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MASTER THESIS

The Commuters' Carbon Footprint Between the City of Munich and the Metropolitan Region: An Investigation of the Technical Improvements and the Corresponding Environmental Impact.

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Abstract

The following thesis covers the European Metropolitan Region of Munich's approximation of the carbon footprint and pollutant emissions for commuters who are subject to social insurance contribution. The two main transport modes of individual- and public transport are compared for the years 1987 and 2011. Technical improvements, emission limitations, and the corresponding environmental impact are observed for the greenhouse gas carbon dioxide and the selected pollutants carbon monoxide, nitrogen oxides, non-methane hydrocarbons, sulphur dioxide, and particulate matter, which are partly precursors to greenhouse gases. The underlying question is whether *the latest technical improvements outweigh the increased mobility of employees in the European Metropolitan Region of Munich?*

The supreme compulsory regulation for the reduction of emissions for individual- and public transport is the Kyoto Protocol. Considering individual transport, car manufacturers are bound to mandatory carbon dioxide emission limitations since December 2008. The corresponding pollutant emissions are observed by the Euro-norm Standards, which are compulsory since 1992. Furthermore, the public transport fuel mix is covered in correspondence to the resulting emission factors.

The analysis is framed by the life-cycle assessment approach. The emission calculation is conducted by emission factors, which are based on the well-to-wheels lifecycle on a person-kilometre emission base, which comprises the transport mode's direct combustive- as well as indirect emissions that stem amongst others, from the resource extraction and distribution. Besides the altered emission factors, the main influencing factors are the longer travel distances in correspondence to an increased number of commuters. A shift in the previously named factors is approached by two assumptions of (1) all commuters to travel by either individual- or by public transport as well as by assumption (2) which estimates the emissions by a simplified modal split of individual- and public transport.

In reference to the simplified modal split and by the generation of a carbon footprint for the years 1987 and 2011, carbon emissions are mitigated by -6.81%. This is mainly based on significant carbon dioxide emission reduction concerning public transport. The relevant pollutant footprint is significantly mitigated, except for sulphur dioxide, which is not comprised in the emission standard programme and stands out from other the emission standardized pollutants.

The greenhouse gas carbon dioxide, and hence, the corresponding carbon footprint, is reduced under the assumption (2) of the simplified modal split. Accordingly, the global warming effect may be considered decelerated. Furthermore, the pollutants, which are subject to the European standardisation programme, are significantly mitigated. However, although sulphur dioxide is not part of the regulation, it is nevertheless a strong pollutant, which has a severe impact on human health as well as on the environment. Therefore, sulphur dioxide needs to be subject to further mitigation measures.

The conducted analysis may be further specified with respect to more advanced, and adapted emission factors, further transport modes as well as the carbon footprint may be extended by further greenhouse gases, such as methane or nitrous oxides.

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List of abbreviations

A (City):	City of Augsburg
A (R.D.):	Rural district of Augsburg
AIC:	Aichach-Friedberg
AÖ:	Altötting
BA:	Bundesagentur für Arbeit
BMU:	Bundesmininsterium für Umwelt, Naturschutz und Reaktorsicherheit
CO:	Carbon monoxide
CO_2:	Carbon dioxide
CO_2e:	Carbon dioxide equivalent
DAH:	Dachau
DB :	Deutsche Bahn AG
DGF:	Dingolfing-Landau
DLG:	Dillingen an der Donau
DON:	Donau-Ries
EBE:	Ebersberg
EC:	EuroCity
EF:	Emission factor
EI:	Eichstätt
ED:	Erding
EMM:	European Metropolitan Region of Munich
OEMM:	Outer European Metropolitan Region of Munich
FFB:	Fürstenfeldbruck
FS:	Freising
gCO:	Grams of carbon monoxide
gCO_2:	Grams of carbon dioxide
gNO_x:	Grams of nitrogen oxides
gNMHC:	Grams of non-methane hydrocarbons
gPM:	Grams of particulate matter
gSO_2:	Grams of sulphur dioxide
GAP:	Garmisch-Partenkirchen
GIZ:	Deutsche Gesellschaft für Internationale Zusammenarbeit
GTZ:	Deutsche Gesellschaft für Technische Zusammenarbeit
ICE:	Intercity-Express
IN (City):	Ingolstadt
Infas:	Institut für angewandte Sozialwissenschaften GmbH
IRE:	Interregio-Express
IPCC:	Intergovernmental Panel on Climate Change
IT:	Individual Transport
KBA:	Kraftfahrt-Bundesamt
KF (City):	City of Kaufbeuren
$kgCO_2$:	Kilograms of carbon dioxide
LA (City):	City of Landshut
LA (R.D.):	Rural district of Landshut
LCA:	Life cycle assessment
LfStaD:	Bayerisches Landesamt für Statistik und Datenverarbeitung
LL:	Landsberg am Lech
$mtCO_2e$:	Megatons of carbon dioxide equivalent
M (R.D.):	Regional District of München
MB:	Miesbach
MÜ:	Mühldorf am Inn
MVG:	Münchner Verkehrsgesellschaft mbH
MVV:	Münchner Verkehrs- und Tarifverbund GmbH
ND:	Neuburg-Schrobenhausen
NMHC:	Non-methane hydrocarbons
NO_x:	Nitrogen oxides
OAL:	Ostallgäu
PAF:	Pfaffenhofen an der Ilm
PKM:	Person-kilometre
PM:	Particulate matter
PT:	Public Transport
RO (City):	City of Rosenheim
RO (R.D.):	Rural district of Rosenheim
R.D.:	Rural district
SO_2:	Sulphur Dioxide
STA:	Starnberg
STMUG:	Bayerisches Staatsministerium für Umwelt und Gesundheit
SWM:	Stadtwerke München GmbH
tCO_2:	Tons of carbon dioxide
TS:	Traunstein
TÖL:	Bad Tölz-Wolfratshausen
UNFCCC:	United Nations Framework Convention on Climate Change
VW	Volkswagen AG
WM:	Weilheim-Schongau

1. INTRODUCTION

Consumption is widely believed to provide happiness and wellbeing (Caldas, 2010). Germany's affluent consumer society spends most disposable income on leisure, goods and services. Mobility may be considered a part of this and today people are increasingly fighting the two fronts of consumer society. On the one hand, this consumer trend may be underlined by President Bush's message to the US citizens in 2001 to "go out and shop" to support the economy (Murse, 2010, n.p.). On the other hand the awareness grows to decrease consumption and *planned obsolescence*[1] of products as well as to increase longevity and sharing of products. This may be exemplified by shared mobility, as it exists in several forms, as for car sharing or sharing amongst neighbours. Today's society basically consumes mobility as a standard good. Therefore, the city of Munich's increasing number of inhabitants and corresponding affluence affect the environmental impact.

In the South Bavarian Metropolis Munich, cars are omnipresent. The number of cars per household steadily increases. In spite of a fine network of public transport, the incremental availability of cars is remarkable. Car registration constantly grows and according to the in 2010 published study, *Mobilität in Deutschland 2008* (Deutsches Zentrum für Luft- und Raumfahrt e.V.; infas Institut für angewandte Sozialwissenschaften GmbH [infas], 2010), 18% of all German households do not possess an automobile; whereas 53% own one, 24% own two and 5% possess three or more cars. However, according to Munich's cross-linked public infrastructure the number of cars is expected to decrease, which is not recognizable.

According to the *Münchner Verkehrs- und Tarifverbund* (MVV, n.d., see addendum p.109), in 2012, the city of Munich accumulates about 619,000 cars, whereas the rural districts have a stock of about 803,000 vehicles. The inner city has a slightly larger population, nevertheless, on the rural sites, about 59.68% own a private automobile, whereas in the inner city only about 45.16% own a vehicle. With respect to the current technology, this cumulative car usage is inevitably connected to external effects, such as noise pollution, carbon dioxide, nitrogen oxide and further emissions and effects. Technology is one factor, which can outrun this impact to some degree. *What has been effect of technical improvements on carbon- or pollutant emissions since the introduction of relevant policies?*

Since the mid 50s, Germany fostered the so-called *Autogerechte Stadt*, which defines a city development concept that is adapted to free and fluent car movement (Schmucki, 2001). In the 70s, however, transport and city planners detected the idea of continuous traffic flow could not be realized as well as the existing traffic put a strain on the urban environment (Schmucki, 2001). This is also based on an unexpected explosion of individual motorization in the 60s (Schmucki, 2001). According to Wolf (1987),

[1] According to Belz and Peattie (2009), planned obsolescence mainly exists in three forms of built-in, psychological, and technological obsolescence. Built-in defines that the manufacturer intentionally built a product with a limited lifetime (Belz & Peattie, 2009). Psychological obsolescence regards fashionably products that may be regarded outdated after some time (Belz & Peattie, 2009). The last term encompasses the substitution and updating of technological products and gadgets (Belz & Peattie, 2009).

individual transport (IT) comprised 30% in the 50s, whereas it exceeded 80% by 1985. Additionally, rail traffic decreased from 40% to about 5% within the same time span (Wolf, 1987). Furthermore, the driven person-kilometres proportionately have multiplied by 20 times between 1950 and 1984, whereas for rail traffic the amount of person-kilometres stagnated (Wolf, 1987).

Hence, this city-planning idea had been redeveloped and abandoned for more environmental awareness as it especially kicked off in the 90s (Schmucki, 2001). However, now the city of Munich follows the plan of a car free and more sustainable city, which is to be classified as a *local Agenda 21* and executed by the city planning agenda *Perspektive München* (Perspective Munich; Landeshauptstadt München [LHST München], n.d.c). According to this plan, the city council presented a three-pillar programme, which is related to the *Avoid-Shift-Improve*[2] approach by the *Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH* (GIZ, n.d.). The city plans to *reduce traffic*, hence, to increase sustainable mobility; to *shift traffic*, which comprises the extension of the public transport network and to decrease individual transport as well as to *manage traffic* (LHST München, n.d.a). Traffic management defines city-friendly traffic and the support of better traffic management as for instance, by the support of vehicle telematics systems (LHST München, n.d.c).

According to Monheim, Muschwitz and Philippi (2011), in 2011, Munich is split up into four main mobility options with an estimated percentage of selection: Private car or additional passenger usage (32.5%), by foot (27.2%), by bike (17.4%) or by public transport (22.8%). Munich continuously provides alternative transport possibilities to combat the negative external effects of individual transport. The infrastructure network is densified and the MVV coordinates the U-Bahn[3], the S-Bahn[4], buses, regional trains and the tramway.

The urban development plan *Perspektive München* is based on 14 guidelines, which have been established in 1998 and expanded ever since. They serve as strategic development goals and proof of practical applications and improvements (LHST München, n.d.b). For this analysis relevant are the guidelines 1, 2 5, 7 and 10 (LHST München, 2007; Thierstein & Reiss-Schmidt, 2008).

Amongst others, guideline one's - *employment & economic prosperity* - relevant aims encompass for instance, a polycentric settlement structure as well as the creation of a collective identity in the economic region of Munich (LHST München, 2007). Guideline two's - *cooperation in the region* - relevant aims encompass the intensification of communication and collaboration between communities, other local authorities, etc. as well as the development of regional land use planning on a cooperative basis (LHST München, 2007). Amongst others, guideline five's - *inner-city development* - relevant aims encompass the reduction of land use, polycentric development and urban densification in the catchment area of efficient public transport (LHST München, 2007). Guideline seven – *mobility* – for instance, focuses on residential densification and

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[2] Avoid unneccessary trips, shift to more sustainable modes of transport, and improve the existing modes (GIZ, n.d.).

[3] U-Bahn refers to a subway or metro. The U-Bahn in this context refers to a over- and mostly underground train, which is being controlled and owned by the city of Munich and covers the inner-city network.

[4] S-Bahn refers to a subway or metro. The S-Bahn in this context refers to a mostly over- but also underground train, which is being controlled and owned by the Deutsche Bahn AG. The S-Bahn covers the inner city but also encompasses the nearer surrounding rural districts of Munich.

sustainable, "city-friendly" urban transport (LHST München, 2007). Guideline ten's - *ecological standards & natural resources* – main aims focus on the minimization of impacts and adverse effects of air and noise pollution as well as on the sustainable and environmentally-friendly handling of energy (LHST München, 2007).

The main idea shows that industry shall be fostered in combination to intensified cooperation with the rural districts (R.D.). This is to be connected to improved and integrated mobility as well as to urban densification. Improved mobility is connected to the mitigation of transport-related environmental- or health effects. Munich's city planning agenda is based on the idea of mobility without private car usage for e.g., shopping trips, commuting and other daily activities. Munich tries to establish a more sustainable way of transportation by polycentric and transport integrated infrastructure. According to this concept, the city has partly been restructured as it may be recognized for the Trade Fair City of Riem or Theresienhöhe (Thierstein & Reiss-Schmidt, 2008). Additionally, the city expands the pedestrian precinct network as it may be exemplified by the latest example of the Sendlinger Straße, plans more bicycle lanes and focuses on an interconnected network of public transport (PT) (LHST München, n.d.c; n.d.d; Patzig, 2011). A current example for the connection of the city of Munich to the rural districts is represented in the project of a second main S-Bahn line to make public commuting more attractive due to reduced travel time, which is based on less stops (Deutsche Bahn [DB], n.d.a).

Nevertheless, it is to be observed from recent mobility trends that more people commute to work. Overall, in Germany, there is to be recognized an upwards trend to commuting behaviour. In 1999, about 54% commuted to work and this number increased to about 59%, by 2009 (Gatzweiler, 2012). Throughout the previously named period, the average commuting distance increased from 14.6 to about 16.6 kilometres (Gatzweiler, 2012). *In what extend do increased travel distances affect the commuters' carbon footprint?*

Changes and policies within the city, may have long-lasting and unforeseeable external effects on the rural districts. Guidelines one and two foster regional cooperation. Hence, the city of Munich is not an administrative island but interacting with its environment, such as with the adjacent rural districts, namely the *Planning Region 14 (PR14)*, which encompasses the city of Munich as well as eight rural districts: *Dachau*, *Freising*, *Fürstenfeldbruck*, *Landsberg am Lech*, *München*[5] and *Starnberg* with which the city interacts but does not manage. For reasons of better understanding and differentiation throughout the analysis, the selected rural districts will be called *Outer Planning Region 14 (OPR14)*, which is based on the fact that Munich is not encompassed in the city's in-commuters from the Outer Planning Region 14. The city of Munich is relevant for the out-commuters that travel to the OPR14. The Planning Region 14 is part of a larger economic area. It is enclosed in the *European Metropolitan Region of Munich (EMM)*, which comprises and manages large parts of Upper Bavaria, Swabia and some parts of Lower Bavaria. This will be further discussed in chapter 4.3.2.

Mobility and the corresponding environmental impact, which is regularly associated with sustainable mobility is essential to the environment, economy and society. This analysis focuses on the commuters' interaction between the city of Munich and the surrounding European Metropolitan Region of Munich. This work covers the analysis of individual

[5] This rural district is not translated in order to better differentiate between the city of Munich and adjacent the rural district of München.

motorized- and public transport as they represent the commuters' basic modes of transportation. In this aspect, the technical improvements as well as the shift in the travel distance and the number of commuters within the EMM in direct interaction with the city of Munich shall be disclosed.
The calculation of the year 2011's and 1987's carbon footprint for individual- and public transport as well as the main environmental pollutants emissions are to be conducted. In this analysis, the carbon footprint comprises *carbon dioxide* only, since it represents the largest greenhouse gas. Additionally, the pollutants *carbon monoxide*, *nitrogen oxide*, *non-methane hydrocarbon* and *particulate matter*, are - except for particulate matter - precursors to greenhouse gases but as a whole, subject to Euro-norm regulations. Additionally the pollutant *sulphur dioxide* is comprised in this analysed.

It is to be investigated how the Euro-norm Standards and carbon dioxide emission limitations, which are managed by the European Union, have influenced the anthropogenic pollutant- and carbon dioxide emissions that are caused by individual transport. Hence, potential technical improvements are to be displayed. For reasons of comparability, this is set in relation to public transport, which shall expose the transport modes' efficiency with respect to the corresponding mitigation activities for the previously named time frame. Concerning public transport, the fuel mix is to be analyzed, which results in the relevant public transport emission factors for carbon- and pollutant emissions.

In order to derive an emission approximation, the life cycle assessment in combination to the well-to-wheels approach is applied. Overall, the process from input to emission output is observed, since the fuel input results in pollutants, which may evolve to greenhouse gases. For instance, the pollutant carbon monoxide may evolve to the main greenhouse gas carbon dioxide. Furthermore, the analysis is framed by two assumptions: (1) The total number of commuters travels by either individual- or public transport, whereas assumption (2) conducts the emission approximation by a simplified modal split of individual- and public transport.

The first section of this thesis concentrates on background knowledge, such as on mobility, pollutants and global warming. Next, the methodology and the applied emission factors will be outlined. Subsequently, the data analysis and the data output will be represented. This will, hence, be aligned with a future outlook and a comparative business-as-usual scenario, which is combined with further implications. Accordingly, the following chapter focuses on mobility and the corresponding societal changes.

2. MOBILITY

The term *mobility* as it is applied in this day and age, has been coined by the American sociologist Pitirim Sorokin (Steinkohl, 1999). In his book, the *Social and Cultural Mobility*, which was published in 1927, he defines mobility as the movement of individuals of a collective in the corresponding socio-cultural environment (Steinkohl, 1999). In reference to Canzler, Kaufmann and Kesselring (2008), there are three categories for the connection of movement and mobility:

1. Movement without mobility: This reflects business people travel behaviour, who travel distances, which does not change their social status (Canzler et al., 2008).

2. Movement and mobility: This outlines geographical as well as social mobility (Canzler et al., 2008).
3. Mobility without movement: This defines the connection to "specific and different social universes" (p.4), such as being conducted via Internet communication (Canzler et al., 2008).

Movement with and without mobility is reflected in the classic understanding of commuting behaviour. Mobility is often constrained by the understanding of locomotion (Steinkohl, 1999). However, not only the social status and mobility are frequently intertwined. According to Kesselring (2005), they may additionally be constrained by, for instance, technology, economy, virtual elements or as previously described, by geographical restrictions. There may be geographical movement to maintain employment as well as it may foster an employee's social and hierarchical status by conducting commuting behaviour.

According to Kaufmann and Montulet (Canzler et al., 2008), irreversible mobility, such as residential mobility is, due to increased speed, more and more being substituted by non-permanent forms such as daily trips. "Travelling rather than emigrating, commuting rather than moving, make social networks and anchoring easier to maintain" (Canzler et al., 2008, p.48).

People need to deploy strategies to connect mobility and fluidity and to be able to adapt to external constraints (Kesselring, 2005). In order to manage mobility and societal demands, there are, according to Kesselring (2005), three main strategies: (1) centralized (2) decentralized[6] and (3) virtual mobility[7], which are comparable to the formerly outlined categories of movement and mobility. According to Kesselring (2005), the most prevailing mobility pattern remains with a person's centred mobility management, which defines movement without mobility as it may be outlined as follows:

> "People view themselves as actors in private and economic life who manage their situations in order to exploit economic and social opportunities and avoid risks. The pursuit of career and individual satisfaction and the maintenance of social networks are basically grounded in spatial mobility. This mobility type deploys a high level of motility, using spatial networks such as transport and communication systems to establish a strongly focused social and professional network around a clearly defined centre of life" (Kesselring, 2005, p.139).

This reflects the classical commuter type with a fixed home and social life but active daily movements. As it was mentioned earlier, travel distances increase due to the increasing availability of cars, speed and societal demand. In general, commuting is considered strict movement between an origin and various destinations, which can be retraced geographically (Canzler, Kaufmann & Kesselring, 2008). However, mobility does not only refer to geographical but also to social changes (Kaufmann & Montulet, 2008) and hence, defines vertical status movement.

According to Urry, as cited by Kesselring (Canzler et al., 2008), the car is often inevitably connected to people's scripts of modernity. In order to connect society and

[6] Decentralized mobility mainly encompasses the strict movement without a fixed centre in life (Kesselring, 2005).

[7] Virtual movement defines to have a fixed centre and to be virtually mobile via internet communication, such as E-Mails, etc. (Kesselring, 2005).

movement, the vehicle is regarded a tool in that "[m]obility is a value where norms can be manipulated, suggesting a reference to competences" (Canzler et al., 2008, pp.4). Mobility and hence, flexibility, is demanded for personal success in society. Being able to move quickly has been established a prerequisite in business life. Job descriptions regularly demand a driving license, next to the professional qualifications. Franz Steinkohl defines some characteristics to be associated with mobility, such as: Energetic, dynamic, vital, independent and successful (Steinkohl, Knoepffler & Bujnoch, 1999).

This may be exemplified by the publication *The European Labour Market. Success Through Flexibility and Mobility*, which outlines that Germany's low rate of unemployment and the corresponding economical success is connected to increased mobility and flexibility (Eichhorst, 2013). To increase economic efficiency and to decrease unemployment, mobility shall even exceed national borders as well as employment contracts, such as temporary employment or mini jobs, to get more adaptable (Eichhorst, 2013). This is aligned with decentralized mobility.

The idea of increased mobility to be associated with societal freedom is supported by Kaufman and Montulet (Canzler et al., 2008). Nevertheless, it is crucial to socially integrate and manage these different lives. Hence, according to Kaufmann and Montulet: "individual players tend to expand their mobility potential as much as possible, in order to guard against undesirable changes in their socioeconomic status" (Canzler et al., 2008, p.52). In the following chapter, commuter types and social characteristics are to be further outlined.

2.1. Commuters

In Germany, commuters are employees that contribute to social security, whose location of work, e.g., municipality, district or federal state, differs from their residential municipality, district or federal state (Wiethölter, Bogai & Carstensen, 2009). In Germany, the Bundesagentur für Arbeit (employment agency, [BA]) determines the number of commuters according to the declared places of work and living, which are indicated by the employer, due to the mandatory social security registration instructions (BA, 2011). With respect to this analysis, the analysed commuters are employees who are liable to social security, which excludes for instance students, the self-employed or mini-jobbers (Bauch, Böhme, Wenzlaff, 2012). Commuters are categorized as follows:

1. Commuter: The German commuter is defined as an employee whose place of work differs from the place of living (BA, 2011).
2. Intramunicipal commuter: Are employees, whose place of work and place of living lie within the same municipality (Information und Technik Nordrhein Westfalen, 2013).
3. In-commuter: In-commuters are employees that do not live at the place of work (BA, 2011). In this case, in-commuters define employees that travel to the city of Munich from the surrounding section of the European Metropolitan Region of Munich.
4. Out-commuter: Out-commuters are employees that do not work at the place of living (BA, 2011). Out-commuters in this analysis describe the employees that commute from the city of Munich to a working place from the rest of the EMM.

Germany proofs of an upwards trend in commuting behaviour. In 2005, Bavaria proofs of 4,207,000 employees that are bound to social security contributions of which 1,571,000 are intramunicipal commuters, whereas about 2,635,999 are out-commuters (Böhme & Eigenhüller, 2005). The mobility degree increases by 3.5%, from a share of 59.1% to about 62.6% in 2005 (Böhme & Eigenhüller, 2005). According to Böhme and Eigenhüller (2005), this increased mobility trend may be based on the increasing suburbanization of industry and employees to the rural areas. The educational level influences these numbers. Jobs are perceived to be more stable for commuters than for non-commuters (Böhme & Eigenhüller, 2005). In recent years, there has been a trend towards a lower employment-rate but a higher level of mobility (Böhme & Eigenhüller, 2005). Overall, the mobility increase is based on the fact that the willingness of high-qualified people to travel is higher (Gatzweiler, 2012; Haas & Hamann, 2008).

Table 1: The Planning Region 14's number of employees and in- and out-commuters.

City of Munich	Workplace: Employees being subject to social security
1987	660,241
2011	709,580
Change	+7.47%

	Sum of in-commuters	Sum of out-commuters	In-commuters from the OPR14[8]	Out-commuters to the OPR14[9]	Share in-commuters from the OPR14	Share out-commuters to the OPR14
1987	289,612	56,876	191,166	48,210	66.24%	84.76%
2011	325,204	135,291	177,451	93,445	54,57%	69.07%
Change	*+12.29%*	*+137.87%*	*-7.17%*	*+93.82%*	*-11,67%*	*-15.69%*

Source: Own representation based on Bayerisches Landesamt für Statistik und Datenverarbeitung (Bavarian State Office for Statistics and Data Processing [LfStaD]), 1991; 2012; BA, 2012 (see addendum, pp.107); BA cited by Bauch, Böhme, Wenzlaff, 2012; BA cited by LfStaD, n.d.g; n.d.h.

The following analysis only considers employees who are liable to social security. The table displays Munich's total number of in- and out-commuters for the years 1987 and 2011. In 1987, the city of Munich proofs of 660,241 employees of which 289,612 are in-commuters, whereas only about 56,876 inhabitants commute to an external workplace. In 2011, the city of Munich has about 709,580 employees, of which 325,204 people come from external regions and 135,291 commute to Munich's surrounding regions.

From 1987 to 2011, there is a recorded increase of in-commuters by +12.29% and a rise of out-commuters by +137.87%. In 1987, the net commuter number accounts for 232,738 employees, which decreases to a net number of 189,913 employees in 2011. This means that the larger share of employees commutes to the city of Munich for work, which nevertheless, decreases over time.

This is put in contrast to the proportional share of in- and out-commuters from the adjacent Outer Planning Region 14. In 1987, the OPR14's number of in-commuters (191,166 employees), which is set in comparison to the total amount of Munich's in-commuters (289,612 employees), results in a share of approximately 66.24%. The

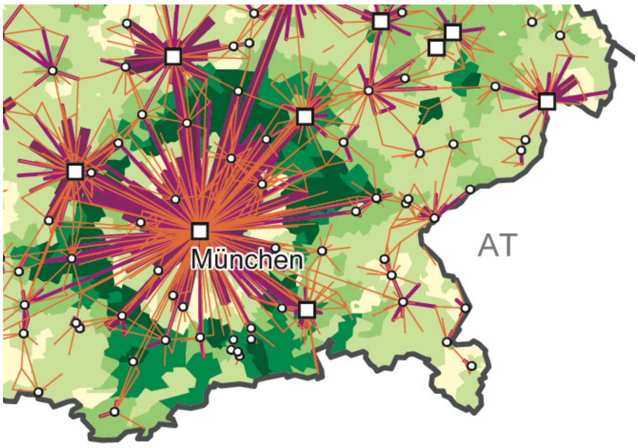
[8] In-commuters travel from the rural districts to work in the city of Munich.
[9] Out-commuters travel from the city of Munich to a workplace on the countryside.

corresponding out-commuters from Munich to the OPR14 represent a share of about 84.76%. This indicates a shift to an increased amount of out-commuters to rural workplaces. In 2011, there are about 177,451 in-commuters from the OPR14 and about 93,445 recorded out-commuters. This results in a total in-commuter share of about 54.57% of the OPR14, in comparison to the total number of in-commuters. In consideration of out-commuters, the relevant share amounts to 69.07%. Overall, from 1987 to 2011, the number of in-commuters from the Outer Planning Region 14 decreases by -7.17% and the number of out-commuters increases by +93.82%.

Furthermore, from 1987 to 2011, the relative proportion of the OPR14's in-commuters to the risen total amount of in-commuters decreases by -11.67% and the corresponding amount of out-commuters decreases by -15.69%. Therefore, this decrease in commuters from the OPR14 with respect to the incremental number of all commuters shows that an increasing amount of employees travels to Munich from more distant regions.

This intensified economic interactivity led to the establishment of the *Munich Metropolitan Region*. The region encompasses 32 cities and rural districts in Bavaria, which exceed the city of Munich's public transport network. However, these cities and rural districts are strongly interconnected to Munich in an economic matter, which may be exemplified by the cities of Ingolstadt and Augsburg or by the rural administrative district of Miesbach (Munich Metropolitan Region, n.d.). The PR14 is a sub-category to the European Metropolitan Region of Munich. This is going to be further explained in chapter 4.3.2. The following diagram reflects the year 2009's commuter data and the corresponding commuter network for the EMM.

Figure 1: Commuter networks based on the year 2009's commuter data.



Source: Bundesinstitut für Bau-, Stadt- und Raumforschung, 2009.

Table 2: Underline to the commuter network figure.

Share of commuters who travel more than 50 km in 2009 that are liable to social security contributions		Commuter network between municipalities according to the number of commuters in 2009		Central locations	
(light yellow)	< 7%	(light line)	200 ≤ 500	(square)	Major regional centre
(light green)	7 ≤ 12%	(thin line)	500 ≤ 1,000	(circle)	Regional centre
(green)	12 ≤ 17%	(medium line)	1,000 ≤ 2,000		
(darker green)	17 ≤ 22%	(thick line)	≥ 2,000		
(dark green)	≥ 22%				

Source: Own representation based Bundesinstitut für Bau-, Stadt- und Raumforschung, 2009.

The table reflects figure 1's underline. The commuter streams from the EMM to the city of Munich are significant, whereas the interactivity between rural districts only is considerably low. A clear, interactive network is recognizable, which for instance, the streams from the cities of Ingolstadt or Augsburg's of more than 2,000 commuters represent. Furthermore, the direct interactivity between the city of Munich and the surrounding regions is outstanding. Streams between the individual cities and regions are less prominent. It is to be observed from recent mobility trends that employees travel longer distances. As already mentioned, from 1999 to 2009, the average commuting distance increased from 14.6 to about 16.6 kilometres (Gatzweiler, 2012). According to Thierstein and Reiss-Schmidt (2008):

> "The population of the city of Munich will grow further according to recent forecast mainly by immigration from other parts of Germany and Europe by 5 percent until the year 2020; the region even more by more than 10 percent. Expected are an increasing number of commuters not only from the suburban fringe but also from the second and third rings in a distance of up to 80 kilometres" (p.2).

This study's average commuter travels 77.59 kilometres[10] to work (GeoBasis-DE/BKG & Google Inc., n.d.a – n.d.abg, see Individual Transport Addendum, CD, pp.1-226). This number is composed of an average distance of 41.09 km for the commuters of the PR14 and of 98.75 km for commuters of the remainder of the EMM (GeoBasis-DE/BKG & Google Inc., n.d.a – n.d.abg, see Individual Transport Addendum, CD, pp.1-226). This coincides with the previous figure of the commuter network. The next paragraph outlines the term of sustainable mobility and the corresponding consequences for the future.

2.2. Sustainable mobility

Hans Carl von Carlowitz, who was born in 1645 near Chemnitz, coined the term sustainability, which he derived by the observation of forest clearing and the corresponding scarcity of wood (Grober, n.d.). Hence, he outlined the idea of sustainable forestry in his book *Sylvicultura Oeconomica* (Grober, n.d.). The term sustainability has

[10] Presumably, the average travel distance is higher in comparison to Gatzweiler (2012), because this estimation does not include intramunicipal commuters.

further expanded and according to the *triangle of sustainability* it encompasses the fulfilment of needs without harming the environment, economy and society, now and in the future (Institut Bauen und Umwelt e.V., n.d.). There is no general definition for sustainable mobility, however, the Technical University of Munich's Chair of Urban Structure and Transport Planning defines and adapts it as follows (Wulfhorst, 2013): Sustainable mobility

> "requires affordable accesses to multiple mobility options, freedom of choice in terms of mode and access to life opportunities. Sustainable mobility, however, does not and should not require a reduction in mobility. Instead, it should be safe for all users and therefore minimize any type of negative effects on individuals, communities, the private sector and the environment" (Wulfhorst, 2013, n.p.).

According to the Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit (Federal Ministry for the Environment, Nature Conservation and Nuclear Safety [BMU], 2008), sustainable transport- and environmental policies cover the aim of socially necessary mobility for goods and passengers to be as environmentally friendly as possible. The BMU (2008), names five main areas of action: (1) *Climate protection*, which focuses transport related greenhouse gas emission reduction. (2) *Pollutant reduction*, such as the mitigation of nitrogen oxides, volatile organic compounds, etc. (BMU, 2008). (3) *Noise reduction* and the (4) *protection of natural and landscape areas*, which comprises the reduction of new land use for settlements and traffic (BMU, 2008). (5) The *urban quality of life*, which encompasses the positive and negative effects of transport on ecological, economical and social spheres (BMU, 2008).

Accordingly, the negative anthropogenic impact has to be mitigated. Hence, with respect to the IPAT formula it is to be determined further how this impact, namely the commuter's carbon footprint evolves, fundamentally. This is aligned with the three main influencing factors of (1) more commuters, (2) increased travel distances and (3) the applied transport mode and the corresponding emission factor:

$$\text{Impact} = \text{Population} \times \text{Affluence} \times \text{Technology}$$

According to Belz and Peattie (2009), the population defines the earth's total number of inhabitants. Affluence regards the consumption level per person, which may be split up in income categories of the poor, middle and the affluent consumer class, whose income is above 7,500$ annually and thus, the relevant consumer class in this study (Belz & Peattie, 2009). Disregarding the other two income classes, the affluent consumers' transport modes are private cars and airplanes (Belz & Peattie, 2009). According to Belz and Peattie (2009), technology is to be split up into two categories. Firstly, it may define technological measures to mitigate the human impact and secondly

> "[…] technology is the current state of our knowledge of how to combine resources to produce desired products, to solve problems, to fulfil needs or to satisfy wants. Technology, in this sense, includes skills, processes, technical methods, tools and raw materials" (Belz & Peattie, 2009, p.51).

Accordingly, knowledge and its technical implementation are relevant. Hence, the Bavarian car fleet's technical improvements are to be taken into account. Accordingly, measures as set by the European Union, such as the Euro norms from 1 to 6, which regulate the pollutant emission standards for cars, are not to be disregarded. Amongst other measures, such as the phasing out of cars by the car-scrap bonus in 2009 (Höpfner, Hanusch & Lamrecht, 2009) or further technical improvements, such as particulate filters for diesel engines or improved three-way- or oxidation catalytic converters, may have diminished emissions to a level that makes the outcome of carbon emissions and pollutants per commuter somewhat unpredictable (Sonnenschein, Wimmer, Class, Kamps, Tröger, Pfeil, Boysen, Kiefer & Gillet, 2009). *Do the latest technical improvements outrun the increased mobility of employees in the European Metropolitan Region of Munich?*

3. EMISSIONS AND POLLUTANTS

This report analyzes the main pollutants and carbon dioxide emissions. Anthropogenic emissions do not only affect nature but they may also have a strong effect on humans. First, the combustion process and evolvement of pollutants will be outlined. Afterwards, the impact of the selected pollutants and carbon dioxide will be disclosed.

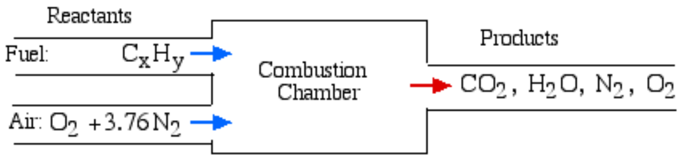
3.1. Combustion

Mostly, pollutants evolve from incomplete fossil fuel burning. The following quotation outlines the simplified combustion process.

"[…] Common fuels consist of compounds containing certain amounts of hydrogen and carbon. These fuels are commonly called hydrocarbons. For example, methane (CH4) is a hydrocarbon gas that burns as follows:

$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O + 1{,}013$ Btu/ft[11]" (Gilson Engineering Sales, Inc., n.d., p.3).

Figure 2: The combustion process.



Source: Urieli & Bayless, 2013, n.p.

If there are adequate conditions according to the fuel to air ratio, the outcome results in the so-called *stochiometric combustion* (Gilson Engineering Sales, Inc., n.d.). Both, quotation and figure show how fuel (e.g., CH_4) and air (O_2 and N_2) come together in the combustion chamber and ideally result in CO_2, H_2O, air (N_2 and O_2) and energy as it is disclosed in the formula above. However, since there may be lean or excess supply in air, pollutants, such as carbon monoxide, *volatile organic compounds* (VOC), nitrogen oxides, sulphur dioxides, etc., evolve (Gilson Engineering Sales, Inc., n.d.). For instance, if the burner operates with a lean amount of air, not all fuel will be combusted, which

[11] Btu = British thermal unit. Defines the "[a]mount of heat required to raise the temperature of one pound of water (at or near 39.2 degrees Fahrenheit) by one degree Fahrenheit in practical terms, the amount of heat generated by one lighted stick of match. One Btu is equal to about 252 small calories or 0.252 kilocalories, 778.17 foot pounds or 1055.06 joules" (Business Dictionary, n.d.).

results in incomplete combustion and hence, in the products of carbon monoxide and hydrogen (Gilson Engineering Sales, Inc., n.d.).

3.2. Pollutants

According to Gwilliam, Kojima and Johnson (2004) pollutants are mainly to be categorized in primary and secondary pollutants as follows:

> "Primary pollutants are emitted directly and include lead, PM, sulfur dioxide (SO_2), oxides of nitrogen (NO_x) and carbon monoxide (CO). Secondary pollutants are formed in the atmosphere from primary pollutants; the most common examples are ozone and PM from NO_x and SO_2" (Gwilliam, Kojima and Johnson, 2004, p.1).

Secondary pollutants, which are mainly being formed via oxidations and/or sunlight are categorized as greenhouse gases, which are responsible for radiation and hence, global warming. For instance, *hydrocarbons* (HC) and nitrogen oxides plus sunlight form the greenhouse gas *ozone* (O_3) (Stroh, Referat 76, Mante, Körner, Bleckmann, Schwegler & Fromme, 2013; GreenFacts, n.d.). This will be further outlined in the next chapter.

This study focuses on selected pollutants, which are formed by fuel combustion, such as carbon monoxide (CO), nitrogen oxides (NO_x), non-methane hydrocarbons (NMHC), particulate matter (PM), sulphur dioxide (SO_2) and the main greenhouse gas carbon dioxide (Union of Concerned Scientists, 2008). The amount of pollutant emissions varies with the combusted fuel type (see chapters 5.3 and 5.4).

Lead and benzene are excluded for this study, because for instance, by the supply of lead-free gasoline, lead has been reduced and phased out since 1985 (Finanzen.net, n.d.). Benzene belongs to the group of aromatic hydrocarbons, which is for instance contained in gasoline and toxic to humans (STMUG, 2013). It has been strictly reduced and since the year 2000 a maximum a share of 1% is permitted (STMUG, 2013). Accordingly, benzene is not encompassed in the analysis.

Figure 3: Comparison of pollutants according to engine- and fuel types.

Engine Type	Fuel Type	Vehicle Type	Major Emissions
4-Stroke cycle	Gasoline	Cars (also trucks, aircraft, motorcycles)	HC, CO, NO_X
Diesel	Diesel Oil	Trucks, buses, tractors (also cars)	NO_X, SO_X, soot, particulates
2-Stroke cycle	Gasoline/oil mixture	Motorcycles, outboard motors	HC, CO, particulates
Gas turbine	Jet	Aircraft, marine applications	NO_X, particulates

Source: Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ), 2009, p.6.

Figure 3 shows the major pollutant types that are emitted for each engine type and the corresponding fuel type such as gasoline, diesel, gasoline-oil mixture and jet. For instance, the four-stroke cycle uses gasoline and mainly emits hydrocarbons, carbon monoxide and nitrogen oxides. A diesel engine for instance, mostly emits nitrogen oxides, sulphur dioxide, soot and particulate matter. The following table analyzes the environmental- and health effects of carbon dioxide and the selected pollutants.

Table 3: The health- and environmental effects of carbon dioxide and the selected pollutants.

	Source	Health impact	Environmental effect
CO_2	Fossil fuel burning.	E.g., head aches. Can cause death. CO_2 inhibits the blood to carry oxygen.	Global warming.
CO	Incomplete fossil fuel burning.	E.g., chest pain. Can cause death: CO inhibits the blood to carry oxygen.	Precursor of ground-level ozone and CO_2[12]. Ground-level ozone can lead to leaf injury and inhibit plants to store or produce food.
NO_x (NO, NO_2)	Fossil fuel burning.	E.g., NO_2 causes changes in lung functions for asthmatics.	E.g., loss of plant biodiversity, acidification of soils and waters. Contributes to acid rain. Precursor of ground-level ozone.
VOC (e.g., benzene)	Fossil fuel burning, refuelling; domestic solvents, (e.g., paint or varnishes).	Toxic: Affects central nervous system.	Affects plants and crops when it reacts with carbon monoxide, nitrogen oxides and sunlight to form ground-level ozone.
SO_2	Fossil fuel burning; mainly diesel fuelled engines.	E.g., respiratory symptoms by changes in lung functions for asthmatics.	E.g., acid rain; acidification of soils, lakes, etc.
PM (PM_{10}; $PM_{2,5}$; $PM_{<0,1}$)	Incomplete fossil fuel burning; construction sites; fires.	E.g., respiratory illness, such as asthma, chronic bronchitis, etc.	It may alter "nutrient and chemical cycles in soils and surface water" (Commission for Environmental Cooperation, n.d.b) and may soil buildings.

Source: Own representation based on Commission for Environmental Cooperation, n.d.a; n.d.b; Department of the Environment, Community and Local Government, n.d.; GTZ, 2009; Gwilliam, Kojima & Johnson, 2004; Kampa & Castanas, 2008; UBA, 2013; Tyczka Kohlensäure GmbH & Co. KG, 2010; United States Environmental Protection Agency, 2012.

Table 3 reflects the various emissions' impact for two spheres of action, namely the effect on human health as well as the environmental impact. It is to be recognized that in humans, pollutants mostly affect lungs and nerves, whereas for the environment, changes in vegetation or acidification may result.

[12] Ground level ozone, outlines ozone in the troposphere, which is unwanted, whereas ozone in the stratosphere is wanted.

3.3. Greenhouse effect and ozone

As previously outlined, the main greenhouse gases, such as carbon dioxide, *methane* (CH_4), *nitrous oxide* (N_2O), ozone or water vapour (H_2O), contribute to global warming (IPCC, 2007a). There are direct and indirect greenhouse gases (IPCC, 2007b): The Kyoto Protocol demands improvements and concentrates on the following direct gases: Carbon dioxide, methane, nitrous oxide, *hydrofluorocarbons* (HFCs), *perofluorocarbons* (PFCS) and *sulphur hexafluoride* (SF_6) (United Nations Framework Convention on Climate Change [UNFCCC], 2008). The set of HFC, PFC and SF_6, is commonly abbreviated with the term *F-gases*. Further greenhouse gases are for instance *chlorofluorocarbons* (CFCs) or *hydrochlorofluorocarbons* (HCFCs), which are covered by the *Montreal Protocol* (IPCC, 2007b.) Indirect GHGs do not contribute to the greenhouse effect but when emitted they do form harmful substances, such as ozone or *water vapour* (IPCC, 2007a; 2007b). Therefore, they are precursor pollutants to produce GHGs, such as sulphur dioxide, nitrogen oxides, *non-methane volatile organic compounds (NMVOC)*[13] and carbon monoxide are (IPCC, 2007b). Another indirect GHG is *ammonia* (NH_3) (IPCC, 2007).

