City of Hannover, Germany | Directorate of Economic and Environmental Services

CO_2 audit 1990/2005

Emissions from energy generation and transport

Hannover

City of Hannover

The Lord Mayor
Directorate of Economic and Environmental Services

Environment and City Greenspace
Environmental Protection Division
Address Prinzenstraße 4 | D-30159 Hannover
Telephone +49 511 | 168 | 43500
Fax +49 511 | 168 | 43689
Email 67.11@hannover-stadt.de
Internet www.hannover.de

Compilers, Editors Birgit Lüth, Astrid Hoffmann-Kallen
Translator, English Editor Mic Hale, VHS Hannover Community Collage
Text GEO-NET Umweltconsulting GmbH, Hannover
Christa Etling, Peter Trute

E 4-Consult, Hannover
Dedo von Krosigk

Originally published in German as
'CO_2-Bilanz 1990/2005 – Energie- und verkehrsbedingte Emissionen'

Layout m.göke, Hannover
Printed by Interdruck Berger und Herrmann GmbH, Hannover
gedruckt auf 100% Recyclingpapier

Published July 2007

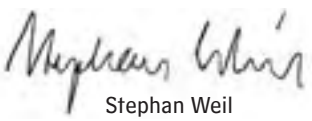
Foreword

Climate protection is very much in the news these days. The City of Hannover has long been strongly committed to improving its climate protection measures; as early as 1992 the City Council supplemented its 1986 resolution to reject electricity from nuclear power with the aim of reducing energy related CO_2 emissions in Hannover by 25% by 2005, compared to the existing level in 1990.

Much progress has been made since then. Since 1994 the civic administration has included a dedicated and dynamic energy and climate protection unit. A municipal climate protection programme has active since 1996. The city's Stadtwerke AG (enercity) energy utility – of which the Municipality owns 76% – is committed to environmentally friendly energy generation. A climate protection fund was established 7 years ago and dispenses 5 million € in grants each year. A regional climate protection agency brings together around 60 institutions and companies from the energy sector in close co-operation.

Hannover has an excellent and extensive local public transport system. We have gathered very positive experiences with Low Energy House construction from the 3,000 dwellings in the new Kronsberg residential development. To date about 80 companies have become involved in Hannover's 'Ecoprofit' programme.

After 15 years of dedicated and active climate protection, it is now time for Hannover to take stock of what has actually been achieved so far and what conclusions can be drawn for the future. In areas where the city administration is able to exert a direct influence there have been visible achievements. On balance, however, our overall gains are less satisfying. If we follow the motto, 'think global – act local' there is still much to do, and we must face up to the challenges of worldwide climate protection.



Stephan Weil
Lord Mayor and Chief Executive

Hans Mönninghoff
Director of Economic and
Environmental Services

Contents

1 Abstract

There were two studies investigating changes in energy related CO_2 emissions (including CO_2 equivalents) for Hannover within the period 1990 to 2005. CO_2 emissions result from the combustion of fossil fuels. These have been divided into emissions due to energy consumption (electricity and heating) and the transport sector.

The first study, 'Emissions caused by energy consumption (electricity and heating)' depicts the development of energy and CO_2 audits[1] for the years 1990 to 2005 (see table 1).

Heating energy demand for 2005 was 8% lower than for 1990. This was due to increased energy efficiency, for example achieved through improved thermal insulation and heating technologies. Furthermore, CO_2 emissions were in effect reduced by 19% due to increases in the use of district heating and natural gas as alternatives to heating oil and coal.

Although electricity consumption rose by 17% between 1990 and 2005 an increase of only 1% in CO_2 emissions was registered. This was due to improved energy efficiency through the deployment of combined heat and power plants for electricity generation. Private households showed the largest increase in electricity consumption (32%) as a result of increases in living space per person and a growing demand for computers and other electronic devices.

The second study, 'CO_2 emissions from the transport sector' examined data for motorised traffic[2], local public transport, rail and air travel (see table 2).

Although traffic volume for these areas of transport increased during the period 1990 to 2005, effectively energy consumption for the total distance travelled decreased.

Road traffic increased by 9% in Hannover over the period but fuel savings from more efficient vehicle engines resulted in an overall reduction of 6% in CO_2 emissions. Private cars on Hannover's motorways are responsible for 46% of the total motorised traffic emissions in Hannover.

Energy consumption for the city of Hannover has decreased by 2% (to about 12,200 GWh p.a.) in the last 15 years. Over the same period, energy related CO_2 emissions decreased by almost 9% to approximately 5,000 kilotonnes p.a.

In tram operations, the lower energy consumption of the newer rolling stock led to a significant reduction in CO_2 emissions. Despite an increase in carrying capacity of 31% (measured in seat-kilometres), CO_2 emissions could be reduced by 22%.

A similar trend was identified in the German rail traffic sector (local- and long-distance). Despite an overall increase in traveller kilometres across Germany, when relating this to the population of Hannover a local reduction in CO_2 emissions of 17% was recorded.

Table 1 | audit results for 2005, change since 1990 in electricity and heating consumption

		Changes in energy consumption 2005 compared to 1990 [%]			Changes in CO_2 emissions 2005 compared to 1990 [%]		
		heating	electricity	totals	heating	electricity	totals
	Overall energy consumption	- 8%	+ 17%	- 2%	- 19%	+ 1%	- 9%
of which	Industry	- 16%	+ 12%	- 9%	- 23%	- 4%	- 12%
	Small commercial	- 3%	+ 16%	+ 2%	- 21%	± 0%	- 8%
	Domestic	- 4%	+ 32%	± 0%	- 15%	+ 14%	- 5%

Table 2 | Extract from the 2005 CO_2 audit of the transport sector

		Changes in energy consumption 2005 compared to 1990 [%]
	Total transport group	- 1%
of which	Motorised road traffic (incl. buses)	- 6%
	Tram	- 22%
	Rail	- 17%
	Air	+ 72%

1 *Electricity, district heating, natural gas, coal, oil, others*

2 *Private cars, trucks, buses*

Air travel has doubled in Germany over the last 15 years. Thus the increase in CO_2 emissions from the air traffic sector, despite lower fuel consumption, remains extremely high. CO_2 emissions from air traffic increased by 72%.

Overall CO_2 emissions in the energy and transport sector decreased by 7.5% from 1990 to 2005. This corresponds to a CO_2 reduction of 495,000 kilotonnes in 2005 compared to the baseline year 1990.

Ultimately, despite significant efforts in energy saving, the City of Hannover has to date not achieved its target of a 25% reduction in CO_2 emissions.

48% of the CO_2 emissions for the year 2005 were from electricity consumption, 34% from heating and 17% from the transport sector.

The average Hanoverian (when industrial and commercial figures are reckoned in terms of individual residents) produced 11.8 tonnes of CO_2 in the year 2005.

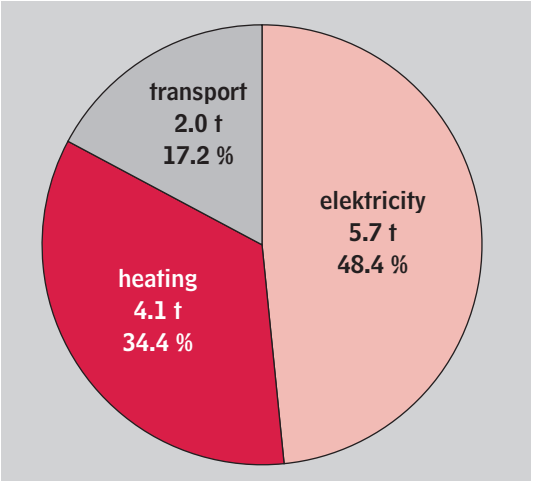


Figure 1 | CO_2 emissions in 2005 per capita

Table 3 | Summary of the CO_2 total audit 1990 & 2005		CO_2 emissions 1990 in 1000 t	CO_2 emissions 2005 in 1000 t	Changes compared to 1990	
energy sector	electricity	2,921	2,944	+ 1%	- 8.8%
	heating	2,602	2,095	- 19%	
transport	road traffic	836	784	- 6%	- 1%
	tram	82	65	- 22%	
	rail (local and long distance)	43	36	- 17%	
	air	94	161	+ 72%	
totals		6,578.5	6,083.6	- 7.5%	

Table 4 | Proportions of individual sectors of the CO_2 total balance 2005		Proportions of CO_2 total emissions 2005
Energy sector	electricity	48.4%
	heating	34.4%
Transport	road	12.9%
	tram	1.0%
	rail	0.6%
	air	2.7%

2

Energy Sector Emissions (Electricity and Heating)

E4-Consult
Dipl.-Ing. Dipl. Wirt.-Ing. Dedo v. Krosigk
Walderseestraße 7
D-30163 Hannover

Telephon +49 511 - 519 48 80
Fax +49 511 - 519 48 81
Email info@e4-consult.de

2.1 Introduction

The City of Hannover had carried out 2 extensive studies in 1990 and 1997 of energy consumption and emissions of climate-altering gases. Nevertheless, a further study embracing 15 years of investigation was commissioned. The objective of this study – a CO_2 audit – was to examine if and to what extent the climate protection programme [1] measures had been successfully implemented, and also to assess whether the goal of a reduction in CO_2 emissions in the energy sector had been achieved.

