Cities and Climate Change: Ruhr Area 2050

Integrated Ruhr Area Model and Regional Modal Shift

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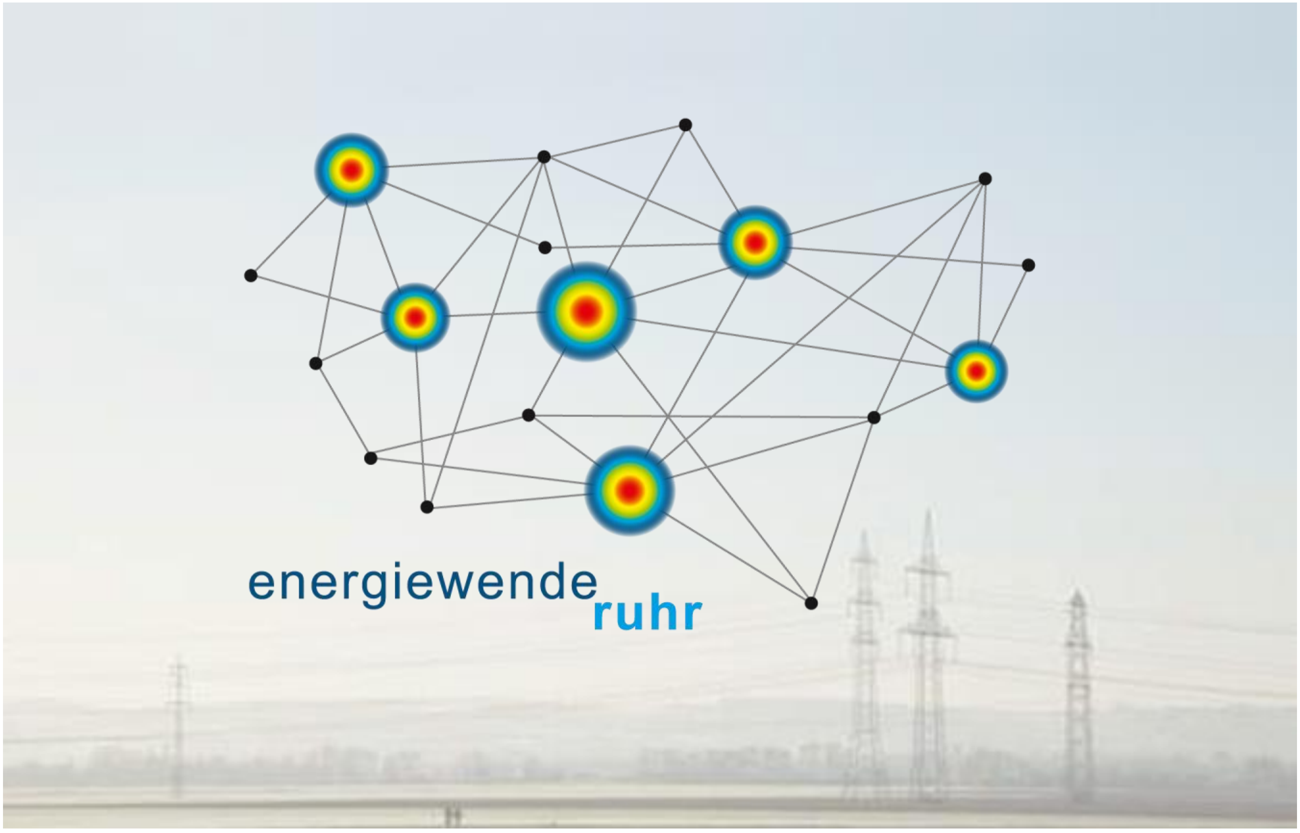

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as subprojects

- Integrated Ruhr Area model 2050 (S&W, LUIS)
- Regional Modal Shift (WI)

in the Framework Programme for the Implementation of the Energy Transition in the Municipalities of the Ruhr Area.

Contents

1 Research problem and objectives

Climate researchers agree that anthropogenic greenhouse gas emissions contribute significantly to climate change and that drastic policies to mitigate greenhouse gas emissions and to adapt to the consequences of no longer avoidable climate changes are needed. The Federal Government with its Climate Protection Plan 2050 has confirmed its target to reduce the greenhouse gas emissions of Germany until the year 2050 by 80 to 95 percent compared with 1990, i.e. to aim at almost complete greenhouse gas neutrality (BMUB 2016). The state government of North-Rhine Westphalia with its Climate Protection Law of 2013 wants to reduce the greenhouse gas emissions of the state until 2020 by 25 percent and until 2005 by at least 80 percent (Landtag Nordrhein-Westfalen 2013). Many cities have joined climate alliances or have adopted ambitious climate protection programmes.

Cities are the largest emitters of greenhouse gases through heating, air conditioning, production and transport. At the same time cities, through their high density, are particularly vulnerable by negative climate consequences, such as floods, droughts or heat waves. With its population of more than five million the Ruhr Area is one of the major agglomerations in Europe. How can the climate protection targets be achieved in the Ruhr Area?

Current policy approaches in the Ruhr Area mainly focus on small-scale measures to adapt to no longer avoidable climate changes and approach climate protection policies, i.e. policies to reduce greenhouse gas emissions, still not resolutely enough. Because of its industrial past and polycentric settlement structure (Figure 1) the Ruhr Area has a particular future potential for climate protection and the energy transition that could be activated, for instance through the rezoning of former industrial areas for an urban landscape that uses less land, transport and energy. In addition the Ruhr Area has a mature transport infrastructure developed over two centuries, connecting its polycentric urban cores (Figure 2).

One of the reasons why this potential has not been utilised so far is the lack of knowledge about the particular potential for climate protection of land use and transport planning policies and their potential impacts.

1.1 The projects Integrated Ruhr Area Model 2050 and Regional Modal Shift

This is the point of departure of two projects of the Framework Programme for the Implementation of the Energy Transition in the Municipalities of the Ruhr Area funded by the Stiftung Mercator, the project “Integrated Ruhr Area Model 2050” of Spiekermann and Wegener Urban and Regional Research (S&W) and the Department of Sustainable Infrastructure and Urban Planning (LUIS) of the University of Wuppertal and the project “Regional Modal Shift“ of the Wuppertal Institute (WI):

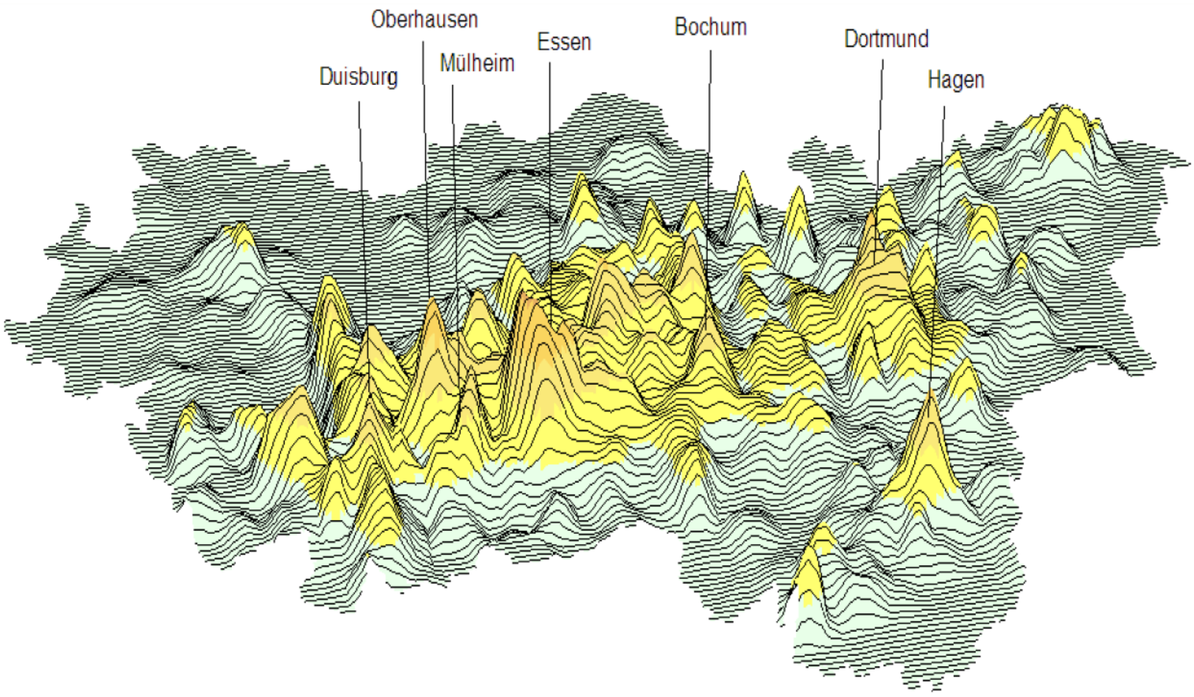

Figure 1. The polycentric Ruhr Area: population density

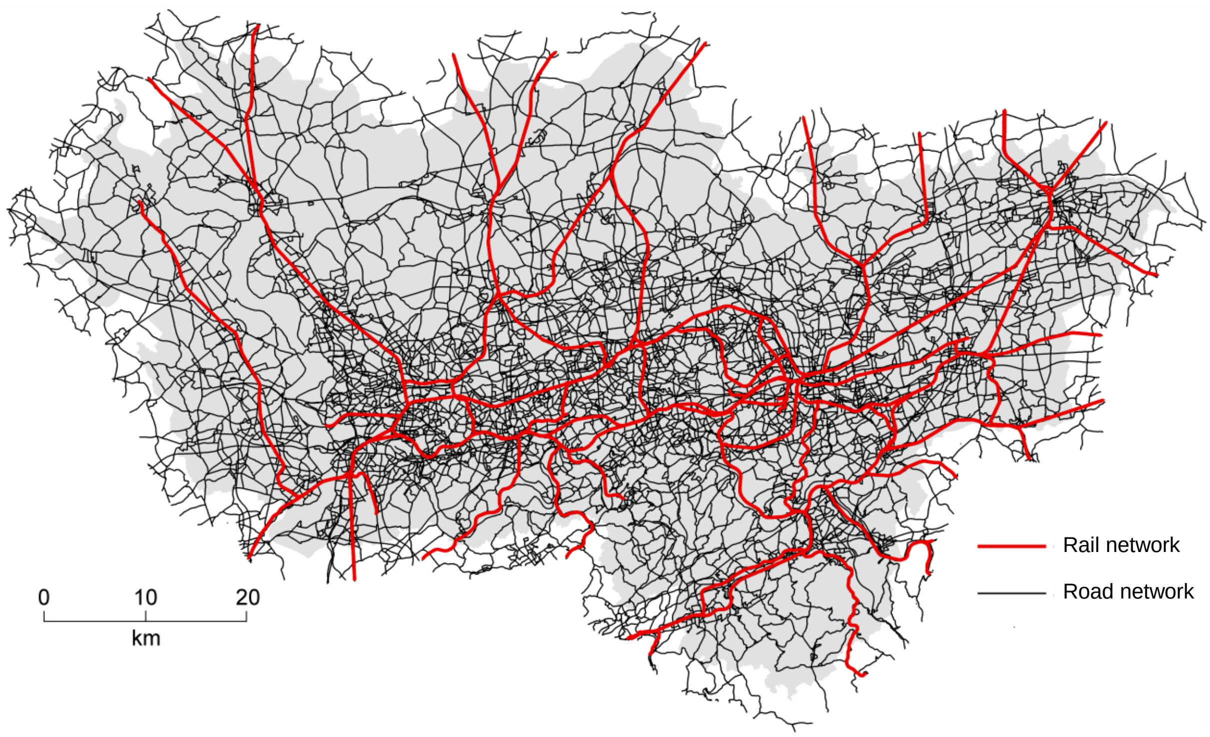

Figure 2. The polycentric Ruhr Area: transport network

- The aim of the project **“Integrated Ruhr Area Model 2050“** was the development and application of an integrated model system, with which the impacts of policy approaches to reduce energy consumption and greenhouse gas emissions in urban regions until the year 2050 could be assessed and evaluated. In the project an existing land use and transport model for the eastern Ruhr Area was enlarged to the whole Ruhr Area and extended by submodels of energy consumption of buildings and transport. The results were to inform civil society, planning and politics which policies at the European, national regional and local level need to be implemented in order to achieve the targets of the energy transition in the Ruhr Area.
- The focus of the project **“Regional Modal Shift“** was the regional passenger transport in the Ruhr Area. Here currently 53 percent of all trips are made by car (Sagolla 2012) compared with a target modal split of 25 percent car and 25 percent each for walking, cycling and public transport. (WI 2013; WI 2015; RVR 2014). A central approach to reduce energy consumption and greenhouse gas emissions is the modal shift from car traffic to more environment-friendly travel modes (walking, cycling, public transport or car sharing). The polycentric structure of the transport network in the Ruhr Area offers good starting conditions for a climate-friendly mobility by walking, cycling, public transport or car sharing. In addition electromobility can further contribute to the reduction of energy consumption and greenhouse gas emissions.

This report presents the results of the co-operation between the two projects in an integrated form. According to the specific objectives of the two projects, the specific characteristics of the participating institutions led to their individual contributions to this report. The tasks of S&W were predominantly the further development of the Ruhr Area model, the elaboration of the required database, the new model elements, the implementation of the examined scenarios and the evaluation of the results. LUIS developed the theoretical and empirical foundations for the integration of electromobility and cycling into the model. The focus of WI was the development of the transport policy measures and their analysis with respect to their impact on the model shift.

1.2 Controlling land use development, mobility and the energy transition

The accessibility of work places, retail and education facilities and other destinations determines the length of trips and choice of travel mode and so the energy consumption of trips. Accessibility is determined by both the location of residences and trip destinations and the available travel modes and their quality and so is also an explanatory factor for the location choice of firms and households. In the Ruhr Area model therefore both land use and transport policies were developed and modelled in an integrated way.

Altogether three possibilities to influence land use that might have an impact on energy consumption and transport volumes in the region were analysed:

- **Return to high-density, mixed-use settlement structures by containment of further urban sprawl**: Due to its industrial past and polycentric settlement structure the Ruhr Area has a particular future potential for an urban landscape that uses less land, transport and energy. Therefore different concepts for the promotion of high-density, mixed-use settlement structures were modelled, such as comprehensive densification (compact city), promotion of small and medium-sized centres (polycentric city) and promotion of densification at railway stations (transit-oriented development) combined with containment of urban development in other areas.
- **Incentives for smaller distances between residential and work locations**: When planning new residential areas there is a great potential for an inner reorganisation of cities whereby households in the long term move closer to their work and education locations as the costs of spatial mobility rise. Therefore higher fuel prices are also a way to reduce daily trip distances.
- **Incentives for energy retrofitting**: A third group of policy approaches aims at increasing the acceptance of energy retrofitting of residential and commercial buildings. The willingness of building owners to energy retrofit their buildings is to a large degree determined by the time, by which the retrofitting measurers are paid back through energy cost savings. In the rental market landlords can pass the costs of energy retrofitting on to their tenants through rent increases only partly. By promotion measures, such as partly coverage of the retrofitting costs the payback period is shortened and so the willingness of owners to retrofit increased.

As land use policies, also policies to reduce car travel or to shift car travel to other more environment-friendly travel modes can be either positive incentives (pull policies) or restrictions (push policies):

- **Pull policies** aim at making environment-friendly mobility, i.e. walking, cycling, public transport or car sharing more attractive, for instance by improvement of mobility options, lower public transport fares or investment in cycling and walking networks.
- **Push policies** aim at making car driving less attractive, for instance by higher driving costs, lower speeds or restricted car parking.

The basic question was: Which potential for the transition from car traffic to walking, cycling, public transport and car sharing can be achieved through a combination of push and pull policies? Which effects with respect to the reduction of energy consumption and CO_2 emissions will result, and what can be the contribution of electromobility?

2 Methodology and policy fields

2.1 The Ruhr Area model

The Ruhr Area model was developed to assess the long-term impacts of public planning policies in the policy fields economic promotion, housing, public facilities and transport on land use, transport and the environment in the Ruhr Area.

The Ruhr Area model is a simulation model of intraregional location and mobility decisions in an urban region. The model originally developed at the Institute of Spatial Planning of the University of Dortmund (IRPUD model) has been applied in different projects for the urban region of Dortmund (Lautso et al. 2004; Fiorello et al. 2006; Spiekermann and Wegener 2005; Beckmann et al. 2007). In this project it was extended to the Ruhr Area model (see Section 2.1.4). The model receives its spatial dimension by the subdivision of the study area into zones, which are linked with each other by transport networks. The transport networks contain the most relevant links of public transport and roads in the form of an integrated multimodal network including walking and cycling links and all network changes of the past and future. The model receives its temporal dimension by the subdivision of time into periods of one or more years duration.

2.1.1 Theoretical foundations

The process of urban development is understood as a sub-process of societal development in which public and private actors interact with each other, each of them pursuing their different objectives:

- *Public actors* of urban development are public authorities from the national to the municipal level. For spatial urban development relevant decisions are all direct investment or construction policies of municipalities or other public authorities as well as all indirect national, state or municipal policies in the fields of taxation and the land and construction markets, including land use planning. The public interventions in spatial urban development constitute the planning sector of urban development.
- *Private actors* of urban development are firms, households or individuals. Their location and mobility decisions, which cannot or can only indirectly be influenced by public planning decisions, are also relevant for urban development. Private actors of urban development interact with each other on special markets as the land and construction or housing market. The private decisions constitute the market sector of spatial urban development.

'Plan' and 'market' are therefore two fundamentally different categories of urban development, which mutually condition each other. Public planning sets the framework conditions for the behaviour of private market actors or intervenes in the market directly. Conversely, public planning is often a reaction on market developments or even assists economically powerful market forces. Often its only role is to compensate for discrimination caused by the market. Depending on the social and economic system, the relationship between 'plan' und 'market' is different. More recently the distinction between public and private actors is becoming more difficult because of semi-public actors such as public-private partnerships or privatised public agencies.

However, for the Ruhr Area model it is only important which decisions by which actors are to be simulated *endogenously* in the model and which are to be assumed *exogenously*.

Decisions of public actors are entered into the model exogenously as well as decisions of semi-public or private actors if they are largely determined by public actors, plus large private decisions, such as major industrial establishments, as historical singular events which cannot be predicted by any model. All other decisions are private decisions which are simulated endogenously in the model. It is assumed that most decisions relevant for urban spatial development are made by private actors. Therefore the model predominantly simulates the behaviour of private actors within the framework of public decisions.

The following basic assumptions are made about the behaviour of private actors based on action theory and social psychology theory:

- Actors attempt to act rationally, i.e. to follow and realise their interests (preferences).
- Doing that they are subject to group-specific economic, legal and informational constraints.
- In the face of these constraints they are satisfied with the realisation of aspiration levels.
- The aspiration levels of actors are determined by their experience during their realisation.
- Economically weaker actors are frequently forced to reduce unfeasible aspiration levels.

So preferences and constraints are the determining factors for the behaviour of actors in decision situations in which they choose between alternatives. It is assumed that in doing this they apply heuristic decision rules, with the effect that the results of the decisions are not always optimal with respect to individual utility maximisation, but represent systematic deviations from the optimum, the distribution of which can be estimated.

Land use and transport

With these basic assumptions about the behaviour of private actors the location and mobility decisions relevant for spatial urban development are modelled. Figure 3 shows the modelled relationships in the ‘land-use transport feedback cycle’:

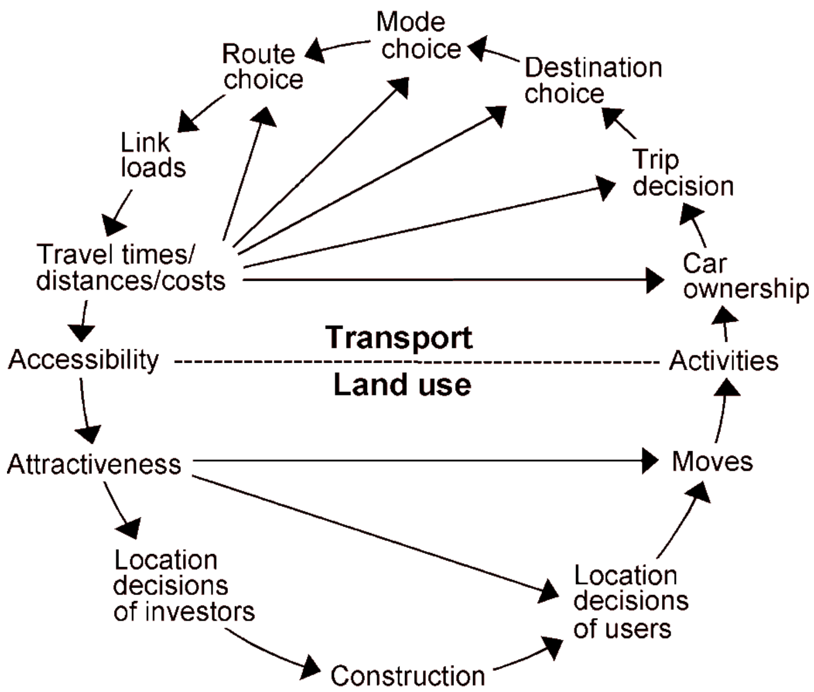

Figure 3. The land-use transport feedback cycle (Wegener 1999)

- The distribution of land uses, such as residential areas or industrial or commercial areas, determines the location of households and firms and so also die locations of human activities, such as living, working, shopping, education and recreation.
- The distribution of activities requires mobility to overcome the distances between these locations.
- This mobility occurs over the transport system based on decisions of travellers on the availability of a travel mode, the frequency of trips and destinations and the travel mode used and the chosen route. The consequences of these decisions are traffic flows and, in the case of congestion, increases of travel times, trip distances and costs.
- Travel times, trip distances and costs generate opportunities for mobility, i.e. accessibility. The spatial distribution of accessibility influences, together with other activity indicators, the location decisions of real estate investors and results in new construction, retrofitting or demolition, i.e. in changes of the settlement structure. These changes finally determine the relocation decisions of households and firms and so the distribution of activities in space.

The modelling of daily mobility decisions is based on the following assumptions about user behaviour:

It is assumed that people organise their lives spatially in their daily *action spaces* (Hägerstrand 1970). The action spaces of individuals are the total of opportunities available to them based on their age, income residential location and other determining factors. The action spaces are restricted by three kinds of constraints:

- *Capacity constraints*: person-related non-spatial constraints of mobility, such as money budget, time budget, availability of travel modes and ability to use them;
- *Coupling constraints:* constraints of linkage of activities through their location and the time schedules of facilities and other individuals;
- *Institutional constraints:* constraints of access to facilities through public or private definitions such as property rights, opening hours, entrance fees or prices.

For daily mobility decisions money and time budgets are the most important restrictions. Zahavi (Zahavi et al. 1981) proposed the hypothesis based on action space theory, that individuals do not, as conventional travel theory assumes, *minimise* spatial impedance, but that they instead try to *maximise* the number of reachable opportunities within the constraints of their time and money budgets for travel available to them. In addition he found through analyses in a large number of cities in different countries that time and money budgets for travel differ within urban areas as a function of age, income and residential location, but that their averages across whole urban regions showed a high stability over time.

The stability of the time and money budgets explains why every acceleration of transport in the past has not led to time savings but to more and longer trips – with the result that the time spent by an average traveller per day has stayed at somewhat more than an hour per day. It also explains why the fact that real fuel prices have in the last forty years fallen to less than half has not led to a decrease of transport expenditures but to an enormous expansion of car traffic. It finally explains why acceleration and decreasing costs together have allowed more and more people to choose residential locations at the urban fringe connected with longer trips without large increases of their time and money budgets for transport, and why shopping centres in low-density suburbs attract customers from ever larger catchment areas.

2.1.2 Model structure

The Ruhr Area model predicts for each simulation period:

- intraregional location decisions of firms, housing investors and households,
- the resulting migrations and transport flows,
- the development of construction activity and land use and
- the impacts of public planning policies in the fields of economic promotion, housing , infrastructure and transport.

