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Modelling the Great Transformation in the Ruhr Area

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Abstract

Climate researchers agree that anthropogenic greenhouse gas emissions significantly contribute to climate change, and that radical measures to reduce greenhouse gas emissions and to adapt to the impacts of no longer avoidable climate change are needed. The German Federal Government with its Climate Protection Plan 2050 reinforced its target to reduce Germany's greenhouse gas emissions by 80 to 95 percent compared with 1990. The achievement of these targets requires nothing less than a fundamental transformation of spatial planning.

In the paper a methodology to scientifically assess the likely impacts of possible combinations of policies or strategies to achieve the *energy transition*, i.e. to reduce the greenhouse gas emissions of urban mobility and transport is proposed and demonstrated, using the Ruhr Area, the largest conurbation in Germany, as an example.

The results of the policies examined so far can be summarised as follows: Push measures as high energy prices, speed limits or reduction of the number of lanes of main roads are more effective in reducing greenhouse gas emissions than pull measures as the promotion of cycling, walking, electric cars or public transport. Between policies or policy packages there can be positive or negative synergies, i.e. the impacts of measures can reinforce or weaken each other. The results show that even with ambitious policies the greenhouse gas emission targets of the national and state governments will not be achieved and that more radical policies are needed.

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1. Introduction

Climate researchers agree that anthropogenic greenhouse gas emissions significantly contribute to climate change, and that radical measures to reduce greenhouse gas emissions and to adapt to the impacts of no longer avoidable climate change are needed. The German Advisory Council on Global Change (WBGU) in its expertise of 2011 called for a societal contract for a great transformation to implement these radical measures, i.e. a process of change also of cultural identities and established value perceptions and action patterns in politics, economy and private consumption (WBGU, 2011). In its expertise of 2016 the Council emphasised the central role of urban and regional planning for the achievement of this transformation (WBGU, 2016). The German Federal Government with its Climate Protection Plan 2050 reinforced its target to reduce Germany's greenhouse gas emissions by 80 to 95 percent compared to 1990. The state government of North-Rhine Westphalia with its Climate Protection Law of 2013 plans to reduce the greenhouse gas emissions of the state by 25 percent by 2020 and at least 80 percent by 2050. The achievement of these targets requires nothing less than a fundamental transformation of spatial planning.

This fundamental transformation will affect mobility and transport in cities. Daily mobility and transport today account for about one fifth of the greenhouse gas emissions of urban regions. Because of technical progress, travel times and costs will continue to decrease and so induce more rather than less personal mobility. Therefore urban mobility and transport will constitute an important policy field of the transformation called for by the WBGU. But mobility and transport cannot be analysed separately but have to be assessed together with urban spatial development, i.e. decisions by households and firms where to select their residences or to locate their businesses. Urban mobility planning and urban land use planning therefore need to respond to the challenges of the transformation together in an integrated way.

However, the present practice of urban planning in Germany does not seem to be able to cope with these challenges. Since the 1970s, with the advent of neoliberal economic principles and, at the same time, the idea of communicative bottom-up planning, the demand by public planning authorities for scientific, analytical-rational planning support has decreased. The result is that ambitious greenhouse gas emission targets have been concluded by the European Union, by EU member states and by regions and cities (see above), but that, because of lack of reliable information on what needs to be done to achieve these targets, necessary action is largely missing.

This is why in this paper a methodology to scientifically assess the likely impacts of possible combinations of policies or strategies to reduce the greenhouse gas emissions of urban mobility and transport is proposed and demonstrated, using the Ruhr Area, the largest conurbation in Germany, as an example. According to the theme of *mobil.TUM*, the focus is on policies to reduce the greenhouse gas emissions of mobility and transport, but because of the interactions between urban transport and land use, the perspective will be an integrated one combining urban transport, land use and environment.

To accomplish this, the paper starts from the methodology developed in a research programme funded by the Mercator Foundation in the years 2013-2016 to promote knowledge and awareness of the necessity and challenges of the energy transition in the Ruhr Area, explains the scenarios tested, summarises the results achieved so far and concludes with an outlook on further research.

2. Method

In the programme of the Mercator Foundation two projects dealt with the contribution of land use and transport planning to achieve the energy transition: the projects *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):

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. In the project an existing land use and transport model for the eastern Ruhr Area was enlarged to the whole Ruhr Area and the planning horizon of 2050 and extended by submodels of energy consumption and greenhouse gas emissions of buildings and transport under the assumption of new developments and planning policies in the fields of land use and transport.