It should be noted that Hannover's population had not changed significantly (+ 0.5%) during the investigated period (1990: 513,010; 2005: 515,729). Population was therefore not a factor in emission change. However, both the total residential living space increased by 10% (from 19.13 to 21.02 million m²) and the number of households grew by 9% (from 261,597 to 284,362).

Methodology and Data Quality

The audit presented for electricity and heating is mainly based on data provided by the Stadtwerke Hannover energy utility, Hannover City Council and the Lower Saxony Statistics Agency [9] and refers exclusively to the City of Hannover geographical area and to energy uses in the narrower sense i.e. excluding climate-altering emissions from farming or waste treatment. The CO_2 audit for the transport sector is presented in a separate report.

The audit parameters were chosen on the 'territorial' principle i.e. all emissions were ascribed to the city area which are associated with energy use in the city. An exception is the electricity sector, where the producer principle is applied; emissions from all large power stations, wherever they are located, that supply electricity to the Hannover area, are included in the city calculations, although the fuel-to-energy conversion may happen outside the city[3].

With energy supplies through fixed lines – gas, district heating and electricity, the database is good (primary data from Stadtwerke Hannover), while consumption of heating oil and solid fuel must be calculated from statistics and estimates which may be imprecise. The distinctions between consumption sectors should be regarded with reservations as here, too, Stadtwerke data are vague to a certain extent. Because of the methodological and statistical differences in details, a direct comparison of findings for the years 1990 and 2000 is only possible to a limited extent.

All the data presented for heating energy are, unless otherwise noted, adjusted for weather conditions and annualised to the average climate over many years.

2.2 Energy Provision

With the exception of heating oil and solid fuels, most of the energy supplies in the city of Hannover come from the 'Stadtwerke Hannover' energy utility. Even though liberalisation of the electricity and, increasingly, gas supply industry means that external suppliers are pushing into the market, their share of it has so far remained small. Distribution of energy to the customers is still via the Stadtwerke network, which includes the private suppliers' volumes in its statistics. Illustration 2 shows consumption in the city area, comparing the years 1990 and 2000.

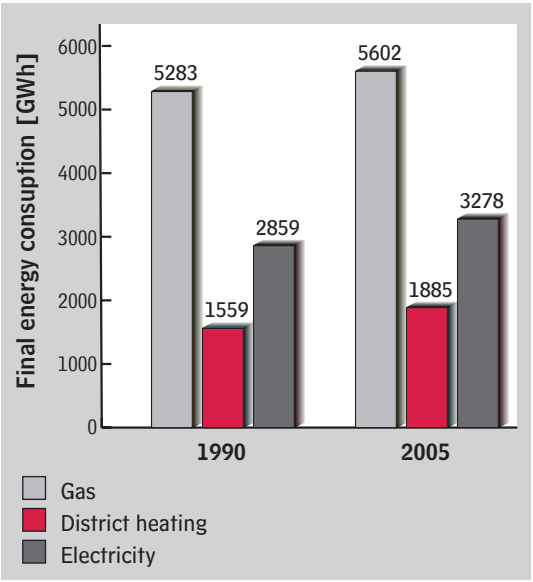


Figure 2 | Final energy consumption through supply lines in Hannover, GWh/a

It is noticeable that gas, and even more so district heating demand rose (weather adjusted). This was, however, mainly due to conversion from oil to gas-fired and district heating. Oil use fell between 1990 and 2005 from around 1,630 to 620 GWh/a. Increases in electricity volumes are, by contrast, directly attributable to increases in consumption.

3 On the other hand, the proportion of fuel consumed by power stations within the Hannover is not counted when it was used to supply consumers outside Hannover even though the emissions came from Hannover. As it is not possible to ascribe individual power stations' pollution to specific consumers, for the purpose of the CO_2 audit customers within and outside Hannover were treated the same and calculated with a unitary emission factor (cf. Chap. 2.2).

Electricity Generation

As figure 3 shows, the structure of electricity generation at the Stadtwerke Hannover has undergone dramatic changes since 1990: the electricity produced has almost doubled since 1990. Along with the increase in electricity in the city (see fig. 2) and the Hannover Region this can also to a large extent be traced to the acquisition of new customers all over Germany since liberalisation of the energy market began, which nowadays accounts for almost 30% of the Stadtwerke energy production[4]. Delivery of electricity from other suppliers by the Stadtwerke has varied considerably in the past and has declined since 2003.

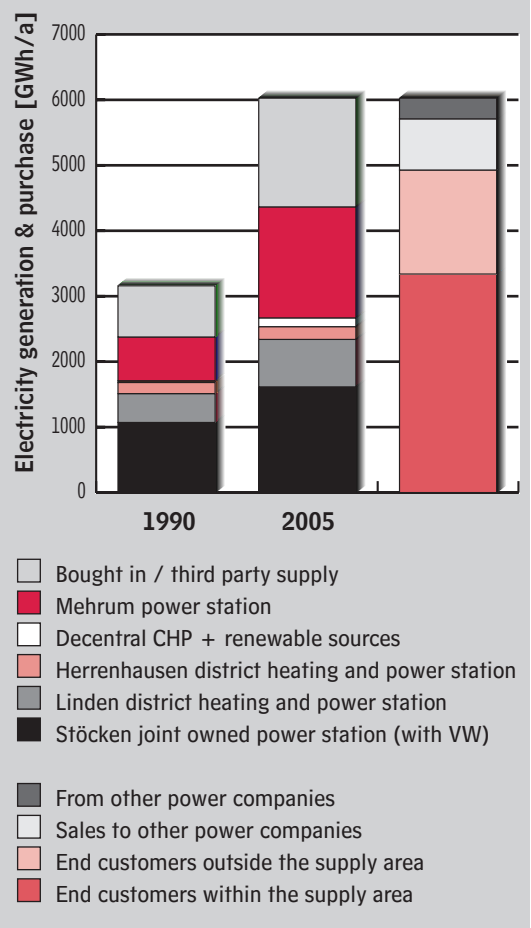


Figure 3 | Stadtwerke Hannover electricity generation and sales structure in GWh/a

To meet the increased demand, on the one hand the Stadtwerke's own power stations had to be run at a higher load, on the other hand buying in electricity from external suppliers or on the electricity exchanges rose markedly. A positive aspect of electricity generation is, in this, the significant increase in electricity generated at the environmentally friendly combined cycle CHP station in Linden to deliver around 17% of the Stadtwerke's own generation. The strong increase in electricity fed into the grid from decentral CHP plants and renewable energy sources (together around 3.1%) should also be mentioned.

A negative effect on the climate protection balance was caused by doubling of generation at the Mehrum coal-fired power station (to around 39% of the total). The Stadtwerke's own power stations and private decentral power plants provide enough electricity to meet demand within its own network area without nuclear power, but not to supply customers in the rest of Germany. Therefore, almost a quarter of the electricity for its own customers must be bought on the electricity market. Third party access to the Stadtwerke supply area amounts to just under 6% and thus is (so far) relatively insignificant. Because of the small proportion of coal in the national power station mix these electricity 'imports' improve the local climate protection figures[5] but on the other hand undermine the City Council's non-nuclear policy.

Combined Heat and Power

Combined heat and power generation (CHP) uses fuel much more efficiently than conventional condensation power stations without heat exchangers and is thus particularly environmentally friendly. Apart from Mehrum coal-fired power station, all the Stadtwerke Hannover power stations also produce district heating; 60% of enercity electricity is generated in CHP plants. As only just under half of the theoretical potential for using steam in district heating has so far been exploited, however, the proportion of 'true' CHP electricity with maximised district heating connection is 'only' around 30%; compared to the national average of around 12%, though, this is already a good figure. Power input from decentral CHP plants has risen dramatically since 1990. In the Hannover area in 2005, 91 plants with a total capacity of around 7.6 MW supplied electricity to the public grid; in 1990 the decentral CHP contribution was just 1.35 MW.

Decentral CHP plant

4 To this is added almost 12 times as much electricity trading on the power market, intended to secure favourable supply conditions and to a large extent comprising multiple payments that, in the course of a year, are traded as short, medium-term or long-term options. This trading is thus partly 'virtual' and not taken into account in this audit.