Of all anthropogenic emissions, carbon dioxide represents the most prominent greenhouse gas. Carbon dioxide amounts to about 77%, whereas methane represents a share of 15%, nitrous oxides comprise 7% and F-Gases define 1% (Herzog, 2009).

A certain level of greenhouse gases is also produced by nature. Anthropogenic emissions are set into relation to the pre-industrial revolution level of the year 1750. This change is measured on a comparability level of *parts per million (ppm)* meaning the GHG particles per one million of volume (IPCC, 2007a). It is estimated that the base year in 1750 represents a carbon dioxide level of about 280 ppm, which has risen to about 379 ppm in 2005 (IPCC, 2007a). For instance, since the year 1998, carbon dioxide increased by 13 ppm in 2005 (IPCC, 2007a).

The *CO_2equivalent* (CO_2e) is the adaption of all greenhouse gases to the radiation level of carbon dioxide by multiplying the greenhouse-gas emissions by its *Global Warming Potential (GWP)* with respect to a specific time period, which is regularly the time-span of 100 years (IPCC, 2007a). There exist GHGs, which heat or cool down the environment, which is defined by its *radiative forcing*:

> "Radiative forcing is a measure of the influence that a factor has in altering the balance of incoming and outgoing energy in the Earth-atmosphere system and is an index of the importance of the factor as a potential climate change mechanism" (IPCC, 2007a).

There are GHGs with so called *positive forcing* that have a warming effect, such as carbon dioxide or methane and GHGs with a *negative forcing*, which have a cooling effect in the stratosphere, such as aerosols (IPCC, 2007a). Carbon dioxide has a positive forcing, which thus results in global warming. Global warming leads to severe permanent environmental changes. They are already determinable at for instance, sea level rise, heat waves as well as storms or hurricanes, which may become more severe (IPCC, 2007a).

According to the IPCC (2007a), the following main categories are subject to temperature increase: Amongst others, (1) the discrepancies between droughts and floods become

[13] Non-methane volatile organic compounds are VOCs, which do not include the share of the GHG methane.

more severe, (2) plants and animals are increasingly subject to extinction, (3) agriculture is projected to decrease in productivity for in specific regions, (4) coasts are increasingly affected by floods and storms as well as temperature increase may lead to (5) increased malnutrition, diseases and mortality with respect to the previous factors. Furthermore, temperature increase leads to permanent changes as for instance, a stabilisation does not inhibit the sea level rise but decelerates the process.

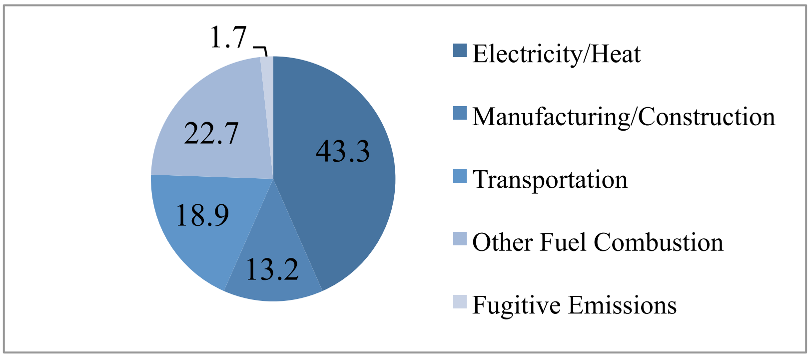
An estimation of a 100-year trend scenario from 1906 to 2005 results in a temperature increase of about 0.74°C (IPCC, 2007a). The IPCC estimated several scenarios for future levels of temperature increase and the corresponding environmental effects. For instance, the worst-case scenario reflects an emission level between 660-790 ppm of carbon dioxide, whereas the peaking year of emissions stabilisation is estimated to be in between the years 2060 and 2090 (IPCC, 2007a). This represents a global temperature increase of 4.9°C to 6.1°C and results in an estimated sea level rise between 1.0 to 3.7 metres (IPCC, 2007a). According to the IPCC (2007a), the best estimate for future stabilisation is a temperature increase of 2.8°C to 3.2°C (440 to 485 ppm of CO_2), which reflects a sea level rise of 0.6 to 1.9 metres. However, this requires early investments and further abatement options in the long term and more advanced low emission technologies (IPCC, 2007a).

According Herzog (2009), by 2005, about 44.153 million tons of CO_2e were emitted. The environment provides carbon sinks, which means that nature, such as, plants, soil or oceans take up carbon dioxide (IPCC, 2007a). Since the 1980s, plants and oceans removed and stored about 50% of all human made carbon emissions (IPCC, 2007b). According to Nestler (2009), oceans comprised about 140 billion tons of carbon dioxide since the beginnings of industrialisation. However, the absorbing capacity decreases (Nestler, 2009).

In order to mitigate emissions, international agreements, such as the Kyoto- or the Montreal Protocol came into force. The Kyoto protocol has been elaborated in 1997 and went into force into 2005 (UNFCCC, 2008). The Kyoto participants, such as France, Italy, the United Kingdom and other countries agreed to reduce their anthropogenic generated GHG emissions below -4.7% in reference to the respective emission level in 1990, whereas Germany set the ambitious goal of a -21% emission reduction (International Energy Agency, 2009, p.xxxii). In 1990, Germany emitted about 1,246 $mtCO_2e$, whereas by the year 2010, CO_2e emissions diminished to about 936 $mtCO_2e$, which accounts for a mitigation of about -24.8%[14] (UNFCCC, 2012). Global transport emissions, define a share of 14.3% of all anthropogenic CO_2e (Herzog, 2009). This is composed of 10.5% of road transport, 1.7% of air transport and 2.5% of rail, ship or others (Herzog, 2009). Furthermore, globally produced transportation emissions increased by 12% between the years 2000 and 2005 (Herzog, 2009).

[14] Carbon dioxide only: 1,042 megatons of carbon dioxide in 1990 and 818 megatons of carbon dioxide by 1990 (-21.4%) (UNFCCC, 2012).

Figure 4: The Federal Republic of Germany's energy emissions by sub-sector in 2009.



Source: Own representation based on World Resources Institute, n.d.a; n.d.b.

Germany's energy emissions by sub-sector are comprised as follows: Electricity/Heat emissions for 2009 result in 334.02 mtCO_2e (43.4%), manufacturing and construction define 101.63 mtCO_2e (13.2%), the transportation subsector amounts to 145.73 mtCO_2e (18.9%), other fuel combustion results in 174.94 mtCO_2e (22.7%) as well as fugitive emissions amount to 13.3 megatons of CO_2e (1.7%) (World Resources Institute, n.d.b).

In order to mitigate transport emissions, the IPCC suggests the following policies, which are in its core also supported by Gwilliam, Kojima and Johnson (2004):

> "More fuel-efficient vehicles; hybrid vehicles; cleaner diesel vehicles; biofuels; modal shifts from road transport to rail and public transport systems; non-motorised transport (cycling, walking); land-use and transport planning; second generation biofuels; higher efficiency aircraft; advanced electric and hybrid vehicles with more powerful and reliable batteries" (IPCC, 2007a, p.60).

The IPCC (2007a) also advises several policies, such as a mandatory fuel economy, taxes on vehicle purchase, land-use regulations and investment in public transport as well as carbon dioxide standards for road transport. Amongst other measures, fuel tax, tolls, car-scrap bonuses or subsidies to particle-filters, have been applied by the federal government (BMU, 2013; Höpfner, Hanusch & Lambrecht, 2009).

However, with respect to carbon dioxide standards for road transport, it previously has not been mandatory for the car industry to improve the car fleet. Therefore, the EU initiated discussions in 2007, which in December 2008 were fixed to in a phase-in emission goal of the car fleet (BMU, n.d.). This phase-in declares that between 2012 and 2015, the new car fleet needs to integrate the 130 gCO_2/PKM emission goal by the following shares as follows: (1) 65% by 2012; (2) 75% by 2013; (3) 80% by 2014 and (4) finally 100% of the new car fleet emits 130 gCO_2/PKM to the maximum, by 2015.

The BMU (n.d.) assumes the following average carbon emissions for the new car fleet according to the phase in: (1) 157 g/PKM by 2012; (2) 142 g/PKM by 2013; (3) 133 g/PKM by 2014 and accordingly, (4) 130 g/PKM to be emitted by 2015. The BMU (n.d.) projects that according to a 50% phase in, the European car fleet will emit in average 156 gCO_2/PKM, whereas for a 90% phase in the fleet will emit 140 grams of carbon dioxide in the future. As previously mentioned, with respect to pollutant emissions, the applied emissions standards are to be envisaged in this study. This will be covered in the chapters 5.3 and 5.4. The next section will cover the carbon footprint definition.

3.4. Carbon footprint limitation

The carbon footprint is not based on a general definition. It may define carbon emissions only as well as direct emissions or the consideration of the relevant its upstream chain of emissions. It may be defined in comprising at least the greenhouse gases of carbon dioxide, methane and nitrous oxides, which are recalculated to the CO_2equivalent (Wiesmann & Winx, 2007). With respect to its share, carbon dioxide is the largest greenhouse gas (see p.21).

Wiesmann and Winx define the carbon footprint as follows: "The carbon footprint is a measure of the exclusive total amount of carbon dioxide emissions that is directly and indirectly caused by an activity or is accumulated over the life stages of a product“ (2007, p.4). This is based on the fact that the other gaseous emissions are not based on carbon, which could otherwise be called a *climate footprint* (Wiesmann & Winx, 2007). Accordingly, this study concentrates on carbon dioxide emissions in correspondence to its upstream chain only. Thus, all emissions that derive along the well-to-wheels life cycle (see chapter 4.1.) from the fuel resource extraction to the combustion on the street are encompassed. With respect to the term carbon footprint, the selected pollutants' emission approximation will be termed *pollutant footprint* for this analysis.
The next chapter outlines the methodology and the emission estimation approach as well as the analysis of emission factors for individual- and public transport for the years 1987 and 2011.

4. METHODOLOGY AND LIFE CYCLE ASSESSMENT

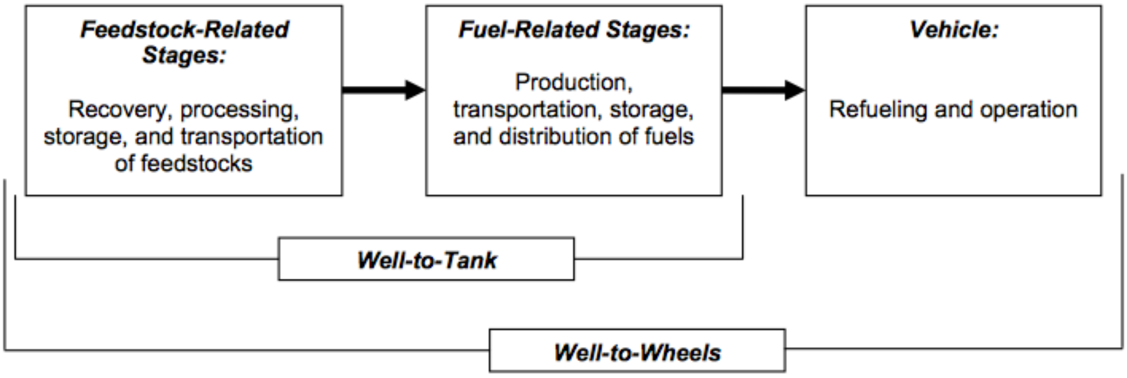
This chapter covers the approach to the analysis' execution as well as a deeper look into the applied methodology and the corresponding data input and calculation approach.

4.1. Life cycle assessment

The carbon footprint estimation is be strategically approached by a lifecycle assessment (LCA). The assessment's initiative step is a definition of the product's life cycle. This analysis' product is transportation, which is comprised of the fuel and the relevant vehicle.

In order to estimate the life cycle's impact, an investigative process on motor vehicles is chosen. The *well-to-wheels* approach encompasses the vehicle's emissions in combination to its upstream chain as it is displayed by the following figure:

Figure 5: Well-to-wheels analysis of vehicles.

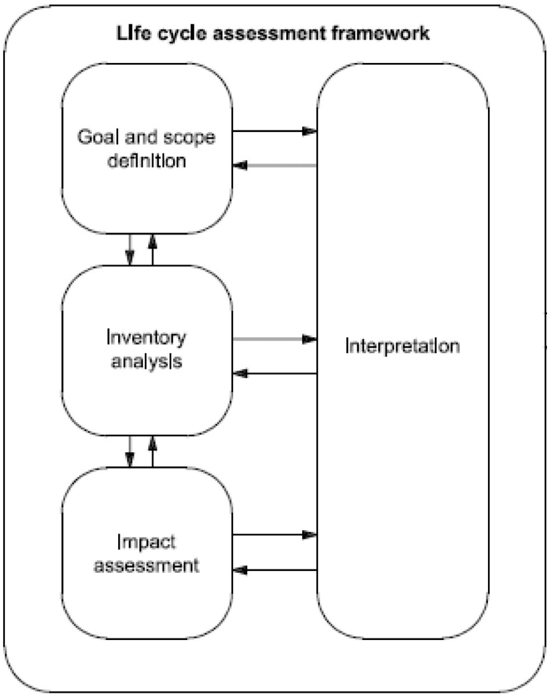


Source: Brinkman, Wang, Weber & Darlington, 2005, p.11.

The first two steps are the feedstock-related stages and the fuel-related stages, which define the *well-to-tank* approach. The last step of the well-to-wheels approach, the vehicle stage, is known as the *tank-to-wheels* stage (Brinkman et al., 2005). The first stage investigates for instance, on feedstock storage or the transportation of fuels. The fuel-related stage focuses for instance, on the distribution of fuels. The last stage concentrates on the refuelling and operation of vehicles, which defines direct - including evaporative - emissions (Knörr, Heidt & Schacht; 2012).

The well-to-tank stages represent the indirect - the upstream chain - of emissions, which define emissions that range from resource extraction to gas station distributions (Knörr, Heidt & Schacht, 2012). For example, refuelling is important, because VOCs emit during the fill up process (Brinkman et al., 2005). The relevant energy feedstocks of investigation are gasoline, diesel and electricity (Brinkman et al., 2005). Accordingly, the analysed vehicles are gasoline and diesel vehicles as well as electric and diesel trains. The official guideline is provided by the ISO norms 14040 and 14044 (Belz & Peattie, 2009).

Figure 6: Life-cycle analysis framework.



Source: Trustly, n.d.

The first step regards the goal and scope definition of the project. According to Belz and Peattie (2009), an objective may be the comparison of alternatives. In this analysis this represents the comparison of individual- to public transport. "The scope refers to the functional unit of analysis, the system boundaries and the geographic stage of coverage" (Belz & Peattie, 2009, p.61). The boundaries are covered in chapter 4.3. and the goal is outlined in the introduction (see page pp.10).

The inventory analysis focuses on the material flows in connection to the functional unit of analysis (Belz & Peattie, 2009). According to Belz and Peattie (2009), the resource or energy inputs and -outputs are measured in physical terms. Accordingly, the input of fuel is measured in litres of fuel and the output is measured in grams, kilograms or tons of emissions per travelled person-kilometre (see chapter 5.1.).

This data output and hence, the inventory analysis, leads to the impact assessment, which involves the at least the steps "selection and definition of impact categories; assignment of inventory output and output data to the selected impact categories, and aggregation of inventory output data within the category" (Belz & Peattie, 2009, p.62). According to the Umweltbundesamt (UBA, 2000), relevant impact categories are for instance, the greenhouse effect, which is to be determined by the indicator of CO_2-equivalents, acidification or direct health impacts by hazardous substances or noise. This output leads to the for instance, political conclusions or advice for producers (UBA, 2000).

A basic impact assessment of the selected pollutants is outlined in chapter 3.2 as well as carbon dioxide is disclosed in the chapters 3.2 and 3.3. This analysis approaches the determination of the commuters' carbon footprint as it is explained on p.24 and pollutant emissions. The final results in the chapters 6 and 7 will represent the degree of improvement and hence, in what extent the global warming impact of carbon dioxide is mitigated and whether pollutant emissions and their described effects are mitigated by the application of the euro norm regulations for IT or an improved fuel mix for PT. This is set into an estimation of the sustainability potential of individual- and public transport for the EMM commuters.

4.2. Methodology

The GTZ (now Deutsche Gesellschaft für Internationale Zusammenarbeit [GIZ]) established a guideline for emission inventories. According to the GTZ (2009), there are three main categories for assessing emissions. Those source groups are mainly

1. Point sources, such as factories or industrial sites (GTZ, 2009).
2. Mobile sources, such as caused by motor vehicles (GTZ, 2009).
3. Area sources, e.g., forest fires or domestic fuel combustion (GTZ, 2009).

So called mobile sources, such as emissions caused by motor vehicles, are not to be calculated separately but to be summed up along the road, as it is to be analyzed in this study for Munich’s in- and out commuters (GTZ, 2009).

According to the GTZ (2009) there are three major steps to conduct an emission inventory for mobile sources:

1. The assignment of pollutant categories: The determination of categories for primary and secondary pollutants (see pp.19) (GTZ, 2009).
2. Data compilation: The source strength, hence, the amount of emissions for the area of analysis needs to be determined (GTZ, 2009). The following list is adapted to mobile sources (GTZ, 2009).
   - 2.1. Establishment of a list of mobile sources.
   - 2.2. The acquisition of raw data and the subsequent deduction of “activity data on such factors as the size and classification of the vehicle fleet, kilometres travelled”, etc. (p.13).
   - 2.3. Data review for “validity and suitability” (p.13).
   - 2.4. Conversion of “the individual source and activity level data to provide a spatially desegregated source inventory” (p.13).
3. The emission factor determination:

E = Emission factor x Activity Intensity

The formula outlines the simplified approach to the conducted calculation process. It outlines in what extent emissions may vary according to the specific emission factor (EF), which varies for instance, with the transport mode or the commuting intensity in this analysis.

> “When source data are missing, it is common to use general emission factors for both point and diffuse sources”, such as emissions from motor vehicles […] Emission factors for diffuse sources are usually calculated using data specific for each source type. For example motor vehicle emissions may be estimated by calculations involving the distance travelled by vehicles, the number of vehicles, temperature, fuel consumption and the composition and properties of the fuels used“ (GTZ, 2009, p.13).

Accordingly, the emission factors are subject to specifications and as far as possible to derive more accurate results.

Figure 7: Calculation example.

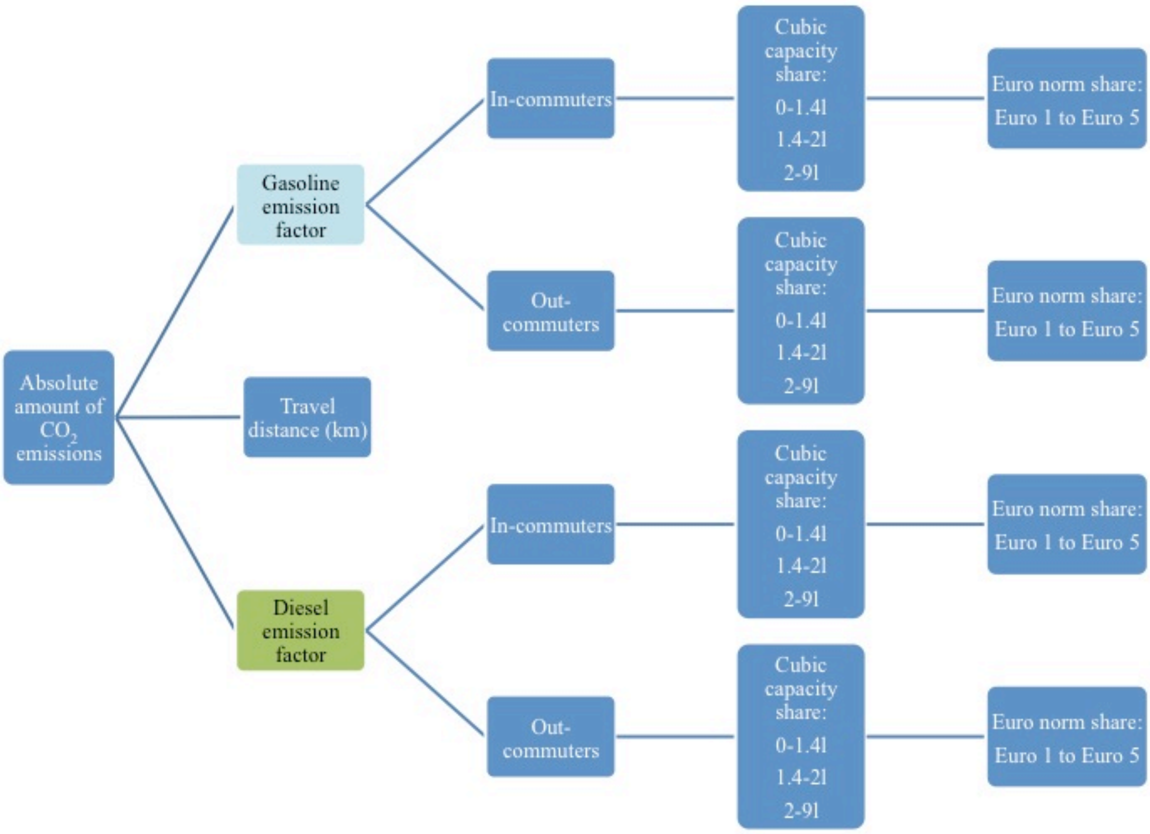
Source	Pollutant	Activity level
Four-stroke gasoline vehicle	NO_X	grams of NO_X per km travelled
	CO	grams of CO per km travelled

Source: GTZ, 2009, p.14.

Figure 7 depicts two representative pollutants for fours-stroke gasoline exhaust as well as the corresponding simplified reflection of the polluting activity's estimation, as for instance, the grams of nitrogen oxides to be emitted per kilometre travelled.

After the inventory's completion, an emission verification for transparency and internal consistency is to be conducted (GTZ, 2009). In the following, the two basic ways of estimating the emissions for individual- and public transport are depicted to reflect the output composition. The following figure represents an overview of the emission calculation approach for individual transport.

Figure 8: Emission inventory approach for the individual transport's carbon dioxide emissions in 2011.



Source: Own representation.

Figure 8 reflects the formula for the calculation of carbon dioxide emissions for individual transport commuters for the year 2011. The Euro norms, the corresponding engine class, the amount of in- or out-commuters, the engine type as well as the kilometres travelled result in the amount of carbon dioxide emissions. The approach for pollutant emissions coincides. In comparison to 2011, in 1987, no shares for Euro norms are taken into account.

4.2.1. Individual transport emission inventory approachrbe

The emission inventory for carbon dioxide and the selected pollutants is approached as follows for the years 1987 and 2011 in consideration of individual transport:

1. The European Metropolitan Region of Munich's relevant rural districts and cities are determined. The rural districts are sub-categorized and aligned with their corresponding municipalities.
2. The best travel route, which is based on a combination of travel times and travel distance is determined and aligned to each municipality. The routes are standardized under the assumption of the commuter to travel from the municipality's centre to the Munich central station. The public platform *Googlemaps*[15] is applied for this search only.
3. The second best route is entered. Hence, the mean of the two routes is taken, due to the consideration and integration of an alternative route management, which commuters may apply.
4. The municipalities' travel distance data is aligned with each rural district and city.
5. The entire calculation is split up into two categories, in fact, into diesel- and the gasoline driven passenger cars. For each engine category, the specific share is assigned to each rural district and city. The engine category data is provided by the *Kraftfahrt-Bundesamt* (Federal Office for Motor Vehicles [KBA]).
6. The engine category data is further subdivided into cubic capacities of 0 to 1.4 litres, 1.4 to 2 litres and from 2 to 9 litres. However, for the 1987 scenario, the engine sizes range from 0 to 1.5 litres, from 1.5 to 2 litres and from 2 to 9 litres. The cubic capacity data is provided by the Kraftfahrt-Bundesamt.
7. The specific emission factor for both engine categories in combination to the three cubic capacity categories are identified. The emission factors are provided by the *Transport Emission Model* (TREMOD), which will be outlined in chapter 5.3.
8. The allocated emission factor is multiplied by the amount of driven kilometres for each rural district or city and hence, being multiplied by the amount of in- and out-commuters. This is conducted for the gasoline- and diesel engine categories. The number of in- and out-commuters is derived by the Bayerisches Landesamt für Statistik und Datenverarbeitung for the year 1987 as well as by the Bundesagentur für Arbeit, for the year 2011.
9. The output data is recalculated for the cubic capacity shares as well as with the corresponding Euro norms shares from 1 to 5, whereas for the year 1987, only the pre Euro 1 emission category is applied.
10. The gasoline and diesel categories are summed up and thus, the specific carbon- and pollutant emissions result for each rural district or city, for all in- and out-commuters.

The following figure represents an excerpt of the previously outlined calculation. It reflects the carbon dioxide calculation of gasoline engines for the Euro norm 1 in 2011.

[15] Googlemaps: https://maps.google.de

Figure 9: Excel-excerpt for the exemplary calculation of carbon dioxide emissions in 2011.

Carbon dioxide													
Cities and rural districts (R.D.) (2011)		Fuel type: Gasoline Emission class: Euro 1 Cubic capacity (cc): 0-1.4l											
		Emission factor (g/PKM)	gCO_2/ dist.	$kgCO_2$/ dist.	tCO_2/ dist.	CO_2/ R.D./ in-commuters	CO_2/ R.D./ out-commuters	Gasoline share/ R.D./ in-commuters	Gasoline share/ R.D./ in-commuters	CC share/ in-commuters	CC share/ out-commuter	Share of Euro norm/ in-commuters	Share of Euro norm/ out-commuters
09161	Ingolstadt (City)	201	16713	16.713	0.0167	35.148	19.32	21.43	12.219	5.6513	2.7679	0.315	0.1978
09163	Rosenheim (City)	201	14140	14.14	0.0141	27.772	7.7206	18.429	4.883	5.4776	1.1061	0.305	0.079
09171	Altötting	201	21269	21.269	0.0213	25.586	3.5944	17.859	2.2733	5.125	0.515	0.2675	0.0368
09173	Bad Tölz-Wolfratshausen	201	10766	10.766	0.0108	73.242	15.32	47.178	9.6894	13.173	2.1948	0.7777	0.1569
09174	Dachau	201	7218.3	7.2183	0.0072	173.49	28.685	119.18	18.142	34.19	4.1096	1.9232	0.2937
09175	Ebersberg	201	7613.1	7.6131	0.0076	139.57	33.886	91.416	21.431	24.595	4.8546	1.3305	0.3469
09176	Eichstätt	201	22830	22.83	0.0228	23.515	5.0454	15.294	3.191	4.4564	0.7228	0.2828	0.0517
09177	Erding	201	10360	10.36	0.0104	117.57	15.042	77.316	9.5135	22.02	2.155	1.2076	0.154
09178	Freising	201	10599	10.599	0.0106	166.83	99.652	105.58	63.025	28.384	14.277	1.8008	1.0203
09179	Fürstenfeldbruck	201	7373.2	7.3732	0.0074	238.47	40.538	165.71	25.638	47.449	5.8076	2.8765	0.415
09180	Garmisch-Partenkirchen	201	17386	17.386	0.0174	30.373	4.1551	20.886	2.6279	6.3217	0.5953	0.3784	0.0425
09181	Landsberg am Lech	201	12568	12.568	0.0126	76.89	8.6593	49.541	5.4766	14.328	1.2406	0.8814	0.0887
09182	Miesbach	201	10732	10.732	0.0107	61.152	15.916	39.317	10.066	10.666	2.2802	0.6317	0.163
09183	Mühldorf a.Inn	201	15560	15.56	0.0156	61.962	3.3922	42.538	2.1454	12.746	0.486	0.7474	0.0347
09184	München	201	3699.8	3.6998	0.0037	206.18	229.11	123.38	144.9	28.187	32.823	1.4331	2.3457
09185	Neuburg-Schrobenhausen	201	18498	18.498	0.0185	23.4	3.7736	15.623	2.3866	4.3153	0.5406	0.2923	0.0386
09186	Pfaffenhofen a.d.Ilm	201	13671	13.671	0.0137	104.64	13.097	67.044	8.283	17.963	1.8763	1.1274	0.1341
09187	Rosenheim	201	15122	15.122	0.0151	108.97	16.831	71.949	10.645	21.403	2.4112	1.239	0.1723
09188	Starnberg	201	6643.9	6.6439	0.0066	91.732	40.222	59.432	25.439	14.895	5.7624	0.8598	0.4118
09189	Traunstein	201	21724	21.724	0.0217	38.994	5.4309	26.231	3.4348	7.8097	0.778	0.4582	0.0556
09190	Weilheim-Schongau	201	15052	15.052	0.0151	67.841	13.908	45.321	8.7964	13.018	1.9926	0.8458	0.1424
09261	Landshut (City)	201	15789	15.789	0.0158	29.461	6.6943	19.788	4.2339	5.7434	0.9591	0.3268	0.0685
09273	Kelheim	201	21312	21.312	0.0213	40.642	3.7509	26.061	2.3723	7.3529	0.5374	0.4055	0.0384
09274	Landshut (R.D.)	201	17656	17.656	0.0177	64.18	5.1026	41.691	3.2272	11.335	0.731	0.6914	0.0522
09279	Dingolfing-Landau	201	23842	23.842	0.0238	40.341	2.6941	28.448	1.7039	7.2877	0.386	0.4645	0.0276
09761	Augsburg (City)	201	16281	16.281	0.0163	106.04	22.842	74.881	14.447	22.121	3.2725	1.3726	0.2339
09762	Kaufbeuren (City)	201	18804	18.804	0.0188	9.5898	1.1658	6.6553	0.7373	2.2406	0.167	0.1208	0.0119
09771	Aichach-Friedberg	201	12746	12.746	0.0127	63.796	3.4288	44.042	2.1685	12.899	0.4912	0.7443	0.0351
09772	Augsburg (R.D.)	201	18249	18.249	0.0182	70.04	4.8543	49.886	3.0701	15.131	0.6954	0.8413	0.0497
09773	Dillingen a.d.Donau	201	25645	25.645	0.0256	12.335	0.9745	8.5955	0.6163	2.5596	0.1396	0.152	0.01
09777	Ostallgäu	201	21829	21.829	0.0218	32.613	9.4739	21.894	5.9918	6.9831	1.3573	0.4096	0.097
09779	Donau-Ries	201	27339	27.339	0.0273	18.864	6.0967	12.839	3.8559	3.6318	0.8734	0.2455	0.0624
	Sum												

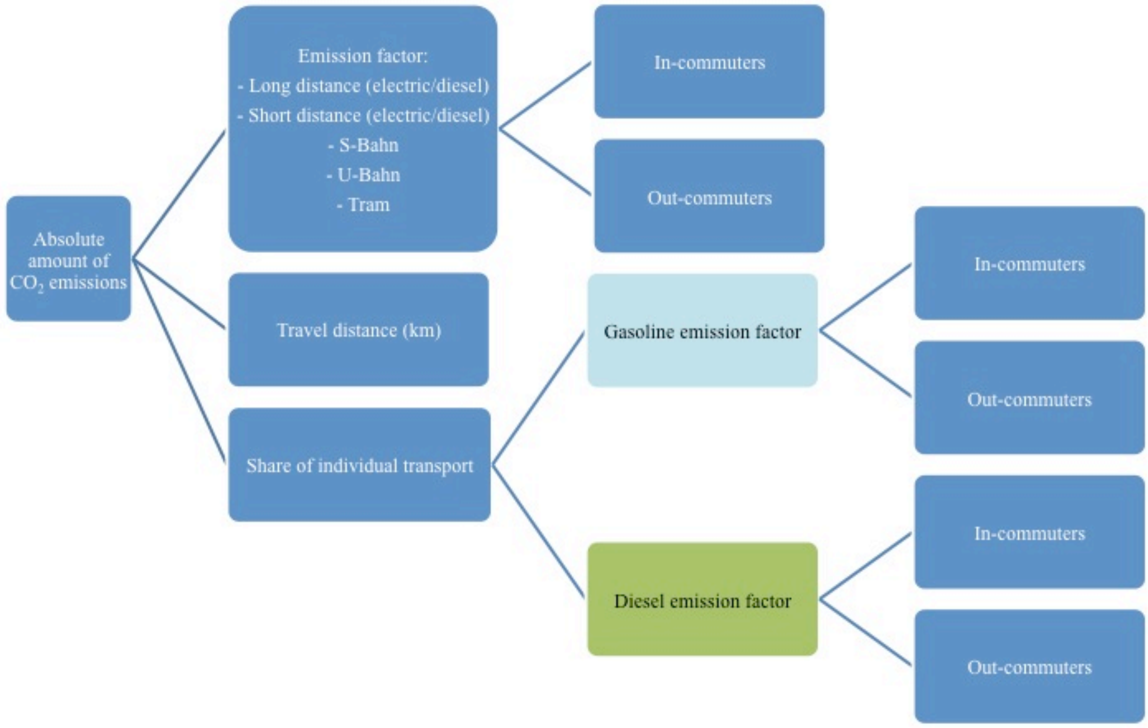
Source: Own representation based on LfStaD, 1991; n.d.c; BA, 2012 (see addendum, pp.107); GeoBasis-DE/BKG & Google Inc., Google Inc., n.d.a - n.d.abg (see CD, Individual Transport addendum, pp.1-226); KBA, 1987 (see addendum, pp.105); 2012; UBA, 2010d - 2010f.

The last two columns depict the amount of emissions in tons of carbon dioxide for in- and out-commuters. For instance, the city of Ingolstadt's out-commuters proof of an absolute emission per trip and day of 0.19781 tons of carbon dioxide (tCO_2) or 197.81 kilograms of carbon dioxide ($kgCO_2$) emissions for all Euro 1, gasoline driven cars with a cubic capacity range of 0 to 1.4 litres.

4.2.2. Public transport emission inventory approach

The next figure reflects the formula for the calculation of carbon dioxide emissions for public transport commuters for the year 2011. The figure represents the process of the applied differentiation between public local transport (PLT), long distance passenger transport (LPT), S-Bahn, U-Bahn, Tram, the amount of in- and out-commuters and the kilometres travelled, which is combined with an estimated share of individual transport, which result in the estimated amount of carbon dioxide emissions. The approach for pollutant emissions coincides.

Figure 10: Emission inventory approach for the public transport's carbon dioxide emissions in 2011.



Source: Own representation.

The figure depicts the exemplary process of deriving for instance carbon dioxide emissions for public transport. The following approach discloses the steps for the PT emission inventory, whereas steps one and two are to be derived by the previous inventory for individual transport and thus, continues with step 3.

3. For the individual municipalities, the travel distance from the city centre to the Munich central station is standardized. The time and transport modes are recorded for two alternative routes. Regularly, the first available train from 07:00 AM as well as the next possible alternative in the schedule are determined. If no second travel route data is available, the first route's data is entered.
4. If available, the travel distance is measured from the city's own train station. The travel distance is derived by the Deutsche Bahn AG (DB) timetables - *Kursbuch*[16]. If there is no local train station, the travel distance measure from the city centre to the next possible train station is recorded under the assumption of individual transport[17]. Accordingly, this estimation also encompasses individual transport. Frequently, the next train station is not located within the city boundaries but can only be reached by bus or car. Hence, IT is assumed for locomotion and taken into account to get more veridical results for commuting behaviour.

[16] Deutsche Bahn AG Kursbuch: http://kursbuch.bahn.de/hafas/kbview.exe.
[17] For the origins of Ehekirchen, Rohrenfels (rural districts of Neuburg-Schrobenhausen) and Chiemsee (rural district of Rosenheim) no reliable data is available.

The year 1987's individual transport emission factor is derived by the TREMOD data pre Euro 1, which is adapted to the average German car fleet. The year 2011's emission factor is derived by the conducted calculation for individual transport. The specialized emission factor, which is adapted to the relevant car fleet's characteristics, is applied. The estimated emission factor may be derived by table 14.

The best travel route and corresponding transport mode is derived by Googlemaps, which is supported by the Deutsche Bahn. Alternatively, the Deutsche Bahn online-service[18] is applied, since services by other companies, such as offered by *Agilis Eisenbahngesellschaft mbH & Co. KG*, are not displayed on Googlemaps.

For instance, the derived information provides the following recommendation to travel from the municipality of *Teising*, which is located in the rural district of Altötting, to the Munich central station: The best travel route suggests to drive for 1.8 km to the train station in the city *Heiligenstatt*, in order to change for the regional train (RB 27148) to travel to Mühldorf and to then change for the regional train (RB 27040) to reach the final destination.

5. Distances below 1.5 kilometres of individual transport are not included. The following table depicts an excerpt from the year 1987's modal split data for Munich's out-commuters.

Table 4: The commuter's travel time and corresponding transport mode.

The city of Munich's out-commuters in 1987				
Transport mode	Total	<15 minutes	15-30 minutes	>60
Car	35,283	3,223	15,814	2,383
U-Bahn; S-Bahn; Tram	11,971	32	1,655	2,695
Train	801	.	.	616
Bus	3,025	63	831	425
Bike	764	205	339	23
Others (motorcycle, moped, etc.)	318	33	161	24
Non-motorized: walking	225	117	81	9
Total	52,387	3,673	18,881	6,175

Source: Own representation based on LfStaD, 1991; n.d.b.

The people's modal split data shows that from 52,387 out-commuters, 3,673 out-commuters travel less than 15 minutes to work. The data reflects that 3,223 employees travel by car and only 117 commuters walk to work. Assuming an average walking speed of about 5 kilometres per hour the employee walks at the most 1.5 kilometres in 15 minutes. Hence, already due to the low relative amount, the 1.5 kilometre radius is applied for calculations. With respect to the next assumption of a travel time, which ranges from 15 to 30 minutes, the number further reduces to 81 walkers, whereas from a total 18,881 employees, 15,814 commuters go by car. This shows that even for short distances, employees rather accept the car for a transport mode.

6. In the case of a change of transport modes, such as a change from regional train to S-Bahn, the relevant travel distance share is calculated and multiplied by the

[18] Deutsche Bahn AG online service: http://www.deutschebahn.com/de/start.html

corresponding emission factor. Thus, the result is multiplied by the number of in- and out-commuters.

7. There are three major decision factors, which define the applied emission factor: (1) The suggested train type such as Intercity-Express (ICE), Interregio-Express (IRE), etc., (2) the trip length and (3) the distance. Accordingly, if travelling by ICE is available and trip length is longer than 60 minutes and the distance exceeds 50 km, the long distance passenger transport emission factor is applied. However, if for instance, the regional train is suggested and the distance exceeds 50 km but the travel time does not exceed 60 minutes, the emission factor for public local transport is applied. This is further based on the differentiation between PLT and LPT transport, which is further outlined on p.48.
8. The individual transport share and the public transport share are added, which results in the emission output.

4.3.Boundaries

The following section covers the study's boundaries, such as the base year, scope, the methodology's main limitations and the differentiation between the Planning Region 14 and the European Metropolitan Region of Munich.

4.3.1. Base year

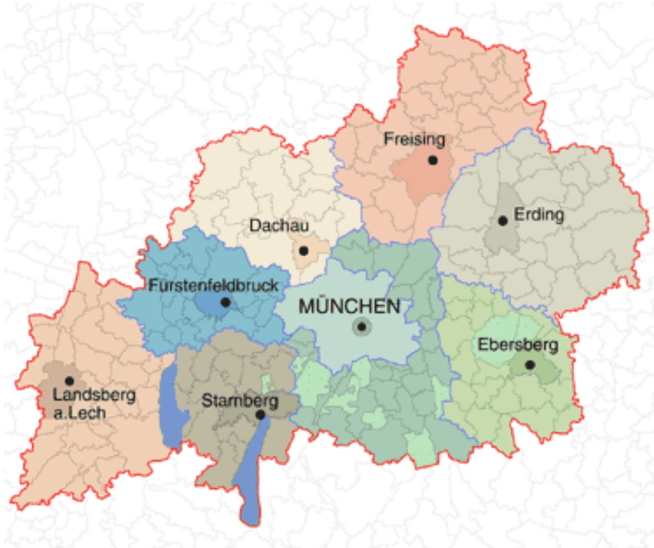
Two base years, namely 1987 and 2011, are applied for data comparison. The year 1987 is chosen due to data availability for most relevant commuter data. Additionally, the second last population census was conducted in 1987. The year 2011 is applied, because it provides a larger share of statistical data in comparison to the year 2012. Information and reports for the year 2012 are uncommonly published at the time of analysis. Accordingly, this is the most recent year of data availability.

4.3.2. Scope

The scope defines and constrains the subject of analysis. In the following, the Planning Region 14 and the European Metropolitan Region of Munich are outlined. In this analysis, the European Metropolitan Region of Munich is to be split up into three separate areas of analysis.

The state of Bavaria is split up into 18 planning regions, whereas the Planning Region 14 (PR14) comprises the city of Munich and its various adjacent rural districts, which are displayed in figure 11. The PR14 encompasses the rural districts: *Dachau, Erding, Ebersberg, Freising, Fürstenfeldbruck, Landsberg am Lech* and *Starnberg*as well as the city of Munich. As previously mentioned, the adjacent districts only are represented by the Outer Planning Region 14.

Figure 11: Planning Region 14.



Source: Der Regionale Planungsverband München, 2005.

The city of Munich comprises about 1,410,741 inhabitants in 2012 LfStaD (2013). However, the PR14's inhabitants account to the surrounding population of the city of Munich, which are being administered independently.

Table 5: The EMM's number of inhabitants for the years 1987 and 2011.

City of Munich	**1987**	**2011**
Sum	1,201,479	1,364,920
Outer Planning Region 14	**1987**	**2011**
Sum	1,029,703	1,325,233
Outer European Metropolitan Region	**1987**	**2011**
Sum	2,534,850	3,017,865
Total sum	4,766,032	5,708,018

Source: Own representation based on LfStaD, n.d.c; n.d.e; n.d.f.

The table reflects the entire EMM's inhabitants for 1987 and 2011. In 1987, the total European Metropolitan Region's inhabitants amount to about 4,766,032 people. In 2011, this number grows to 5,708,018 inhabitants. By exceeding a mark of five million inhabitants, this reflects a growth of 19.76% from 1987 to 2011 and highlights the importance of the European Metropolitan Region of Munich.

Figure 12: European Metropolitan Region of Munich.

Source: Europäische Metropolregion München, n.d.c.

The figure reflects the entire European Metropolitan region of Munich (EMM). The EMM is subcategorized into the city of Munich, the surrounding Outer-Planning Region 14 and the remainder of the European Metropolitan Region. Hence, this remainder is abbreviated with the *Outer Metropolitan Region of Munich (OEMM)*.

In 1995, the larger area around Munich was defined to reflect a Metropolitan Region, meaning an area, which is composed of the Planning Region of Munich as a core and the other surrounding regions with which it is strongly intertwined (Europäische Metropolregion München e.V., n.d.a). It is "comprised of 25 South Bavarian Districts, more than 30 district towns and municipalities and the six independent cities of Augsburg, Ingolstadt, Kaufbeuren, Landshut, Munich and Rosenheim" (Europäische Metropolregion München e.V., n.d.b, n.p.). The EMM reflects a strongly interacting economical region that is not only connected by infrastructure but also interacting on a technologic and intellectual basis (Europäische Metropolregion München, n.d.b). The next chapter will cover the commuter data for the years 1987 and 2011.

