CECILIA 2050
OPTIMAL EU CLIMATE POLICY

Choosing Efficient Combinations of Policy Instruments for Low-carbon development and Innovation to Achieve Europe's 2050 climate targets

Macroeconomic routes to 2050

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CGE	Computable General Equilibrium
ETR	Environmental Tax Reform
ETS	European Trading System
GDP	Gross Domestic Product
WIOD	World Input Output Database
WP	Work Package

1 Executive summary

The international negotiations on climate policy have not been successful in the last years. Scepticism is a common appraisal concerning the 2 degrees warming target for 2100. Nevertheless policy has still options to be successful. Whether an active climate policy that reaches this target can be enforced will to a large extend depend on the structure of the policy mix and the economic effects which are induced. The paper at hand evaluates such policies and shows their direct and indirect economic and environmental effects till the year 2050. This study applies the global economic environmental model GINFORS to analyse the economy wide effects of future policy instrument mixes. GINFORS belongs to a class of models which is appropriately designed for this task. The model has a deep country and sector structure depicting the international as well as the inter-sectoral interdependences with flexible price dependent structures. The relations between energy use, resource use and economic development are reported in deep sector detail, which allows for a realistic analysis of policy impacts. This ability is further underlined by the empirical evaluation of the model: GINFORS is an econometric model with parameters estimated over the period 1995 – 2009. This means that the theory behind the model has been evaluated and that only equations which passed statistical testing are implemented within our modelling framework.

The paper discusses two plausible policy scenarios which may be realized: Alternative scenario I “Global Cooperation” assumes that a global treaty will be established, which gives a commitment for the implementation of a policy mix, which is consistent with a climate gas concentration path described in the RCP3-PD(2.6) by van Vuuren et al., 2007. This scenario meets with 1.7 degrees in 2100 (Schaeffer & van Vuuren, 2012) the 2 degree warming target.
Alternative scenario II “Middle of the Road” assumes that the international community fails to establish a climate treaty, but that there is at least some uncoordinated action: The European countries retain the strong reduction targets for climate gases (80% against the emissions of 1990) consistent with the 2 degrees warming target. The Non- European countries install some climate instruments with a reduced intensity resulting in a climate gas concentration path which is consistent with the RCP 4.5 development described by Clarke et al., 2007. We could interpret this constellation till 2050 as a delayed reaction of the Non-European countries, which may after 2050, follow the EU example. This perspective should provide a motivation for EU countries to go in front although in 2050 the 2 degrees emission path might probably not be met. Depending from the development after 2050 global warming in 2100 might then end up somewhere between 2 and 2.6 degrees.[1]
These two alternative scenarios will be compared with a third scenario “No active climate policy globally” which is used as baseline assuming a business as usual behaviour of policy. For the EU countries the binding targets of a 20 % reduction of CO2 emissions (compared to the level of 1990), a share of 20 % renewables in final electricity consumption and a rise of energy efficiency by 20 % will be met in the year 2020.[2] After 2020 no **additional** climate policy activity is assumed for the EU countries. This means that the ETS is reformed and plays a role that it has had from 2005 to 2009. Further renewables are installed after 2020