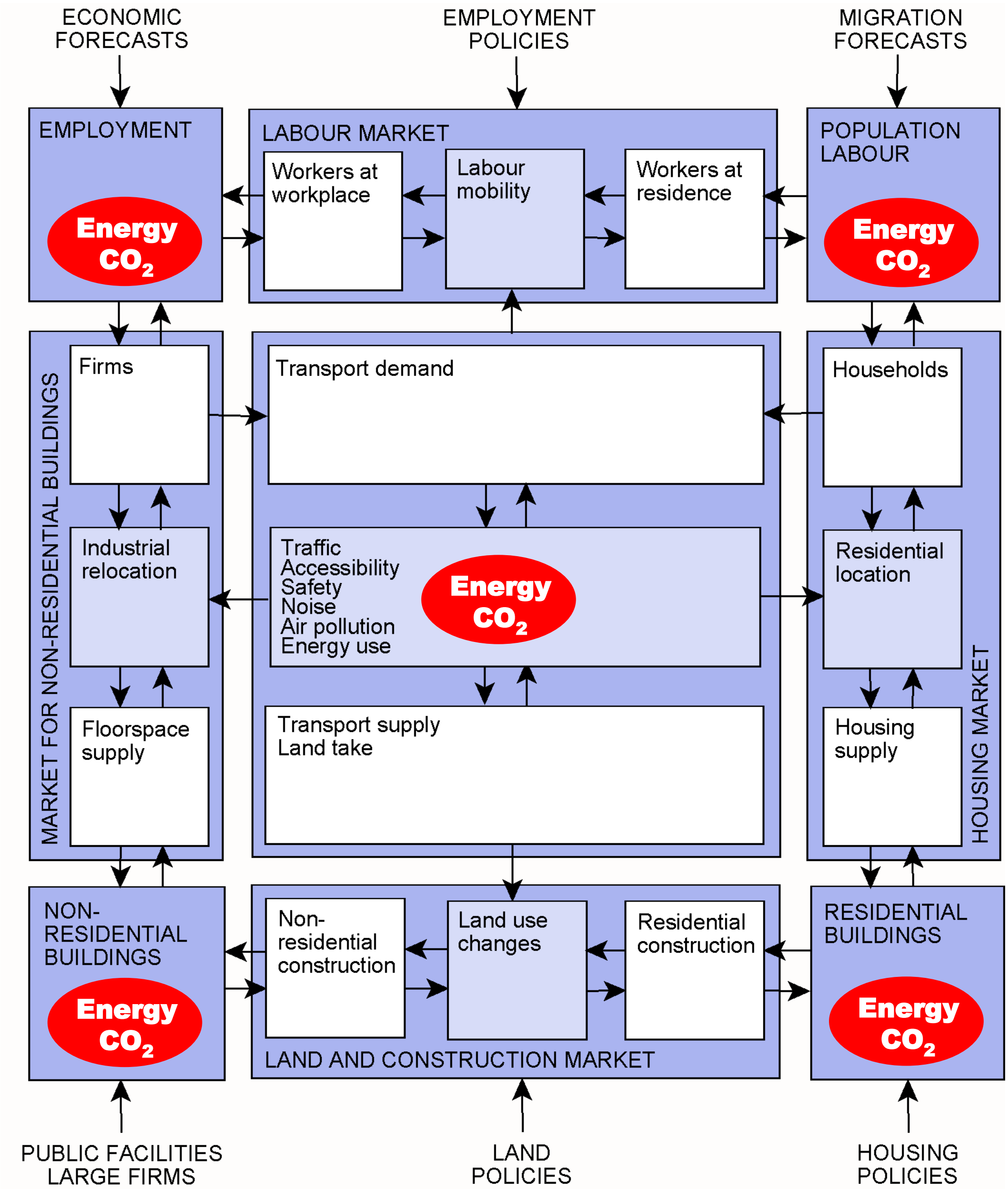

Figure 4. The integrated Ruhr Area model

Figure 4 is a schematic presentation of the most important subsystems and the interactions between them and the most important planning policies the impacts of which can be analysed with the model.

The four squares in the corners of the diagram show the main stock variables of the model: population, employment, residential buildings (housing) and non-residential buildings (industrial and commercial workplaces and public facilities).

The actors representing these stock variables are individuals, households, workers, firms and housing investors. These actors interact on five submarkets of urban development:

- the labour market (new jobs and redundancies),
- the market for non-residential buildings (new firms, firm relocations and firm closures),
- the housing market (immigration, outmigration and moves),
- the land and construction market (new construction, retrofitting and demolition) and
- the transport market (trips and their impacts: accessibility, congestion, accidents, traffic noise and energy consumption).

For each submarket the diagram shows supply and demand and the resulting market transactions. The supply in the submarkets is a function of demand, and the demand in the total region a function of exogenous assumptions about, for instance, immigration or total economic development. The demand in the subregions of the urban region is a function of total demand, and its spatial distribution determined by the supply of work places, buildings and land in the subregions and their attractiveness. The attractiveness of supply is in general a user-group specific function of location (accessibility), quality and price. The large arrows in the diagram indicate exogenous assumptions, either forecasts of the economic and population development of the total region based on long-term economic and demographic trends or policies in the fields of economic promotion, housing construction, public facilities and transport.

2.1.3 Submodels

The Ruhr Area model has a modular structure and consists of six interconnected submodels, which are executed in cyclical sequence using a common spatio-temporal database (for detailed descriptions see Wegener 2011).

(1) In the *transport* submodel work, shopping, services/social and education trips of four socioeconomic groups and four travel modes (car, public transport, cycling and walking) are calculated. The model determines a solution in which car ownership, trip rates, destination, mode and route choice and congestion in the transport network are in equilibrium.

(2) In the *ageing* submodel changes of the model variables resulting from biological, technological and long-term socioeconomic trends are simulated using probabilistic transition models of the Markov type with dynamic transition rates. There are three such models, for employment, population and households/housing.

(3) In the public programmes submodel public planning policies designed by the user in the fields of economic promotion, housing construction, health and social facilities, education, recreation and transport are executed.

(4) In the *private construction* submodel location decisions of private investors, who demolish or retrofit commercial or residential buildings or construct new buildings for sale or rent or their own use are simulated. So the submodel is a model of the regional land and construction market.

(5) In the *labour market* submodel intraregional labour mobility, i.e. the choice of workers between free jobs in the region, is simulated.

(6) In the *housing market* submodel intraregional moves of households are modelled as search processes on the regional housing market. The housing market model is a stochastic microsimulation model of Monte-Carlo type. The results of the housing market model are intraregional migration flows of households by household type between residences by housing type in the zones.

2.1.4 Model extensions

During the project the original IRPUD model was extended in space, time and substance to the Ruhr Area model:

- The study area was extended to the whole area of the Regional Association Ruhr (Regionalverband Ruhr or RVR) with its 53 municipalities.
- The planning horizon of the model was extended to the time period between 1990 and 2050 to examine the achievement of the energy transition targets at the national and state governments.
- The land use part of the model was extended by the building energy component (Fuerst and Wegener 2017).
- The transport submodel was extended by modelling cycling and walking separately and by the new component electromobility.

The principle applied in the new building energy submodel was to first model the motivation of building owners to energy retrofit their buildings and then to estimate their decision about the degree of energy efficiency to be achieved. In this the payback period, i.e. the number of years after which the energy savings exceed the costs of the energy retrofitting proved to be an important variable.

In the extension of the transport model the two modes cycling and walking, which were modelled together in the IRPUD model, were separated. For this it was necessary, in addition to the two indicators used in the IRPUD model for modelling travel behaviour, travel time and travel cost, to consider a third indicator called comfort factor in order to take account of the physical effort, weather dependency and subjective safety perception of cyclists. When modelling the market penetration of electric cars different measures to subsidise the purchase of electric cars and the charging infrastructure were examined.

2.1.5 Study area

The simulation model works with zones as units of analysis and forecasting. Zones can be municipalities or parts of municipalities, such as urban districts, statistical tracts of parts of statistical tracts. A distinction is made between internal and external zones: Internal zones cover the study area proper, i.e. the area of the Regional Association Ruhr (RVR). External zones represent the outer environment of the study area, i.e. origins and destinations of trips from and to the internal zones.

To define the system of zones, the Ruhr Area was subdivided into urban districts or statistical tracts or parts of them of the 53 municipalities of the Ruhr Area. Such a subdivision has the advantage that it can be immediately linked with the subdivision used for municipal statistics. In the few municipalities in which such subdivision does not exist, a subdivision following cadastre borders as closely as possible was applied.

Figure 5 shows the resulting spatial subdivision of the Ruhr Area into 687 internal zones, Figure 6 shows the 134 external zones.

2.2 Scenario system

With the model different scenarios of the development of the Ruhr Area until the year 2050 under different assumptions about the development of external framework conditions and possible planning policies were analysed in a scenario approach.

Scenarios are no forecasts but possible futures under assumptions about different framework conditions and planning measures. Scenarios do not need to be realistic in the sense of practical feasibility. Also visionary scenarios can be useful for stimulating the discussion.

In all applications the first simulation is the so-called base or reference scenario. The base scenario serves as basis for the comparison between the simulated scenarios. It is defined as the most probable development of the region if all trends of today remain in effect during the whole forecasting period. That does not imply that in the base scenario no planning policies are implemented, rather it contains all policies already being implemented or decided upon.

Policy scenarios are simulation runs in which the impacts of political or planning measures are analysed. With the model policies to change urban land use and transport planning were analysed as well as integrated strategies containing elements of both. Land use policies are, for instance, land use plans to create compact or polycentric cities, new housing measures or promotion of energy retrofitting of buildings. Transport policies are, for instance, measures to promote the shift from car to more environment-friendly travel modes or measures to restrict car driving, such as speed limits or the reduction of lanes of main roads.

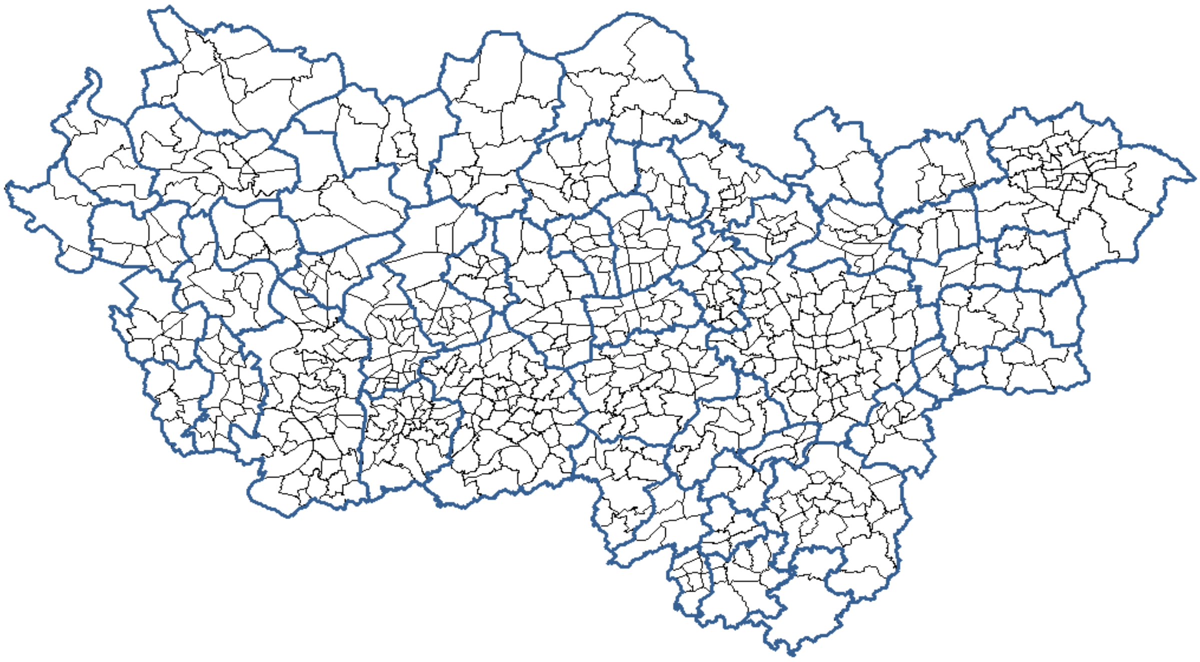

Figure 5. The 687 internal zones of the Ruhr Area model

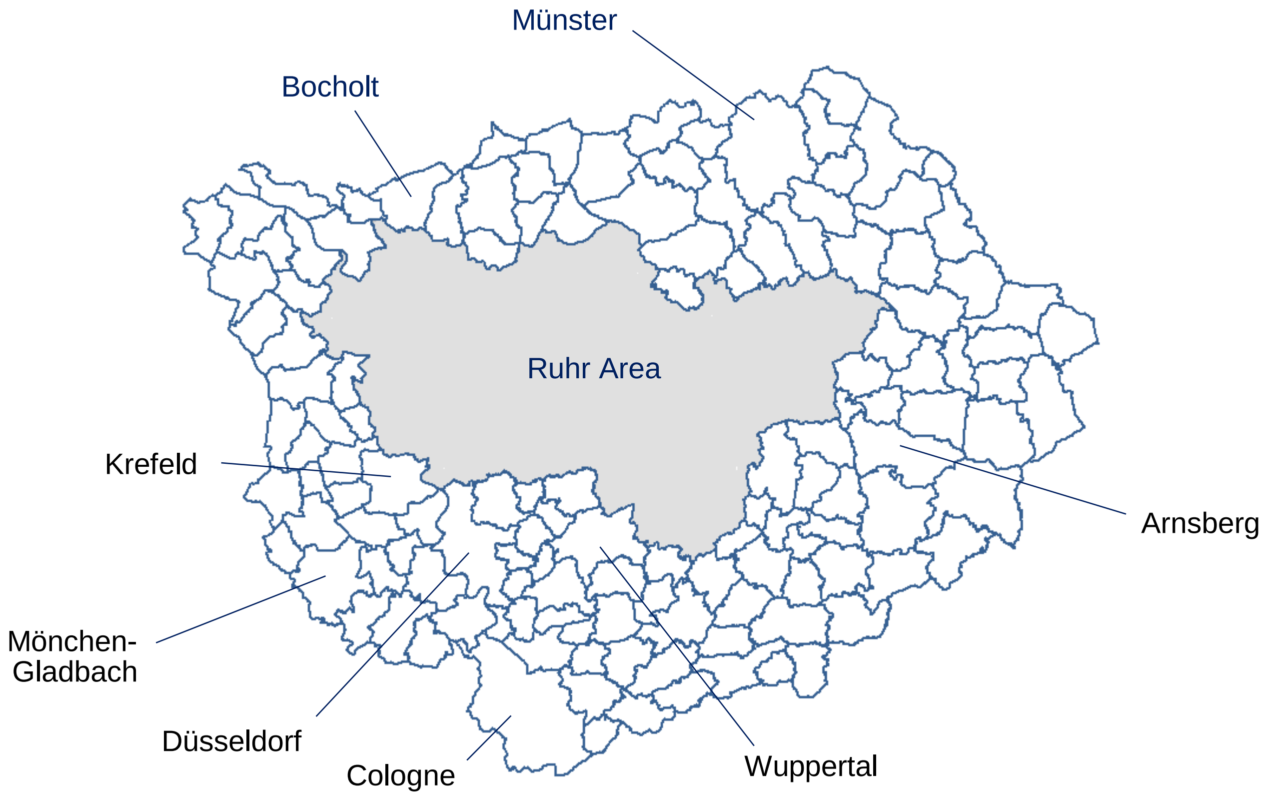

Figure 6. The 134 external zones (municipalities) of the Ruhr Area model

In principle the analysed policies are known strategies to promote the shift from car to more environment-friendly travel modes, such as service improvement of public transport, comprehensive promotion of cycling and walking or speed limits, the reduction of road lanes or increased parking charges.

But also innovative policies, such as the introduction of a regional cordon fee and a citizen ticket are part of the policy portfolios for the shift from car traffic to more environment-friendly travel modes. Fundamental for the modelled measures is that they can be implemented by regional or state authorities ambitiously and area-wide in the whole Ruhr Area.

Finally several different combinations of land use and transport scenarios were simulated. By that synergies between the individual measures become visible: Measures to promote high-density and mixed-use settlement structures support measures to promote more environment-friendly travel modes. The concentration of housing in the vicinity of railway stations leads to better utilisation of trains.

2.3 Scenario assumptions

Altogether 26 different policy scenarios were simulated with the Ruhr Area model. (Table 1):

- 1 base scenario,
- 19 individual policy scenarios from seven policy fields and
- 6 combination scenarios in which individual policy measures were combined to integrated strategies.

The base or reference scenario serves as the basis for the comparison between all other scenarios. It shows the most probable development of the region if all trends of today remain in effect until the year 2050. The base scenario also contains planning policies currently in implementation, such as for instance the municipal land use plans and the planned RRX regional train or the express cycling route (Radschnellweg) RS1. Policy scenarios are simulations in which the impacts of political or planning policies are analysed. In the scenarios the time between 1990 and 2015 presents the development until today and the time between 2015 and 2050 the anticipated future development.

All 26 scenarios were simulated with two different assumptions about the development of fuel prices. In the scenarios called A scenarios a moderate fuel price increase of 1 percent per year was assumed. In the scenarios called B scenarios a significant long-term increase of fuel prices of 4 percent per year was assumed. Such massive increase of fuel prices is not unrealistic and is therefore analysed as a substantial change in the framework conditions of the policy scenarios. It does not matter how the fuel price increases come about, through a new co-ordinated policy of the oil producing countries or through higher fuel taxes caused by policy changes of the EU or the Federal Government in the interest of climate protection.

Table 1. Integrated Ruhr Area model 2050 scenarios

Policy fields		Measures[1]
0	Base scenario	All current measures will be continued.
1	Land use	11 Compact city 12 Densification at S-/U-Bahn stations 13 Densification at railway stations 14 Densification of main cities
2	Housing	23 New housing at railway stations
3	Energy efficiency	31 Energy retrofitting of buildings 32 Promotion of electromobility 33 Free-floating car sharing 34 Reduction of fuel consumption
4	Car (Push)	41 Regional cordon fee 42 Reduction of lanes of main roads 43 Area-wide speed limits 44 Higher parking fees
5	Public transport (Pull)	51 Extension of public transport network 52 More trains/buses per hour 53 Citizen ticket
6	Cycling (Pull)	61 Faster cycling 62 Express cycling routes
7	Walking (Pull)	71 Shorter walking distances
8	Integrated strategies	Six different combinations of policies (see Table 2)

[1] All scenarios were combined with two different assumptions about fuel price increases: one percent per year (A scenarios) or four percent per year (B scenarios).

2.3.1 Land use scenarios

Compact city (A11/B11)

Current land use planning is not very restrictive with respect to zoning of new land for construction. In this scenario beginning in the year 2020 the concept of the compact city of short distances is consistently implemented. In order to prevent further urban sprawl future construction projects for new housing, retail or commercial use are permitted only in city centres and neighbouring districts with significantly above-average population and building density. This is the case in 225 zones of the Ruhr Area model. In these zones the current land use plans are maintained but adjusted with additional land for densification. In the remaining 482 zones new construction is no longer permitted after 2020.

Densification at S-/U-Bahn stations (A12/B12)

In this scenario beginning in the year 2020 the concept of a polycentric settlement structure through transit-oriented development (TOD), i.e. concentration of spatial development at S- and U-Bahn stations, is consistently followed. To prevent further decentralisation of urban development, future construction projects for housing, retail or commercial use are permitted exclusively in those zones of the Ruhr Area model in which at least one S- or U-Bahn station exists in walking distance. This is the case in 380 zones of the Ruhr Area model. In the remaining 307 zones new construction is no longer permitted after 2020.

Densification at railway stations (A13/B13)

In this scenario beginning in the year 2020 the concept of a polycentric settlement structure through transit-oriented development (TOD), i.e. concentration of spatial development at railway stations, is consistently followed. To prevent further decentralisation of urban development, future construction projects for housing, retail or commercial use are permitted exclusively in zones in which at least one railway or S-Bahn station exists. That is the case in 170 zones of the Ruhr Area model. In the remaining 517 zones after 2020 new construction projects are no longer permitted.

Densification of main cities (A14/B14)

This scenario follows the concept of the compact city. Beginning in the year 2020 future construction projects for housing, retail or commercial use are permitted only in the inner cities of the five main cities of the Ruhr Area Duisburg, Essen, Bochum, Dortmund and Hagen and within ten kilometres around their city centres. This is the case in 194 zones of the Ruhr Area model. Here significant densification through zoning measures is envisaged. In the remaining 493 zones no further construction projects are permitted after 2020.

2.3.2 Housing scenarios

New housing at railway stations (A23/B23)

In this scenario beginning in the year 2020 public authorities construct 13,000 dwellings annually in order to create affordable housing. This publicly subsidised housing will be constructed only in the immediate vicinity of railway and S-Bahn stations. These are the same 170 zones of the Ruhr Area model as in Scenario A13/B13. The scenario promotes densification following the concept of polycentric development through transit-oriented development (TOD). The new housing will be constructed according to the energy efficiency standards of the years of construction, i.e. not as zero-energy housing. In addition private construction by land owners and investors will be possible but will be permitted only in the 170 zones near rail stations. In the remaining 157 zones after 2020 new construction projects are no longer permitted.

2.3.3 Energy efficiency scenarios

Energy retrofitting of buildings (A31/B31)

The energy needed for heating buildings represents for a significant share of the energy consumption of urban systems. Therefore energy retrofitting can make a large contribution to energy saving. In the base scenario without substantial public subsidies only few buildings are energy retrofitted. In this scenario it is assumed that the subsidy of the investment needed for energy retrofits will be increased from 10 percent of the investment cost in the base scenario to 50 percent of the investment cost, with the effect that the payback period for house owners is significantly reduced making energy retrofitting of residential buildings much more attractive.

Promotion of electromobility (A32/B32)

In this scenario it is assumed that beginning in 2020 the subsidy for the purchase of battery-powered electric vehicle will be increased to 33 percent of the purchase price and that the installation of charging stations in inner cities will be completely financed from taxes. Without such subsidies the market penetration of electric vehicles will remain small. Important barriers addressed in this scenario are high purchase prices and the low availability of charging stations. A good example for the promotion of electromobility is Norway where electromobility is subsidised so that they are equally or even less expensive than conventional vehicles, so that today almost every fifth new car in Norway is an electric vehicle (Energiezukunft 2016). After 2025 only electric vehicles will be sold in Norway (ibidem).

Free-floating car sharing (A33/B33)

In this scenario an area-wide free-floating car sharing network will be established in the Ruhr Area. Car sharing supply will increase from 2 cars per 1,000 population in 2020 to 3 cars per 1,000 population in 2030 and 4 cars per 1,000 population in 2040. These assumptions are based on the ‘car sharing capital of Germany’, Karlsruhe, where in 2015 already 2.15 cars per 1,000 population existed (bcs 2015), significantly more than in the Ruhr Area, e.g. Essen with 0.14 cars per 1,000 population (bcs 2013). Car sharing promotes multimodal, less car-oriented mobility (‘using ínstead of owning’). A car sharing vehicle replaces between one and 20 privately owned cars (bcs 2016; BMW et al. 2016; Team Red et al. 2015). In Bremen car sharing is actively promoted by making public parking spaces available for car sharing (‘mobil.punkte’). Until 2020 20,000 car sharing users are expected, which will make 6,000 parking spaces redundant in Bremen. (Stadt Bremen 2016, 133).

Reduction of fuel consumption (A34/B34)

Energy savings in transport can be achieved also without changes in travel behaviour through technological improvements. A car fleet policy aimed at the reduction of fuel consumption is in the responsibility of higher-level authorities, such as the Federal Government or the European Union. In addition municipalities can demonstrate their political will to promote the shift from fossil to renewable energy through an efficiency-oriented transport policy, for instance through public buses with alternative or electric fuel engines, more energy efficient local authority vehicles or restrictive measures against not environment-friendly vehicles, such as a ‘climate zone’ in which only vehicles with low CO_2 emissions are admitted. In this scenario it is assumed that through such measures the average fuel consumption of conventional cars will be reduced from 8.3 l/100 km today gradually to 3.0 l/100 km until the year 2050 (compared to the base scenario with 6.7 l/100 km).

2.3.4 Car scenarios (Push)

Regional cordon fee (A41/B41)

In this scenario in the year 2020 a cordon fee for the Ruhr Area will be introduced. All private cars will pay a monthly fee of 75 Euro for a vignette, which will be increased to 138 Euro in 2050. These costs correspond to the costs of the citizen ticket (A53/B53) and with 2.50 Euro per day approximately to the costs of existing cordon fee systems in Europe, e.g. in Milan 2-5 Euro/day and in Stockholm 1.10-6.60 Euro/day (Europäische Kommission 2014). Cordon fee systems reduce trip generation of vehicles subject to the fee and congestion and increase the use of public transport (Hautzinger et al. 2011, 38). The revenues of cordon fee systems can be used for investments in public transport, for more trains and buses or acceleration of walking and cycling. In Stockholm, after a test phase and a subsequent positive citizen referendum, an inner-city cordon fee was permanently introduced in 2007 (ibidem).

Reduction of lanes of main roads (A42/B42)

In this scenario in the year 2020 on all six- and four-lane roads two lanes will be closed for car traffic, in 2030 also on the remaining four-lane roads. The space gained will be used in other scenarios for more environment-friendly travel modes, such as extension of public transport network (A51/B51), more trains and buses (A52/B52), faster cycling (A61/B61) and shorter walking distances (A71/B71). In Vitoria-Gasteiz in Spain the redistribution of road space in favour of more environment-friendly travel modes in combination with traffic calming in large parts of the city contributed to the fact that the city in a few years won the reputation of ‘cycling capital of Spain’ (CIVITAS 2014). The share of cycling trips rose from 1 to 13 percent, and the share of car trips was reduced from 36 to 25 percent between 2002 and 2014 (EPOMM, no year).

Area-wide speed limits (A43/B43)

In this scenario beginning in 2020 the following speed limits will be introduced area-wide in the Ruhr Area: 80 km/h on motorways, 60 km/h on fast roads, 30 km/h on all other roads. Studies show that speed limits reduce CO_2 emissions, noise and pollutants of transport (UBA 1999). In particular in cities and villages speed limits have positive effects: lower accident risks, more feeling of security, especially for cyclists, pedestrians, children and elderly people and a more pleasant atmosphere in public places. On the one hand, speed limits make car driving slower and so less attractive. On the other hand mobility with more environment-friendly travel modes becomes significantly more attractive. Good examples for traffic calming are the cities of Munich, where by now 80 to 85 percent of the whole road network are 30-km/h zones (muenchen.de 2016) and Moers, where the introduction of 30 km/h on several main roads is being tested (Stadt Moers 2016).