5 If one were to ascribe the emissions from the Stadtwerke's own power stations, using the unitary emission factors, to customers in its own supply area, and the electricity bought on the open market to external customers all over Germany, the CO_2 emission figures for 2005 would be around 6% higher!

Renewable energy sources

Reliable figures on the use of energy from renewable sources are mainly available for electricity supply governed by the national power input statute (EEG), according to which 12,677 MWh of electricity were generated in Hannover, excluding power from waste and sewage treatment, in 2005. In 1990 the figure was only around 125 MWh (a hundredfold increase!). To this may be added the Glocksee gas decompression plant production (1,700 MWh/a).

For heating from renewables[6] only rough estimates are available for wood-fuelled plants, otherwise the data is relatively reliable. Overall, heating from renewables in Hannover, excluding energy from waste and sewage, amounts to around 9,740 MWh. Wood fuels probably make up about three-quarters of this and solar thermal about a quarter.

A further significant data cluster is the sale of 'green power'. In 2005 Stadtwerke Hannover sold around 10,800 MWh of zero-emission electricity: 54% in the city of Hannover, 6% in the Hannover region and 40% in the rest of Germany! Private households bought most of it (98%). Representing just 0.2% of total electricity consumption or 0.83% of domestic consumption, the proportion of 'eco-electricity' consumed in Hannover is, however, still very low, especially when compared to the national average (0.69% and 2.5%)[7].

Energy from Waste and Sewage Treatment

Since 1990 the importance of waste treatment for climate protection has increased due to the national 'Technical Directive on Municipal Solid Waste' (TASI), which states that no untreated waste may be landfilled and that gas from old waste dumps must be collected. Hannover's waste incineration plant, commissioned in 2005 with a maximum capacity of 280,000 tonnes p.a. (about the amount of waste produced in the Hannover area) can generate up to 200 GWh/a of electricity, of which around 33 GWh were delivered to the city of Hannover in 2005 (the plant began operations in the middle of the year)[8]. Additionally CHP plants fuelled from landfill gas and gas from the biological waste treatment plant generate 19.2 GWh/a of electricity.

When one considers that the embodied energy of the waste stored at the central dump used to escape into the atmosphere as methane gas and that methane has an drastic effect on climate change, the climate protection effects of the new waste treatment plant have an importance beyond its calculated energy gains. This audit, however, only addresses the effects from electricity generation; a quantitative assessment of the climate protection effect of reduced methane emissions was not attempted.

The methane collected at Herrenhausen and Gümmerwald sewage treatment plants was all used in 2005, as in 1990, for electricity generation, most of which (in 2005 around 9.9 GWh, of which about 70% was allotted to the City of Hannover) was, however, consumed by the treatment plants on site and is thus included indirectly in the energy accounting.

6 The consumption data are stated here for information only as important indices; they are not included in the final energy audit because of the relatively poor database and comparability with 1990. In the CO_2 audit they do not appear, as their use (disregarding unquantifiable conversion and transport losses) is regarded as climate neutral.

7 The figures refer to eco-electricity supplied by Stadtwerke Hannover to customers in the city area. The amount of eco-electricity from outside suppliers to Hannover is not known. If the overall proportion in Hannover corresponds with the national average, this means that the Stadtwerke's market share of this sector is only around 30%.

8 This electricity is not included in the energy and CO_2 audit, as it is fed into the E.ON supply grid.

2.3 Heating Energy and Electricity Consumption

Table 5 shows weather-adjusted final energy consumption in the City of Hannover in 1990 and 2005. Distinctions between different consumer sectors should be regarded with reservations, above all in comparing across the years, as the data can only be for orientation partly because of unclarity in allotting consumers to particular sectors and in the Stadtwerke's accounting systems. Renewable energy sources[9] are not included, as they were not being documented in 1990 and are of minimal significance for the overall CO_2 audit. The section, 'other' brings together energy sources (except heating oil) which are not delivered through lines: coal above all, but also small quantities of waste, liquefied gas and other fuels.

Comparing the figures for 1990 and 2005 shows that total non-renewable energy consumption decreased by 2% over 15 years. While heating energy demand is today about 8% less than in 1990, electricity demand has risen dramatically since then, and is today about 17% higher. This development can be ascribed to several overlapping trends. The total residential living area has increased by 10% over this period and the number of households by 9%, which increases demand just as strongly as economic growth[10]. Against this may be set increased energy efficiency; while the influences to increase electricity consumption were dominant, the threatening trend to higher demand for heating could be halted and even reversed with energy-saving measures.

Energy audit, 1990 [GWh/a]	Gas	District heating	Electric heating	Oil-fired heating	Other	Total heating	Electricity	Totals
Industrial	1,296	732	0	184	911	3,124	1,175	4,299
Small commercial	1,152	643	10	831	101	2,736	1,055	3,791
Domestic	2,835	183	84	614	139	3,854	535	4,389
Totals	5,283	1,559	94	1,628	1,151	9,714	2,765	12,479

Energy audit, 2005 [GWh/a]	Gas	District heating	Electric heating	Oil-fired heating	Other	Total heating	Electricity	Totals
Industrial	1,081	666	0	83	789	2,618	1,312	3,930
Small commercial	1,514	872	3	251	8	2,648	1,222	3,670
Domestic	3,007	347	37	289	7	3,687	705	4,391
Totals	5,602	1,885	40	622	804	8,953	3,238	12,191

Energy audit, 2005 [% compared to 1990]	Gas	District heating	Electric heating	Oil-fired heating	Other	Total heating	Electricity	Totals
Industrial	83%	91%	–	45%	87%	84%	112%	91%
Small commercial	131%	136%	33%	30%	8%	97%	116%	102%
Domestic	106%	190%	44%	47%	5%	96%	132%	100%
gesamt	106%	121%	43%	38%	70%	92%	117%	98%

Table 5 | Final energy use in the City of Hannover in GWh/a according to consumer sectors and fuels, 1990 – 2005

9 Waste to energy in the industrial sector is, however, included, along with its biogenic component, in the calculations.

10 Reliable figures for the price-adjusted gross economic product of Hannover are not available for the period under consideration, so that no quantitative statements can be made on economic growth. The data that are available, however, cannot account on their own for the considerable increase in electricity demand from commerce and industry.

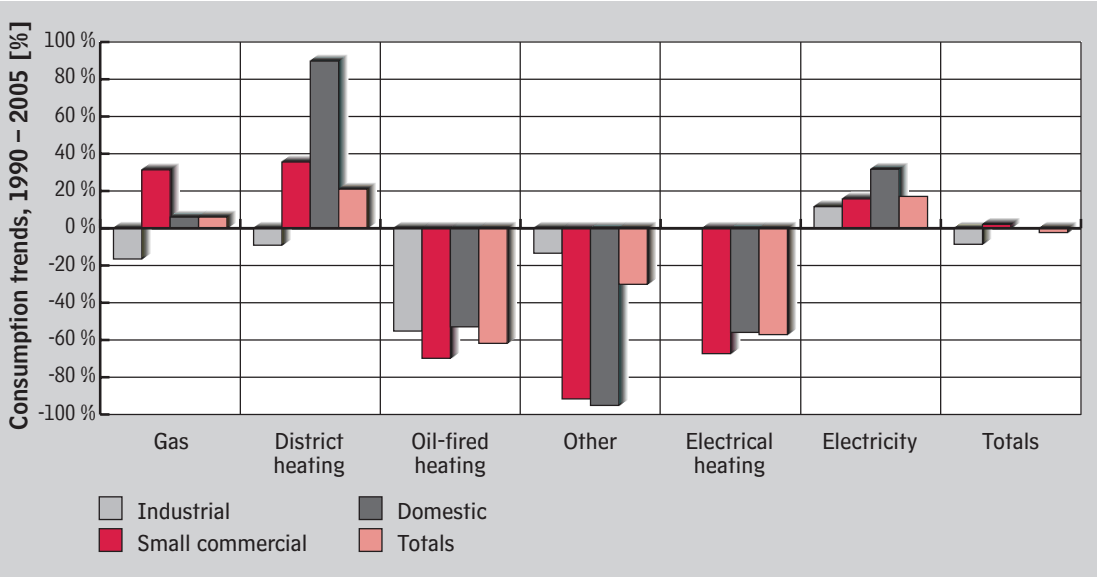


Figure 4 | Developments in final energy consumption, 1990 – 2005

Differentiating between energy sources shows that gas and, even more so, district heating consumption (except in the industrial sector) have risen considerably since 1990. This can be mainly ascribed to conversion from other fuels, reflected in a decrease in oil demand of over 60%. Electricity demand for heating has declined steadily to less than half the 1990 figures. Consumption of other fuels, especially coal has also fallen dramatically and today plays an insignificant role in the domestic, small business, trade and services sectors.

