08.03 Carbon Dioxide Emissions / 08.04 Carbon Dioxide Emissions - Arranged by Sectors and Floor Spaces (Edition 1998)

Overview

It has been known since the end of the last century that certain gasses in the atmosphere, such as water vapor, carbon dioxide and methane, have radiative effects and lead to a general rise in temperature. These gasses allow sunlight to enter the atmosphere almost unhindered, but do not allow the heat radiated by the earth to be completely given off into space. This is often called the **"greenhouse effect"** and it is a factor in the average temperature on the earth required for our form of life. The greenhouse effect is a critical factor for human existence and the existence of nature as we know it.

The anthropogenic (caused by humans) greenhouse effect has become increasingly important since the beginning of industrialization. The increased use of fossil energy sources such as coal, fuel oil, and natural gas increased the release of climate gasses, particularly **carbon dioxide (CO_2)**.

The amount of carbon dioxide in the atmosphere has increased from about 280 ppm at the beginning of industrialization to about 358 ppm in 1994, an increase of about 28 %. Methane emissions also contribute to atmospheric heating. Methane is released in the extraction of oil and natural gas and in agriculture, such as by rice fields and cattle ranches. Methane amounts have increased from about 700 ppm to 1,720 ppm in comparison to pre-industrial times.

Current knowledge and experiments with complex computer simulations indicate that continuous development will have serious results.

- By 2100, an extremely brief period of time in the history of the earth, the **average global temperature** could rise by 1 to 3.5 °C. These changes in temperature could greatly change precipitation (rain) patterns and cause changes in vegetation zones. This would have great consequences for agriculture. These changes would be more extreme in certain regions.
- Average **sea level** could increase by 15 to 95 cm by 2100, according to model calculations. This could cause great problems, especially for islands and coastal areas.

The most important anthropogenic climate gasses are carbon dioxide, methane, nitrous oxide (laughing gas), N_2O; hydrofluorocarbons, HFC; perfluorocarbons, PFC; and sulphur hexafluorides, SF_6.

Relatively small amounts of these substances are released, but their specific effects (greenhouse potential) often exceed those of carbon dioxide by several times.

Globally carbon dioxide emissions make up more than half of the anthropogenic greenhouse effects, and more than 80 % in Germany (see Tab. 1). Carbon dioxide is thus an indicator for climate gas emissions.

Tab. 1: Important climate gasses and the greenhouse effect in Germany (IPCC 1996, BMU 1996)

	CO_2	CH_4	N_2O	HFC	PFC	SF_6
Emissions (thousand tons)	904,500	4,849	219	1,942	0.244	0.242
Greenhouse potential	1	21	310	140 - 11,700	6,500 - 9,200	23,900
Greenhouse effect	83.30 %	9.40 %	6.30 %	0.40 %	0.10 %	0.50 %

Tab. 1: Important climate gasses and the greenhouse effect in Germany (IPCC 1996, BMU 1996)

Since 1990 the German federal government has developed a **national goal for reduction** of climate gasses. The intent is to reduce CO_2 emissions by 2005 to a level of 25 % under the 1990 values. The fulfillment of this ambitious goal requires vigorous and comprehensive changes in all areas of energy use (BMU 1996, Ziesing u.a. 1997, Schön u.a. 1997).

Tab. 2: CO_2 Emissions in Germany (BMU 1996)		
	1990	1995
	Million tons	
Power plants and heating plants	439.4	373.2
Industry	197.2	152.0
Traffic	158.6	170.7
Household	128.4	135.2
Small-scale use	69.8	50.9
Other	20.6	12.5
Ocean travel	8.0	7.2
International Aviation	11.6	12.9

Tab. 2: CO_2 Emissions in Germany (BMU 1996)

CO_2 Emissions in Berlin

The development of **CO_2 emissions in Berlin** (Fig. 1) clearly shows the influence of industrialization and economic growth, as well as the considerable reduction of emissions resulting from the reunification of Germany. There was a discussion of climate protection in Germany, and the Berlin government chose to set their own goal for CO_2 reduction. By 2010, Berlin CO_2 emissions per inhabitant are to be reduced to a level 25 % under that of 1990.