Higher parking fees (A44/B44)

In this scenario beginning in 2020 inner-city parking fees will be gradually increased, so that in 2050 they are four times higher than in 2020. Cars use more space than all other travel modes so that functionally and economically valuable space is lost. Parking fees should represent the real costs of parking and therefore be significantly higher. The revenues from parking management could be used for financing more environmental travel modes. The impacts of parking fees on travel behaviour were demonstrated in several studies (LK-Argus GmbH 2011; BASt 2000). In cities of the Netherlands parking management is used area-wide and with high parking fees, e.g. in Amsterdam with 5 to 7 Euro per hour or 30 to 45 Euro per day (amsterdam.info 2016).

2.3.5 Public transport scenarios (Pull)

Extension of public transport network (A51/B51)

In this scenario a concept for the extension of the tramway and underground network oriented at the density of the tramway network of the 1950s and 1960s in the Ruhr Area is analysed. In particular the network extensions envisaged in the north of the Ruhr Area and between the core cities of this scenario will be implemented in the next 20 years (Figure 7). In addition in this scenario a railway line between Hamm and Recklinghausen will be reactivated as an S-Bahn line. In many cities world-wide the attractiveness of public transport is increased through efficient infrastructure by the extension of regional and urban rail systems (tramway, U-Bahn, S-Bahn etc.). An example is the city of Nantes, which was the first city in France to reintroduce the tramways closed in 1958 in 1985 (Reutter und Müller 2016, 42).

More trains/buses per hour (A52/B52)

Beginning in 2020 the headways of all public transport lines will be gradually reduced (bus, tramway, U-Bahn, S-Bahn and regional trains, RRX), so that the number of trains and buses will be four times as high in 2050 than in 2020. Revenues from the citizen ticket (A53/B53), the regional cordon fee (A41/B41) and higher parking fees (A44/B44) could be used to finance the costs of more trains and buses. More frequent trains and buses making mobility

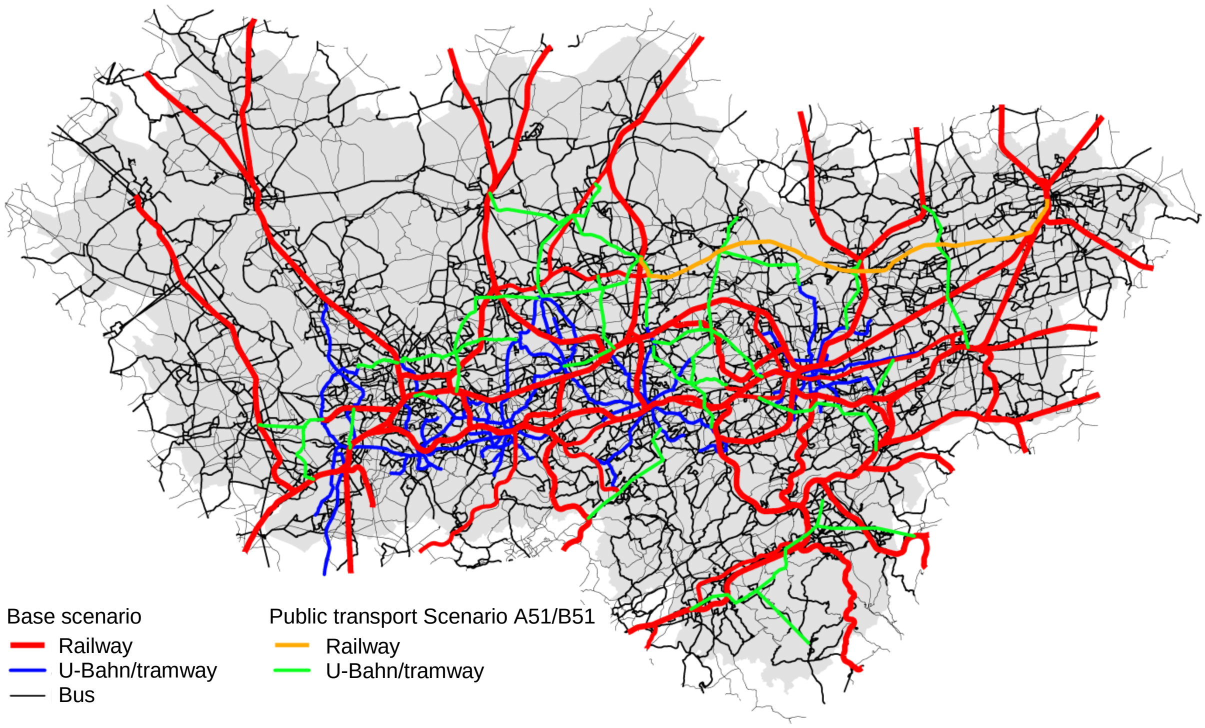

Figure 7. Extension of public transport network: Base scenario and Scenarios A51/B51

By public transport without time tables possible, would greatly increase the attractiveness of public transport and mean better mobility by public transport. In Vienna the annual public transport subscription was reduced to 365 Euro (Wetz 2015). Because of the increased demand public transport supply was extended and headways reduced. Vienna tramways today run every four to six minutes, underground trains every three minutes (Stadt Wien 2015).

Citizen ticket (A53/B53)

In this scenario in 2020 an area-wide citizen ticket will be introduced. All households pay an obligatory monthly fee of 75 Euro (increasing to 137 Euro until 2050), corresponding to the monthly costs per car assumed in the model in the Ruhr Area cordon fee (A41/B41). With this ticket the whole public transport in the Ruhr Area can be used without buying a ticket. The assumptions are based on model calculations in which a citizen ticket in Wuppertal would cost 42-82 Euro per month per household (Waluga 2016, 146f.). A citizen ticket would significantly increase the use of public transport, generate higher and more secure revenues and create secure prospects for public transport planning. Accompanying public revenues, such as the Ruhr Area cordon fee (A41/B41) or higher parking fees (A44/B44), could reduce the price of the citizen ticket and help to finance investments in public transport, such as network extension (A51/B51) or more trains and buses (A52/B52). Similar tariffs are event, renter or semester tickets. In North-Rhine Westphalia students can be mobile using public transport in the whole state with their semester ticket (Müller 2011).

2.3.6 Cycling scenarios (Pull)

Faster cycling (A61/B61)

In this scenario cycling in the Ruhr Area is comprehensively promoted. By that cycling speed after 2020 grows gradually, so that in 2050 it is 30 percent faster than in 2020. As with any other travel mode, shorter travel times increase its attractiveness. Measures such as safe cycling lanes without intersections and cycling-friendly traffic light programming can increase cycling speed (Oegel 2011). In Germany the average cycling speed in 2008 was 10.8 km/h (Difu 2012, 64). In Copenhagen, where the share of cycling trips of all trips in 2014 was 30 percent, cycling speed could be increased from 15.3 km/h in 2004) to 16.4 km/h ín 2014 (City of Copenhagen 2015, 4). There is a ‘green wave’ for cycling with an average speed of 20 km/h (Ramboll no year). Until 2025 cycling travel times are to be reduced by 15 percent compared with 2012 (City of Copenhagen 2011, 22).

Express cycling routes (A62/B62)

This scenario is a consistent implementation of the principle of express cycling routes in the Ruhr Area. Following examples from the Netherlands and Denmark, in Germany in the last years the concept of express cycling routes as instruments to promote cycling has become prominent. The express cycling route RS1, which is in its final planning phase and already under construction and therefore part of the base scenario, is complemented by a network of express cycling routes covering the whole Ruhr Area. The result will be a raster of express cycling routes consisting of four east-west and eight north-south routes with a raster size in the core of the Ruhr Area of about 5 km (Figure 8). Internationally express cycling routes are very successful. For instance, on the Nørrebrogade in Denmark’s capital Copenhagen about 36,000 cyclist are underway every day (ADFC 2011).

2.3.7 Walking scenarios (Pull)

Shorter walking distances (A71/B71)

In this scenario walking in the Ruhr Area is comprehensively promoted. Beginning in 2020 walking trips will become gradually shorter, so that in 2050 they will be 20 percent shorter than in 2020. Attractive walking requires as much as possible direct ways. Detour factors for walking amount to between 1.1 and 1.4 compared with the shortest possible ways. (FUSS e.V. no year). Detour-free pedestrian crossings, pedestrian-friendly traffic light programmes and barrier-free road crossings make walking trips shorter, speed limits (A43/B43) and redistribution of traffic lanes (A42/B42) in favour of walking increase walking-friendliness. Walking is a cost-free and health-promoting mobility for everybody creating neither emissions nor pollutants. Berlin has a walking strategy aimed at the avoidance of detours (Senatsverwaltung für Stadtentwicklung Berlin 2011, 8).

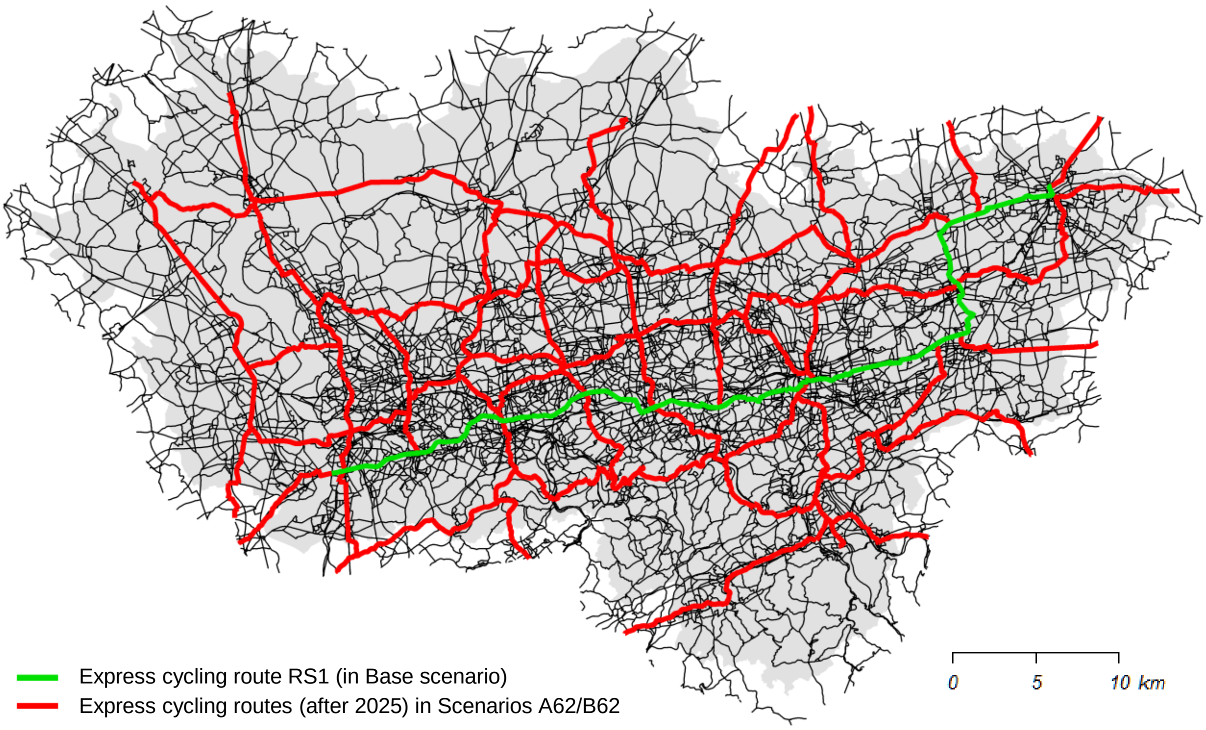

Figure 8. Express cycling routes network: Scenarios A62/B62

2.3.8 Integrated strategies

Finally several different combinations of land use and transport scenarios were analysed, first within five policy fields and then across all policy fields. The objective of these integrated strategies was to identify positive synergies (measures reinforce each other) and negative synergies (measures weaken each other) and to utilise them for land use and transport planning. Table 2 shows the policy combinations analysed:

Table 2. Integrated strategies

Scenarios		Policies	
A81/B81	Land use	13 Densification at railway stations 23 New housing at railway stations	
A82/B82	Energy efficiency	31 Building energy 32 Electromobility	33 Car sharing 34 Fuel consumption
A83/B83	Car (Push)	41 Regional cordon fee 42 Main roads	43 Speed limits 44 Higher parking fees
A84/B84	PT/cycle/walk (Pull)	51 Public transport 52 More trains/buses 53 Citizen ticket	61 Faster cycling 62 Express cycling routes 71 Shorter walking distances
A85/B85	All policies	All policies	
A86/B86	Selected policies	All policies except 23 and 52	

3 Central results

In this chapter the results of the analysed scenarios will be presented. First the base scenario will be described. Then the examined individual policies of the seven policy fields will be presented in five groups. Finally the policy combinations summarised in integrated strategies will be presented and compared. As lead indicator for the success of the energy transition the cumulated CO_2 emissions of buildings and transport are used, a measure that takes account of both the volume of energy consumption and energy efficiency. In addition the results regarding the modal shift will be put in relation to the CO_2 emissions of transport.

3.1 Base scenario

The basis of the comparison between all scenarios is the Base Scenario A00/B00. In the base scenario it is assumed that all currently implemented policies will be continued in the future. Figure 9 shows the two variants of the base scenario, A00 (low fuel prices: price increases 1 percent per year) and B00 (high fuel prices; price increases 4 percent per year). It can be seen that through energy retrofitting and more fuel-efficient cars also in the base scenario energy consumption and CO_2 emissions decline after 2015. Figures 10-15 show the spatial distribution of selected indicators in the year 2050 in the Base Scenario A00.

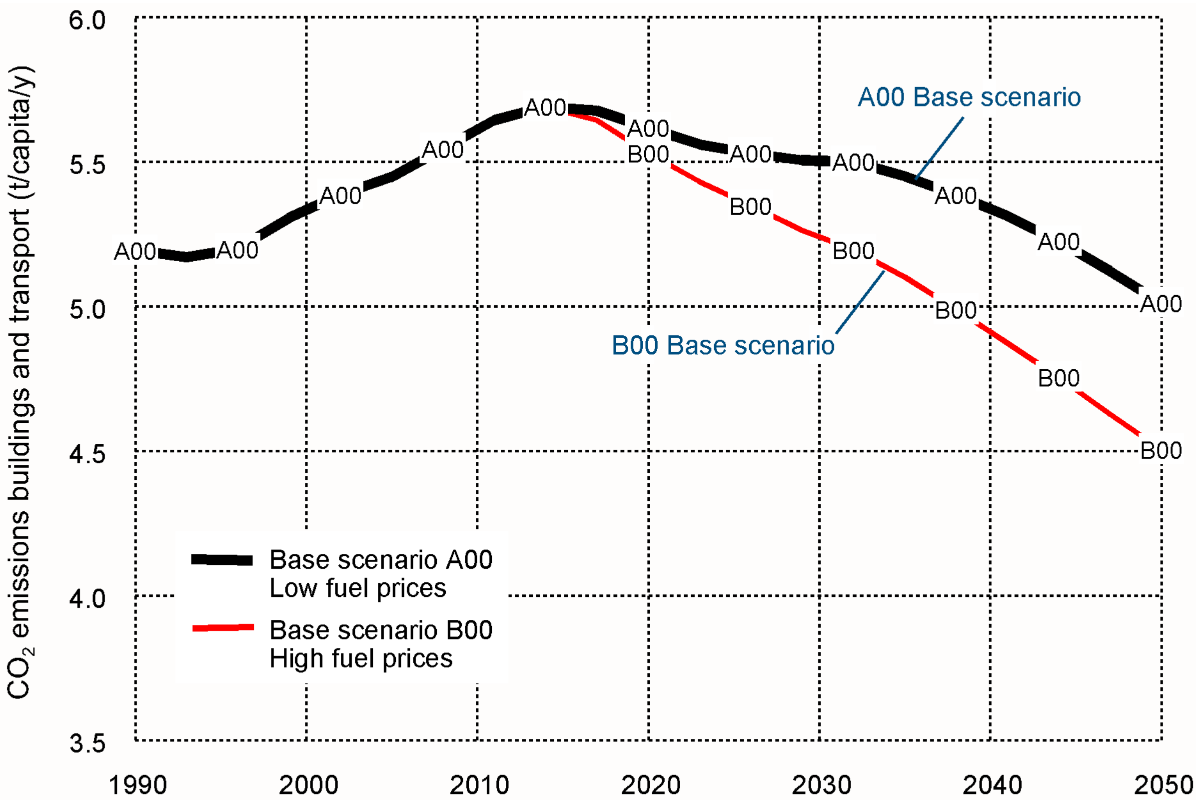

Figure 9. CO_2 emissions of buildings and transport 1990-2050: Base scenarios

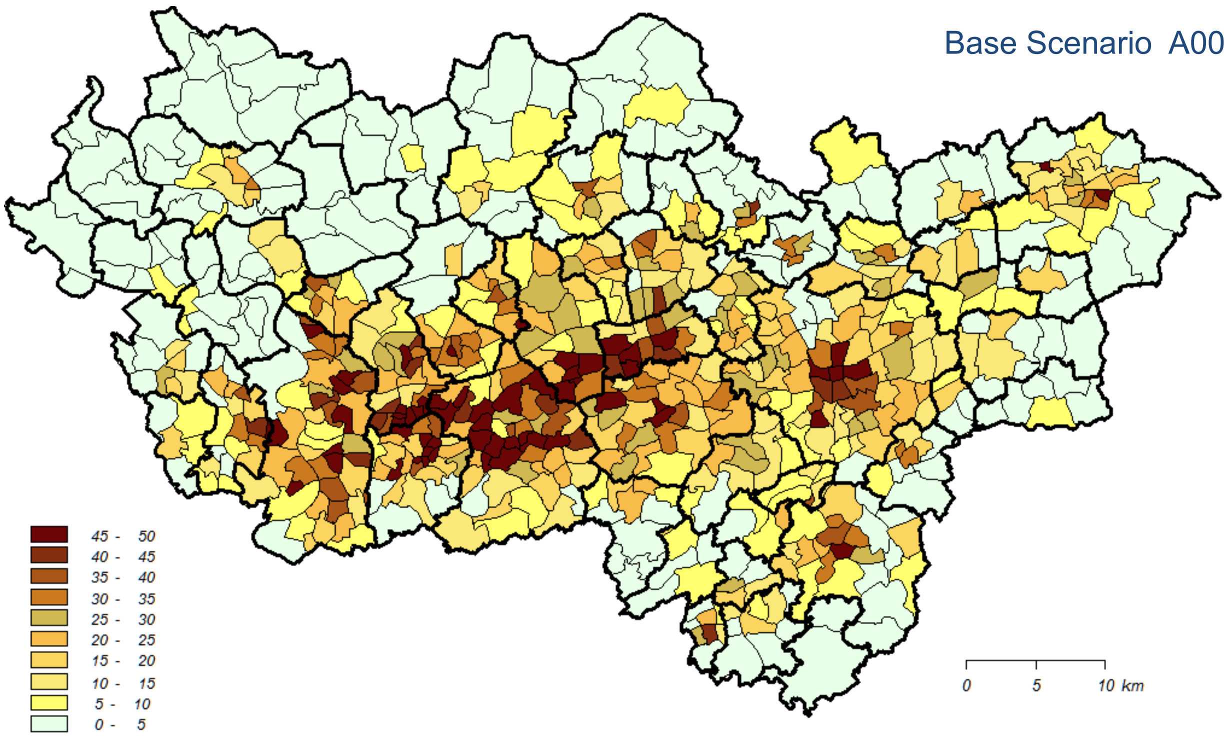

Figure 10. Population density (pop/ha) 2050: Base Scenario A00

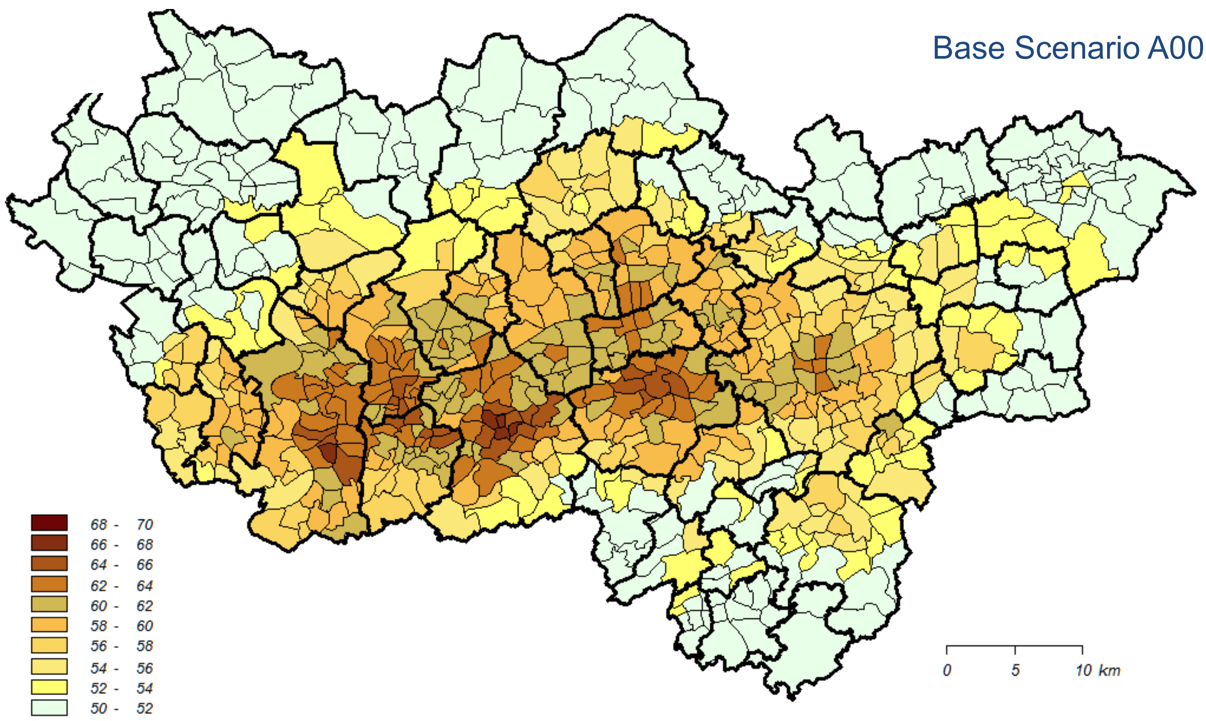

Figure 11. Accessibility of jobs 2050: Base Scenario A00

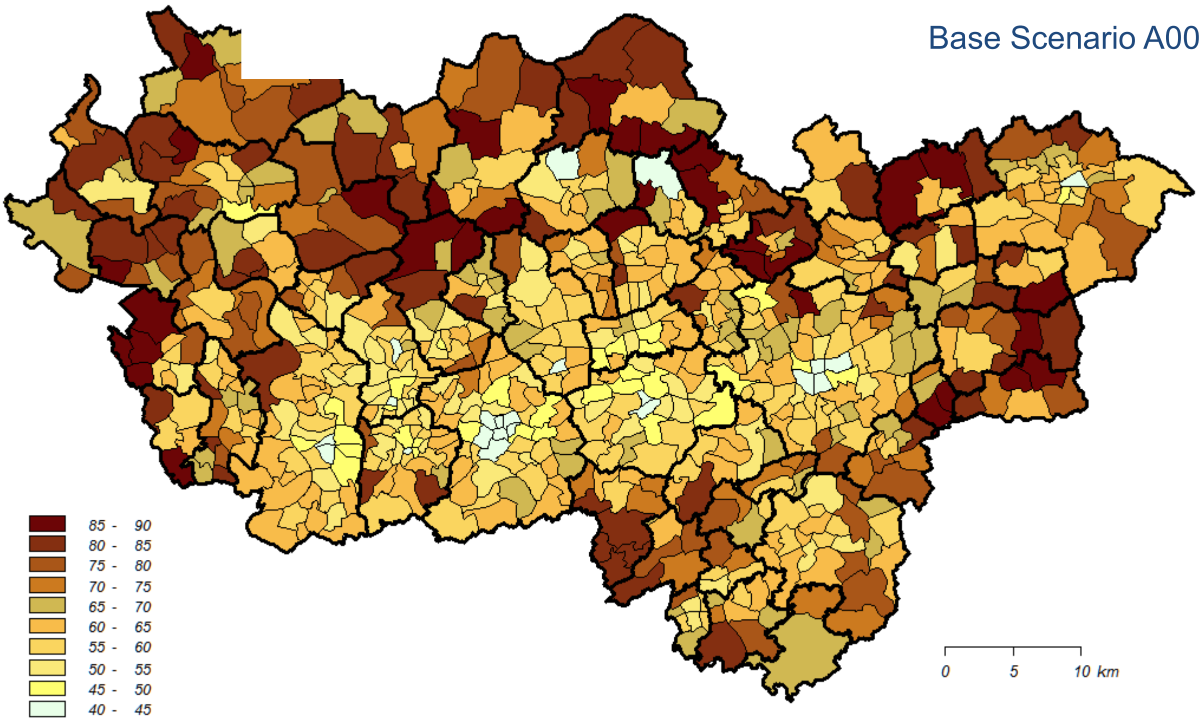

Figure 12. Share of car trips of all trips (%) in 2050: Base Scenario A00

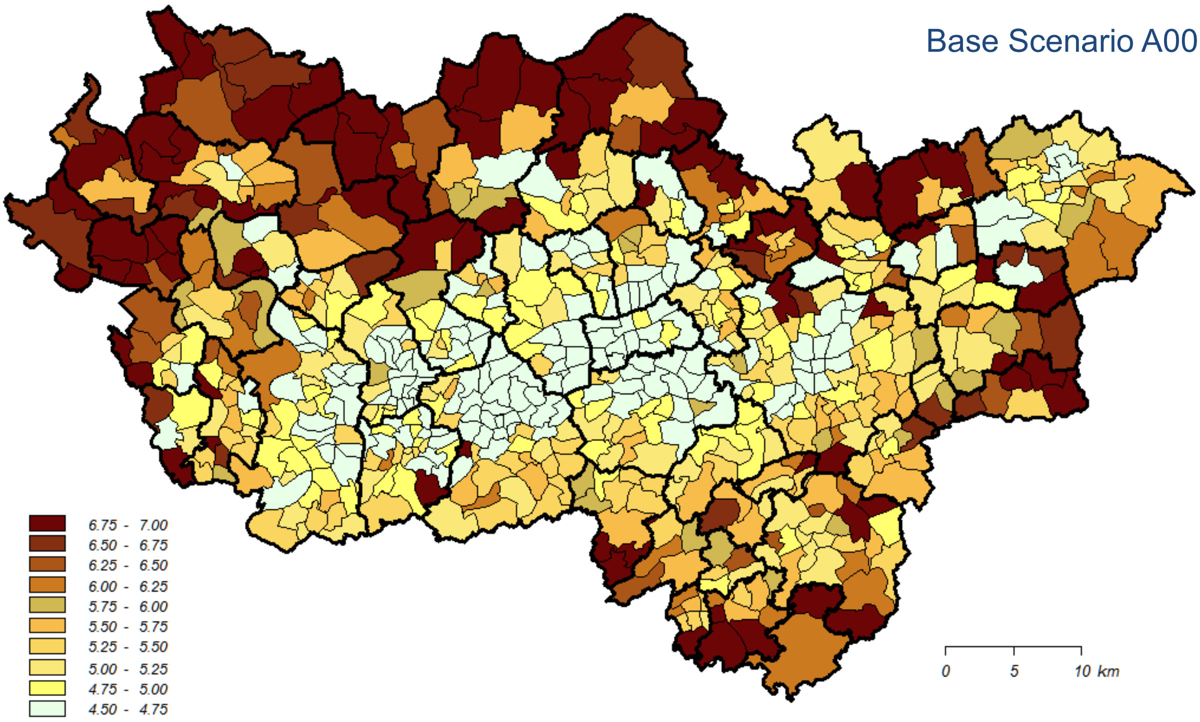

Figure 13. CO_2 emissions of buildings and transport (t/capita/y): Base Scenario A00