4.3.3. Comparison of the number of commuters from 1987 to 2011

The commuter data encompasses the in-commuters from the Outer Planning Region 14 and Outer Metropolitan Region of Munich that travel to the city of Munich as well as the out-commuters from the city of Munich who commute to the rural districts for work.

Table 6: Comparison of the number of commuters for the years 1987 and 2011.

	In-commuters		Out-commuters	
European Metropolitan Region of Munich				
Sum 1987	247,479		56,144	
Sum 2011	252,039		106,046	
Change	*+1.84%*		*+104.4%*	
Outer Planning Region of Munich				
1987	191,166		48,210	
2011	177,451		93,445	
Change	*-7.18%*		*+93.83%*	
Outer European Metropolitan Region of Munich				
1987	56,313		3,671	
2011	74,588		12,601	
Change	*+32.45%*		*+273.81%*	
	1987		2011	
Dachau (DAH)	22,737	1,679	24,035	3,974
Ebersberg (EBE)	19,289	1,877	18,333	4,451
Erding (ED)	10,247	518	11,349	1,452
Freising (FS)	13,664	2,478	15,740	9,402
Fürstenfeldbruck (FFB)	40,923	3,582	32,343	5,498
Landsberg am Lech (LL)	4,754	257	6,118	689
München (M)	62,589	34,364	55,726	61,925
Starnberg (STA)	16,963	3,455	13,807	6,054
Sum	191,166	48,210	173,072	89,764
Ingolstadt (IN)	1,581	147	2,103	1,156
Rosenheim (RO City)	1,794	176	1,964	546
Altötting (AÖ)	919	21	1,203	169
Bad Tölz-Wolfratshausen (TÖL)	6,486	798	6,803	1,423
Eichstätt (EI)	776	36	1,030	221
Garmisch-Partenkirchen (GAP)	1,253	84	1,747	239
Miesbach (MB)	5,414	334	5,698	1,483
Mühldorf am Inn (MÜ)	3,903	91	3,982	218
Neuburg-Schrobenhausen (ND)	841	52	1,265	204
Pfaffenhofen an der Ilm (PAF)	6,437	123	7,654	958
Rosenheim (RO R.D.)	5,982	280	1,964	546
Traunstein (TS)	1,133	70	1,795	250
Weilheim-Schongau (WM)	3,810	266	4,507	924
Landshut (LA City)	1,358	168	1,866	424
Kelheim (KEH)	1,775	53	1,907	176
Landshut (R.D.)	2,480	34	3,635	289
Dingolfing-Landau	289	13	1,692	113
Augsburg (City)	3,566	646	6,513	1,403

Kaufbeuren	312	30	510	62
Aichach-Friedberg (AIC)	3,118	85	5,005	269
Ausgburg (A R.D.)	1,973	144	3,838	266
Dillingen an der Donau (DLG)	155	n/a	481	38
Ostallgäu (OAL)	648	20	1,494	434
Donau Ries (DON)	310	n/a	690	223
Sum	**56,313**	**3,671**	**74,588**	**12,601**

Source: Own representation based on LfStaD, 1991; n.d.c; BA, 2012 (see addendum, pp.107); Schäfer, n.d.

Table 6 depicts the change in- and out commuters of the entire European Metropolitan Region, which is also subcategorized into the OPR14 and the OEMM. The data is provided for the two base years 1987 and 2011. The table depicts the applied abbreviations for the municipalities and cities. The abbreviations are adapted to the official license plates.

At first sight, the information shows that there are far less out-commuters than in-commuters. Overall, a clear workplace shift is recognizable for the entire EMM. Whereas the number of in-commuters is consistent with +1.84%, the number of out-commuters increases by +104.4%. Individually, the OPR14's number of in-commuters decreases by -7.18% and the number of out-commuters increases by +93.83%. With respect to the OEMM, the number of in-commuters, to the city of Munich, rises by +32.45% and the number of employees who work in the OEMM increases by +273.81%. Hence, the interactivity between the city of Munich and the Outer European Metropolitan Region of Munich projects a shift in workplace, whereas the overall number in-commuters remains about constant.

The larger commuter share stems from the OPR14, however, there is a trend of urban commuters to have a place of work in the OPR14. Nevertheless, it is more denotative that people travel to even more distant places of work in the Outer EMM.

4.4. Limitations

This study solely focuses on the European Metropolitan Region of Munich. Rural districts or cities, which exceed this region, such as for instance, commuters from the city of Nuremberg, are not included in this study. The named example is categorized under the European Metropolitan Region of Nuremberg (Europäische Metropolregion Nürnberg e.V., n.d.).

The city and administrative partnership of Mainburg are part of the rural district of Kelheim. However, only the city and administrative partnership of Mainburg are members of the European Metropolitan Region of Munich (Europäische Metropolregion München e.V., n.d.d). However, no specific commuter data is available. Hence, the entire rural district of Kelheim serves as a substitute.

This study only investigates on business in- and out-commuters that travel from Munich to the rural districts and vice versa. It does not encompass intramunicipal employees for both, the city of Munich or the surrounding rural districts and cities. Additionally, the study does not encompass training commuters, such as students, self-employed, mini-jobbers, etc., who are not liable to social security (Bauch, Böhme, Wenzlaff, 2012).

One part of the study is based on the assumption (1) that all commuters travel by either individual or public transport. On the one hand it makes the transport modes comparable, on the other hand it does not reflect the true mobility streams, due to the larger variety of transport modes. In chapter 7.9., a simplified modal split of individual- and public transport is represented. Nevertheless, the transport mode selection may be subject to change, according to for instance, seasonal reasons.

Emission data varies with the travel distance, which is estimated by finding the mean trip length from the individual municipality's city centre to the Munich central station. The calculated average distance as well as the two selected routes may vary strongly, since the routes are standardized as well as commuters may not live in the city centre or travel less or more far than to the Munich central station.

5. EMISSION FACTORS

This chapter outlines the applied data of the previously outlined methodology concept. It covers the implemented emission factors for individual- and public transport. First, the emission factor dimension is defined, which is essential for the corresponding output.

5.1. Passenger-kilometre

The emission factor is based on the passenger-kilometre (PKM) calculation. It explains the transportation performance in the number of passengers and the travelled kilometres. In this analysis, the number of passengers defines the theoretical total amount of commuters and the amount of kilometres defines the mean travel distance from the individual rural districts' centre or railway station to the Munich central station and vice versa (Krieger, n.d.). The output is represented in emitted grams, kilograms or tons of for instance, carbon dioxide per person-kilometre.

5.2. European Emission Standards programme for passenger cars

For years there had been set emission limitations for cars, trucks, light vehicles, etc. (Rabl, 2003). According to Burkhard, Hörder, Pohl, Große Wichtrup and Wilke (2005), there are earlier regulations, such as the introduction of the three-way catalyst with Lambda sensor in 1985, however, the Euro norms are on a mandatory basis. This study investigates on the European Emission Standards programme for passenger cars. The following table gives an overview of the date of entry and the relevant pollutants:

Figure 13: The European Emission Standards for passenger cars.

Stage	Date	CO	HC	HC+NOx	NOx	PM	PN
		g/km					#/km
Compression Ignition (Diesel)							
Euro 1†	1992.07	2.72 (3.16)	–	0.97 (1.13)	–	0.14 (0.18)	–
Euro 2, IDI	1996.01	1.0	–	0.7	–	0.08	–
Euro 2, DI	1996.01[a]	1.0	–	0.9	–	0.10	–
Euro 3	2000.01	0.64	–	0.56	0.50	0.05	–
Euro 4	2005.01	0.50	–	0.30	0.25	0.025	–
Euro 5a	2009.09[b]	0.50	–	0.23	0.18	0.005[f]	–
Euro 5b	2011.09[c]	0.50	–	0.23	0.18	0.005[f]	6.0×10^{11}
Euro 6	2014.09	0.50	–	0.17	0.08	0.005[f]	6.0×10^{11}
Positive Ignition (Gasoline)							
Euro 1†	1992.07	2.72 (3.16)	–	0.97 (1.13)	–	–	–
Euro 2	1996.01	2.2	–	0.5	–	–	–
Euro 3	2000.01	2.30	0.20	–	0.15	–	–
Euro 4	2005.01	1.0	0.10	–	0.08	–	–
Euro 5	2009.09[b]	1.0	0.10[d]	–	0.06	0.005[e,f]	–
Euro 6	2014.09	1.0	0.10[d]	–	0.06	0.005[e,f]	6.0×10^{11} [e,g]

* At the Euro 1..4 stages, passenger vehicles > 2,500 kg were type approved as Category N_1 vehicles
† Values in brackets are conformity of production (COP) limits
a. until 1999.09.30 (after that date DI engines must meet the IDI limits)
b. 2011.01 for all models
c. 2013.01 for all models
d. and NMHC = 0.068 g/km
e. applicable only to vehicles using DI engines
f. 0.0045 g/km using the PMP measurement procedure
g. 6.0×10^{12} 1/km within first three years from Euro 6 effective dates

Source: Dieselnet, 2013.

The figure depicts the European Emission Standards for passenger cars for the Euro norms 1 to 6. The emission factors are represented in grams per kilometre for the pollutant categories carbon monoxide, hydrocarbons, nitrogen oxides, particulate matter, particle number per kilometre as well as a combination of hydrocarbons and nitrogen oxides.

Vehicle exhaust estimation is based on the *New European Driving Cycles* (NEDC), which is also confronted with criticism. To have vehicles on a comparable basis, the driving cycles adhere to fixed tests and schedules, which are for instance, following strict timing or gear shifting (Barlow, Latham, McCrae & Boulter, 2009). As outlined in chapter 5.3 and 5.4, the amount of pollutant emissions is connected to factors, such as engine category, size, level of technology, speed, road type, etc. (Barlow, Latham, McCrae & Boulter, 2009). The cycle can be manipulated as for instance, fuel consuming technology, such as air conditioning or heated-seats, etc., may be switched off as well as carmakers frequently mask cracks or improve the car inflation to an extreme to reduce air and rolling resistance (Dings, 2013). Furthermore, cars may be reduced to minimum weight, which results in fuel reductions of up to 12%.

These measures are of course intertwined with the amount of carbon dioxide- and pollutant emissions (Dings, 2013). According to Dings (2013), the European Commission disclosed that between 2002 and 2010 about 30% of the reported carbon emission reductions do not result from technology but from flexibilities in the NEDC test cycle, loading, the previously named omissions (e.g., heated-seats) as well as other measures (Dings, 2013).

Hence, the table's content may show discrepancies to the applied emission factors in the following chapter. Additionally, the data reflects direct emissions, whereas the applied emission factors comprise the upstream chain.

5.3. Individual transport emission factors

The emission calculations are based on various estimations and platforms. The *Transport Emission Model – TREMOD –* is a system to estimate emissions in Germany. Since 1993, the project is managed by the *Institut für Energie- und Umweltforschung Heidelberg GmbH (IFEU)* on behalf of the Umweltbundesamt (IFEU, 2012). According to IFEU (n.d.), it is based on a handbook and calculation software *Handbuch für Emissions-faktoren HBEFA 3.1*[19], which is not publically available. The handbook's overview conveys that emission factors may be merged according to vehicle category and concept (e.g., passenger car), fuel type and sub-segment, by engine size (from 0 to 1.4 litres, from 1.4 to 2 litres or greater than 2 litres) as well as by the euro norms 1 to 5 (Keller, 2010).

Amongst others, TREMOD is applied by institutions, such as the Deutsche Bahn AG or *Deutsche Lufthansa AG* (IFEU, 2012). TREMOD it is also applied locally, as it may be derived by the *Verkehrsprognose 2025 als Grundlage für den Gesamtverkehrsplan Bayern* (Traffic forecast for the year 2025 as a basis for the Bavarian traffic master plan), which has been elaborated by *INTRAPLAN Consult GmbH* on behalf of the Bayerisches Staatsministerium für Wirtschaft, Infrastruktur, Verkehr und Technologie (Bavarian Ministry of Economic Affairs, Infrastructure, Transport and Technology) in 2010. The applied TREMOD data is derived by the year 2012's final report as well as it is derived by the online Platform *Prozessorientierte Basisdaten für Umweltmanagement-Instru-mente (ProBas)*, which is monitored by the UBA. Accordingly, the TREMOD dataset is applied to derive individual- and public transport emission factors. Via ProBas, emission factors can be varied according to the following main categories:

1. Fuel type (gasoline and diesel)
2. Engine size
3. Road type
4. Emission class

Furthermore, this source is applied due to the fact that TREMOD indicates emissions on a more detailed basis than other models. In the opposite, the provider *Global Emissions Model for integrated Systems (GEMIS),* which is managed by the *International Institute for Sustainability Analysis and Strategy (IINAS*), does not specific modification possibilities and the data is only available for engine categories (IINAS, n.d.; UBA, n.d.). Additionally, TREMOD provides the emission factors including the upstream chain.

Sulphur dioxide is not encompassed in the euro norm regulations. Nevertheless, it is regarded an important pollutant and subject to regulation, such as by the sulphur- free or reduced fuel since the year 2000 (BMU, 2000). E.g., the Deutsche Bahn also investigates on sulphur dioxide as it may be derived by the sustainability report 2011 (DB, 2012a). As also applied in this analysis, the company concentrates on CO_2, NO_x, NMHC, SO_2 and

[19] Handbook emission factors for road transport (HBEFA). HBEFA 3.1: http://www.hbefa.net/e/index.html.

PM in their analysis (ifeu, 2011). Additionally, the IPCC (2006) recommends the investigation of sulphur dioxide in an emission inventory.

The following table contains the corresponding emission factors for carbon dioxide, carbon monoxide, non-methane volatile hydrocarbons, nitrogen oxides, sulphur dioxide and particulate matter. This is split up into diesel and gasoline engines. The table depicts the various cubic capacity ranges, such as from 0 to 1.4 litres, from 1.4 to 2 litres as well as from 2 to 9 litres. The emission factors represent the average of all road types, which comprises urban, suburban as well as motorway commuting. This is based on the fact that a common commute is likely to encompass all three categories, since the employee will travel from one city to another. The emission factors are displayed in emitted grams per person-kilometre.

Table 7: Individual transport emission factors.

Individual transport					
Fuel type			Gasoline		
Engine size			0-1.4l; 1.4-2l; 2-9l		
Road type			Average		
Emission class			Pre Euro 1		
		0-1.4l			
CO_2	**CO**	**NO_x**	**NMHC**	**SO_2**	**PM**
219	14.3	1.31	2.15	0.0926	0.0123
		1.4-2l			
CO_2	**CO**	**NO_x**	**NMHC**	**SO_2**	**PM**
267	10.3	1.21	1.44	0.113	0.015
		2l-9l			
CO_2	**CO**	**NO_x**	**NMHC**	**SO_2**	**PM**
358	13.1	1.53	1.86	0.152	0.0201
Fuel type			Gasoline		
Engine size			0-1.4l; 1.4-2l; 2-9l		
Road type			Average		
Emission class			Euro 1		
		0-1.4l			
CO_2	**CO**	**NO_x**	**NMHC**	**SO_2**	**PM**
201	5.74	0.691	0.652	0.0849	0.0122
		1.4-2l			
CO_2	**CO**	**NO_x**	**NMHC**	**SO_2**	**PM**
256	4.49	0.793	0.641	0.109	0.0144
		2l-9l			
CO_2	**CO**	**NO_x**	**NMHC**	**SO_2**	**PM**
337	4.12	0.723	0.802	0.143	0.0189
Fuel type			Gasoline		
Engine size			0-1.4l; 1.4-2l; 2-9l		
Road type			Average		
Emission class			Euro 2		
		0-1.4l			
CO_2	**CO**	**NO_x**	**NMHC**	**SO_2**	**PM**
183	4.64	0.258	0.465	0.0775	0.0102

1.4-2l					
CO_2	**CO**	**NO_x**	**NMHC**	**SO_2**	**PM**
235	4.28	0.338	0.661	0.0997	0.0132
2l-9l					
CO_2	**CO**	**NO_x**	**NMHC**	**SO_2**	**PM**
315	7.1	0.511	0.716	0.133	0.0176

Fuel type	Gasoline
Engine size	0-1.4l; 1.4-2l; 2-9l
Road type	Average
Emission class	Euro 3

0-1.4l					
CO_2	**CO**	**NO_x**	**NMHC**	**SO_2**	**PM**
179	2.72	0.164	0.41	0.0758	0.01
1.4-2l					
CO_2	**CO**	**NO_x**	**NMHC**	**SO_2**	**PM**
229	2.18	0.154	0.0877	0.0969	0.0128
2l-9l					
CO_2	**CO**	**NO_x**	**NMHC**	**SO_2**	**PM**
306	2.47	0.255	0.529	0.129	0.017

Fuel type	Gasoline
Engine size	0-1.4l; 1.4-2l; 2-9l
Road type	Average
Emission class	Euro 4

0-1.4l					
CO_2	**CO**	**NO_x**	**NMHC**	**SO_2**	**PM**
172	1.53	0.116	0.364	0.0727	0.0096
1.4-2l					
CO_2	**CO**	**NO_x**	**NMHC**	**SO_2**	**PM**
216	1.21	0.116	0.424	0.0917	0.0121
2l-9l					
CO_2	**CO**	**NO_x**	**NMHC**	**SO_2**	**PM**
296	1.16	0.188	0.523	0.125	0.0166

Fuel type	Gasoline
Engine size	0-1.4l; 1.4-2l; 2-9l
Road type	Average
Emission class	Euro 5

0-1.4l					
CO_2	**CO**	**NO_x**	**NMHC**	**SO_2**	**PM**
166	1.34	0.0908	0.328	0.0702	0.0093
1.4-2l					
CO_2	**CO**	**NO_x**	**NMHC**	**SO_2**	**PM**
204	1.05	0.0937	0.382	0.0863	0.0144
2l-9l					
CO_2	**CO**	**NO_x**	**NMHC**	**SO_2**	**PM**
287	0.915	0.144	0.502	0.122	0.0161

Fuel type	Diesel
Engine size	0-1.4l; 1.4-2l; 2-9l

Road type			Average		
Emission class			Pre Euro 1		
			0-1.4l		
CO_2	**CO**	**NO_x**	**NMHC**	**SO_2**	**PM**
123	0.622	0.641	0.119	0.0455	0.119
			1.4-2l		
CO_2	**CO**	**NO_x**	**NMHC**	**SO_2**	**PM**
212	0.577	0.656	0.145	0.0786	0.121
			2l-9l		
CO_2	**CO**	**NO_x**	**NMHC**	**SO_2**	**PM**
292	0.619	0.815	0.161	0.108	0.168

Fuel type			Diesel		
Engine size			0-1.4l; 1.4-2l; 2-9l		
Road type			Average		
Emission class			Euro 1		
			0-1.4l		
CO_2	**CO**	**NO_x**	**NMHC**	**SO_2**	**PM**
117	0.494	0.58	0.0798	0.0433	0.0759
			1.4-2l		
CO_2	**CO**	**NO_x**	**NMHC**	**SO_2**	**PM**
204	0.458	0.616	0.0977	0.0756	0.0864
			2l-9l		
CO_2	**CO**	**NO_x**	**NMHC**	**SO_2**	**PM**
280	0.506	0.792	0.125	0.104	0.111

Fuel type			Diesel		
Engine size			0-1.4l; 1.4-2l; 2-9l		
Road type			Average		
Emission class			Euro 2		
			0-1.4l		
CO_2	**CO**	**NO_x**	**NMHC**	**SO_2**	**PM**
100	0.269	0.664	0.0525	0.0371	0.0512
			1.4-2l		
CO_2	**CO**	**NO_x**	**NMHC**	**SO_2**	**PM**
179	0.266	0.706	0.0621	0.0662	0.0557
			2l-9l		
CO_2	**CO**	**NO_x**	**NMHC**	**SO_2**	**PM**
245	0.582	0.828	0.147	0.0906	0.0631

Fuel type			Diesel		
Engine size			0-1.4l; 1.4-2l; 2-9l		
Road type			Average		
Emission class			Euro 3		
			0-1.4l		
CO_2	**CO**	**NO_x**	**NMHC**	**SO_2**	**PM**
123	0.246	0.715	0.0516	0.0456	0.0361
			1.4-2l		
CO_2	**CO**	**NO_x**	**NMHC**	**SO_2**	**PM**
176	0.234	0.755	0.0572	0.0651	0.04

		2l-9l			
CO_2	**CO**	**NO_x**	**NMHC**	**SO_2**	**PM**
241	0.51	0.881	0.132	0.0894	0.0413
Fuel type			Diesel		
Engine size			0-1.4l; 1.4-2l; 2-9l		
Road type			Average		
Emission class			Euro 4		
		0-1.4l			
CO_2	**CO**	**NO_x**	**NMHC**	**SO_2**	**PM**
134	0.213	0.496	0.0477	0.0497	0.013
		1.4-2l			
CO_2	**CO**	**NO_x**	**NMHC**	**SO_2**	**PM**
178	0.201	0.527	0.0522	0.0661	0.014
		2l-9l			
CO_2	**CO**	**NO_x**	**NMHC**	**SO_2**	**PM**
245	0.434	0.618	0.117	0.0908	0.017
Fuel type			Diesel		
Engine size			0-1.4l; 1.4-2l; 2-9l		
Road type			Average		
Emission class			Euro 5		
		0-1.4l			
CO_2	**CO**	**NO_x**	**NMHC**	**SO_2**	**PM**
131	0.212	0.495	0.0471	0.0484	0.0161
		1.4-2l			
CO_2	**CO**	**NO_x**	**NMHC**	**SO_2**	**PM**
174	0.2	0.526	0.0516	0.0646	0.0097
		2l-9l			
CO_2	**CO**	**NO_x**	**NMHC**	**SO_2**	**PM**
238	0.0433	0.616	0.116	0.0882	0.013

Source: Own representation based on UBA, 2010a; 2010b; 2010c; 2010d; 2010e; 2010f; 2010g; 2010h; 2010i; 2010j; 2010k; 2010l; 2010m; 2010n; 2010o; 2010p; 2010q; 2010r; 2010s; 2010t; 2010u; 2010v; 2010w; 2010x; 2010y; 2010z; 2010aa; 2010ab; 2010ac; 2010ad; 2010ae; 2010af; 2010ag; 2010ah; 2010ai; 2010aj.

The table represents the applied emission factors for the estimation of the corresponding carbon footprint and pollutant emissions for commuters per private vehicle. The category pre Euro 1 is applied for the year 1987, whereas the Euro norms 1 to 5 are considered for the year 2011's estimation. With respect to the year 2011, a difference in the amount of gasoline and diesel engines is determinable for the OPR14 and the OEMM. The Outer Planning Region 14 comprises 38.74% of diesel and 61.26% of gasoline cars, whereas the OEMM is split up into 32.03% of diesel and 67.97% of gasoline cars, which may influence the results. Accordingly, carbon dioxide and pollutant emissions vary according to the chosen engine and the corresponding fuel (KBA, 2012).

5.4. Public transport emission factors

With respect to data sources for PLT and LPT emission factors, for a combined EF of electricity and diesel engines, ProBas provides an emission factor of 59.7 grams of carbon dioxide (gCO_2) per PKM (UBA, n.d.aq). However, the Deutsche Bahn sustainability report for 2011 provides separate data sources per engine category (DB, 2012a). The following carbon dioxide emission factors for the years 2011 are derived by the Sustainability Report *Kennzahlen und Fakten zur Nachhaltigkeit 2011* of the Deutsche Bahn AG and have been confirmed by Herr Thomas Klein, employee in the department of Environmental Management and Consultancy at the Deutsche Bahn (see addendum, p.110). With respect to the year 2011, the report states 73.2 grams of carbon dioxide per PKM for PLT and 41.9 gCO_2 for LPT (DB, 2012a).

The year 1987's pollutant emission factors are derived by the year 1996's sustainability report and are confirmed by Herr Arno Seifert, head of the department of Environmental Management and Consultancy at the Deutsche Bahn (see addendum, p.112). The year 2011's pollutant emission factors are derived by ProBas. The relevant emission factors contain the renewable energy share and the corresponding upstream chain. The emission factors are based on the average degree of capacity and represented in emissions per person-kilometre (DB, 2012a).

Table 8: Public transport emission factors.

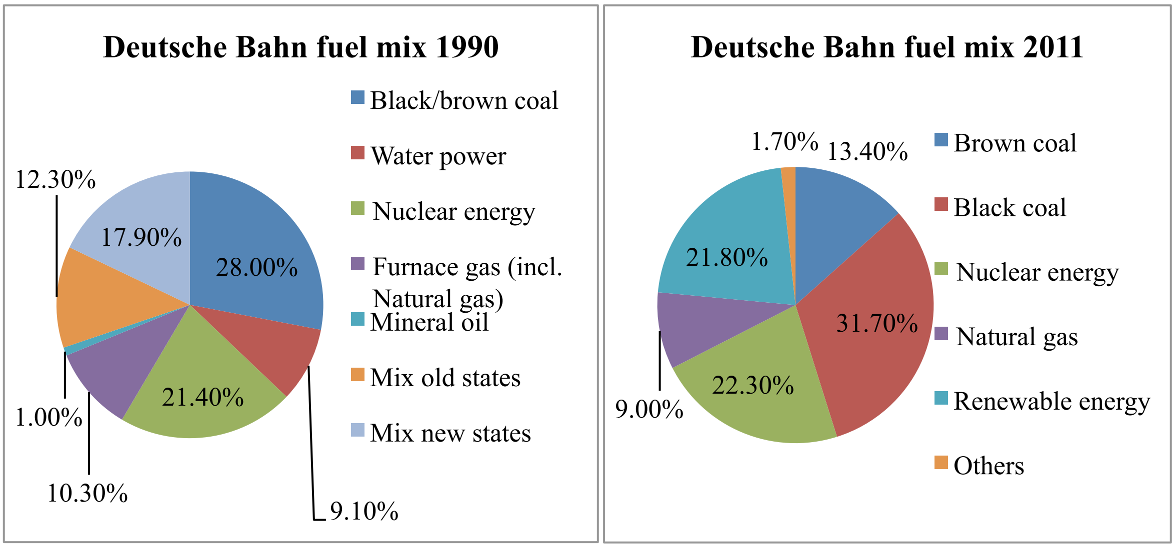
		Public Transport 1987		
1990* CO_2 PLT			138.8 grams of CO_2/PKM	
1990 CO_2 LPT			55.1 grams of CO_2/PKM	
		1993		
CO	**NO_x**	**HC**	**SO_2**	**Soot**
0.0886	0.336	0.0561	0.0392	0.017
		2011		
2011 CO_2 PLT			73.2 grams of CO_2/PKM	
2011 CO_2 LPT			41.9 grams of CO_2/PKM	
Operated by		Electricity		
Capacity		Average		
Type		Public local transport		
Share		83%		
CO	**NO_x**	**NMHC**	**SO_2**	**Soot**
0.0254	0.0529	0.00245	0.0311	0.00334
Fuel		Electricity		
Capacity		Average		
Type		Long-distance passenger transport		
Share		97.8%		
CO	**NO_x**	**NMHC**	**SO_2**	**Soot**
0.0155	0.0323	0.00149	0.019	0.00204
Fuel		Diesel		
Capacity		Average		
Type		Public local transport		
Share		17%		

CO	**NO_x**	**NMHC**	**SO_2**	**PM**
0.125	1.07	0.0566	0.0332	0.0195
Fuel		Diesel		
Capacity		Average		
Type		Long-distance passenger transport		
Share		2.2%		
CO	**NO_x**	**NMHC**	**SO_2**	**PM**
0.154	1.01	0.0553	0.0262	0.0163

Source: Own representation based on DB, 1996; 2012a; UBA, 2010ak; 2010al; 2010am; 2010an.

Table 8 shows that from 1987 to 2011, the emission factors decreased. This is based on either cleaner sources of energy or on the use of better technology. For instance, public local transport decreased from about 138.8 grams of carbon dioxide per person-kilometre in 1987, to about 73.2 gCO_2 in 2011 (European Environment Agency, 2012). According to the Deutsche Bahn, rail transportation emits far less carbon dioxide and pollutants than car or (air-)freight do (DB, n.d.b). Additionally, the composition of electricity gains more importance (DB, n.d.b). Since 1990, the Deutsche Bahn cut carbon dioxide emissions per person-kilometre in half by raising the amount of green electricity production in the process as it may be derived by the following figures:

Figure 14: The Deutsche Bahn fuel mix for the years 1990 and 2011.



Source: Own representation based on Arno Seifert (see addendum, p.111) and DB, 2012a.

The left diagram depicts the Deutsche Bahn fuel mix for the year 1990 and the right diagram depicts the year 2011's fuel mix. It outlines the primary energy composites, which result in the available electricity and the corresponding amount of emissions (Paschotte & RP Photonics Consulting GmbH, n.d.). According to Herr Arno Seifert, the 1990 electricity mix is composed of 9.1% water power, 28.0% black and brown coal, 10.3% furnace gas (including natural gas), 1.0% mineral oil, 21.4% nuclear energy as well as 12.3% are derived by the fuel mix by the old federal states (Federal Republic of Germany) and 17.9% are derived by the new federal states (former German Democratic Republic) (see addendum, p.111). According to Herr Thomas Klein, the carbon dioxide emission-factor results in 749 grams of carbon dioxide per kilowatt-hour (see addendum, p.110). The split up fuel mix for former east and west is not available, however, the year 1990's fuel mix by the Federal Republic of Germany is composed of 35.0% mineral oil, 15.6% of black coal, 21.5% brown coal, 15.4% natural and petroleum gas, 11.2% nuclear energy, 0.4% water and wind power, 0.9% other renewable sources and 0.1 of other sources (Bundesministerium für Wirtschaft und Technologie [German Federal Ministry of Economics and Technology], 2013).

The 2011 Deutsche Bahn fuel mix is composed of 13.4% brown coal, 31.7% black coal, 22.3% nuclear energy, 9% natural gas, 21.8% renewable energy and 1.7% other sources. However, 2.5% of the total electricity consumption is externally produced green energy (DB, 2012a). It is significant that the share of renewable resources increases, which leads to a lower emission factor. Nevertheless, the amount of coal may be subject to criticism. Amongst the named resources, brown coal is the top carbon dioxide emitter (Schrader, 2010). However, the carbon dioxide emission factor amounts to about 589 grams per kilowatt-hour in 2011 (DB Mobility Logistics AG, 2012). Hence, in comparison to 1990, carbon dioxide emissions per kWh are mitigated by -21.36%, which is based on a more environmentally friendly fuel mix.

Munich's public transport system, which is being managed by the Münchner Verkehrs-gesellschaft mbH is being served by the public utility company *Stadtwerke München GmbH (SWM)* (LHST München, 2012). For the year 2011, it provides the following fuel mix, which serves U-Bahn and Tram with an emission factor of about 503 grams of carbon dioxide per kilowatt-hour: The fuel mix is composed of 22% of coal, 19% of renewable energy, 27% natural gas, 31% of other renewable sources and 1% of other fossil fuels (SWM, 2013).

The applied pollutant emission factors are supported by a publication of the Umwelt-bundesamt in 2012, which provides similar emission factors for individual- and public transport, which are derived by the HBEFA, TREMOD 5.32 programme for the year 2011 (UBA, 2012).

5.5. Limitations and substitutes

With respect to individual transport, pre Euro 1 and Euro 6 are not included in the year 2011's calculation. This decision is based on the fact that Euro 1 was introduced in 1992 already (see figure 13) and that the pre Euro 1 share of 1.4% in 2011 is negligible (KBA, 2012).

Considering the analysed cities and rural districts, only gasoline and diesel engines are considered. Liquefied Petroleum Gas (LPG) or Liquefied Natural Gas (LNG) cars define a share of 0.79% and the remainder only represents a share of 0.16% (KBA, 2012). In 1987, solely diesel and gasoline are indicated in separate categories, for rotary piston or electric vehicles only a share of 0.04% is determinable (KBA, 1987). For the year 2011, the euro norms 1 to 5 are taken into account. Due to their low share, pre Euro 1 cars and others are disregarded, as for gasoline cars, pre Euro 1 amounts to about 2.01% and others amount to about 0.72%. For diesel, pre Euro 1 amounts to about 1.3% and others account for 0.98%.

The cubic capacity ranges for the year 1987 differ to the year 2011. Whereas for the year 2011, the cubic capacity categories range from 0 to 1.4 litres, from 1.4 to 2 litres and from 2 to 9 litres, the 1987 categories range from 0 to 1.5 litres, from 1.5 to 2 litres and from 2 to 9 litres (KBA, 1987 [see addendum, pp.105); 2012). Accordingly, the last category is consistent with the year 2011. However, the results may vary slightly.

With respect to public transport, the first official emission factor data is available for the year 1990. According to Herr Thomas Klein, no earlier data is available (see addendum, p.110). Since the German Reunion in 1990, the Federal Republic of Germany was supported by the companies *Deutsche Bundesbahn* and *Deutsche Reichsbahn* until 1994 (DB, 2012c). In 1994, the Deutsche Bahn AG was merged out of the two companies (DB, 2012d). Hence, due to data availability, the 1990 data is applied for substitution. The carbon dioxide emission factors are based on the year 1990 and provided by Herr Thomas Klein (see addendum, p.108). No extreme discrepancies are to be expected. The 1993 emission factors are based on the year 1992's fuel mix (DB, 1996). For the public transport's electrically driven trains, no upstream chain emission factor for particular matter is available. This has been replaced by the emission factor for soot instead. Furthermore, only the hydrocarbon emission factor is available, which contains a share of methane.

The emission factors for Agilis and Alex trains are being substituted by the Deutsche Bahn emission factors. Since they are served by the Deutsche Bahn electricity supply. This is also being applied by the TREMOD model (Knörr, Heidt & Schacht, 2012).

The allocation of emission factors for PLT and LPT is based on the German Passenger Transportation Act §8(1) Förderung der Verkehrsbedienung und Ausgleich der Verkehrsinteressen im öffentlichen Personennahverkehr (Personenbeförderungsgesetz [PBefG]) defines public transport as follows:

> "Öffentlicher Personennahverkehr […] ist im Zweifel der Fall, wenn in der Mehrzahl der Beförderungsfälle eines Verkehrsmittels die gesamte Reiseweite 50 Kilometer oder die gesamte Reisezeit eine Stunde nicht übersteigt" (Personenenbeförderungsgesetz, 2013, p.3).

This defines that PLT is the transportation of passengers, which does not exceed either 50 kilometres of travel distance or a maximum travel time of one hour (Passenger Transportation Act, 2013). Overall, ICE, IRE and EC (EuroCity) are aligned with the long distance emission factor, whereas RegionalExpress (RE), Regionalbahn (RB), Bayerische Regiobahn (BRB), Alex and Agilis are allocated the short distance emission factor, due to the amount of stops and speed differences. This is applied due to the discrepancies between time length and travel distance for the various municipalities.

The TREMOD data's year of origin is the year 2010, whereas the data capture is based on the year 2008. This is used as a substitute for the year 2011. The TREMOD dataset's emission factors are based on an average capacity of about 1.5 persons, which may represent an overestimation. Due to data availability for the 1987's calculations for cars only the TREMOD pre Euro 1 category could be applied. However, as it may be derived by figure 13, Euro 1 has been introduced in 1992, therefore pre Euro 1 emission factors may be regarded applicable for the 1987 carbon footprint and pollutant emission calculation. Requests for further data by the Umweltbundesamt or Infas did result in non-response or no further data availability.

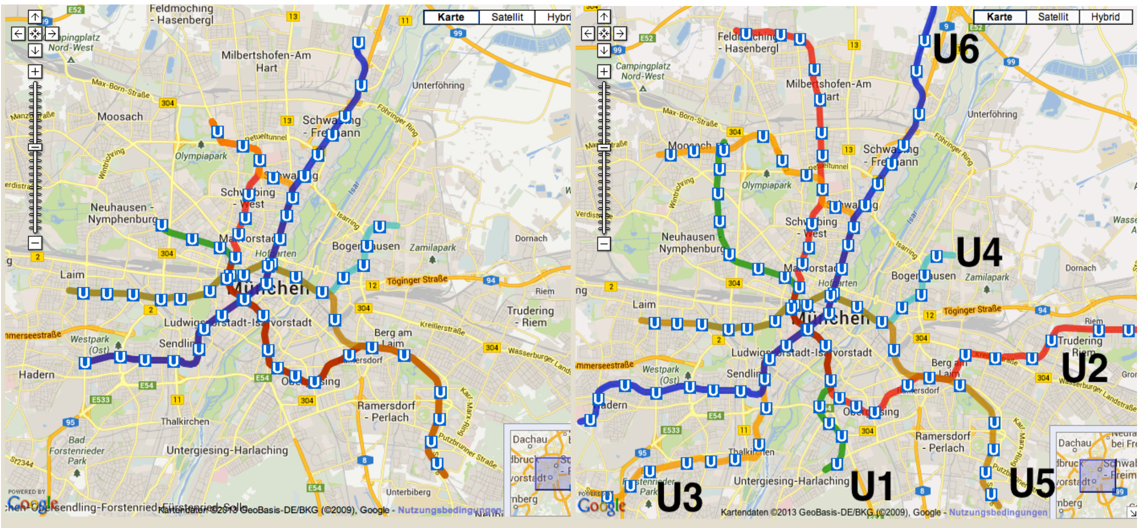
The emission calculations' results may vary according to several following factors, such as the use of summer- or winter tyres, cold start emissions, loading, route choice, age of the vehicle, which is connected to technical factors, such as catalysts or filters, etc., are not being accounted for. Additionally, traffic jams, which lead to higher emissions due to for instance, stop and go or a following change of routes, which influence combustion and hence, the amount of emissions, are not considered. According to Volkswagen AG (VW), every seventh combusted litre of gasoline is consumed by stop and go driving (VW, 2009).

The estimated departure time for public transport commuters is at about 07:00AM. However, commuters may travel earlier or later as well as the return trip is not considered. However, morning is preferred to evening, due to the fact that employees may work half time and hence, return earlier as well as there is a larger time frame variance for the return trip, overall. Furthermore, the fixed time of travel has a strong influence on the route availability. Some rural districts, such as *Obing* in the rural district of Traunstein, offer only one travel route, whereas the next available option in the schedule is hours in the future. This would not be suitable for frequent public transport usage (GeoBasis-DE/BKG, Google Inc. & Deutsche Bahn AG, n.d.sc, see CD, Public Transport addendum, pp.1-748). As for *Heldenstein*, which is part of the district of Mühldorf am Inn, the first available trip from 07:00AM is from 07:11AM to 08:11AM to reach the Munich Central Station. The next available train leaves at 05:55PM, which arrives at 06:56PM. People may be very likely to choose the car instead (GeoBasis-DE/BKG, Google Inc. & Deutsche Bahn AG, n.d.lp, see CD, Public Transport addendum, pp.1-748).

The emission factors for S-Bahn, U-Bahn and tramway are derived by the publishment *CO_2-Monitoring* by the Referat für Gesundheit und Umwelt (2012), which are based on GEMIS. This has been approved by Frau Juliane Pötzsch, employee at the Stadtwerke München (Strategic planning projects, dedicated quality management officer, see addendum, p.112) and by Frau Ann-Christin Krüger, who is an employee at the city of Munich (Health and Environment, environmental protection, environmental care, RGU-UW 11, team for climate protection and energy, see addendum, p.113). However, the emission factors are not estimated internally but the city of Munich derives them from the GEMIS platform. This makes them less reliable, since emission factors are based on a specific fuel mix and the corresponding primary energy, which results in a specific amount of carbon and pollutant emissions.
With respect to public transport, mostly the provided Googlemaps information is applied. For the municipality of *Rückholz* in the rural district of Ostallgäu at the point of data collection, solely replacement service data is available, which implicates longer travel distances (GeoBasis-DE/BKG, Google Inc. & Deutsche Bahn AG, n.d.afx, see CD, Public Transport addendum, pp.1-748).

The following figures depict the Munich U-Bahn network for the years 1988 on the left and 2011 on the right.

Figure 15: Munich's U-Bahn network for the years 1988 and 2010.



Source: Own representation based on Schütz, 2010.

Googlemaps route data is applied for the years 1987 and 2011. However, the year 1987's dataset is adapted to the limited U-Bahn network in 1988 by substituting missing U-Bahn rail tracks by Deutsche Bahn transport or if necessary by individual transport. It is to be recognized by figure 15 that several subway routes are unavailable, such as the line *U2*. Furthermore, most lines expanded, such as the lines *U1* or *U6.* Further investigation on changes in network availability for the Deutsche Bahn in 1987 is not conducted. Additionally, the streets for individual transport are not adapted to the year 1987. Hence, for the previously named U-Bahn network exception, all network data provided by Googlemaps or Deusche Bahn is based on the information from the year 2013.

6. CARBON DIOXIDE EMISSIONS

The following chapter covers the relative carbon dioxide consumption data for the Outer Planning 14 and the Outer European Metropolitan Region for individual- and public transport, over time.

In order to estimate the results, the following factors affect the output: Accessibility to public transport influences the use additional individual transport as well as the travel distance is influential. A change in the number of commuters influences the absolute consumption data. The applied transport mode, also amongst public transport, strongly varies with its emission factor as for instance, a differentiation between diesel or electricity trains is necessary.

The following data represents the relative carbon dioxide emissions for the assumption (1) of all commuters to travel by either car or train.

Table 9: Kilograms of carbon dioxide emissions per person, trip and day for individual- and public transport.