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 compared with a proposed target modal split of 25 percent car and 25 percent each for public transport, cycling and walking. A central approach to reduce energy consumption and greenhouse gas emissions is the modal shift from car traffic to more environment-friendly travel modes public transport, cycling or walking. The polycentric structure of the transport network in the Ruhr Area offers good starting conditions for climate-friendly mobility by public transport, cycling or walking. In addition electromobility can further contribute to the reduction of energy consumption and greenhouse gas emissions.

In the two projects an integrated simulation model of urban land use, transport and environment was applied to the Ruhr Area. The model includes submodels of demographic and household development, the regional labour market, the markets of residential and non-residential buildings, the land and construction markets and a multimodal travel model (car, public transport, cycling, walking) and predicts the interactions between these submodels and the travel model in response to policies of European, national, regional and local authorities in the field of land use and transport (Wegener, 2018). The output of the model consists of maps and trajectories of socio-economic indicators, such as population, households, migration, employment, dwellings, land use, accessibility, attractiveness, travel by trip, capita and mode, and environmental indicators, such as CO_2 emissions.

The results are 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.

3. Scenarios

With the model altogether 52 different scenarios of the likely impacts of different planning policies on the development of 687 neighbourhoods in the Ruhr Area until the year 2050 were simulated taking account of exogenous assumptions about regional economic development, net immigration, technical and behavioural trends (see Table 1). 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 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 decisions 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 the promotion of energy retrofitting of buildings.

Transport policies are either push strategies to promote the shift from car to more environment-friendly travel modes by making car-driving slower or more expensive, such as a regional cordon fee, reduction of lanes on major roads, area-wide speed limits or higher parking fees, or pull strategies to make environment-friendly modes more attractive, such as extension of the public transport network, more buses and trains per hour, introduction of a citizen ticket making public transport more affordable or comprehensive promotion of cycling and walking. Some of these policies are well-known, but also innovative policies, such as the introduction of a regional cordon fee or the citizen ticket are part of the policy portfolio. 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. In addition, different assumptions about the development of fuel consumption and fuel prices are treated as scenarios.

Finally several 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. But there are also negative synergies where policies address the same choices of behaviour and so only repeat each other's effects.

Table 1. Integrated Ruhr Area model 2050 scenarios

Policy fields		Policies[1]
0	Base scenario	All current measures will be continued.
1	Land use	A11/B11 Compact city A12/B12 Densification at S-/U-Bahn stations A13/B13 Densification at railway stations A14/B14 Densification of main cities
2	Housing	A23/B23 New housing at railway stations
3	Energy efficiency	A31/B31 Energy retrofitting of buildings A32/B32 Promotion of electromobility A33/B33 Free-floating car sharing A34/B34 Reduction of fuel consumption
4	Car (Push)	A41/B41 Regional cordon fee A42/B42 Reduction of lanes of main roads A43/B43 Area-wide speed limits A44/B44 Higher parking fees
5	Public transport (Pull)	A51/B51 Extension of public transport network A52/B52 More trains/buses per hour A53/B53 Citizen ticket
6	Cycling (Pull)	A61/B61 Faster cycling A62/B62 Express cycling routes
7	Walking (Pull)	A71/B71 Shorter walking distances
8	Integrated strategies	A81/B81 Land use: A13/B13, A23/B23 A82/B82 Energy efficiency: A31/B 31, A32/B32, A33/B33, A34/B34 A83/B83 Car (Push): A41/B41, A42/B42, A43/B43, A44/B44 A84/B84 Public transport/cycle/walk: A51/B51, A52/B52, A61/B61, A71/B71 A85/B85 All policies: A81/B81, A82/B82, A83/B83, A84/B84 A86/B86 Selected policies: all policies except A23/B23 and A52/B52

[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).

4. Results

In this section the results of the analysed scenarios are presented. First the base scenario is described. For lack of space the results of the individual policies cannot be presented here. A complete presentation of all individual policies is contained in the reports of the two projects (Schwarze et al., 2017, Reutter et al., 2017, 2018). Here only the policy combinations or integrated strategies with high fuel prices are 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 modal split, i.e. the share of car trips, is analysed.