Tab. 3: CO_2 Emissions in Berlin (Öko-Institut calculations)		
	1990	1995
	Million tons	
Power plants and heating plants	14.9	12.5
Industry	1.5	0.8
Traffic	4.3	5.0
Household / Small-scale use	6.9	6.5
Imported electricity	4.5	4.8
Total	32.1	29.6
Temperature increase	0.8	0.0
Total (climate adjusted)	32.9	29.6

Tab. 3: CO_2 Emissions in Berlin (Öko-Institut calculations)

Berlin CO_2 emissions decreased approx. 10 % to 29.6 million tons between 1990 and 1995, with electricity imports and singularities of the Berlin climate taken into consideration. The greatest reduction was made by the Power and Heating Works. Electrical and district heating works alone have reduced CO_2 emissions by 2.4 million tons since 1990. A considerable amount of this reduction was due to the reduced electrical and heating demands of end consumers (indirect reduction). Households, industry, and the service sector made a direct reduction of over 1 million tons of CO_2. The only emission increases were in traffic and electricity imports.

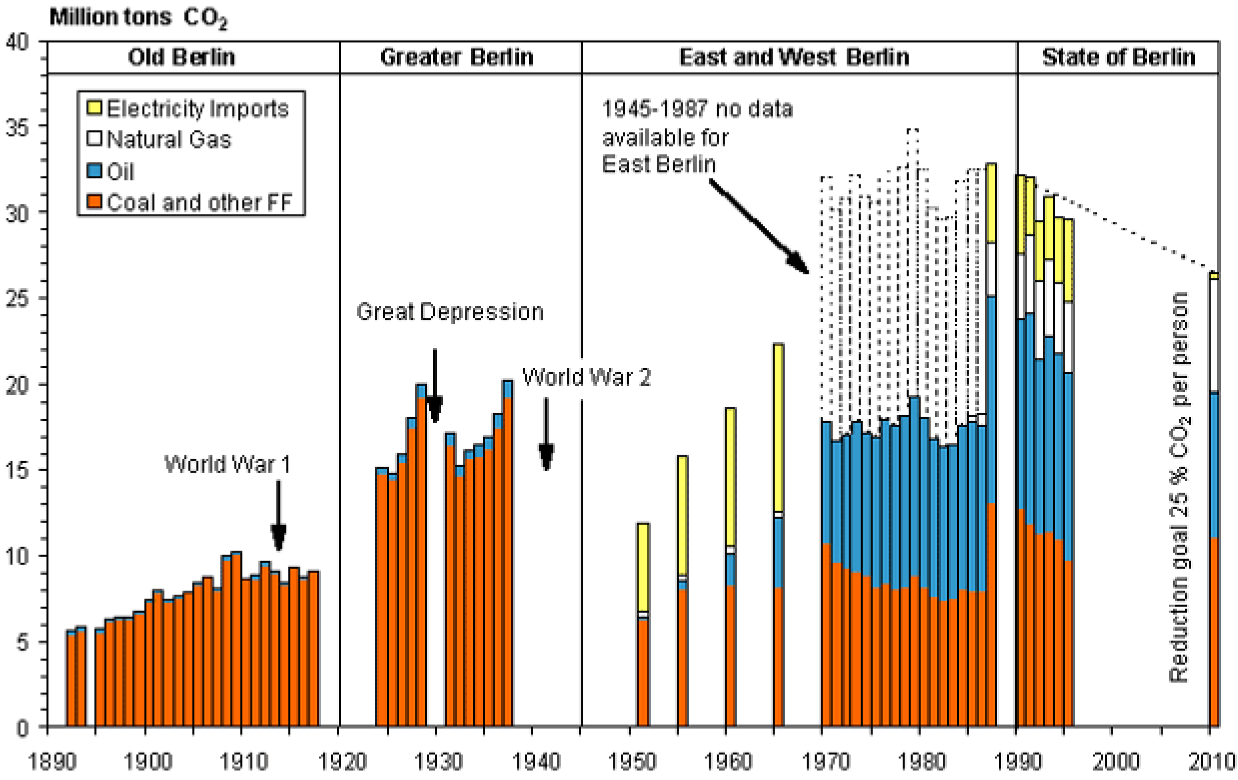

Fig. 1: Berlin CO_2 Emissions since 1892 (Öko-Institut 1994)