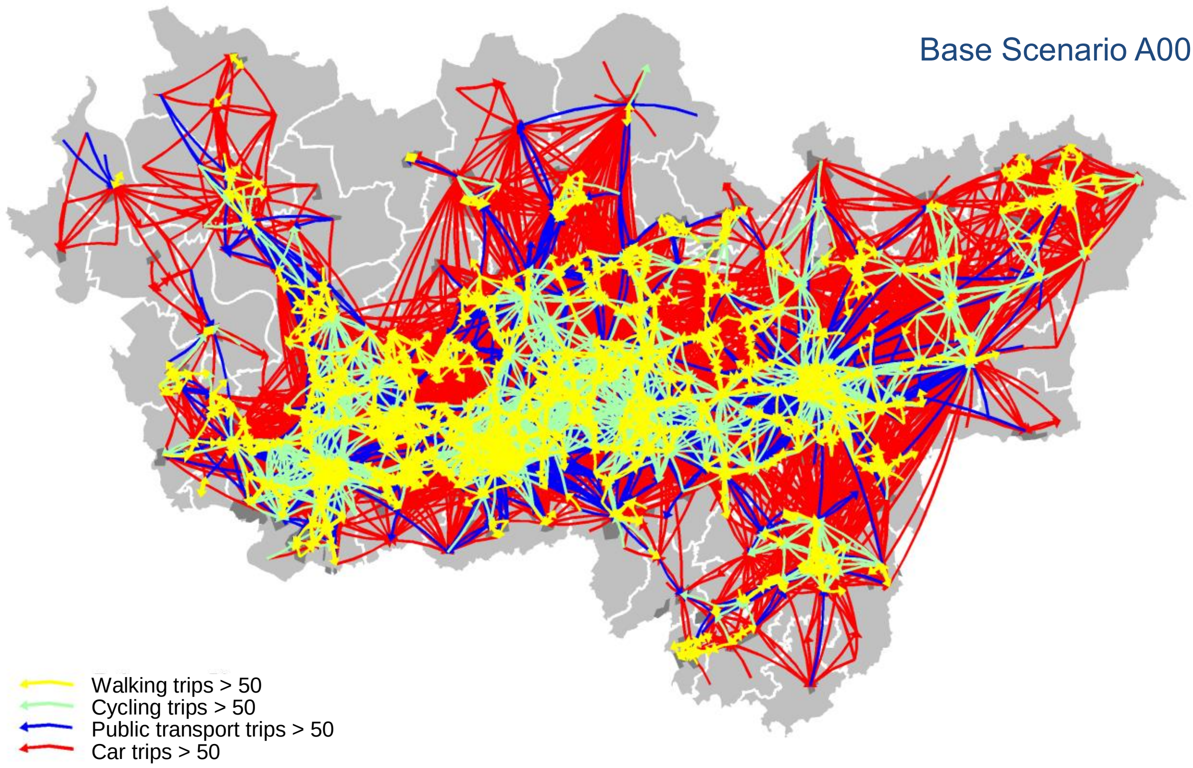

Figure 14. Trips by mode (> 50 trips per day) between internal zones 2050: Base Scenario A00

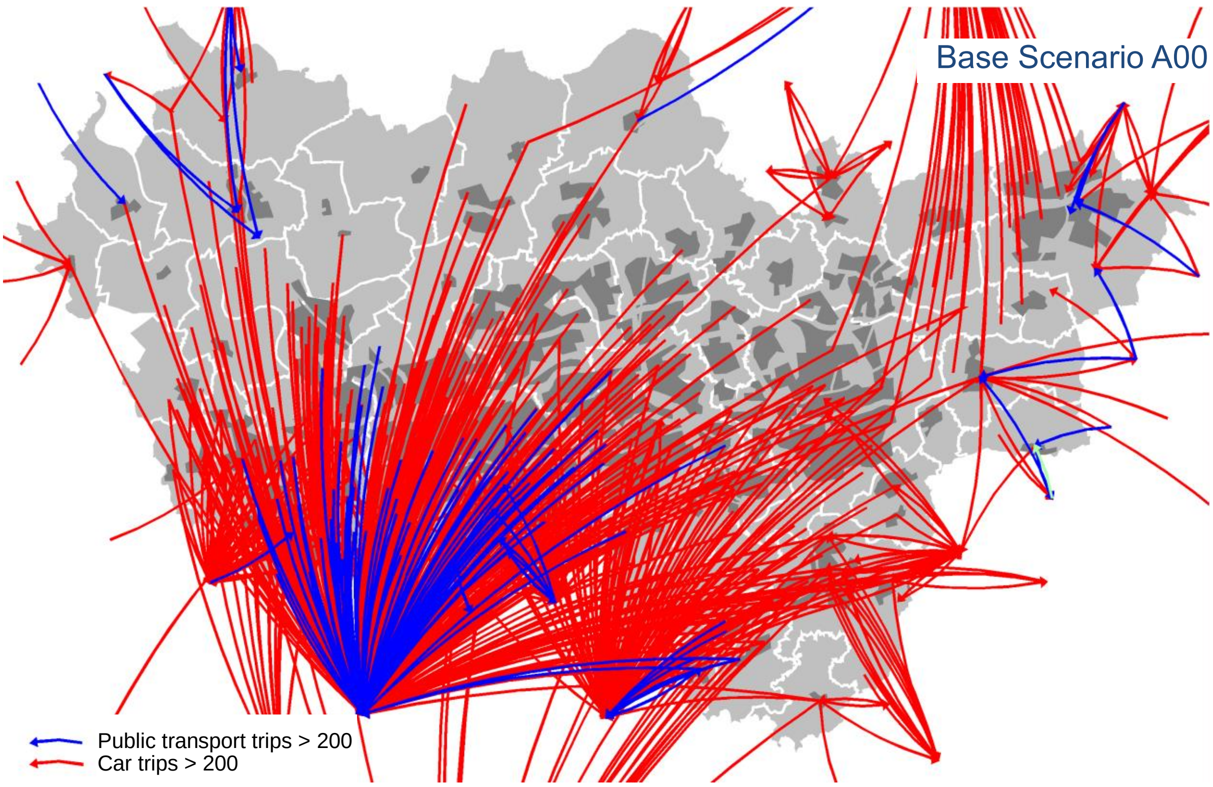

Figure 15. Trips by mode (> 200 trips per day) between internal and external zones 2050: Base Scenario A00.

The first two maps in Figures 10 and 11 underline the polycentric settlement structure of the Ruhr Area with its seven core cities Duisburg, Oberhausen, Mülheim, Essen, Bochum, Dortmund and Hagen and their wide rural environment in the counties of Wesel, Recklinghausen, Unna and Ennepe-Ruhr. The maps in Figures 12 and 13 show the impacts of this spatial structure on energy consumption and greenhouse gas emissions. If no effective policies for the promotion of environment-friendly travel modes and energy retrofitting of buildings are implemented, it must be expected that the share of car trips and the greenhouse emissions particularly of the peripheral municipalities will still be high even in the year 2050. Figures 14 and 15 show the trips by mode between zones.

3.2 Individual policies

As explained in Section 2.3, in the project, besides the two base scenarios, 25 policy scenarios were simulated, each of them under two different assumptions about the development of fuel prices. Of these 19 scenarios analysed the impact of individual policies implemented alone and the remaining six scenarios analysed the impacts of different combinations of policies from the same or different policy fields. Below first the impacts of individual policies will be presented.

3.2.1 Land use

Two kinds of policies to influence the development of land use were analysed: changes of the land use plans of the municipalities and public housing construction.

In the land use scenarios A11/B11-A14/B14 different strategies of spatial densification were analysed. Future construction was permitted only in existing settlement cores, at public transport stops or railway stations or in the five main cities Duisburg, Essen, Bochum, Dortmund und Hagen. In all other zones no further construction was permitted. The trajectory diagrams in Figures 16 and 17 show that these policies would have almost no effect for the energy transition. The CO_2 emissions of these scenarios do not differ from those of the Base Scenarios A00 and B00. The reason is that because of the population decline expected for the time after 2030 in the thirty years between 2020 and 2030 total housing does not grow by more than 7 percent. Therefore the number of dwellings in the land use scenarios different from the base scenarios is too low to result in recognisable effects as individual policies. Different results appear if the land use scenarios are combined with other policies to achieve the energy transition (see Section 3.3).

If as in Scenario A23/B23 housing construction in the vicinity of railway and S-Bahn stations is more than doubled through public policies, significantly different results appear – though not in the desired direction as the newly constructed dwellings are built with relatively high energy standards but not as zero-emission buildings.

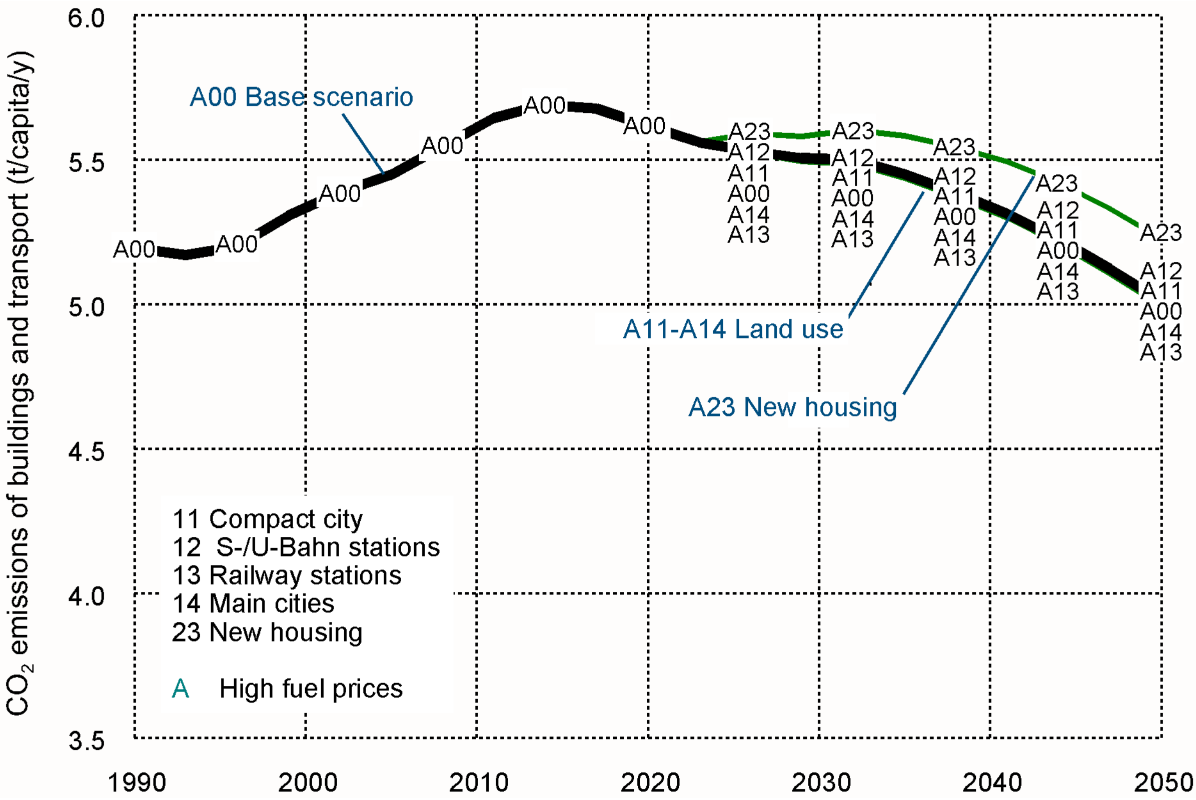

Figure 16. CO_2 emissions of buildings and transport 1990-2050: Scenarios A11-A23

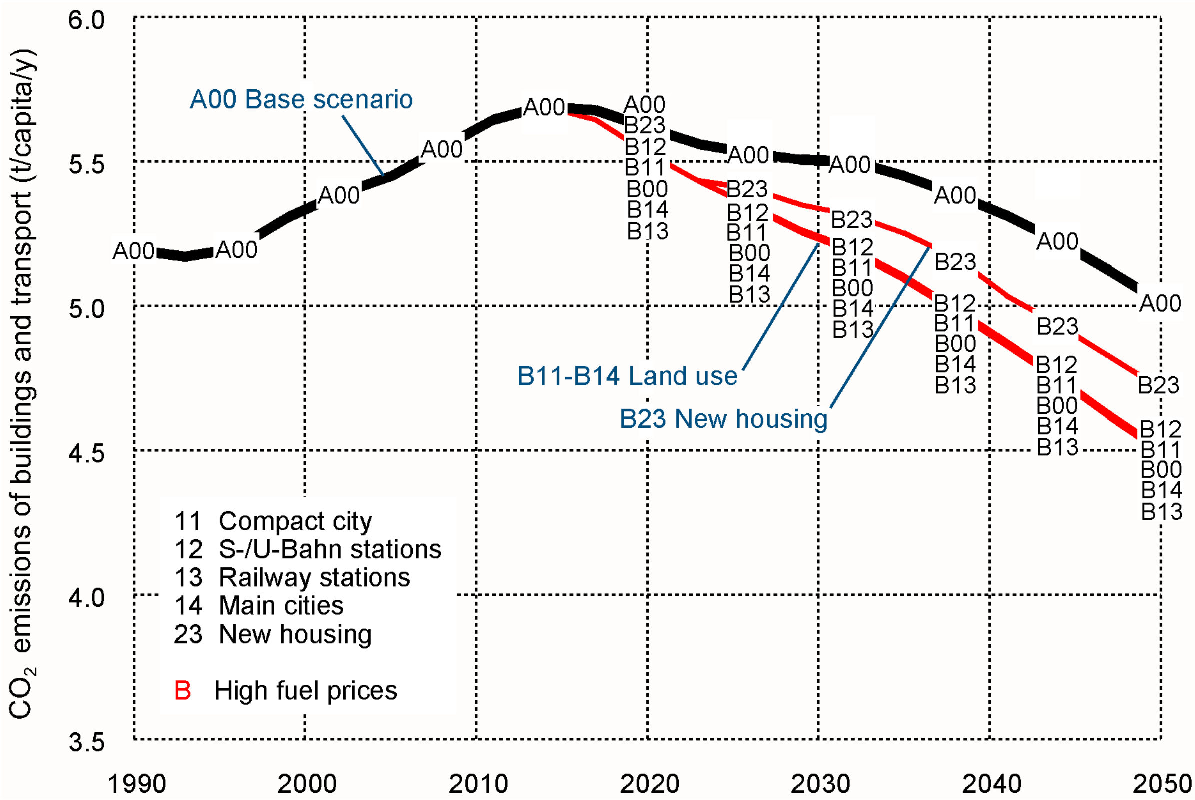

Figure 17. CO_2 emissions of buildings and transport 1990-2050: Scenarios B11-B23

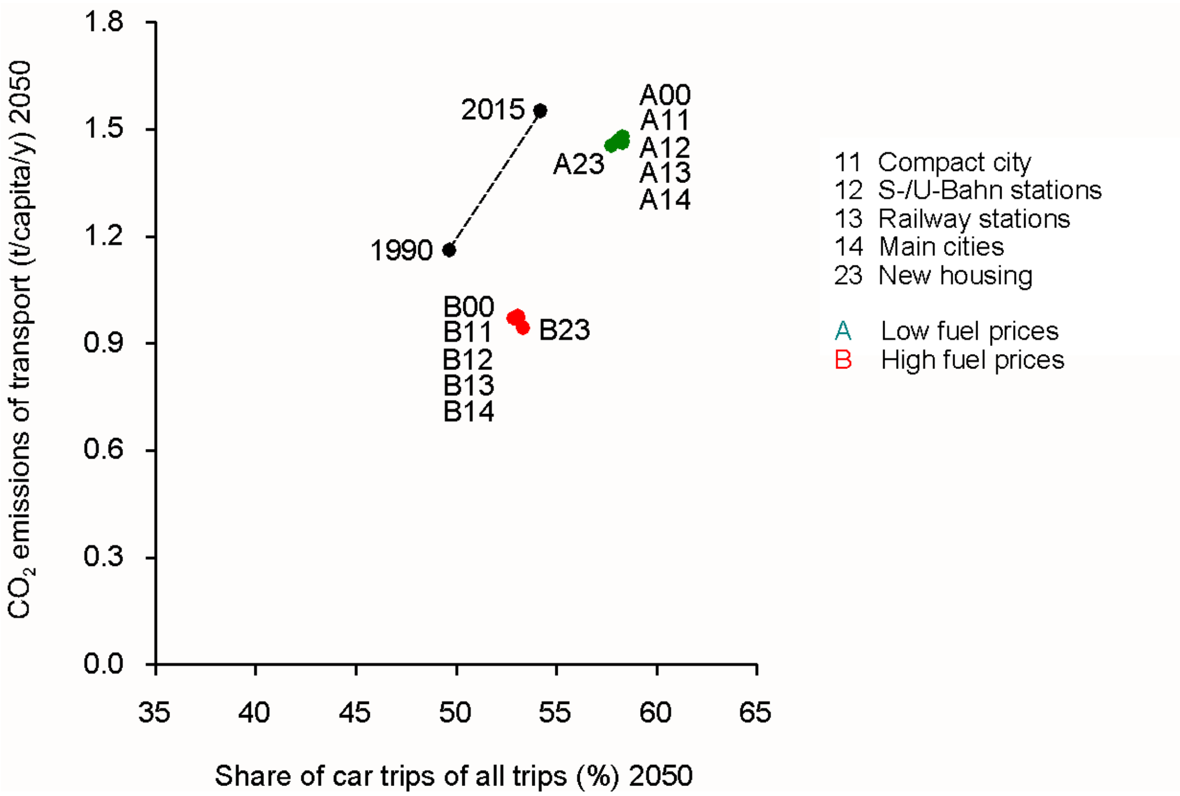

Figure 18. Share of car trips (%) v. CO_2 emissions of transport 2050: Scenarios A11/B11-A23/B23

Figure 18 shows the development of car trips as shares of all trips compared with the development of CO_2 emissions of transport in the land use scenarios. From 1990 until today both variables have strong grown in the Base Scenario A00 in which fuel costs rise by 1 percent per year, The share of car trips of all trips will grow further until about 58 percent of all trips in 2050, but CO_2 emissions will be slightly reduced because of technological progress. In the Base Scenario B00, in which it is assumed that fuel prices rise by about 4 percent per year, there will be no further rise of the share of car trips of all trips, and the CO_2 emissions of transport will be reduced significantly. The land use scenarios A11/B11-A14/B14 have practically no impact on the share of car trips and CO_2 emissions of transport until 2050 compared with the Base Scenarios A00/B00. Only Scenario A23/B23 shows a minimal hardly relevant reduction of both. The changes the A and B scenarios show since 2015 are only caused by the developments in the Base Scenarios A00 and B00 or by the assumptions about the rise of fuel prices in the base scenarios.

3.2.2 Energy efficiency

As explained in Section 2.3, in the policy field “energy efficiency” scenarios are analysed together which aim at lower energy consumption and greenhouse gas emissions by technological innovations in the fields of building energy and transport. The trajectory diagrams in Figures 19 and 20 show the development of CO_2 emissions in the energy efficiency scenarios A31/B31-A34/B34.

A large contribution to energy saving are made by savings in building energy. In Scenario A31/B31, in which the subsidies for energy retrofitting of buildings are increased to 50 percent of investment costs, the share of energy retrofitted dwellings rises from one third in the year 2050 to about 50 percent. As building energy constitutes by far the largest part of energy consumption of households, promotion of energy retrofitting can lead to energy savings of almost 10 percent of total energy consumption of households. The map in Figure 21 shows the spatial distribution estimated by the model of energy retrofitted residential buildings in the year 2050. The basis of this estimation is the hypothesis that owner-occupied residential property is more likely to be retrofitted than rented housing the owner of which can only pass part of the investment cost of retrofitting to their tenants.

High energy savings are also achieved by policies to reduce energy consumption of conventional cars. In Scenario A34/B34 it is assumed that the average fuel consumption will be reduced gradually from 8.3 l/100 km today to 3.0 l/100 km in the year 2050 compared with 6.7 l/100 km in the base scenario. The reduction of the average fuel consumption of cars by more than half can reduce total CO_2 emissions of residential buildings and transport by about 10 percent until 2050. This shows that to improve the energy efficiency of vehicles is a high priority task to reduce CO_2 emissions, but is not sufficient for climate protection.

Another technological measure to save energy is the stronger market penetration of electric vehicles as simulated in Scenario A32/B32. Basis of the scenario is the assumption that the purchase of electric vehicles will be subsidised with 33 percent of vehicle cost, more than in the base scenario, and that charging stations in inner cities are fully financed from taxes. Under these assumptions the share of electric cars of all cars in the year 2050 rises from 30 percent in the base scenario to nearly 50 percent. The CO_2 emissions of buildings and transport are reduced by about 5 percent.

A particular difficulty is connected with the modelling of car sharing (A33/B33). In particular with free-floating car sharing two factors are at work: On the one hand there are car owners who sell their car and only occasionally use car sharing cars. On the other hand there are mostly younger persons who so far had no car but now use the convenient possibility of car sharing not requiring a large investment. The question is which of these two influence factors will have the larger impact – the answer to this question will decide whether car sharing will reduce or increase car availability – one of the most important factors of trip decisions – and so whether car sharing can be considered as a policy to achieve the energy transition.