4.1 Base scenarios

The basis of the comparison between all scenarios are the base scenarios A00 and B00. in which it is assumed that all currently implemented policies will be continued in the future. Figure 1 shows the development of CO_2 emissions of buildings and transport in the two base scenarios A00 (low fuel prices: price increases one percent per year) and B00 (high fuel prices: price increases four percent per year). It can be seen that through energy retrofitting and more fuel-efficient cars also in the base scenarios energy consumption and CO_2 emissions decline after 2015.

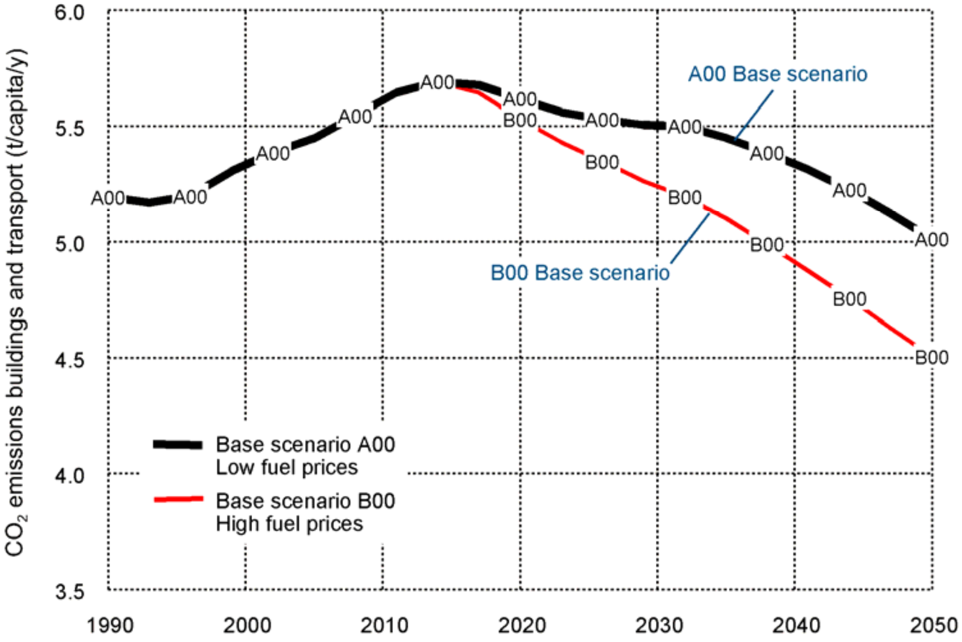

Fig. 1. CO_2 emissions of buildings and transport 1990-2050: Base scenarios A00/B00

4.2 Integrated strategies

As indicated above, here only the policy combinations or integrated strategies with high fuel prices can be presented. As shown in Table 1, in addition to the individual policies, six different combinations of land use and transport policies were simulated, first within four 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).

Figure 2 shows the development of CO_2 emissions of buildings and transport in the combination scenarios with high fuel prices. The combination scenarios B81 (land use) und B84 (public transport, cycling, walking) score worse than in the corresponding base scenarios A00 and B00, because they contain scenarios B23 (new housing at railway stations) and B52 (more trains/buses per hour), both of which generate not less but more CO_2 emissions. The combination scenarios B82 (energy efficiency) and B83 (car traffic), however, result in larger reductions of CO_2 emissions than if the individual policies are considered separately. If all policies are modelled together as in scenario 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 the maximum CO_2 reduction that can be achieved with the analysed policies, scenario B86 *Selected policies* was developed. In it all policies are modelled except scenarios B23 (new housing at railway stations) and B52 (more trains and buses per hour), as these were the ones in which under the assumptions made the CO_2 emissions were increased rather than reduced. This deliberate selection of environmentally effective policies resulted in a reduction of CO_2 emissions by 29 percent compared with the base scenario A00 and of 22 percent compared with the base scenario B00.