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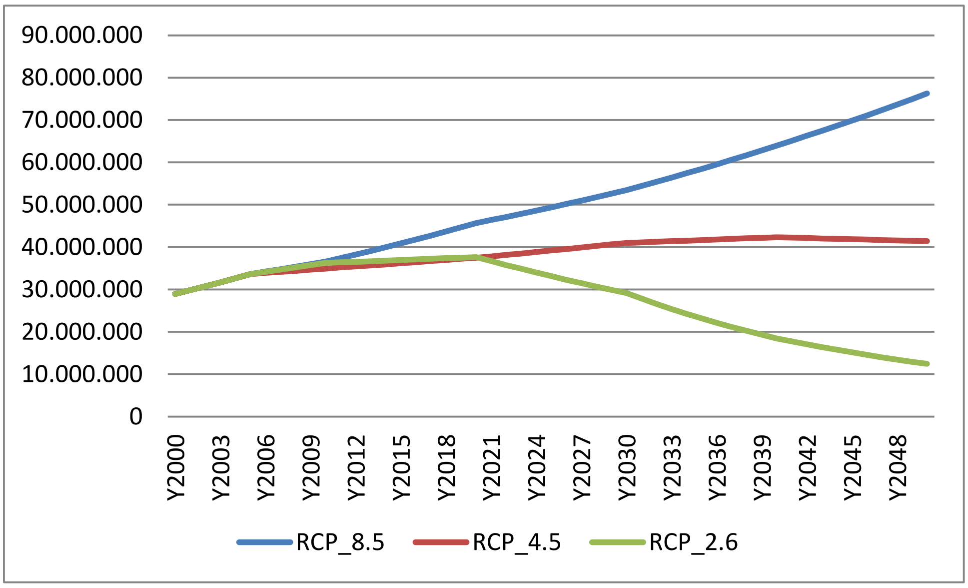
[1] Schaeffer & van Vuuren, 2012, p. 7, calculate 2.6 degrees in 2100 for RCP 4.5.

[2] See EEA, 2013.

following the EU reference scenario.[3] For Non EU countries we assume no climate policy activities already from the beginning of the simulation in 2010. The tax rates are constant and the impacts of regulations are captured in the econometrically estimated parameters of the behavioural equations of the model. Our so defined “No active climate policy globally” scenario still has improvements of energy efficiency also in the non-EU countries, because the relative energy prices rise as the result of strongly rising world market prices for fossil fuels. Insofar the baseline has lower CO2 emissions than RCP 8.5 which is based on the assumption of given energy efficiencies.[4] Further GINFORS calculates endogenously the economic development, which differs from the assumptions made in the RCP 8.5 scenario. This means that in our baseline the emission path has the implication of a global warming in 2100 between 2.6 (RCP 4.5) and 5.1 (RCP 8.5) degrees (Schaeffer & van Vuuren, 2012, p.7).

Figure 1 reproduces the global CO2 emission pathways of the just mentioned RCP simulation studies. In the “Middle of the road” scenario (RCP 4.5) emissions will still rise, reach their maximum in 2040 and will then slightly be reduced. The emissions in 2050 exceed that of 2010 by about 19 %. In the “Global cooperation” scenario (RCP 2.6) the emissions reach their maximum already in 2020 and fall then strongly till 2050 reaching a level which is about 66 % lower than the actual.

Figure 1: Global CO2 emissions in kilo tons of selected RCP simulations



Source: RCP Database (Version 2.0.5), http://www.iiasa.ac.at/web-apps/tnt/RcpDb (Riahi & Nakicenovic, 2007, Clarke et al., 2007, Smith & Wigley, 2006, Wise et al., 2009, van Vuuren et al., 2007, van Vuuren et al., 2006)

What are the implications for the policy instruments? Economic theory suggests internalizing the externalities induced by the carbon emissions, which means to install a global carbon price. A huge literature[5] based on the application of neoclassical economic environmental models has shown that this is principally thinkable. But we should not rely totally on this

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[3] European Commission, 2013

[4] Riahi et al., 2007.

[5] An overview is given by Stern, 2007.

instrument. Market imperfections will impede the functioning of this approach which means that it is dangerous to rely on it as the single instrument.[6]

Concerning the policy choice for the EU member states we are close to Huppes & Huele, 2014, who derived plausible policy mixes for the EU member states from a governance approach: Strict behavioural controls in a weak governance situation will not work. On the other side: In more planning type societies, market developments may be overruled, leading to unnecessary costs. Technology specific measures are politically attractive because they are easy to understand for a broader public. On the other side they may generate substantially higher costs per unit of emission reduction than more generic emission pricing. Further emission reduction by economic instruments requires a good functioning of the market system. Based on such considerations Huppes & Huele, 2014, derived four different thinkable governance storylines for the EU and the related policy mixes: The EU might develop during the next decades into the direction of

a market federation,
a planning federation,
a mixed system,
or a re- nationalized EU.

