CO_2 TARGETS FOR NON-FREIGHT TRANSPORT AND HOW THEY CAN BE MONITORED, WITH EXAMPLES FROM ESSEN IN GERMANY AND HONGQIAO / SHANGHAI IN CHINA

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ABSTRACT

The Federal government in Germany has set itself ambitious climate protection targets, aiming for a 40% reduction in CO_2 emissions (1990 - 2020). In China the government has announced its target of increasing energy efficiency by 45% in the period 2010 to 2020. The question is whether, and if so, how these targets can be applied to transport and to particular places, e.g. regions, towns or parts of a town. There is also the related question of whether these targets can be achieved in the timeframes specified. The article will consider the approaches and measures which may be used to apply the policy targets to the transport of people in specific places. To answer the question whether the target of reducing CO_2 in the two cities can be achieved it is necessary to use a monitoring tool, which will be developed in the co-operative project Shanghai (01LG0514A1). The Dynamic Energy and CO_2 Controller EEC® includes the monitoring of three areas of activity: transport, building usage and renewable energy production. In keeping with the aforementioned targets it delivers (a) information on the current status, (b) a prognosis model and (c) verification of targets. The information on the current situation is drawn from the models outlined using empirical data ("sensor technology"). If, in monitoring the targets, it is shown that the target could be missed there is a way out by introducing other measures. If new measures are defined, the models are adjusted in the three areas of activity and the monitoring is carried out again. The task of reporting is a major function and enables public access to the most important daily results as well as to the prognoses via the Internet.

Keywords: CO_2 emissions, CO_2 targets, monitoring tool, Dynamic Energy and CO_2 Controller

INTRODUCTION

The Federal government in Germany has set itself ambitious climate protection targets, aiming for a 40% reduction in CO_2 emissions (1990 - 2020).

In China the government has announced its target of increasing energy efficiency by 45% in the period 2010 to 2020.

The question is whether, and if so, how these targets can be applied to transport and to particular places, e.g. regions, towns or parts of a town. There is also the related question of whether these targets can be achieved in the timeframes specified.

These policy targets cover all emitters: commerce and industry, domestic households, the public sector and the transport of people and goods. The following submission will look only at the specific field of transport. It will consider the approaches and measures which may be used to apply the policy targets to the transport of people in specific places.

TERRITORIAL PRINCIPLE VERSUS CONSUMER RESPONSIBILITY PRINCIPLE

There are two different approaches to calculating transport-related CO_2 emissions: (1) calculation using the territorial principle and (2) calculation using the consumer responsibility principle. In the first case CO_2 emissions are calculated for all emitters in the area under consideration. The second approach considers CO_2 emissions caused by people living in the area under consideration. This must also include emissions from all freight transport generated by businesses located in the planning area. The territorial principle approach focuses on the responsibility of the public sector; the consumer responsibility principle in contrast places more emphasis on the responsibility of individual people and companies.

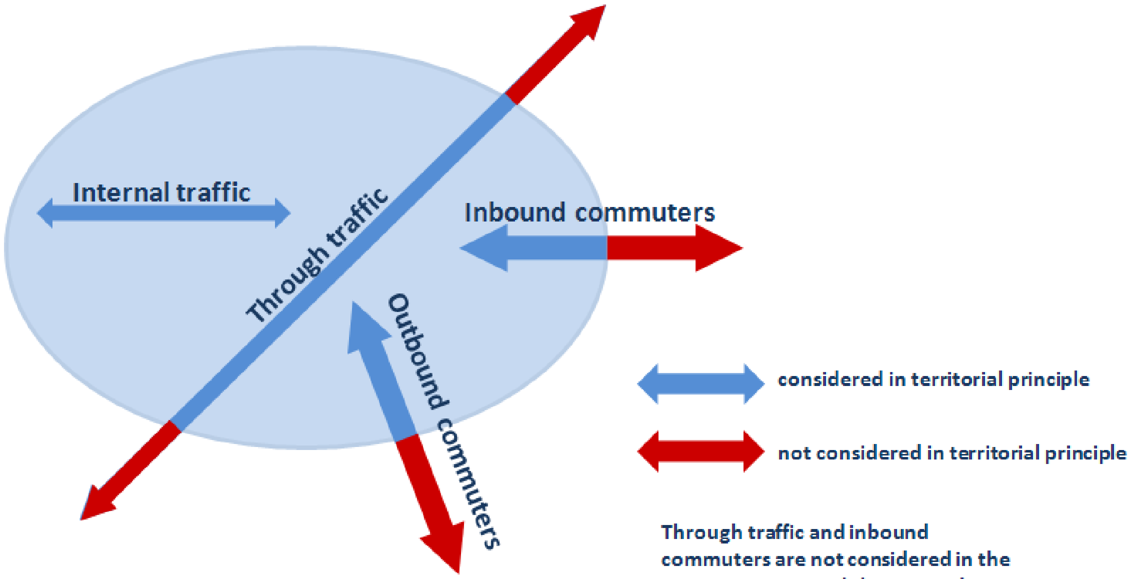

Figure 1: Territorial principle and consumer responsibility principle

A further aspect to consider is the question of the term efficiency. Since the socio-economic data of an area under consideration (population, employment etc) can change dynamically over a period of time, it is not appropriate to set targets in the form of absolute emissions levels. Rather, CO_2 emissions must be relativised in such a way as to show CO_2 efficiency. For both approaches it is helpful to use the CO_2 emissions related to the inhabitants of eternal as the basis for an efficiency criterion.

The methodologies differ in their dependence on the modes of transport. This is considered in detail in the following chapters using the examples of the respective areas.

DEVELOPMENT OF THE TARGETS FOR ESSEN, A CITY IN THE RUHR METROPOLITAN AREA

Territorial principle

Taking the policy target of reducing CO_2 emissions by 40% between 1990 and 2020 as a starting point, the first task which presents itself is to determine the start position in 1990 ex post. Both the territorial principle and the consumer responsibility concept are use to determine the start position and the current (2009) position. The trend is then estimated from 2009 - 2020. This trend view is required in order to assess the extent to which the trend is thus far on target to achieve the goal. The efficiency increase target is compared with this trend.

Motorised road transport

The change in miles travelled 1990 - 2009 - 2020

From data gathered manually and automatically on changes in road transport it can be determined that miles travelled on the Essen road network have increased by 11.5% between 1990 and 2009. The city of Essen traffic development plan foresees a further 3% increase in miles travelled between 2009 and 2020.

Fuel usage 1990 - 2009 - 2020

Energy consumption and CO_2 emissions on a road network depend largely on the characteristics of the traffic infrastructure, the amount of vehicles, journey progress with acceleration and deceleration, sections with consistent progress and waiting times, the mix of vehicles on the individual sections of the network and on the current temperatures. As a rule this data is not always available in such detail. Also, because of the immense amount of data, the necessity for taking hourly samples generally creates difficulties.