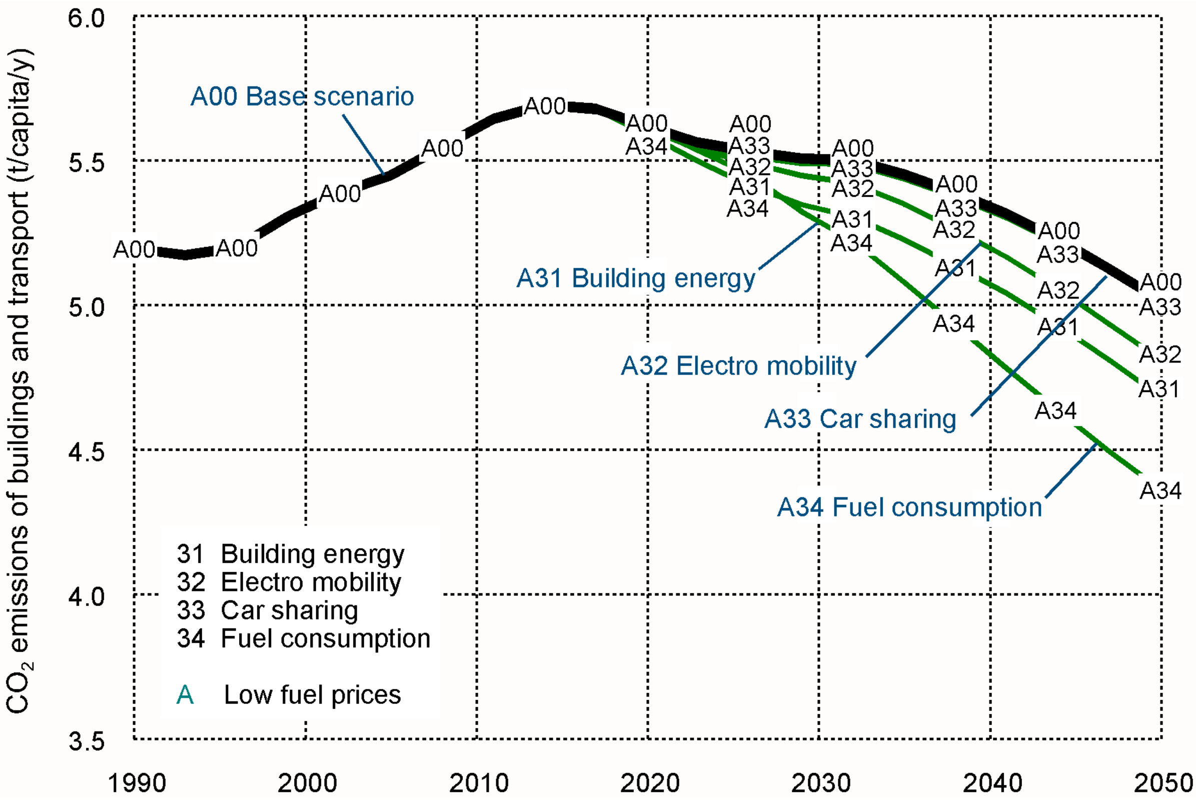

Figure 19. CO_2 emissions of buildings and transport 1990-2050: Scenarios A31-A34

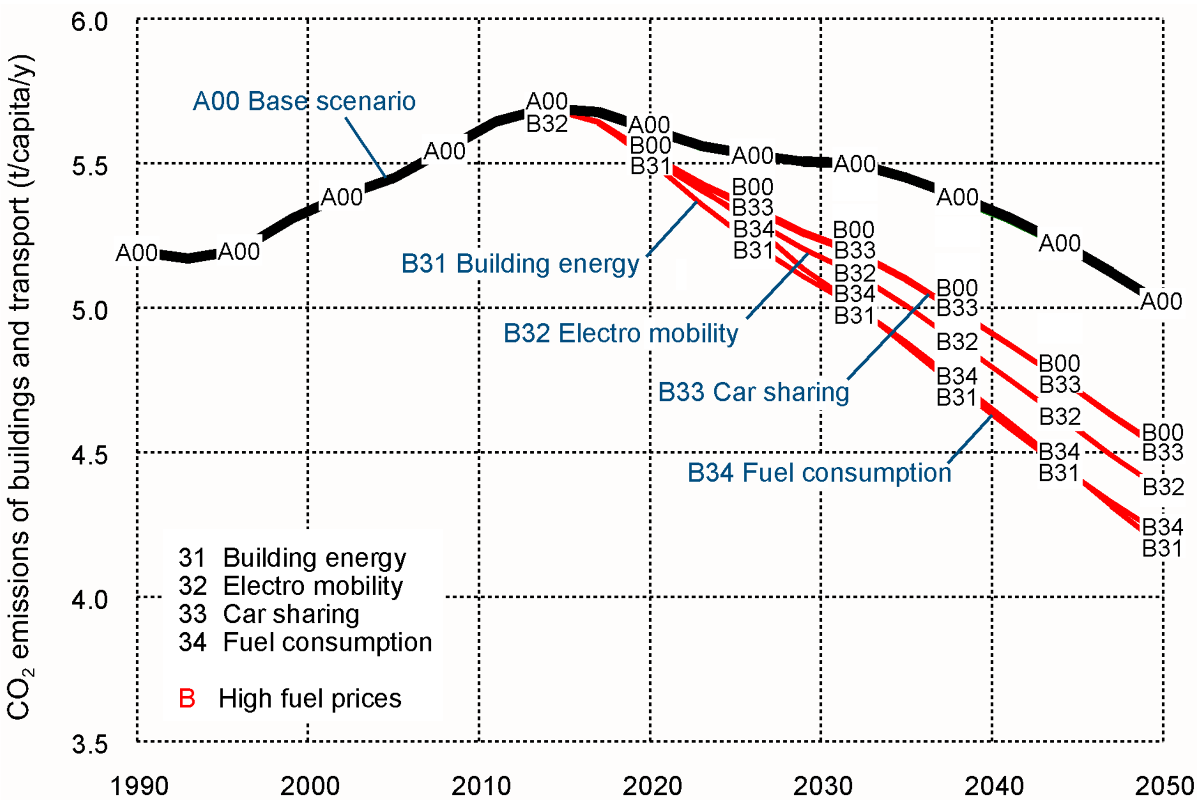

Figure 20. CO_2 emissions of buildings and transport 1990-2050: Scenarios B31-B34

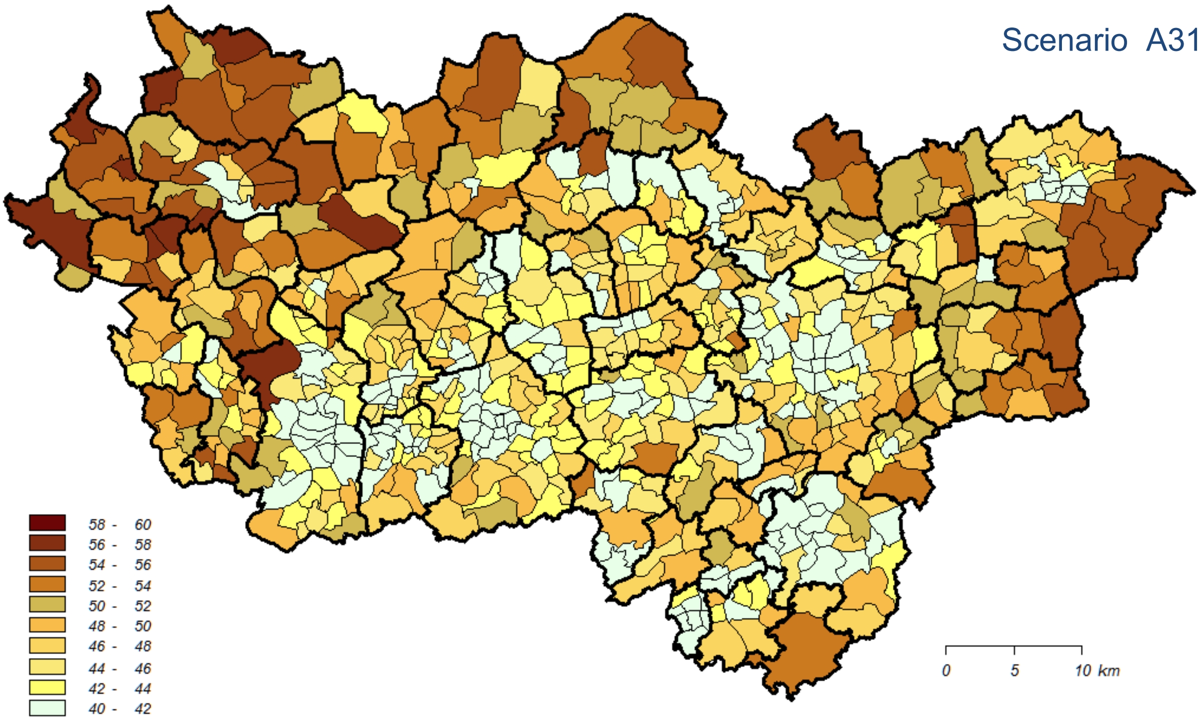

Figure 21. Share of energy retrofitted residential buildings (%) 2050: Scenario A31

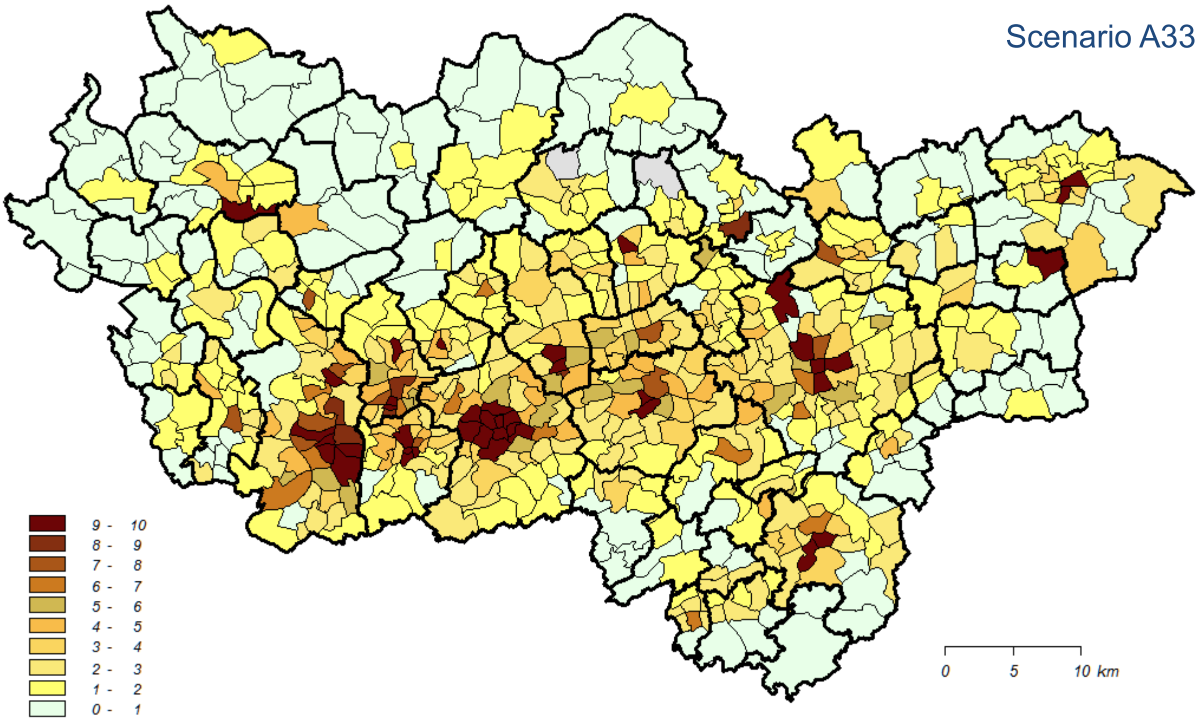

Figure 22. Number of car sharing cars per 1,000 population 2050: Scenario A33

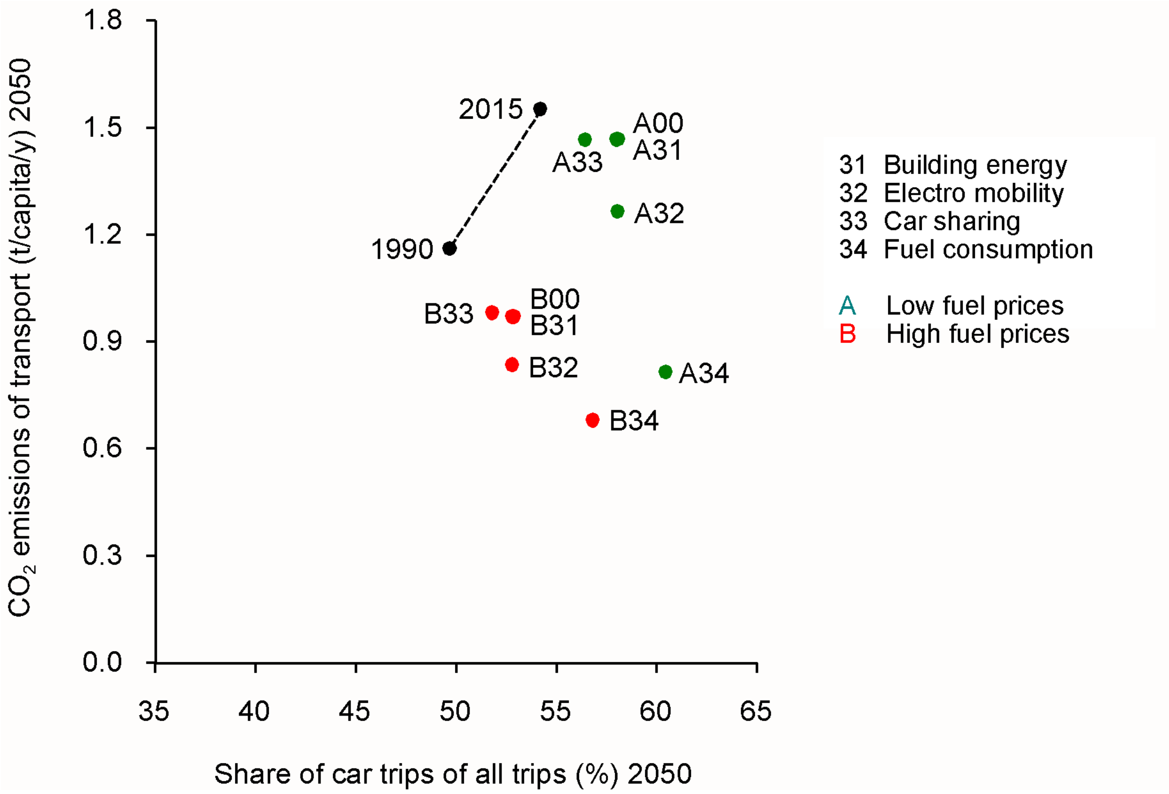

Figure 23. Share of car trips (%) v. CO_2 emissions of transport 2050: Scenarios A31/B31-A34/B34

Given the current state of empirical research this question cannot yet be answered reliably. In the current version of the model used here a balanced combination of the two influence factors was assumed, assuming that free-floating car sharing contributes to the energy transition in the sense of energy saving, although to a small degree only – this assumption, however, requires further empirical studies. The map in Figure 22 shows the spatial distribution of car sharing supply expected by the model.

With respect to modal split (Figure 23) Scenarios A31/B31 (promotion of energy retrofitting of buildings) and A32/B32 (promotion of electromobility) do not result in significant effects to reduce the share of car trips of all trips. Increasing the supply of car sharing (A33/B33) reduces the share of car trips by about 2 percentage points. The reduction of average fuel consumption of cars (A34/B34), however, increases the share of car trips because of the significant reduction of car driving costs associated with it. The examples show that a smaller share of car trips does not always lead to lower CO_2 emissions of transport, but that it depends on the combination of number of car trips, trip length and fuel consumption resulting from the interaction between location choice and trip decisions.

3.2.3 Car traffic (Push)

The scenarios A41/B41-A44/B44 show the possible impacts of measures, which restrict car traffic and so make car driving less attractive, i.e. more expensive or slower (push policies). The trajectory diagrams in Figures 24 and 25 show the impacts of the scenarios on CO_2 emissions.

It can be seen that measures that make car driving slower have the largest impacts on the reduction of CO_2 emissions (Figures 24-26). This includes the reduction of lanes of main roads (A42/B42), in which the road space of car traffic is reduced and can be made available for the more environment-friendly travel modes cycling and walking, and speed limits (A43/B43), in which car driving is made slower and more time consuming.

Price signals that make car driving more expensive as the regional cordon fee (A41/B41) or higher inner-city parking fees (A44/B44), show relatively smaller reductions of CO_2 emissions, in particular if they are not felt at each trip as the regional cordon fee.

However, for the shift from car driving to more environment-friendly travel modes the introduction of the regional cordon fee (A41/B41) has the greatest effect. Compared to the Base Scenarios A00/B00 the cordon fee reduces the share of car trips of all trips by up to 4 percentage points in the year 2050 (Figure 26). Speed limits (A43/B43) and the reduction of lanes of main roads (A42/B42) reduce the share of car trips by one to two percentage points, but they result in large reductions of CO_2 emissions. The reason for this is that the frequency of car use is only changed very little, but that trip lengths because of the longer travel times caused by the two measures are significantly reduced. The increase of parking fees shows hardly any effect on the regional model shift.

3.2.4 Public transport (Pull)

In the scenarios A51/A51-A53/B53 measures are analysed that contribute to making public transport more attractive and motivate car drivers to shift to public transport (pull measures). These measures include investment in the public transport infrastructure oriented at the tramway network available in the Ruhr Area in the 1950s and 1960s (A51/B51), the provision of more trains and buses (A52/B52) and the introduction of a citizen ticket (A53/B53). The trajectory diagrams in Figures 27 and 28 show the development of CO_2 emissions in the three scenarios.

The scenario of large-scale extension of public transport network (A51/B51), in which again tramways run between the core cities of the Ruhr Area and in the northern Ruhr Area, results in only small energy savings because of its increased vehicle-km and hence higher energy consumption. Wirth respect to modal split the extension of the public transport network brings only a very small shift from car traffic to public transport. However, the now more attractive public transport attracts many former cyclists and walkers.

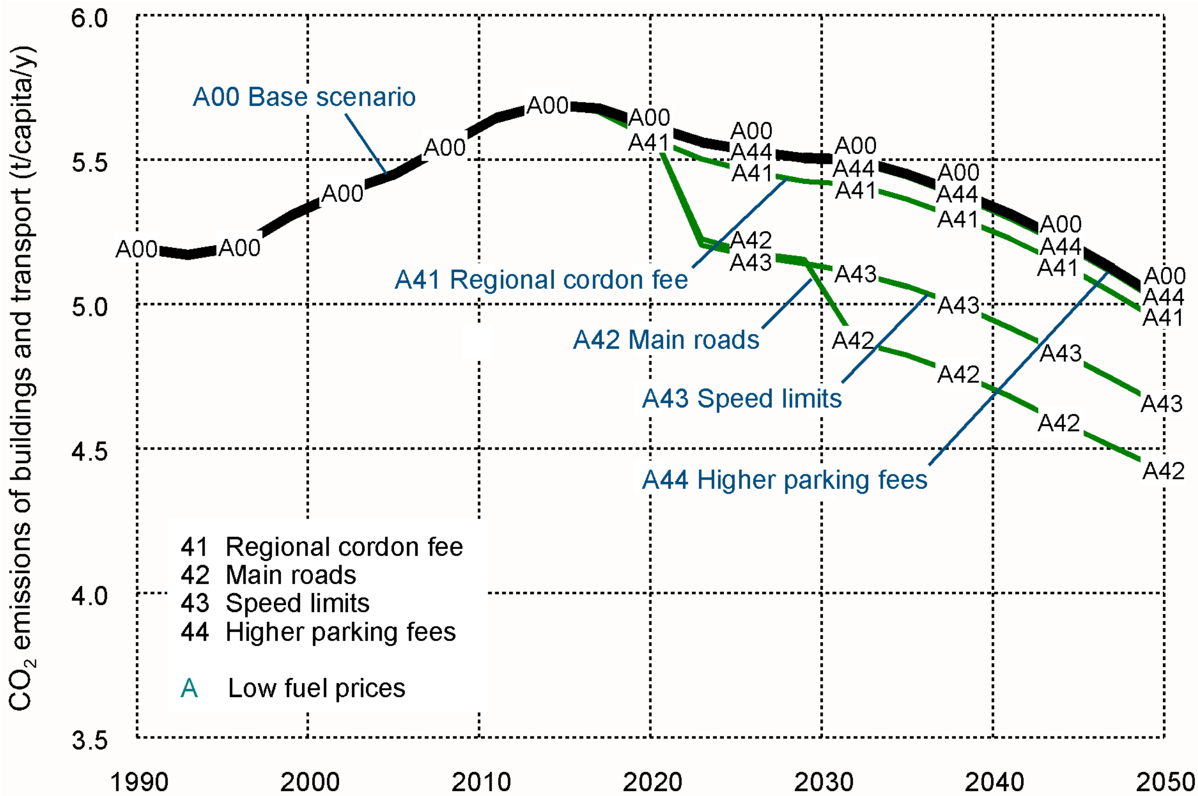

Figure 24. CO_2 emissions of buildings and transport 1990-2050: Scenarios A41-A44

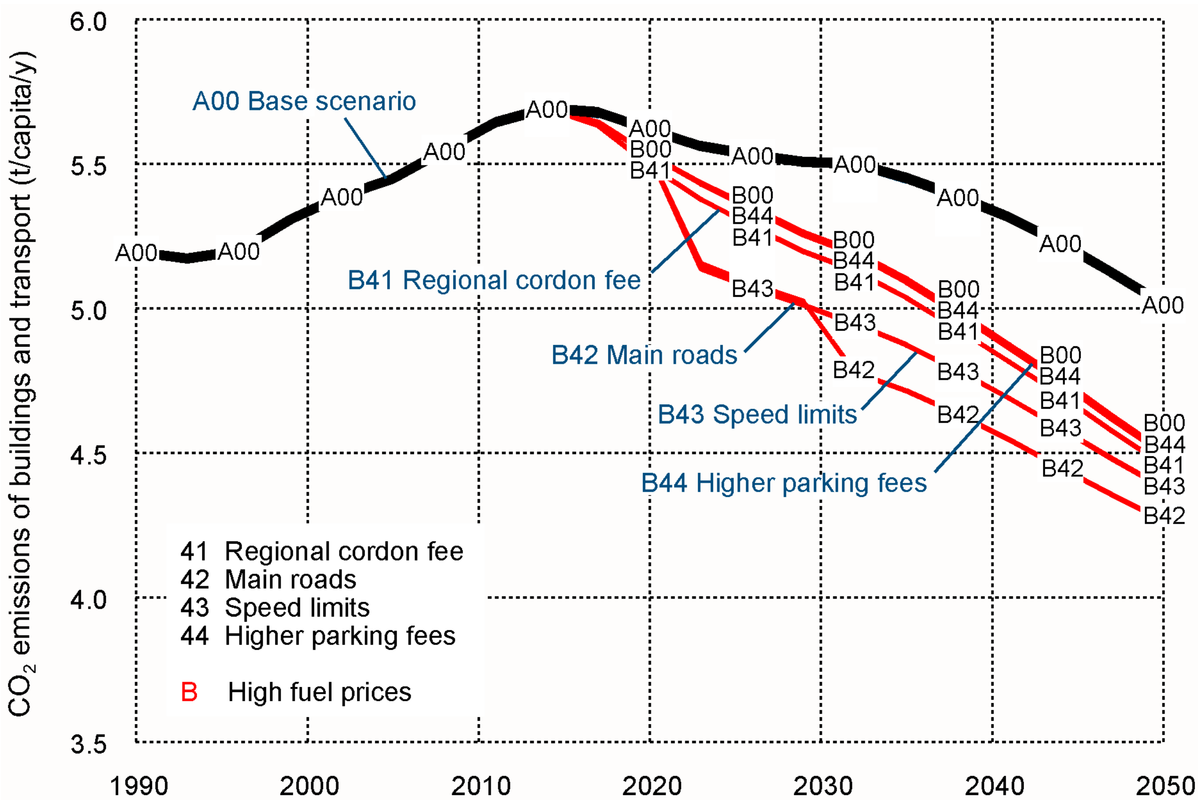

Figure 25. CO_2 emissions of buildings and transport 1990-2050: Scenarios B41-B44

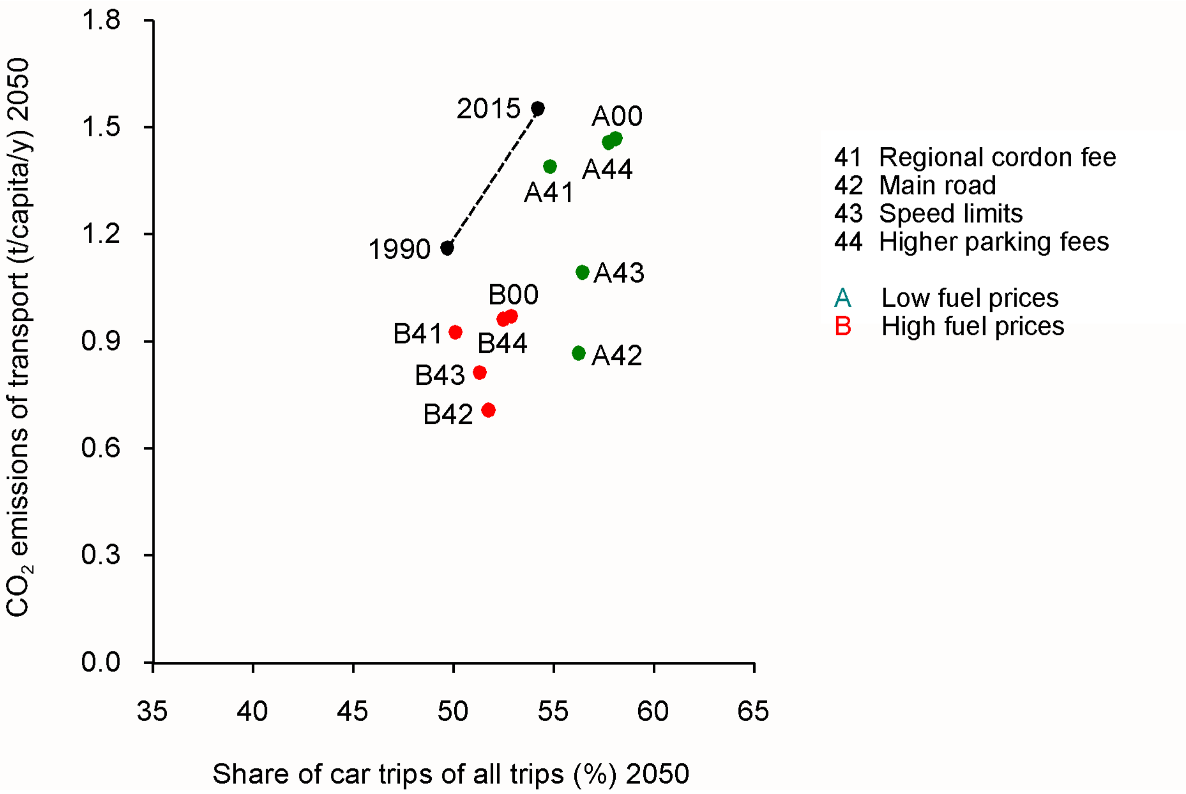

Figure 26. Share of car trips (%) v. CO_2 emissions of transport 2050: Scenarios A41/B41-A44/B44

Scenario A52/B52 analyses the impacts to be expected if the frequencies of trains and buses are consistently and gradually increased area-wide in the Ruhr Area, so that in the year 2050 four times as many trains and buses are run than in the base scenario. The model shows that energy consumption and CO_2 emissions increase and do not decrease compared with the base scenario. The explanation for this is that through the significant increase of trains and buses also significantly more energy is consumed, but that not so many new public transport passengers are attracted to change from car to public transport to achieve a reduction of emissions. The modal shift from car to public transport amounts to only 2 percentage points compared with the Base Scenarios A00/B00 in the year 2050 (Figure 29).