The EU is already close to a mixed system of market and planning elements with no clear ideological picture. It thus seems plausible that it might develop further into this direction.

For both alternative scenarios, we propose, in line with Huppes & Huele, 2014, the following climate policy instrumentation in the EU member states, which fits the governance of the mixed system. Carbon pricing plays a central role to decarbonize all production processes. The EU ETS in its given domain should be equipped with a flexible supply that allows creating stable carbon price developments. For the other sectors of the economy a second cap and trade system should be installed, which would allow higher carbon prices than in the ETS. To reach deep targets it will be necessary to install additional sectoral instruments for electricity production, traffic and dwelling:

For electricity production the realization of quotas for renewable energies should be obligatory to trigger innovations. An option for decarbonisation of land traffic is e-mobility which should be pushed by regulations in city traffic in favour of emission free cars. Further emission standards for cars should be implemented. Our analysis does not describe the effects of a concrete action plan; it is a conservative estimation of the potential that such a technology change has.

Energy efficiency of buildings should be improved by subsidies for investments in the energy efficiency of the stock of buildings and further development of standards for the new buildings should be given.

An information program for the dematerialization of production is implemented, which reduces the inefficiencies in material use in all industries, especially in small and medium sized firms. So the firms at the end of the supply chain use fewer materials, which means less steel, ceramics, chemicals etc. – products, whose production processes emit much carbon.

Concerning the NON-European countries we follow Zelljadt, 2014, who distinguished four plausible scenarios: “Status quo”, “Middle of the Road”, “Global Deal” and “Non Global Deal

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[6] Bowen, 2011, p.27, gives an overview of the literature. He especially discusses the point that the carbon price alone is not able to trigger innovations.

Path”. The “Staus quo” is identical with our reference scenario. Our “Middle of the Road” is based on that of Zelljadt.

For the “Global Cooperation” scenario we assume that the global treaty is oriented to the implementation of instruments. This means that the non-European countries install the same policy mix as the EU.

For the “Middle of the road” scenario uncoordinated policies are assumed. This means of course that there will be no global carbon price, but quotas for renewables in electricity production should be introduced, but with weaker developments as inEU27. It makes sense to assume that e-mobility is also implemented in the non- EU countries, because the markets for cars are strongly linked internationally. The material saving information policy is very feasible, because it reduces costs of firms. Therefore it should also be part of the policy mix of the non-EU countries in the scenario “Middle of the Road”.

In both scenarios CCS and biofuels are excluded as policy options. CCS is problematic from the resource use perspective, because more input is needed of the resource. Further it is not for sure that the gas remains under the surface for thousands of years. Biofuels restrict the agricultural land use for feed and food, which is not acceptable with respect to the population growth of about 40 % in the next forty years. An exemption is the seaweed technology, which does not need agricultural land. But for the implementation into the model the existing knowledge about it is not sufficient.

For the model GINFORS the CO2 emissions are the result of the policy mix and the assumptions about exogenous variables. This means that a lot of simulations had to be calculated with different values of the policy instruments to get acceptable results. The results of our simulations show that the RCP 2.6 target can nearly be met in the “Global Cooperation” scenario as our respective simulation results indicate global CO2 emissions to range at about 15.4 Gt in 2050.[7]

The “Middle of the Road” scenario reaches 33.4 Gt CO2 emissions, which is much better than 41.4 Gt given for RCP 4.5.

Concerning the EU27 reduction target of 80 % in relation to the emissions of 1990, we reach in both scenarios about 1.5 Gt, which is 0.4 Gt too high meaning that our reduction of CO2 emissions of EU27 against the 1990 values are about 70 %.

The economic implications are mainly triggered by two effects: Investments for renewables, grids and the energy efficiency of buildings on the one side and the demeterialization program.