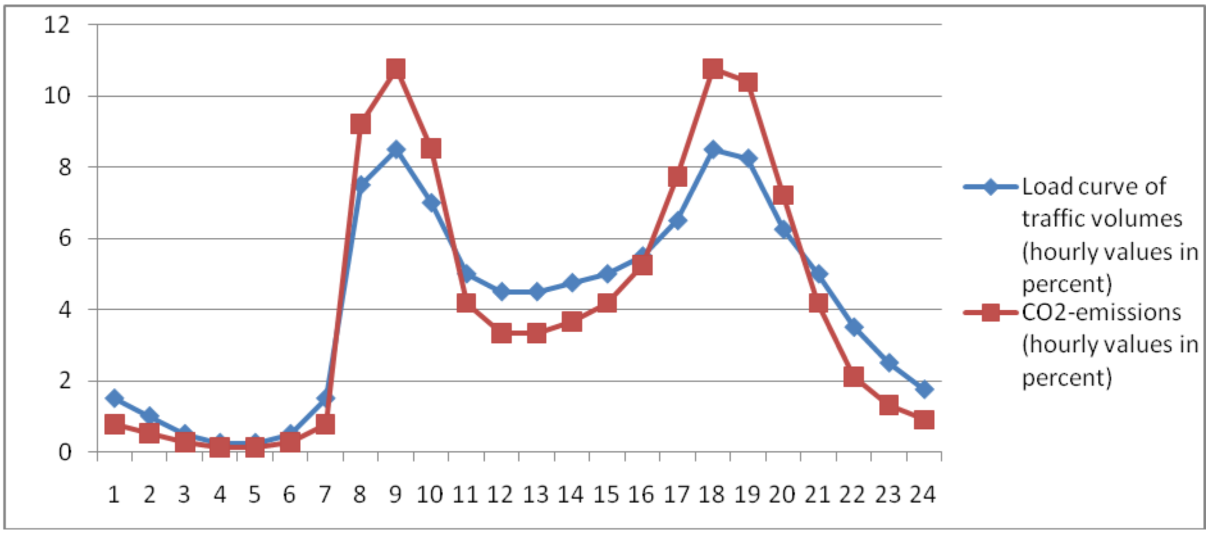

Figure 2: Record of traffic volume and CO2 over the course of a day for a characteristic section of the urban network

Figure 2 clearly shows that it is necessary to make the effort required to show values differentiate hour by hour. The influence of traffic flow can be clearly seen from the peak hours of fuel consumption and/or CO_2 emissions: the peaks of fuel consumption are higher than traffic volumes would suggest.

In the case above, a traffic planning model was used to determine the hourly traffic volumes (diesel cars, petrol cars, light commercial vehicles, articulated lorries, other commercial vehicles), the average hourly traffic speeds and the average traffic load (v/c ratio) were determined for every hour of the day and every day of one year.

Fuel consumption was calculated using the formulae set out in the EWS[1] for every section of road and every hour, differentiated according to the types of vehicle specified.

[1] EWS: Empfehlung für die Wirtschaftlichkeitsuntersuchung an Straßen (1997), FGSV

Over the last few years the average specific fuel consumption has decreased. This reduction in specific consumption by vehicles on the road is taken into account until 2010 in the EWS formulae by the use of an annual factor. A decrease is assumed in the future, too. This decrease is also taken into account in the HBEFA[2] 2010 and continues until 2020. The trend set out in the HBEFA permits us to deduce reduction ratios for future fuel consumption by the various vehicle types. For petrol-driven cars this produces an average reduction ratio of 0.70 in relation to 1990, for diesel- driven cars 0.777, for light commercial vehicles 0.87and for the remaining commercial vehicles 0.92.

Private vehicle mix 1990, 2009 and 2020

The mix of cars on the road (proportion of petrol-driven cars and diesel-driven cars, weighted with mileage) was determined according to EWS and HBEFA as follows:1990 82:18; 2009 59.7:40.3; 2020 46.5:53.5.

Mixing fuels with biofuels

For several years now, ordinary petrol and diesel fuels have been mixed with biofuels. The HBEFA 2010 takes the proportions of biofuels into account in a differentiated manner and these proportions were used to calculate the trend.

It was possible to calculate the energy and CO_2 efficiency of the traffic with these values:

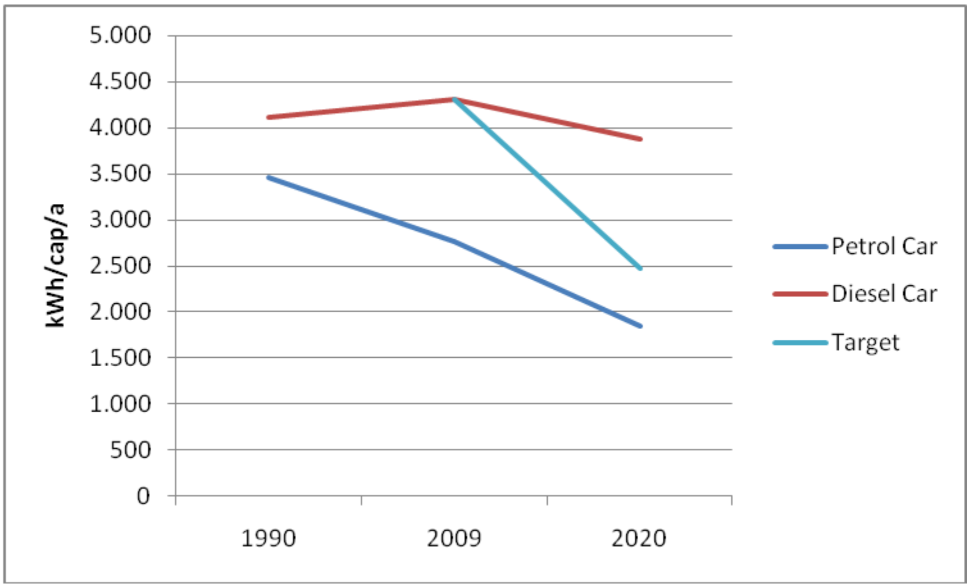

Figure 3: Energy and CO2 efficiency in road traffic, 1990 to 2020

[2] HBEFA – Handbuch für Emissionsfaktoren (Handbook of Emission Factors for Road Transport), Version 3.1, January 2010. The HBEFA was developed by INFRAS, Bern on behalf of the environment authorities of Germany (UBA), Austria (UBA) and Switzerland (BUWAL).