The **emission decrease** in some sectors is due to various factors. The most important factor is the **conformance shock** exerted by the Reunification of Germany on the economy of East Berlin. The economic **structural transformation** in the entire city that began in 1990 is also important. Less energy-intensive service providers are replacing industrial production, which is usually energy-intensive. There was also considerable investment in the **renovation** and modernization of buildings and facilities, with increased energy efficiency. The liberation of Berlin from its island status and the transition to a market economy in the East increased the availability and price attractiveness of **natural gas** for Berlin energy consumers. Natural gas, the energy source with the least carbon content and thus the least CO_2 emissions, replaced much high-CO_2 lignite and peat coal. The district heating pipelines, generally produced with the waste heat of power plants, were modernized and extended, too.

Tab. 4: Specific CO_2 Emissions of Various Energy Sources (Öko-Institut calculations)	
Energy sources	**Emission factor g CO_2/kWh**
Electricity (Mixed)	922
Raw lignite coal (Lausitz mines)	396
Lignite coal briquetts	360
Coal	335
Heavy fuel oil	281
Light fuel oil	266
Natural gas	198
District heating (according to network)	72 ... 493

Tab. 4: Specific CO_2 Emissions of Various Energy Sources (Öko-Institut calculations)

The emissions decrease of the 90´s is a result of changes in economic structures, increased energy efficiency, and transitions to less CO_2 -intensive energy sources.

Besides fossil fuels three other areas are significant in CO_2 emissions:

- CO_2 emissions occur in chemical processes in the production of certain products, including cement, lime, soda, glass, and primary aluminium. But these non-energy CO_2 emissions are not a factor in Berlin.
- CO_2 emissions are created by changes in soil use. This complex is of little influence in Berlin.
- Fixations of CO_2 are also to be considered. Photosynthesis takes up CO_2 from the atmosphere and transforms it into vegetative biomass. Trees and forests are of particular importance. The binding of carbon dioxide by trees and forests in Berlin has not been quantified, but its influence on climate is relevant.

Anthropogenic climate change is a **global problem**. There is no direct space-time relationship between cause and effect. This means that a spatial depiction of emissions on a map is not particularly useful in the context of the problem. A spatial and chronological depiction is more meaningful for SO_2 emissions because they have direct local effects. A spatial depiction of CO_2 emissions is more useful for the identification of important areas of action. In addition to such a **graphic presentation of problem causes**, a longterm spatial depiction of causes of CO_2 emissions can be used in **monitoring**. The effects of demographic, economic developments, and climate protection policies can be followed spatially.

Data bases and methodology have been systematized and prepared so that the determination of spatially differentiated CO_2 emissions on the basis of updated data can be made relatively simply.

Statistical Base

Carbon dioxide emissions were not directly measured, but were **calculated** according to the use of fuels. CO_2 emissions differ from the classical air pollutants, such as sulphur dioxide and nitrogen oxide. There is directly measured data on these substances in large combustion facilities. Energy consumption data is an important basis for the CO_2 Map.

Existing Berlin energy consumption data in the Berlin energy balance is given according to sectors, but is not spatially differentiated. Other data sources differentiate **energy use data** spatially, but only for selected sectors or fuels:

- The Berlin Department for Urban Development, Environmental Protection and Technology has data on energy use in **facilities requiring permits**. This data must be provided to the Berlin government by the facility operators.
- The Berlin Department for Construction, Housing and Traffic systematically registered the energy use of a large number of **public buildings** in the last year.
- The Berlin Power Works BEWAG provided spatially-differentiated **electricity use data**. The information was aggregated in conformance with Information Protection Laws.