In EU27 investments rise in both alternative scenarios against the baseline by 7.6 % in the first years of the programs starting in 2015 and end with a plus of 4.5 % in 2050. Summarized over the whole period from 2015 to 2050 investment in the EU27 is in both alternative scenarios about 7.4 trillion US-$ in constant prices higher than in the baseline. This has two effects on the economy. First the circular flow of income is triggered rising GDP. Secondly the capital costs rise and induce higher prices, which reduce GDP. The net effect of investment is clearly positive for GDP.

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[7] For being precise we have to annotate that the RCP2.6 target value equals 12.4 Gt in 2050. However, given a baseline amount of 63.3 Gt global CO2 emissions in 2050, we do not think that a numerical difference of 3 Gt in the 2050 results of the RCP2.6 simulations and our own calculations indicates significant qualitative deviations between both scenarios.

The dematerialization program has the following economic implication: The firms at the end of the supply chain improve their economic efficiency, which means directly higher value added. Further an indirect effect is induced: Lower costs dampen their price dynamics which fosters competitiveness and stimulates demand, production and value added. However, for basic industries at the bottom of the supply chain the dynamics of demand, production and value added are subject to opposing trends. What is the net effect for the whole economy? The strength of the positive effect of the firms at the end of the supply chain is depending from the indirect effect on competitiveness. In former studies we discussed this instrument for a single region (EU27)[8] or country (Germany)[9]. Then of course the effect on competitiveness is positive and the total effect on GDP also. But if – as in our case – this instrument is implemented globally, the competitiveness effect is reduced and can even be negative for the EU27, if in the other countries the material input coefficients are higher than in the EU. Already the reduction of the competitiveness effect can mean that the net effect of dematerialization for GDP can be negative.

Since the positive investment effect is stronger in the first twenty years of the period and further the negative dematerialization effect is rising because from year to year the number of improved firms rises, we watch first positive impacts and after 2035 negative impacts on GDP. But the total effect is very small. Summing up all deviations from the baseline over the period 2015 to 2050 for the global cooperation scenario gives nearly zero. In case of the EU27 aggregate the percentage deviation equals - 4 percent in 2050. This means a reduction of the average annual growth rate of 0.1 % from 1.7 % in the baseline to 1.6 % in the scenario global cooperation.

These weak effects on the macroeconomic aggregates are of course accompanied by strong structural effects. The basic goods industries suffer directly from the dematerialization impact, whereas the industries at the end of the supply chain benefit from dematerialization and the strongly rising investment demand. A further strong structural impact on the economy is directly related to the structural change in the energy system: Mineral oil production is strongly reduced, whereas electricity production is winning against the baseline.

Employment is slightly reduced against the baseline, but this means that the high tension at the labour market in the baseline will be solved. The number of working persons as a percentage of the age group 15-65 will still be about 5 points higher than today.

The results of the scenario “Middle of the Road” are also remarkable, because they show that with a less active climate policy in the non-European countries (no carbon price, no investments in energy efficiency of buildings, less intensive push on renewables) CO2 emissions of 33 Gt can be reached in 2050, which is far below the RCP 4.5 number of 41.4 Gt. This offers perspectives for another policy option: To start from this in negotiations seems to be promising because the assumed instruments of this scenario (less intensive push on renewables, e-mobility, and information for dematerialization) could be accepted for a broader community as for example the G20 countries. If this policy mix would be enlarged by sectoral agreements like recycling in the metals industry or substitution of oil engines by gas turbines in water transport, the reductions of emissions could be much deeper.

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[8] See Meyer, 2012.

[9] See Meyer et al., 2007

The general result is that the targets can be reached with conventional technologies. We do not have to wait till the big techno-jump solves our problems. But what we need is time to do in 35 years all the marginal steps from year to year that are described in the paper. The philosophy behind our policy mix is close to that of Deetman et al., 2014 who came with the global energy simulation model TIMER to similar results.