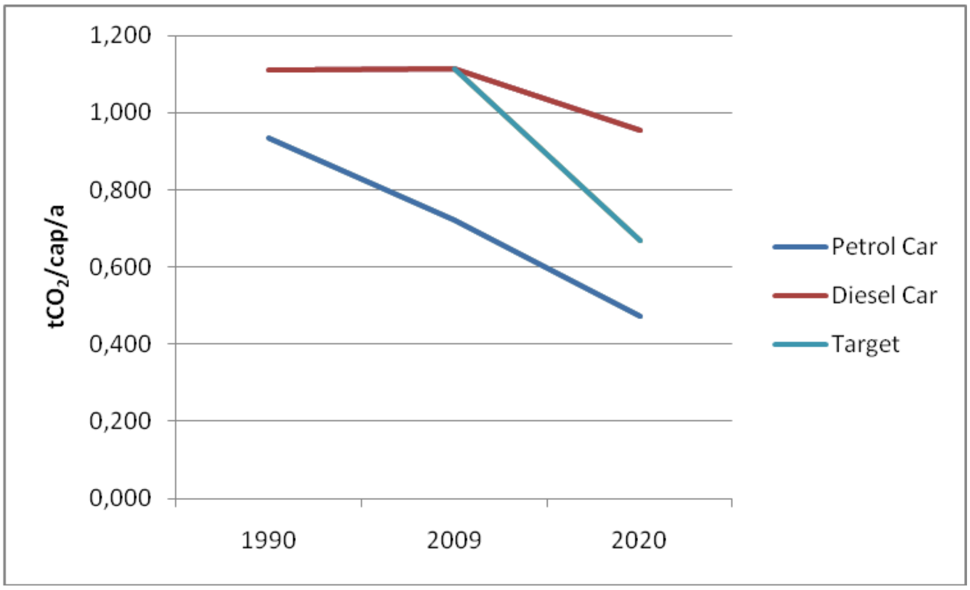

Figure 4: CO2 efficiency in road traffic, 1990 to 2020

Local public transport

Annual mileage

Calculating energy consumption in local public transport using the territorial principle requires, similarly to the procedure with other road traffic, that the mileage of the local public transport vehicles be shown according to type of transport (regional express railway, suburban railway, underground train, tram, bus), within Essen's city limits.

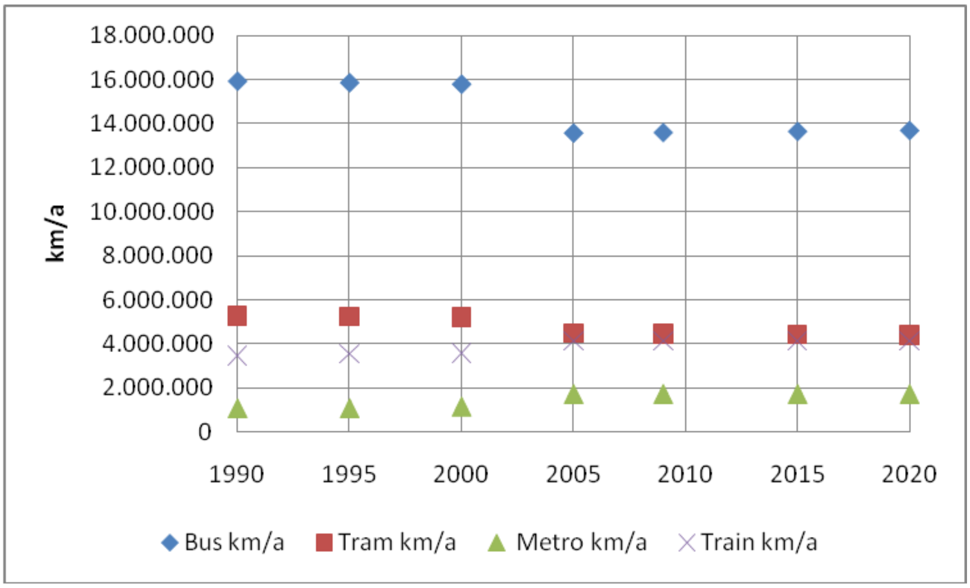

Figure 5: Change in annual mileage in public transport (territorial principle)

The graph shows that the mileages have increased in the course of the extension to the underground network and the increase in reservations on the railways, whereas on the other hand bus and tram mileages have decreased. In future largely constant mileages will be assumed.

Specific consumption

The specific consumption or CO_2 emissions for buses were calculated using the calculation methods for urban buses in the HBEFA 2010. The specific consumptions for trams, underground trains and suburban and regional express trains were taken from the documentation of the individual transport companies.

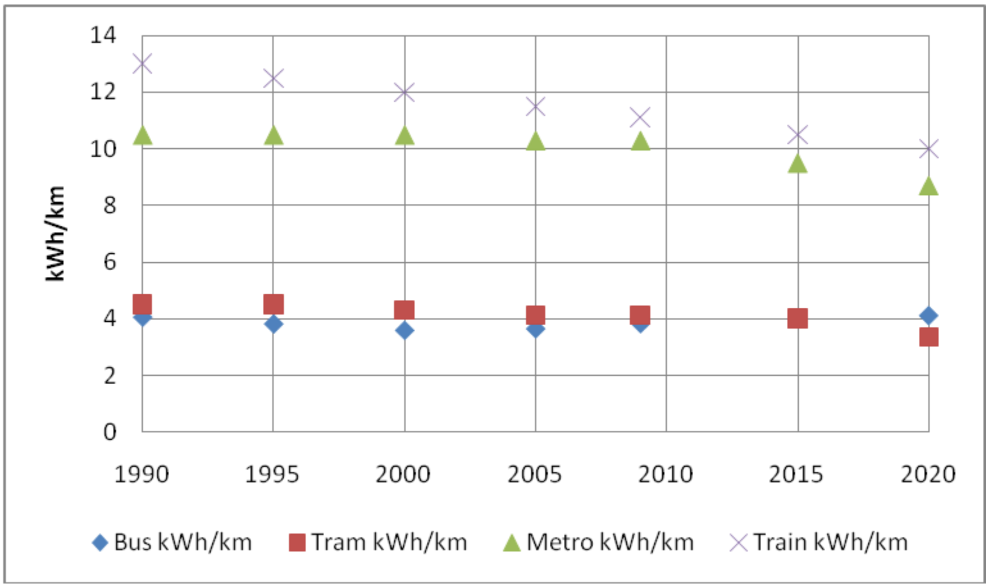

Figure 6: Specific energy consumption in public transport

In the area of bus transport consumption falls at first, then rises again and in 2020 attains approximately the level of 1990. This development can be explained by the increased use of larger and more powerful vehicles (bendy buses). In the case of trams, underground trains and - particularly strikingly - in the case of suburban and regional express trains, vehicle related electricity consumption is falling.

The national fuel mix for primary energy was used as the basis for the calculation of the CO_2 emissions.