Hannover City Council Buildings

An analysis by the City Council property management department showed that, taking into consideration buildings acquired and disposed of, between 2005 and 1997[11] comparable buildings reduced their heating demand by an overall 24%, while electricity consumption rose by about 2% in the same period. This resulted in a reduction of about 16% in CO_2 emissions. This is less than the decrease in final energy use, as the considerable increase in environmentally friendly district heating to public buildings could not compensate for the growth in CO_2-intensive electricity consumption.

Of the city's public buildings, however, only those run by the property management department could be assessed on a differentiated basis. Important properties not included in the calculations were, for example, Hannover Congress Centre, the municipal inland port facilities, Sprengel Museum, some old people's homes and other buildings. Furthermore, the new data are not directly comparable with previous audits, as properties have been acquired and transferred to other owners; in 2001, especially, the municipal hospitals, vocational schools and waste management services were transferred to the Hannover Region authority. In the results tables of this climate protection audit, then, public buildings are not listed separately but included in the 'small commercial' sector.

11 Comparison with the 1990 buildings stock cannot be retrospectively reconstructed, and so only the changes since 1997 can be documented here.

2.4 Greenhouse Gas Emissions

From the developments in final energy consumption presented here, with the help of specific emission factors for each energy source the climate-altering emission attributable to the City of Hannover may be calculated[12]. The emissions presented in Table 6 refer not only to the direct emissions at the energy conversion locations but also consider the entire supply chain from primary energy extraction to the consumer including materials use, transport and all conversion stages. Other climate-altering emissions such as methane are converted to their CO_2 equivalents.

Compared to the reference year, 1990, there has been a general decrease in greenhouse gas emissions from energy use of about 9%, whereby the disproportional increase in electricity demand with its high specific emission factor shows up very clearly in the accounts[13]. Emissions per head of population have, over the 15-year period, decreased from 10.8 to 9.8 tonnes of CO_2.

An overall decrease of 19% in emissions from heating demand can be determined. For private households CO_2 emissions from heating have fallen by 'only' 15%; adjusting this figure for the 10% increase in total residential space gives a 23% improvement. The reasons are both better energy efficiency and increases in the proportion of district and natural gas-fired heating replacing oil and coal-fired heating. CO_2 emissions from domestic electricity use rose disproportionately to 114% of 1990 levels. The increasing numbers of domestic electrical appliances (especially computers, tumble driers, dishwashers, microwaves and video recorders – increases of between 60 and 210% in the last 10 years)[14] and the 9% increase in the number of households could not be compensated for by increased energy efficiency and saving measures.

CO_2 audit, 1990 [kt/a]	Gas	District heating	Electric heating	Oil-fired heating	Other	Totals heating	Electricity	Totals
Industrial	301	98	0	58	404	860	1,241	2,102
Small commercial	281	86	10	261	45	683	1,114	1,797
Domestic	692	24	89	192	62	1,059	565	1,625
Totals	1,274	208	99	511	510	2,602	2,921	5,523

CO_2 audit, 2005 [kt/a]	Gas	District heating	Electric heating	Oil-fired heating	Other	Totals heating	Electricity	Totals
Industrial	251	65	0	26	317	660	1,189	1,849
Small commercial	369	85	3	79	4	540	1,113	1,653
Domestic	734	34	34	91	3	895	642	1,537
Totals	1,354	185	37	195	324	2,095	2,944	5,039

CO_2 audit, 2005 [% compared to 1990]	Gas	District heating	Electric heating	Oil-fired heating	Other	Totals heating	Electricity	Totals
Industrial	83%	67%	–	45%	79%	77%	96%	88%
Small commercial	131%	100%	28%	30%	8%	79%	100%	92%
Domestic	106%	139%	38%	47%	5%	85%	114%	95%
Totals	106%	89%	37%	38%	64%	81%	101%	91%

Table 6 | CO_2 audit for the City of Hannover, 1990 – 2005, in 1,000 t/a

12 In this, the source of the emission factors applied is important. The calculations of this audit are based on the current version (4.3) of the GEMIS software programme, adapted to the specific conditions in Hannover (especially the Stadtwerke power station structure). Fuels summarised as 'other' were all calculated using the emission factor for coal. The emission factors of fuels used, some of which have been markedly increased in GEMIS versions since 1997 in the light of new scientific discoveries, were retrospectively adjusted, i.e., the same fuel emission values were used for every year.

13 Although the emission factor for electricity has improved since 1990, because of the significant increase in the proportion generated by CHP plants, from 1,056 to 911 g/kWh, emissions from electricity consumption have still increased, by 1%, due to higher consumption.

14 National average values for 2003 compared to 1993 according to the Federal Statistical Office general environmental accounting for 2006 [9].

2.5 Comparisons with other German Cities and National Trends

Comparing the Hannover CO_2 audit with those of other local authorities and developments at national level [10] is difficult, as the methodologies are usually different, results are often inadequately documented and baseline reference points can be very diverse. Data on CO_2 emissions from electricity generation, particularly, are seldom comparable; depending on whether the city in question has its own energy utility or power stations, and which auditing parameters are chosen (geographical or the polluter principle), emissions from electricity generation appear to various extents and with varying CO_2 factors in the calculations. Furthermore, not all audits are weather-adjusted.

On climate protection, Hannover had a comparatively favourably starting position because, even in 1990, it used a high proportion of environmentally friendly energy sources (natural gas and district heating supplied 96% of households in 2005 compared to the national average of 59%) and thus had less room for further improvements. The CHP contribution to electricity generation by the Stadtwerke was also already above the national average in 1990.

Statistics from other local authorities should, then, be critically examined in terms of comparability. Comparing against the Federal Government's announcement that German CO_2 emissions fell by 19% between 1987 and 2004 is misleading because this figure is not weather-adjusted and can be mainly ascribed to the collapse of the East German economy in 1990.

Comparison between municipalities becomes simpler when it is based not on CO_2 emissions but on developments in final energy consumption (excluding transport)[15] and refers to the respectively documented study period. Looked at this way, Hannover acquits itself very well in comparison to other Climate Alliance municipalities and the general developments across Germany, as Figure 5 shows.

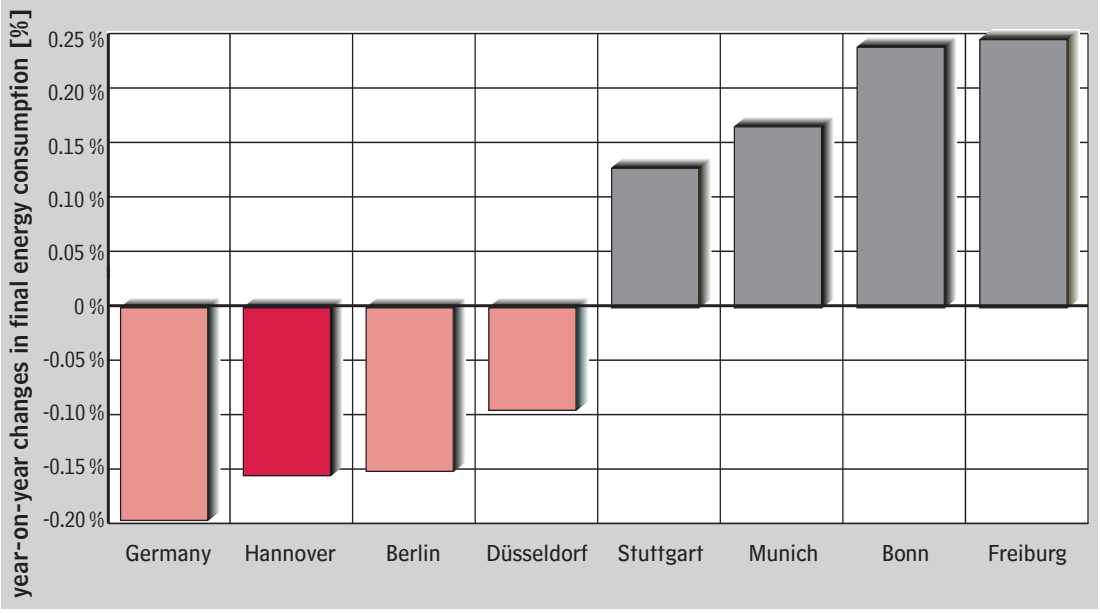


Figure 5 | Average year-on-year changes in final energy consuption

15 Through the simple addition of electricity and heat energy to give a combined final energy value, however, detailed information is lost in this form of presentation.