2 General Characteristics of the Model GINFORS

2.1 Methodological Annotations

From a methodological viewpoint GINFORS might be characterised as a dynamic Input-Output simulation model which is based on a comprehensive MRIO database. GINFORS evolved from the COMPASS model (see Meyer & Uno, 1999, or Uno, 2002, for references with regards to the COMPASS model) in the course of the MOSUS project.[10] As a global input-output simulation model, aims and scope of the GINFORS model are generally closely related to GTAP applications. However, whereas the later follows a standard Computable General Equilibrium (CGE) approach, GINFORS does not rely on long run equilibria of competitive markets or Say's law for a macroeconomic closure. Moreover, GINFORS assumes that agents have to make their decisions under conditions of bounded rationality on imperfect markets.

Yet, this section is not intended to echo relevant distinctive features with regards to CGE models. Interested readers are referred to Giljum et al., 2009, for a short comparison of COMPASS/GINFORS with GTAP or the related annotations of Wiedmann et al., 2007, in this regard. We would rather like to point out that the modelling of bounded rationality is not a straightforward task: Apparently, the models' reaction functions cannot be derived explicitly by applications of plain optimisation calculus. According to our view, an empirical analysis of historical developments therefore represents the natural starting point for model calibration. Economic theory provides competing behavioural hypotheses which, for each reaction function under consideration, are subject to statistical falsification tests. Accordingly, GINFORS is often also classified as an econometric model (see, e.g., Wiedmann et al., 2007).[11] From this follows, that the availability of historical time series datasets constitutes a necessary condition for the implementation of our bounded rationality philosophy. Up to now, essential model building efforts therefore had to be devoted to the (more or less preparatory) compilation and maintenance of sufficient datasets. We do not intend to recapitulate individual challenges and possible shortcomings of this extensive and time consuming traditional practice but rather annotate that the GRAM-accounting method is

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[10] The MOSUS project was funded by the Fifth Framework Programme (FP5) of the European Union. In this project GINFORS was used to simulate sustainability scenarios until 2020. See http://www.mosus.net/ for details.

[11] This paper should not be occupied by lengthy taxonomic discussions. Thus, we will retain to this well established label. But for being precise, we like to annotate that other research disciplines would most likely prefer a distinction between econometric textbook models, and (i.a.) models of the INFORUM type as suggested by Almon, 1991. Actually, GINFORS accrued from the INFORUM philosophy which is characterized by a comprehensive mapping of variable Input Output Coefficients by means of econometric regression techniques.

basically rooted upon identical practice. Interested readers might therefore, e.g., look-up Wiebe et al., 2012, and their corresponding annotations with regards to the construction of their latest database. Apart from that, technical details of selective former GINFORS implementations were, e.g., also documented by Meyer et al., 2007b, or Barker et al., 2011.

But when we started our latest model revision this situation had changed tremendously. Hence, the empirical backbone of $GINFORS_3$ is now given by the fully harmonized annual set of national Supply and Use Tables (SUTs) as outlined by Dietzenbacher et al., 2013. The WIOD (World Input Output Data Base) contains these time series and further a consistent set of environmental time series data including energy demand and supply and emissions documented by Timmer, 2012.

Having completed this set of bottom up information with population and SNA datasets of the UN Statics Division as well as financial data of the International Monetary Fund, our model now enables us to simulate global developments until the year 2050, especially with regards to:

- the evolution of 35 industries in 38 national economies and a Rest of World region,
- international patterns of trade for 59 products,
- the resulting effects on main economic aggregates of national economies (e.g., public debt or disposable income of private households),
- emissions stemming from 28 energy carriers
- and global resource demand (incl. water demand and agricultural land use).

This list already reflects that GINFORS features a high degree of endogeneity. Actually, only national population growth rates as well as world market basic prices for fossil fuels and minerals have to be determined exogenously. The computational implementation is then based on an iterative solve algorithm. However, as we rather prefer to provide our readers with an adequate representation of the contents of $GINFORS_3$, a detailed discussion of the underlying C++ environment is omitted.