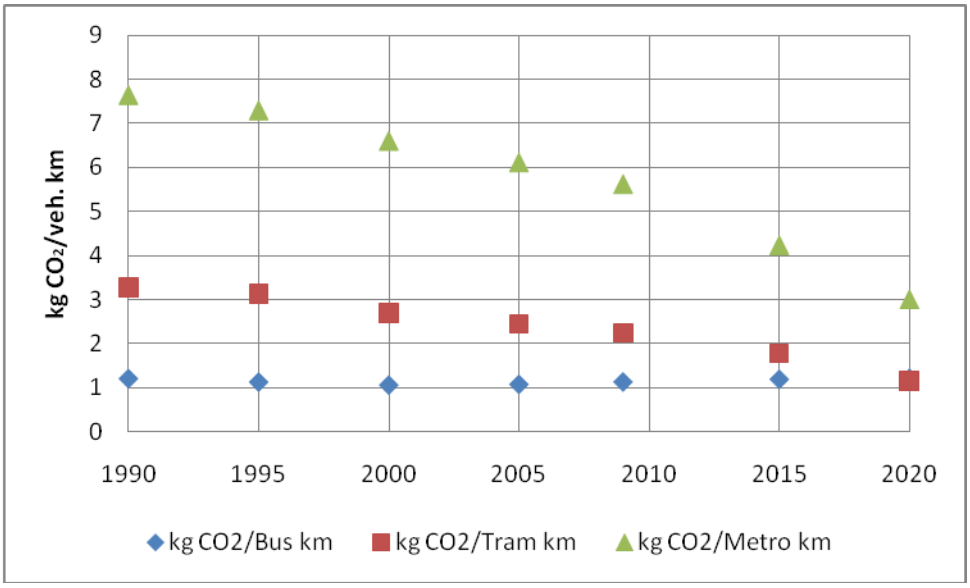

Figure 7: Changes in specific CO_2 emissions

The graph shows that the specific CO_2 emissions in rail and tram transport have fallen drastically and are set to fall further and more steeply than the specific energy consumption. This is a result of the improved fuel mix in Germany in the future.

Summary of the results according to the territorial principle

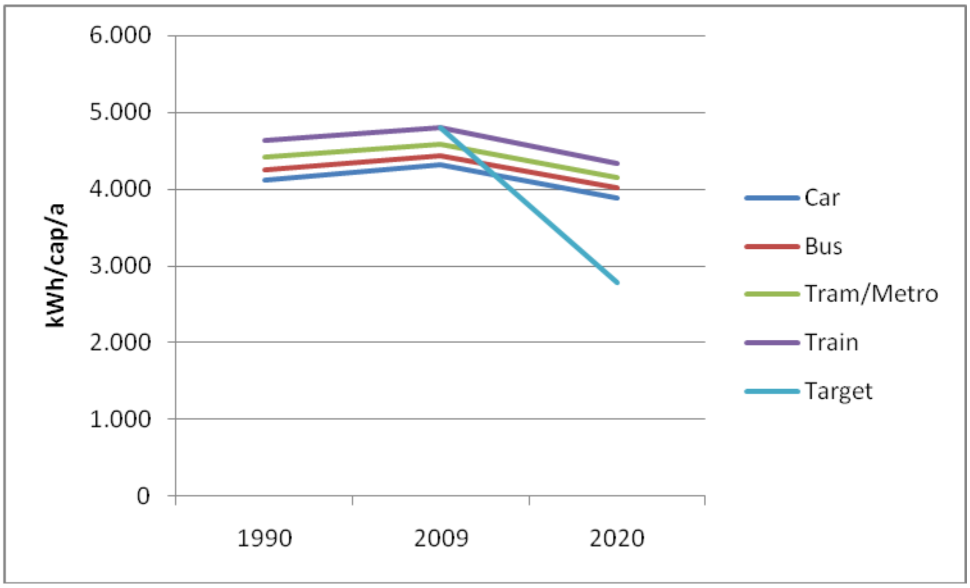

Figure 8: Change in energy efficiency according to the territorial principle (primary energy, stacked graph)

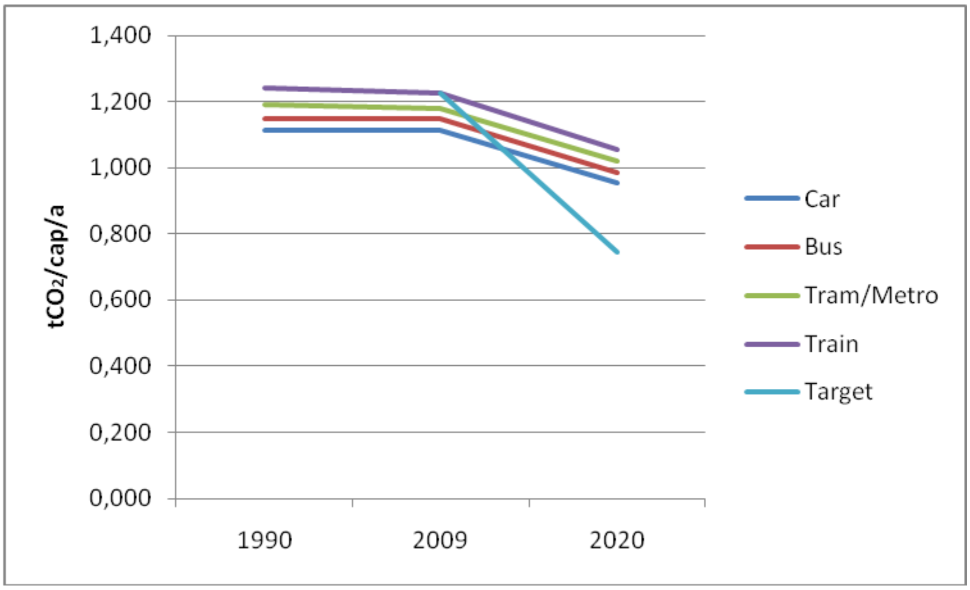

Figure 9: Change in CO_2 efficiency according to the territorial principle (stacked graph)

These graphs show the trend (purple) and the target (light blue). The total CO_2 emissions per inhabitant per year will, according to this estimation, only be reduced by around 13% by 2020. Energy used will show an even smaller reduction.

It can be clearly seen that CO_2 emissions have not yet been sufficiently reduced and that, according to the trend, sufficient reduction cannot be expected in the current decade. The policy targets can therefore not be achieved without further measures. Private motorised transport is the actual problem in Essen. This result is typical for other German cities. Against this background urgent action is required.

Consumer responsibility principle

In comparison to the territorial principle, estimating energy consumption and CO_2 emissions in personal transport using the method of the consumer responsibility principle is far simpler.

Energy efficiency and CO_2 efficiency are derived here from the annual average personal mileage for the transport types "private car", "local public transport", "long-distance public transport", "public inland shipping" and "air traffic"[3], the average specific energy consumption per vehicle kilometre and the average CO_2 emissions per unit of energy.