2.6 Summary

Taken as a whole it must be said that despite strenuous efforts to save energy, Hannover has clearly failed to achieve its climate protection objectives. Although specific CO_2 emissions per head of the population have sunk by 9% since 1990, the city has not even got halfway to meeting its ambitious target of reducing greenhouse gas emissions by 25%.

Nevertheless, within the limited possibilities available to a local authority, where the City Council could exert a direct or indirect influence (public buildings managements, the work of the energy and climate protection unit and the climate protection agency providing energy-saving advice services, the proKlima funding programme, increasing the proportion of CHP from the city energy utility) the programme has been a success.

Positive developments have been:

- A significant 9% reduction in heating energy demand despite economic growth and 10% more residential space
- Expansion (by 21%) of the environmentally-friendly district heating network, mainly replacing oil-fired heating systems (62% reduction), 57% reduction in electric storage heaters (now representing less than 1% of domestic heating energy consumption)
- Expansion of CHP at the Stadtwerke power stations to meet 30% of demand, and addition of 6.25 MWel from decentral CHP plants
- A significant increase in energy from renewables: around 12,500 MWh more electricity (excluding that from waste and sewage treatment), about 400 solar thermal installations.

Negative trends are, above all:

- A marked rise in electricity demand (17% overall, and 32% in private households)
- Increased use of the Mehrum coal-fired power station (electricity supply has doubled to meet 39% of the grid power input) to meet increased electricity sales by Stadtwerke Hannover, with a corresponding negative influence on the electricity/emissions factor.

Even if further improvements in the climate protection balance are possible and necessary through measures lying within the municipality's remit (energy saving counselling, least-cost-planning, further extension to the district heating network and promoting decentral CHP, energy-efficient optimisation of public buildings), Hannover's influence will be limited without complementary measures at national and international level.

2.7 Sources (in German – for actual titles see the German version of this booklet)

[1] A Municipal Climate Protection Programme for the City of Hannover, municipal environmental series, No. 13, Hannover 1996

[2] GERTEC GmbH and Wuppertal Institut für Klima, Umwelt, Energie: measures-oriented continuation of the CO_2 study for Greater Hannover and development of an ongoing CO_2 auditing procedure, Hannover und Wuppertal 2000

[3] diverse evaluations and documents of Hannover City Council (Energy and Climate Protection Unit, Elections and Statistics Office, Property Management Department) and Hannover Region Waste Management Services

[4] Stadtwerke Hannover AG 2005 Annual Business and Sustainability Report plus reports from its departments: energy management/strategic planning, sales and trading, with the customer data reporting department

[5] Survey of Energy Use by Manufacturing Industry and Mining, Quarrying and Earthmoving in 2005, Niedersächsisches Landesamt für Statistik

[6] Evaluation of 49 questionnaires completed by service companies in the City of Hannover

[7] Evaluation of furnaces requiring certificates of inspection according to § 1 BImSchV, combustion exhaust engineers and inspectors guild, Hannover (own research, 2006)

[8] GEMIS, Version 4.3 (www.gemis.de)

[9] Federal Statistical Office Environmental and Economic Survey for 2006

[10] Evaluation of various energy and climate audits (sources: Climate Alliance and Internet)

3

GIS-based audit for traffic related CO_2 emissions (reference year 2005)

GEO-NET Umweltconsulting GmbH
Große Pfahlstraße 5 A
D-30161 Hannover

Telephone +49 511 - 388 72 00
Fax +49 511 - 388 72 01
www.geo-net.de
Peter Trute, Christa Etling
Email trute@geo-net.de

3.1 Introduction

GEONET was commissioned by Hannover City Council to determine levels of traffic-related CO_2 emissions for the reference year 2005. Based on traffic data for the urban area, the total emission of CO_2 and CO_2 equivalents produced by motorized individual traffic was calculated using the emission factor handbook (UBA 2004). In the public transport sector CO_2 emissions from the ÜSTRA urban light rail system and due to Hanoverians' use of German Rail services and flights to and from Hannover airport were determined. Comparison of the findings of the new CO_2 audit with those from 1990 should reveal trends in CO_2 emissions over the 15-year period.

3.2 CO_2 audit for motorised road traffic in 2005

In order to calculate road traffic emissions, the City of Hannover provided traffic volume prognosis data from the 'VISUM' traffic model for the year 2002.

According to the Lower Saxony Statistics Office, the total number of registered motor vehicles did not change significantly between 2002 and 2004. While vehicle registrations in the Hannover urban area showed a slight decrease (-0.3%), the number of motor vehicles in the Hannover region increased by 1.1%. The City of Hannover Statistics Office noted 214,851 registered motor vehicles in the year 2005.

The traffic data of the prognosis model provided for the year 2002 was also compared with traffic census data for some street sections in 2005 (Argus, 2005; Schnüll, Haller and Partner, 2005). Model values and census data were similar. Thus, determination of CO_2 emissions was based on predicted traffic volume data and traffic conditions for the year 2002.

The street sections monitored within the Hannover urban area were classified by traffic conditions as presented in Table 7. The designation of traffic conditions complies with the guidelines of the emission factor handbook (UBA 2004), where further descriptions of the respective traffic conditions can be found. Considering the pre-determined average traffic load on the particular street sections, the mean daily CO_2 emissions were calculated on the basis of the emission factor handbook for the reference year 2005. It was found that the emissions calculated according to the handbook corresponded with the actual vehicle emissions measured in situ. This procedure is the most modern available and is also used for assessment of traffic-related emmissions in the context of approval procedures. To determine total emissions from private vehicles, all emissions were added together to a yearly CO_2 environmental load.

All essential input data is shown in Tables 7 and 8. A detailed listing of the monitored street sections was provided in an annex to the study.

Table 8 summarises the section lengths for every traffic situation as well as the total kilometres driven (vehicles per day x section length) and CO_2 emissions according to the emission factor handbook (UBA 2004) for the reference year 2005. The percentage of heavy goods vehicles (HGV) as given in table 8 includes light commercial vehicles, heavy commercial vehicles and buses.

The input data is given graphically in figure 6 and 7 (see appendix). Figure 6 shows the traffic situations in the considered street sections, while figure 7 illustrates the corresponding traffic volume in the respective section (DTV / daily traffic volume, average number of vehicles per day). Figure 8 (see appendix) shows the calculated CO_2 emissions in tonnes per year and kilometre.

On the basis of this data, total emissions of 786,487 t/a as direct CO_2 emissions from road traffic within the Cty of Hannover were calculated for the year 2005, of which 283,135 t/a are emitted by HGVs or buses (36%), and 503,352 t/a bei passenger cars (64%).

Table 8 shows the proportional contribution of various traffic conditions to total emissions. The high emissions from motorway sections is noticeable: Within the urban area, 60.2 km of motorways were observed, constituting just 15% of the total observed road network. For this road type, CO_2 emissions of 359,215 t/year have been calculated, which represents a share of ~ 46% of total emissions from individual traffic in the urban area. In particular, these emissions are caused for the most part by long-distance traffic and commuters from the hinterland and not primarily by Hannover residents.

Traffic situation	Description
AB_100	Motorway, speed limit 100 km/h
AB_120	Motorway, speed limit 120 km/h
AB_80	Motorway, speed limit 80 km/h
IO_HVS>50_1	Urban main road / highway, speed limit > 50 km/h, minor flow interruptions
IO_HVS>50_2	Urban main road / highway, speed limit > 50 km/h, average flow disruptions
IO_HVS1	Urban main road, priority right of way, no flow disruptions
IO_HVS2	Urban main road, priority right of way, minor flow disruptions
IO_HVS3	Urban main road, priority right of way, average flow disruptions
IO_HVS4	Urban main road, priority right of way, serious flow disruptions
IO_LSA1	Urban main road with traffic lights, minor flow disruption
IO_LSA2	Urban main road with traffic lights, average flow disruption
IO_LSA3	Urban main road with traffic lights, serious flow disruption
AO	Rural traffic – average
IO	Urban traffic – average

Table 7 | Traffic situations considered in the audit

Traffic situation	Section length total km	Driven km/day	HGV share* in%	CO_2 emissions in t/a
AB_100	20.3	982,979	14.65	87,592
AB_120	27.6	2.339,386	17.45	225,310
AB_80	12.3	570,278	13.82	46,313
IO_HVS>50_1	8.5	343,563	12.43	23,528
IO_HVS>50_2	3.9	131,162	13.30	10,671
IO_HVS1	13.4	118,655	12.96	8,119
IO_HVS2	36.0	469,555	13.02	37,594
IO_HVS3	4.0	53,636	16.17	4,874
IO_HVS4	0.3	10,868	14.29	1,080
IO_LSA1	24.6	412,179	13.86	35,948
IO_LSA2	25.9	742,260	15.44	76,877
IO_LSA3	1.3	55,327	15.92	5,888
AO	35.9	472,028	14.20	38,136
IO	181.8	1,854,269	12.79	184,557
Totals	395.8	8,556,145	–	786,487

** including buses*

Table 8 | Driven kilometres and CO_2 emissions from traffic in 2005

Furthermore, the emission of methane (CH_4) produced by individual traffic has been calculated using the emission factor handbook (UBA 2004). The effects of emitted methane on the climate have been converted to that of the equivalent amount of carbon dioxyde; one tonne of methane has the same effect as 21 tonnes of CO_2. For 2005, this resulted in an additional burden of 249 t CO_2 equivalent.