  All other energy use data had to be determined on the basis of various structural data. Data used included:

- The Environmental Information System (EIS) of the Berlin Department for Urban Development, Environmental Protection and Technology. The EIS contains information about **land use**, including residential areas, industrial/commerce areas, and public facilities, etc. Information is differentiated according to a land use scheme with a total of 60 land use types and with high spatial resolution (cf. Map 06.07, SenStadtUmTech 1996a, 1996e).
- The EIS also contains data on the structure of **space heating networks** according to fuels, as well as the heated areas of residential and other use types (cf. Maps 08.01 and 08.02, SenStadtUmTech 1996c/d, 1996g/h).
- The State of Berlin Mandatory Inhabitant Registration Agency provided spatially differentiated data on **inhabitants**.
- The **Household Fuel Database** of the Berlin Department for Urban Development, Environmental Protection and Technology enabled the spatial differentiation of residences.
- A subsidy program for **Building Modernization** enables the identification of some buildings modernized with energy-saving effects.
- The Berlin State Agency for Work Safety has data which enables spatial identification of

workplaces according to specific economic activities.

- The preparation of data bases for the CO_2 Map used the described energy use and structure data, and the CO_2 emissions of **traffic** in the primary and secondary road system. Traffic emissions were determined in the course of the creation of the emission data base caused by traffic (cf. Map 07.01, SenStadtUmTech 1996b, 1996f).

Fig. 2 shows the interfacing of data sources used to spatially differentiate CO_2 emissions. White fields show data sources available as data bases for determination of CO_2. Gray fields show data used for calculations. The sources are structural data, use data, and parameters and formulas for specific energy use values and emission factors, etc.