2.2 The General Structure of GINFORS

From a logical perspective, four interdependently linked modules can be distinguished: The economy module, the bilateral trade module, the energy-emissions module and the resource use module. The following paragraphs provide introductory insights into the respective modelling approaches.

2.2.1 The economy module

For 38 national economies and a Rest of World region the economic relationships are modelled by individual **economy modules** with market clearing mechanisms. Suppliers set mark-up prices with regards to local currency denominated unit costs and demanders take these prices as one determinant of their decisions. Suppliers produce the demanded volumes. This structure ensures a balanced influence of supply and demand on the solution of the model avoiding the supply dominance of neoclassical modelling. All macro variables like GDP and its components as well as aggregate price indices or employment are calculated by explicit aggregation from the sectoral variables. In this sense the model has a bottom up structure as outlined below.

As regards the **supply side,** the following modelling scheme applies for any of the 35 industries of a given national economy:[12] The 35 industries are an aggregation of 59 product groups. The aggregation scheme is variable and defined by a time series of so called supply matrices. Input Coefficients for intermediate inputs are modelled as price dependent variables. In the case of energy inputs these coefficients are driven by the inputs of related energy carriers (which are predetermined in physical units by the energy module). The capital stock is calculated from gross investment and the depreciation rate by definition. Gross investment is explained by gross production and the interest rate. Labour input in hours depends on gross production and sectorial real wage rates which are influenced by an average macroeconomic wage rate (Phillips curve approach). Compensation of employees is given by definition; the number of persons engaged can be derived from the average working time per person and the employment in hours. Unit costs are given by definition. Basic prices for sectors agriculture as well as mining and quarrying are calculated by definition from the aggregation of 8 exogenous product prices for fossil fuels, minerals and agricultural products. For all other 33 industry prices, unit costs and prices of competing import goods represent the relevant drivers. Domestic prices for 51 product groups are disaggregated from the industry prices via the make matrix. Basic prices for the 59 product groups are defined as weighted averages of import prices and domestic prices. Purchasers' prices for the 59 product groups are derived from basic prices adding tax rates and transport and trade margins. For all 35 industries value added can be calculated subtracting the sum of intermediate inputs from gross production. For 59 product groups total use is defined as the sum of intermediate and final demand. Import shares are depending from the relation of the import price and the basic price. Gross output for the 59 product groups can be calculated subtracting imports from total use. The imports in local currency are converted into dollars and given to the bilateral trade model.

With regards to the **demand side,** the following impacts are explicitly captured by our modelling scheme: Intermediate demand of 59 product groups for 35 industries is implicitly given by the inputs of intermediate demand in the 35 industries. Final demand for each of the 59 product groups is sub-divided to private consumption, public consumption, gross fixed capital formation, inventory investments and exports. For each product group of private consumption real consumption per capita is explained by real disposable income per capita and relative prices. Special attention is given to private mobility in relation to mobility services, which are separated for land, water and air traffic. Energy product groups are explained in the energy module. Water demand is driven by physical water demand estimated in the resource use module. Real public consumption per capita is explained by the real sum of disposable income and net lending of the government and by relative prices of the product group. Gross fixed capital formation for 59 product groups can be calculated using the vector of gross fixed capital formation for 35 industries (see above) and a capital transformation matrix. Inventory investment is estimated by the change of gross output of the 59 product groups. Exports are given by the bilateral trade module (see above).

The internally consistent bottom-up presentation of the flows of goods and services within the economy as well as the use of primary inputs within the production process inside the Input-Output system is completely embedded in the sequence of national accounts and balancing items for the institutional sectors for 36 countries in units of local currency. Missing countries are Malta, Turkey and Rest of the World. This second major internally consistent national accounts data set provides a synthesis of the entire institutional sector accounts and

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[12] The Rest of World region exhibits a slightly less complex modelling scheme.

it shows the amounts of uses and resources of each institutional sector for all transactions and thus providing figures with regard to the extremely policy relevant variables like disposable income of households or net lending / net borrowing of general government which directly affects national debt.