The results are similar for the citizen ticket (A53/B53), i.e. for the financing of public transport by a monthly fee paid by all households instead of through tickets – to buy a ticket is no longer required. The citizen ticket results in energy savings, however, these savings are small because the majority of the new public transport passengers are recruited not from former car drivers but from former cyclists and pedestrians. The shift from car to public transport through the citizen ticket of up to 2 percentage points is similar to that of the increase of trains and buses (Figure 29).

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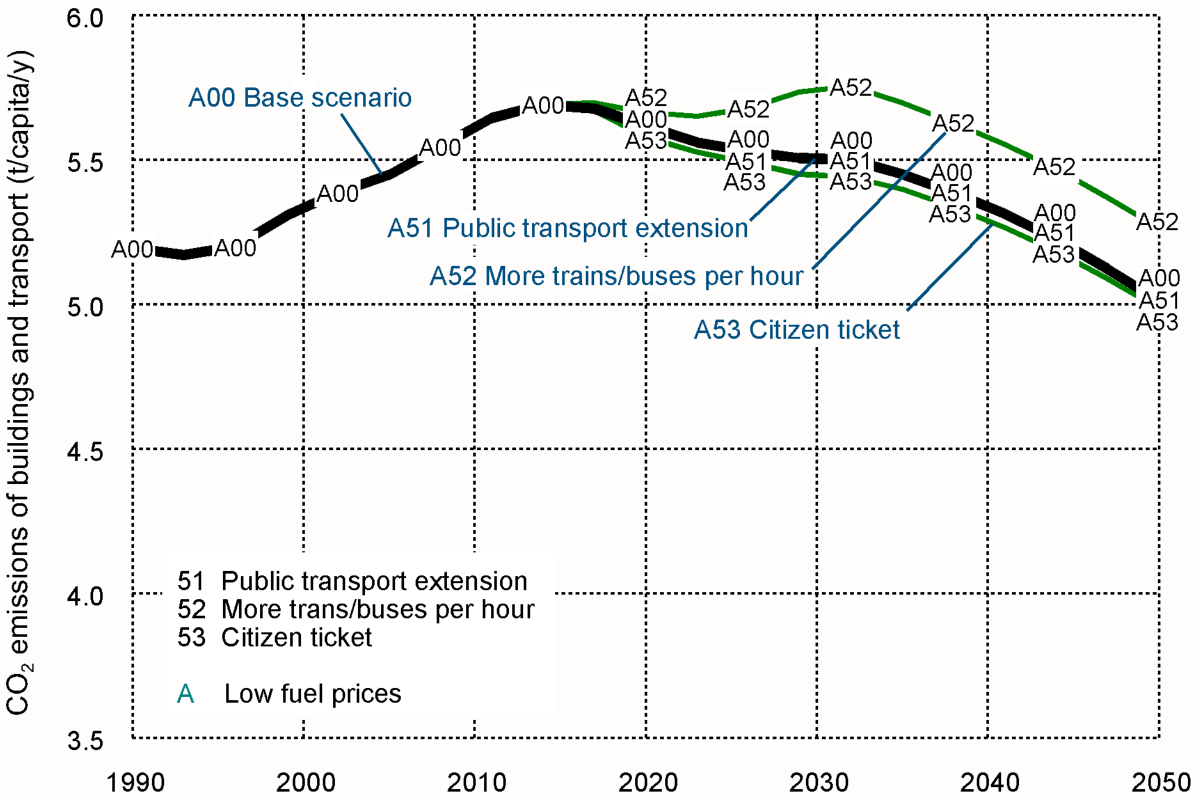

Figure 27. CO_2 emissions of buildings and transport 1990-2050: Scenarios A51-A53

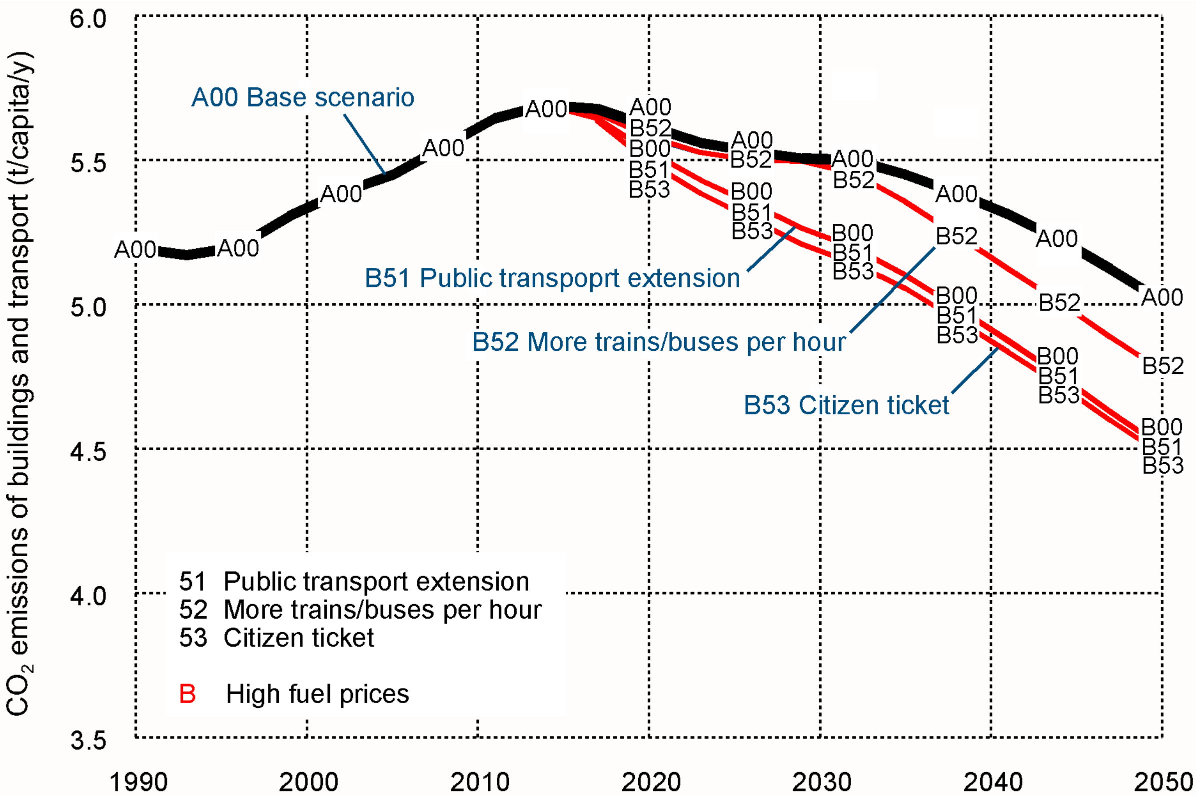

Figure 28. CO_2 emissions of buildings and transport 1990-2050: Scenarios B51-B53

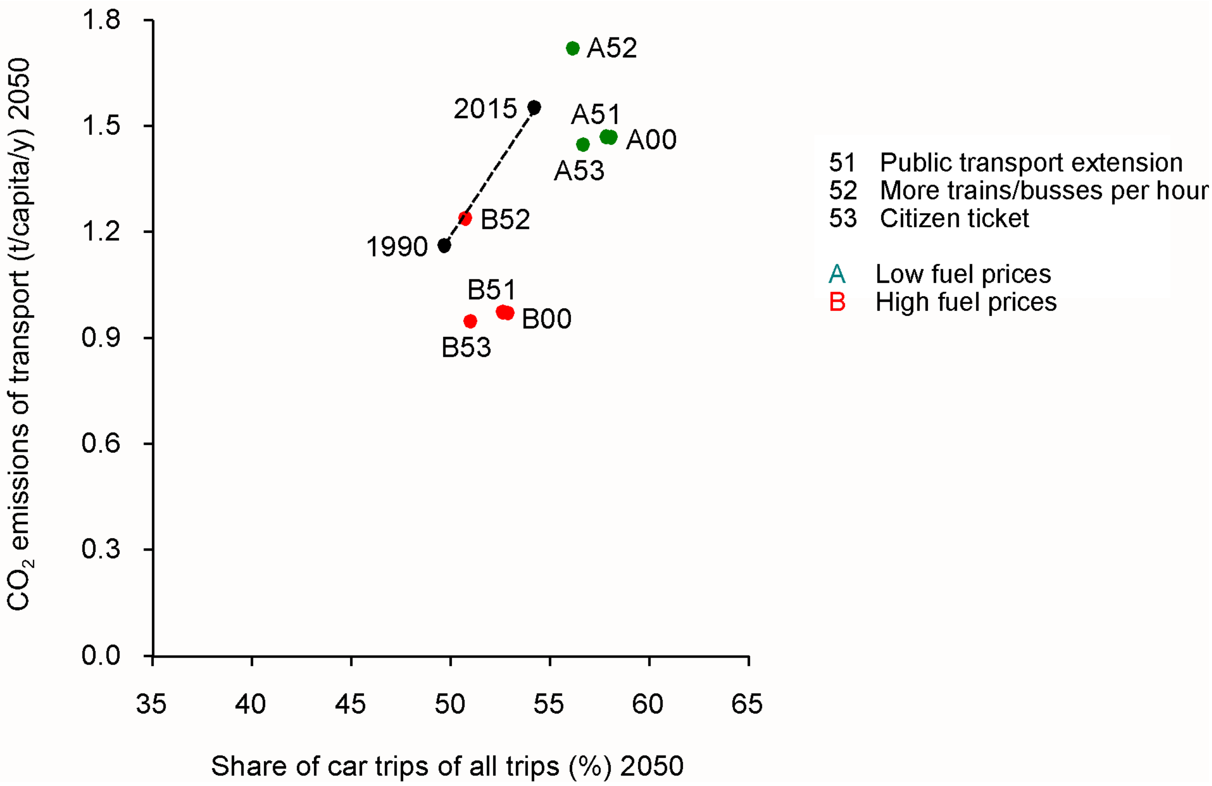

Figure 29. Share of car trips (%) v. CO_2 emissions of transport 2050: Scenarios A51/B51-A53/B53

3.2.5 Cycling/walking (Pull)

In the policy field cycling/walking measures are analysed that aim at making cycling and walking more attractive. There are measures to make cycling faster, for instance through high-quality cycling lanes, cycling-friendly traffic light programming and the conversion of road lanes to cycling lanes (A61/B61). Still more radical is Scenario A62/B62, in which the whole Ruhr Area, starting from express cycling route RS1 already implemented in the base scenario, is equipped with a tight raster of express cycling routes. In the Scenario A71/B71 the impacts of reducing walking distances by making walking trips more direct are analysed.

The trajectory diagrams in Figures 30 and 31 show the development of CO_2 emissions in these scenarios, Figure 32 shows their effects on modal split. None of the three measures to promote cycling and walking contributes to the reduction of energy consumption and greenhouse emissions to a relevant degree. The reason for this is that the pull measures motivate only few car drivers to leave their car at home and change to cycling or walking. To achieve that, integrated combinations of push and pull policies are required. (see Section 3.3). Nevertheless the analysed measures are successful as they attract additional cyclists and pedestrians. An area-wide promotion of cycling in the Ruhr Area can result in an increase of cycling in the modal split of up to 5 percentage points compared with the Base Scenario A00.

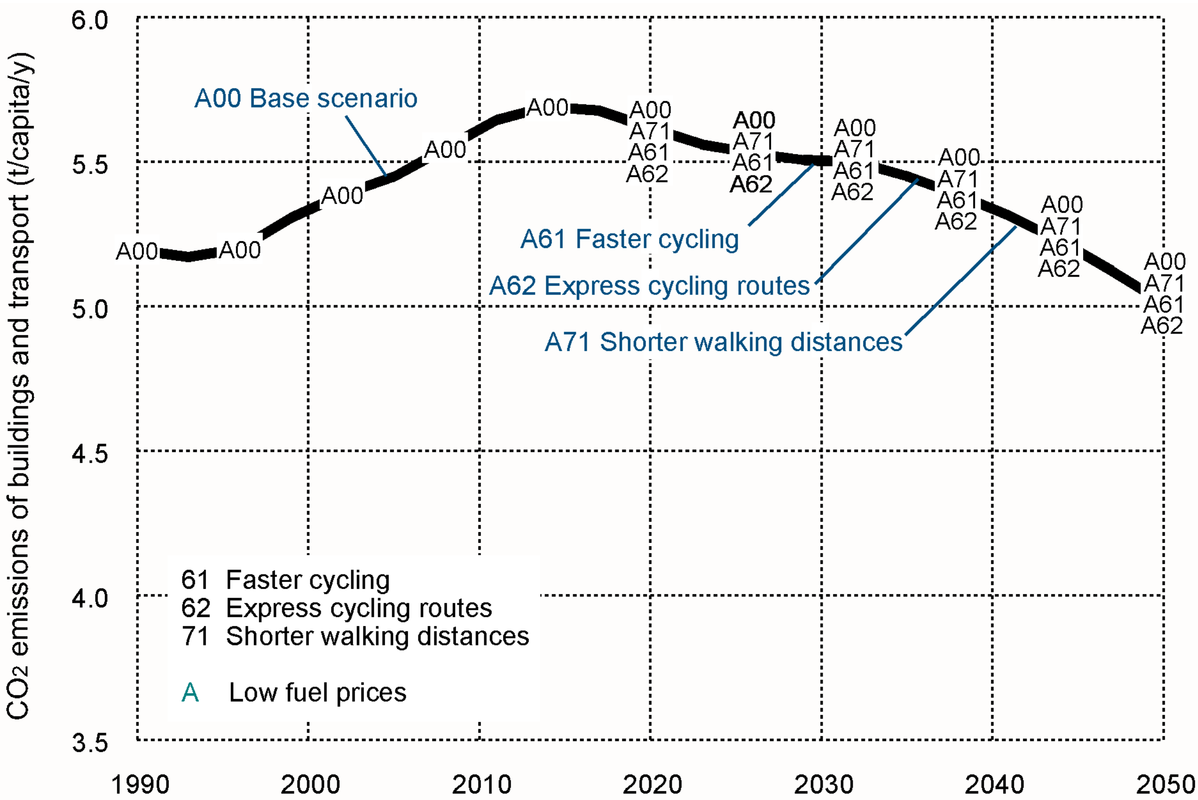

Figure 30. CO_2 emissions of buildings and transport 1990-2050: Scenarios A61-A71

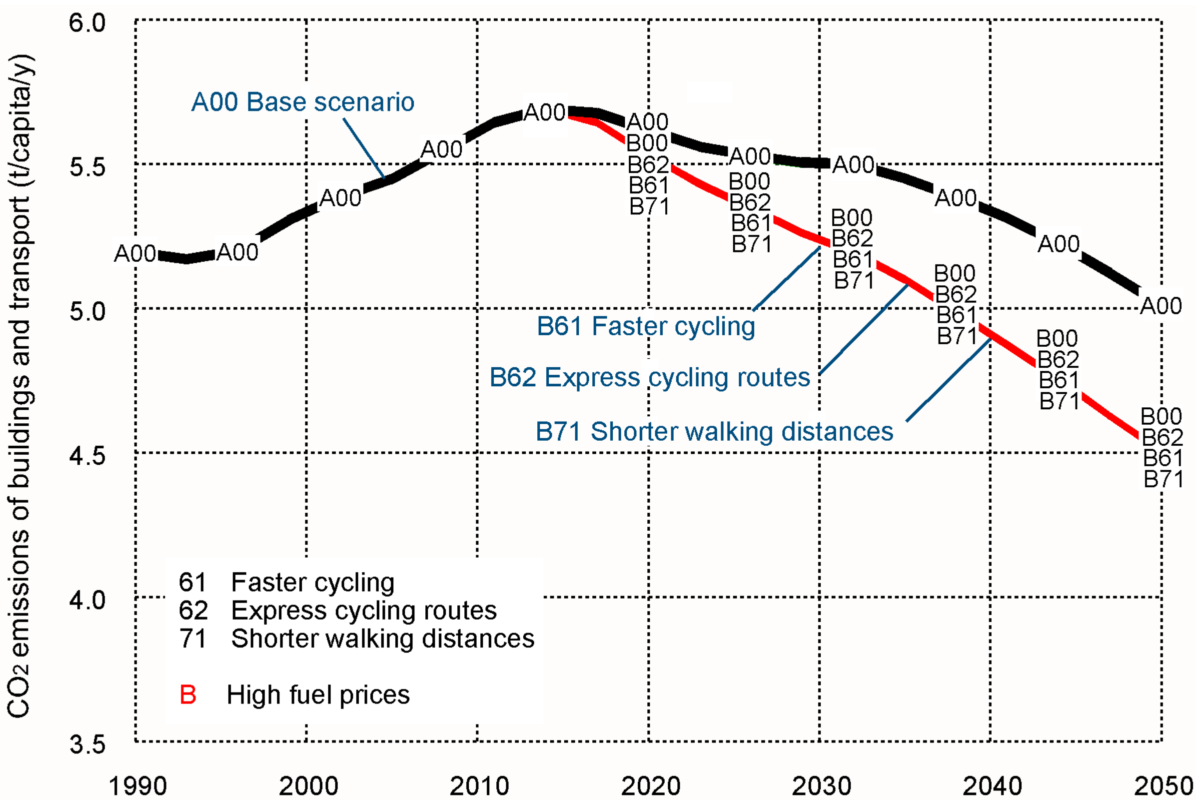

Figure 31. CO_2 emissions of buildings and transport 1990-2050: Scenarios A61-A71

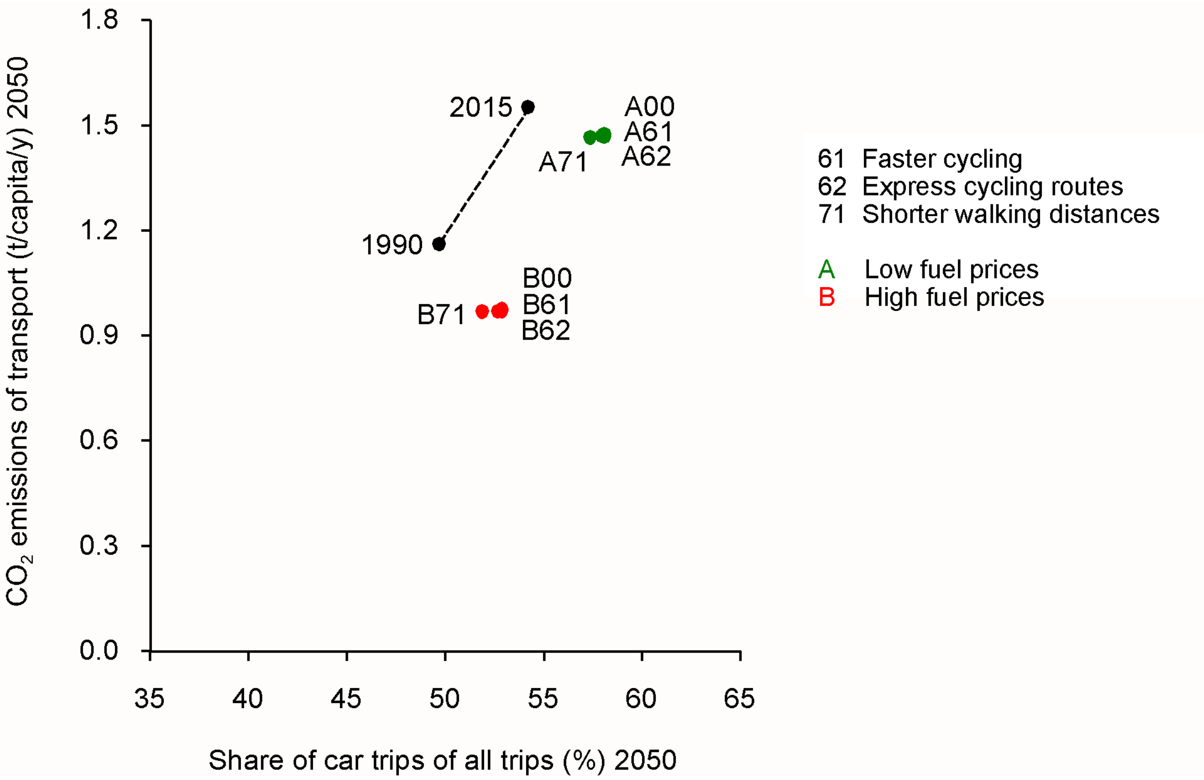

Figure 32. Share of car trips (%) v. CO_2 emissions of transport 2050: Scenarios A61/B61-A71/B71

The small effect of the cycling scenarios on car trips seems to contradict the experience of successful cycling cities (see 2.3.6 and 2.3.7). That this can be overcome by a combination of push and pull policies will be discussed in the next section.

3.3 Integrated strategies

In addition to the individual policies different combinations of land use and transport policies were simulated, first within five policy fields and then across all policy fields. The objective of the integrated strategies was to identify positive synergies (policies reinforce each other) and negative synergies (policies weaken each other).

The trajectory diagrams in Figures 33 and 34 show the development of CO_2 emissions of buildings and transport in the analysed combination scenarios. The combination scenarios A81/B81 (land use) und A84/B84 (public transport/cycling/walking) score worse than in the corresponding Base Scenarios A00 and B00, because they contain Scenarios A23/B23 (new housing) and A52/B52 (more trains/buses), both of which generate not less but more CO_2 emissions (see 3.2.1 and 3.2.4). The combination scenarios A82/B82 (energy efficiency) and A83/B83 (car traffic), however, result in larger reductions of CO_2 emissions than if the individual policies are considered separately.