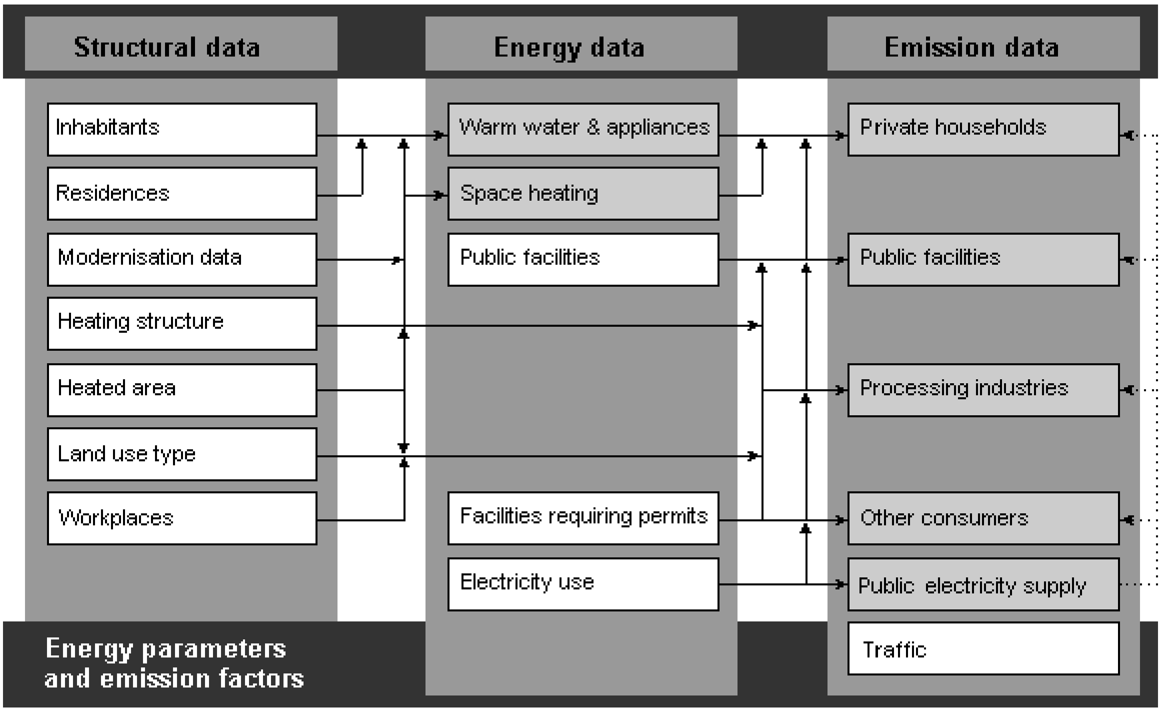

Fig. 2: Data sources and their interlinking (Öko-Institut 1998)

Where required energy use data were calculated for various use sectors by evaluating structural data and the corresponding **energy consumption parameters**, such as energy consumption per square meter of residential area, and energy consumption per workplace, etc. These parameters were assembled or determined from various sources.

Specific values for Berlin, or further differentiations, such as between East and West Berlin, were used as much as possible. A comparison was made of sector energy use data from various sources, such as households, public facilities, processing businesses, other users, and electricity use. Duplications were eliminated. Emissions were then calculated from energy use and fuel-specific emission factors.

Methodology

Certain basic delimitations had to be made in order to depict **causers of CO_2 emissions** on a map. Table 3 shows that public power suppliers of electricity and district heating are especially prominent in CO_2 emissions. Emissions are produced in power and heating works of the energy providers (EVU). In the strictest sense, emissions are caused by the **consumers** of electricity and heating. It is initially sensible to categorize electricity and heating emissions to the consumers, although the emissions are produced in the EVU facilities. This was done by formulating an average value for all Berlin for CO_2 emissions per kilowatt-hour of electricity. Specific emission factors were formulated for various district heating networks from calculations of CO_2 emissions from each heating facility.

Emissions from energy production **outside** of Berlin for consumption within Berlin are also relevant. Electricity is delivered to Berlin primarily from power facilities in the Lausitz area. The production of fuel oil in refineries requires heat and electricity, which leads to CO_2 emissions in the State of Brandenburg and other places.

Analyses show that CO_2 emitted in other places in the course of supplying fuel oil, natural gas and coal to Berlin amounts to about 5 % of the emissions produced by the combustion of these fuels in Berlin. These "grey-zone emissions" are significant for Berlin, particularly those connected with imports of electricity, for in 1995 one-fourth of all electricity used in Berlin was produced in power facilities outside the city. These CO_2 emissions amount to **about one-fifth** of total emissions produced in Berlin.

A simplified procedure was chosen because of the size of these "grey zone" energy import emissions. CO_2 emissions related to electricity were considered in the average value for consumption of electricity. The "grey zone emissions" related to coal, fuel oil, and natural gas supplies were not taken into consideration.

This allocation according to the "**pollution causer principle** in its broadest sense" is somewhat problematic. Electricity consumers can influence emissions from electricity production only by dealing sparingly with electricity. At the other side electricity provider decisions on production facilities have considerable influence on CO_2 emissions. That means: Berlin consumers can reduce their use of electricity in order to reduce CO_2 emissions. And the Berlin EVU energy producers could also reduce emissions by refitting power plants with more efficient technologies, such as energy/heat units, and use of low-CO_2 fuels like natural gas. This form of emission reduction has pretty much escaped the influence of energy consumers up to now. The future **liberalized electricity market** could give energy consumers a method of achieving emission reductions by giving them a choice between energy suppliers. This is the reason that a consideration of the two aspects has been attempted both in the determination of data, and in its depiction:

- Emissions from the supplying of electricity and heating are allocated to consumers.
- A special calculation run and depiction was made nevertheless for CO_2 emissions of the most important electricity and heating production facilities.