Including methane CO_2 equivalents, total emissions in 2005 were 786,736 tonnes of CO_2 equivalents for motorised road traffic.

3.3 Comparison of the CO_2 audits for road traffic from 1990 & 2005

1990 Database

The volume of individual traffic for the CO_2 reduction study within the Hannover region (Region Hannover from 1992) was mainly derived from analysis of the Greater Hannover local government association study (ZGH 1990). This data was based on the traffic volume map of Lower Saxony from 1985 and censuses by the City of Hannover in 1987. Kilometres driven on motorways have been estimated by the Greater Hannover local government association on the basis of the 1990 traffic census. Due to the strong increase in inter-regional traffic after opening of the East-West German border, a case study estimate indicates that this count may have been underestimated.

Taken as a whole, the driven kilometres within the Hannover region increased continuously in the period prior to the 1990 audit. Between 1985 and 1990 the number of vehicle registrations increased by about 50,000 in the rural district and 25,000 in the City of Hannover – an increase of more than 15% in 5 years. According to information from the City of Hannover Statistics Office, there were 199,624 registered vehicles in Hannover in 1990.

City of Hannover 1990: driven km/day	
Motorway	1,545,426
National highway	1,563,247
State highway	192,151
Country road	56,277
Main road	3,147,366
Other roads	6,289,426
total	7,834,852

Table 9 | Driven kilometres by individual traffic in km/day in 1990

For the CO_2 reduction study conducted by the Greater Hannover area (Region Hannover from 1992), emissions from individual traffic were estimated from fuel consumption (according to estimations by the Federal Environment Agency, UBA 1987). To determine CO_2 emissions a linear relationship with fuel consumption was assumed (3.125 g CO_2/g fuel). In this study (Region Hannover 1992) no CO_2 equivalents were determined for the year 1990.

The driven kilometres as shown below in Table 9 formed the basis for the 1990 CO_2 reduction study (Region Hannover 1992). Detailed calculations of the CO_2 emissions cannot be verified because the relevant information on the traffic situation and proportion of HGVs is not given in the study from 1990.

Assessment of trends in road traffic CO_2 emissions, 1990 – 2005

Because the differentiated traffic situations and proportion of HGVs that formed the basis for the 1990 study are not precisely known, emissions for 1990 had to be recalculated according to the emission factor handbook (UBA 2004). Thus calculations for both audits are set on as similar as possible and thereby comparable data base.

To analyse development of the CO_2 emissions caused by motor vehicles, first the trends in fuel consumption were considered. The fuel consumption and emission factors for carbon dioxide and methane as shown in Table 10 are derived from the emissions factor handbook for the years 1990 and 2005. CO_2 emissions are commensurate with the fuel consumption of vehicles. During the 15-year period under consideration the fuel consumption of passenger cars per journey decreased by about 16%, and consumption by heavy goods vehicles by about 10%. Thus direct CO_2 emissions have fallen by the same factor. This decrease in emissions per journey must, however, be juxtaposed with an 8% increase in the number of vehicle registrations and a 9% increase in total driven kilometres.

In what follows CO_2 emissions for the years 1990 and 2005 are determined on the basis of the same calculation procedure to gain a comparison through a uniform calculation method. For both audits a heavy goods vehicle (HGV) share of 14.5% of the traffic volume was assumed, permitting reconstruction of the calculated CO_2 total output for the year 2005. On the basis of the average emission factors for CO_2 and CH_4 (methane) as given in Table 10, total CO_2 emissions including equivalents were calculated for the stated total driven kilometres and respective reference years of both audits. The findings are also shown in table 10.

Estimation of emissions for the years 1990 and 2005, based on a uniform calculation procedure, shows a decrease in CO_2 emissions due to individual traffic of about 6% despite an increase in individual traffic of about 9%.

		1990	2005	Change compared to 1990
Registered passenger cars	Pass. cars	199,624	214,851	+ 8%
Driven km/day	Total vehicles	7,834,852	8,556,145	+ 9%
Average fuel	Cars	67	56	- 16%
consumption in g/km	HGVs	240	216	- 10%
CO_2 emission factor in g/km	Cars	212	177	- 16%
(rounded)	HGVs	764	686	- 10%
Total CO_2 emissions in t/a	Total vehicles	834,656	783,252	- 6%
CH_4 emission factor in g/km	Cars	0.03	0.003	- 90%
(average driving conditions)	HGVs	0.02	0.009	- 55%
Total emissions of CO_2 equivalents in t/a	Total vehicles	836,371	783,506	- 6%

Table 10 | Estimation of CO_2 emissions based on total driven kilometers

3.4 CO_2 emissions caused by the ÜSTRA light rail public transport system

In 2005 the electricity consumption by ÜSTRA in operating its tram and underground railway system in the Hannover urban area was, as stated by the City of Hannover, 70,865 MWh traction current provided by the city energy utility (Stadtwerke Hannover AG). On the basis of CO_2 emission factors for the production of electricity (see Table 11, Stadt Hannover, 2007) and taking CO_2 equivalents into consideration this means that CO_2 emissions caused by the operation of the ÜSTRA light rail system amounted to 4,558 t in 2005.

The reduction study (Region Hannover, 1992) noted CO_2 emissions of 58,890 t from the ÜSTRA light rail system in 1990. However, direct and indirect (from the supply chain) CH_4 was excluded from this calculation. Thus a direct comparison of CO_2 emissions from the two audits is not useful, and so CO_2 emissions in 1990 have also been calculated on the basis of the ÜSTRA power consumption as stated in the reduction study (Region Hannover 1992) and CO_2 emission factors for electricity production (Stadt Hannover, 2007) including CO_2 equivalents.

Table 11 shows emissions in 1990 and 2005, calculated from the same data basis and including CO_2 equivalents.

To evaluate developments in operating performance, information on ÜSTRA driven kilometres and passenger numbers on the entire route network in the Hannover region was compared (the route network extends beyond the city limits). Data on these developments was published by the GVH (Großraum-Verkehr Hannover) municipal public transport operator in 2005. This data, covering the period 1970 to 2004, was analysed in order to determine changes within the 14-year period (1990 to 2004). The indicators, 'seat kilometres' and 'person kilometres' quantify the driven kilometres of the ÜSTRA light rail system. In this context the seat kilometres parameter represents the sum of the tram seats times the distance covered, the person kilometres figure refers to the distance covered times the number of passengers. Table 12 shows the data on trends in operating performance.

It becomes apparent that ÜSTRA has significantly increased its carrying capacity over the 14-year period, but the increase in seat kilometres of ÜSTRA trams (31%) is less pleasing in the light of an effective increase in person kilometres on all public transport of just 4%. Due to the markedly lower power consumption of the new trams, CO_2 emissions declined significantly despite an increase in carrying capacity.

Evaluation of power consumption of all trams in the Hannover city area shows a decrease in CO_2 emissions of a magnitude of 22% while carrying capacity increased by about 31% in the same period.

	1990	2005	Change compared to 1990
ÜSTRA-traction current in MWh	78,000	70,865	- 9%
CO_2 emission factor	1.0564	0.9110	-
Total CO_2 emission in t/a	82,399	64,558	- 22%

Table 11 | CO_2 emissions (incl. equivalents) from ÜSTRA light rail system operations

	1990	2004	Change compared to 1990
Seat kilometres of ÜSTRA trams, in millions	2,802	3,667	+ 31%
Person kilometres on the entire Hannover region public transport system, in millions	1,335	1,391	+ 4%

Tabelle 12 | Operating performance of ÜSTRA trams in the Hannover region

3.5 CO_2 emissions caused by rail traffic

A detailed database of the number of passengers and power consumption of heavy rail traffic within Hannover city and region is unfortunately not available, and so the CO_2 emissions caused by rail traffic (commuter and mainline passenger systems) have been determined on the basis of a statistical analysis of nationwide rail traffic and a weighting related to the population of Hannover (Niedersächsisches Landesamt für Statistik, 2006). Information was provided for this by the Federal Environment Agency. However, emissions of CO_2 equivalents were not included. Table 13 shows developments in rail traffic.