$KgCO_2$ per trip per person per day	**1987 IT**	**PT 1987**	***Relative emission share***	**2011 IT**	**2011 PT**	***Relative emission share***
			Outer Planning Region 14			
DAH	8.65 kg	5.01 kg	*57.91%*	8.4 kg	3.01 kg	*35.85%*
EBE	9.37 kg	4.09 kg	*43.67%*	7.8 kg	2.97 kg	*38.04%*
ED	13.1 kg	6.66 kg	*50.82%*	10.25 kg	4.44 kg	*43.26%*
FS	13.49 kg	8.58 kg	*63.59%*	11.39 kg	5.4 kg	*47.4%*
FFB	8.76 kg	4.06 kg	*46.3%*	7.46 kg	2.95 kg	*39.56%*
LL	16.86 kg	10.72 kg	*63.56%*	12.43 kg	6.33 kg	*50.95%*
M	4.27 kg	2.1 kg	*49.17%*	4.11 kg	1.62 kg	*39.36%*
STA	8.98 kg	3.01 kg	*37.23%*	7.12 kg	2.45 kg	*34.47%*
PR 14 Mean	**10.33 kg**	**5.53 kg**	***53.54%***	**8.62 kg**	**3.65 kg**	***42.3%***
			Outer European Metropolitan Region of Munich			
IN (City)	23.29 kg	4.46 kg	*19.17%*	17.43 kg	3.39 kg	*19.48%*
RO (City)	19.9 kg	9.02 kg	*45.35%*	14.54 kg	4.76 kg	*32.72%*
AÖ	37.93 kg	18.01 kg	*47.49%*	21.21 kg	9.85 kg	*46.46%*
TÖL	14.18 kg	8.38 kg	*59.14%*	10.9 kg	5.4 kg	*49.49%*
EI	37.41 kg	14.18 kg	*37.9%*	22.84 kg	8.48 kg	*37.12%*
GAP	27.34 kg	14.34 kg	*52.46%*	17.33 kg	7.87 kg	*45.41%*
MB	14.3 kg	7.84 kg	*54.87%*	11.05 kg	4.79 kg	*43.34%*
MÜ	24.4 kg	13.09 kg	*53.65%*	15.03 kg	7.49 kg	*49.87%*
ND	28.65 kg	14.73 kg	*51.41%*	18.52 kg	9.45 kg	*51.03%*
PAF	18.1 kg	9.33 kg	*51.56%*	13.51 kg	5.86 kg	*43.36%*
RO (R.D.)	22.93 kg	12.49 kg	*54.46%*	15.02 kg	7.23 kg	*48.13%*
TS	38.12 kg	18.82 kg	*49.39%*	21.44 kg	10.59 kg	*49.39%*
WM	21.69 kg	12.49 kg	*57.27%*	15.12 kg	7.16 kg	*47.09%*
LA (City)	22.52 kg	10.55 kg	*46.85%*	15.99 kg	5.56 kg	*34.79%*
KEH	33.02 kg	20.24 kg	*61.3%*	20.53 kg	11.77 kg	*57.34%*
LA (R.D.)	25.84 kg	13.94 kg	*53.96%*	17.19 kg	8.54 kg	*49.69%*
DGF	42.19 kg	21.19 kg	*50.23%*	24.56 kg	12.48 kg	*50.84%*
A (City)	23.23 kg	3.47 kg	*14.94%*	16.53 kg	2.64 kg	*15.97%*
KF (City)	28.75 kg	12.21 kg	*42.49%*	18.21 kg	6.44 kg	*35.38%*
AIC	17.8 kg	11.42 kg	*64.17%*	12.38 kg	7.81 kg	*63.08%*
A (R.D.)	27.44 kg	10.28 kg	*37.47%*	17.82 kg	6.94 kg	*38.98%*
DLG	45.66 kg	14.98 kg	*32.8%*	24.98 kg	9.8 kg	*39.23%*
OAL	35.69 kg	16.57 kg	*46.43%*	22.0 kg	9.47 kg	*43.23%*
DON	49.9 kg	16.0 kg	*32.06%*	28.33 kg	9.75 kg	*34.41%*
OEMM Mean	**28.34 kg**	**12.83 kg**	***45.28%***	**18.02 kg**	**7.65 kg**	***42.43%***
Total Mean	**24.0 kg**	**11.01 kg**	***45.91%***	**15.67 kg**	**6.63 kg**	***42.33%***

Source: Own representation based on LfStaD, 1991; n.d.c; BA, 2012 (see addendum, pp.107); Buslinie Deutschland, n.d.; DB, 1996; 2012a; 2013a – 2013ay; n.d.a – n.d.fi (see CD, Public Transport addendum, pp.749-914); GeoBasis-DE/BKG, Google Inc. & Deutsche Bahn AG, n.d.a – n.d.ail (see CD, Public Transport addendum, pp.1-748); GeoBasis-DE/BKG & Google Inc., n.d.a – n.d.abg (see addendum, pp.1-226); KBA, 1987 *(see addendum, pp.105); 2012; Schütz, 2007; Schütz & Merath, 2011; UBA, 2010a – 2010an.*

Table 9 represents the carbon dioxide emissions for individual- and public transport per person, trip and day, for the years 1987 and 2011. The relative emission share compares public transport in comparison to individual transport emissions. The following section gives an overview of output composition. With respect to the year 2011, the largest carbon dioxide saving potential in 2011 is given the city of Augsburg with a relative emission share of 15.97% and the city of Ingolstadt with 19.48% in carbon emissions. The low relative emission share is based on the direct ICE travel option for public transport. This origins in the low emission factor for LPT as well as the direct travel option without a change for additional transportation such as to PLT or IT.

In 2011, the least emission saving potential represents the rural district of Aichach-Friedberg, which amounts to a relative emission share of about 63.08%. With regard to the mean travel distance by PT to the mean distance by IT, the commuter spends in a relative aspect about 11.97% of the travel distance by individual transport to get to the next train station. This defines about 16.14 tons of carbon dioxide, which are emitted by car in comparison to the total amount of 38.24 tCO_2. Car travelling accounts for an emission share of 40.01% in relation to a distance share of 11.95%. After all, accessibility is very influential for the public transport's emissions. Presumably, Aichach-Friedberg's emissions per person were lower if accessibility to PT is improved. In fact, 19 out of 24 municipalities are departed by additional transport such as by bus or car.

Overall, of 748 cities and municipalities, 484 municipalities demand further individual or public transport to reach the next train station. This accounts for a share of 64.71%. In 2011, individual transport reflects carbon dioxide emissions of 512.93 tons of CO_2 an emission share of 39.07%.

With respect to the year 2011's accessibility, the difference between cities and regional districts is remarkable. The first three lowest emitters are cities. On fourth place after the cities of Augsburg, Ingolstadt and Rosenheim, ranges the rural district of Donau Ries with a relative emission share of 34.41%. On the one hand, 33 of 44 municipalities are reached by IT, which accounts for a distance share of 8.19% and a consumption share of 27.65% in carbon dioxide emissions per person, trip and day. However, 33 municipalities are partly to be departed by LPT, which proofs of the low emission factor. This is set in comparison to Aichach-Friedberg, whereat out of 24 municipalities, 20 are mostly travelled by PLT, only one is travelled by PLT and two by S-Bahn. Accordingly, the emission output is higher due to the available transport mode.

The following table depicts the OEMM's highest and lowest emitters for IT and PT and the corresponding composition of the results:

Table 10: Comparison of the year 2011's output compositions.

	Donau-Ries (IT)	Bad Tölz-Wolfrats-hausen (IT)	Dingolfing-Landau (PT)	Augsburg city (PT)
Average EF	206.9 gCO_2/PKM	206.9 CO_2/PKM	73.2 grams of CO_2/PKM	41.9 grams of CO_2/PKM
Mean travel distance	136.0 km	53.56 km	124.38 km (mixed modal split)	63 km (PT only)

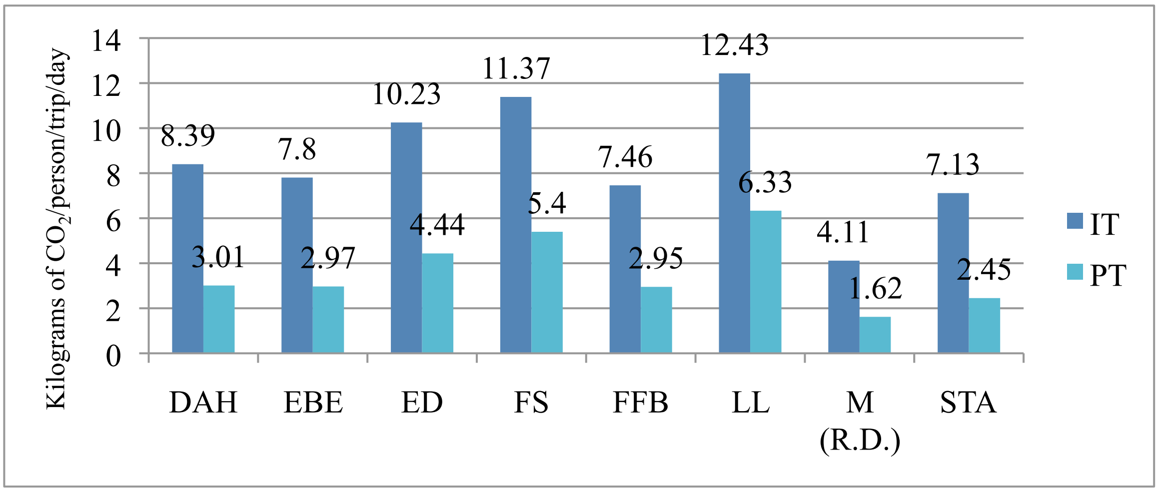
Source: Own representation based on DB 2012a; n.d.aj; n.d.au; n.d.ci; n.d.dp; n.d.ej; (see CD, Public Transport addendum, pp. 749-914); GeoBasis-DE/BKG & Google Inc., n.d.aa – n.d.bf; n.d.aja – n.d.abg (see CD, Individual Transport addendum, pp.1-226); GeoBasis-DE/BKG, Google Inc. & Deutsche Bahn AG, n.d.ze – n.d.zu (see CD, Public Transport addendum, pp.1-748; KBA, 2012 (see addendum, pp.107); LfStaD, n.d.c; UBA, 2010a – 2010aj.

The results are mainly based on the trip length and the corresponding emission factor. For instance, Donau Ries' travel distance and carbon dioxide emission factor vary with respect to the available and selected transport mode and lead to the given result of 28.33 kilograms of carbon dioxide per individual, per trip and day, as it may be derived by table 9, for individual transport in 2011.

6.1. The Planning Region 14's relative carbon dioxide emissions

This chapter covers the Outer Planning Region 14's carbon dioxide emissions per person, trip and day with respect to the table 9's content.

Figure 16: The OPR14's carbon dioxide emissions per person, trip and day in 2011.



Source: Own representation based on LfStaD, 1991; n.d.c; BA, 2012 (see addendum, pp.107); DB, 1996; 2012a; 2013a – 2013ay; n.d.i, n.d.l; n.d.m; n.d.ad – n.d.ae; n.d.am; n.d.ap; n.d.av; n.d.bj; n.d.bn; n.d.bu; n.d.bv; n.d.cs; n.d.do; n.d.dw; n.d.dz; n.d.ed; n.d.el; n.d.ep; n.d.es; n.d.eu (see CD, Public Transport addendum, pp.749-914); GeoBasis-DE/BKG, Google Inc. & Deutsche Bahn AG, n.d.av – n.d.ci; n.d.dw – n.d.he; n.d.id – n.d.ko; n.d.mn – n.d.nr; n.d.ra – n.d.rn; n.d.aif – n.d.ail (see CD, Public Transport addendum, pp.1-748); GeoBasis-DE/BKG & Google Inc. n.d.bg – n.d.ct; n.d.eo – n.d.ig; n.d.jh – n.d.lk; n.d.nu – n.d.pi; n.d.tq – n.d.ue (see CD, Individual Transport addendum, pp.1-226); KBA, 1987 (see addendum, pp.105), 2012; Schütz, 2007; Schütz & Merath, 2011; UBA, 2010 a – 2010an.

Figure 16 reflects the Outer Planning Region 14's carbon dioxide emissions for individual- and public transport in 2011. The diagram as well as the following analysis compares the amount of kilograms emitted per person, trip and day for the years 1987 and 2011.

In 1987, the largest emitter for individual- and public transport is the rural district of Landsberg am Lech, which emits in average 16.86 kilograms of carbon dioxide by individual transport and 10.72 $kgCO_2$ by public transport. The lowest emitter is the rural district of München, which emits 4.27 $kgCO_2$ by IT and 2.1 kilograms of carbon dioxide by PT.

For the years 2011, the highest and lowest emitters remain unchanged. In consideration of carbon dioxide emissions per person, trip and day, in 2011, the largest emitter is Landsberg am Lech with 12.43 kilograms of carbon dioxide to be emitted by individual transport and 6.33 $kgCO_2$ by public transport. Per person, trip and day, the rural district of München as the lowest emitter, proofs of 4.11 $kgCO_2$ by IT and of 1.62 kilograms of carbon dioxide by PT.

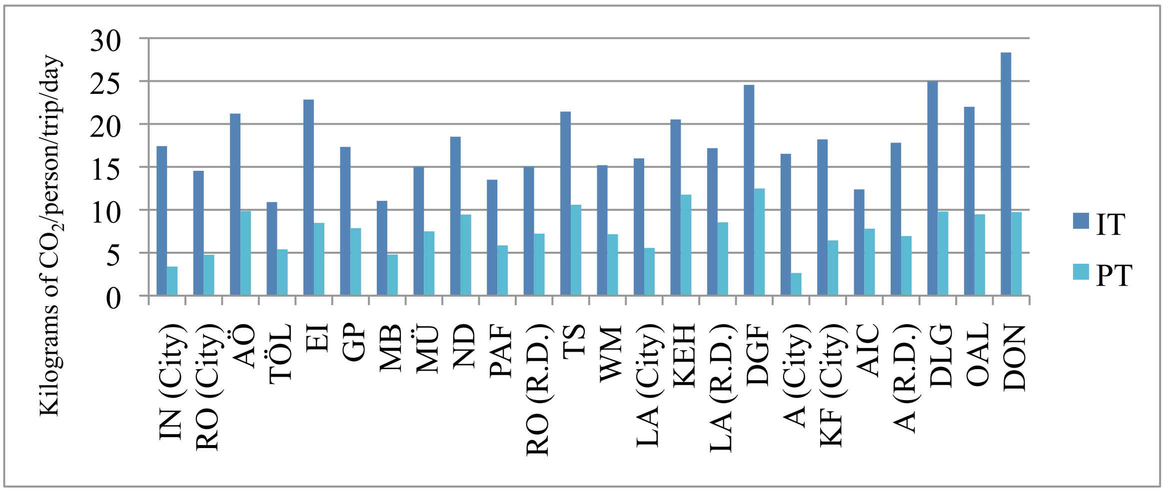
Accordingly, Landsberg am Lech is the largest emitter, overall. The average travel distance from this rural district is 66.76 kilometres by PT and 62.53 km by IT to reach the Munich central station. Respectively, from the rural district of Munich, commuters travel in average 17.38 km by PT and 18.41 km by IT only. According to the relative travel distance for each transport mode, the individual transport share for Landsberg am Lech is 15.22%, whereas the IT share for the rural district of Munich defines only 7.89%.

With respect to the relative emission of public to individual transport, the most efficient solution is determinable for the rural district of Starnberg, which proofs of an emission share of 37.23%. In 1987, the least efficient location for public transport is reflected in the rural district of Freising, which represents an emission share of 63.59%. In 2011, the most efficient rural district remains consistent with Starnberg, which proofs of 34.42%, whereas the least efficient rural district switches to Landsberg am Lech with a share of 50.95%.

Overall from 1987 to 2011, the modes of individual and public transport increase in the efficiency of carbon dioxide mitigation. The average commuter emits about 10.33 kilograms of carbon dioxide by individual transport and 5.53 $kgCO_2$ by public transport. By comparing public to individual transport, this accounts for a relative emission share of 53.54%. In 2011, the average commuter emits 8.62 $kgCO_2$ by individual transport and 3.65 kilograms by PT, which further reduces the comparative emission share to only 42.32%. By comparing PT to IT, a more efficient carbon dioxide reduction is to be determined for public transport, which is based on more intense emission factor improvements, which are discussed in chapter 5.4 and 7.11.

6.2. The Outer European Metropolitan Region of Munich's absolute carbon dioxide emissions

Figure 17: The OEMM's carbon dioxide emissions per person, trip and day in 2011.



Source: Own representation based on LfStaD, 1991; n.d.c; BA, 2012 (see addendum, pp.107); Buslinie Deutschland, n.d.; DB, 1996; 2012a; 2013a – 2013aj; 2013al – 2013ay; n.d.a – n.d.h; n.d.j; n.d.k; n.d.n – n.d.ac; n.d.af – n.d.al; n.d.an; n.d.ao; n.d.aq - n.d.au; n.d.aw – n.d.bi; n.d.bk – n.d.bm; n.d.bo – n.d.bt; n.d.bw – n.r.cr; n.d.ct – n.d.dn; n.d.dp – n.d.dv; n.d.dx; n.d.dy; n.d.ea – n.d.ec; n.d.ee – n.d.ek; n.d.em – n.d.eo; n.d.eq; n.d.er; n.d.et; n.d.ev –n.d.fi (see CD, Public Transport addendum, pp.749-914); GeoBasis-DE/BKG, Google Inc. & Deutsche Bahn AG, n.d.a – n.d.au; n.d.cj – n.d.dv; n.d.hf – n.d.ic; n.d.kp – n.d.mn; n.d.ns – n.d.ol; n.d.rp – n.d.aie (see addendum, pp.1-748); GeoBasis-DE/BKG & Google Inc., n.d.a – n.d.bf; n.d.cu – n.d.en; n.d.ij – n.d.jg; n.d.ll – n.d.nt; n.d.pj – n.d.tp; n.d.ug – n.d.abg (see addendum, pp.1-226); KBA, 1987 (see addendum, pp.105); 2012; Schütz, 2007; Schütz & Merath, 2011; UBA, 2010a – 2010an.

The figure shows the OEMM's carbon dioxide emissions per commuter, trip and day, for individual- and public transport in 2011. The following analysis compares the modes of transport as well as the years 1987 and 2011. The exact emissions are disclosed in table 9.

With respect to the year 1987, the largest emitter by IT is the rural district of Dillingen an der Donau with 49.9 kgCO_2 and the lowest emitter is the rural district of Miesbach with 14.3 kilograms of carbon emissions per person, trip and day. The highest public transport emitter is the rural district of Dingolfing-Landau with 21.19 kilograms of carbon dioxide and the lowest emitter is the city of Augsburg with carbon emissions of 3.47 kgCO_2.In 2011, the largest individual transport emitter is the rural district of Donau-Ries with 28.33 kilograms of carbon dioxide, whereas the lowest emitter is Bad Tölz-Wolfrats-hausen with 10.9 kgCO_2. In consideration of public transport, the largest emitter is the rural district of Dingolfing-Landau, which emits 12.48 kilograms of carbon dioxide, whereas the lowest emitter remains consistent with the city of Augsburg, which emits in average 2.64 kilograms per person, trip and day.

In terms of the relative emission share in 1987, the least efficient public transport connection is found for Aichach-Friedberg, which proofs of an emission share of 61.3%. The best public transport location is represented in the city of Augsburg, which reflects a share of 14.94%. In 2011, the least and most efficient public transport connections remains unchanged for the previously named locations as Aichach-Friedberg represents a share of 63.08% and Augsburg city proofs of 15.97%.

Overall from 1987 to 2011, the efficiency of individual- and public transport, with respect to mitigated carbon emissions, increases. With respect to the OEMM, the average commuter emits about 28.34 kilograms by individual- and 12.83 kilograms by public transport. This defines a share of 45.28% in emissions. In 2011, the average commuter emits 18.02 kilograms to travel from the Outer European Metropolitan Region to the Munich central station. By public transport, the average commuter emits 7.65 kilograms, which further reduces the comparative share of emissions to only 42.43%. The reduction in individual transport emissions is successful, however, public transport improves to a higher degree due to reasons, which are to be further outlined in chapter 5.4.

For the entire Outer European Metropolitan Region of Munich the PT to IT emission share represents 45.91% in 1987 and 42.33% in 2011. Accordingly, the PT mitigation is slightly more efficient. Nevertheless, both transport modes show similar mitigation trends. Individual transport decreases from 24.0 kilograms of carbon dioxide to 15.67 $kgCO_2$ and PT decreases from 11.01 kilograms to 6.63 $kgCO_2$ in 2011. Accordingly, the average IT emissions from 1987 to 2011, per person, trip and day are mitigated by -34.71% and the corresponding public transport emissions are mitigated by -39.78%.

6.3. Absolute carbon dioxide emissions

The following data represents the absolute carbon dioxide emissions for the assumption (1) of all commuters to travel by either car or train.

6.3.1. The Planning Region 14’s absolute carbon dioxide emissions

Table 11 reflects the absolute amount of emitted carbon dioxide for the total amount of in- and out-commuters per car, day and trip for the Outer Planning Region 14 and the Outer European Metropolitan Region of Munich. The following table focuses on the OPR14’s absolute emission results.

Table 11: The OPR's absolute carbon dioxide emissions for individual transport in 1987 and 2011.

Absolute amount of CO_2	**1987 IT**	**2011 IT**	***Change***	**1987 PT**	**2011 PT**	***Change***
DAH	211.7 t	235.27 t	*+11.13%*	122.36 t	85.22 t	*-30.35%*
EBE	184.42 t	177.83 t	*-3.58%*	86.58 t	67.69 t	*-21.82%*
ED	143.07 t	131.23 t	*-8.27%*	71.65 t	57.03 t	*-20.41%*
FS	220.42 t	286.28 t	*+29.88%*	138.5 t	135.69 t	*-2.03%*
FFB	387.54 t	282.3 t	*-27.16%*	172.94 t	111.97 t	*-37.99%*
LL	88.5 t	84.62 t	*-4.38%*	53.74 t	43.11 t	*-19.77%*
M	387.71 t	484.13 t	*+24.87%*	203.61 t	190.59 t	*-6.39%*
STA	155.95 t	141.32 t	*-9.38%*	61.53 t	48.73 t	*-20.8%*
Sum	1,779.32 t	1,822,99 t	*+2.45%*	918.53 t	740.03 t	*-19.43%*

Source: Own representation based on LfStaD, 1991; n.d.c; BA, 2012 (see addendum, pp.107); Buslinie Deutschland, n.d.; DB, 1996; 2012a; 2013a - 2013d; 2013g; 2013h; 2013i; 2013o; 2013p; 2013r; 2013v; 2013w; 2013x; 2013y; 2013aa - 2013af; 2013ah; 2013aj; 2013ak; 2013an; 2013ao; 2013as; n.d.i, n.d.l; n.d.m; n.d.ad – n.d.ae; n.d.am; n.d.ap; n.d.av; n.d.bj; n.d.bn; n.d.bu; n.d.bv; n.d.cs; n.d.do; n.d.dw; n.d.dz; n.d.ed; n.d.el; n.d.ep; n.d.es; n.d.eu (see CD, Public Transport addendum, pp.749-914); GeoBasis-DE/BKG, Google Inc. & Deutsche Bahn AG, n.d.bg – n.d.ct; n.d.eo – n.d.ig; n.d.jh – n.d.lk; n.d.nu – n.d.pi; n.d.tq – n.d.ue (see addendum, pp.1-748); GeoBasis-DE/BKG & Google Inc., n.d.bg – n.d.ct; n.d.eo – n.d.ig; n.d.jh – n.d.lk; n.d.nu – n.d.pi; n.d.tq – n.d.ue (see addendum, pp.1-226); KBA, 1987 (see addendum, pp.105), 2012; Schütz, 2007; Schütz & Merath, 2011; UBA, 2010a – 2010an.

In reference to individual transport in 1987, the largest emitter is the rural district of München with 387.71 tons per trip and day, whereas the smallest amount of carbon emissions origins in the rural district of Landsberg am Lech with 88.5 tons of carbon dioxide. With respect to the year 2011, the highest and lowest emitters remain unchanged. The largest emitter is the rural district of München with 484.13 tons of carbon dioxide and the lowest emitter is Landsberg am Lech with 84.62 tCO_2 per day.

With respect to absolute emissions, individual transport emissions rise for the rural districts of Dachau, Freising and München, whereas the other districts' emissions are mitigated. The strongest improvement is determinable for the rural district of Fürstenfeldbruck, which decreases from 387.54 tCO_2 in 1987 to 282.3 tCO_2, which results in a -27.16% mitigation. The least improvement is reflected in the emission increase of the rural district of Freising. Carbon dioxide emissions increase from 220.42 tons of carbon dioxide to 286.28 tCO_2, which accounts for an increase by +29.88%. In referece to the entire OPR14, emissions increase by +2.45%, from 1,779.32 tons to 1,822.99 tons of carbon dioxide per trip and day, which may be regarded to remain about constant.

As previously mentioned, the results are linked to the number of commuters. Accordingly, the rural district of München has 96,953 in- and out-commuters in 1987 and 117,651 commuters in 2011. This is contrary to Landsberg am Lech, which has 5,011 commuters in 1987 and 6,807 commuters in 2011.

The highest public transport emitter in 1987 is the rural district of München with about 203.61 tons of carbon dioxide. The lowest emitter is the rural district of Landsberg am Lech with 53.74 tCO_2 per trip and day. In 2011, the highest and lowest emitters remain unchanged with the previously named rural districts. In 2011, the rural district of München emits 190.59 tCO_2 and Landsberg am Lech emits 43.11 tCO_2.

With respect to public transport, the emissions for all rural districts are mitigated. The strongest improvement is reflected for Fürstenfeldbruck. In an absolute matter, emissions decrease from 172.94 tons to about 111.97 tons. This defines a decrease of -37.99%. The least improvement is determinable for the rural district of Freising, which only reflects a -2.03% emission reduction. Overall, absolute emissions decrease from 918.53 tons of carbon dioxide to about 740.03 tCO_2, which represents a mitigation action of about -19.43%.

The Outer European Metropolitan Region of Munich's absolute carbon emissions will be outlined in the next chapter.

6.3.2. The Outer European Metropolitan Region of Munich's absolute carbon dioxide emissions

This chapter covers the Outer European Metropolitan Region of Munich's absolute carbon emissions for individual- and public transport for the years 1987 and 2011.

Table 12: The OEMM's absolute carbon dioxide emissions for individual- and public transport in 1987 and 2011.

Absolute amount of CO_2	**1987 IT**	**2011 IT**	***Change***	**1987 PT**	**2011 PT**	***Change***
IN (City)	40.24 t	56.79 t	*41.13%*	7.71 t	11.06 t	*+43.42%*
RO (City)	39.2 t	36.5 t	*-6.87%*	17.77 t	11.94 t	*-32.81%*
AÖ	35.66 t	29.1 t	*-18.4%*	16.93 t	13.54 t	*-17.96%*
TÖL	103.26 t	89.69 t	*-13.14%*	61.06 t	44.41 t	*-27.58%*
EI	31.44 t	28.58 t	*-9.11%*	11.72 t	11.01 t	*-5.58%*
GAP	35.53 t	34.42 t	*-3.15%*	19.17 t	15.65 t	*-18.3%*
MB	78.3 t	79.31 t	*1.29%*	45.11 t	34.38 t	*-23.83%*
MÜ	101.21 t	63.11 t	*-37.64%*	52.28 t	31.54 t	*-39.61%*
ND	27.75 t	27.2 t	*-1.97%*	13.15 t	13.93 t	*+8.23%*
PAF	115.27 t	116.35 t	*0.94%*	61.22 t	50.4 t	*-17.03%*
RO (R.D.)	143.32 t	124.97 t	*-12.8%*	78.2 t	60.22 t	*-22.84%*
TS	48.65 t	43.85 t	*-9.87%*	22.64 t	21.7 t	*-4.0%*
WM	87.78 t	82.54 t	*-5.96%*	50.64 t	38.94 t	*-22.66%*
LA (City)	55.38 t	36.62 t	*-33.87%*	16.1 t	12.74 t	*-20.86%*
KEH	62.42 t	42.76 t	*-31.87%*	37.0 t	24.48 t	*-33.23%*
LA (R.D.)	39.16 t	67.43 t	*72.21%*	32.67 t	27.91 t	*-21.57%*
DGF	12.44 t	44.32 t	*256.19%*	6.4 t	22.98 t	*+262.21%*
A (City)	97.84 t	130.82 t	*33.71%*	14.62 t	20.9 t	*+42.92%*
KF (City)	9.83 t	10.41 t	*5.91%*	4.18 t	3.68 t	*-11.8%*
AIC	57.01 t	65.29 t	*14.53%*	36.66 t	40.35 t	*+11.5%*
A (R.D.)	58.08 t	73.12 t	*25.89%*	21.76 t	28.66 t	*+32.5%*
DLG	7.08 t	12.96 t	*83.19%*	2.32 t	5.1 t	*+121.96%*
OAL	23.84 t	42.42 t	*77.92%*	11.07 t	18.28 t	*+58.04%*
DON	15.47 t	25.86 t	*67.21%*	4.96 t	8.92 t	*+80.65%*
Sum	1,326.12 t	1,364.46 t	*2.89%*	645.35 t	572.7 t	*-11.26%*
Total sum	3,105.37 t	3,187,45 t	*+2.65%*	1,563.88 t	1,312.73 t	*-16.06%*

Source: Own representation based on LfStaD, 1991, n.d.c; BA, 2012 (see addendum, pp.107); Buslinie Deutschland, n.d.; DB, 1996; 2012a; 2013a – 2013aj; 2013al – 2013ay; n.d.a – n.d.h; n.d.j; n.d.k; n.d.n – n.d.ac; n.d.af – n.d.al; n.d.an; n.d.ao; n.d.aq - n.d.au; n.d.aw – n.d.bi; n.d.bk – n.d.bm; n.d.bo – n.d.bt; n.d.bw – n.r.cr; n.d.ct – n.d.dn; n.d.dp – n.d.dv; n.d.dx; n.d.dy; n.d.ea – n.d.ec; n.d.ee – n.d.ek; n.d.em – n.d.eo; n.d.eq; n.d.er; n.d.et; n.d.ev –n.d.fi (see CD, Public Transport addendum, pp.749-914); GeoBasis-DE/BKG, Google Inc. & Deutsche Bahn AG, n.d.a – n.d.bf; n.d.cu – n.d.en; n.d.ij – n.d.jg; n.d.ll – n.d.nt; n.d.pj – n.d.tp; n.d.ug – n.d.abg (see addendum, pp.1-748); GeoBasis-DE/BKG & Google Inc., n.d.a – n.d.bf; n.d.cu – n.d.en; n.d.ij – n.d.jg; n.d.ll –

n.d.nt; n.d.pj – n.d.tp; n.d.ug – n.d.abg (see addendum, pp.1-226); n.d.a – n.d.fi; KBA, 1987 see addendum, pp.1-226); 2012; Schütz, 2007; Schütz & Merath, 2011; UBA, 2010a – 2010an.

Table 12 depicts the carbon dioxide emissions for the rural districts for the Outer European Metropolitan region for the years 1987 and 2011. It shows the absolute consumption data for in- and out commuters per trip and day.

With respect to the year 1987's individual transport emission data, the largest emitter is the rural district of Rosenheim with 143.32 tons of carbon dioxide, whereas the smallest amount origins in Dillingen an der Donau with only 7.08 tCO_2. In 2011, the highest individual transport emitter is the city of Augsburg, which emits 130.82 tCO_2 and the lowest emitter changes to the city of Kaufbeuren with 10.41 tons of carbon dioxide. It is to be recognized that for the cities of Ingolstadt, Augsburg and Kaufbeuren as well as for the rural districts of Miesbach, Pfaffenhofen an der Ilm, Landsberg, Dingolfing-Landau, Aichach-Friedberg, Augsburg, Dillingen an der Donau, Ostallgäu and Donau-Ries, a higher carbon dioxide consumption is significant. This means that for 12 of 24 cities and rural districts in the OEMM, there is an increase in carbon emissions.

The rural district Dingolfing-Landau proofs of an emission increase of +256.19%, in that emissions rise from 12.44 tCO_2 in 1987 to 44.32 tCO_2 in 2011. The highest emission mitigation is reflected for Mühldorf am Inn. Emissions decrease from 101.21 tons of carbon dioxide to 63.11 tCO_2, which accounts for a mitigation of -37.64%.

Concerning public transport in 1987, the largest carbon dioxide emitter is the rural district of Rosenheim with about 78.2 tons. The lowest emitter is the rural district of Dillingen an der Donau with 2.32 tons. In 2011, the largest emitter remains with the rural district of Rosenheim, which proofs of 60.22 tons of carbon dioxide emissions, whereas the smallest emitter is the city of Kaufbeuren with 3.68 tons of carbon dioxide.

The strongest improvement is reflected for the rural district of Mühldorf am Inn with an emission reduction from 52.28 tons of carbon dioxide to about 31.54 tCO_2, which reflects a -39.61% decrease. The most remarkable emission increase is determinable for Dingolfing-Landau, in which emissions increase by +262.21% as they rise from 6.4 tCO_2 in 1987 to 22.98 tons of carbon dioxide in 2011.

A significant trend of emission increase is determinable for the rural districts, which proof of a strong rise in commuters (see table 6). In regard of the selected time span, the OEMM's total individual transport emissions increase by +2.89% as carbon dioxide emissions increase from 1,326.12 tons to 1,364.46 tons per trip and day. The OEMM's public transport emissions decrease from 645.35 tons of carbon dioxide in 1987, to 572.7 tCO_2 in 2011, which represents a mitigation by -11.26%.

With respect to the entire European Metropolitan Region of Munich's individual transport a total emission of 3,105.37 tons in 1987 and 3,187.45 tons of carbon dioxide is estimated. An emission increase of +2.65% is determinable, which may be considered to remain about constant. Public transport emissions are projected to account for 1,563.88 tons of carbon dioxide in 1987 and for 1,312.73 tons in 2011, which represents a decrease of -16.06%.

In reference to the contemplated time-span, the following assumption evolves: If all commuters travel by individual transport, the technical improvements may be regarded to outweigh the increase in commuters, whereas if all commuters travel by public transport, emissions decrease by about -16.06%.

With respect to individual transport in 1987 the relative emission share of the Outer European Metropolitan Region of Munich (1,779.32 tCO_2) to the Outer Planning Region 14 (1,236.15 tCO_2) accounts for 74.53% in carbon dioxide emissions. This share increases to 76.99% in 2011, as the OPR14 emits 1,822.99 tons of carbon dioxide and the OEMM emits 1,364.46 tons of carbon dioxide per trip and day. In reference to public transport in 1987, the relative emission share of the OEMM (918.53 tCO_2) to the OPR14 (645.35 tCO_2) represents 70.26% in carbon dioxide emissions. This share increases to 77.39% in 2011 as the OPR14 emits 740.03 tons of carbon dioxide and the OEMM emits 527.7 tons of carbon dioxide per trip and day. Accordingly, the emission assimilation is recognizable for both transport modes. As based on the emission factors, the increased number of commuters and longer travel distances, emissions for both selected regions increase but it shows a trend of emission assimilation of the OEMM in comparison to the OPR14.

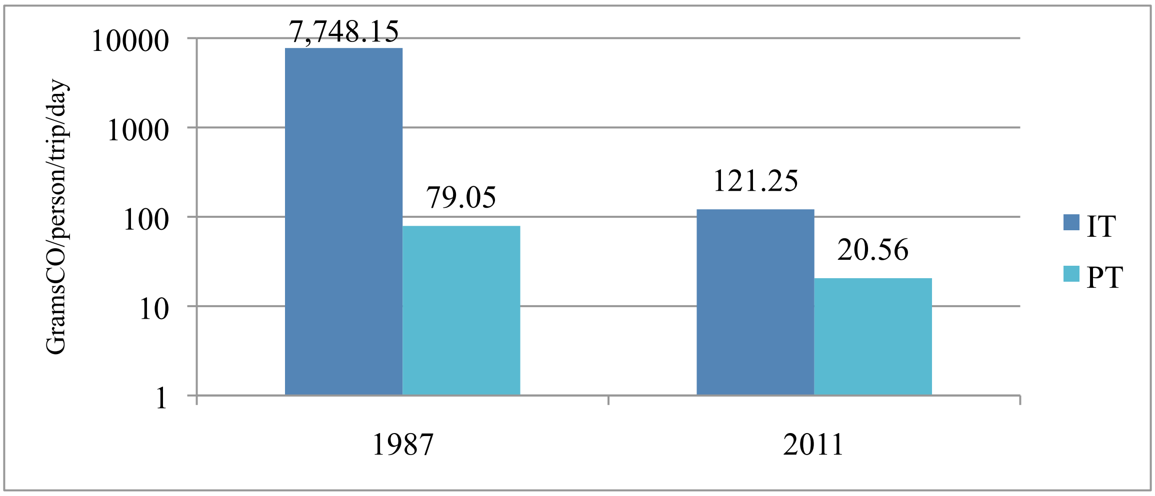
7. POLLUTANT EMISSIONS

This chapter outlines the selected pollutants of carbon monoxide, nitrogen oxide, non-methane hydrocarbons, sulphur dioxide and particulate matter. For the next as well as for the following pollutants, the data is depicted in emitted grams per person, trip and day. In the following, the total emissions for each pollutant will be estimated for individual- and public transport for the years 1987 and 2011. Furthermore, the relative emission share of public transport emissions in comparison to individual transport emissions is under investigation for the selected pollutants.

7.1. Carbon monoxide

The graph depicts the carbon monoxide emissions per commuter, trip and day for individual- and public transport for the entire European Metropolitan Region of Munich.

Figure 18: The EMM's carbon monoxide emissions per commuter, trip and day for individual- and public transport from 1987 to 2011.



Source: Own representation based on LfStaD, 1991; n.d.c; BA, 2012 (see addendum, pp.107); Buslinie Deutschland, n.d.; DB, 1996; 2012a; 2013a – 2013ay; n.d.a – n.d.fi (see CD, Public Transport addendum, pp.749-914); GeoBasis-DE/BKG, Google Inc. & Deutsche Bahn AG, n.d.a – n.d.ail (see addendum, pp.1-748); n.d.a – n.d.fi; GeoBasis-DE/BKG & Google Inc., n.d.a – n.d.abg (see addendum, pp.1-226); KBA, 1987 (see addendum, pp.105); 2012; Schütz, 2007; Schütz & Merath, 2011; 2007; UBA, 2010a – 2010an.

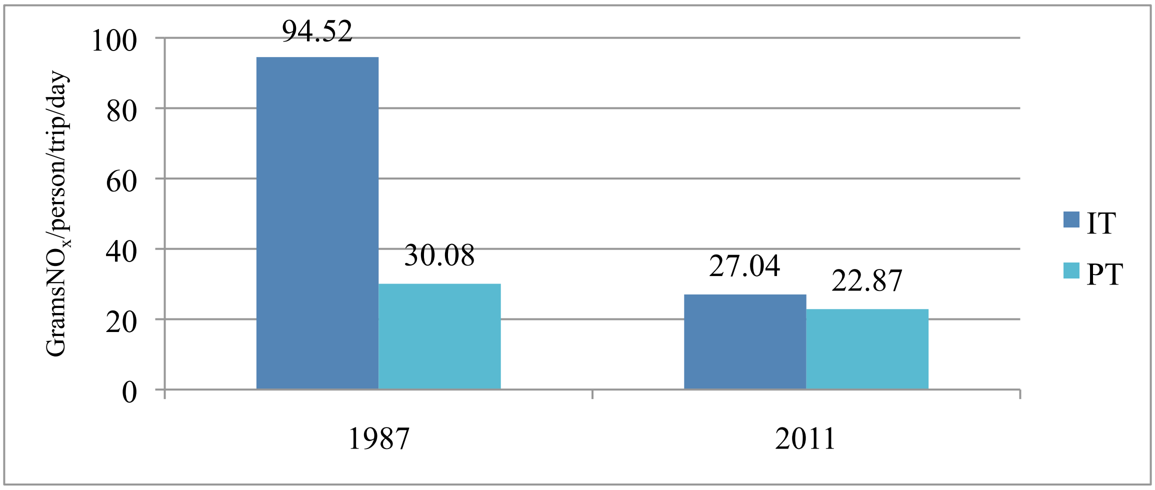
In 1987, the individual transport's mean amounts to about 7,7748.15 grams of carbon monoxide (gCO) per person, whereas public transport commuting emits 79.05 gCO. In comparison to individual transport, public transport defines a relative emission share of about 1.02% in 1987.

In 2011, commuting per individual transport decreases to 121.25 gCO as well as travelling by public transport is mitigated to about 20.56 gCO per person. According to the mitigation actions, the relative share of carbon monoxide emissions of public to individual transport amounts to 16.96%. Hence, the recorded technical improvement of cars is relatively stronger than that of public transport. The emission reduction for individual transport amounts to about -98.44%. The emission mitigation for public transport accounts for about -73.99%. Nevertheless, public transport represents the lower emitting transport mode.

7.2. Nitrogen oxides

The graph represents the average nitrogen oxide emissions for the European Metropolitan Region of Munich.

Figure 19: The EMM's nitrogen oxide emissions per person, trip and day for individual- and public transport from 1987 to 2011.



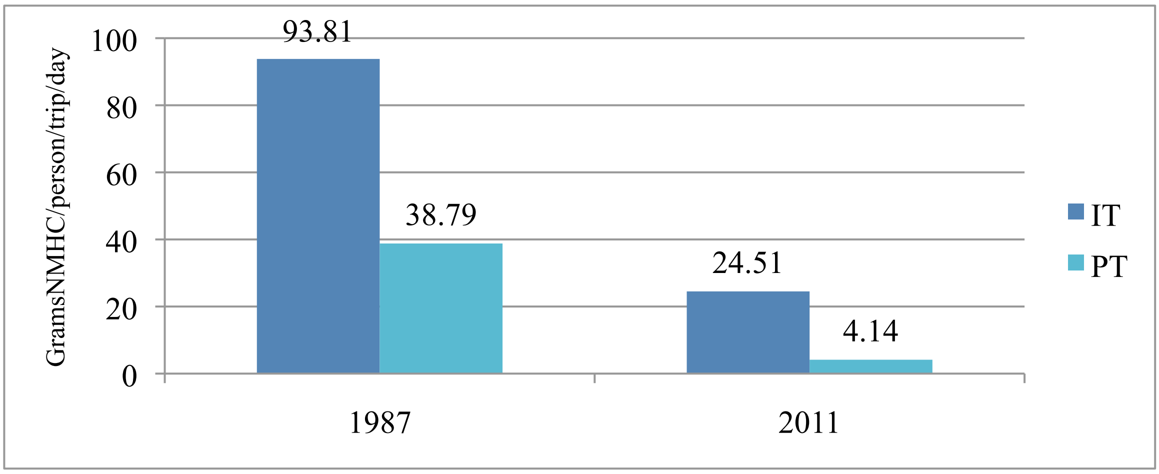
Source: Own representation based on LfStaD, 1991; n.d.c; BA, 2012 (see addendum, pp.107); Buslinie Deutschland, n.d.; DB, 1996; 2012a; 2013a – 2013ay; n.d.a – n.d.fi (see CD, Public Transport addendum, pp.749-914); GeoBasis-DE/BKG, Google Inc. & Deutsche Bahn AG, n.d.a – n.d.ail (see addendum, pp.1-748); n.d.a – n.d.fi; GeoBasis-DE/BKG & Google Inc., n.d.a – n.d.abg (see addendum, pp.1-226); KBA, 1987 (see addendum, pp.105); 2012; Schütz, 2007; Schütz & Merath, 2011; 2007; UBA, 2010a – 2010an.

The nitrogen oxide emissions for individual transport in 1987 amount to about 94.52 grams of nitrogen oxides (gNO_x) per person, trip and day. This is mitigated to about 27.04 gNO_x per person, which defines a decrease of -71.39%. Public transport emissions in 1987 are projected to amount to about 30.08 gNO_x per person, which is reduced to 22.87 grams of nitrogen oxides in 2011. This reflects a decrease in emissions by -23.96%. The relative share of emissions of public- to individual transport in 1987 accounts for about 31.82% and in 2011 the share increases to about 84.57%. Hence, concerning nitrogen oxide emissions, the technical improvements result in an emission assimilation of individual- to public transport.