2.2.2 The bilateral trade module

The **bilateral trade module** takes for 59 product groups the export prices and the import values from the country models and converts them from local currency into dollars. Our modelling strategy distinguishes import shares for intermediate inputs from import shares for final demand goods. Both types of import shares are determined according to the following procedure: For each product group the respective shares of exports from a delivering country within the imports of a receiving country are depending from the relation between the export price and the aggregated import price for that product in the receiving country. Multiplying the trade shares with imports and summing up over importing countries gives the exports by definition. The import prices are calculated as a weighted average of export prices with the trade shares as weights. The exchange rates between the different currencies are explained by the relation of the GDP deflators of the countries in question.

2.2.3 The energy and emissions module

For each country the demand of 35 industries and private households for 28 energy carriers in physical terms (TJ) is explained by the **energy and emissions module**. The conversion of primary energy into secondary energy is done by the sectors sector coke, refined petroleum and by electricity, gas, water supply. Final energy demand is modelled in a two stage approach: In a first stage the <u>energy intensities (energy consumption in physical terms divided by real gross production) of an industry</u> for mobility, heating and electricity are explained by the specific aggregated energy price in relation to the basic price of the industry. Energy for heating of a sector is the aggregate of the use of coal, gas, light fuel oils, heavy fuel oils and some waste, energy for mobility of a sector contains its use of diesel, gasoline, bio-diesel, biogasoline and electricity for e-mobility is mentioned. Energy for heating is in most sectors used for the heating of buildings. In the basic industries (steel, non-metallic minerals, chemicals etc.) heating also means process heat. In mobility the sector water transport is an exemption, because it uses light fuel oil and heavy fuel oil for mobility. Electricity is separated, because it is used primarily for the use of machines. One exemption is here is the electric arc furnace (EAF) technology in steel production, were electricity is used for process heat.

In the second stage the shares of the different carriers in energy demand for heating and for mobility purposes are determined by the relation of the price of the carrier in relation to the aggregated energy price of the activity in the industry.

<u>Energy demand for private households</u> is in the first stage separated for the three purposes heating, mobility and household appliances. The energy intensity for heating is defined as the energy use per real capital stock of the real estate services industry. It´s evolvement is tested for dependency on relative price developments and time trends. Multiplication of the energy intensity with the real capital stock gives energy demand. Energy for mobility is explained by real disposable income of private households and the relation between the aggregated energy mobility price and the aggregated price for mobility services. A further differentiation between private mobility and public traffic services is modelled price dependent. Energy demand for household appliances depends from real disposable income and the relation

between the household's electricity price and the price for aggregated private consumption. In the second stage in each purpose the relative prices of the energy carriers determine the structure of demand. At his point, energy demand and it´s structure have been determined for private households and all 35 industries.

Price dependent import ratios divide the demand for oil, gas, coal and electricity into imports and domestic supply.

In the case of electricity production competition between the different technologies is depicted: The level of nuclear in total electricity production is taken as exogenous since policy decisions determine the long run use of this technology to a large extent. The total share of the renewable energies is also modelled as a policy variable because the scenarios contain explicit targets for renewable electricity production. In the next stage the shares of the different renewable technologies (biogas, hydro, geothermal, photovoltaic, solarthermal heat, solarthermal electricity and wind) in the renewable total are modelled depending from unit costs with the exemption of hydro, which remains exogenous. Electricity production from fossil fuels is defined as the rest. The shares of electricity production from oil, gas and coal are depending from relative prices.