The following changes have taken place for the city of Essen:

[3] Due to its low significance for the population of Essen shipping is not considered here.

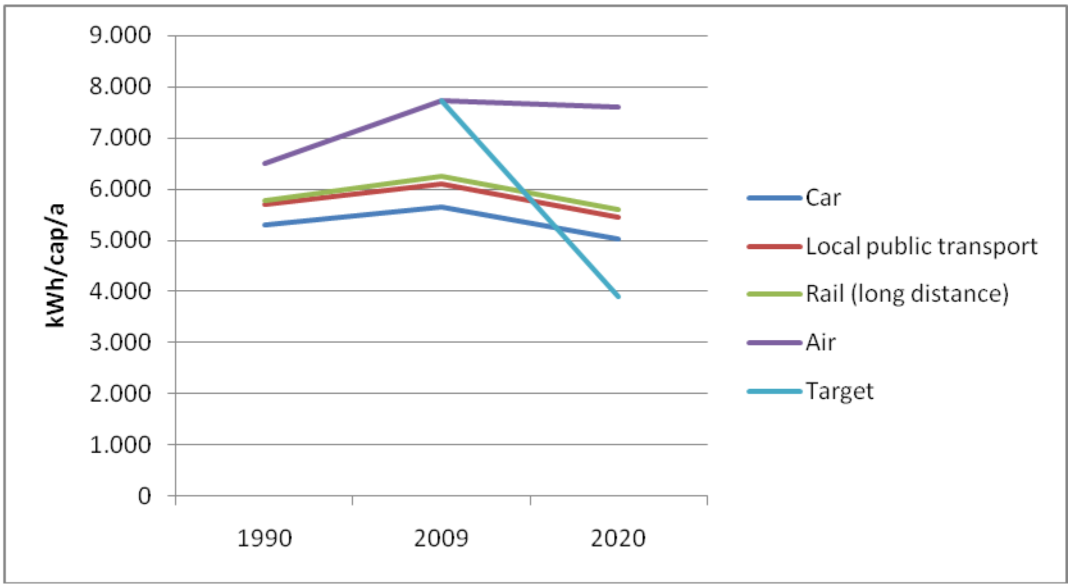

Figure 10: Energy efficiency according to the consumer responsibility principle (primary energy, stacked graph)

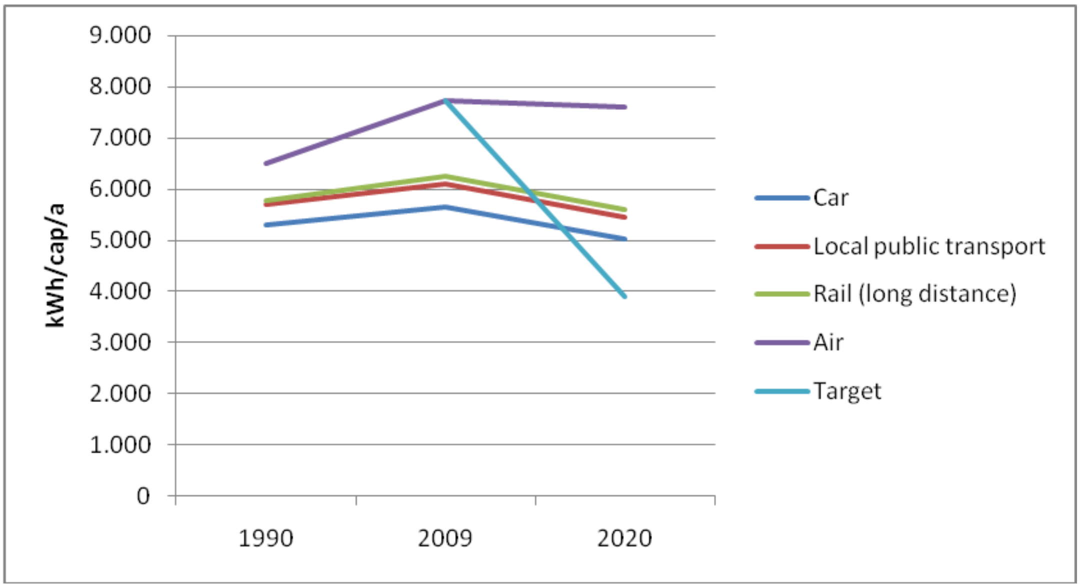

Figure 11: CO_2 efficiency according to the consumer responsibility principle (primary energy, stacked graph)

According to this estimation for local transport (total composed of car and local public transport), person-related emissions are decreasing, as in the calculation using the territorial principle. The overall result however is dominated by the increase in air traffic. If we consider the size of the vehicles then it again becomes clear that private motorised transport and air transport cause by far the largest share of the emissions. Strategies for achieving the policy targets for reduction must therefore be applied here before anywhere else.

Comparison with other cities4 also provides indications of measures which could be taken. Such a comparison makes clear that shorter journeys and/or higher proportions of non-motorised traffic or public transport are common practice in comparable cities in Germany.

Table 1: Comparison of CO_2 efficiency in other German cities

City	Population	Modal split local traffic				Car CO_2 emissions per year [kg/P]	Public transport CO_2 emissions per year [kg/P]	Car + public transport CO_2 emissions per year [kg/P]
		Public trans.	Motorised personal transport	Bicycle	Foot			
Leipzig	515,418	17.4	36.1	16.0	30.4	893,58	244,26	1137,84
Dresden	512,546	21.3	37.6	17.4	23.8	939,00	229,89	1168,89
Berlin	3,506,239	26.2	30.9	13.1	29.8	1.092,43	211,93	1304,36
Dusseldorf	629,005	22.5	33.6	12.5	31.4	1.147,66	237,08	1384,74
Frankfurt a. M.	670,170	23.6	27.2	14.5	34.6	1.141,53	283,77	1425,30
Bremen	547,735	14.6	36.6	26.5	22.3	1.252,00	204,75	1456,75

The values for CO_2 efficiency in the "best" German cities, at approximately 1200 kg per inhabitant per year, are at their highest approximately 22% lower than the values for Essen (consumer responsibility principle). This is primarily due to the higher proportion of car transportation in Essen. Measures to increase the potential in Essen must therefore begin with private vehicle transport.

HONGQIAO, PART OF A SUBURB OF SHANGHAI

As with the example of Essen, in China statement has been made at central government level on energy and CO_2 deficiency: they should develop in parallel with the expected growth in GDP of 45% between 2010 and 2020. However here there is a lack of direct concrete targets as far as individual emitters, individual towns or suburbs are concerned. Shanghai's city government is going its own way with the "Hongqiao Low Carbon Business District" project.