7.3. Non-methane hydrocarbons

The graph shows the average non-methane hydrocarbons emissions per commuter for the European Metropolitan Region of Munich.

Figure 20: The EMM's non-methane hydrocarbon emissions per person, trip and day for the individual- and public transport from 1987 to 2011.



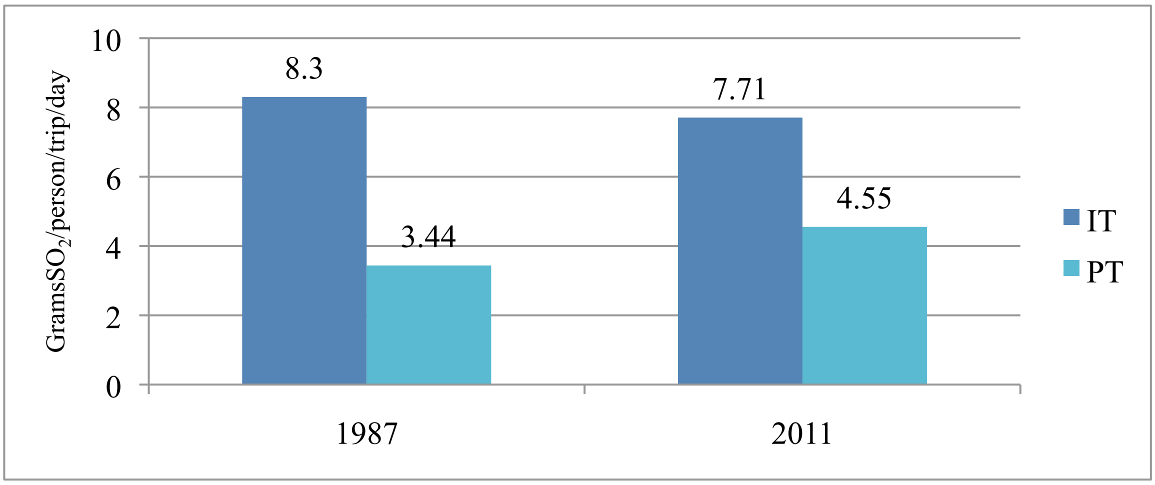
Source: Own representation based on LfStaD, 1991; n.d.c; BA, 2012 (see addendum, pp.107); Buslinie Deutschland, n.d.; DB, 1996; 2012a; 2013a – 2013ay; n.d.a – n.d.fi (see CD, Public Transport addendum, pp.749-914); GeoBasis-DE/BKG, Google Inc. & Deutsche Bahn AG, n.d.a – n.d.ail (see addendum, pp.1-748); n.d.a – n.d.fi; GeoBasis-DE/BKG & Google Inc., n.d.a – n.d.abg (see addendum, pp.1-226); KBA, 1987 (see addendum, pp.105); 2012; Schütz, 2007; Schütz & Merath, 2011; 2007; UBA, 2010a – 2010an.

In 1987, the non-methane hydrocarbon emissions amount to 93.81 grams of non-methane hydrocarbons (gNMHC) per person for individual transport. The emissions are mitigated to 24.51 gNMHC per trip and day in 2011, which accounts for a decrease of -73.87%. In 1987, the mean public transport emissions are 38.79 gNMHC per commuter, which decrease to about 4.14 gNMHC per person, trip and day. It reflects a decrease of -89.34%. The juxtaposition of public to individual transport emissions in 1987 defines a share 41.35%. In 2011, the relative emissions reduce to a share of 16.89%. Therefore, concerning the technical improvements, public transport shows an increasing emission reduction in the opposite to individual transport.

7.4. Sulphur dioxide

The graph depicts the sulphur dioxide emissions for public- and individual transport for the years 1987 and 2011.

Figure 21: The EMM's sulphur dioxide emissions per person, trip and day for individual- and public transport from 1987 to 2011.



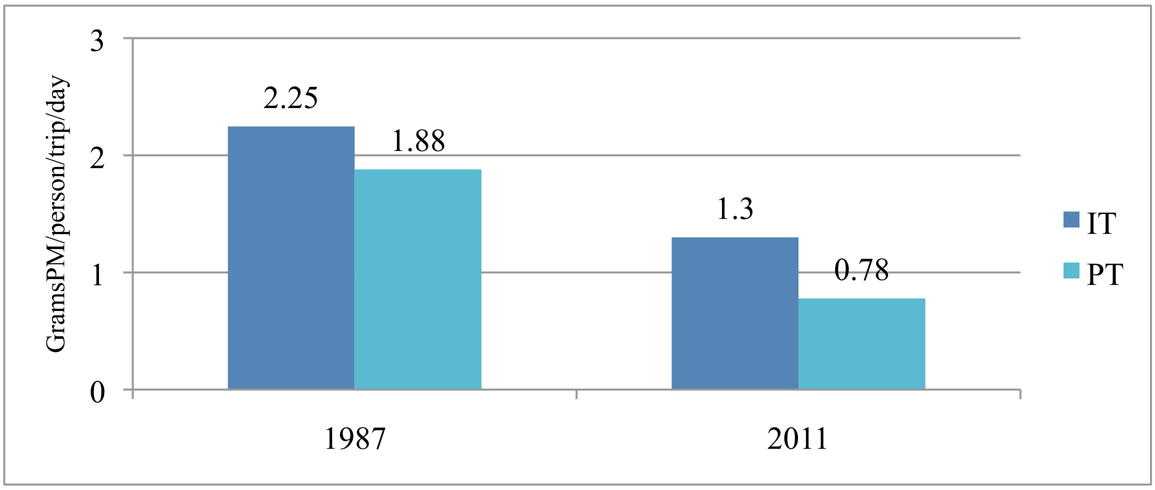
Source: Own representation based on LfStaD, 1991; n.d.c; BA, 2012 (see addendum, pp.107); Buslinie Deutschland, n.d.; DB, 1996; 2012a; 2013a – 2013ay; n.d.a – n.d.fi (see CD, Public Transport addendum, pp.749-914); GeoBasis-DE/BKG, Google Inc. & Deutsche Bahn AG, n.d.a – n.d.ail (see addendum, pp.1-748); n.d.a – n.d.fi; GeoBasis-DE/BKG & Google Inc., n.d.a – n.d.abg (see addendum, pp.1-226); KBA, 1987 (see addendum, pp.105); 2012; Schütz, 2007; Schütz & Merath, 2011; 2007; UBA, 2010a – 2010an.

In 1987, individual transport emissions decrease from 8.3 grams of sulphur dioxide (gSO_2) per person, trip and day, to 7.71 gSO_2. This represents a decrease of -7.17%. The mean public transport emissions increase from 3.44 gSO_2 to 4.55 grams of sulphur dioxide per commuter, trip and day. This is an estimated increase in mean emissions of +32.41%. The relative emission share of public to individual transport represents 41.41%, in 1987. In 2011, the relative emission share results in 59.97%. Accordingly, the technical improvements for individual transport are more efficient than the improvements for public transport, since the mean IT emissions slightly decrease, whereas PT emissions increase.

7.5. Particulate matter

The graph represents the particulate matter emissions for public- and individual transport for the years 1987 and 2011.

Figure 22: The EMM's particulate matter emissions per person, trip and day for individual- and public transport from 1987 to 2011.



Source: Own representation based on LfStaD, 1991; n.d.c; BA, 2012 (see addendum, pp.107); Buslinie Deutschland, n.d.; DB, 1996; 2012a; 2013a – 2013ay; n.d.a – n.d.fi (see CD, Public Transport addendum, pp.749-914); GeoBasis-DE/BKG, Google Inc. & Deutsche Bahn AG, n.d.a – n.d.ail (see addendum, pp.1-748); n.d.a – n.d.fi; GeoBasis-DE/BKG & Google Inc., n.d.a – n.d.abg (see addendum, pp.1-226); KBA, 1987 (see addendum, pp.105); 2012; Schütz, 2007; Schütz & Merath, 2011; 2007; UBA, 2010a – 2010an.

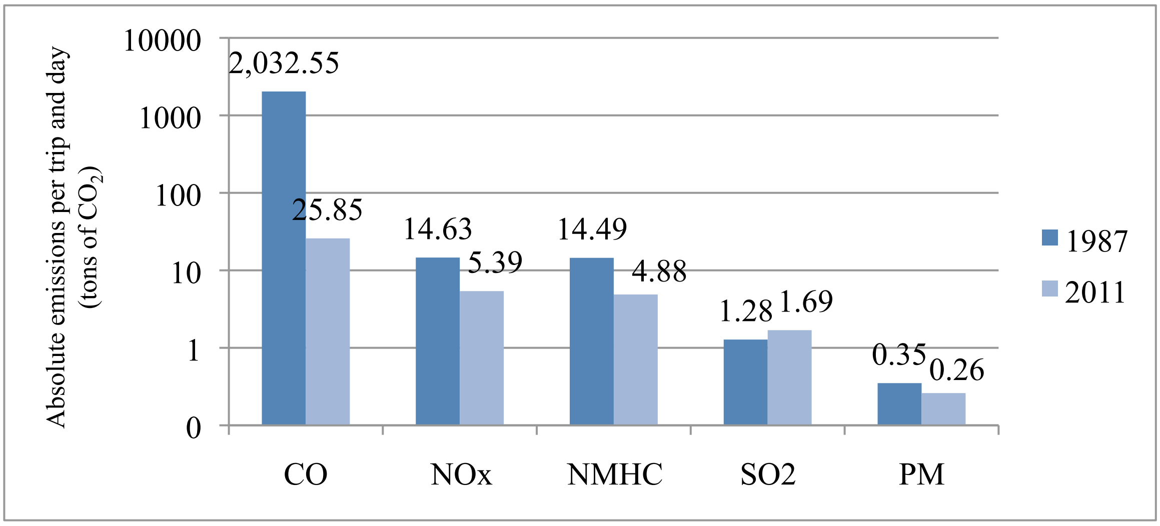
From 1987 to 2011, individual transport emissions per commuter decrease from 2.25 grams of particulate matter (gPM) to 1.3 gPM per person, trip and day. This accounts for a decrease of -42.13%. Public transport emissions decrease from 1.88 grams of particulate matter to 0.78 gPM with respect to the mean travel distance from the European Metropolitan Region of Munich's municipalities and cities to the Munich Central Station and vice versa. This results in a mitigation of -58.6%. In 1987, the comparative emission share accounts for 83.68%. In 2011, the relative emission share for public to individual transport results in 59.86%. Hence, contrary to the previous pollutants the mitigation of public transport emissions is more successful in comparison to the individual transport measures.

In the following chapter, individual- and public transport emissions are to be analyzed individually. The following diagram concentrates the individual transport's change in absolute emissions from 1987 to 2011.

7.6. Absolute pollutant emissions for individual transport for the years 1987 and 2011

The following data output depicts all selected pollutants, namely carbon monoxide, nitrogen oxides, non-methane hydrocarbons, sulphur dioxide and particulate matter for individual transport only. The years 1987 and 2011 are observed. The data is reflected in tons of emitted pollutants per trip and day, for all commuters.

Figure 23: Change in absolute pollutant emissions for individual transport from 1987 to 2011.



Source: Own representation based on LfStaD, 1991; n.d.c; BA, 2012 (see addendum, pp.107); GeoBasis-DE/BKG & Google Inc., n.d.a – n.d.abg (see addendum, pp.1-226); KBA, 1987 (see addendum, pp.105); 2012; UBA, 2010a – 2010aj.

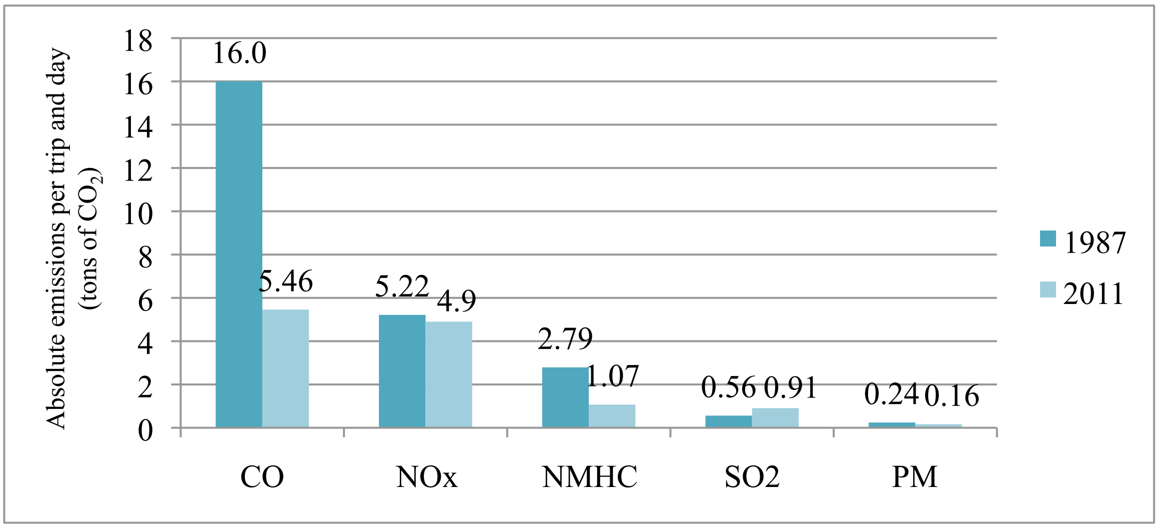
The strongest mitigation is to be determined for carbon monoxide emissions, which decrease from 2,032.55 tons of carbon monoxide for all in- and out-commuters per trip and day, to about 25.85 tCO for all commuters. This reflects a reduction of -98.73%.

Nitrogen oxide emissions reduce from 14.63 tNO_x to about 5.39 tons of nitrogen oxides, which accounts for a mitigation by -63.13%. Non-methane hydrocarbons further diminish from 14.49 tons of non-methane hydrocarbons to about 4.88 tNMHC in 2011. This represents a reduction of -66.32%. Furthermore, sulphur dioxide as the only pollutant, which is not encompassed in the emission standards by the European Union, slightly increases from 1.28 tons of sulphur dioxide to about 1.69 tSO_2, which results in an emission increase of +32.18%. Particulate matter emissions are mitigated from 0.35 tons of particulate matter to about 0.26 tPM for all commuters in 2011, which discloses diminished PM emissions of -25.63%.

7.7. Absolute pollutant emissions for public transport for the years 1987 and 2011

The following graph shows the selected pollutants estimated emissions for public transport only. The years 1987 and 2011 are observed. The data is reflected in tons of emitted pollutants per trip and day, for all commuters.

Figure 24: Change in absolute pollutant emissions for public transport from 1987 to 2011.



Source: Own representation based on LfStaD, 1991; n.d.c; BA, 2012 (see addendum, pp.107); Buslinie Deutschland, n.d.; DB, 1996; 2012a; 2013a – 2013ay; n.d.a – n.d.fi (see CD, Public Transport addendum, pp.749-914); GeoBasis-DE/BKG, Google Inc. & Deutsche Bahn AG, n.d.a – n.d.ail (see addendum, pp.1-748); n.d.a – n.d.fi; KBA, 1987 (see addendum, pp.105); 2012; Schütz, 2007; Schütz & Merath, 2011; UBA, 2010ao; 2010ap.

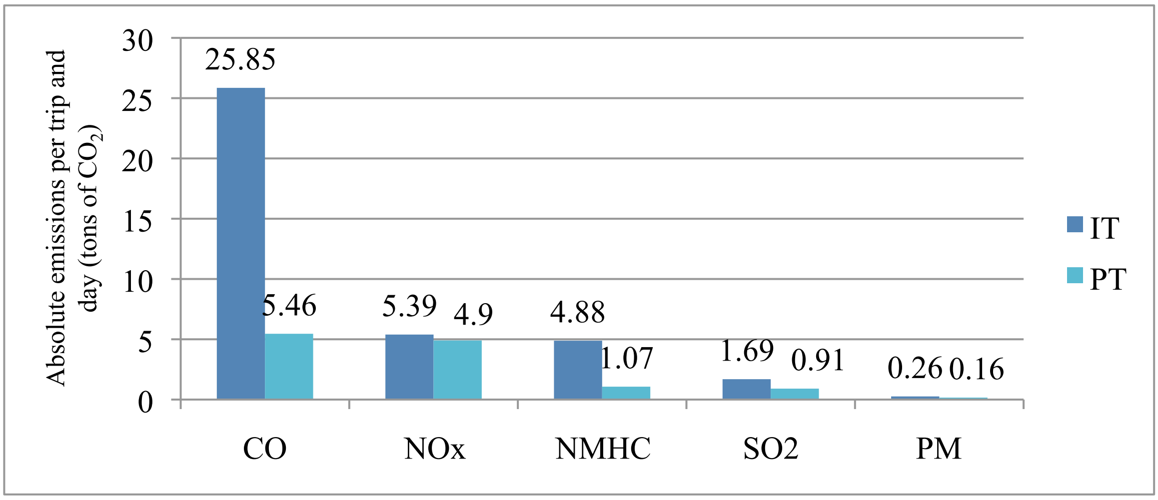
Carbon dioxide emissions in 1987 amount to 16.0 tons, which decrease to 5.46 tons of carbon monoxide, per trip and day. This reflects an emission decrease of -65.9%.

Nitrogen oxide emissions reduce from 5.22 tons of nitrogen oxides to about 4.9 tons of nitrogen oxides, which results in a mitigation of -6.03%. Non-methane hydrocarbons diminish from 2.79 tons of non-methane hydrocarbons, in 1987, to about 1.07 tons of NMHC, in 2011. This represents a reduction of -61.68%. As for individual transport, sulphur dioxide as the only pollutant, increases from 0.56 tons of sulphur dioxide to about 0.91 tons of sulphur dioxide. This reflects an emission increase of +61.56%. Particulate matter emissions are mitigated from 0.24 tons of particulate matter to about 0.16 tPM for all commuters in 2011, which discloses diminished PM emissions of -32.92%.

7.8. Absolute pollutant emissions for individual- and public transport in 2011

The next figure depicts the absolute amount of pollutant emissions for individual- and public transport for the year 2011. The data is represented in absolute emissions for the total amount of commuters, per trip and day. The data is reflected in emitted tons of pollutants.

Figure 25: Absolute pollutant emissions for individual- and public transport in 2011.



Source: Own representation based on LfStaD, 1991; n.d.c; BA, 2012 (see addendum, pp.107); Buslinie Deutschland, n.d.; DB, 1996; 2012a; 2013a – 2013ay; n.d.a – n.d.fi (see CD, Public Transport addendum, pp.749-914); GeoBasis-DE/BKG, Google Inc. & Deutsche Bahn AG, n.d.a – n.d.ail (see addendum, pp.1-748); n.d.a – n.d.fi; GeoBasis-DE/BKG & Google Inc., n.d.a – n.d.abg (see addendum, pp.226); KBA, 1987 (see addendum, pp.105); 2012; Schütz, 2007; Schütz & Merath, 2011; UBA, 2010a – 2012an.

It is significant that carbon monoxide emissions for individual transport exceed those of public transport by far. Additionally, public transport emissions are constantly lower than those of individual transport.

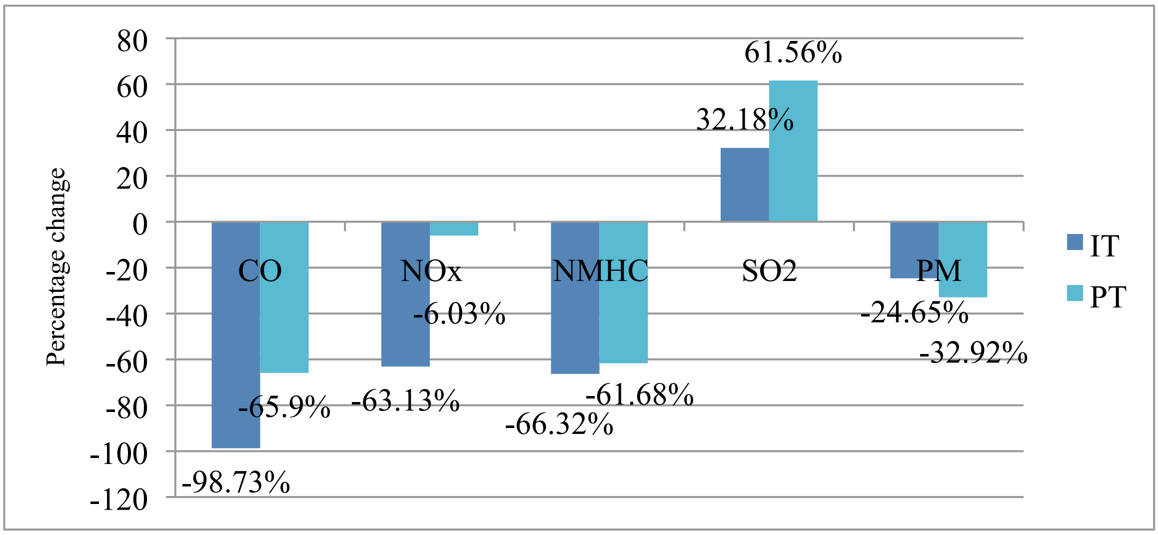
With respect to carbon dioxide, individual transport emits 25.85 tCO, whereas public transport merely emits 5.46 tons of carbon monoxide. Accordingly, carbon monoxide emissions by individual transport are about 4.7 times higher than the corresponding public transport emissions.

The most similar emission output is determinable for nitrogen oxide emissions as follows: Individual transport emits 5.39 tons per trip and day and public transport emits 4.9 tons per trip and day, for all commuters. Individual transport exceeds public transport by 1.1 times in NO_x emissions per trip and day. Non-methane hydrocarbon emissions amount to 4.88 tNMHC for individual transport and sum up to 1.07 tons of non-methane hydrocarbons for public transport. Non-methane hydrocarbon emissions for IT are about 4.6 times higher than the emitted amount of NMHC emissions by public transport.

Sulphur dioxide emissions for individual transport accumulate to an output of 1.69 tSO_2, whereas PT emits 0.91 tSO_2, per trip and day. Sulphur dioxide emissions by individual transport exceed those of public transport by 1.9 times. With respect to individual transport, particulate matter emissions rise above public transport emissions by 1.6 times.

The next figure represents the percentage change of the previously outlined consumption data. The data reflects the European Metropolitan Region of Munich's change in pollutant emissions from 1987 to 2011.

Figure 26: Percentage change of absolute pollutant emissions for individual- and public transport from 1987 to 2011.



Source: Own representation based on LfStaD, 1991; n.d.c; BA, 2012 (see addendum, pp.107); Buslinie Deutschland, n.d.; DB, 1996; 2012a; 2013a – 2013ay; n.d.a – n.d.fi (see CD, Public Transport addendum, pp.749-914); GeoBasis-DE/BKG, Google Inc. & Deutsche Bahn AG, n.d.a – n.d.ail (see CD, Public Transport addendum, p.1-748); n.d.a – n.d.fi; GeoBasis-DE/BKG & Google Inc., n.d.a – n, y.abg (see addendum, pp.1-226); KBA, 1987 (see addendum, pp.105); 2012; Schütz, 2007; Schütz & Merath, 2011; UBA, 2010a – 2010an.

With respect to individual transport, the figure depicts that carbon monoxide emissions decrease by -98.73%, whereas public transport emissions are reduced by -65.9%. Concerning individual transport, nitrogen oxides emissions diminish by -63.13% and public transport emissions are diminished by -6.03%. Non-methane hydrocarbons decrease by about -66.32% in correspondence to individual transport as well as public transport emissions are mitigated by -61.68%.

In regard of particulate matter, the output diminishes by -24.65% by individual transport and by -32.92% by public transport. Concerning individual transport, sulphur dioxide emissions significantly increase by +32.18%, whereas by public transport emissions rise by +61.56%. As it may be derived by the graph, in an absolute degree, emission decrease more efficiently for individual than for public transport.

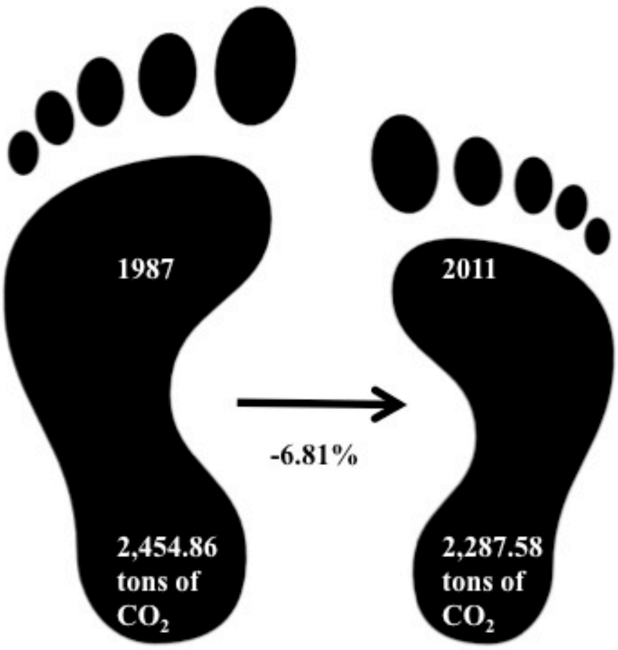
7.9. Carbon footprint approximation for the years 1987 and 2011

In order to assess a simplified commuter footprint for individual- and public transport the following estimated modal split is taken into account for the years 1987 and 2011: The Bayerisches Landesamt für Statistik und Datenverarbeitung (n.d.a ([see addendum p.113]; n.d.b) provides vehicle choice data for the year 1987 for Munich's in- and out-commuters. Information is available for individual transport, U-Bahn, S-Bahn, Tram, train, bus, bike, non-motorized transport and other transport modes, such as motorcycles or mopeds.

For this purpose, U-Bahn, S-Bahn, Tram, train and buses are comprised under a general public transport category. Bike, non-motorized transport as well as other modes are disregarded, since they only amount to about 0.24% (LfStaD, n.d.a [see addendum p.113]; n.d.b). The year 1987's dedicated shares of 94.04% of in-commuters and 5.96% of out-commuters, are aligned. According to this calculation, the composition of 57.3% of individual transport and 42.46% of public transport represents the simplified modal split.

Simplified modal split data from the year 2005, which substitutes the year 2011, is provided by Thierstein and Reiss-Schmidt (2008) who outline a modal split of 52% for individual and 48% for Munich's job commuters. Hence, an approximation of the carbon footprint according to the provided modal split results in the following output for the years 1987 and 2011:

Figure 27: Carbon footprint approximation for the years 1987 and 2011 in correspondence to a simplified modal split.



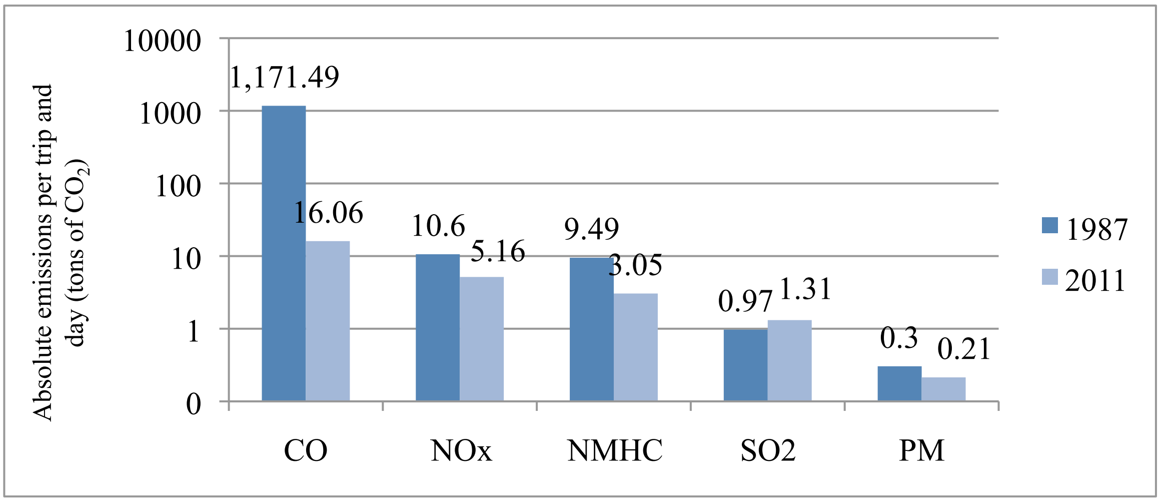
Source: Own representation based on LfStaD, 1991; n.d.a (see addendum p.113); n.d.b; n.d.c; BA, 2012 (see addendum, pp.107); Buslinie Deutschland, n.d.; DB, 1996; 2012a; 2013a – 2013ay; n.d.a – n.d.fi (see CD, Public Transport addendum, pp.749-914); Park, 2009; GeoBasis-DE/BKG, Google Inc. & Deutsche Bahn AG, n.d.a – n.d.ail (see CD, Public Transport addendum, pp.1-748); n.d.a – n.d.fi; GeoBasis-DE/BKG & Google Inc., *n.d.a – n.d.abg (see addendum, pp.1-226); KBA, 1987 (see addendum, pp.105); 2012; Schütz, 2007; Schütz & Merath, 2011; Thierstein & Reiss-Schmidt, 2008, UBA, 2010a – 2010an; MVV, 2012.*

With respect to the simplified modal split, 2,454.86 tons of carbon dioxide are emitted in 1987 and about 2,287.58 tons of carbon dioxide are emitted in 2011. Accordingly, the estimated footprints result in a carbon dioxide reduction of -6.81%. This is, as previously outlined, based on the emission factor improvements with respect to public transport. Therefore, the emission factor mitigation activities outweigh the increase in commuters and the higher share of individual transport in reference to the years 1987 and 2011.

7.10. Pollutant footprint approximation for the years 1987 and 2011

The following analysis estimates the pollutant footprint per trip and day, for the years 1987 and 2011. The simplified modal splits are applied.

Figure 28: Pollutant footprint in correspondence to a simplified modal split.



Source: Own representation based on LfStaD, 1991, n.d.c; BA, 2012 (see addendum, pp.107); Buslinie Deutschland, n.d.; DB, 1996; 2012a; 2013a – 2013ay; n.d.a – n.d.fi (see CD, Public Transport addendum, pp.749-914); Park, 2009; GeoBasis-DE/BKG, Google Inc. & Deutsche Bahn AG, n.d.a – n.d.ail (see CD, Public Transport addendum, pp.1-748); n.d.a – n.d.fi; GeoBasis-DE/BKG & Google Inc., n.d.a – n.d.abg (see addendum, pp.1-226); KBA, 1987 (see addendum, pp.105); 2012; Schütz, 2007; Schütz & Merath, 2011; Thierstein & Reiss-Schmidt, 2008, UBA, 2010a – 2010an; MVV, 2012.

In reference to the previous modal split estimations, carbon monoxide emissions are reduced from 1,171.49 tons of carbon monoxide in 1987, to about 16.06 tCO in 2011. This results in a mitigation of -98.63%. Nitrogen oxide emissions are mitigated from 10.6 tons of nitrogen oxides in 1987, to 5.16 tNO_x in 2011, which defines a decrease of -51.33%. The non-methane hydrocarbon emissions are mitigated from 9.49 tNMHC to about 3.05 tons of non-methane hydrocarbons in 2011. This outlines an output mitigation of -67.84%. Sulphur dioxide emissions increase from 0.97 tons of sulphur dioxide to 1.31 tSO_2 per trip and day, for all commuters, which accounts for an increase of +35.34%. Particulate matter emissions are reduced from 0.3 tPM to 0.21 tons of particulate matter in 2011, which represents a decrease by -29.68%. Accordingly, with respect to the environmental effects, as it may be derived by table 3, the impact is mitigated for carbon dioxide as well as all pollutants, except for sulphur dioxide.

Accordingly, with respect to assumption (2), the global warming effect concerning the greenhouse gas carbon dioxide is decelerated, however, not directly reduced as temperature continues to rise due to the anthropogenically produced emissions, which is for instance connected to sea level rise, droughts, ecosystem changes, animals and plants are subject to extinction, etc. (IPCC, 2007a). Carbon monoxide, which is a precursor to carbon dioxide and ground level ozone is heavily diminished and nitrogen oxide reduction leads to a lower degree of soil acidification or a lower evolvement of ground level ozone (Gwilliam, Kojima & Johnson, 2004; GTZ, 2009, Commission for Environmental Cooperation, n.d.b; Kampa & Castanas, 2008; United States Environmental Protection Agency, 2012.).

Non-methane hydrocarbon reduction results in fewer reactions with nitrogen oxides and light to form ground level ozone, which does hence, implicate fewer plants to be affected (BMU, 2013; Gwilliam, Kojima & Johnson, 2004, GTZ; 2009, Commission for Environmental Cooperation, n.d.b; Kampa & Castanas, 2008; Department of the Environment, Community and Local Government, n.d.; United States Environmental Protection Agency, 2012; UBA 2013). The increase in sulphur dioxide results in a higher degree of acid and accordinly, increased soil and water acidification (Gwilliam, Kojima & Johnson, 2004; GTZ, 2009; Kampa & Castanas, 2008). The lower emission of particulate matter leads to a lower alteration of nutrient and chemical cycles as well as buildings are facing less surface soiling (Gwilliam, Kojima & Johnson, 2004; GTZ, 2009; Commission for Environmental Cooperation, n.d.a; Kampa & Castanas, 2008).

Therefore, with respect to the European emission standardisation for carbon monoxide, nitrogen oxides, non-methane hydrocarbons and particulate matter, policies may be regarded successful in the sense of absolute mitigation. Although sulphur dioxide is slightly mitigated per person for IT and increases per person by PT, which is hence, subject to further mitigation measures, such as better antecedent fuel filtration.

7.11. Public transport emission factor limitation and pollutant output reasoning

The following diagram represents the added individual transport share to public transport in comparison to public transport only.

Table 13: Comparison of the absolute pollutant emissions of the applied combination of individual- and public transport versus public transport only.

Absolute amount of pollutants	CO	NO_x	NMHC	SO_2	PM
1987 IT and PT	16.00	5.22	2.79	0.56	0.24
1987 PT	0.92	3.5	0.58	0.41	0.18
Relative emission share	*5.77%*	*67.06%*	*20.9%*	*73.27%*	*73.08%*
2011 IT and PT	5.46	4.9	1.07	0.91	0.16
2011 PT	0.83	3.81	0.23	0.69	0.12
Relative emission share	*15.39%*	*78.83%*	*22.23%*	*77.13%*	*71.45%*

Source: Own representation based on LfStaD, 1991; n.d.c; BA, 2012 (see addendum, pp.107); Buslinie Deutschland, n.d.; DB, 1996; 2012a; 2013a – 2013ay; GeoBasis-DE/BKG, Google Inc. & Deutsche Bahn AG, n.d.a – n.d.ail (see CD, Public Transport addendum, p.1-748); n.d.a – n.d.fi; KBA, 1987 (see addendum, pp.105); 2012; Schütz, 2007; Schütz & Merath, 2011; UBA, 2010ak – 2010an.

In reference to table 13, the relative emission shares represent the following: The higher the share, the more public transport is involved. As it may be recognized, the largest discrepancies are to be observed for carbon monoxide, as the consumption in 1987 for public transport only amounts to 0.92 tons of carbon monoxide for the total number of commuters per trip and day. However, including the individual transport share, this number increases to about 16.0 tons of carbon monoxide. This reflects a relative emission share of PT to IT versus PT of 5.77%. This is mainly based on the large emission factor of carbon monoxide for individual transport in 2011. In 2011, due to the mitigated individual transport emissions, the individual- and public transport combination diminishes to about 5.46 tons of carbon monoxide. Public transport only amounts to 0.83 tons for the total number of commuters per trip and day. This represents a relative share of 15.39% in carbon emissions.

The most similar emission share for public transport in comparison to the applied combination in 1987 is determinable for particulate matter. The relative share of PT to IT versus PT only amounts to 73.08%. In 2011, the most similar amount of emissions is found for nitrogen oxides. In 2011, the PT and IT combination emits 4.9 tons for the total number of commuters per trip and day. Public transport emits 3.81 tons of nitrogen oxides for all commuters per trip and day. This defines a share of 78.83%. From 1987 to 2011, all relative emission shares, except for particulate matter, increase, which speaks for a relative emission reduction in individual transport.

It is to be elaborated why sulphur dioxide emissions increase over the selected time period. In order to determine the technical improvements, the estimated emission factors are to be observed. Additionally, the evolved emission factors will be set in relation to the number of commuters, which shifted since 1987. The emission factors of carbon dioxide, monoxide, nitrogen oxides, non-methane hydrocarbons, sulphur dioxide and particulate matter are displayed in the following table for the years 1987 and 2011:

Table 14: The emission factor improvement of individual- and public transport.

Grams/PKM	CO_2	CO	NO_x	NMHC	SO_2	PM
EF 1987	254.73	10.8	1.22	1.57	0.11	0.029
EF 2011	206.89	1.7	0.35	0.32	0.08	0.017
Change	*-18.78%*	*-84.28%*	*-71.72%*	*-79.28%*	*-24.41%*	*-42.39%*
EF 1987 PLT CO_2		138.8		1987 LPT	55.1	
EF 2011 PLT CO_2		73.2		2011 LPT	41.9	
Change		*-47.26%*			*-23.96%*	
Pollutants PLT/LPT 1987		0.08	0.336	0.056	0.039	0.017
EF 2011 PLT[20]		0.042	0.022	0.012	0.026	0.0174
EF 2011 LPT		0.019	0.054	0.002	0.031	0.0023
Change PLT		*-52.22%*	*-32.8%*	*-79.22%*	*-32.76%*	*+2.5%*
Change LPT		*-79.07%*	*-83.99%*	*-95.63%*	*-20.94%*	*-86.15%*

[20] PLT electric: 83%; diesel: 17%; LPT electric: 97.8%; diesel: 2.2% (Knörr, Heidt & Schacht, 2012).

Source: Own representation based on LfStaD, 1991; n.d.c; DB, 1996; 2012a; KBA, 1987 (see addendum, pp.105); 2012; UBA, 2010a – 2010ap.

With respect to the outlined methodology in chapter 5, the 1987 emission factor is composed of the PROBAS platform's pre Euro 1 data and the year 2011's data is comprises the Euro norms 1 to 5. All applied Euro-norms are combined with the corresponding capacity range and engine type. The displayed public transport emission factors are lower, because they do not include the individual transport share. Hence, without IT, the emission factors in table 13 appear more efficient.

With respect to individual transport, the estimated emission factor in 1987 emits in average 254.73 grams of carbon dioxide per person-kilometre, which improves to 206.89 gCO_2/PKM in 2011. This reflects a mitigation of -18.78%. The estimated carbon monoxide' emission factor for the year 1987 results in 10.8 grams of carbon monoxide per PKM. The 2011 emission factor amounts to 1.7 grams of carbon monoxide per PKM, which accounts for a mitigation of -84.28%. The year 1987's nitrogen oxide emission factor of 1.22 gNO_x per PKM is mitigated to about 0.35 gNO_x per PKM, which defines a reduction of -71.72% in emitted grams of nitrogen oxides per PKM. The non-methane hydrocarbon emission factor is estimated to reach about 1.57 gNMHC/PKM for individual transport. By 2011, the emission factor diminishes to 0.32 gNMHC/PKM, which outlines an output mitigation of -79.28% in non-methane hydrocarbon emissions.

Considering the pre Euro 1 emission factor of about 0.11 grams of sulphur dioxide per PKM in 1987 and the estimated emission factor in 2011, which emits 0.08 gSO_2/PKM, the output proofs of an emission reduction of -24.41%. Particulate matter decreases from a previous emission factor of 0.029 grams of particulate matter for pre Euro 1, to an emission factor of 0.017 grams of particulate matter per person-kilometre, in 2011. This results in a mitigation of about -42.39%.

In regard of public transport, the year 1987's PLT emission factor accounts for 138.8 grams of carbon dioxide, whereas LPT accounts for an emission factor of 55.1 grams of carbon dioxide per PKM. The PLT emission factor reduces by -47.26% to 73.2 gCO_2/PKM as well as the LPT emission factor is mitigated by -23.96% to amount to an emission factor of 41.9 gCO_2/PKM in 2011.

Concerning the previously disclosed absolute emission data for individual- and public transport, the emission factor improvement for individual transport is basically sufficient but not mitigating the increase in commuters with respect to assumption (1). The public local transport emission factor decreases by -47.26% in carbon dioxide emissions, whereas the long-distance passenger transport emission factor is mitigated by -23.96%. This is contrary to the individual transport emission factor, which is reduced by -18.78%. Accordingly, the mitigation activities are more sufficient for public transport.

In the following, the PT emission factors for the year 1987 are comprised of the combination of public local- and long-distance passenger transport. Accordingly, in 1987, carbon monoxide accounts for an emission factor of 0.08 grams of carbon monoxide per person-kilometre. It is reduced by -52.22% for PLT to an emission factor of 0.042 gCO/PKM and by -79.07% for LPT to an emission factor of 0.019 gCO/PKM. Nitrogen oxides account for 0.336 gNO_x in 1987, which diminishes to 0.022 gNO_x by PLT (-32.8%) and to 0.054 grams of nitrogen oxides by LPT (-83.99%), in 2011. The year 1987's, non-methane hydrocarbon emission factor defines 0.056 gNMHC, which is reduced by -79.22% to emit 0.012 gNMHC by PLT and mitigated by -95.63% to amount to an emission factor of 0.002 gNMHC, in 2011. Sulphur dioxide in 1987, accounts for an emission factor of 0.039 grams of sulphur dioxide, which is diminished to 0.026 gSO_2 per PLT and to 0.031 gSO_2 per LPT, in 2011. This outlines a PLT emission factor mitigation of -32.76% and a LPT emission factor reduction by -20.94%. With respect to particulate matter, 0.017 grams of particulate matter are emitted in 1987. Concerning PLT, the emission factor increases by +2.5% to an emission factor of 0.0174 gPM/PKM, whereas the LPT emission factor is reduced to 0.0023 gPM/PKM in 2011, which outlines a mitigation of -86.15%.

Table 14 significantly displays that the lowest emission factor mitigation is determinable for sulphur dioxide. This is the case for individual transport, for public local- as well as for long-distance passenger transport. With respect to the previously outlined mean emission data, as disclosed in figure 24, sulphur dioxide slightly decreases for individual transport but it increases in reference to public transport.

Particulate matter in an absolute sense, is constantly reduced for individual- as well as for public transport. This is contrary to the sulphur dioxide emission factor improvement, which is hence, not strong enough to outweigh the increase in commuting activities. Hence, with respect to this analysis' influencing factors, either the amount of commuters needs to decrease or technology needs to improve more efficiently. Hence, the particulate matter improvement is strong enough to mitigate emissions, whereas sulphur dioxide mitigation in an absolute sense is not sufficient for this analysis' assumptions (1) and (2).