Calculations and comparisons were made to allocate the diverse data into six areas:

- **Households** include energy use or the corresponding CO_2 emissions in production of space heating, hot water, cooking, and use of electrical appliances.
- **Public facilities** include the energy use or the corresponding CO_2 emissions of public facilities. These figures were determined separately, as whole blocks or block segments, or as facilities which require operating permits. A school which occupies an entire block or block segment can be identified and classified as a public facility. A child-care facility on the ground floor of a building, however, cannot be identified and classified.
- **Industry** was allocated the energy use or CO_2 emissions calculated from workplace statements made for that industry, or from operator statements of facilities requiring permits.
- **Other** was allocated the energy use or CO_2 emissions that could be calculated from area, workplace, or facility data, but which could not clearly be classified into the other categories. This area includes statements regarding private sector service activities as well as "remainders" from other sectors.
- The prominent significance of **electrical supplies** for the CO_2 complex led us to determine electricity use for individual blocks and to study them separately sometimes.
- The determined emissions of the **primary road network** were directly allocated to road segments. The study was made in commission of the Berlin Department of Urban Development, Environmental Protection and Technology.

In addition to the absolute CO_2 emissions per block, the effective floor space per block was also determined. This not only allowed the depiction of emissions but also specific statements such as emissions per square meter of the floor space.

Map Description

Map 08.03 Carbon Dioxide Emissions

The Map shows **CO_2 emissions in absolute numbers** per block as well as the polluter to which the majority of the emission are allocated. This map clarifies three facts.

There is a clear **gradient** in CO_2 emissions from the city center to outlying districts. The only exception is the northeast edge of the city. High block emissions here remain almost constant. This situation results mainly from urban density. The densely built and densely inhabited city center areas and the large settlements in the Hellersdorf and Marzahn districts cause considerably more CO_2 pollution than the villa and the single-house settlements in Dahlem and in Rahnsdorf.

The decrease in emissions from dense city centers to outlying areas is overlaid with clearly delimited **areas of high emissions**. These areas – in contrast to the areas named above - are primarily large-sized blocks which naturally have more emissions in absolute numbers.

There is a methodological problem in the definition of blocks. Sometimes only relatively small segments of very large blocks are built-up. Prominent examples are the Tierpark Friedrichsfelde (a zoo in a park), the Volkspark Friedrichshain park, and the Tegel and Tempelhof airports. If the effective floor spaces are particularly large, such as the airport terminal in Tempelhof; or if they have a particularly high specific energy use, such as large swimming halls and sport centers, then the entire area is given this emission value even though emissions may be emitted only from a segment, possibly a very small one.

The road network emissions are highest on the city expressways (especially the Stadtring), the east-west boulevards (Frankfurter Allee, Straße des 17. Juni, Kaiserdamm), and the southern accesses to the city center (Tempelhofer Damm). The other main roads, particularly in the city center, form a second class of emitters in road traffic.

The CO_2 Map also illustrates – at least qualitatively – the considerable **CO_2 sinks** formed by the large areas of Berlin forests, particularly in the southeast and southwest.

The legend of Map 08.03 gives information on the distribution of **aviation fuel** tanked in Berlin in terms of its CO_2 emissions which are **not** depicted in the Map. About 75 % of these emissions are from the Tegel airport, which has the largest airport passenger and freight volume.

Map 08.03.2 CO_2 Emissions of Selected Power and Heating, Power, and Heating Stations of the Berlin Public Energy Supply

The map shows the number, structure and spatial distribution of CO_2 emissions from the most important energy production facilities of public suppliers. The largest **single source** of CO_2 emissions is the BEWAG power and heating plant Reuter West. It emitted more than 2.5 million tons of CO_2. Six other power and heating power plants emitted more than 1 million tons of CO_2. Power plants in Berlin are subject to a continual modernization process. The conditions of the Berlin market for power and district heating are also changing due to liberalization of the electrical sector. Some measures have been completed or announced:

- The Mitte power and heating plant received a modern gas and steam turbine unit with natural gas fuel (about 90 % energy efficiency) in 1997.
- The oil-fired power and heating plant in the Steglitz district was shut-down in 1995.
- Two of the three blocks in the power and heating plant Lichterfelde were refitted from fuel oil to natural gas. CO_2 emissions from natural gas combustion are about one-fourth lower than fuel oil.
- The district heating supply of the Märkischen Viertel area was mostly changed to natural gas.