The task here is to define the low carbon target for a commercial district and to achieve sustainable control of the development of CO_2 emissions. One of the major tasks involved is to ensure favourable planning conditions and to set down CO_2 targets in writing in contracts with investors - primarily for buildings.

Although in contracts with investors this concentrates thinking first of all on the control of building quality and use with the related energy consumption and CO_2 emissions, transport

[4] Biniok, K.: Energieeffizienter Verkehr in deutschen Städten; eine Auswertung der Verkehrserhebung „Mobilität in Städten – SrV 2008“ der TU Dresden bezüglich Energieeffizienz im Verkehr. Essen, 2010 (n.v.).

plays an important role from the beginning with regard to controlling the type and number of car and bicycle parking places and the number of electric vehicles (pure electric (BEV) and vehicles with range extender or plug-in (PBEV, REEV)) as well as the later monitoring of emissions.

Figure 12: Hongqiao master plan, first stage of the development.

Reference base

The particular problem with this example is that it must be clarified which emissions are to be attributed to the commercial district and which reference bases can be meaningfully selected in order to make a comparison with other suburbs of Shanghai possible.

It is not possible to use residents as a base in this case because no or very few people live in Hongqiao. The district, which lies on the edge of a large traffic hub, will be used for office space, shopping, entertainment etc.

Following intensive agreements with the Chinese research partners a method was selected which is to be documented and registered as an EEC® Method[5]. The reference base here is the usable surface area in the commercial district (excluding car parking areas). The total energy consumption and total emissions from transport are therefore measured here as

5 Registration ongoing

[kWh/m^2/a] and [kgCO_2/m^2/a].This reference base will be used to determine the responsibility of the people who manage property in the area, work, shop or entertain themselves there.

It can immediately be seen that this approach is a new variant between the territorial and the consumer responsibility principles.

Proportional attribution of transport-related emissions

Transport plays a special role in the question of which emissions and what energy consumption should be attributed to an area. Starting from the basic principle that adding together all the results for the parts of a city must add up to the total value for the city, only half of the transport-related emissions can be attributed to one area. The other half must be attributed to the respective destination or source district. This is the only way to fulfil the condition that the sum of all the emissions from the parts of the town must add up to the total for the city.

The territorial method can similarly be used here with regard to transport. With this method the sum criterion (all parts of the city added together give the total transport-related emissions for the city) is fulfilled if the total emissions in the area are added to this one. This method will therefore also be used for the monitoring planned for later.

Characteristics of the area

Hongqiao is situated in the south-west of the mega-city of Shanghai, directly west of the airport of the same name. A large railway station is also squeezed in between the airport and the actual commercial district at which five metro lines, a maglev line and the local and national railways come together (Figure 12). Hongqiao is also connected to Shanghai's motorway network on three sides.

Hongqiao will be developed as a district in three stages. The following relates to stage one, which is in preparation. According to the plans almost 60,000 people will work in this area. On average at least a further 80,000 people are expected each day to visit, shop and attend the entertainment events.

The city government wants Hongqiao to become a "Low Carbon Business District". What this means in terms of energy consumption and CO_2 emissions was at first unclear. This issue was particularly problematic for the area of transport because here - unlike with buildings - no current standards exist. Below there follows an explanation of how the Hongqiao research team proposes to define the Low Carbon Standard. First of all an ex-ante estimation is required.

Ex-ante estimation of transport in the area based on a traffic model

The ex-ante estimation relates to the time horizon of 2020. In this period the GDP, according to policy guidelines, is set to grow by 45% in relation to 2010; at the same time however it is intended that energy efficiency should increase by the same percentage. It is unclear how these guidelines are to be implemented in the area of transport. In the following explanations proposals will be discussed.

The targeted growth in GDP will result in an increase in income of a similar order. It can be assumed that the strategic transport reference figures such as motorised transport, level of private motorisation and mileages of motorised journeys will come closer to those of western megacities over the next 10 years. This would lead to a considerable increase in motorised transport, energy consumption and CO_2 emissions. This would, however, be inconsistent with the targets of the Chinese government.

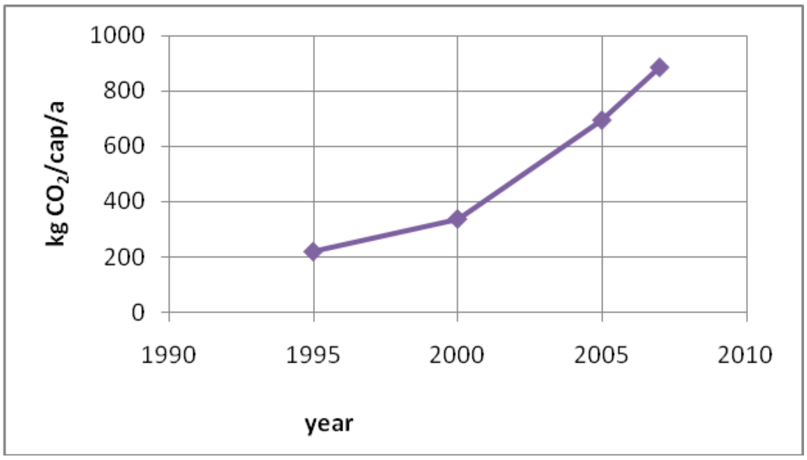

Figure 13: Change in person specific CO_2 emissions for transport (ground traffic only) in Shanghai in 1995 to 2007 (source: Statistical Yearbook Shanghai, 2010 and XIE Shi-chen, 2009).

The rapid increase in the CO_2 emissions related to the population of Shanghai for ground traffic (percentage of the total transport related CO_2 emissions approximately 34%, compared with shipping 47% and air traffic 19%) is already a major challenge. In 2009 the figure was already comparable with those of western cities. However, this is largely not due to a high level of private motorised transport but is rather an expression of inefficient vehicles (mopeds, cars, taxis, freight vehicles and buses).

Definition of a comparable case

A case which could be compared to the yet to be defined plans for Hongqiao, may be drawn from the current situation in a similarly high value office area, whereby however it must be assumed that the modal split will be similar to that of western megacities. These cities, despite good public transport provision, have comparatively a very high percentage of personal individual transport, e.g. Berlin: 45% public transport and 55% personal individual transport[6]. This kind of percentage share should be attributed to the comparable case. This would not be far from reality if we consider the increasing wealth and car-orientation of the population. This scenario is described as an "adjustment scenario".

The current average values have been used in this scenario as vehicle specific energy consumption. The specific energy consumption according to this for cars and taxis is on average 104 kWh/100 vehicle kilometres and for buses and freight vehicles 337 kWh/100km. The energy consumption for the metro was established as being 21 kWh per person kilometre based on statistical data.

The specific CO_2 emissions according to these figures are approximately 28 kg CO_2/100 person-km for car traffic, 11 kgCO_2/100 person-km for the metro and 91kg CO_2/100km for buses and freight vehicles.