The increase in sulphur dioxide for public transport may be based on the individual transport share as well as on the diesel trains, which are taken into account for the 2011 data. According to Knörr, Heidt and Schacht (2012), public local transport has a 17% share of diesel engines and long-distance passenger transport has a share of 2.2% diesel engines. The PLT emission factor for particulate matter proofs of a 2.5% increase, which may be based on the 17% share of diesel engines, whereas LPT only comprises 2.2% of diesel engines, which may lead to the diminished emission factor of -86.15% for LPT (Knörr, Heidt & Schacht, 2012). Additionally, sulphur dioxide is not part of the Euro-norm standardisation and is hence, not part of the active mitigation programme (Eur-Lex, n.d.).

With respect to individual transport and as earlier outlined, the absolute sulphur dioxide increase may be based on the incremental number of diesel engines as the diesel engine share increases from a mean of 12.87% in 1987, to a share of 32.6% in 2011 (KBA, 1987 [see addendum, pp. 105]; 2012).

However, with respect to the individual transport emission factors, it is remarkable that the mandatory emission standard programme proofs of significant emission factor reductions in contrast to recently mandatory or less regulated greenhouse gases and pollutants as it may be recognized for carbon dioxide and sulphur dioxide.

8. FUTURE OUTLOOK

This chapter covers selected declared political and environmental aims, which have an effect on future emissions. The future scenario focus in this chapter is on carbon dioxide emissions.

8.1. Business-as-usual scenarios

For developments and technical improvements a future trend analysis may be established, which will outline future limitations as set by the European Union for individual transport or as declared by the Deutsche Bahn or the Stadtwerke München with respect to public transport.

This is contrasted with the business-as-usual (BAU) scenario. According to the IPCC (2011), those scenarios investigate on how the future may develop, which is based on the integration and possible change of past trends. Mostly BAU scenarios consider

> "constraints on future development (e.g., finite resources, limits on consumption). However, the term "business-as-usual" may be misleading because exploratory scenarios also can describe futures that bifurcate at some point (an example might be uptake or rejection of a new technology) or that make some assumptions about regulation and/or adaptation of a system" (IPCC, 2011, p.150).

Concerning this analysis, fuel resources are finite but may be influenced or with respect to the future, be abandoned by renewable resources, such as for hydrogen fuel cells, which proof of a low amount of pollutants as well as electric motors, which nevertheless, must be based on a more environmentally friendly fuel mix (Inform, Inc., n.d.). The next chapters will represent future scenarios for individual- and public transport according to set and published goals, policies and guidelines.

Nevertheless, the applied business-as-usual scenario in this analysis is directed to the described bifurcate manner of technology adaption and limitations, which are set by the European Union. In this case, the amount and type of cars, namely gasoline or diesel as well as the corresponding cubic capacity ranges are projected to remain unchanged as well as technology does not adapt. However, the projected amount of commuters is adapted to the 2011 level. Hence, the emission outcome is to be observed.

8.2. Future outlook for individual transport

Improvement for individual transport means amongst other measures, to reduce carbon dioxide emissions, which basically results in more sustainable mobility. Lately, improvements in the emission reduction are mostly enforced by the European Union. As outlined on p.23, the previously voluntary mitigation of carbon dioxide emissions shifted from a voluntary to a mandatory basis. Since December 2008, a phase-in programme is conducted to reach an emission from tank-to-wheel of 130 gCO_2/PKM (BMU, n.d.). With respect to the phase-in, the newly produced car fleet is to integrate stepwise emission goals to reach the direct emission factor of 130 grams of carbon dioxide by 2015 (BMU, n.d.). Furthermore, by 2020, the average carbon dioxide emissions are to be lowered to a tank-to-wheel emission factor of about 95 grams per person-kilometre (BMU, n.d.).

The conducted future scenario calculation is based on the 2011 dataset, which means that the numbers of commuters and the car fleet profile remain unchanged, whereas the emission factor is substituted by 95 grams of CO_2/PKM. This may represent an underestimation in comparison to the entire well-to-wheels emission. As the EU plans this goal for all new cars this may represent an underestimation, since an unpredictable number of vehicles will be older and not meet this emission goal. Additionally, the number of hybrid- or electric vehicles is subject to change, which may alter the total carbon footprint.

Nevertheless, the business-as-usual scenario may reflect by how much the future technological improvement can decrease the amount of carbon dioxide to be emitted by the total number of commuters. In comparison to the BAU scenario and the actual improvement for 2011, the 2020 scenario predicts significant emission reductions as it may be derived by chapter 8.4.

8.3. Future outlook for public transport

Overall, the Deutsche Bahn plans to be emission free by 2050 (DB, 2012a), however, the mid-time goal is to reach about 35% of renewable energy in 2020 for the traction current. According to the DB (2012a), the amount of renewable energy in 2011 amounts to about 21.8%, which exceeds the year 2010's share by 2%.

This improvement is based on the internal strategy *DB2020*, which encompasses the three pillars of being a *profitable market leader*, a *top employer* and *eco-pioneer*. The latter, focuses on setting "standards for the efficient use of resources. DB is striving to further expand its leading environmental position by using resources even more efficiently and further reducing emissions of CO2 and noise" (DB, 2012b, n.p.).

Amongst further projects, such as cooperations with external organizations, as for instance, *Bund für Umwelt und Naturschutz Deutschland* (BUND) or *Naturschutzbund Deutschland e.V.* (NABU), the carsharing organization *Flinkster* or *call a bike*, the Deutsche Bahn contributes to the research project *Eco Rail Innovation*. Hereby, the DB cooperates with 12 partners to work on the vision to be carbon free by 2050 (DB, 2012 a). The Deutsche Bahn plans to reduce their carbon footprint by increasing the amount of green energy, to be more energy efficient in terms of modern trains, efficient business management, intelligent connection of various transport modes as well as by energy efficient driving for train, bus and truck-drivers (DB, 2012a).

The Deutsche Bahn network serves the short distance traffic, long distance traffic and the public urban transport of the S-Bahn. The U-Bahn and tram are supplied by the generated electricity of the public utility company Stadtwerke München GmbH (Referat für Gesundheit und Umwelt, 2012). Amongst other sustainable projects, such as emission free district heating by 2040, the SWM plans for the future to be the first megacity, which is served by self-made green electricity by 2025 (SWM, 2012). According to the SWM (2012), projects and constructions had been initialized, which prospectively may exceed the operation of households in that subway and tramway are prospectively also to be served by green electricity.

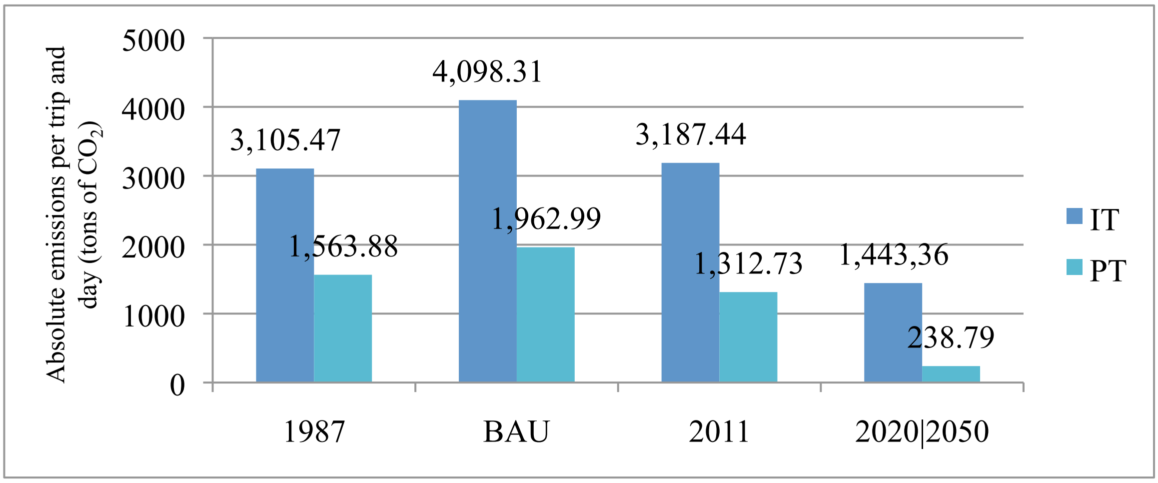
Accordingly, PLT, LPT, S-Bahn, U-Bahn and tramways are replaced for a zero emission factor. With respect to the individual transport share, the IT emission factors are replaced by the 2020's projected emission factor. Otherwise the dataset remains unchanged.

The previously outlined limitations in chapter 5.5 are still valid for this estimation, such as that these estimations are based on the current transportation network. However, the future network of public transport is subject to change and the future network is not encompassed in this study, which means that more train-stations as well as a better network of routes are projected to follow, which cannot be encompassed in this work. Additionally, with respect to the year 2050's public transport emissions, which comprises the individual transport share, the year 2020's early emission goal of 95 grams of carbon dioxide is applied as a substitute, which may alter the results.

8.4. Business-as-usual- and future scenario outlook

Figure 32 depicts the BAU scenario for in- and out commuters for the projected year 2011. Under the assumption of non-adaption to carbon dioxide emission limitations it shows that the amount of carbon dioxide emissions increases, which is based on the increasing amount of commuters. As the BAU scenario's discrepancies appear more severe in direct comparison to car mobility may be based on the shift in emission factors. As it may be derived by table 15, the emission factor improvement proofs of the effect of emission limitations, whether set on a mandatory or on a voluntary base, if technology had remained unchanged.

Figure 32: Absolute carbon dioxide emissions per trip and day for the business-as-usual- and future scenario.



Source: LfStaD, 1991; n.d.c; BA, 2012 (see addendum, pp.107); Buslinie Deutschland, n.d.; DB, 1996; 2012a; 2013a – 2013ay; n.d.a – n.d.fi (see CD, Public Transport addendum, pp.749-914); GeoBasis-DE/BKG, Google Inc. & Deutsche Bahn AG, n.d.a – n.d ail (see addendum, pp.1-748); GeoBasis-DE/BKG & Google Inc., n.d.a – n, d.abg (see addendum, pp.1-226); KBA, 1987 (see addendum, pp.105); 2012; Schütz, 2007; Schütz & Merath, 2011; UBA, 2010a – 2010an; SWM, 2012.

The figure depicts the absolute commuter emissions for individual- and public transport for the years 1987, 2011 the estimated BAU scenario and the projected emission limitations for the year 2020 in reference to individual transport as well as the year 2050 for public transport. The following table represents the absolute emission data per trip and day.

Table 15: Estimation of the BAU- and future scenario carbon dioxide emissions per trip and day for individual- and public transport.

Tons of CO_2/day	1987	BAU	2011	Future scenario 2020 IT; 2050 PT
IT	3,105.47 t	4,098.31 t	3,187.44 t	1,443.36 t
PT	1,563.88 t	1,962.99 t	1,312.73 t	238.79 t
Difference	1,541.59 t	2,135.31 t	1,823.87 t	1,204.56 t

Own representation based on LfStaD, 1991; n.d.c; BA, 2012 (see addendum, pp.107); Buslinie Deutschland, n.d.; DB, 1996; 2012a; 2013a – 2013ay; n.d.a – n.d.fi (see CD, Public Transport addendum, pp.749-914); GeoBasis-DE/BKG, Google Inc. & Deutsche Bahn AG, n.d.a – n.d.ail (see CD, Public Transport addendum, pp.1-748); n.d.a – n.d.fi; GeoBasis-DE/BKG & Google Inc., n.d.a – n.d.abg (see addendum, pp.1-226); KBA, 1987 (see addendum, pp.105); 2012a; Schütz, 2007; Schütz & Merath, 2011; UBA, 2010a – 2010an; SWM, 2012.

As it may be derived by the previous analysis, table 15 compares the absolute emissions for individual- and public transport. The consumption data for the years 1987 and 2011 for IT and PT remains unchanged. Accordingly, the following analysis only focuses on the BAU as well as on the future scenario.

In reference to table 15, the estimated business-as-usual scenario in correspondence to individual transport accumulates emissions of about 4,098.31 tons of carbon dioxide. Public transport emissions sum up to a projected amount of 1,962.99 tons of carbon dioxide. This defines a difference in carbon emissions of 2,072.59 tons of carbon dioxide, which represents a relative emission share of PT to IT of 48.29%. By comparing the BAU emissions to the year 2011's emissions, carbon emissions by individual transport decrease by -21.75% as well as public transport emissions decrease by -33.21% in comparison to non-adaption to technological improvements.

With respect to the year 2020's individual transport emissions, an output of about 1,443.36 tons of carbon dioxide for all commuters, per trip and day, is estimated. The year 2050's public transport emissions are estimated to account for 238.79 tons of carbon dioxide per trip and day. Certainly, those two points in time are difficult to be compared. Hence, the future outlook data is only to be analyzed internally, in reference to the same transport mode, over time.

With respect to the time frame from 1987 to 2020 for individual transport and from 1987 to 2050, for public transport, IT emissions are diminished by -43.27%. Public transport emissions are mitigated by -85.03%, respectively. From 2011 to 2020, individual transport emissions are reduced by -54.72%. Public transport emissions, with respect to the time frame from 2011 to 2050, are mitigated by -81.89% to an estimated remainder of individual transport. By comparing the year 2020's output to the BAU scenario, individual transport emissions are diminished by -64.57%, whereas the year 2050's output in comparison to the corresponding BAU emissions is mitigated by -87.91%.

Accordingly, as individual transport emissions are mostly cut in half, whereas public transport emissions proof of a more efficient emission reduction concerning carbon dioxide emissions.

9. CONCLUSION

This analysis focuses on the commuters' interaction between the city of Munich and the surrounding European Metropolitan Region of Munich. It covers the investigation of individual motorized mobility and public transport as they represent the commuters' basic modes of transportation. In this aspect, the technical improvements as well as the shift and increase in the number of commuters within the EMM in direct interaction with the city of Munich, is disclosed.

The analysis is split into two assumptions: (1) The first part is conducted under the assumption of all commuters to travel by either individual- or public transport, whereas the (2) second part covers the approximation of a simplified modal split of individual- and public transport. The calculations are conducted for the years 1987 and 2011. The observed scope represents the Outer Planning Region 14 and the surrounding Outer European Metropolitan Region of Munich, which, in interaction with the city of Munich, form the entire European Metropolitan Region of Munich. Overall, since the year 1987, more commuters travel between the city of Munich and the rest of the European Metropolitan Region of Munich.

The following commuter trends are significant: With respect to all in- and out-commuters, from 1987 to 2011, the number of out-commuters from the city of Munich increases and the number of in-commuters from the region outside of Munich remains about unchanged. However, commuters travel longer distances. A shift of commuters from the Outer Planning Region 14 to the Outer Metropolitan Region of Munich is recognizable. The number of in-commuters from the OPR14 decreases, whereas the number of out-commuters increases. Furthermore, a significant in- and out-commuter increase from and to the Outer European Metropolitan Region of Munich is determinable.

The study's basic methodology is framed by the life-cycle assessment, whereat the emission factors are based on a well-to-wheels approach, which includes the direct emissions from tank-to-wheel as well as the emissions, which derive from other previous processes, such as the extraction, conversion, transport and distribution of the fuel. The applied emission factors for individual- and public transport are based on the person-kilometre emission estimation. Accordingly, three main factors influence the results: (1) The number of commuters (2), the longer travel distances as well as (3) the applied emission factors. Furthermore, these three factors are subject to change from 1987 to 2011.

Two main types of output are observed. The relative emission data per average commuter, which observes the average commuter's emitted grams, kilograms or tons per person, trip and day as well as the absolute emission data, which considers the total sum of emissions for the assumptions (1) and (2), whereat the carbon- as well as the pollutant footprints are estimated for the years 1987 and 2011.

The Kyoto protocol demands a reduction in greenhouse gas emissions. Carbon dioxide represents the largest greenhouse gas and is hence, investigated on. Accordingly, the carbon footprint in this analysis comprises carbon dioxide only. Nevertheless, pollutants, such as carbon monoxide, nitrogen oxides, non-methane hydrocarbons, are precursors to greenhouse gases. In consideration of individual transport, the previously named pollutants and particulate matter are subject to limitations as conducted by the Euro-norm standards since 1992. Sulphur dioxide, which is also covered in this analysis, is not comprised in the standardisation programme but a human irritant, which may result in environmental impacts, such as acid rain. Furthermore, carbon dioxide emissions are subject to a mandatory limitation programme since December 2008. Public transport as the main alternative to individual transport is encompassed in the investigation of the carbon- and the selected pollutant footprint, in order to estimate the environmental impact of carbon dioxide, carbon monoxide, non-methane hydrocarbons, sulphur dioxide and particulate matter.

Certainly, the Outer Planning Region 14's emissions are lower than those of the Outer European Metropolitan Region of Munich, because of the shorter travel distances. The average commuter travels 77.59 km, the OPR14 commuter travels 41.09 km and the OEMM commuter travels about 98.75 km.

With respect to the entire European Metropolitan Region of Munich in 1987, the average IT commuter emits 24.0 kilograms of CO_2 per person, trip and day, whereas the average PT commuter emits 11.01 kgCO_2, which accounts for a relative emission share of PT to IT emissions of 45.91%. In reference to the year 2011, the individual transport commuter emits in average 15.67 kgCO_2, per person, trip and day. The average PT commuter emits 6.63 kilograms of carbon dioxide, which represents a relative emission share of 42.33%. Accordingly, in relative terms, public transport carbon dioxide emissions are more efficiently mitigated from 1987 to 2011.

Considering the absolute consumption level according to the transport mode, in 1987, all IT commuters emit about 3,105.37 tons of carbon dioxide and 3,187.45tCO_2 in 2011. This even reflects a +2.65% increase in emissions. This is based on the risen amount of commuters, which increasingly come from more distant regions. Hence, the increased number and the longer travel distances have a significant effect on the absolute outcome. Therefore, the mitigation activities are not sufficient to outweigh the increase in commuters under the assumption of all commuters to go by car.

With respect to public transport, all commuters in 1987, emit 1,563.88 tons of carbon dioxide and 1,312.73 tCO_2 in 2011. This accounts for a carbon dioxide emission decrease of -16.06%. Accordingly, in absolute terms, public transport is more efficient in carbon dioxide emission reduction. This improvement is based on the public transport's more sustainable fuel mix, with a lower emitting resource imput, such as a higher share of renewable energy, which increased from a minimum in the year 1990 to a share of 21.8% in 2011. Accordingly, the public local transport emission factor decreases by -47.26% in carbon dioxide emissions as well as the long-distance passenger transport emission factor is mitigated by -23.96%. This is contrary to the individual transport emission factor, which is reduced by -18.78%. Therefore, the carbon dioxide mitigation activities are more sufficient for public transport.

With respect to the relative pollutant emissions from 1987 to 2011 by individual- and public transport, at first sight, public transport emits less per person, trip and day. From

1987 to 2011, carbon monoxide and nitrogen oxide emissions are relatively lower for public transport. However, in both cases, individual transport proofs of a relatively more efficient emission reduction with respect to the mean relative emissions of public to individual transport. Non-methane hydrocarbon emissions are lower for public transport as well as PT is more successful in the relative emission reduction. Sulphur dioxide emissions are lower for public transport, however, individual transport proofs of a slight reduction, whereas PT emissions per person, trip and day, increase. Hence, IT is more efficient in mitigating sulphur dioxide emissions. Particulate matter emissions decrease for individual as well as for public transport, whereas PT mitigation measures are relatively more efficient.

In consideration of PT and the corresponding carbon dioxide as well as the selected pollutant emissions, higher emissions are based on the individual transport share, which is encompassed in the emission calculation. Individual transport represents carbon dioxide emissions of 512.93 tCO_2, which represents an emission share of 39.07%.

Considering the year 2011's absolute pollutant emissions for the assumption (1), it is significant that carbon monoxide emissions per person, trip and day, for individual transport exceed those of public transport by a factor of 4.7 times. Additionally, public transport emissions are constantly lower than those of individual transport. Nitrogen oxide emissions for IT are about 1.1 times higher than PT emissions are. Non-methane hydrocarbon emissions by IT are about 4.6 times higher than the amount of emitted NMHC by public transport. Sulphur dioxide emissions by individual transport exceed those of PT by 1.9 times. Particulate matter emissions by individual transport are about 1.6 times higher for individual transport. The most similar amount of emissions is to be recognized for nitrogen oxide, as individual transport emits 5.39 tons per trip and day and public transport emits 4.9 tons per trip and day for all commuters.

By comparing individual transport from 1987 to 2011, all pollutants, except for sulphur dioxide, are mitigated in an absolute sense for assumption (1). Carbon monoxide emissions are reduced by about -98.63%, nitrogen oxide emissions are diminished by -63.25%, non-methane hydrocarbons are reduced by -66.24% and particulate matter decreases by -25.71%. However, sulphur dioxide emissions increase by about +32.54% in an absolute sense.

With respect to public transport from 1987 to 2011, a similar trend is observable. Carbon monoxide emissions decrease by -66.56%, nitrogen oxide emissions are reduced by -7.47%, non-methane hydrocarbons are diminished by -62.37%, particulate matter emissions decrease by -33.33%, whereas sulphur dioxide emissions increase by +58.93%. Therefore, both transport modes show an increase in sulphur dioxide emissions.

With respect to assumption (2), of a carbon footprint approximation based on a simplified modal split of individual- and public transport in 1987, IT defines a share of 57.3% and PT accounts for 42.46%. In 2005, which is used as the year 2011' substitute, individual transport represents a share of 52% and PT a share of 48%. The estimations disclose 2,454.86 tons of carbon dioxide, per trip and day for the year 1987 and 2,278.58 tons of carbon dioxide to be emitted in 2011. Accordingly, carbon emissions are reduced by -6.81%. The mitigation effect of public transport is remarkable. As it is previously outlined under assumption (1) of all commuters to travel by IT only, emissions would increase by 1%. Hence, the share of the mitigated PT, diminishes the entire commuter carbon footprint.

Additionally, the greenhouse gas precursors and other pollutants, which are subject to European mitigation policies are observed in correspondence to the second assumption's modal split for the years 1987 and 2011. Again, all individual transport pollutants, except for sulphur dioxide, decrease in their absolute emissions. Carbon monoxide emissions decrease by -98.63%, nitrogen oxide emissions are mitigated by -51.33%, non-methane hydrocarbon emissions are reduced by -67.84% and particulate matter decreases by -29.68%. Again, sulphur dioxide emissions absolutely increase by +35.34%.

In consideration of carbon dioxide emissions, the conducted business-as-usual scenario for individual- and public transport additionally confirms the technical improvements, since they point out the outweighed impact in the commuter increase. Furthermore, two future outlook-scenarios are investigated on. The European Union declares to limit direct carbon dioxide emissions to 95 grams of carbon dioxide for the new car fleet by the year 2020, which represents that carbon emissions are to be cut by -54.72% in comparison to the year 2011. The Deutsche Bahn declares to be emission-free by the year 2050. As well as the SWM plans to run U-Bahn and tram by green electricity by the year 2025. Accordingly, carbon dioxide emissions are to be mitigated by -81.89% in comparison to the year 2011. However, these goals are built on vague estimations and limitations, such as the 2020 IT goal does not comprise the upstream chain as well as it only analyses the new car fleet and not the actual composition of old and new cars on the streets. Additionally, PT still comprises an individual transport share, which comprises the year 2020's emission goal. Therefore these future estimations only serve as a direction giving estimation.

The significant reductions with respect to carbon monoxide, non-methane hydrocarbons and nitrogen oxides, lead to a lower composition of ground level ozone, which may hence, decreasingly harm vegetation. Ground level ozone for instance, inhibits plants to produce or store food as well as it causes leaf injury, which is thus, reduced. Additionally, the mitigation of carbon monoxide leads to a decreased formation of carbon dioxide, which results in a lower contribution to the positive radiation of carbon dioxide. To continue these mitigations should in the future result in a stabilisation of temperature increase, which decelerates the sea level rise as well as mitigates the future predictions of heavy storms, hurricanes, droughts as well as the population may under the given conditions still be able to adapt to the permanent environmental changes.

Furthermore, nitrogen oxide reduction leads to a lower degree of soil acidification as well as non-methane hydrocarbon reduction results in fewer reactions with nitrogen oxides and light to form ground level ozone, which does hence, implicate fewer plants to be affected. The decreased particulate matter emissions lead to a lower alteration of nutrient and chemical cycles as well as buildings are facing a lower impact of surface soiling.

Therefore, with respect to the European emission standardisation for carbon monoxide, nitrogen oxides, non-methane hydrocarbons and particulate matter, policies may be regarded successful in the sense of absolute mitigation.

Nevertheless, the increase in sulphur dioxide results in a higher degree of acid rain as well as increasing soil and water acidification. Sulphur dioxide is slightly mitigated per person for IT and increased per person for public transport. The sulphur dioxide emission factor for individual transport decreases by -24.41% and by -32.76% for PLT as well as by -20.94% for LPT. However, this mitigation is not sufficient to outweigh the increase in commuters.

To put it into a nutshell, the greenhouse gas carbon dioxide and the corresponding carbon footprint are effectively mitigated under the assumption (2) of a simplified modal split. Accordingly, concerning carbon dioxide and the corresponding mixed modal split, the global warming effect may be considered decelerated. Furthermore, the pollutants, which are subject to the European standardisation programme, are significantly mitigated. Although sulphur dioxide is not part of the standardisation, it nevertheless is a strong pollutant, human irritant and an acid to water and soil, which is hence, subject to further mitigation measures, such as better antecedent filtration of fuel before the combustion process.

The conducted carbon footprint and pollutant footprint analyses may further be improved by encompassing for instance, buses and further transport modes into the analysis of the public transport's individual transport share. Furthermore, a mixed modal split can be conducted to observe future-outlook- and BAU scenarios. Additionally, the PT's individual transport share in 1987 is estimated by the application of a non-adapted IT emission factor, which can be further specified according to the available car fleet. With respect to BAU- and future scenarios, the selected pollutants can be taken into account and projected as previously conducted for carbon dioxide to observe the technical adoptions, future estimations and impacts. Furthermore, other greenhouse gases, such as methane, nitrous oxides and F-gases, can extend the carbon footprint to derive a more specific greenhouse effect evaluation.

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11. ADDENDUM

The car fleet profile data with respect to the engine type and cubic capacity ranges for the year 1987.

UEBERSICHT 2 - BESTAND NACH ZULASSUNGSBEZIRKEN AM 1. JULI 1987 (FORTSETZUNG)

ZULASSUNGSBEZIRK (KREISFREIE STADT BZW. LANDKREIS)	KRAFTRAEDER ZUSAMMEN	KRAFTRAEDER DAVON LEICHT-KRAFT-RAEDER	KRAFTRAEDER DAVON MOTOR-ROLLER	KRAFTRAEDER DAVON MOTOR-RAEDER	PERSONENKRAFTWAGEN INSGESAMT1)	UND ZWAR MIT DIESEL-ANTRIEB	MIT HUBKOLBENMOTOR VON ... CM3 HUBRAUM BIS 999	1000 BIS 1499	1500 BIS 1999	2000 UND MEHR
	1	2	3	4	5	6	7	8	9	10
					BAYERN					
RB OBERBAYERN										
KREISFREIE STAEDTE										
INGOLSTADT	3 104	696	269	2 139	50 709	5 623	3 070	14 559	25 080	7 981
MUENCHEN	26 699	4 473	2 181	20 045	546 485	61 510	35 635	144 037	250 068	116 466
ROSENHEIM	1 323	232	89	1 002	24 030	3 285	2 138	7 381	10 587	3 911
LANDKREISE										
ALTOETTING	3 171	779	233	2 159	44 740	5 505	3 554	14 364	20 898	5 909
BAD TOELZ-WOLFRATSHS.	3 357	728	158	2 471	50 076	6 506	3 673	15 045	23 093	8 237
BERCHTESGADENER LAND	2 852	660	146	2 046	42 338	4 782	3 472	14 940	18 545	5 363
DACHAU	3 462	955	141	2 366	49 713	6 745	3 877	14 709	23 069	8 041
EBERSBERG	3 003	694	130	2 179	46 684	6 021	3 886	13 828	21 335	7 617
EICHSTAETT	3 004	983	149	1 872	44 428	5 672	2 890	14 428	22 263	4 842
ERDING	2 563	664	86	1 813	42 614	6 854	3 295	13 200	19 993	6 114
FREISING	3 697	955	180	2 562	58 450	8 586	4 844	17 339	27 200	9 042
FUERSTENFELDBRUCK	5 144	1 044	336	3 764	81 221	9 206	6 463	23 699	37 620	13 405
GARMISCH-PARTENKIRCHEN	3 226	615	101	2 510	37 332	3 873	2 940	12 377	16 012	5 990
LANDSBERG A.LECH	3 038	784	151	2 103	42 339	5 008	3 521	14 309	18 831	5 662
MIESBACH	2 707	591	117	1 999	42 715	5 382	3 158	12 900	19 268	7 361
MUEHLDORF A.INN	2 842	677	116	2 049	43 482	6 074	3 535	13 929	20 062	5 939
MUENCHEN	7 099	1 370	465	5 264	130 421	15 392	9 737	34 610	59 651	26 352
NEUBURG-SCHROBENHAUSEN	2 132	667	114	1 351	35 504	4 339	2 566	11 968	16 620	4 339
PFAFFENHOFEN A.D.ILM	3 121	1 186	135	1 800	44 080	6 637	2 845	13 211	21 611	6 395
ROSENHEIM	5 681	1 432	275	3 974	93 562	13 664	8 014	30 341	41 413	13 752
STARNBERG	3 610	741	243	2 626	57 225	6 472	4 430	17 259	24 371	11 123
TRAUNSTEIN	4 592	1 127	226	3 239	71 349	9 921	5 729	23 971	32 439	9 189
WEILHEIM-SCHONGAU	3 971	762	186	3 023	52 457	6 455	3 788	17 416	24 139	7 093
RB ZUSAMMEN	103 398	22 815	6 227	74 356	1 731 954	213 512	127 060	509 820	794 168	300 123
KREISFREIE STAEDTE	31 126	5 401	2 539	23 186	621 224	70 418	40 843	165 977	285 735	128 358
LANDKREISE	72 272	17 414	3 688	51 170	1 110 730	143 094	86 217	343 843	508 433	171 765

1) EINSCHLIESSLICH DER IN DEN SPALTEN 7 BIS 10 NICHT AUSGEWIESENEN PERSONENKRAFTWAGEN MIT ROTATIONSKOLBEN- UND ELEKTRON
BUNDESGEBIET: 9 763.

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UEBERSICHT 2 - BESTAND NACH ZULASSUNGSBEZIRKEN AM 1. JULI 1987 (FORTSETZUNG)

ZULASSUNGSBEZIRK (KREISFREIE STADT BZW. LANDKREIS)	KRAFTRAEDER				PERSONENKRAFTWAGEN					
	ZU-SAMMEN	DAVON			INS-GESAMT1)	UND ZWAR				
		LEICHT-KRAFT-RAEDER	MOTOR-ROLLER	MOTOR-RAEDER		MIT DIESEL-ANTRIEB	MIT HUBKOLBENMOTOR VON ... CM3 HUBRAUM			
							BIS 999	1000 BIS 1499	1500 BIS 1999	2000 UND MEHR
	1	2	3	4	5	6	7	8	9	10
RB NIEDERBAYERN										
KREISFREIE STAEDTE										
LANDSHUT	1 548	396	148	1 004	24 006	2 788	1 884	7 556	10 908	3 651
PASSAU	1 285	328	97	860	21 408	2 640	1 797	7 002	9 454	3 149
STRAUBING	742	175	39	528	18 028	2 176	1 534	5 968	7 721	2 796
LANDKREISE										
DEGGENDORF	2 843	916	115	1 812	47 246	5 951	3 695	16 700	21 205	5 642
DINGOLFING-LANDAU	2 298	957	59	1 282	36 541	5 153	2 548	11 335	17 006	5 642
FREYUNG-GRAFENAU	2 135	820	40	1 275	32 551	4 130	2 556	11 782	14 929	3 276
KELHEIM	2 932	1 033	130	1 769	42 156	5 648	2 862	13 446	20 639	5 190
LANDSHUT	4 032	1 406	138	2 488	55 658	8 670	4 452	17 849	26 127	7 217
PASSAU	4 831	1 585	146	3 100	76 191	9 795	6 276	26 612	34 760	8 515
REGEN	1 797	683	38	1 076	31 875	3 612	2 441	11 385	14 692	3 350
ROTTAL-INN	2 745	749	120	1 876	50 172	6 736	3 919	17 826	22 487	5 928
STRAUBING-BOGEN	2 094	762	47	1 285	36 451	5 057	3 082	12 887	16 464	4 004
RB ZUSAMMEN	29 282	9 810	1 117	18 355	472 283	62 356	37 046	160 348	216 392	58 360
KREISFREIE STAEDTE	3 575	899	284	2 392	63 442	7 604	5 215	20 526	28 083	9 596
LANDKREISE	25 707	8 911	833	15 963	408 841	54 752	31 831	139 822	188 309	48 764

UEBERSICHT 2 - BESTAND NACH ZULASSUNGSBEZIRKEN AM 1. JULI 1987 (FORTSETZUNG)

ZULASSUNGSBEZIRK (KREISFREIE STADT BZW. LANDKREIS)	KRAFTRAEDER				PERSONENKRAFTWAGEN					
	ZU-SAMMEN	DAVON			INS-GESAMT1)	UND ZWAR				
		LEICHT-KRAFT-RAEDER	MOTOR-ROLLER	MOTOR-RAEDER		MIT DIESEL-ANTRIEB	MIT HUBKOLBENMOTOR VON ... CM3 HUBRAUM			
							BIS 999	1000 BIS 1499	1500 BIS 1999	2000 UND MEHR
	1	2	3	4	5	6	7	8	9	10
RB SCHWABEN										
KREISFREIE STAEDTE										
AUGSBURG	5 622	1 013	422	4 187	103 050	11 423	6 895	31 264	48 839	16 015
KAUFBEUREN	1 033	184	59	790	18 184	2 143	1 316	6 007	8 289	2 563
KEMPTEN (ALLGAEU)	1 631	325	103	1 203	27 758	3 273	2 222	9 273	12 626	3 624
MEMMINGEN	1 246	192	83	971	18 334	2 659	1 355	5 844	8 405	2 719
LANDKREISE										
AICHACH-FRIEDBERG	3 144	917	119	2 108	49 715	6 836	4 028	15 629	23 153	6 892
AUGSBURG	5 870	1 348	336	4 186	92 585	11 465	6 937	29 931	42 723	12 953
DILLINGEN A.D.DONAU	2 197	686	117	1 394	36 533	4 955	2 480	11 870	17 422	4 749
DONAU-RIES	3 526	1 095	132	2 299	53 426	7 220	3 715	18 182	24 819	6 695
GUENZBURG	3 097	827	141	2 129	49 265	6 135	3 596	16 503	22 900	6 246
LINDAU (BODENSEE)	2 444	560	165	1 719	32 904	3 643	2 639	11 687	14 313	4 245
NEU-ULM	4 139	832	275	3 032	67 353	7 798	5 964	20 952	31 145	9 270
OBERALLGAEU	4 333	1 029	218	3 086	62 416	7 182	5 428	21 471	27 686	7 813
OSTALLGAEU	4 161	1 108	127	2 926	55 415	6 330	4 338	19 421	24 969	6 679
UNTERALLGAEU	3 732	885	182	2 665	55 313	7 203	4 226	18 930	25 722	6 423
RB ZUSAMMEN	46 175	11 001	2 479	32 695	722 251	88 265	55 139	236 964	333 011	96 886
KREISFREIE STAEDTE	9 532	1 714	667	7 151	167 326	19 498	11 788	52 388	78 159	24 921
LANDKREISE	36 643	9 287	1 812	25 544	554 925	68 767	43 351	184 576	254 852	71 965
LAND INSGESAMT	309 098	78 221	14 831	216 046	5 113 450	601 806	384 329	1 642 128	2 352 576	732 460
KREISFREIE STAEDTE	76 914	14 708	5 328	56 878	1 478 852	161 021	103 641	433 085	681 782	259 669
LANDKREISE	232 184	63 513	9 503	159 168	3 634 598	440 785	280 688	1 209 043	1 670 794	472 791

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Bundesagentur für Arbeit
Statistik

Sozialversicherungspflichtig Beschäftigte am Wohn- und Arbeitsort nach Kreisen mit
Bayern
Stichtag: 30.06.2011 [1)]

Wohnort		Arbeitsort		Insgesamt
				1
09161	Ingolstadt, Stadt			
		09162	München, Landeshauptstadt	2.103
09162	München, Landeshauptstadt			
		09161	Ingolstadt, Stadt	1.156
		09162	München, Landeshauptstadt	384.376
		09163	Rosenheim, Stadt	546
		09171	Altötting	169
		09173	Bad Tölz-Wolfratshausen	1.423
		09174	Dachau	3.974
		09175	Ebersberg	4.451
		09176	Eichstätt	221
		09177	Erding	1.452
		09178	Freising	9.402
		09179	Fürstenfeldbruck	5.489
		09180	Garmisch-Partenkirchen	239
		09181	Landsberg am Lech	689
		09182	Miesbach	1.483
		09183	Mühldorf a.Inn	218
		09184	München	61.925
		09185	Neuburg-Schrobenhausen	204
		09186	Pfaffenhofen a.d.Ilm	958
		09187	Rosenheim	1.113
		09188	Starnberg	6.105
		09189	Traunstein	250
		09190	Weilheim-Schongau	924
		09261	Landshut, Stadt	424
		09273	Kelheim	176
		09274	Landshut	289
		09279	Dingolfing-Landau	113
		09761	Augsburg, Stadt	1.403
		09762	Kaufbeuren, Stadt	62
		09771	Aichach-Friedberg	269
		09772	Augsburg	266
		09773	Dillingen a.d.Donau	38
		09777	Ostallgäu	434
		09779	Donau-Ries	223
		09780	Oberallgäu	76
		097	Schwaben	3.222
09163	Rosenheim, Stadt			
		09162	München, Landeshauptstadt	1.964
09171	Altötting			
		09162	München, Landeshauptstadt	1.203

09173	Bad Tölz-Wolfratshausen	09162 München, Landeshauptstadt	6.803
09174	Dachau	09162 München, Landeshauptstadt	24.035
09175	Ebersberg	09162 München, Landeshauptstadt	18.333
09176	Eichstätt	09162 München, Landeshauptstadt	1.030
09177	Erding	09162 München, Landeshauptstadt	11.349
09178	Freising	09162 München, Landeshauptstadt	15.740
09179	Fürstenfeldbruck	09162 München, Landeshauptstadt	32.343
09180	Garmisch-Partenkirchen	09162 München, Landeshauptstadt	1.747
09181	Landsberg am Lech	09162 München, Landeshauptstadt	6.118
09182	Miesbach	09162 München, Landeshauptstadt	5.698
09183	Mühldorf a.Inn	09162 München, Landeshauptstadt	3.982
09184	München	09162 München, Landeshauptstadt	55.726
09185	Neuburg-Schrobenhausen	09162 München, Landeshauptstadt	1.265
09186	Pfaffenhofen a.d.Ilm	09162 München, Landeshauptstadt	7.654
09187	Rosenheim	09162 München, Landeshauptstadt	7.206
09188	Starnberg	09162 München, Landeshauptstadt	13.807
09189	Traunstein	09162 München, Landeshauptstadt	1.795
09190	Weilheim-Schongau	09162 München, Landeshauptstadt	4.507
09261	Landshut, Stadt	09162 München, Landeshauptstadt	1.866
09273	Kelheim	09162 München, Landeshauptstadt	1.907
09274	Landshut	09162 München, Landeshauptstadt	3.635
09279	Dingolfing-Landau	09162 München, Landeshauptstadt	1.692
09761	Augsburg, Stadt	09162 München, Landeshauptstadt	6.513
09762	Kaufbeuren, Stadt	09162 München, Landeshauptstadt	510
09771	Aichach-Friedberg	09162 München, Landeshauptstadt	5.005
09772	Augsburg	09162 München, Landeshauptstadt	3.838
09773	Dillingen a.d.Donau	09162 München, Landeshauptstadt	481
09777	Ostallgäu	09162 München, Landeshauptstadt	1.494
09779	Donau-Ries	09162 München, Landeshauptstadt	690

Erstellungsdatum: Februar 2012, Zentraler Statistik-Service

Bundesagentur für Arbeit (2012), "Sozialversicherungspflichtig Beschäftigte am Wohn- und Arbeitsort nach Kreisen mit Angaben zu den Auspendlern" (see

pp.14; 30; 36; 37; 51; 52; 53; 55; 56; 58; 60; 61; 62; 63; 64; 65; 66; 67; 68; 69; 70; 71; 77; 78; 124-136).

Information about the number of cars in the city of Munich and the surrounding Planning Region 14.

Daten, Zahlen, Fakten

Wie entwickelt sich die Einwohnerzahl im Verbundraum? Und wie der Autoverkehr? Wie viele Trambahnen sind unterwegs? Und wie lang ist die Streckenlänge der MVV-Regionalbusse?

- **Verbundraumdaten 2011**
- **Statistiken rund um den MVV**
- **Strecken- und Linienlängen 2011**
- **Fahrzeuge 2011**
- **Berichte nach VO 1370**

Verbundraumdaten 2011

Einwohner-Entwicklung
Im Jahr 2011 ist die Bevölkerung der Landeshauptstadt München um 1,70 % auf 1,363 Mio. gegenüber dem Vorjahr angestiegen.

In den Landkreisen und Gemeinden des Umlandes stiegen die Einwohnerzahlen leicht um 0,93 % auf rund 1,373 Mio. Insgesamt lebten in den 175 Gemeinden des MVV-Verbundraumes rund 2,736 Mio. Menschen.

An den Münchner Universitäten, Hochschulen und Fachhochschulen waren im Wintersemester 2010/2011 circa 95.000 Studenten immatrikuliert – gegenüber ca. 85.000 im Vorjahr.Die Zahl der Schüler an den Haupt-, Real- und Berufsschulen sowie an den Gymnasien und sonstigen weiterführenden Schulen betrug im Herbst 2010 für die Landeshauptstadt München ca. 184.000 und für die Landkreise knapp 188.000 Schüler. (Dies sind die derzeit aktuellsten Zahlen.)

Größe des MVV-Gebietes
Der MVV bedient ein Gebiet von 5.470,36 km². Dies umfasst die Landeshauptstadt München mit 310,59 km² und die Landkreise Bad Tölz-Wolfratshausen, Dachau, Ebersberg, Erding, Freising, Fürstenfeldbruck, München, Starnberg sowie Teile der Landkreise Landsberg/Lech, Pfaffenhofen/Ilm, Miesbach, Weilheim-Schongau und Aichach mit 5.159,77 km².

Individualverkehr
PKW-Bestand München: 619.000
PKW-Bestand Landkreise: 803.000

Münchner Verkehrs- und Tarifverbund GmbH (n.d.), “Daten, Zahlen, Fakten: Verbundraumdaten 2011”, available at: http://www.mvv-muenchen.de/de/der-mvv/mvv-in-zahlen/index.html#c2221 (accessed 5 May 2013, see p.8).

The emission factor information as received via E-Mail by Herr Thomas Klein (Deutsche Bahn AG).

