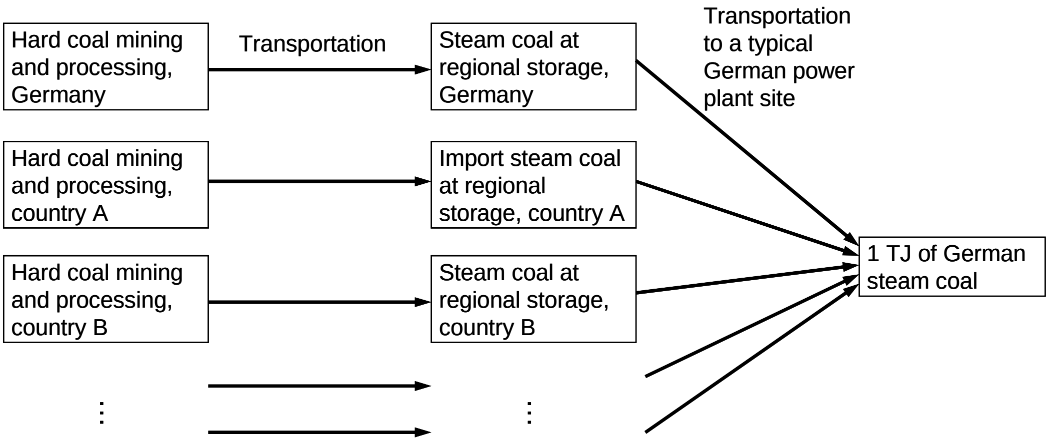

Figure 1: Simplified process chain of the German steam coal supply chain source: IER

Producing country	**Transport distance transoceanic freight ship**	**Transport distance freight train**	**Transport distance barge**
	km	**km**	**km**
Germany		120	140
South Africa	12.500	700	140
Poland and Czech Republic		670	140
Russia and CIS	3.500	4.120	140
Columbia and Venezuela	9.500	320	140
Norway	1.200	370	140
Australia	23.000	320	140
Indonesia	24.000	270	140
USA and Canada	7.500	1.120	140
China	29.000	720	140

Table 2: Transport distances for steam coal, transported from mines in different countries to a typical German power plant site Source: [2], [6], IER

Results

The amount of steam coal used for electricity generation in Germany was approximately constant between 50 and 55 million tons of steam coal within the years 1990 to 2005, as also shown by table 1. The share of domestic steam coal, however, was declining during this period due to high costs of mining and was gradually replaced by the cheaper import of steam coal. For the LCI data of the German hard coal supply chain, this increase of imports entails a higher amount of transport services, which again increases the release of emissions. This is obvious for the specific CO_2-emissions of the German hard coal supply chain, which increases from 2.8 to 4.6 kg CO_2 / MJ steam coal in the years 1990 to 2005 (figure 2).
Except for the years 1993 and 2005, which both feature an intermediate decline of the steam coal imports, the specific CO_2-emissions free of power plant site show an increase.
Looking at the results for the specific emissions of sulfur dioxide (SO_2), nitrogen oxides (NO_x) and carbon monoxide (CO) in figure 3 a similar increasing tendency as for the specific CO_2 emissions can be seen. Also here the years 1993 and 2005 show a decline of the emissions due to the minor steam coal imports within these years.