This data would produce a current energy usage per m^2 of usable surface area in Hongqiao of 291 kWh/m^2/a and a CO_2 emission of 89 kg CO_2/m^2/a. By 2015 the figures would, because of increasing technical progress, be reduced to 278 kWh/m^2/a and to 85 kg CO_2/m^2/a and by 2020 to 258 kWh/m^2/a and 79 kg CO_2/m^2/a.

These figures are the starting point for determining the targets.

Determining the targets and defining the Hongqiao case

The following variables come into consideration for increasing efficiency in the area of transport according to policy targets:

(a) The modal split. A higher percentage of non-motorised transport and within motorised transport a higher percentage of public transport will reduce the energy requirements and CO_2 emissions.

(b) The specific consumption of fuel per vehicle type per 100 km. This applies to fuel driven vehicles as well as for electric rail transport.

(c) The introduction and prioritisation of electric traction for cars and delivery vehicles. Electric vehicles are locally emissions-free; from the point of view of primary energy usage the fuel mix is definitive. For this reason local electricity generation from renewable energy sources is of major significance.

Hongqiao then will meet the policy target if it can achieve an efficiency increase of 45%. This means that per m^2 of usable surface area, energy consumption by transport in Hongqiao is at least 45% lower than in the comparison case. How can this be achieved?

[6] Figures from SrV+2008 for Berlin.

The majority of those working in and visiting Hongqiao will, according to the planners', use local public transport. Currently, i.e. in 2010, the modal split across all city blocks will be 90% public transport and 10% motorised individual transport. The fact that investors will be set prescribed limits on the number of car parking spaces will help to achieve this goal. In order to improve the CO_2 balance - in combination with decentralised production of renewable energies - there are plans to prioritise electric vehicles in the parking spaces. The research team also envisages a set number of cycle parking spaces to be set out in the investor contracts, in this case a minimum number, combined with a minimum number of electric charging points.

Over the course of time however, the assumed modal split will decrease due to increasing motorisation to (2015) 85:15 and 2020 to 80:20.

There is little influence possible over mileages, however the network of paths in the district and their design should make it possible to achieve a high number of pedestrians and cyclists. Another significant aspect is the development of vehicle technologies. This should make it possible for the mileages to be achieved with significantly lower energy consumption over time, whereby an increasing percentage of electric transport with an increasingly favourable fuel mix is also supposed.

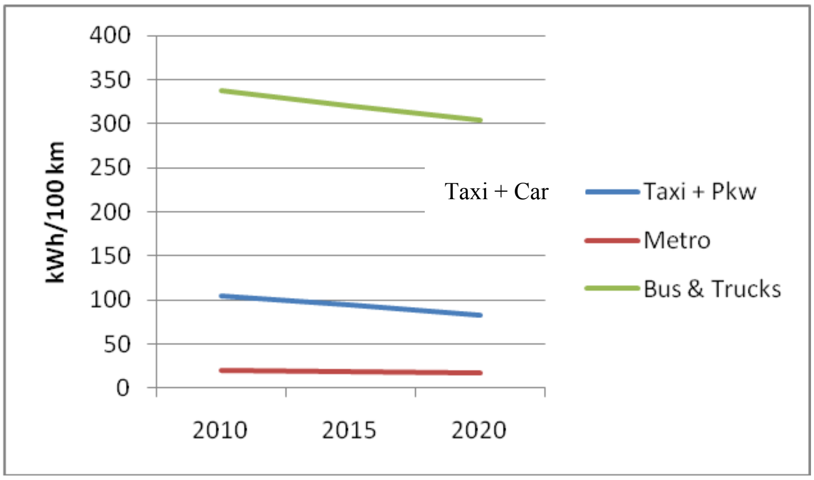

Figure 14: Assumed changes in specific energy consumption

With these assumptions, energy usage for transport in Hongqiao in 2010 and in 2015 will be 134 kWh/m^2/a and will increase in 2020 to 154 kWh/m^2/a (+15%). The CO_2 emissions on the other hand will decrease from 62 kg/m^2/a (2010) through 59 kg/m^2/a (2015) to 56 kg/m^2/a (2020).

In comparison to the adjustment scenario, CO_2 efficiency will be increased by 39%. This does not yet achieve the policy target, however, further reduction is entirely possible if the average vehicle-specific consumption can be decreased still further.

DYNAMIC ENERGY AND CO_2 CONTROLLER EEC®

Methodological system concept

The reasonable question of whether the target of reducing CO_2 in the two cities can be achieved depends on many factors. It is therefore necessary to use a monitoring tool. This monitoring tool will be developed as part of the research project "Shanghai Link project: integrated approaches for a sustainable and energy-efficient city development, city planning, transport, construction and living" (FKZ 01LG0514A1) and will be described here. Because CO_2 cannot be directly measured but must be estimated using a number of variables, the models and methods described above also form the basis for the monitoring.