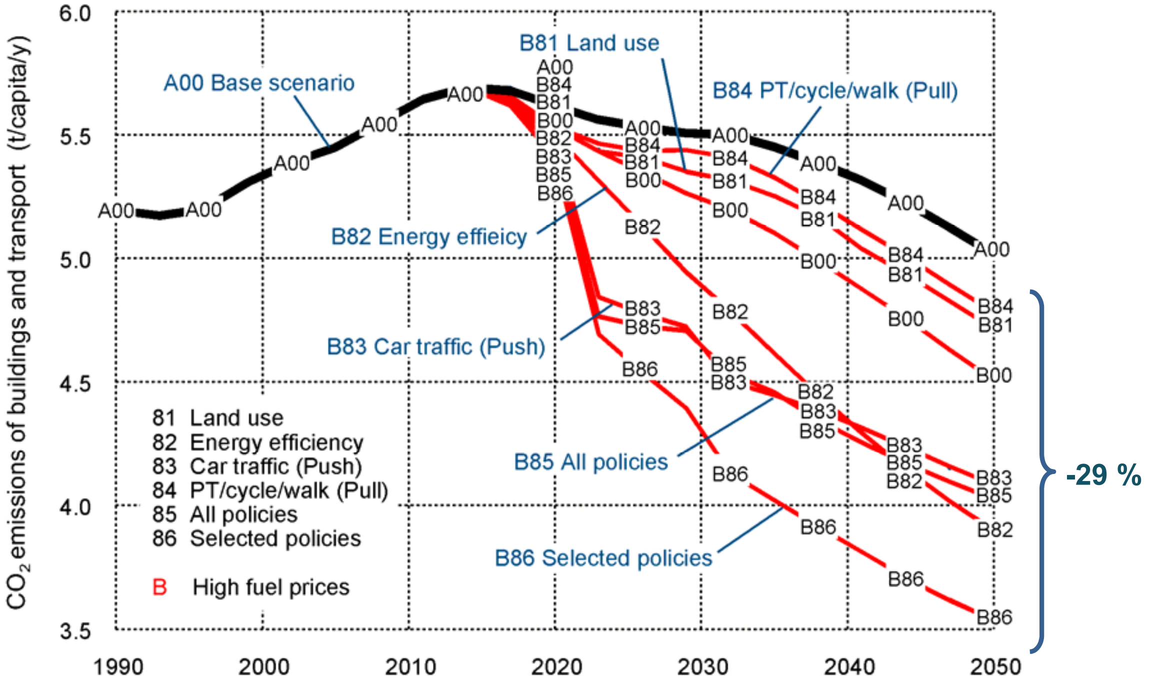

Fig. 2. CO2 emissions of buildings and transport 1990-2050: Scenarios B81-B86

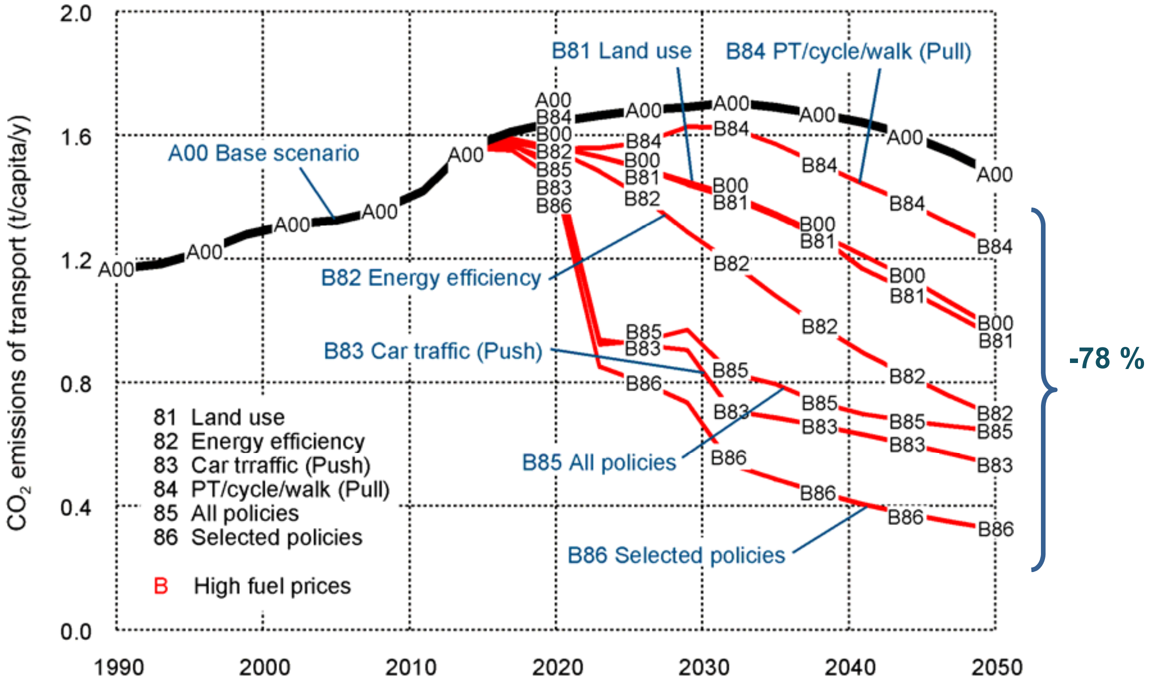

Fig. 3. CO2 emissions of transport 1990-2050: Scenarios B81-B86

Even larger positive effects for the energy transition and quality of life of the population could be achieved if the policies on new housing at railway stations and more trains and buses per hour 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 reduction of CO_2 emissions by about 20 percent if all policies are implemented as in scenario B85 or by about 30 percent if selected policies are implemented as in scenario 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 in Figure 3. The diagram shows that the analysed policies lead to significantly higher reductions of CO_2 emissions of transport only. The reduction compared with the base scenario A00 amounts to about 55 percent if all policies are implemented as in scenario B85 and to about 40 percent compared with the base scenario B00. If only the selected policies of scenario B86 are implemented, the CO_2 reduction amounts to about 78 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.