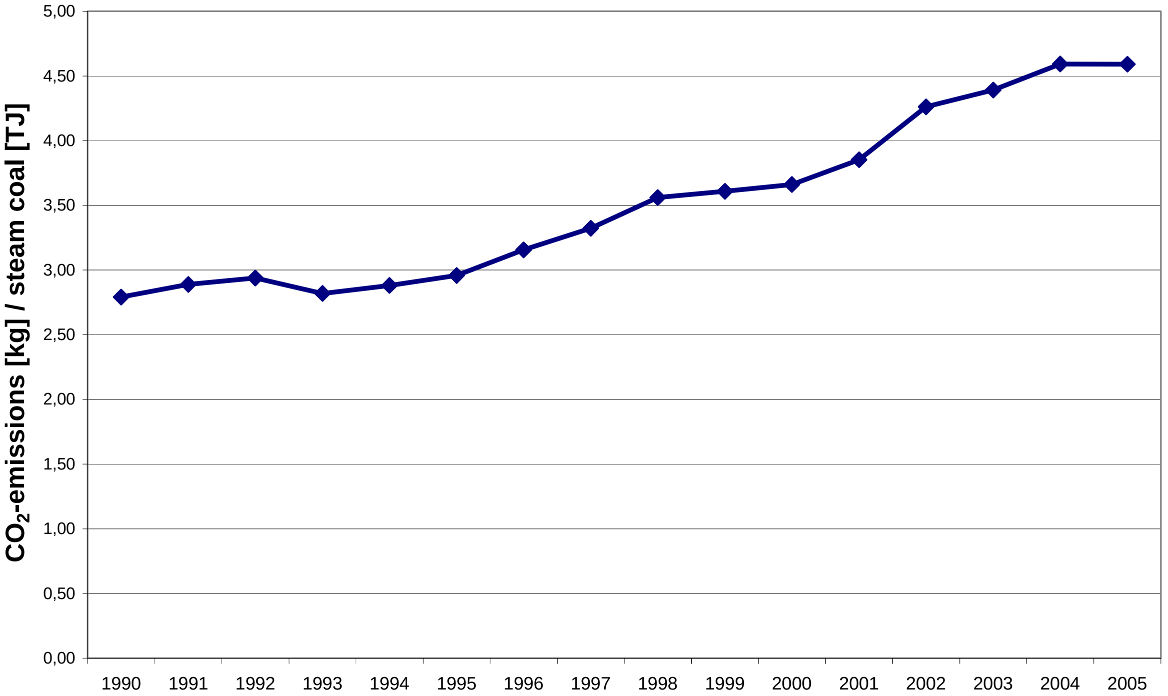

Figure 2: Specific carbon dioxide emissions of the German steam coal supply chain in the years 1990 to 2005

Further important changes in the amplitudes of the specific NO_x and SO_2 emissions can be explained by the fact that half of the NO_x emissions and three-quarters of the SO_2 emissions originate from the transoceanic freight ship transport. This also highlights that the specific emissions of the German steam coal supply chain are locally spread over the entire process chain from mining over transportation up to the power plant site. In 2002 there is a decline in the freight train based imports from Poland and an increase of steam coal import from countries with high transport distance of the transoceanic freight ship, as for example South Africa and Australia.