The map does not depict CO_2 emissions of imports of electricity into Berlin. Imports in 1995 amounted to about 4.8 million tons of CO_2, almost double the emissions of the largest single source in Berlin.

Map 08.04 Carbon Dioxide Emissions - Arranged by Sectors and Floor Spaces

Map 08.04.1 CO_2 Emissions of all Recorded Polluters per Square Meter of the Effective Floor Space

This map shows **specific** CO_2 emissions per square meter for all use domains. Measuring the building area eliminates the influence of block size and enables better comparisons of emission data.

The gradient, particularly between the city center and outlying areas, falls back to a **relatively homogeneous distribution**. The energy demand and/or CO_2 emissions per sq. meter differ indeed considerably, but the extremes clearly flatten out. **Emission centers** are formed particularly by capital-intensive, and thus often energy-intensive, industries. Areas of intensive industrial use (cf. Goerzallee, Am Juliusturm/Nonnendammallee, Grünau/Teltowkanal, etc.) become clear. There are also clearly higher CO_2 emissions for parts of the universities, and for individual special uses such as the Tierpark, zoo, and the sport and recreation center in Friedrichshain.

Map 08.04.2 CO_2 Emissions from Electricity Consumption per Square Meter of the Effective Floor Space

The map shows the CO_2 emissions per sq. meter of effective floor space which are solely due to electricity consumption. Electricity is evaluated for the entire city with a uniform emission factor, so the map also corresponds to a floor-space related depiction of **electricity consumption intensity**.

The marked area differences of CO_2 emissions from electricity supply show a chear **difference** between the previously separated areas of the city (cf. the bordering districts of Wedding and Prenzlauer Berg). This difference is primarily due to different patterns of household electricity consumption. In 1995 average household electricity consumption in East Berlin was about one-fourth below West Berlin. The average number of inhabitants per household in East Berlin was 5 % **greater** than in West Berlin (BEWAG 1997, BMWi 1997). Household consumption of electricity was about **30 % lower in East Berlin than in West Berlin.** Large industrial areas are intensive electricity and emission locations. They are depicted with greater differentiation than in Map 8.03.

Map 08.04.3 CO_2 Emissions of Households without an Emission Share from the Public Electricity Supply

More than three-quarters of household CO_2 emissions are caused by production of heating. The **space heating demand** and/or the CO_2 emissions related to it, depend on the area to be heated as well as the heating insulation and/or the heating system used, such as district heating, fuel oil, natural gas, coal, etc. Map 08.04.3 depicts CO_2 emissions from households in absolute numbers, but without the emissions calculated from electricity consumption. It thus initially reflects the density situation presented in Map 08.03. The city center areas in particular, but also the large settlements of Marzahn, Hellersdorf and the Märkisches Viertel, show high emission values. This effect is overlaid in the Prenzlauer Berg and Friedrichshain districts especially, but also the Kreuzberg and Neukölln districts. These districts use more household coal heating furnaces that produce above-average emissions.

Map 08.04.4 CO_2 Emissions from Public Facilities, Industry/Commerce, Trade and Service Sectors, without Emission Share from the Public Electrical Supply

The map depicts CO_2 emissions for all **value producing (economic activity) sectors**, without inclusion of emissions calculated from electrical consumption. The map shows two clear differing distribution patterns for CO_2 emissions resulting from value production.

Value production (economic) activities cause almost **homogeneous** CO_2 emissions at a comparatively **low level** across the entire city area. Primary polluters are mainly small and medium enterprises and the diverse decentralized services of the public and private sectors. There is also a clear number of **focuses** of CO_2 emissions from centers of industrial production, trade (Westhafen, Hermannplatz), and services (universities, Alexanderplatz square). It is to be emphasized that these emission focuses are located less often in the city center and more often in the direction of the outlying areas, and that they form a belt around the inner city areas.

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Analogous Maps

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