The impacts of the integrated strategies on the modal split in the Ruhr Area (Figure 4) show that the largest effects towards a reduction of the share of car trips are achieved with scenario B85, in which all analysed policies are assumed to be implemented. In scenario B85 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 car trips are the push policies restricting car traffic in scenario B83, which reduce the share of car trips from 58 percent to 46 percent. The pull measures promoting public transport, cycling and walking in scenario B84 reduce the share of car trips to 48 percent, the policies promoting energy efficiency in scenario B82, however, result in a more car trips because they make car driving less expensive.

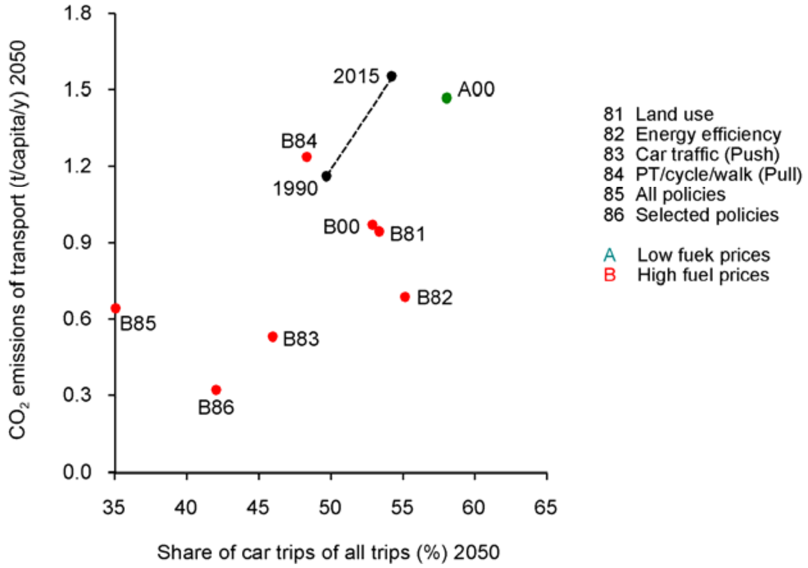

Fig. 4. Share of car trips (%) v. CO_2 emissions of transport 2050: Scenarios B81-B86

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 Figures 5 and 6. It becomes again apparent that the reduction of CO_2 emissions by transport as in Figure 6 is more successful than if both buildings and transport are considered together as in Figure 5, even though in scenarios A31/ B31 (building energy) already the very far-reaching assumption is 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.