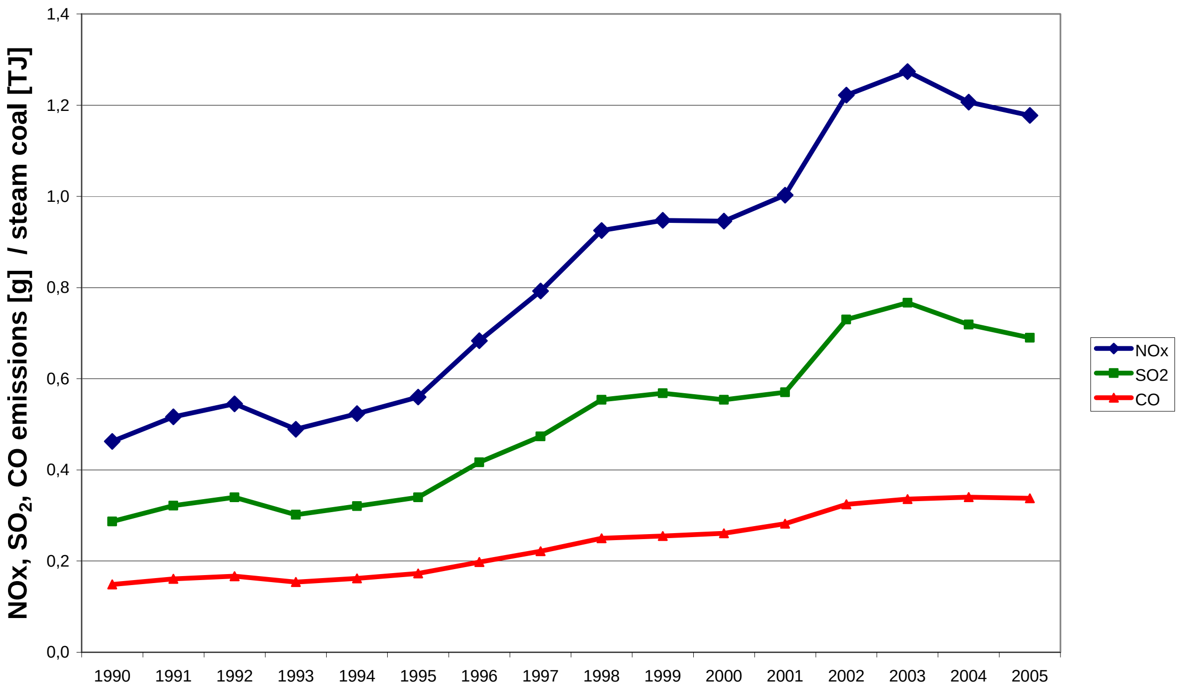

Figure 3: Specific emission of sulfur dioxide, nitrogen oxides and carbon monoxide of the German steam coal supply chain in the years 1990 to 2005

The decline of SO_2 and NO_x emissions in the year 2004 mainly arises from a reduction of ship-intensive imports from Australia, Indonesia and Columbia.

Further interesting results are sown by the decline of the specific methane emissions of German steam coal supply chains from 0.42 to 0.31 kg methane / TJ steam coal in the years 1990 to 2005 (figure 4). These emissions are declining with further increase of steam coal imports. This is due to the fact that for German hard coal mines the release of methane is higher than for hard coal mines in other countries. The methane emissions resulting from mining in different countries, which are used in this study originate from ecoinvent data and are based on a literature research made in [4]. Influencing factors on the methane emissions of hard coal mining are the applied technology of hard coal mining, the working depth in the mine, the type of ventilation and methane capture systems and geological factors as for instance the density of the hard coal seams. Solely Russian hard coal mining comes along with similar high methane emissions as in German hard coal mines, and this is the reason for the slight increase of the specific methane emissions in the years 2004 and 2005.

Looking at the specific greenhouse gas emissions in the time series of German steam coal supply chains figure 5 shows that the increase in specific CO_2-emissions is nearly compensated by the decline in the methane emissions. The specific greenhouse gas emissions remain approximately constant over the considered years at 11 to 12 kg CO_2-equivalents / TJ steam coal.