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Sehr geehrte Damen und Herren,

mein Schreiben richte ich an Sie, da ich momentan meine Masterarbeit zu dem
Thema der Pendlermobilität der Metropolregion München verfasse. Hierzu
erfasse ich momentan Daten zur Berechnung des CO2-Fußabdrucks des
Pendlerverkehrs der Jahre 2011 und 1987. Dieser Fußabdruck basiert auf der
Verwendung von Emissionsfaktoren.
      Aus dem Bericht Kennzahlen und Fakten zur Nachhaltigkeit 2011* habe
      ich folgende Emissionsfaktoren entnommen: Für den Personennahverkehr
      sind 73,2 g CO2/Pkm und für den Personenfernverkehr 41,9 g CO2/Pkm zu
      vermerken. Ist hier der anteilige Ökostrom mit dem Emissionsfaktor
      verrechnet worden?
      -> ja.
Zum Personentransport der Jahre 2011 und 1987 (oder vergleichbare
Jahrgänge) wollte ich erfragen:
      Wie viele Züge im Personenverkehr werden in Bayern mit Diesel
      und/oder Strom (absolut und in Prozent) betrieben?
      -> Hierzu kann ich Ihnen im Moment keine Angaben machen. Sofern Sie
      hierzu tatsächlich Angaben benötigen, bitte ich Sie darum, ab Mitte
      Juli nochmals anzufragen.
      Wie viel Prozent Ökostrom wird deutschland- oder bayernweit für
      Personennah- bzw. Fernverkehr verwendet?
      -> Der Anteil Erneuerbarer Energien im Bahnstrom der DB betrug 2011
      21,8%. Dieser Wert gilt für den SPNV und SPFV gleichermaßen. Angaben
      zu 1987 bzw. 1990 können wir nicht machen. Sie könnten sich hierzu an
      den BDEW wenden, vielleicht liegen dort Angaben zur damaligen
      Bundesbahn vor.
Für das Jahr 1987 (oder vergleichbare Jahrgänge):
      Können Sie mir die Emissionsfaktoren für den Personennah- und
      Fernverkehr nennen?
      -> für das Jahr 1987 liegen uns keinerlei Daten vor, da dies vor der
      Bahnreform liegt und damals in Westdeutschland noch die Bundesbahn
      existierte.
      Näherungsweise können Sie mit folgenden Werten aus dem Jahr 1990
      arbeiten: 55,1 (SPFV) und 138,8 (SPNV).
      Ist ein DB Strommix verfügbar?
      -> wie oben. Emissionsfaktor Bahnstrom für 1990: 749 g CO2/kWh
Bereits kleine Hinweise oder verfügbare Daten anderer Jahrgänge würden die
Genauigkeit meiner Arbeit enorm unterstützen. Über eine Rückmeldung würde
ich mich sehr freuen.


Vielen Dank für Ihre Zeit und mit freundlichen Grüßen,
Teresa Kreuzer

* (
http://www.deutschebahn.com/file/2832210/data/nachhaltigkeitskennzahlen_2011.pdf
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Herr Thomas Klein (Deutsche Bahn; Environmental Management and Consultancy; Responsible for Climate Protection, Energy Efficiency and Energetic Vehicle Technology; DB Environment Centre [TUM(3)]) (accessed 24 June 2013, see pp. 45; 46; 47; 48) [21].

[21] The arrow represents Herr Klein's reply to the asked questions.

The year 1990's fuel mix information as received via E-Mail by Herr Arno Seifert (Deutsche Bahn AG).

arno.seifert@deutschebahn.com
An Ich, thomas.th.klein@deutschebahn.com

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Sehr geehrte Frau Kreuzer,

wie besprochen hier Unterlagen zur Beantwortung Ihrer Fragen:


  Bahnstrommix 1990

  Wasserkraft         9,1 %
  Steinkohle/Braunkohle    28,0 %
  Gichtgas (incl. Erdgas)    10,3 %
  Mineralöl            1,0 %
  Kernkraft            21,4 %
  Umformung Netz West    12,3 %  -> öffentlicher Mix Altbundesländer
  Umformung Netz Ost    17,9 %    -> öffentlicher Mix Neue Bundesländer

  Die öffentlichen Mixe müßten Sie noch recherchieren. beispielsweise aus
  "Energie in Zahlen" vom BMWi oder öffentliche Statistik

  Zahlen zu Verkehrsleistungsanteile Diesel/ E-Traktion in Bayern halten
  wir hier nicht vor. Ich wüßte auch nicht, wo man hier nachfragen kann.
  Was ich habe sind die Betriebsleistungen der früheren
  Bundesbahndirektion München und Nürnberg von 1992:



  Bei den Emissionsfaktoren  für 1990 muß ich passen. Hinsichtlich CO2
  habe ich noch eine Veröffentlichung gefunden,  bei den übrigen
  Schadstoffen nichts.



    Die Werte für 2011  versuche ich noch zusammenzustellen


Mit freundlichen Grüßen

Arno Seifert
Umweltmanagement und -beratung,
Leiter der Fachfunktion "Energie, Klimaschutz, Luftreinhaltung,
Transportökologie und Gewässerschutz" (TUM(3))
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Herr Arno Seifert (Deutsche Bahn; head of the department Environmental Management and Consultancy; Responsible for Climate Protection, Air Monitoring; Ecological Transport and Water Conservation [TUM(3)])" (received 24 June 2013, see p.46).

The confirmation of the year 1993's emission factor information as received via E-Mail by Herr Arno Seifert (Deutsche Bahn AG).

arno.seifert@deutschebahn.com 7. Okt
An Ich

Sehr geehrte Frau Kreuzer,

diese sind Zahlen einschließlich Vorkette und stellt den Mix aus Diesel- und E-Traktion dar.

Nachrichtenverlauf ausblenden

Mit freundlichen Grüßen

Arno Seifert
Umweltmanagement und -beratung,
Leiter der Fachfunktion "Energie, Klimaschutz, Luftreinhaltung, Transportökologie und Gewässerschutz" (TUM(3))

Deutsche Bahn AG

Herr Arno Seifert (Deutsche Bahn; head of the department Environmental Management and Consultancy; Responsible for Climate Protection, Air Monitoring; Ecological Transport and Water Conservation [TUM(3)]) (reveived 7 October 2013, see p.45).

The confirmation of the CO_2-Monitoring emission factors as received via E-Mail by Frau Juliane Pötzsch (Stadtwerke München GmbH).

Poetzsch.Juliane@swm.de 22. Au
An Ich, Pedall.Guenter@swm.de

Sehr geehrte Frau Kreuzer,

ich hoffe Ihnen mit den folgenden Aussagen weiterhelfen zu können:

Hierzu wird für die UBahn des Jahres 2010 ein Wert von 21 Gramm CO2 pro Personenkilometer angegeben*.
- Wird dieser auch von Ihnen verwendet oder können Sie mir andere Angaben nennen?
Unsere Emissionsfaktoren basieren auf der CO2-Kennzeichnung der Stromlieferung der SWM, z.B.:
https://www.swm.de/dms/swm/dokumente/m-strom/stromkennzeichnung.pdf

Der angegebene Wert stammt aus dem Jahr 2010.
- Hat sich dieser für das Jahr 2011 verändert?
Falls Sie die Daten des CO2-Monitorings der Stadt München verwenden wollen können Sie wahrscheinlich die 21 Gramm CO2 pro Personenkm beibehalten.

Für das Jahr 1987 oder angrenzende Jahrgänge kann ich keinen Wert ausfindig machen.
- Können Sie mir einen CO2-Emissionsfaktor für das Jahr 1987 oder vergleichbare Jahrgänge nennen?
Da ich inklusive Vorkette rechne wollte ich zuletzt noch erfragen, ob Sie mir für die Jahre 2011 und 1987 die Emissionsfaktoren der Schadstoffe** nennen können die bei der Stromproduktion entstehen können.
Leider nein, da wir dafür keine Aufschlüsselung der Daten von den SWM erhalten (haben). Eine entsprechende Bilanzierung gibt es nur für den Geschäftsbereich Versorgung und Technik (siehe Anhang).

Für weitergehende Fragen stehe ich Ihnen gerne zur Verfügung.

Mit freundlichen Grüßen
Juliane Pötzsch
SWM - Wir fahren für die MVG
Strategische Planungsprojekte
Nachhaltigkeits- und Qualitätsmanagementbeauftragte

Frau Juliane Pötzsch (Stadtwerke München GmbH, Strategic planning projects, dedicated quality management officer) (received 22 August 2013, see p.49).

The confirmation of the city of Munich to apply GEMIS as an emission factor source, which is used in the CO_2-Monitoring as received via E-Mail by Frau Ann-Christin Krüger (Landeshauptstadt München).

Ann-Christin Krueger 25. Jun

An Ich

Sehr geehrte Frau Kreuzer,

über Umwege habe ich Ihre Anfrage gelesen. Ich kann Ihnen insofern weiterhelfen, als dass ich Ihnen sagen kann, dass die Landeshauptstadt München mit den Emissionsfaktoren aus GEMIS rechnet. Die Software ist frei verfügbar und können Sie problemlos installieren und verwenden. Hier der link: http://www.iinas.org/gemis-de.html
Die Faktoren sind mit Vorkette (Prozesse) und fachlich anerkannt und werden stetig aktualisiert!

Es könnte sein, dass die Münchner Verkehrsgesellschaft (MVG) intern andere Faktoren verwendet, die uns aber nicht vorliegen.

Mit freundlichen Grüßen,

--
Ann-Christin Krüger

Landeshauptstadt München
Referat für Gesundheit und Umwelt
Umweltschutz, Umweltvorsorge
RGU-UW 11
Team Klimaschutz, Energie

Frau Ann-Christin Krüger (Department of Health and Environment, environmental protection, environmental care, RGU-UW 11, team for climate protection and energy) (received 25 June 2013, see p.49).

The year 1987's number of in-commuters with respect to the selected transport mode.

Volkszählung(Pendler): Gemeinden, Auspendler/Einpendler/ innergemeindliche Pendler,Verkehrsmittel(6)/Zeitaufwand(4), Stichtag

Volkszählung
25.05.1987

Gemeinden Bayerns (einschl. gemeindefreie Gebiete)		Berufseinpendler (Tagespendler) überwiegend benutztes Verkehrsmittel						
		Insgesamt	kein Verkehrsmittel (zu Fuß)	PKW	U-Bahn, S-Bahn, Straßenbahn	Eisenbahn	Bus, sonstiges öffentliches Verkehrsmittel	Fahrrad, so.Verkehrsmittel (Motorrad, Moped, Mofa)
		Anzahl	Anzahl	Anzahl	Anzahl	Anzahl	Anzahl	Anzahl
09	Bayern	2029349	7281	1555532	104700	91912	201927	67997
091	Oberbayern	679121	2370	477563	94489	34212	50160	20327
09161	Ingolstadt (Krfr.St)	33353	21	23901	-	602	8161	668
09162	München, Landeshauptstadt	251492	556	141459	72217	24659	10304	2297
09163	Rosenheim (Krfr.St)	16581	59	12799	-	1527	1295	901
09171	Altötting (Lkr)	20280	96	13483	-	144	4967	1590

Bayerisches Landesamt für Statistik und Datenverarbeitung (n.d.a), "Volkszählung (Pendler). Gemeinden, Auspendler/ Einpendler /innergemeindliche Pendler, Verkehrsmittel(6)/ Zeitaufwand(4), Stichtag", available at: https://www.statistikdaten.bayern.de/genesis/online/data?operation=abruftabelleAbrufen&selectionname=12111-401r&levelindex=1&levelid=1386285691045&index=1 (accessed 10 May 2013, see pp.68; 69).

Excerpt of the individual transport carbon dioxide and pollutan emission calculation for the year 2011.

Cities and rural districts (R.D.) (2011)		In-commuters from R.D.s to Munich	Out-commuters from Munich to R.D.s	Sum of in- and out-commuters	Fuel type		
		Total	Total		Total	Gasoline	Diesel
0916	Ingolstadt (City)	2103	1156	3259	84943	51791	32132
0916	Munich (City)	.	.	.	663127	419398	238535
0916	Rosenheim (City)	1964	546	2510	31309	20776	10310
0917	Altötting	1203	169	1372	61884	43194	18176
0917	Bad Tölz-Wolfratshausen	6803	1423	8226	70742	45567	24495
0917	Dachau	24035	3974	28009	76742	52720	23423
0917	Ebersberg	18333	4451	22784	71195	46631	24003
0917	Eichstätt	1030	221	1251	70677	45969	24075
0917	Erding	11349	1452	12801	74667	49102	24873
0917	Freising	15740	9402	25142	93483	59162	33382
0917	Fürstenfeldbruck	32343	5498	37841	108635	75487	32146
09180	Garmisch-Partenkirchen	1747	239	1986	46598	32044	14134
0918	Landsberg am Lech	6118	689	6807	68390	44064	23521
0918	Miesbach	5698	1483	7181	57411	36912	19949
0918	Mühldorf a.Inn	3982	218	4200	62879	43168	19097
0918	München	55726	61925	117651	221552	132582	87518
0918	Neuburg-Schrobenhausen	1265	204	1469	54767	36566	17706
0918	Pfaffenhofen a.d.Ilm	7654	958	8612	69757	44696	24118
0918	Rosenheim	7206	1113	8319	145445	96033	48226
0918	Starnberg	13807	6054	19861	78795	51050	27159
0918	Traunstein	1795	250	2045	100788	67799	32180
0919	Weilheim-Schongau	4507	924	5431	76096	50836	24523
0926	Landshut (City)	1866	424	2290	31980	21480	10176
0927	Kelheim	1907	176	2083	68037	43628	23296
0927	Landshut (R.D.)	3635	289	3924	91667	59547	30986
0927	Dingolfing-Landau	1692	113	1805	56645	39946	18995
0976	Augsburg (City)	6513	1403	7916	119803	84601	33539
09762	Kaufbeuren (City)	510	62	572	21238	14739	6241
0977	Aichach-Friedberg	5005	269	5274	74848	51672	22332
0977	Augsburg (R.D.)	3838	266	4104	141968	101117	39287
0977	Dillingen a.d.Donau	481	38	519	56635	39465	16584
0977	Ostallgäu	1494	434	1928	77810	52237	24585
0977	Donau-Ries	690	223	913	79448	54074	24640
	Sum	247660	102365	358085	3209961	2108053	1074342

Fuel type share in %				Rural districts			Munich			
Gasoline share (%)	Diesel share (%)	Munich's share of gas. engines	Munich's share of dies. engines	0-1.5l	1.5-2l	>2l	0-1.5l share in %	1.5-2l share in %	>2l share in %	Not emission-reduced (no. of vehicles)
60.97	37.8	63.246	35.9712	26.4	52.3	21.3	22.7	53.7	23.6	1306
63.25	36	63.246	35.9712	22.7	53.7	23.6	22.7	53.7	23.6	15710
66.36	32.9	63.246	35.9712	29.7	50.5	19.8	22.7	53.7	23.6	397
69.80	29.4	63.246	35.9712	28.7	54.9	16.4	22.7	53.7	23.6	574
64.41	34.6	63.246	35.9712	27.9	52.3	19.7	22.7	53.7	23.6	970
68.70	30.5	63.246	35.9712	28.7	52.7	31.6	22.7	53.7	23.6	652
65.50	33.7	63.246	35.9712	26.9	53.2	19.8	22.7	53.7	23.6	765
65.04	34.1	63.246	35.9712	29.1	55.4	15.5	22.7	53.7	23.6	868
65.76	33.3	63.246	35.9712	28.5	54.1	17.4	22.7	53.7	23.6	722
63.29	35.7	63.246	35.9712	26.9	54.4	18.7	22.7	53.7	23.6	970
69.49	29.6	63.246	35.9712	28.6	52.1	19.3	22.7	53.7	23.6	1202
68.77	30.3	63.246	35.9712	30.3	50.8	18.9	22.7	53.7	23.6	539
64.43	34.4	63.246	35.9712	28.9	53.4	17.7	22.7	53.7	23.6	779
64.29	34.7	63.246	35.9712	27.1	51.5	21.4	22.7	53.7	23.6	773
68.65	30.4	63.246	35.9712	30	53.2	16.8	22.7	53.7	23.6	494
59.84	39.5	63.246	35.9712	22.8	54.3	22.8	22.7	53.7	23.6	2605
66.77	32.3	63.246	35.9712	27.6	55.1	17.2	22.7	53.7	23.6	458
64.07	34.6	63.246	35.9712	26.8	55.3	17.9	22.7	53.7	23.6	691
66.03	33.2	63.246	35.9712	29.7	51.9	18.4	22.7	53.7	23.6	1694
64.79	34.5	63.246	35.9712	25.1	50.2	24.7	22.7	53.7	23.6	1433
67.27	31.9	63.246	35.9712	29.8	54.3	15.9	22.7	53.7	23.6	1391
66.81	32.2	63.246	35.9712	28.7	53.8	17.5	22.7	53.7	23.6	1054
67.17	31.8	63.246	35.9712	29	53.2	17.8	22.7	53.7	23.6	288
64.12	34.2	63.246	35.9712	28.2	56	15.8	22.7	53.7	23.6	543
64.96	33.8	63.246	35.9712	27.2	56	16.8	22.7	53.7	23.6	653
70.52	33.5	63.246	35.9712	25.6	57.5	16.8	22.7	53.7	23.6	445
70.62	28	63.246	35.9712	29.5	52.1	18.3	22.7	53.7	23.6	1321
69.40	29.4	63.246	35.9712	33.7	50.6	15.8	22.7	53.7	23.6	241
69.04	29.8	63.246	35.9712	29.3	53.1	17.6	22.7	53.7	23.6	684
71.23	27.7	63.246	35.9712	30.3	52.1	17.5	22.7	53.7	23.6	1496
69.68	29.3	63.246	35.9712	29.8	54.2	16	22.7	53.7	23.6	550
67.13	31.6	63.246	35.9712	31.9	52.6	15.5	22.7	53.7	23.6	639
68.06	31	63.246	35.9712	28.3	55	16.7	22.7	53.7	23.6	600
66.55	32.6									Sum

Share of Euro norms in comparison to all emission reduced cars

Input										
							gas.			
Euro 1	Euro 2	Euro 3	Euro 4	Euro 5	Euro 6	Others	Gasoline engines emission-reduced (no. Of vehicles)	Euro 1 share	Euro 2 share	Euro 3 share
2878	10458	4793	18778	12971	0	1754	51632	5.57	20.3	9.28
29322	85712	53079	164878	72777	0	4532	410300	7.15	20.9	12.9
1151	4441	2631	9801	2561	0	83	20668	5.57	21.5	12.7
2257	9698	6021	20667	4404	0	189	43236	5.22	22.4	13.9
2679	9903	6352	21215	4901	0	329	45379	5.9	21.8	14
2968	11664	7775	24602	5515	0	241	52765	5.62	22.1	14.7
2516	9815	6386	22089	5470	0	235	46511	5.41	21.1	13.7
2911	11781	4806	21335	4799	0	234	45866	6.35	25.7	10.5
2697	11039	7092	23296	4886	0	167	49177	5.48	22.4	14.4
3758	13791	8426	26773	6122	0	363	59233	6.34	23.3	14.2
4574	16667	10742	35087	7975	0	404	75449	6.06	22.1	14.2
1915	6820	4636	15011	3421	0	192	31995	5.99	21.3	14.5
2656	9006	6228	20431	4539	0	315	43175	6.15	20.9	14.4
2178	7363	4831	17761	4391	0	253	36777	5.92	20	13.1
2542	10506	6140	19791	4149	0	224	43352	5.86	24.2	14.2
6693	23187	16491	57561	27080	0	632	131644	5.08	17.6	12.5
2483	10003	5011	15733	3181	0	247	36658	6.77	27.3	13.7
2825	10840	6058	20458	4545	0	285	45011	6.28	24.1	13.5
5540	21044	12707	45397	10331	0	680	95699	5.79	22	13.3
2904	9532	6889	24103	6556	0	324	50308	5.77	18.9	13.7
3960	14749	9061	32148	7294	0	278	67490	5.87	21.9	13.4
3296	12313	7461	22667	4717	0	276	50730	6.5	24.3	14.7
1226	4881	2998	10018	2326	0	97	21546	5.69	22.7	13.9
2441	10454	5883	20871	4348	0	260	44257	5.52	23.6	13.3
3667	14865	8635	27323	5252	0	377	60119	6.1	24.7	14.4
2375	9066	5263	16121	4188	0	253	37266	6.37	24.3	14.1
5282	19817	12156	37308	10188	0	371	85122	6.21	23.3	14.3
799	3242	2013	7129	1589	0	47	14819	5.39	21.9	13.6
2995	12169	7508	23858	5113	0	260	51903	5.77	23.4	14.5
5636	23109	14529	46805	10846	0	439	101364	5.56	22.8	14.3
2352	9806	5900	17895	3505	0	137	39595	5.94	24.8	14.9
3090	12283	7464	24225	5266	0	352	52680	5.87	23.3	14.2
3677	14543	7847	23224	4820	0	283	54394	6.76	26.7	14.4
128243	464567	283812	934359	270026	0	15113	2096120			
6.1181	22.163	13.54	44.576	12.882	0	0.721				

Euro 4 share	Euro 5 share	Euro 1 share Munich	Euro 2 share Munich	Euro 3 share Munich	Euro 4 share Munich	Euro 5 share Munich	Euro 1	Euro 2	Euro 3	Euro 4	Euro 5
36.4	25.1	7.1465	20.89	12.937	40.185	17.738	329	2773	5448	6947	15126
40.2	17.7	7.1465	20.89	12.937	40.185	17.738	2420	17749	44251	72679	95916
47.4	12.4	7.1465	20.89	12.937	40.185	17.738	131	1338	2879	3434	2405
47.8	10.2	7.1465	20.89	12.937	40.185	17.738	266	2329	5136	6857	3341
46.8	10.8	7.1465	20.89	12.937	40.185	17.738	418	3330	6854	8669	4881
46.6	10.5	7.1465	20.89	12.937	40.185	17.738	344	2845	6674	8961	4256
47.5	11.8	7.1465	20.89	12.937	40.185	17.738	293	2637	6454	9319	4975
46.5	10.5	7.1465	20.89	12.937	40.185	17.738	392	3720	7179	8576	3932
47.4	9.94	7.1465	20.89	12.937	40.185	17.738	335	3100	7014	9697	4489
45.2	10.3	7.1465	20.89	12.937	40.185	17.738	522	4026	8826	12496	7075
46.5	10.6	7.1465	20.89	12.937	40.185	17.738	496	3800	8853	12099	6395
46.9	10.7	7.1465	20.89	12.937	40.185	17.738	361	2239	4127	4748	2390
47.3	10.5	7.1465	20.89	12.937	40.185	17.738	321	3985	6421	8582	4871
48.3	11.9	7.1465	20.89	12.937	40.185	17.738	285	2414	5526	7131	4309
45.7	9.57	7.1465	20.89	12.937	40.185	17.738	337	2735	5578	7032	3167
43.7	20.6	7.1465	20.89	12.937	40.185	17.738	620	5692	16238	25893	38241
42.9	8.68	7.1465	20.89	12.937	40.185	17.738	236	2563	5189	6666	2837
45.5	10.1	7.1465	20.89	12.937	40.185	17.738	341	3330	6811	9193	4198
47.4	10.8	7.1465	20.89	12.937	40.185	17.738	741	6589	14047	17579	8641
47.9	13	7.1465	20.89	12.937	40.185	17.738	320	2887	6860	9820	6896
47.6	10.8	7.1465	20.89	12.937	40.185	17.738	567	4456	9324	11726	5636
44.7	9.3	7.1465	20.89	12.937	40.185	17.738	461	3749	7203	8693	3959
46.5	10.8	7.1465	20.89	12.937	40.185	17.738	139	1137	2639	3751	2387
47.2	9.82	7.1465	20.89	12.937	40.185	17.738	289	2703	6396	9327	4347
45.4	8.74	7.1465	20.89	12.937	40.185	17.738	453	4120	8743	11819	5500
43.3	11.2	7.1465	20.89	12.937	40.185	17.738	281	2213	4961	6800	4520
43.8	12	7.1465	20.89	12.937	40.185	17.738	394	3307	8324	12001	8963
48.1	10.7	7.1465	20.89	12.937	40.185	17.738	92	783	1796	2348	1104
46	9.85	7.1465	20.89	12.937	40.185	17.738	317	2973	6329	8666	3790
46.2	10.7	7.1465	20.89	12.937	40.185	17.738	559	4642	10878	15429	7213
45.2	8.85	7.1465	20.89	12.937	40.185	17.738	238	2241	4802	6475	2625
46	10	7.1465	20.89	12.937	40.185	17.738	452	3638	7207	8892	4043
42.7	8.86	7.1465	20.89	12.937	40.185	17.738	244	3650	7031	9173	4161
						Sum	13994	1E+05	3E+05	4E+05	3E+05
			Share of Euro norms in comparison to all emission reduced cars				1.309	11.19	24.87	34.74	26.8

			Fuel type: Gasoline Emission class: Euro 1 Cubic capacity (cc): 0-1.4l								
Euro 5 shareMunich	Mean dist. (km)	Mean time per car (min)	Emission factor (g/ PKM)	gCO2/ dist.	kgCO2 / dist.	tCO2/ dist.	CO_2/ R.D./ in-commuters	CO_2/ R.D./ out-commuters	gas. share/ R.D./ in-commuters	gas. share/ R.D./ in-commuters	CC share/ in-commuters
40.451	83.15	60	201	16713	16.71	0.017	35.148	19.32	21.43	12.219	5.6513
40.451											
40.451	70.35	58	201	14140	14.14	0.014	27.772	7.7206	18.429	4.883	5.4776
40.451	105.8	93.7	201	21269	21.27	0.021	25.586	3.5944	17.859	2.2733	5.125
40.451	53.56	50.6	201	10766	10.77	0.011	73.242	15.32	47.178	9.6894	13.173
40.451	35.91	40.1	201	7218	7.218	0.007	173.49	28.685	119.18	18.142	34.19
40.451	37.88	42.1	201	7613	7.613	0.008	139.57	33.886	91.416	21.431	24.595
40.451	113.6	86	201	22830	22.83	0.023	23.515	5.0454	15.294	3.191	4.4564
40.451	51.54	48.7	201	10360	10.36	0.01	117.57	15.042	77.316	9.5135	22.02
40.451	52.73	47.7	201	10599	10.6	0.011	166.83	99.652	105.58	63.025	28.384
40.451	36.68	38.2	201	7373	7.373	0.007	238.47	40.538	165.71	25.638	47.449
40.451	86.5	70.2	201	17386	17.39	0.017	30.373	4.1551	20.886	2.6279	6.3217
40.451	62.53	52.9	201	12568	12.57	0.013	76.89	8.6593	49.541	5.4766	14.328
40.451	53.39	50.6	201	10732	10.73	0.011	61.152	15.916	39.317	10.066	10.666
40.451	77.42	75.1	201	15560	15.56	0.016	61.962	3.3922	42.538	2.1454	12.746
40.451	18.41	26.5	201	3700	3.7	0.004	206.18	229.11	123.38	144.9	28.187
40.451	92.03	74.5	201	18498	18.5	0.018	23.4	3.7736	15.623	2.3866	4.3153
40.451	68.01	55.4	201	13671	13.67	0.014	104.64	13.097	67.044	8.283	17.963
40.451	75.23	69.2	201	15122	15.12	0.015	108.97	16.831	71.949	10.645	21.403
40.451	33.05	35.5	201	6644	6.644	0.007	91.732	40.222	59.432	25.439	14.895
40.451	108.1	93.2	201	21724	21.72	0.022	38.994	5.4309	26.231	3.4348	7.8097
40.451	74.89	63.4	201	15052	15.05	0.015	67.841	13.908	45.321	8.7964	13.018
40.451	78.55	59.5	201	15789	15.79	0.016	29.461	6.6943	19.788	4.2339	5.7434
40.451	106	76.2	201	21312	21.31	0.021	40.642	3.7509	26.061	2.3723	7.3529
40.451	87.84	69.1	201	17656	17.66	0.018	64.18	5.1026	41.691	3.2272	11.335
40.451	118.6	93.3	201	23842	23.84	0.024	40.341	2.6941	28.448	1.7039	7.2877
40.451	81	62.5	201	16281	16.28	0.016	106.04	22.842	74.881	14.447	22.121
40.451	93.55	71	201	18804	18.8	0.019	9.5898	1.1658	6.6553	0.7373	2.2406
40.451	63.41	59.9	201	12746	12.75	0.013	63.796	3.4288	44.042	2.1685	12.899
40.451	90.79	69.1	201	18249	18.25	0.018	70.04	4.8543	49.886	3.0701	15.131
40.451	127.6	94.4	201	25645	25.64	0.026	12.335	0.9745	8.5955	0.6163	2.5596
40.451	108.6	79.6	201	21829	21.83	0.022	32.613	9.4739	21.894	5.9918	6.9831
40.451	136	97.6	201	27339	27.34	0.027	18.864	6.0967	12.839	3.8559	3.6318
Mean	**77.59**	**64.5**									

Carbon dioxide										
			Fuel type: Diesel Emission class: Euro 1 Cubic capacity (cc): 0-1.4l							
CC share/ out-com-muters	Share of Euro norm/ in-com-muters	Share of Euro norm/ out-com-muters	EF (g/ PKM)	gCO2/ dist.	kgCO2 / dist.	tCO2/ dist.	CO_2/ R.D./ in-com-muters	CO_2/ R.D./ out-com-muters	gas. share/ R.D./in-com-muters	gas. share/ R.D./ out-com-muters
2.7679	0.315	0.1978	117	9729	9.729	0.01	20.459	11.246	7.7392	4.0454
1.1061	0.305	0.079	117	8231	8.231	0.008	16.166	4.4941	5.3233	1.6166
0.515	0.2675	0.0368	117	12380	12.38	0.012	14.894	2.0923	4.3744	0.7526
2.1948	0.7777	0.1569	117	6267	6.267	0.006	42.634	8.9178	14.762	3.2078
4.1096	1.9232	0.2937	117	4202	4.202	0.004	100.99	16.697	30.823	6.0063
4.8546	1.3305	0.3469	117	4432	4.432	0.004	81.243	19.725	27.391	7.0952
0.7228	0.2828	0.0517	117	13289	13.29	0.013	13.688	2.9369	4.6625	1.0564
2.155	1.2076	0.154	117	6030	6.03	0.006	68.437	8.7559	22.798	3.1496
14.277	1.8008	1.0203	117	6170	6.17	0.006	97.109	58.006	34.677	20.866
5.8076	2.8765	0.415	117	4292	4.292	0.004	138.81	23.597	41.076	8.488
0.5953	0.3784	0.0425	117	10120	10.12	0.01	17.68	2.4187	5.3625	0.87
1.2406	0.8814	0.0887	117	7316	7.316	0.007	44.757	5.0405	15.393	1.8131
2.2802	0.6317	0.163	117	6247	6.247	0.006	35.596	9.2644	12.369	3.3325
0.486	0.7474	0.0347	117	9058	9.058	0.009	36.067	1.9745	10.954	0.7103
32.823	1.4331	2.3457	117	2154	2.154	0.002	120.01	133.36	47.408	47.972
0.5406	0.2923	0.0386	117	10768	10.77	0.011	13.621	2.1966	4.4036	0.7901
1.8763	1.1274	0.1341	117	7958	7.958	0.008	60.908	7.6234	21.058	2.7422
2.4112	1.239	0.1723	117	8802	8.802	0.009	63.429	9.797	21.032	3.5241
5.7624	0.8598	0.4118	117	3867	3.867	0.004	53.397	23.413	18.405	8.4219
0.778	0.4582	0.0556	117	12645	12.65	0.013	22.698	3.1613	7.2471	1.1371
1.9926	0.8458	0.1424	117	8762	8.762	0.009	39.489	8.0959	12.726	2.9122
0.9591	0.3268	0.0685	117	9190	9.19	0.009	17.149	3.8967	5.4569	1.4017
0.5374	0.4055	0.0384	117	12405	12.41	0.012	23.657	2.1834	8.1003	0.7854
0.731	0.6914	0.0522	117	10277	10.28	0.01	37.358	2.9702	12.628	1.0684
0.386	0.4645	0.0276	117	13878	13.88	0.014	23.482	1.5682	7.8743	0.5641
3.2725	1.3726	0.2339	117	9477	9.477	0.009	61.724	13.296	17.28	4.7828
0.167	0.1208	0.0119	117	10945	10.95	0.011	5.5821	0.6786	1.6404	0.2441
0.4912	0.7443	0.0351	117	7420	7.42	0.007	37.135	1.9959	11.08	0.7179
0.6954	0.8413	0.0497	117	10623	10.62	0.011	40.77	2.8256	11.282	1.0164
0.1396	0.152	0.01	117	14928	14.93	0.015	7.1802	0.5672	2.1025	0.204
1.3573	0.4096	0.097	117	12707	12.71	0.013	18.984	5.5147	5.9981	1.9837
0.8734	0.2455	0.0624	117	15914	15.91	0.016	10.981	3.5488	3.4055	1.2765

					Fuel typ					
					Emission					
					Cubic cap					
CC share/ in-com-muters	CC share/ out-com-muters	Share of Euro norm/ in-com-muters	Share of Euro norm/ out-com-muters		EF (g/ PKM)	gCO2/ dist.	kgCO 2/ dist.	tCO2/ dist.	CO_2/ R.D./ in-com-muters	CO_2/ R.D./ out-com-muters
2.0409	0.9164	0.021	0.0094		0.016	1.339	0	1E-06	0.0028	0.0015
1.5822	0.3662	0.0202	0.0037		0.016	1.133	0	1E-06	0.0022	0.0006
1.2553	0.1705	0.0185	0.0017		0.016	1.704	0	2E-06	0.002	0.0003
4.1218	0.7266	0.0706	0.0074		0.016	0.862	0	9E-07	0.0059	0.0012
8.8422	1.3605	0.1304	0.0139		0.016	0.578	0	6E-07	0.0139	0.0023
7.3694	1.6072	0.0903	0.0164		0.016	0.61	0	6E-07	0.0112	0.0027
1.3586	0.2393	0.0222	0.0024		0.016	1.829	0	2E-06	0.0019	0.0004
6.4927	0.7134	0.0878	0.0073	(...)	0.016	0.83	0	8E-07	0.0094	0.0012
9.3225	4.7265	0.1462	0.0482		0.016	0.849	0	8E-07	0.0134	0.008
11.762	1.9227	0.1824	0.0196		0.016	0.591	0	6E-07	0.0191	0.0032
1.6231	0.1971	0.0417	0.002		0.016	1.393	0	1E-06	0.0024	0.0003
4.4518	0.4107	0.061	0.0042		0.016	1.007	0	1E-06	0.0062	0.0007
3.3555	0.7549	0.0482	0.0077		0.016	0.86	0	9E-07	0.0049	0.0013
3.2822	0.1609	0.0581	0.0016		0.016	1.246	0	1E-06	0.005	0.0003
10.831	10.867	0.0769	0.1109		0.016	0.296	0	3E-07	0.0165	0.0184
1.2163	0.179	0.0163	0.0018		0.016	1.482	0	1E-06	0.0019	0.0003
5.6422	0.6212	0.08	0.0063		0.016	1.095	0	1E-06	0.0084	0.001
6.2565	0.7983	0.0965	0.0081		0.016	1.211	0	1E-06	0.0087	0.0013
4.6127	1.9077	0.0546	0.0195		0.016	0.532	0	5E-07	0.0073	0.0032
2.1577	0.2576	0.0383	0.0026		0.016	1.74	0	2E-06	0.0031	0.0004
3.6555	0.6597	0.0693	0.0067		0.016	1.206	0	1E-06	0.0054	0.0011
1.5838	0.3175	0.0217	0.0032		0.016	1.265	0	1E-06	0.0024	0.0005
2.2854	0.1779	0.0284	0.0018		0.016	1.707	0	2E-06	0.0033	0.0003
3.4334	0.242	0.0503	0.0025		0.016	1.414	0	1E-06	0.0051	0.0004
2.0172	0.1278	0.0299	0.0013		0.016	1.91	0	2E-06	0.0032	0.0002
5.1046	1.0834	0.0603	0.0111		0.016	1.304	0	1E-06	0.0085	0.0018
0.5522	0.0553	0.0082	0.0006		0.016	1.506	0	2E-06	0.0008	9E-05
3.2451	0.1626	0.0462	0.0017		0.016	1.021	0	1E-06	0.0051	0.0003
3.4221	0.2302	0.0489	0.0023		0.016	1.462	0	1E-06	0.0056	0.0004
0.6261	0.0462	0.009	0.0005		0.016	2.054	0	2E-06	0.001	8E-05
1.9131	0.4493	0.0353	0.0046		0.016	1.749	0	2E-06	0.0026	0.0008
0.9633	0.2892	0.0096	0.003		0.016	2.19	0	2E-06	0.0015	0.0005

Particulate matter										
pe: Gasoline classe: Euro 5 acity (cc): 2-9l										(
gas. share/ R.D./ in-commuters	gas. share/ R.D./ in-commuters	CC share/ in-commuters	CC share/ out-commuters	Share of Euro norm/ in-commuters	Share of Euro norm/ out-commuters	EF (g/ PKM)	gCO2/ dist.	kgCO2 / dist.	tCO2/ dist.	CO_2/ R.D./ in-commuters
0.0017	0.001	0.0004	0.0002	9E-05	4E-05	0.013	1.081	0.001	1E-06	0.0023
0.0015	0.0004	0.0003	9E-05	4E-05	2E-05	0.013	0.915	9E-04	9E-07	0.0018
0.0014	0.0002	0.0002	4E-05	2E-05	8E-06	0.013	1.376	0.001	1E-06	0.0017
0.0038	0.0008	0.0007	0.0002	8E-05	3E-05	0.013	0.696	7E-04	7E-07	0.0047
0.0095	0.0015	0.003	0.0003	0.0003	6E-05	0.013	0.467	5E-04	5E-07	0.0112
0.0073	0.0017	0.0015	0.0004	0.0002	7E-05	0.013	0.492	5E-04	5E-07	0.009
0.0012	0.0003	0.0002	6E-05	2E-05	1E-05	0.013	1.477	0.001	1E-06	0.0015
0.0062	0.0008	0.0011	0.0002	0.0001	3E-05	0.013	0.67	7E-04	7E-07	0.0076
0.0085	0.005	0.0016	0.0012	0.0002	0.0002	0.013	0.686	7E-04	7E-07	0.0108
0.0133	0.0021	0.0026	0.0005	0.0003	9E-05	0.013	0.477	5E-04	5E-07	0.0154
0.0017	0.0002	0.0003	5E-05	3E-05	9E-06	0.013	1.124	0.001	1E-06	0.002
0.004	0.0004	0.0007	0.0001	7E-05	2E-05	0.013	0.813	8E-04	8E-07	0.005
0.0031	0.0008	0.0007	0.0002	8E-05	3E-05	0.013	0.694	7E-04	7E-07	0.004
0.0034	0.0002	0.0006	4E-05	5E-05	7E-06	0.013	1.006	0.001	1E-06	0.004
0.0099	0.0116	0.0023	0.0027	0.0005	0.0005	0.013	0.239	2E-04	2E-07	0.0133
0.0013	0.0002	0.0002	5E-05	2E-05	8E-06	0.013	1.196	0.001	1E-06	0.0015
0.0054	0.0007	0.001	0.0002	1E-04	3E-05	0.013	0.884	9E-04	9E-07	0.0068
0.0058	0.0009	0.0011	0.0002	0.0001	4E-05	0.013	0.978	1E-03	1E-06	0.007
0.0048	0.002	0.0012	0.0005	0.0002	9E-05	0.013	0.43	4E-04	4E-07	0.0059
0.0021	0.0003	0.0003	6E-05	4E-05	1E-05	0.013	1.405	0.001	1E-06	0.0025
0.0036	0.0007	0.0006	0.0002	6E-05	3E-05	0.013	0.974	1E-03	1E-06	0.0044
0.0016	0.0003	0.0003	8E-05	3E-05	1E-05	0.013	1.021	0.001	1E-06	0.0019
0.0021	0.0002	0.0003	4E-05	3E-05	8E-06	0.013	1.378	0.001	1E-06	0.0026
0.0033	0.0003	0.0006	6E-05	5E-05	1E-05	0.013	1.142	0.001	1E-06	0.0042
0.0023	0.0001	0.0004	3E-05	4E-05	6E-06	0.013	1.542	0.002	2E-06	0.0026
0.006	0.0012	0.0011	0.0003	0.0001	5E-05	0.013	1.053	0.001	1E-06	0.0069
0.0005	6E-05	8E-05	1E-05	9E-06	2E-06	0.013	1.216	0.001	1E-06	0.0006
0.0035	0.0002	0.0006	4E-05	6E-05	7E-06	0.013	0.824	8E-04	8E-07	0.0041
0.004	0.0002	0.0007	6E-05	7E-05	1E-05	0.013	1.18	0.001	1E-06	0.0045
0.0007	5E-05	0.0001	1E-05	1E-05	2E-06	0.013	1.659	0.002	2E-06	0.0008
0.0018	0.0005	0.0003	0.0001	3E-05	2E-05	0.013	1.412	0.001	1E-06	0.0021
0.001	0.0003	0.0002	7E-05	2E-05	1E-05	0.013	1.768	0.002	2E-06	0.0012