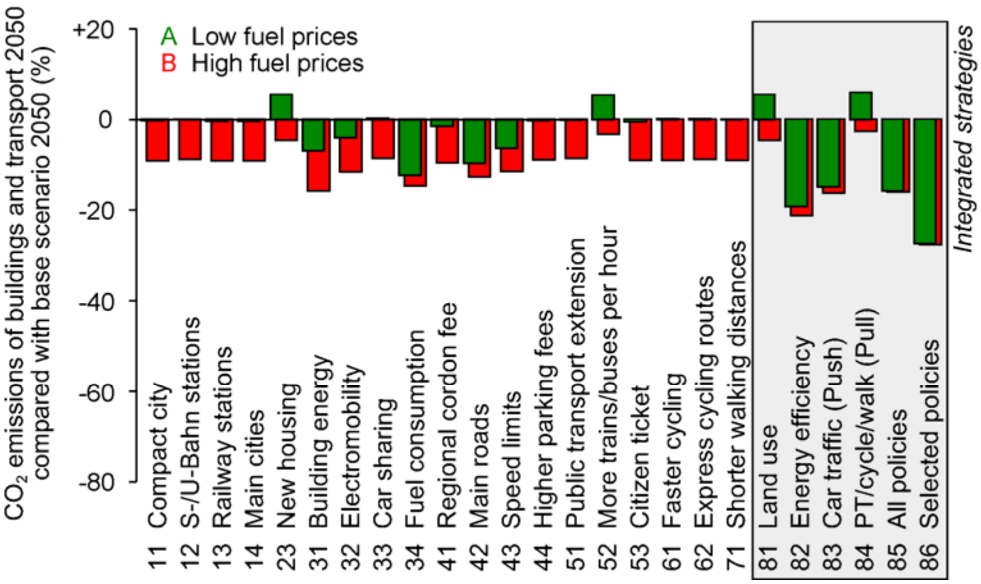

Fig. 5. Reduction of CO_2 emissions of buildings and transport (%) 2050

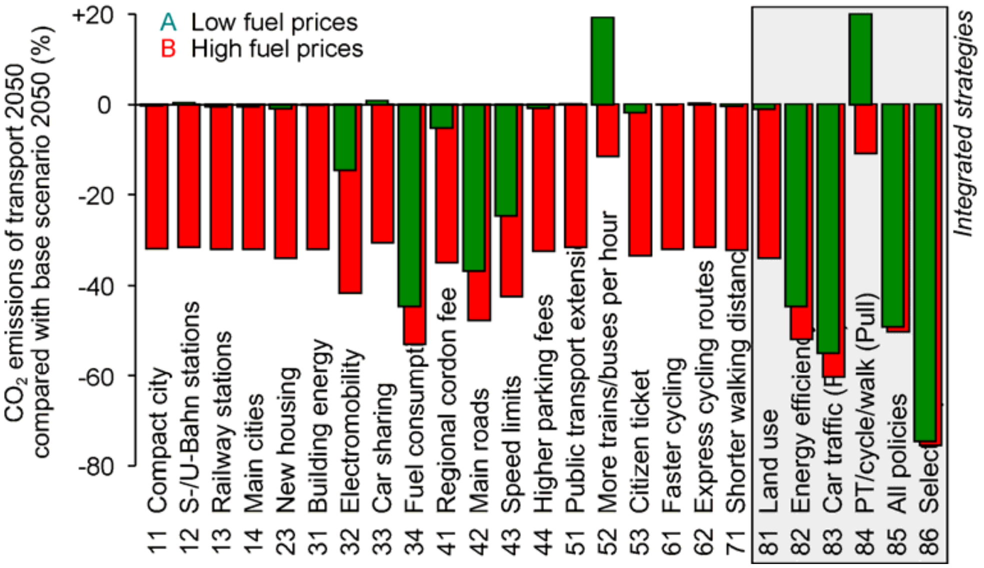

Fig. 6. Reduction of CO_2 emissions of transport (%) 2050

The results of the policies simulated can be summarised as follows: Push measures as high energy prices, speed limits or reduction of the number of lanes of main roads are more effective in reducing greenhouse gas emissions than pull measures as the promotion of cycling, walking, electric cars or public transport. Between policies or policy packages there can be positive or negative synergies, i.e. the impacts of measures can reinforce or weaken each other. The results showed that even with ambitious policies the greenhouse gas emission reduction targets of the national and state governments will not be achieved and that more radical policies are needed.

5. Conclusions and future work

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 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.

However, in summary 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. 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.

The conclusions of the paper corroborate the result of previous work that much more radical policies are needed to achieve the greenhouse gas emission targets of national and state governments. The authors are aware that parts of the results presented in their report will be discussed controversially and stimulate further empirical investigations and expert discussions and possible revisions of the results.

In addition, in future research it will have to be discussed how emerging new technologies and trends need to be integrated into the model, such as telework, online shopping, local goods transport, autonomous vehicles, the Internet of Things and Industry 4.0. One of the major issues in this discussion will be the question to what degree technical innovation will have an impact on behavioural attitudes of travellers, house owners and consumers in the long run: Will their behaviour significantly change, or will anthropological, physical or natural constraints will remain constant over time, even under dramatically changed conditions? Because of the large degree of uncertainty of these explorations into the far-away future, the results will not be a single forecast but a number of scenarios resulting from different possible assumptions. In addition, experiments should be undertaken to use the model iteratively for backcasting scenarios, i.e. for scenarios that achieve the greenhouse gas emission targets.

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