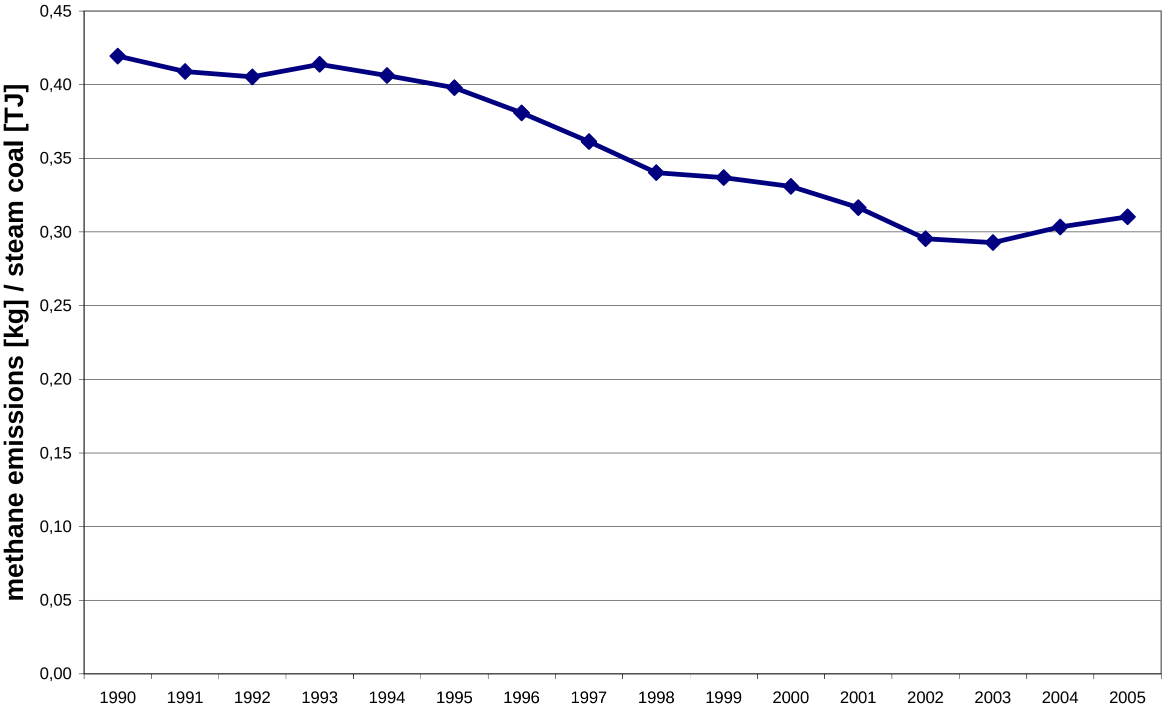

Figure 4: Specific methane emissions of the German steam coal supply chain in the years 1990 to 2005

Conclusions

The specific CO_2-emissions of the German steam coal supply chain increase from 2.8 to 4.6 kg CO_2/ MJ steam coal in the years 1990 to 2000. This increase in the specific emissions also applies for sulphur dioxide, nitrogen oxides and carbon monoxide emissions, which highlights the need for a regularly update of background LCI data.

Specific methane emissions are in opposition to the trend of the development of the other investigated specific emissions and show a decline from 0.42 to 0.31 kg methane / TJ steam coal in the years 1990 to 2000. In terms of greenhouse gas emissions this decline in the specific methane emissions outweighs the influence of the increased CO_2 emissions and causes a slight reduction in the specific greenhouse gas emissions of the German steam coal supply chain in the years 1990 to 2005.

An update of LCI background data may not be very significant in reference to the overall outcome of every LCA study, however for studies with high contribution of steam coal or electricity within the process chain, the trend in the LCI data of supply chains for materials and energy should be carefully followed. Having the methodology of parametrised LCA at hand such an update of LCI background data is done with lower effort than in former times and has the possibility to be automated.