Fuel type: Diesel Emission classe: Euro 5 Cubic capacity (cc): 2-9l								Carbon dioxide					
CO_2/ R.D./ out-commuters	gas. share/ R.D./in-commuters	gas. share/ R.D./ out-commuters	CC share/ in-commuters	CC share/ out-commuters	Share of Euro norm/ in-commuters	Share of Euro norm/ out-commuters		Sum of CO2 emis-sions by in- and out-commuters (kg)	Emitted CO_2 per commuter (kg)	IT share in %	CO_2 share acc. to the modal split (kg)	CO_2 share acc. to the modal split (tons)	CO
0.0012	0.0009	0.0004	0.0002	0.0002	9E-05	7E-05		56789.4545	17.425	52	29531	29.531	391.7
0.0005	0.0006	0.0002	0.0001	6E-05	3E-05	3E-05		36504.1212	14.543	52	18982	18.982	292.7
0.0002	0.0005	8E-05	8E-05	3E-05	1E-05	1E-05		29098.0289	21.208	52	15131	15.131	259.2
0.001	0.0016	0.0004	0.0003	0.0001	6E-05	5E-05		89688.1283	10.903	52	46638	46.638	748
0.0019	0.0034	0.0007	0.0011	0.0002	0.0002	1E-04		235270.55	8.3998	52	1E+05	122.34	2009
0.0022	0.003	0.0008	0.0006	0.0003	0.0001	0.0001		177825.72	7.8049	52	92469	92.469	1420
0.0003	0.0005	0.0001	8E-05	4E-05	1E-05	2E-05		28577.22	22.844	52	14860	14.86	249.7
0.001	0.0025	0.0003	0.0004	0.0001	8E-05	5E-05		131235.893	10.252	52	68243	68.243	1142
0.0064	0.0039	0.0023	0.0007	0.0008	0.0002	0.0003	(...)	286282.559	11.387	52	1E+05	148.87	2125
0.0026	0.0046	0.0009	0.0009	0.0003	0.0002	0.0001		282295.657	7.46	52	1E+05	146.79	2483
0.0003	0.0006	1E-04	0.0001	3E-05	2E-05	1E-05		34414.9898	17.329	52	17896	17.896	316
0.0006	0.0017	0.0002	0.0003	7E-05	6E-05	3E-05		84623.7697	12.432	52	44004	44.004	721.6
0.001	0.0014	0.0004	0.0003	0.0001	6E-05	5E-05		79314.7075	11.045	52	41244	41.244	622.4
0.0002	0.0012	8E-05	0.0002	3E-05	3E-05	1E-05		63112.602	15.027	52	32819	32.819	613.8
0.0148	0.0053	0.0053	0.0012	0.0019	0.0005	0.0008		484130.889	4.115	52	3E+05	251.75	2970
0.0002	0.0005	9E-05	8E-05	3E-05	1E-05	1E-05		27199.1478	18.515	52	14144	14.144	250.2
0.0008	0.0023	0.0003	0.0004	0.0001	7E-05	4E-05		116350.428	13.51	52	60502	60.502	1024
0.0011	0.0023	0.0004	0.0004	0.0001	8E-05	6E-05		124969.739	15.022	52	64984	64.984	1080
0.0026	0.002	0.0009	0.0005	0.0003	0.0001	0.0001		141324.089	7.1157	52	73489	73.489	1022
0.0004	0.0008	0.0001	0.0001	5E-05	2E-05	2E-05		43854.191	21.445	52	22804	22.804	390.1
0.0009	0.0014	0.0003	0.0002	0.0001	4E-05	5E-05		82543.2919	15.199	52	42923	42.923	736.4
0.0004	0.0006	0.0002	0.0001	6E-05	3E-05	2E-05		36623.4907	15.993	52	19044	19.044	309.1
0.0002	0.0009	9E-05	0.0001	3E-05	3E-05	1E-05		42759.7537	20.528	52	22235	22.235	379.1
0.0003	0.0014	0.0001	0.0002	4E-05	4E-05	2E-05		67434.1124	17.185	52	35066	35.066	621.3
0.0002	0.0009	6E-05	0.0001	2E-05	4E-05	9E-06		44325.6184	24.557	52	23049	23.049	412.9
0.0015	0.0019	0.0005	0.0004	0.0002	9E-05	8E-05		130820.399	16.526	52	68027	68.027	1147
8E-05	0.0002	3E-05	3E-05	1E-05	5E-06	4E-06		10413.3834	18.205	52	5415	5.415	95.16
0.0002	0.0012	8E-05	0.0002	3E-05	4E-05	1E-05		65290.9748	12.38	52	33951	33.951	619.9
0.0003	0.0013	0.0001	0.0002	4E-05	4E-05	2E-05		73121.089	17.817	52	38023	38.023	693.8
6E-05	0.0002	2E-05	4E-05	8E-06	6E-06	3E-06		12964.7761	24.98	52	6742	6.7417	125.1
0.0006	0.0007	0.0002	0.0001	8E-05	2E-05	3E-05		42421.6029	22.003	52	22059	22.059	363.9
0.0004	0.0004	0.0001	6E-05	5E-05	1E-05	2E-05		25864.473	28.329	52	13450	13.45	220.3
								3187444.85	8.9014		2E+06	**1657**	25855

Sum pollutant emissions of in- and out-commuters

kg /commuter	Share of the IT modal split	NOx	kg/ commuter	Share of the IT modal split	NMHC	kg/ commuter	Share of the IT modal split	SO_2	kg/ commuter	Share of the IT modal split	PM	kg/ commuter	Share of the IT modal split
0.117	203.67	93.6	0.029	48.68	80.73	0.025	41.98	26.3	0.0078	13.7	4.31	0.001	2.244
0.107	152.22	61.8	0.025	32.14	56.16	0.022	29.2	20.2	0.0072	10.5	3.02	0.001	1.571
0.166	134.78	48.8	0.036	25.36	47.57	0.034	24.74	16.7	0.0106	8.68	2.42	0.002	1.26
0.082	388.94	157	0.019	81.85	137.2	0.017	71.36	49.4	0.0053	25.7	7.71	9E-04	4.011
0.061	1044.8	391	0.013	203.4	373.9	0.012	194.4	129	0.0039	67.1	19.3	6E-04	10.02
0.057	738.43	302	0.013	157	271	0.012	140.9	96.3	0.0038	50.1	14.6	6E-04	7.599
0.178	129.87	51.7	0.04	26.86	45.23	0.036	23.52	15.5	0.0111	8.07	2.51	0.002	1.306
0.079	593.66	232	0.018	120.6	207.7	0.016	108	74.7	0.0051	38.8	11.3	9E-04	5.895
0.081	1104.9	475	0.019	246.9	409.5	0.016	213	134	0.0051	69.8	22.6	9E-04	11.75
0.058	1291.4	472	0.013	245.4	456.3	0.012	237.3	162	0.0037	84.3	23.1	6E-04	12.02
0.138	164.33	58.9	0.03	30.61	55.86	0.027	29.05	20.5	0.0089	10.6	3	0.001	1.56
0.094	375.21	154	0.022	80.2	131.7	0.019	68.47	48.5	0.0062	25.2	7.63	0.001	3.969
0.08	323.62	136	0.019	70.73	119.3	0.017	62.05	43.4	0.0054	22.6	6.62	9E-04	3.444
0.124	319.19	112	0.027	58.47	106.6	0.025	55.44	38.2	0.0077	19.8	5.58	0.001	2.9
0.025	1544.3	762	0.006	396	651	0.006	338.5	206	0.0018	107	35.2	3E-04	18.28
0.148	130.12	49	0.033	25.48	44.01	0.029	22.89	14.8	0.009	7.69	2.35	0.002	1.22
0.105	532.47	212	0.024	110.3	183.1	0.021	95.24	64.3	0.0066	33.4	10.3	0.001	5.337
0.116	561.82	220	0.026	114.6	198	0.024	102.9	72.3	0.0076	37.6	10.9	0.001	5.653
0.049	531.56	231	0.012	120	205.6	0.01	106.9	73	0.0034	38	11.1	6E-04	5.771
0.168	202.88	76.7	0.037	39.88	70.53	0.034	36.68	25.1	0.0107	13.1	3.81	0.002	1.982
0.12	382.93	145	0.026	75.22	130.5	0.024	67.84	44.9	0.0074	23.4	7.12	0.001	3.702
0.122	160.74	62	0.027	32.25	57.49	0.025	29.89	20.1	0.0078	10.5	2.99	0.001	1.554
0.161	197.15	78.1	0.037	40.59	68.29	0.033	35.51	24.3	0.0102	12.6	3.75	0.002	1.949
0.137	323.07	124	0.031	64.42	108.5	0.027	56.44	38	0.0085	19.8	5.99	0.001	3.113
0.193	214.72	78.8	0.042	40.99	72.49	0.038	37.69	24.6	0.0117	12.8	3.77	0.002	1.96
0.129	596.32	214	0.027	111.1	212.8	0.026	110.7	72.8	0.0081	37.8	10.2	0.001	5.317
0.146	49.484	17.8	0.032	9.266	17.39	0.03	9.043	6.42	0.0096	3.34	0.89	0.002	0.461
0.1	322.35	114	0.022	59.38	109.9	0.02	57.16	39.5	0.0064	20.6	5.64	0.001	2.931
0.144	360.77	123	0.031	63.86	124.8	0.029	64.91	44.9	0.0093	23.3	6.08	0.001	3.161
0.205	65.035	22.7	0.044	11.79	21.94	0.041	11.41	7.65	0.0127	3.98	1.11	0.002	0.579
0.171	189.24	72.5	0.038	37.71	66.37	0.034	34.51	22.9	0.0108	11.9	3.58	0.002	1.862
0.218	114.56	44	0.048	22.89	40.49	0.044	21.06	13.2	0.0133	6.86	2.11	0.002	1.096
0.065	**13445**	5392	0.014	**2804**	4882	0.013	**2539**	1690	0.0042	**879**	261	7E-04	**135**

Source: Own representation based on LfStaD, 1991; n.d.c; BA, 2012 (see addendum, pp.107); GeoBasis-DE/BKG & Google Inc., n.d.a – n.d.abg (see addendum, pp.1-226); KBA, 1987 (see addendum, pp.105); 2012; UBA, 2010a – 2010aj.

Excerpt of the public transport carbon dioxide and pollutant emission calculation for the year 2011.

Input									
Cities and rural districts (R.D.) (2011)		In-commuters from R.D.s to Munich	Out-commuters from Munich to R.D.s	Distance				Mean distance	
				Distance from train station (1)	IT distance (1)	Distance from train station (2)	IT distance (2)	Mean PT distance	Mean IT distance
09161	1. Ingolstadt (City)	**2103**	**1156**	81	.	81	.	*81*	*.*
09163	2. Rosenheim (City)	In-commuters	Out-commuters	Dist. from train station (1)	IT dist. (1)	Dist. from train station (2)	IT dist. (2)	Mean PT dist.	Mean IT dist.
		1964	**546**	65	.	65	.	*65*	*.*
09171	3. Altötting (R.D.)	**1203**	**169**	Dist. from train station (1)	IT dist. (1)	Dist. from train station (2)	IT dist. (2)	Mean PT dist.	Mean IT dist.
917111	Altötting, St			98	.	98	.	*98*	*.*
917111	Burghausen, St			163	.	159	.	*161*	*.*
917111	Burgkirchen a.d.Alz			153	.	149	.	*151*	*.*
917111	Emmerting			151	5.7	147	5.7	*149*	*5.7*
917111	Erlbach			98	10.7	98	10.7	*98*	*10.7*
917111	Feichten a.d.Alz			107	3	101	7.6	*104*	*5.3*
917111	Garching a.d.Alz			101	.	208	.	*154.5*	*.*
917111	Haiming			111	7.5	111	7.5	*111*	*7.5*
917111	Halsbach			109	5.4	200	5.4	*154.5*	*5.4*
917112	Kastl			104	.	104	.	*104*	*.*
917112	Kirchweidach			109	.	200	.	*154.5*	*.*
917112	Marktl, M			111	.	111	.	*111*	*.*
917112	Mehring			117	5.2	159	5.2	*117*	*5.2*
917112	Neuötting, St			98	.	98	.	*98*	*.*
917112	Perach			98	8.1	98	8.1	*98*	*8.1*
917112	Pleiskirchen			90	6.8	92	7.3	*91*	*7.05*
917112	Reischach			98	5.6	98	5.6	*98*	*5.6*
917113	Stammham			111	2.8	111	2.8	*111*	*2.8*
917113	Teising			94	1.8	94	1.8	*94*	*1.8*
917113	Töging a.Inn, St			90	.	90	.	*90*	*.*
917113	Tüßling, M			92	.	217	.	*154.5*	*.*
917113	Tyrlaching			109	4.7	200	4.7	*154.5*	*4.7*
917113	Unterneukirchen			94	6.2	87.6	6.2	*90.8*	*6.2*
917113	Winhöring			98	4.8	91.6	4.8	*94.8*	*4.8*
			Mean	**108.5**	**5.59**	**130**	**103**	**118.421**	**5.775**
			Sum					**2842.1**	**80.85**

Travel route				Modal split									
				LPT EF		PLT EF		S-Bahn		U-Bahn		Tram	
Route (1)		Route (2)		gCO2/ PKM	EF share	gCO2/ PKM	EF share	gCO2/ PKM	EF share	gCO2/ PKM	EF share	gCO2/ PKM	EF share
(ICE 9	f (ICE (	(RE 40	f (RE 4	41.9	41.9								
Route (1)		Route (2)		gCO2/ PKM	EF share	gCO2/ PKM	EF share	gCO2/ PKM	EF share	gCO2/ PKM	EF share	gCO2/ PKM	EF share
RE	heim	RB	heim	.	.	73.2	73.2						
Route (1)		Route (2)		gCO2/ PKM	EF share	gCO2/ PKM	EF share	gCO2/ PKM	EF share	gCO2/ PKM	EF share	gCO2/ PKM	EF share
RE	ng	RB	ng			73.2	73.2						
RB	ausen	RE	ausen			73.2	73.2						
RB	rchen	RE	rchen			73.2	73.2						
> RB -	(5,7k	> RB -	(5,7k			73.2	73.2						
> RB -	(10,7	> RB	(10,7)			73.2	73.2						
> RB -	(3,0k	> RB -	(7,6k			73.2	73.2						
RE	ng	RJ	ng(Alz			73.2	73.2						
> RB -	(7,5k	> RB	(7,5k			73.2	73.2						
> RB -	(5,4m	> RB -	(5,4k			73.2	73.2						
RE	(RB	RB	(RB			73.2	73.2						
> RB -	(1,0k	> RB -	(5,4k			73.2	73.2						
RE	(RE	RB	(RE			73.2	73.2						
> RB -	(5,2k	> RB -	(5,2k			73.2	73.2						
> RE	(3,2k	> RB -	(3,2k			73.2	73.2						
> RE	(8,1k	> RB -	(8,1k			73.2	73.2						
> RE	(6,8k	> RB -	(7,3k			73.2	73.2						
> RE	(5,6k	> RB -	(8,1k			73.2	73.2						
> RB -	(2,8k	> RB	(2,8k			73.2	73.2						
> RB -	(1,8k	> RB	(1,8k			73.2	73.2						
RE	g (RE	RB	g (RE			73.2	73.2						
RE	g (RB	RJ	g (RB			73.2	73.2						
> RB -	(4,7k	> RB -	(4,7k			73.2	73.2						
> RB -	(6,2k	> RB -	(6,2k			73.2	73.2						
RE	(4,8) -	RB	(4,8) -			73.2	73.2						

PT emission	Public Transport emissions					IT emission factor					
Average EF	gCO2* dist.	kgCO* dist.	tCO* dist.	In-commuter* tCO* dist.	Out-commuter* tCO* dist.	Gasoline EF	Dies. EF	gCO2* dist.	kgCO* dist.	tCO* dist.	Gas. engine share of in-commuters
41.9	3393.9	3.3939	0.0034	7.137	3.923	225	175	.	.	.	60.971
Average EF	gCO2* dist.	kgCO* dist.	tCO* dist.	In-commuter* tCO* dist.	Out-commuter* tCO* dist.	Gasoline EF	Dies. EF	gCO2* dist.	kgCO* dist.	tCO* dist.	Gas. engine share of in-commuters
73.2	4758	4.758	0.0048	9.345	2.598	225	175	.	.	.	66.358
Average EF	gCO2* dist.	kgCO* dist.	tCO* dist.	In-commuter* tCO* dist.	Out-commuter* tCO* dist.	Gasoline EF	Dies. EF	gCO2* dist.	kgCO* dist.	tCO* dist.	Gas. engine share of in-commuters
73.2	7173.6	7.174	0.007			225	175	.	.	.	
73.2	11785	11.785	0.012			225	175	.	.	.	
73.2	11053	11.053	0.011			225	175	.	.	.	
73.2	10907	10.907	0.011			225	175	1284	1.284	0.0013	
73.2	7173.6	7.174	0.007			225	175	2410	2.41	0.0024	
73.2	7612.8	7.613	0.008			225	175	1194	1.194	0.0012	
73.2	11309	11.309	0.011			225	175	.	.	.	
73.2	8125.2	8.125	0.008			225	175	1689	1.689	0.0017	
73.2	11309	11.309	0.011			225	175	1216	1.216	0.0012	
73.2	7612.8	7.613	0.008			225	175	.	.	.	
73.2	11309	11.309	0.011			225	175	.	.	.	
73.2	8125.2	8.125	0.008			225	175	.	.	.	
73.2	8564.4	8.564	0.009			225	175	1171	1.171	0.0012	
73.2	7173.6	7.174	0.007			225	175	.	.	.	
73.2	7173.6	7.174	0.007			225	175	1824	1.824	0.0018	
73.2	6661.2	6.661	0.007			225	175	1588	1.588	0.0016	
73.2	7173.6	7.174	0.007			225	175	1261	1.261	0.0013	
73.2	8125.2	8.125	0.008			225	175	630.6	0.631	0.0006	
73.2	6880.8	6.881	0.007			225	175	405.4	0.405	0.0004	
73.2	6588	6.588	0.007			225	175	.	.	.	
73.2	11309	11.309	0.011			225	175	.	.	.	
73.2	11309	11.309	0.011			225	175	1059	1.059	0.0011	
73.2	6646.6	6.647	0.007			225	175	1396	1.396	0.0014	
73.2	6939.4	6.939	0.007			225	175	1081	1.081	0.0011	
	8668	**8.668**	**0.009**	**10.43**	**1.46**			**1301**	**1.3**	**0.001**	**69.8**

Carbon dioxide										
Gas. share					Dies. share					
Gas. engine share of out-com-muters	In-com-muter gas. emission share (tCO2)	Out-com-muter gas. emission share (tCO2)	tCO* dist.* in-com-muters	tCO* dist.* out-com-muters	gCO2* dist.	kgCO* dist.	tCO2* dist.	Dies. engine share of in-com-muters	Dies. engine share of out-com-muters	In-com-muter dies. emission share (tCO2)
63.2455	.		.	.	.	.	.	37.828	35.971	.
Gas. engine share of out-com-muters	In-com-muter gas. emission share (tCO2)	Out-com-muter gas. emission share (tCO2)	tCO* dist.* in-com-muters	tCO* dist.* out-com-muters	gCO2* dist.	kgCO* dist.	tCO2* dist.	Dies. engine share of in-com-muters	Dies. engine share of out-com-muters	In-com-muter dies. emission share (tCO2)
63.2455	.		.	.	.	.	.	32.93	35.971	.
Gas. engine share of out-com-muters	In-com-muter gas. emission share (tCO2)	Out-com-muter gas. emission share (tCO2)	tCO* dist.* in-com-muters	tCO* dist.* out-com-muters	gCO2* dist.	kgCO* dist.	tCO2* dist.	Dies. engine share of in-com-muters	Dies. engine share of out-com-muters	In-com-muter dies. emission share (tCO2)
					.	.	.			
					.	.	.			
					.	.	.			
					996.5	0.9965	0.001			
					1870.6	1.8706	0.0019			
					926.57	0.9266	0.0009			
					.	.	.			
					1311.2	1.3112	0.0013			
					944.05	0.944	0.0009			
					.	.	.			
					.	.	.			
					.	.	.			
					909.08	0.9091	0.0009			
					.	.	.			
					1416.1	1.4161	0.0014			
					1232.5	1.2325	0.0012			
					979.01	0.979	0.001			
					489.51	0.4895	0.0005			
					314.68	0.3147	0.0003			
					.	.	.			
					.	.	.			
					821.67	0.8217	0.0008			
					1083.9	1.0839	0.0011			
					839.15	0.8392	0.0008			
63.2455	**0.0009**	**0.0008**	**1.092**	**0.139**	**1009.6**	**1.0096**	**0.001**	**29.371**	**35.971**	**0.0003**

			Carbon dioxide output						
Out-commuter dies. emission share (tCO_2)	tCO* dist.* in-commuters	tCO* dist.* out-commuters	Total in-commuter emissions (tCO_2)	Total out-commuter emissions (tCO_2)	Total in-commuter emissions (kgCO_2)	Total out-commuter emissions (kgCO_2)	**Sum (kgCO_2)**	KgCO_2* in-commuter	KgCO_2* out-commuter
	.	.	7.14	3.92	7137.37	3923.35	**11060.7**	3.39	3.39
Out-commuter dies. emission share (tCO_2)	tCO* dist.* in-commuters	tCO* dist.* out-commuters	Total in-commuter emissions (tCO_2)	Total out-commuter emissions (tCO_2)	Total in-commuter emissions (kgCO_2)	Total out-commuter emissions (kgCO_2)	**Sum (kgCO_2)**	KgCO_2* in-commuter	KgCO_2* out-commuter
	.	.	9.344712	2.597868	9344.712	2597.868	**11942.6**	4.758	4.758
Out-commuter dies. emission share (tCO_2)	tCO* dist.* in-commuters	tCO* dist.* out-commuters	Total in-commuter emissions (tCO_2)	Total out-commuter emissions (tCO_2)	Total in-commuter emissions (kgCO_2)	Total out-commuter emissions (kgCO_2)	**Sum (kgCO_2)**	KgCO_2* in-commuter	KgCO_2* out-commuter
0.0004	**0.3567**	**0.0614**	11.87699	1.665362	11876.99	1665.362	**13542.4**	9.873	9.854

	ollutant emission factors (g/PKM					Carbon monoxide emissions			Nitrogen oxide emissions			No hydroca
Mean (kgCO2)	CO	NOx	NMHC	SO2	PM/ soot	gCO* dist.	kgCO* dist.	tCO* dist.	g*NOx * dist.	kg*NOx * dist.	tNOx* dist.	gNMHC * dist.
3.39	1.9	0.4	0.36	0.1	0.02	.	.	.	.	.	.	.
Mean (kgCO2)	CO	NOx	NMHC	SO2	PM/ soot	gCO* dist.	kgCO* dist.	tCO* dist.	g*NOx * dist.	kg*NOx * dist.	tNOx* dist.	gNMHC * dist.
4.758	1.9	0.4	0.36	0.1	0.02	.	.	.	.	.	.	.
Mean (kgCO2)	CO	NOx	NMHC	SO2	PM/ soot	gCO* dist.	kgCO* dist.	tCO* dist.	g*NOx * dist.	kg*NOx * dist.	tNOx* dist.	gNMHC * dist.
	1.9	0.4	0.36	0.1	0.02	.	.	.	.	.	.	.
	1.9	0.4	0.36	0.1	0.02	.	.	.	.	.	.	.
	1.9	0.4	0.36	0.1	0.02	.	.	.	.	.	.	.
	1.9	0.4	0.36	0.1	0.02	10.602	0.0106	1E-05	2.3826	0.0024	2E-06	2.052
	1.9	0.4	0.36	0.1	0.02	19.902	0.0199	2E-05	4.4726	0.0045	4E-06	3.852
	1.9	0.4	0.36	0.1	0.02	9.858	0.0099	1E-05	2.2154	0.0022	2E-06	1.908
	1.9	0.4	0.36	0.1	0.02	.	.	.	.	.	.	.
	1.9	0.4	0.36	0.1	0.02	13.95	0.014	1E-05	3.135	0.0031	3E-06	2.7
	1.9	0.4	0.36	0.1	0.02	10.044	0.01	1E-05	2.2572	0.0023	2E-06	1.944
	1.9	0.4	0.36	0.1	0.02	.	.	.	.	.	.	.
	1.9	0.4	0.36	0.1	0.02	.	.	.	.	.	.	.
	1.9	0.4	0.36	0.1	0.02	.	.	.	.	.	.	.
	1.9	0.4	0.36	0.1	0.02	9.672	0.0097	1E-05	2.1736	0.0022	2E-06	1.872
	1.9	0.4	0.36	0.1	0.02	.	.	.	.	.	.	.
	1.9	0.4	0.36	0.1	0.02	15.066	0.0151	2E-05	3.3858	0.0034	3E-06	2.916
	1.9	0.4	0.36	0.1	0.02	13.113	0.0131	1E-05	2.9469	0.0029	3E-06	2.538
	1.9	0.4	0.36	0.1	0.02	10.416	0.0104	1E-05	2.3408	0.0023	2E-06	2.016
	1.9	0.4	0.36	0.1	0.02	5.208	0.0052	5E-06	1.1704	0.0012	1E-06	1.008
	1.9	0.4	0.36	0.1	0.02	3.348	0.0033	3E-06	0.7524	0.0008	8E-07	0.648
	1.9	0.4	0.36	0.1	0.02	.	.	.	.	.	.	.
	1.9	0.4	0.36	0.1	0.02	.	.	.	.	.	.	.
	1.9	0.4	0.36	0.1	0.02	8.742	0.0087	9E-06	1.9646	0.002	2E-06	1.692
	1.9	0.4	0.36	0.1	0.02	11.532	0.0115	1E-05	2.5916	0.0026	3E-06	2.232
	1.9	0.4	0.36	0.1	0.02	8.928	0.0089	9E-06	2.0064	0.002	2E-06	1.728
9.86351						**10.74**	**0.011**	**1E-05**	**2.414**	**0.002**	**2E-06**	**2.079**

Public transport pollutant emissions

n-methane rbon emis-sions		Sulphur dioxide emis-sions			Particulate matter emissions					
kg NMHC* dist.	tNMHC *dist.	gSO2* dist.	kgSO2* dist.	tSO2* dist.	gPM* dist.	kgPM* dist.	tPM* dist.	gCO* dist.*in-com-muters	gCO* dist.* out-com-muters	g*NOx* dist.* in-com-muters
.	.	.	.	.	.	.	.	.	.	.
kg NMHC* dist.	tNMHC *dist.	gSO2* dist.	kgSO2* dist.	tSO2* dist.	gPM* dist.	kgPM* dist.	tPM* dist.	gCO* dist.*in-com-muters	gCO* dist.* out-com-muters	g*NOx* dist.* in-com-muters
.	.	.	.	.	.	.	.	.	.	.
kg NMHC* dist.	tNMHC *dist.	gSO2* dist.	kgSO2* dist.	tSO2* dist.	gPM* dist.	kgPM* dist.	tPM* dist.	gCO* dist.*in-com-muters	gCO* dist.* out-com-muters	g*NOx* dist.* in-com-muters
.	.	.	.	.	.	.	.			
.	.	.	.	.	.	.	.			
.	.	.	.	.	.	.	.			
0.0021	2E-06	0.4925	0.0005	5E-07	0.1112	0.0001	1E-07			
0.0039	4E-06	0.9245	0.0009	9E-07	0.2087	0.0002	2E-07			
0.0019	2E-06	0.4579	0.0005	5E-07	0.1034	0.0001	1E-07			
.	.	.	.	.	.	.	.			
0.0027	3E-06	0.648	0.0006	6E-07	0.1463	0.0001	1E-07			
0.0019	2E-06	0.4666	0.0005	5E-07	0.1053	0.0001	1E-07			
.	.	.	.	.	.	.	.			
.	.	.	.	.	.	.	.			
.	.	.	.	.	.	.	.			
0.0019	2E-06	0.4493	0.0004	4E-07	0.1014	0.0001	1E-07			
.	.	.	.	.	.	.	.			
0.0029	3E-06	0.6998	0.0007	7E-07	0.158	0.0002	2E-07			
0.0025	3E-06	0.6091	0.0006	6E-07	0.1375	0.0001	1E-07			
0.002	2E-06	0.4838	0.0005	5E-07	0.1092	0.0001	1E-07			
0.001	1E-06	0.2419	0.0002	2E-07	0.0546	5E-05	5E-08			
0.0006	6E-07	0.1555	0.0002	2E-07	0.0351	4E-05	4E-08			
.	.	.	.	.	.	.	.			
.	.	.	.	.	.	.	.			
0.0017	2E-06	0.4061	0.0004	4E-07	0.0917	9E-05	9E-08			
0.0022	2E-06	0.5357	0.0005	5E-07	0.1209	0.0001	1E-07			
0.0017	2E-06	0.4147	0.0004	4E-07	0.0936	9E-05	9E-08			
0.002	**2E-06**	**0.499**	**5E-04**	**5E-07**	**0.113**	**1E-04**	**1E-07**	**0.0129**	**0.0018**	**0.0029**

Pollutant emission output								Pollutant emission facto			
g*NOx* dist.* out-com-muters	gNMHC* dist.* in-com-muters	gNMHC* dist.* out-com-muters	gSO2*dist.* in-com-muters	gSO2*dist.* out-com-muters	gPM* dist.* in-com-muters	gPM* dist.* out-com-muters		CO	NOx	NMHC	SO2
.	.	.	.	..	.	.		0.15	1.01	0.055	0.03
g*NOx* dist.* out-com-muters	gNMHC* dist.* in-com-muters	gNMHC* dist.* out-com-muters	gSO2*dist.* in-com-muters	gSO2*dist.* out-com-muters	gPM* dist.* in-com-muters	gPM* dist.* out-com-muters		CO	NOx	NMHC	SO2
.	.	.	.	..	.	.		0.15	1.01	0.055	0.03
g*NOx* dist.* out-com-muters	gNMHC* dist.* in-com-muters	gNMHC* dist.* out-com-muters	gSO2*dist.* in-com-muters	gSO2*dist.* out-com-muters	gPM* dist.* in-com-muters	gPM* dist.* out-com-muters	(...)	CO	NOx	NMHC	SO2
								0.15	1.01	0.055	0.03
								0.15	1.01	0.055	0.03
								0.15	1.01	0.055	0.03
								0.15	1.01	0.055	0.03
								0.15	1.01	0.055	0.03
								0.15	1.01	0.055	0.03
								0.15	1.01	0.055	0.03
								0.15	1.01	0.055	0.03
								0.15	1.01	0.055	0.03
								0.15	1.01	0.055	0.03
								0.15	1.01	0.055	0.03
								0.15	1.01	0.055	0.03
								0.15	1.01	0.055	0.03
								0.15	1.01	0.055	0.03
								0.15	1.01	0.055	0.03
								0.15	1.01	0.055	0.03
								0.15	1.01	0.055	0.03
								0.15	1.01	0.055	0.03
								0.15	1.01	0.055	0.03
								0.15	1.01	0.055	0.03
								0.15	1.01	0.055	0.03
								0.15	1.01	0.055	0.03
								0.15	1.01	0.055	0.03
								0.15	1.01	0.055	0.03
0.0004	**0.0025**	**0.0004**	**0.0006**	**8E-05**	**0.0001**	**2E-05**					

rs	Carbon monoxide emissions			Nitrogen oxide emissions			Non-methane hydrocarbon emis-sions			Sulphur dioxide emis-sions			Parti e
PM/ soot	gCO* dist.	kgCO * dist.	tCO* dist.	g*NO x* dist.	kg*N Ox* dist.	tNOx* dist.	gNMH C* dist.	kg NMHC* dist.	tNMHC *dist.	gSO2 * dist.	kgSO2* dist.	tSO2* dist.	gPM* dist.
0.02	12.5	0.01	1E-05	81.8	0.08	8E-05	4.48	0.004	4E-06	2.12	0.0021	2E-06	1.32
PM/ soot	gCO* dist.	kgCO * dist.	tCO* dist.	g*NO x* dist.	kg*N Ox* dist.	tNOx* dist.	gNMH C* dist.	kg NMHC* dist.	tNMHC *dist.	gSO2 * dist.	kgSO2* dist.	tSO2* dist.	gPM* dist.
0.02	10	0.01	1E-05	65.7	0.07	7E-05	3.59	0.004	4E-06	1.7	0.0017	2E-06	1.06
PM/ soot	gCO* dist.	kgCO * dist.	tCO* dist.	g*NO x* dist.	kg*N Ox* dist.	tNOx* dist.	gNMH C* dist.	kg NMHC* dist.	tNMHC *dist.	gSO2 * dist.	kgSO2* dist.	tSO2* dist.	gPM* dist.
0.02	15.1	0.02	2E-05	99	0.1	1E-04	5.42	0.005	5E-06	2.57	0.0026	3E-06	1.6
0.02	24.8	0.02	2E-05	163	0.16	0.0002	8.9	0.009	9E-06	4.22	0.0042	4E-06	2.62
0.02	23.3	0.02	2E-05	153	0.15	0.0002	8.35	0.008	8E-06	3.96	0.004	4E-06	2.46
0.02	22.9	0.02	2E-05	150	0.15	0.0002	8.24	0.008	8E-06	3.9	0.0039	4E-06	2.43
0.02	15.1	0.02	2E-05	99	0.1	1E-04	5.42	0.005	5E-06	2.57	0.0026	3E-06	1.6
0.02	16	0.02	2E-05	105	0.11	0.0001	5.75	0.006	6E-06	2.72	0.0027	3E-06	1.7
0.02	23.8	0.02	2E-05	156	0.16	0.0002	8.54	0.009	9E-06	4.05	0.004	4E-06	2.52
0.02	17.1	0.02	2E-05	112	0.11	0.0001	6.14	0.006	6E-06	2.91	0.0029	3E-06	1.81
0.02	23.8	0.02	2E-05	156	0.16	0.0002	8.54	0.009	9E-06	4.05	0.004	4E-06	2.52
0.02	16	0.02	2E-05	105	0.11	0.0001	5.75	0.006	6E-06	2.72	0.0027	3E-06	1.7
0.02	23.8	0.02	2E-05	156	0.16	0.0002	8.54	0.009	9E-06	4.05	0.004	4E-06	2.52
0.02	17.1	0.02	2E-05	112	0.11	0.0001	6.14	0.006	6E-06	2.91	0.0029	3E-06	1.81
0.02	18	0.02	2E-05	118	0.12	0.0001	6.47	0.006	6E-06	3.07	0.0031	3E-06	1.91
0.02	15.1	0.02	2E-05	99	0.1	1E-04	5.42	0.005	5E-06	2.57	0.0026	3E-06	1.6
0.02	15.1	0.02	2E-05	99	0.1	1E-04	5.42	0.005	5E-06	2.57	0.0026	3E-06	1.6
0.02	14	0.01	1E-05	91.9	0.09	9E-05	5.03	0.005	5E-06	2.38	0.0024	2E-06	1.48
0.02	15.1	0.02	2E-05	99	0.1	1E-04	5.42	0.005	5E-06	2.57	0.0026	3E-06	1.6
0.02	17.1	0.02	2E-05	112	0.11	0.0001	6.14	0.006	6E-06	2.91	0.0029	3E-06	1.81
0.02	14.5	0.01	1E-05	94.9	0.09	9E-05	5.2	0.005	5E-06	2.46	0.0025	2E-06	1.53
0.02	13.9	0.01	1E-05	90.9	0.09	9E-05	4.98	0.005	5E-06	2.36	0.0024	2E-06	1.47
0.02	23.8	0.02	2E-05	156	0.16	0.0002	8.54	0.009	9E-06	4.05	0.004	4E-06	2.52
0.02	23.8	0.02	2E-05	156	0.16	0.0002	8.54	0.009	9E-06	4.05	0.004	4E-06	2.52
0.02	14	0.01	1E-05	91.7	0.09	9E-05	5.02	0.005	5E-06	2.38	0.0024	2E-06	1.48
0.02	14.6	0.01	1E-05	95.7	0.1	1E-04	5.24	0.005	5E-06	2.48	0.0025	2E-06	1.55
	18.2	0.02	2E-05	120	0.12	0.0001	6.55	0.007	7E-06	3.1	0.0031	3E-06	1.93

Electric LPT pollutant emissions

culate matter emissions		Pollutant em									
kgPM* dist.	tPM* dist.	tCO* dist.* in-com-muters	tCO* dist.* out-com-muters	LPT in-commu ter share 2,2%	LPT out-commu ter share 2,2%	tNOx* dist.* in-com-muters	tNOx* dist.* out-com-muters	LPT in-commu ter share 2,2%	LPT out-commu ter share 2,2%	tNMHC * dist.* in-com-muters	tNMHC * dist.* out-com-muters
0.001	1E-06	0.0262	0.0144	0.0006	0.0003	0.172	0.0946	0.0038	0.0021	0.0094	0.0052
kgPM* dist.	tPM* dist.	tCO* dist.* in-com-muters	tCO* dist.* out-com-muters	LPT in-commu ter share 2,2%	LPT out-commu ter share 2,2%	tNOx* dist.* in-com-muters	tNOx* dist.* out-com-muters	LPT in-commu ter share 2,2%	LPT out-commu ter share 2,2%	tNMHC * dist.* in-com-muters	tNMHC * dist.* out-com-muters
0.001	1E-06	0.0197	0.0055	0.0004	0.0001	0.1289	0.0358	0.0028	0.0008	0.0071	0.002
kgPM* dist.	tPM* dist.	tCO* dist.* in-com-muters	tCO* dist.* out-com-muters	LPT in-commu ter share 2,2%	LPT out-commu ter share 2,2%	tNOx* dist.* in-com-muters	tNOx* dist.* out-com-muters	LPT in-commu ter share 2,2%	LPT out-commu ter share 2,2%	tNMHC * dist.* in-com-muters	tNMHC * dist.* out-com-muters
0.002	2E-06										
0.003	3E-06										
0.002	2E-06										
0.002	2E-06										
0.002	2E-06										
0.002	2E-06										
0.003	3E-06										
0.002	2E-06										
0.003	3E-06										
0.002	2E-06										
0.003	3E-06										
0.002	2E-06										
0.002	2E-06										
0.002	2E-06										
0.002	2E-06										
0.001	1E-06										
0.002	2E-06										
0.002	2E-06										
0.002	2E-06										
0.001	1E-06										
0.003	3E-06										
0.003	3E-06										
0.001	1E-06										
0.002	2E-06										
0.002	2E-06	0.0219	0.0031	0.0005	7E-05	0.1439	0.0202	0.0032	0.0004	0.0079	0.0011

ission output

LPT in-commuter share 2,2%	LPT out-commuter share 2,2%	tSO2* dist.* in-com-muters	tSO2* dist.* out-com-muters	LPT in-commuter share 2,2%	LPT out-commuter share 2,2%	tPM* dist.* in-com-muters	tPM* dist.* out-com-muters	LPT in-commuter share 2,2%	LPT out-commuter share 2,2%	Sum of CO in-com-muter emis-sions	Sum of CO out-com-muter emis-sions
0.0002	0.0001	0.0045	0.0025	1E-04	5E-05	0.0028	0.0015	6E-05	3E-05	0.0104	0.0057
										Sum	**0.016**
LPT in-commuter share 2,2%	LPT out-commuter share 2,2%	tSO2* dist.* in-com-muters	tSO2* dist.* out-com-muters	LPT in-commuter share 2,2%	LPT out-commuter share 2,2%	tPM* dist.* in-com-muters	tPM* dist.* out-com-muters	LPT in-commuter share 2,2%	LPT out-commuter share 2,2%	Sum of CO in-com-muter emis-sions	Sum of CO out-com-muter emis-sions
0.0002	4E-05	0.0033	0.0009	7E-05	2E-05	0.0021	0.0006	5E-05	1E-05	0.0078	0.0022
										Sum	**0.01**
LPT in-commuter share 2,2%	LPT out-commuter share 2,2%	tSO2* dist.* in-com-muters	tSO2* dist.* out-com-muters	LPT in-commuter share 2,2%	LPT out-commuter share 2,2%	tPM* dist.* in-com-muters	tPM* dist.* out-com-muters	LPT in-commuter share 2,2%	LPT out-commuter share 2,2%	Sum of CO in-com-muter emis-sions	Sum of CO out-com-muter emis-sions
0.0002	2E-05	0.0037	0.0005	8E-05	1E-05	0.0023	0.0003	5E-05	7E-06	0.0216	0.003
										Sum	**0.025**

Total pollutant emission output data (individual- and public trans

Mean CO in-commuter emissions	Mean CO out-commuter emissions	Sum of NOx in-commuter emissions	Sum of NOx out-commuter emissions	Mean NOx in-commuter emissions	Mean NOx out-commuter emissions	Sum of NMHC in-commuter emissions	Sum of NMHC out-commuter emissions	Mean NMHC in-commuter emissions	Mean NMHC out-commuter emissions	Sum of SO2 in-commuter emissions	Sum of SO2 out-commuter emissions
5E-06	5E-06	0.0476	0.0262	2E-05	2E-08	0.0024	0.00134	1E-06	1.2E-06	0.0086	0.0047
Mean	**5E-06**	**Sum**	**0.074**	**Mean**	**1E-05**	**Sum**	**0.0038**	**Mean**	**1E-06**	**Sum**	**0.013**
Mean CO in-commuter emissions	Mean CO out-commuter emissions	Sum of NOx in-commuter emissions	Sum of NOx out-commuter emissions	Mean NOx in-commuter emissions	Mean NOx out-commuter emissions	Sum of NMHC in-commuter emissions	Sum of NMHC out-commuter emissions	Mean NMHC in-commuter emissions	Mean NMHC out-commuter emissions	Sum of SO2 in-commuter emissions	Sum of SO2 out-commuter emissions
4E-06	4E-06	0.0357	0.0099	2E-05	3.3E-08	0.0018	0.00051	9E-07	9.3E-07	0.0065	0.0018
Mean	**4E-06**	**Sum**	**0.046**	**Mean**	**9E-06**	**Sum**	**0.0023**	**Mean**	**9E-07**	**Sum**	**0.008**
Mean CO in-commuter emissions	Mean CO out-commuter emissions	Sum of NOx in-commuter emissions	Sum of NOx out-commuter emissions	Mean NOx in-commuter emissions	Mean NOx out-commuter emissions	Sum of NMHC in-commuter emissions	Sum of NMHC out-commuter emissions	Mean NMHC in-commuter emissions	Mean NMHC out-commuter emissions	Sum of SO2 in-commuter emissions	Sum of SO2 out-commuter emissions
2E-05	2E-05	0.0427	0.006	4E-05	3.6E-05	0.0045	0.00037	4E-06	2.2E-06	0.0078	0.0011
Mean	**2E-05**	**Sum**	**0.049**	**Mean**	**4E-05**	**Sum**	**0.0049**	**Mean**	**3E-06**	**Sum**	**0.009**

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Mean SO2 in-commuter emissions	Mean SO2 out-commuter emissions	Sum of PM in-commuter emissions	Sum of PM out-commuter emissions	Mean PM in-commuter emissions	Mean PM out-commuter emissions
4E-06	4.1E-06	0.0014	0.00079	7E-07	6.8E-07
Mean	**4E-06**	**Sum**	**0.0022**	**Mean**	**7E-07**
Mean SO2 in-commuter emissions	Mean SO2 out-commuter emissions	Sum of PM in-commuter emissions	Sum of PM out-commuter emissions	Mean PM in-commuter emissions	Mean PM out-commuter emissions
3E-06	3.3E-06	0.0011	0.0003	5E-07	5.5E-07
Mean	**3E-06**	**Sum**	**0.0014**	**Mean**	**5E-07**
Mean SO2 in-commuter emissions	Mean SO2 out-commuter emissions	Sum of PM in-commuter emissions	Sum of PM out-commuter emissions	Mean PM in-commuter emissions	Mean PM out-commuter emissions
6E-06	6.5E-06	0.0013	0.00019	1E-06	1.1E-06
Mean	**6E-06**	**Sum**	**0.0015**	**Mean**	**1E-06**

Source: Own representation based on LfStaD, 1991; n.d.c; BA, 2012 (see addendum, pp.107); Buslinie Deutschland, n.d.; DB, 1996; 2012a; 2013a – 2013ay; n.d.a – n.d.fi (see CD, Public Transport addendum, pp.749-914); GeoBasis-DE/BKG, Google Inc. & Deutsche Bahn AG, n.d.a – n.d.ail (see addendum, pp.1-748); n.d.a – n.d.fi; KBA, 1987 (see addendum, pp.105); 2012; Schütz, 2007; Schütz & Merath, 2011; UBA, 2010ao; 2010ap.

Declaration in Lieu of Oath

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