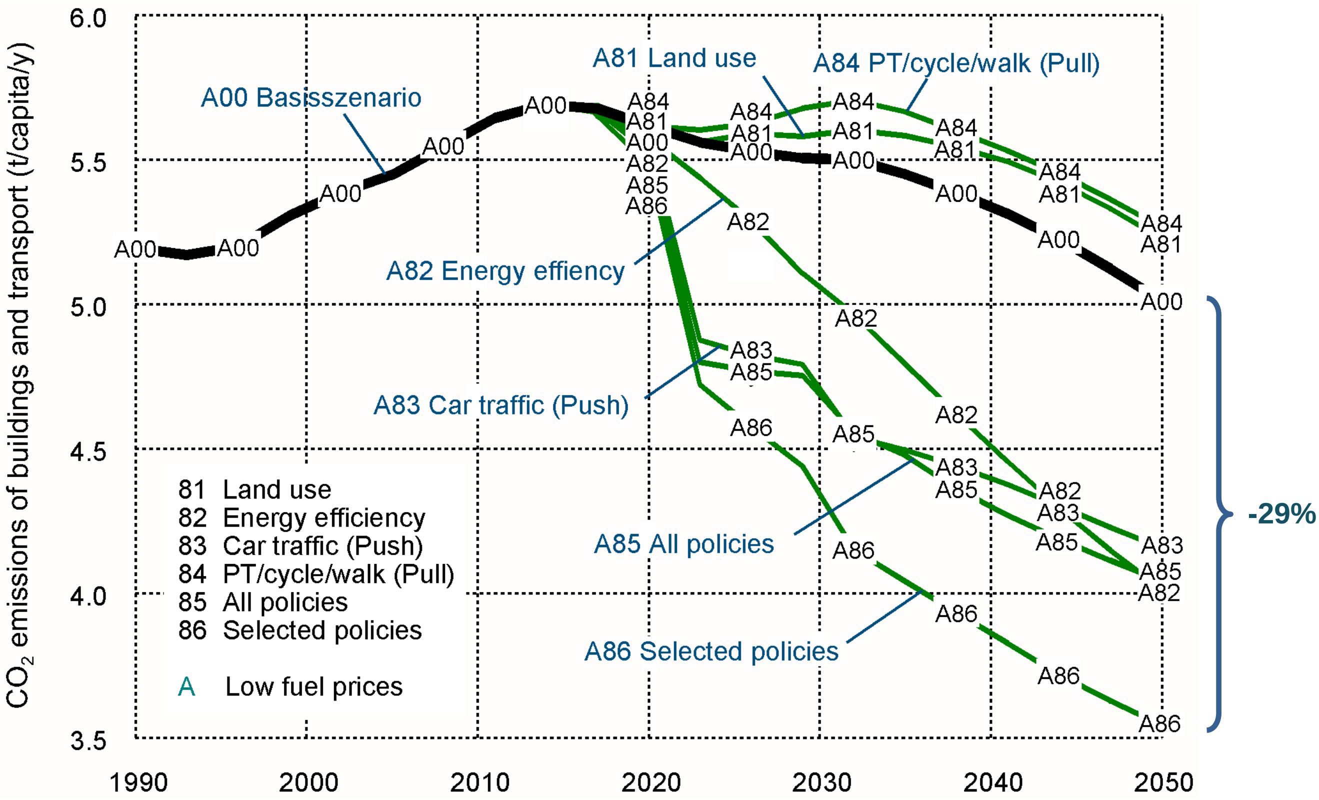

Figure 33. CO_2 emissions of buildings and transport 1990-2050: Scenarios A81-A86

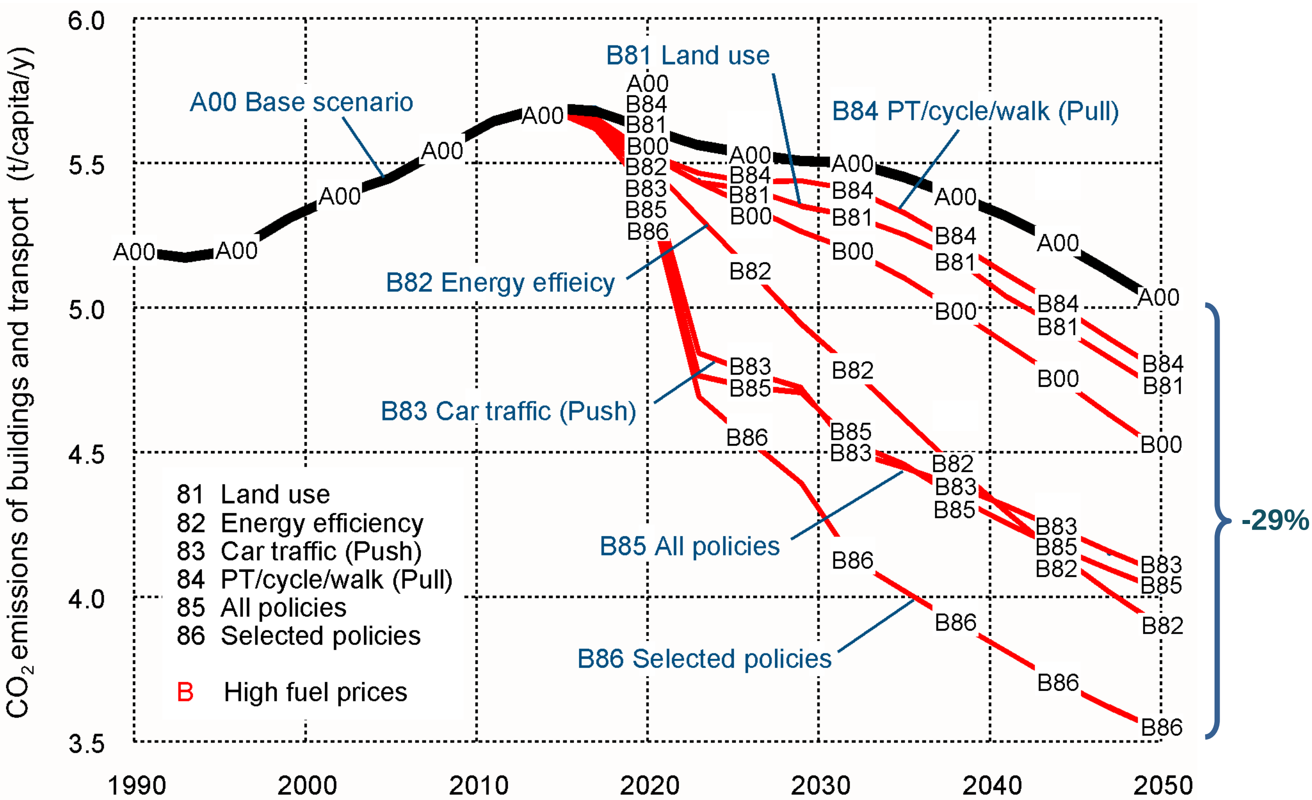

Figure 34. CO_2 emissions of buildings and transport 1990-2050: Scenarios B81-B86

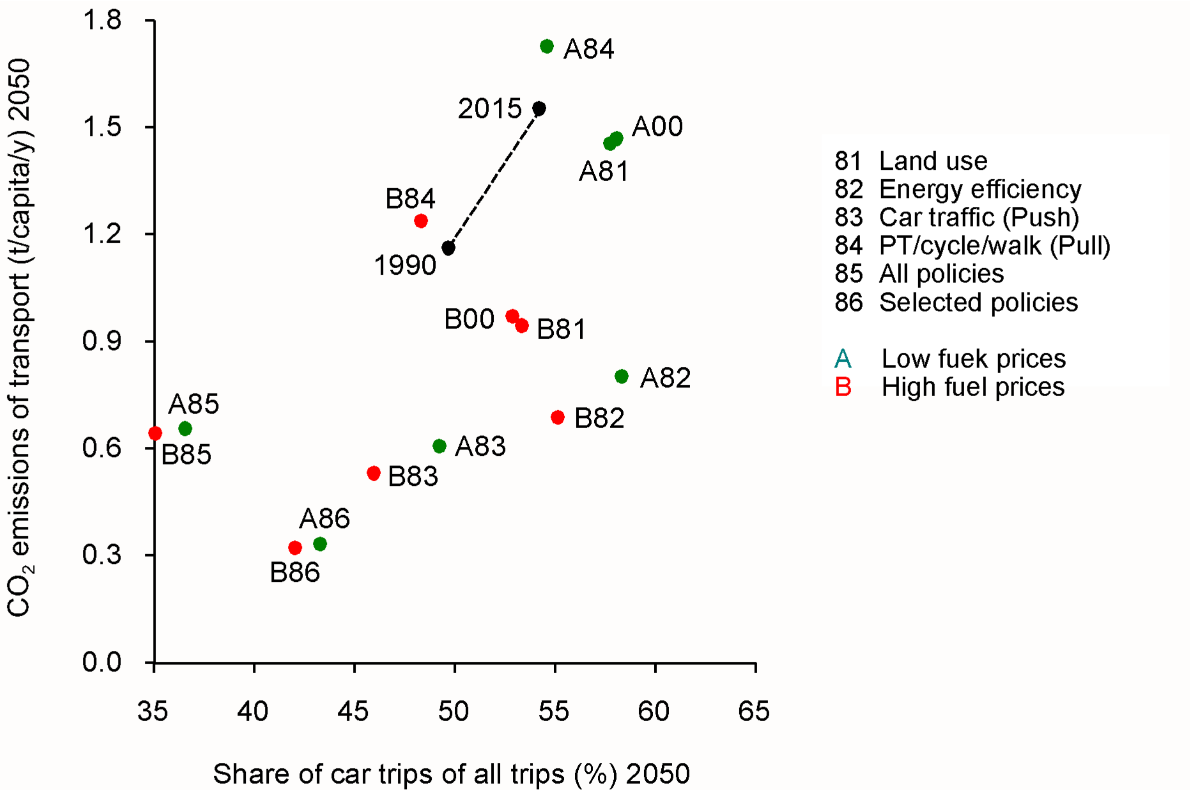

Figure 35. Share of car trips (%) v. CO_2 emissions of transport 2050: Scenarios A81/B81-A86/B86

If all policies are modelled together (A85/B85), the CO_2 emissions of buildings and transport are reduced by about one ton per capita and year compared with the Base Scenario A00 and by about one half ton compared with the Base Scenario B00. The relative CO_2 reduction with all policies implemented amounts to about 20 percent in the year 2050 compared with the Base Scenario A00 and about 10 percent compared with the Base Scenario B00.

In order to examine what maximum CO_2 reduction can be achieved with the analysed policies, the Scenario A86/B86 (selected policies) was developed. In it all policies are modelled except those of Scenarios A23/B23 (new housing at railway stations) and A52/B52 (more trains and buses per hour) as these were the only ones in which under the assumptions made the CO_2 emissions were increased rather than reduced. This selection of policies resulted in a reduction of CO_2 emissions by 29 percent compared with the Base Scenario A00 and 22 percent compared with the Base Scenario B00. Even larger positive effects for the energy transition and quality of life of the population could be achieved if the policies on new housing and more trains and buses would be implemented with zero-emission houses and trains and buses powered by renewable energy. Then their positive effects could develop without an increase in energy consumption.

However, the impacts of the integrated strategies on the modal split in the Ruhr Area (Figure 35) show that the largest effects towards a reduction of the share of car trips are achieved with Scenario 85, in which all analysed policies are assumed to be implemented. In Scenario A85 the share of car trips in the year 2050 is 35 percent compared with 58 percent in the Base Scenario A00, that is about 23 percentage points lower than if no policies were implemented.

The policy field with the largest impact on the reduction of the share of car trips are the push policies restricting car traffic. (A83/B83), which reduce the share of car trips from 58 percent to 46-49 percent. Pull measures promoting public transport, cycling and walking (A84/B84), reduce the share of car trips by about 4 percentage points. Policies promoting energy efficiency (A82/B82), however, result in growth of the share of car trips because they make car driving less expensive.

However, the reduction of CO_2 emissions by about 20 percent if all policies are implemented (A85/B85) or by about 30 percent if selected policies are implemented (A86/B86) is by far not sufficient to achieve the targets of the energy transition. To get a more differentiated result, in addition to the reduction in the total CO_2 emissions of buildings and transport together, the reductions in CO_2 emissions exclusively of transport are presented (Figures 36 and 37).

The results show that the analysed policies lead to significantly higher reductions of CO_2 emissions of transport alone. The reduction compared with the Base Scenario A00 amounts to about 55 percent if all policies are implemented (A85/B85) and to about 40 percent compared with the Base Scenario B00. If only the selected policies of Scenarios (A86/B86) are implemented, the CO_2 reduction amounts to about 77 percent compared with the Base Scenario A00 and to about 65 percent compared with the Base Scenario B00. However, it is important to note that the CO_2 emissions of transport amount to only a quarter of the CO_2 emissions of buildings and transport together.

This large difference in the implementation of the energy transition between buildings and transport becomes even more visible in the comparative presentation of the contribution to the energy transition of all scenarios in the bar diagrams of Figures 38 and 39. It becomes apparent that the reduction of transport-related CO_2 emissions (Figure 39) is more successful than if both buildings and transport are considered together (Figure 38), even though in the Scenarios A31/B31 (building energy) already the very far-reaching assumption was made that energy retrofits of buildings are subsidised by 50 percent of the investment costs. In addition the large contribution of energy prices, here fuel prices in transport, for the implementation of the energy transition becomes apparent.

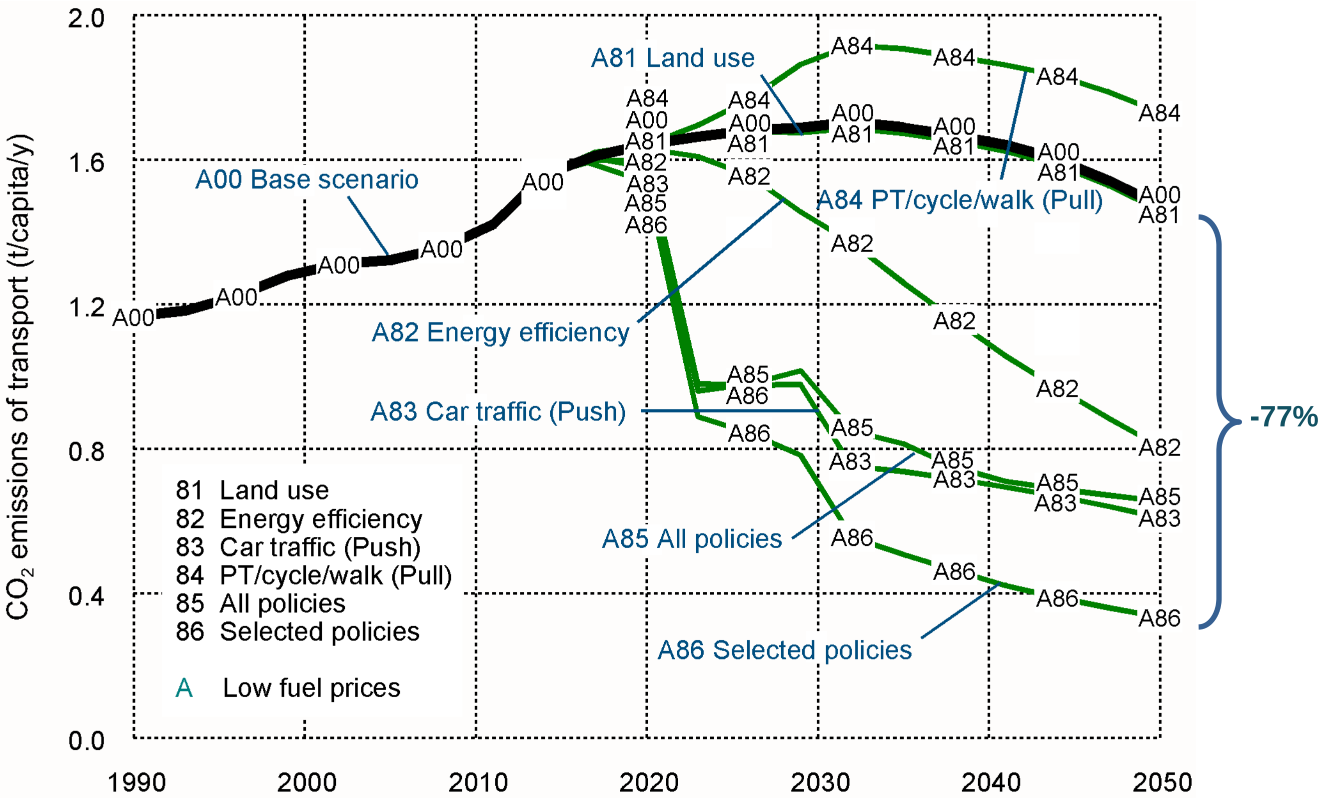

Figure 36. CO_2 emissions of transport 1990-2050: Scenarios A81-A86

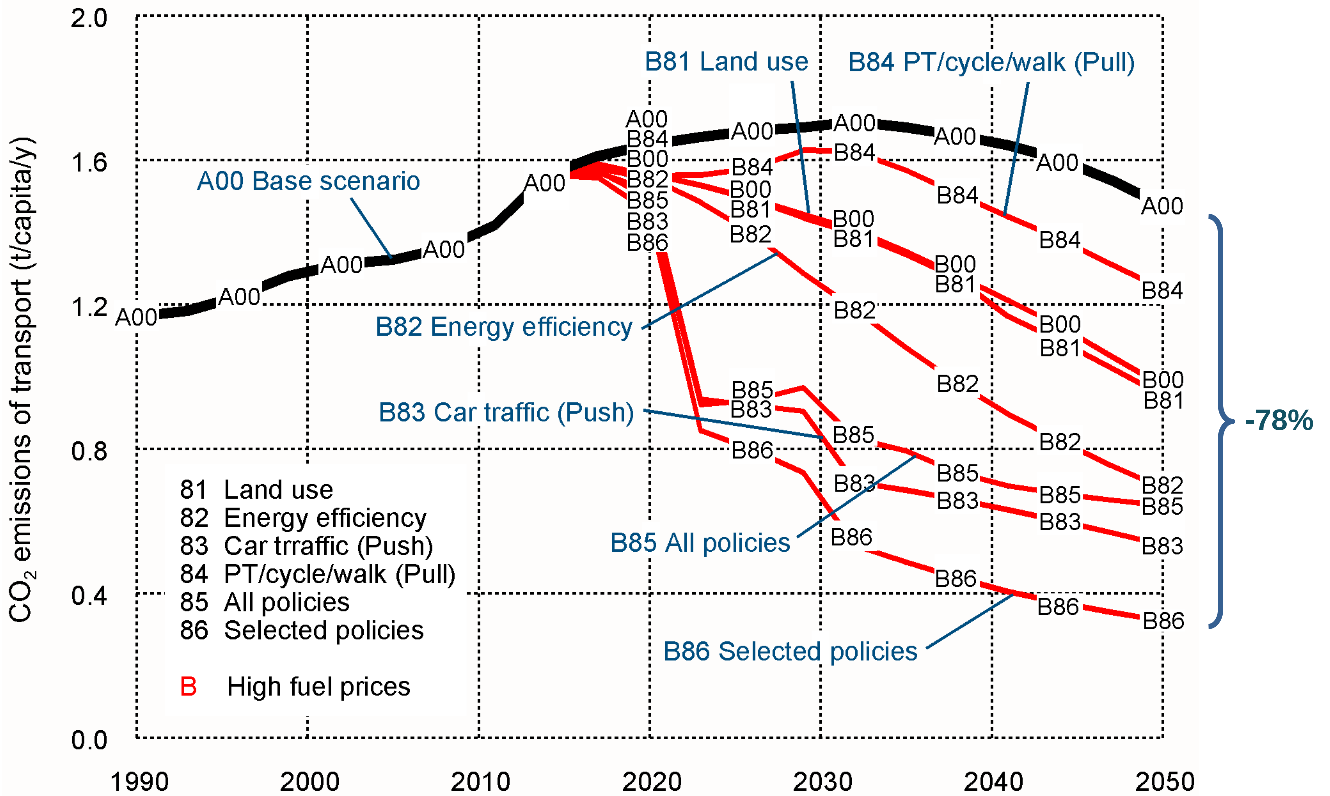

Figure 37. CO_2 emissions of transport 1990-2050: Scenarios B81-B86

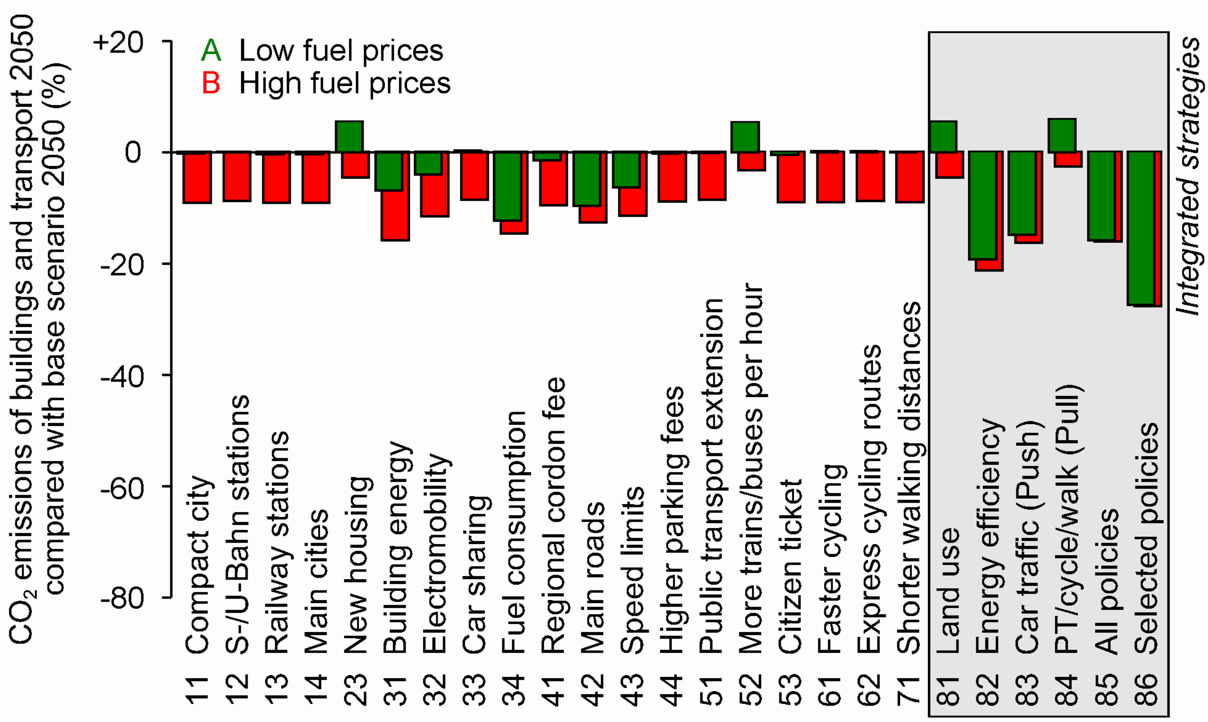

Figure 38. Reduction of CO_2 emissions of buildings and transport (%) 2050

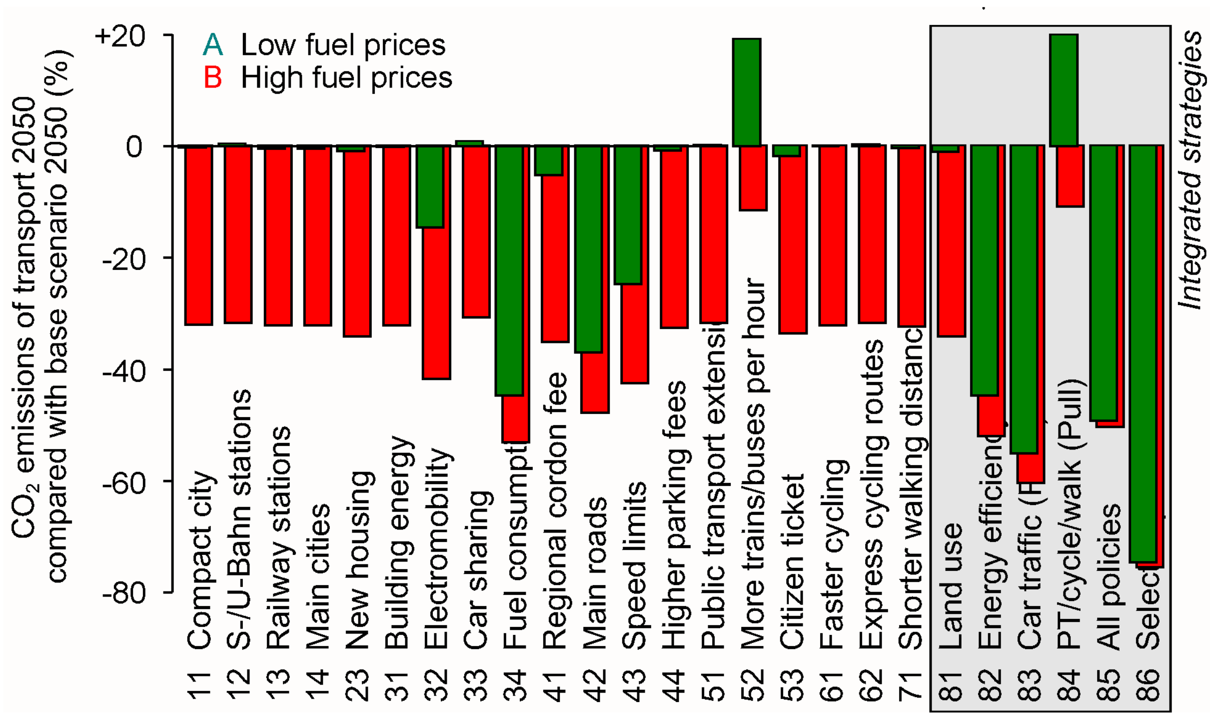

Figure 39. Reduction of CO_2 emissions of transport (%) 2050

3.4 Summary of results

The model results show that with the analysed land use and transport policies significant reductions of energy consumption and greenhouse gas emissions can be achieved.

It becomes apparent that these potentials can be exploited easier in transport than in buildings, although heating and air conditioning of buildings consume three times more energy than vehicles.

In the field of transport, restrictions that make car driving less attractive (push policies), are significantly more successful in reducing car use than incentives that make public transport, cycling and walking more attractive (pull policies).

Of central importance is the combination of individual policies in policy combinations. The common co-ordinated implementation of several individual policies in integrated strategies produces additional reductions of energy consumption and greenhouse gas emissions. Through the combination of different push and pull policies up to 29 percent reduction of energy consumption and greenhouse gas emissions compared with the base scenario is possible, if only transport is considered even up to 78 percent.

With respect to modal shift, the largest shifts from car traffic to more environment-friendly travel modes are achieved if all developed policies are implemented together. In this way the share of car trips of all trips in the Ruhr Area is reduced by about 23 percentage points to about 35 percent. The greatest effects are achieved by push policies restricting car traffic. Policies promoting the energy efficiency of cars, however, result in more car trips because of lower energy costs of car driving.

The authors are aware that parts of the results presented in this report will be discussed controversially and stimulate further empirical investigations and expert discussions.

However, in total the model results show that even with ambitious land use and transport policies applied area-wide in the Ruhr Area the targets of the energy transition and climate protection in the policy fields of buildings and transport will be difficult to achieve. With the policy scenarios modelled a significant gap between the results achieved and the greenhouse gas reduction target of 80 to 95 percent by the year 2050 remains. Such a gap also exists to a target model split with a share of car trips of 25 percent and 25 percent each for walking, cycling and public transport. (WI 2013; WI 2015; RVR 2014). Further ambitious policies applied area-wide in the Ruhr Area are required to close the remaining gap to the energy transition and climate protection targets.

4 Conclusions and policy recommendations

The results of the model simulations towards the energy transition Ruhr can be summarised as follows:

1. Push policies, such as high energy prices, speed limits and the reduction of lanes of main roads, are more effective for energy savings than pull policies, such as the promotion of energy retrofitting of buildings, cycling and walking or electromobility or more trains and buses in public transport.
2. Between individual policies or policy packages there exist synergies, i.e. the effects of policies can reinforce or weaken each other. It is therefore necessary to consider policies from different action and policy fields for urban and transport development in an integrated way.
3. The results show the significant potentials of combined push and pull strategies to develop energy and climate efficient regional land use and transport structures, and which planning policies are needed to achieve the targets of the energy transition and climate change.