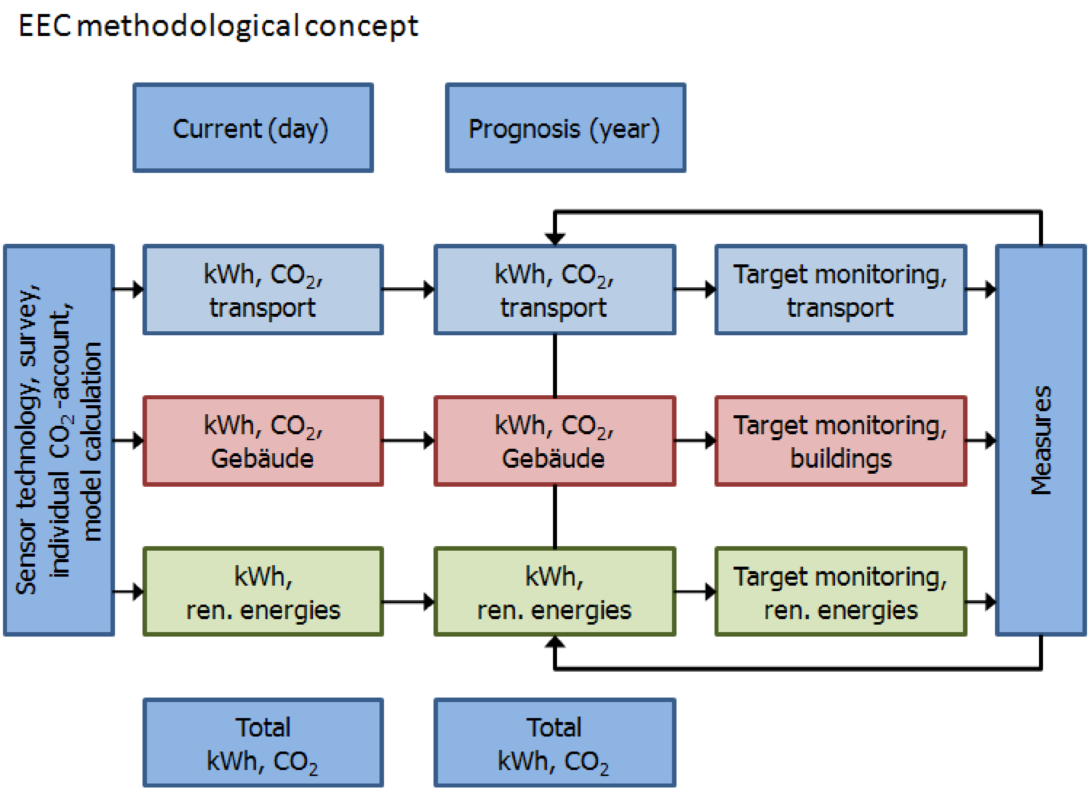

Figure 15: EEC, methodological system concept

The EEC includes the monitoring of three areas of activity: transport, building usage and renewable energy production. In keeping with the aforementioned targets it delivers (a) information on the current status, (a) a prognosis model and (c) verification of targets. The information on the current situation is drawn from the models outlined using empirical data ("sensor technology").

If, in monitoring the targets, it is shown that the target could be missed there is a way out by introducing other measures. If new measures are defined, the models are adjusted in the three areas of activity and the monitoring is carried out again.

Current information relates to one day. In the case of the prognoses which are repeated each day the ongoing year forms the frame of reference over time.

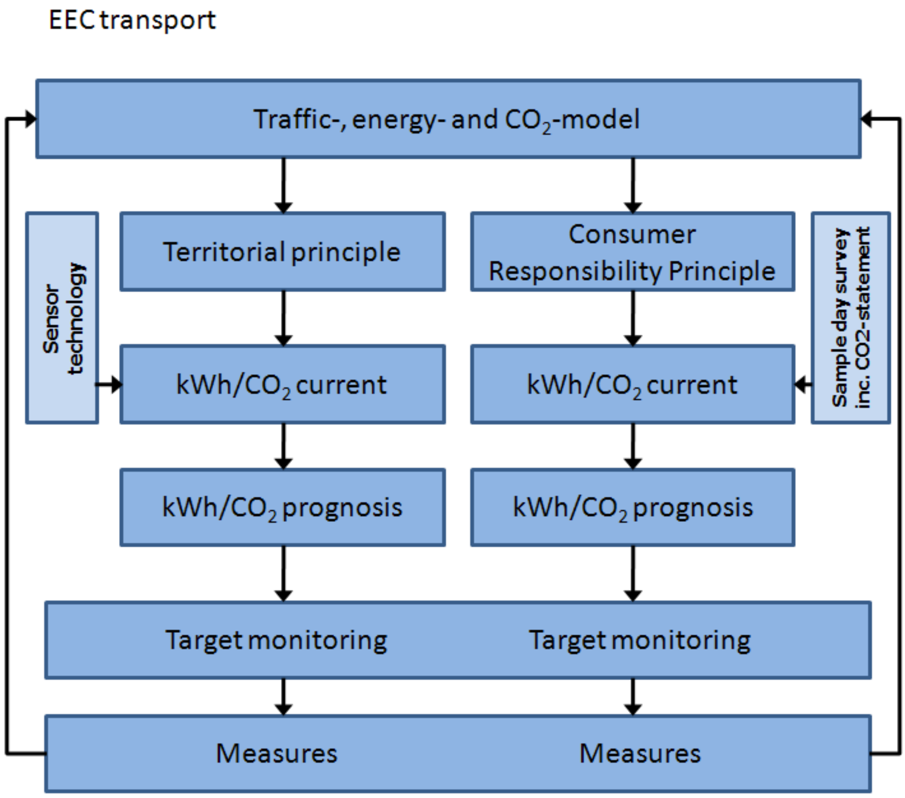

Figure 16: EEC, transport system concepts

The system concept in the area of transport consists of the interplay between models and dynamic empirical data.

To form a picture of energy and CO_2 efficiency in road traffic, hourly dynamic data is used. Sensor technology used here includes automatic traffic monitoring stations and recording the temperature in order to form a better picture of fuel consumption in cold weather. Public transport with its daily mileages is also included in the monitoring. Road freight transport is not monitored as an independent data source but is treated as an addition to the road transport of people. In this way a picture can be formed of energy and CO_2 efficiency according to the territorial principle.

To perform the calculation according to the consumer responsibility principle, transport data specific to groups of people gleaned from annual questionnaires will be evaluated.

Technically, the EEC is a server-client system. The **server** handles central data handling, data archiving and reporting. On the software side open source products are used.

The **clients** handle the individual areas of interest. One client is responsible for the areas of city structure, buildings and renewable energies. Another client is dedicated to the area of transport. The respective current data is processed on these clients. The data required for reporting is made available to the server and from here is archived in a database.

Reporting concept

The task of reporting is a major function. It is localised on the server and enables public access to the most important daily results as well as to the prognoses via the Internet. The following graphs are two examples from the comprehensive reports developed for the Shanghai research project.

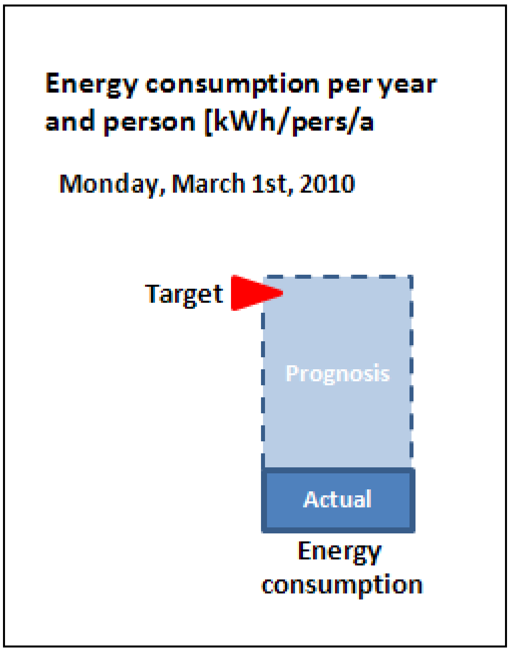

Figure 17: Example of one page from the report

The energy consumption up to the point of sampling ("current") and the prognosis for the year are shown. The red triangle marks the target value for the current year which should be undershot by as wide a margin as possible.

Alongside the highly aggregated results which are differentiated according to geographical units and areas of activity, network-related and building- related results are also shown.

Figure: Example for the network and building related report (Source: research project Shanghai)

The EEC does not foresee an individual questionnaire about personal energy consumption or personal CO_2 emissions.

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