The available traffic data for 1990 is marred by uncertainties, as the transport statistics for the first year after German unification are considered unreliable by the Federal Environment Agency. In spite of an increase in carrying capacity in this transport sector a significant decrease in CO_2 emissions can be ascertained as a trend. This evaluation for the City of Hannover results in heavy rail traffic-related CO_2 emissions of 35,590 t in 2005.

Compared to 1990, a decrease in CO_2 emissions caused by heavy rail traffic of about 17% has been estimated.

	1990	2005	Change compared to 1990
Travelled km per inhabitant (nationwide)	774	909	+ 17%
CO_2 emissions per capita in kg	84	69	- 18%
Inhabitants of the City Hannover	513,000	515,800	+ 0.5%
CO_2 emissions in tonnes caused by inhabitants of Hannover	43,092	35,590	- 17%

Table 13 | CO_2 emissions due to heavy rail traffic, 1990 and 2005

3.6 CO_2 emissions caused by air traffic

Between 1990 and 2005 the kilometres flown by citizens of the Federal Republic of Germany more than doubled. Thus the increase of CO_2 emissions from air traffic is notably high. While Germans flew approx. 134,815 million km in 1990 according to the Federal Statistical Office, in 2005 this figure was 328,000 million km. The number of passengers has also doubled in the considered period. Increases in kerosene consumption were derived from the Working Party on Energy Balance (Arbeitsgemeinschaft Energiebilanzen) figures. Table 14 summarises the national developments in air travel.

The calculated amount of fuelled kerosene per 100 person kilometres does not necessarily correspond to the actual kerosene consumption of the aircraft. The decrease in this value shows only the trend to lower fuel consumption. Furthermore, this decrease in total fuel consumption of about 27% should not be regarded as an absolute value, because changes in fuelling policies of the airlines (the proportion of fuelling abroad) also influence this figure. But the listing shows the enormous growth in air traffic within the period in spite of a decrease in kerosene consumption per 100 person kilometres flown. Nevertheless this growth led to a significant increase in fuel consumption and a corresponding rise in CO_2 emissions 76%.

According to the City of Hannover, 156,320 tons of kerosene were fuelled in 2005 at Hannover airport. Approximately 1/3 of the air passengers were residents of Hannover, so that total kerosene consumption of 52,106 t can be determined for Hanoverians. Assuming an emission factor for CO_2 equivalents (methane and nitrous oxide) of 3.2 g CO_2/g kerosene (IFEU, 2006), an air traffic-related CO_2 output of approx. 166,741 t can be calculated for the year 2005.

As stated by the Federal Environment Agency, the kerosene consumption in Germany required for civil aviation amounts to 97.5 kg per capita (2005). Multiplying this figure by the population of the City of Hannover (approx. 515,800 in 2006 according to the Lower Saxony Statistical Office) produces an estimated aircraft fuel consumption figure of 50,291 t. **Based on this, an output of CO_2 equivalents caused by air traffic of approx. 160,930 t is calculated for 2005.**

The figure so determined is of the same magnitude as that previously determined for Hannover airport. Because the number of flights made by Hanoverians was not precisely known, the lower value of 160,930 t has been adopted for the CO_2 audit. In addition to CO_2, several other pollutants such as nitrogen oxides, particles and sulphur are emitted. Discharged at a higher altitude, they may also have climate-altering effects depending on cruising altitude and atmospheric conditions. The impact on climate of the various emitted substances can be converted to that of carbon dioxide using the 'Radiative Forcing Index' RFI. The RFI-related range of values is between 2 and 4 (IPCC, 1999). At high cruising altitudes (> 9 km above sea level) the effect of these emissions is markedly higher than that of short-distance flights at lower altitudes. An assessment of the activity of the different emitted substances depending on the cruising altitude is not the subject of this investigation. However, it should be born in mind that emissions from aircraft have a demonstrably heavier impact on climate than emissions from surface vehicles.

	1990	2005	Changes compared to 1990
Passengers	66,953,577	147,972,938	+ 121%
Total flown passenger kilometres in Millions	134,815.464	328,000.197	+ 143%
Flown km per inhabitant	1,690	3,978	+ 135%
Fuelled kerosene in t, totals	4,558,000	8,023,000	+ 76%
Fuelled kerosene per 100 passenger kilometres in kg	3.4	2.5	- 27%

Table 14 | National trends in air travel

	1990	2005	Veränderung gegenüber 1990
Total CO_2 emissions in t/a	93,571	160,930	+ 72%

Table 15 | Comparison of CO_2 emissions from Hannoverians' air travel (incl. equivalents) caused by kerosene consumption (fulled kerosene) in 1990 and 2005

Trends in CO_2 output from Hanoverians' air travel in the 15-year period under investigation have been extrapolated from national developments. According to statements by the UBA, aviation fuel consumption per citizen amounted to 57 kg of kerosene in 1990. A population of 513,000 Hanoverians in 1990 would imply fuel consumption of 29,241 tonnes.

Considering the aforementioned emission factors, this would mean CO_2 equivalents from air traffic of approx. 93,571 t in 1990. From 1990 to 2005, air traffic-related CO_2 emissions caused by Hanoverians have increased by about 72%.

3.7 Summary of traffic-related CO_2 emissions

As briefed by Hannover City Council, the study assessed transport-related CO_2 emissions including CO_2 equivalents for the reference year 2005, considering motorised road traffic, ÜSTRA light rail operations, commuter and main line rail traffic as well as air travel at Hannover airport. As far as possible, comparison of the determined emissions with those in 1990 has been conducted. Table 16 shows the calculated CO_2 emissions as well as changes over the 15-year period. With regard to air traffic, absolute emissions of CO_2 and CO_2 equivalents of methane and nitrous oxide have been calculated. The different effects of other emitted pollutants on climate depending on cruising altitude have not been considered.

Within the considered period 1990 to 2005 traffic volumes of all 4 kinds of transportation has increased, while the energy consumption per kilometre has decreased. The fuel consumption of passenger cars and heavy goods vehicles has decreased by about 16% and 10% respectively. Thus the lower energy consumption of newer engines counterbalances the increase in driven kilometres. With regard to motorised individual traffic, the considered motorway sections contribute most to high CO_2 emissions.

Within the scope of ÜSTRA light rail operation the lower energy consumption of the new trams resulted in a significant decrease in CO_2 emissions over the last 15 years. Despite a 31% increase in carrying capacity (measured in seat kilometres), the CO_2 output has been reduced by about 22%.

A comparable tendency was also determined for train traffic on the DB heavy rail network. While the nationwide increase of km per capita was 17%, a reduction in CO_2 output of about 17% has been calculated in relation to the residents of Hannover.

Between 1990 and 2005 the km flown by each Hannoverian more than doubled. Thus increases in CO_2 emissions are notably high despite better fuel efficiency; an increase in CO_2 output of about 72% has been calculated. This dramatic rise is of particular importance because released emissions of aircrafts at high altitudes have a significantly higher impact on the climate than pollutants released at ground level.

Concerning traffic as a CO_2 source, the highest increase in CO_2 emissions in the City of Hannover was caused by motorised road traffic. Even taking into account an RFI factor of between 2 and 4 for aircraft emissions, the discharge of climate-relevant pollutants from air traffic is lower than the total emissions of passenger car and HGV traffic.

	CO_2 emissions 1990 in 1000 t	CO_2 emissions 2005 in 1000 t	Change compared to 1990
1: Motorised road traffic	836.4	783.5	- 6%
2: ÜSTRA light rail	82.4	64.6	- 22%
3: Heavy rail (DB)*	43.1	35.6	- 17%
4: Air	93.6	160.9	+ 72%
Sum 1 – 3: Road and rail	961.9	883.7	- 8%
Sum traffic	1055.5	1044.6	-1%

** without consideration of CO_2 equivalents*

Table 16 | CO_2 emissions (1, 2 and 4 including CO_2 equivalents) in 1990 and 2005

3.8 Sources (in German – for actual titles see the German version of this booklet)

Argus Stadt- und Verkehrsplanung (2005): The former Hannover South railway station, 2nd transport study, report on findings, Hamburg, 2005.

GVH (Grossraumverkehr Hannover) (2005): Mobile in the Hannover Region, 1970 – 2005, 35 years of GVH, Hannover.

IFEU (Institut für Energie und Umweltforschung) (2006): 'EcoMobileCheck', scientific status report, Heidelberg.

IPCC (Intergovernmental Panel on Climate Change) (1999): Special report on air transport.

NLS (Niedersächsisches Landesamt für Statistik) (2004): Vehicle registration statistics

NLS (Niedersächsisches Landesamt für Statistik) (2006): Average population (by year) of urban municipalities and rural districts

Region Hannover (1992): CO_2 reduction strategy for Greater Hannover.