Altogether the results communicate an inconvenient truth: “It would be possible if one really wanted to!”

This means that political decision makers and actor groups of the civil society are called upon to act – immediately, quickly and consistently and area-wide in the whole Ruhr Area.

Even if until the year 2050 more than a generation seems to be remaining, the model results show that in the face of the neglect of action in the past and the magnitude of the challenge of climate protection and the energy transition, there is no more time for hesitation and half-heartedness.

The scenario results also show that even with the assumed ambitious and politically difficult to implement policies the targets of the energy transition and climate protection cannot yet be completely achieved.

Where to begin? There are already many initiatives to decarbonise transport and save building energy. But faster, more resolute and politically more effective action is needed – now! The first steps for this are clear:

1. Politicians are called upon to revise decisions and legal principles, to fundamentally change the priorities of subsidisation and to adjust existing promotion programmes to existing knowledge.
2. Model policies should be promoted, and active and engaged actor groups should be identified, activated and supported, so that they can reach large groups of the population and gain social support for the necessary changes.
3. The Regional Association Ruhr should start a comprehensive regional discourse with actors and decision makers about the individual policies and integrated strategies of decarbonisation and should work out a an integrated master plan for the development of land

use and transport. Both good examples in the Ruhr Area of which the region can be proud and examples from other regions can be concrete, lively and illustrative models to follow and stimulate following. They show as highlights of today what should be standard already tomorrow.

4.1 Perspectives for research and methodology

With the results of the model calculations for the Ruhr Area 2050 in forecasting scenarios a foundation was laid. However, the results have also revealed further research questions. Future research projects can build on this basis to work with higher spatial resolution, analyse selected open questions or conduct more detailed sectoral studies. The Ruhr Area model and its integrated network and structural data should be used for more detailed and complementing studies:

1. With a backcasting scenario approach it should be analysed which more far-reaching policies should be applied for integrated land use and transport development and until when these policies need to be implemented to achieve the government climate targets for Germany (reduction of greenhouse gas emissions compared with 1990 by 55 percent until 2030 and by 80 to 95 percent by 2050) also in the Ruhr Area.
2. So far the analyses were conducted for the whole Ruhr Area. Starting from there, spatial differentiation into core cities, urban fringes and rural spaces could lead to spatially specific policy recommendations.
3. Sensitivity analyses of the policies should be conducted. Also other environmental effects, such as the reduction of traffic noise, air pollution or land consumption should be calculated to assess the co-benefits and positive and negative synergies of the analysed policies and communicate them in the regional policy discourse.
4. The impacts of commercial traffic and goods transport so important for the Ruhr Area and options for their decarbonisation should be analysed.
5. In addition, model extensions, such as energy consumption and CO_2 emissions of non-residential buildings, process energy, solar and wind energy and possible impacts of climate change, such as floods and heat waves should be developed.
6. There are new issues emerging, such as online trade, autonomous vehicles, market entrance of so-called disruptive suppliers (end of public transport?), enforced redirection towards electromobility (for instance through prohibition of combustion vehicles after 2030). Here the model can contribute qualified guidelines for possible policies and their potential impacts.

In addition several more general questions need to be answered:

- With the Ruhr Area model both technological developments and behavioural changes were modelled. It should be analysed in what relationship technological and behavioural policies would be best combined in order to achieve, besides environmental objectives, also urban design and social goals.

- How can the different political decision levels (EU, Federal Government, state of North-Rhine Westphalia, Ruhr Area and municipalities) develop as effectively as possible co-ordinated policy packages to achieve the climate protection targets and communicate them to the people in a reliable, understandable and effective way?
- Which actor groups in politics and administration, economy and civil society, media and research can deliver which contributions to the achievement of the targets?
- What is the cost of all this, and how will it be financed? In which policy fields should contra-productive public funds be reduced and redistributed for the achievement of the policies developed in the project? Which costs of road traffic so far treated as external (e.g. accidents, air pollution, traffic noise etc.) could be saved by society?

4.2 Perspectives for actors / for the region

From the results of the simulations clear action needs for the municipalities of the Ruhr Area and the Regional Association Ruhr arise:

4.2.1 Land use

In the policy field land use a comprehensive land use plan for the whole Ruhr Area should be developed, which is binding for all counties and municipalities, limits the extensions of urban areas by competing municipalities, protects the open space and concentrates urban development at public transport stations.

In this plan the still existing large former industrial but now vacant areas in the core cities of the Ruhr Area should be developed. But also the small and medium-sized cities at the fringe of the Ruhr Area should be reinforced without endangering the requirements of open space. When doing that it should be considered that policies to influence urban spatial development require a long time compared with transport policies and affect trip generation, trip distances and model choice only in the long term. When assigning land uses it should be considered that in all new construction areas there should be a balanced mixture of housing and work places. In addition long-term planning should take account of the housing needs of immigrants likely to grow in the future.

4.2.2 Transport

In the Ruhr Area significant potentials exist for the shift from car traffic to more environment-friendly travel modes, if combined push and pull policies are implemented ambitiously and area-wide. To release these potentials and to satisfy the requirements of the energy transition in transport, quick and consistent action by the municipalities of the Ruhr Area, the Regional Association Ruhr and the state and national governments is required instead of hesitant and less ambitious approaches.

Many policies with high potential for the shift from car traffic to more environment-friendly travel modes are in principle known but have not been implemented consistently enough – this is particularly true for policies restricting car traffic. **Therefore the combined implementation of both pull and push policies is important**: Through restrictive policies the largest effects can be achieved. Positive incentives are needed that create attractive mobility possibilities by walking, cycling and public transport and so facilitate a change in mobility behaviour. Such positive incentives are also important to gain political consciousness and acceptance by the population.

As short-term action goal the municipalities of the Ruhr Area and the Regional Association Ruhr should develop regional strategies to implement effective combinations of push and pull policies area-wide in the Ruhr Area. This includes in particular the development of a regional transport master plan for the Ruhr Area, the conclusion of contracts between municipalities and counties and the Regional Association Ruhr and the improvement of the co-operation between public transport enterprises of the Transport Association Rhine-Ruhr.

Promising combinations of push and pull policies should be developed in an area-wide participatory process including the different actors of politics and administration, economy and civil society, media and research and should be accompanied by communicative policies to gain acceptance. For the development of implementation priorities and first policy combinations criteria such as effectiveness, costs, acceptance and co-benefits, such as less traffic noise, higher environmental quality and greater traffic safety should be considered.

4.2.3 Integrated strategies

To reverse the continuing trend of further urban sprawl and growing car mobility individual solutions are not sufficient. Integrated strategies are required that include land use, transport and fiscal policies to influence transport development.

In all three policy fields far-reaching policies are required:

1. In the land use policy field more effective procedures to control urban development and to protect open space than in the past are required.
2. In the transport policy field the requirements of sustainability and climate protection need to have more priority than in the past.
3. Fiscal policies to influence transport development need to offer stronger incentives for sustainable mobility than in the past.

Because of growing cross-border networks and internationalisation of all spatial processes as commuter flows, migration and trade at regional, national and European level more and more planning and political decisions are required at higher levels than at the municipal or regional level. The required policies to make fossil energy more expensive, the promotion of renewable energy by energy retrofitting of buildings or the promotion of electromobility can be decided only at the national or European level. This requires that municipalities and counties and the state government influence the political bodies at national and European level to pass the necessary resolutions.

Many of the necessary policies, in particular the push policies, are likely to be perceived by many people as restrictions of their mobility and quality of life. It is therefore necessary to communicate that these “inconvenient truths” can also bring about significant co-benefits, such as improved environmental quality, better urban design and the renaissance of neighbourhood relations.

To support the implementation of the necessary policies the potential of integrated strategies need to be more utilised than in the past. Painful restrictions at one place can be compensated by improvement at others. It is more convincing to reduce high subsidies of long commuting trips if the resulting revenues are used in a transparent and understandable way for the improvement of environment-friendly local mobility.

Three concrete recommendations for municipal and regional decision makers for the implementation of the building blocks of a comprehensive roadmap for the energy transition in the Ruhr Area are:

1. Development of a comprehensive land use plan for the whole Ruhr Area, which is binding for all counties and municipalities, limits the extension of urban areas by competing municipalities and has the protection of open space and the concentration of new development at public transport stations as highest objectives.
2. Fast and consistent action by municipalities and the Regional Association Ruhr (and the state and national governments) to implement both pull policies that promote energy saving and climate-sensitive forms of urban mobility and push policies that make climate-adverse car driving less attractive. For this a region-wide participative process is required.
3. To achieve a basic trend reversal in land consumption and mobility, integrated strategies are required that combine policies to influence land use and transport and fiscal policies to influence transport behaviour, which complement and reinforce each other towards the achievement of a more energy efficient and climate-favourable mobility.

For the implementation it is necessary to start immediately. Now!

5 Product overview

Table 3: Overview of the in *Cities and Climate Change: Ruhr Area 2050* generated products

Date	Title	Short description
November 2011	Nachhaltige Mobilität durch Polyzentralität	Conference paper (+)
November 2011	Nachhaltige Verkehrsinfrastruktur Ruhr 2050	Conference paper (+)
June 2012	Entwicklung eines integrierten Modells „Ruhrgebiet 2050“	Project note
May 2013	Entwicklung eines integrierten Modells „Ruhrgebiet 2050“: Projektbeschreibung	Project note
June 2013	Energy efficiency of buildings: a new challenge for urban models	Conference paper (+)
July 2013	Modelling the energy transition in cities	Conference paper (+)
September 2013	Datenbeschaffungsplan Integriertes Modell Ruhrgebiet 2050	Project note
April 2014	Fortschritte in der Modellentwicklung	Project note (+)
May 2014	Handlungsfelder Verkehr und Siedlungsentwicklung	Project note
May 2014	Daten Teil Fahrradverkehr	Project note
July 2014	Teilmodell Verkehr des integrierten Modells Ruhrgebiet 2050	Project note
August 2014	Modelldateien des IRPUD-Modells	Project note
September 2014	Umsetzbarkeit der Maßnahmen	Project note
October 2014	Projektbeschreibung	Project report (+)
October 2014	Modelltechnische Überlegungen zur Integration der Elektromobilität	Project note
October 2014	Regionaler Modal Shift im Ruhrgebiet: Annahmen für die Maßnahmenszenarien	Project note
November 2014	Integriertes Modell Ruhrgebiet 2050: Stand der Forschung	Project report (+)
November 2014	Die Zoneneinteilung des Ruhrgebietsmodells	Project note
February 2015	Modellierung der Verkehrsszenarien	Project note
February 2015	Maßnahmen-Steckbriefe für einen regionalen Modal Shift	Project note
March 2015	Aufbereitung der Strukturdaten	Project note
May 2015	Datenbedarf des Ruhrgebietsmodells: Strukturdaten	Project note
May 2015	Optionen für Verkehrsnetze des Ruhrgebietsmodells	Project note
June 2015	Are polycentric cities more energy-efficient?	Conference paper (+)
August 2015	Eingabedateien des Ruhrgebietsmodells	Project note
August 2015	Potenziale für energie- und klimaeffiziente Stadt- und Regionalstrukturen	Conference paper
October 2015	Potenziale für einen „Regionalen Modal Shift“ im Ruhrgebiet	Conference presentation
November 2015	Vergleich von Zwischenergebnissen	Project note
January 2016	Modellierung der Elektromobilität	Project note

February 2016	Integrierte Stadtmodellierung: Flächennutzung, Verkehr, Energie, Umwelt	Conference paper (+)
Mai 2016	Ruhrgebietsmodell-Szenarien Verkehr	Project note
June 2016	Simulation of the potentials to reduce the modal share of car use in the Ruhr Metropolitan Region	Conference paper
July 2016	Modellierung von raum- und verkehrsplanerischen Maßnahmen zur Veränderung des regionalen Modal Splits im Ruhrgebiet	Conference paper
October 2016	Verkehrswende voran bringen - Hauptverkehrsstraßen zurückbauen	Conference presentation
November 2016	Stadt entwickeln, Mobilität managen – Herausforderungen und zukünftige Trends in den Kommunen. Klimaschutz und Modal Shift im zukunftsfähigen Stadtverkehr	Conference presentation
March 2017	Verkehr verlagern! Szenarioanalysen zu Modal-Shift-Potenzialen im Personenverkehr im Ruhrgebiet 2050	Conference presentation

(+) These products are available at the website of Spiekermann & Wegener Urban and Regional Research http://www.spiekermann-wegener.de/pro/ruhr2050_e.htm.

6 References

ADFC (2011): Von der Vision in die Realität – Radschnellwege in den Niederlanden, Dänemark und Hannover. Artikel vom 21.02.2011. https://www.adfc-nrw.de/kreisverbaende/kv-muenster/willkommen-beim-adfcnbspim-muensterland/aktuelles-aus-muenstermuensterland/article/von-der-vision-in-die-realitaetbrradschnellwege-i.html.

amsterdam.info (2016): Parking your car in Amsterdam. http://www.amsterdam.info/parking/

BASt – Bundesanstalt für Straßenwesen (2000): *Gesamtwirkungsanalyse zur Parkraumbewirtschaftung*. Berichte der Bundesanstalt für Straßenwesen (bast), Heft V75. Bergisch Gladbach.

bcs – Bundesverband CarSharing e.V. (2013): bcs-Städtevergleich: CarSharing-Angebote in deutschen Großstädten über 200.000 Einwohnern. http://www.carsharing.de/sites/default/files/uploads/presse/pdf/liste_bcs-staedteranking_2013_korr.pdf

bcs – Bundesverband CarSharing e.V. (2015): CarSharing-Städteranking 2015: Die CarSharing-Versorgung verbessert sich weiter. Auch viele kleinere Städte sind vorne dabei. Pressemitteilung vom 10.06.2015, Berlin. http://www.carsharing.de/presse/pressemitteilungen/carsharing-staedteranking-2015-carsharing-versorgung-verbessert-sich

bcs – Bundesverband CarSharing e.V. (2016): Mehr Platz zum Leben – wie CarSharing Städte entlastet. Ergebnisse des bcs-Projektes “arSharing im innerstädtischen Raum – eine Wirkungsanalyse“. Endbericht. Berlin. http://www.carsharing.de/sites/default/files/uploads/alles_ueber_carsharing/pdf/endbericht_bcs-eigenprojekt_final.pdf

Beckmann, Klaus J.; Brüggemann, Ulrike; Gräfe, Jürgen; Huber, Felix; Meiners, Hans; Mieth, Peter; Moeckel, Rolf; Mühlhans, Heike; Rindsfüser, Guido; Schaub, Harald; Schrader, Rainer; Schürmann, Carsten; Schwarze, Björn; Spiekermann, Klaus; Strauch, Dirk; Spahn, Michael; Wagner, Peter; Wegener, Michael (2007): *ILUMASS: Integrated Land-Use Modelling and Transport System Simulation*. Endbericht. Berlin: Deutsches Zentrum für Luft- und Raumfahrt (DLR). http://www.spiekermann-wegener.de/pro/pdf/ILUMASS_Endbricht.pdf

BMUB – Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit (2016): *Klimaschutzplan 2050*. http://www.bmub.bund.de/fileadmin/Daten_BMU/Download_PDF/Klimaschutz/klimaschutzplan_2050_bf.pdf

BMW, DLR, DB Rent, Landeshauptstadt München, Universität der Bundeswehr München, Senatsverwaltung für Stadtentwicklung und Umwelt Berlin (2016): Wirkung von E-Car Sharing Systemen auf Mobilität und Umwelt in urbanen Räumen (WiMobil). http://www.erneuerbar-mobil.de/sites/default/files/2016-10/Abschlussbericht_WiMobil.pdf

CIVITAS (2014): CIVITAS Study Tour in Vitoria-Gasteiz, Spain, June 2014. http://www.civitas.eu/sites/default/files/civitas_study_tour_vitoria-gasteiz_june_2014_measure_ description_0.pdf

City of Copenhagen – Technical and Environmental Administration Traffic Department (2011): Good, Better, Best – The City of Copenhagen’s Bicycle Strategy 2011-2025. http://kk.sites.itera.dk/apps/kk_pub2/pdf/823_Bg65v7UH2t.pdf

City of Copenhagen – The Technical and Environmental Administration, Mobility and Urban Space (2015): Copenhagen – City of Cyclists. The Bicycle Account 2014. http://www.cycling-embassy.dk/wp-content/uploads/2015/05/Copenhagens-Biycle-Account-2014.pdf

Energiezukunft (2016): Norwegen macht Ernst mit Elektromobilität. Artikel vom 29.03.2016. http://www.energiezukunft.eu/ueber-den-tellerrand/norwegen-macht-ernst-mit-elektromobilitaet-gn103967/

Difu – Deutsches Institut für Urbanistik (2012): Mobilitätsverhalten in Deutschland. Berlin.

EPOMM – European Platform on Mobility Management (no year): *TEMS – The EPOMM Modal Split Tool*. Vitoria-Gasteiz. http://www.epomm.eu/tems/result_city.phtml?city=158

Europäische Kommission; Sadler Consultants Ltd (2014): Urban Access Regulations in Europe. http://www.urbanaccessregulations.eu

Fiorello, Davide; Huismans, Gé; López, Elena; Marques, Carlos; Steenberghen, Thèrèse; Wegener, Michael; Zografos, Konstantinos G. (2006): *Transport Strategies under the Scarcity of Energy Supply*. STEPs Final Report, hrsg. von A. Monzon und A. Nuijten. Den Haag: Buck Consultants International. http://www.spiekermann-wegener.de/pro/pdf/STEPs_Final_Report.pdf.

Fuerst, Franz; Wegener, Michael (2017): Energy efficiency of buildings: a challenge for urban models. In: Jin, Ying (Ed.): *Applied Urban Modelling: Assessing Pathways towards Energy Efficient and Climate-Wise Regions.* Cambridge: British Academy.

FUSS e.V. – Fachverband Fußverkehr Deutschland (no year): *Handbuch zur Fußwegenetzplanung*. http://www.fuss-ev.de/102-literatur/563-handbuch-fusswegenetzplanung.html

Hägerstrand, Torsten (1970): What about people in regional science? *Papers of the Regional Science Association* 24, 7-21.

Hautzinger, Heinz; Fichert, Frank; Fuchs, Mario; Stock, Wilfried (2011): *Eignung einer City-Maut als Instrument der Verkehrs- und Umweltpolitik in der Freien und Hansestadt Hamburg*. Heilbronn. http://www.hamburg.de/contentblob/2929662/data/city-maut.pdf

Landtag Nordrhein-Westfalen (2013): Gesetz zur Förderung des Klimaschutzes in Nordrhein-Westfalen. https://www.landtag.nrw.de/portal/WWW/dokumentenarchiv/Dokument/MMG16-29.pdf?von=1&bis=0

Lautso, Kari; Spiekermann, Klaus; Wegener, Michael; Sheppard, Ian; Steadman, Philip; Martino, Angelo; Domingo, Roberto; Gayda, Sylvie (2004): *PROPOLIS: Planning and Research of Policies for Land Use and Transport for Increasing Urban Sustainability*. PROPOLIS Final Report. Helsinki: LT Consultants. http://www.spiekermann-wegener.de/pro/pdf/PROPOLIS_Final_ Report.pdf.

LK Argus GmbH (2011): *Machbarkeitsstudie und Wirkungsanalyse zur Parkraumbewirtschaftung Prenzlauer Berg.* Studie im Auftrag des Bezirks Pankow Berlin. Berlin. http://www.prenzlberger-stimme.de/wordpress/wp-content/uploads/downloads/2012/01/ Machbarkeitsstudie.pdf

muenchen.de – ein Service der Landeshauptstadt München und der Stadtwerke München GmbH (2016): Tempo-30-Zonen. https://www.muenchen.de/rathaus/Stadtverwaltung/Kreisverwaltungsreferat/Verkehr/Verkehrssicherheit/Tempo-30-Zonen.html

Müller, Miriam (2011): *Das NRW-Semesterticket. Akzeptanz, Nutzung und Wirkungen dargestellt am Fallbeispiel der Universität Bielefeld*. Wuppertal. http://epub.wupperinst.org/frontdoor /index/index/docId/3936

Oegel, Kersten (2011): Speeding up Cycling through special Infrastructure. Veröffentlicht von der Deutschen Gesellschaft für internationale Zusammenarbeit (GIZ) GmbH. http://www.sutp.org/files/contents/documents/resources/E_Fact-Sheets-and-Policy-Briefs/ SUTP_GIZ_FS_Speeding-up-Cycling-through-special-Infrastructure_EN.pdf

Ramboll (no year): Green Wave for Cyclists. http://www.ramboll.com/projects/rdk/gron-bolge-for-cyklister

RVR – Regionalverband Ruhr (2014): *Perspektiven für die räumliche Entwicklung der Metropole Ruhr*. Essen. http://www.metropoleruhr.de/fileadmin/user_upload/metropoleruhr.de/01_PDFs/ Regionalverband/Regionaler_Diskurs/RF_Zukunft_Perspekt/2014_05_14_Perspektiven.pdf

Reutter, Oscar; Müller, Miriam (2016): Benchmark: Klimaschutz im Stadtverkehr – Die Konzepte der Europäischen Umwelthauptstädte. In: *RaumPlanung* 184/2-2016, S. 38-45.

Sagolla, Winfried (2012): Nahverkehr – Lokales Verkehrswesen. In: *Memorandum zur Bewerbung der Metropole Ruhr als „Grüne Hauptstadt Europas 2015“*, S. 64. https://www.bochum.de/C12571A3001D56CE/vwContentByKey/W28RZDQG323BOLDDE/$FILE/Anlage1_Memorandum_Gruene_Hauptstadt_Europas.pdf

Senatsverwaltung für Stadtentwicklung Berlin, Bereich Kommunikation (2011): Fußverkehrsstrategie für Berlin – Ziele, Maßnahmen, Modellprojekte. Berlin. http://www.stadtentwicklung.berlin.de/verkehr/politik_planung/fussgaenger/strategie/download/fuss_broschuere.pdf

Spiekermann, Klaus; Wegener, Michael (2005): *Räumliche Szenarien für das östliche Ruhrgebiet.* Schlussbericht. Dortmund: Institut für Landes- und Stadtentwicklungsforschung und Bauwesen des Landes Nordrhein-Westfalen (ILS NRW). http://www.spiekermann-wegener.de/pro/pdf/ILS_Raumszenarien.pdf.

Stadt Bremen – Der Senator für Umwelt, Bau und Verkehr (Hrsg.) (2016): *Nachhaltige Mobilität für Menschen und Güter*. Bremen. http://www.bauumwelt.bremen.de/verkehr/nachhaltige_mobilitaet_fuer_menschen_und_gueter-53233

Stadt Moers (2016): Testphase Tempo 30 ist gestartet. Moers. https://www.moers.de/de/ aktuelles/testphase-tempo-30-ist-gestartet/

Stadt Wien – Magistrat der Stadt Wien (2015): Wie finanziert sich der Öffentliche Verkehr in Wien? Artikel vom 13.04.2015. Wien. https://wien1x1.at/site/wie-finanziert-sich-der-oeffentliche-verkehr-in-wien/#02

Team Red, TU Dresden, Omnitrend (2015): *Evaluation CarSharing (EVA-CS) – Endbericht*. Berlin. https://www.ris-muenchen.de/RII/RII/DOK/SITZUNGSVORLAGE/3885730.pdf

UBA Umweltbundesamt (1999): Umweltauswirkungen von Geschwindigkeitsbeschränkungen. UBA-Texte 40/1999. http://www.umweltbundesamt.de/sites/default/files/medien/publikation/long/3136.pdf

Waluga, Gregor (2016): Flexibilisierung des Öffentlichen Personennahverkehrs durch ein umlagefinanziertes Bürgerticket. Emmerich am Rhein. Entwurf der bisher unveröffentlichten Doktorarbeit an der Bergischen Universität Wuppertal

Wegener, Michael. (1999): *Die Stadt der kurzen Wege: müssen wir unsere Städte umbauen?* Berichte aus dem Institut für Raumplanung 43. Dortmund: Institut für Raumplanung, Universität Dortmund. http://www.raumplanung.tu-dortmund.de/irpud/fileadmin/irpud/content/documents/publications/ber43.pdf

Wegener, Michael. (2011): *The IRPUD Model*. Arbeitspapier 11/01. Dortmund: Spiekermann & Wegener Stadt- und Regionalforschung. http://www.spiekermann-wegener.de/mod/pdf/AP_1101_IRPUD_Model.pdf

Wetz, Andreas (2015): 365 Euro: Trägt sich die Jahreskarte von allein? Artikel vom 09.10.2015. http://diepresse.com/home/panorama/wien/4839954/365-Euro_Traegt-sich-die-Jahreskarte-von-allein

WI – Wuppertal Institut (2013): *Metropole Ruhr – Grüne Hauptstadt Europas*. Wuppertal. http://wupperinst.org/uploads/tx_wupperinst/Metropole_Ruhr_Endbericht.pdf

WI – Wuppertal Institut (2015): *Nachhaltiges Nordrhein-Westfalen 2030 – Das Leitbild*. Wuppertal. http://wupperinst.org/uploads/tx_wupperinst/NHS_NRW_AP8-1_Leitbild.pdf

Zahavi, Yakov; Beckmann, Martin J.; Golob, Thomas F. (1981): *The 'UMOT'/Urban Interactions*. Washington, DC: US Department of Transportation.

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