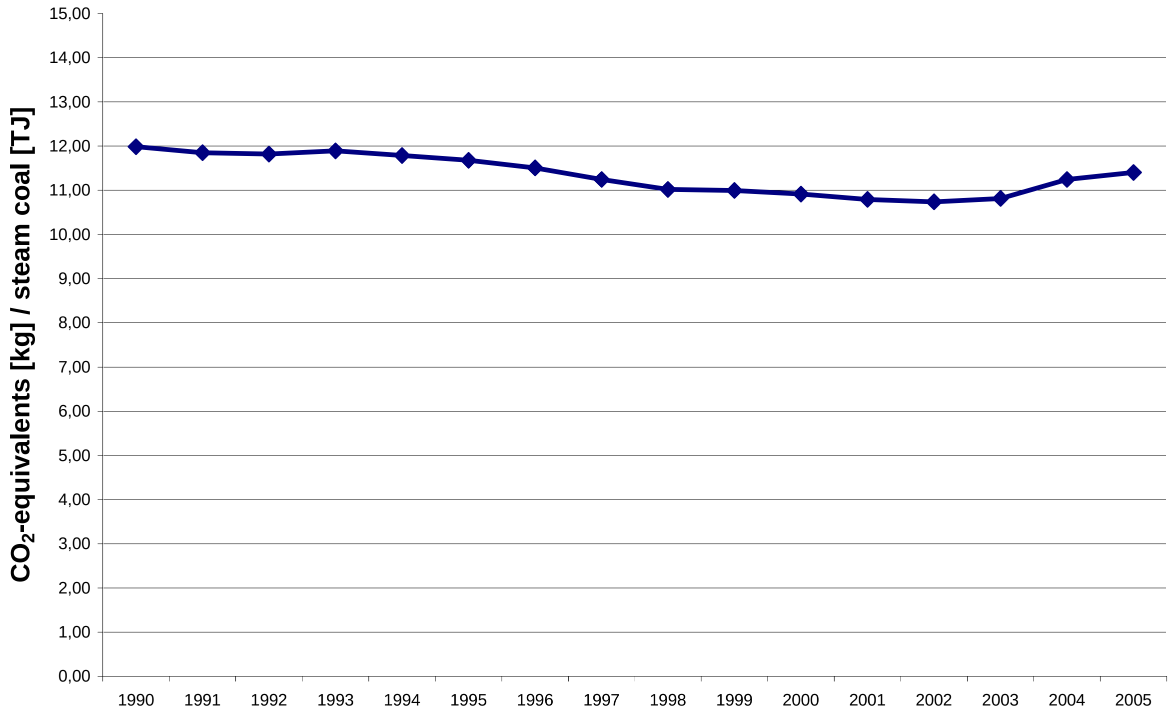

Figure 5: Specific greenhouse gas emissions of the German steam coal supply chain in the years 1990 to 2005

Outlook

Recently a phase-out of the German domestic hard coal mining by the year 2018 was decided. For the next decade this phase-out will necessitate an increase in steam coal imports, which again will lead to ongoing changes in the LCI background data for the German steam coal supply. For the next decade a constant annual level of steam coal used for electricity generation in Germany can be expected. With this anticipation the specific emissions of CO_2, SO_2, NO_x, CO as well as methane, arising from the German steam coal supply chain, are expected to follow the trend that was shown for the years from 1990 to 2005.

References

[1] Viehbahn, P., Patyk, A., Fritsche, U. et al., Fundamentals for a harmonised data set on the German electricity mix with capability of data update (in German), German Network on Life Cycle Inventory Data, Stuttgart, Heidelberg, Darmstadt, February 2007

[2] German Coal Importer Federation (in German: Verein der Kohlenimporteure – VDKI), Annual Reports 1991-2006, ISSN 1612-5371, Hamburg, 1991-2006

[3] German Statistics of Coal Industry, Coal Mining in the Energy Economy of the Federal Republic of Germany in the Year 2005 (in German), www.kohlenstatistik.de, Essen/Cologne, November 2006

[4] Röder, A., Bauer, C. and Dones, R., Coal. In: Dones, R. (Ed.) et al., Life Cycle Inventories of Energy Systems: Fundamentals for the Ecologic Comparison of Energy Systems and the Integration of Energy Systems into LCA Studies for Swiss Conditions (in German). Final report ecoinvent 2000 No. 6-VI, Paul Scherrer Institut Villigen, Swiss Centre for Life Cycle Inventories, Dübendorf (CH), 2003

[5] Arbeitsgemeinschaft Energiebilanzen e.V. (AGEB), Heating values of energy carriers and factors for transformation of specific mass units into heat units for energy balance purposes (in German). Issue 2005, Berlin/Cologne, November 2005

[6] RWE, World Market for Hard Coal (in German), issue 2005, RWE Power, Cologne/Essen, 2005