Schnüll, Haller und Partner (2005): Hannover – supplementary traffic census in the area of Hannover South railway station, report on Project No. 0523 (2), Hannover.

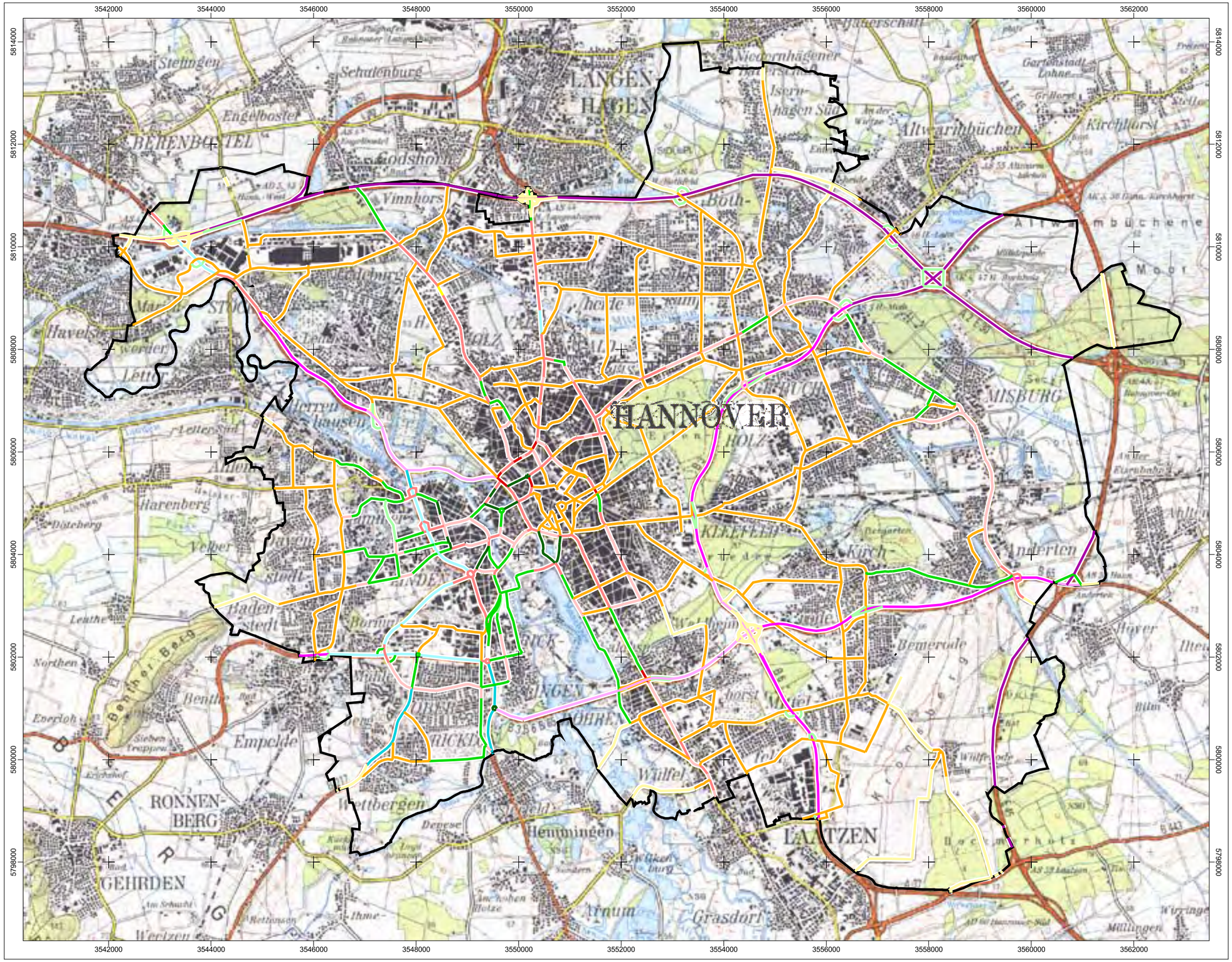
Landeshauptstadt Hannover (2005): predicted data from the 'VISUM' model for traffic volumes in 2002

Stadt Hannover (2007): CO_2 audit for the City of Hannover, Energy, E4-Consult.

UBA (1987): Exhaust emissions from cars in the Federal Republic of Germany, reference year 1985.

UBA (2004): HBEFA Handbook on Emission Factors from Road Traffic. Version 2.1/February 2004. INFRAS AG, Bern, Switzerland (ed.): UBA (Federal Environment Agency) Berlin.

ZGH (Zweckverband Grossraum Hannover) (1990): Driven Kilometres in Greater Hannover, 1990.



Audit of carbon dioxide emissions
from road traffic

Fig. 6:
Traffic conditions in the observed street sections

Key:

Traffic conditions according to HBEFA 2.1)

- *AB_120*
- *AB_100*
- *AB_80*
- *IO_HVS>50_2*
- *IO_HVS>50_1*
- *IO_HVS3*
- *IO_HVS2*
- *IO_HVS1*
- *IO_Kern*
- *IO_LSA3*
- *IO_LSA2*
- *IO_LSA1*
- *IO_Nebenstr_dicht*
- *IO_Nebenstr_locker*
- *ØIO*
- *ØAO*
- *Ø (alle StrKat)*
- Hannover City Limits

Scale 1 : 75 000

0.5 0 0.5 1 1.5 2 Kilometers

N

Based on map TK 100

Client:

City of Hannover

Prepared by:

GEO-NET Umweltconsulting GmbH
Große Pfahlstr. 5a
30161 Hannover
Tel: 0511 - 3 88 72 00
Fax: 0511 - 3 88 72 01
E-Mail: contact@geo-net.de

December 2006

Audit of carbon dioxide emissions
from road traffic

Fig. 7:
Traffic volumes (DTV)
in Hannover city area (2005)

Key:

Average daily traffic volumes (vehicles/day)
(VISUM traffic census model, 2005)

- *<= 2500*
- *2500 - < 5000*
- *5000 - < 10000*
- *10000 - < 25000*
- *>= 25000*
- Hannover City Limits

Scale 1 : 75 000

0.5 0 0.5 1 1.5 2 Kilometers

N

Based on map TK 100

Client:

City of Hannover

Prepared by:

GEO-NET Umweltconsulting GmbH
Große Pfahlstr. 5a
30161 Hannover
Tel: 0511 - 3 88 72 00
Fax: 0511 - 3 88 72 01
E-Mail: contact@geo-net.de

December 2006

Audit of carbon dioxide emissions
from road traffic

Fig. 8:
CO_2 emissions on road sections (2005)

Key:

CO_2 emissions (t/a/km)

- *<= 250*
- *250 - 500*
- *500 - 750*
- *750 - 1000*
- *1000 - 1250*
- *1250 - 1500*
- *1500 - 2000*
- *2000 - 2500*
- *2500 - 3000*
- *3000 - 4000*
- *4000 - 5000*
- *5000 - 7500*
- *7500 - 12000*

Hannover City Limits

Scale 1 : 75 000

0.5 0 0.5 1 1.5 2 Kilometers

N

Based on Map TK 100

Client:

City of Hannover

Prepared by:

GEO-NET Umweltconsulting GmbH
Große Pfahlstr. 5a
30161 Hannover
Tel: 0511 - 3 88 72 00
Fax: 0511 - 3 88 72 01
E-Mail: contact@geo-net.de

December 2006

4 Index

4.1 Abbreviations/Glossary

a	per year
CHP	Combined Heat and Power
CH_4	methane
CO_2	carbon dioxide
CO_2 equivalent	The climate impact of an emission is converted to the effect of a corresponding amount of carbon dioxide
d	per day
DTV	daily traffic value, the mean number of vehicles per day
EEG	German law on renewable energy sources
GIS	Geographic Information System
GWh	gigawatt-hour = 1,000 MWh = 1 million kWh
h	per hour
kWh	kilowatt hour
MW	megawatt (10^6 watts)
MWh	megawatt-hour = 1,000 kWh
seat-km	product of the number of seats in a train or tram times the route in kilometres
other	all fuels not supplied through lines or pipes (coal, waste, liquified gas etc., but excluding heating oil)
t	metric tonne

4.2 Picture credits

Page 6 | Stadtwerke Hannover
Page 7 | Energiewerkstatt Hannover
Page 8 | Hannover City Council
Page 9 | co2online gGmbH
Page 16 | Hannover City Council
Page 19 | Hannover City Council
Page 20 | Hannover City Council
Page 21 | Hannover Airport

4.3 Tables

4.4 Graphics