Energy demand in physical terms feeds back into the economic module as has been shown for intermediate and final demand. The gross energy used is transformed into CO_2-emissions for 35 industries (and private households) and 14 energy carriers assuming constant emission factors as well as constant relations between gross energy uses and emission relevant energy uses. Last but not least the module explains the emissions for 7 further air pollutants (N2O, NOx, SOx, NMVOC, NH3, CH4) in 35 industries and private households using the information from the energy use side as well as from the economy and the resource use module.

3 The baseline simulation: No active climate policy globally

3.1 The assumptions

3.1.1 The policy assumptions

Climate policy

For the EU countries we assume – as already mentioned – a policy that meets the binding 20-20-20 targets for the year 2020. The policy instruments are the EU ETS equipped with a flexible supply of emission rights and quotas for renewable energies in electricity production. We assume that the carbon price will rise continuously up to 47 € in constant prices in 2050. For the share of the renewables total in electricity production and the level of nuclear we overtake the development of the reference scenario of the Commission[13]. All other policy parameters are fixed to the levels of the year 2012.

For the Non - European countries we take the share of renewables in electricity production from the IEA baseline[14]. The actual levels of nuclear energy production have been forecasted with the world average growth rate of the 6 DG scenario of the Energy Technology Perspectives (ETP) from the IEA, 2012. “No active climate policy globally” means that we leave all policy parameters at their level of the last historic data point of our data set which is

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[13] European Commission, 2013

[14] IEA, 2012

the year 2009. All tax rates, carbon prices, subsidies and other economic instruments do not change over the whole simulation period till 2050.

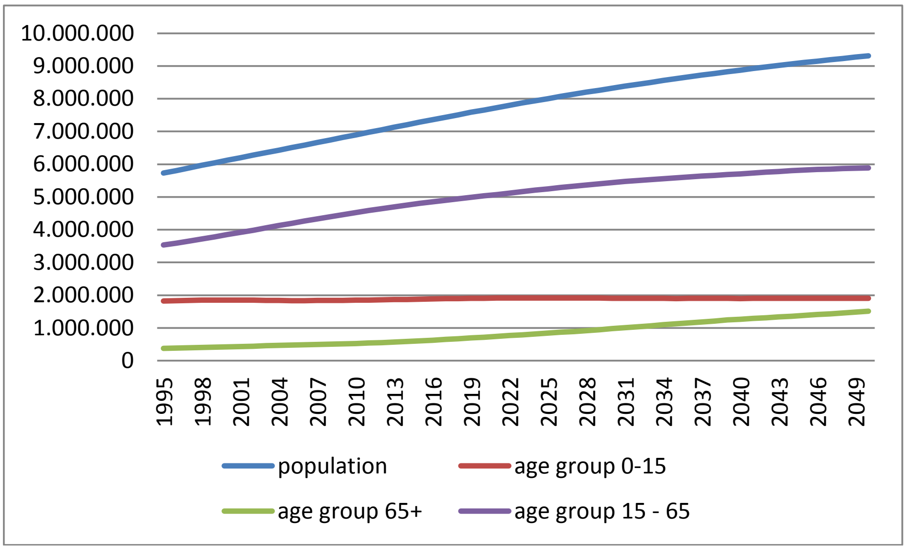
Fiscal policy

Generally all tax rates on income and wealth, goods purchases and production and also the rates for the contributions to social security are constant. But since financial markets react on rising debt/GDP ratios with turbulences which have severe impacts on the development of the real economy, we cannot ignore in our long run simulations an active fiscal policy which may be necessary to control public debt. The following rules for public spending in the EU countries have been implemented: If the net borrowing/ GDP ratio is higher than 3 %, public spending will be reduced. For Non EU countries this border line is 5 %.

3.1.2 The development of the exogenous variables

Population is one of the most important exogenous variables of the model GINFORS. We take the United Nations forecast with its medium variant.[15] For all 39 countries a differentiation of three age groups is given in GINFORS: 0-14 years, 14 to 65 years, over 65 years. According to this scenario global population amounts to 9.5 billion people in 2050 which implies an increase of about 40 % over four decades. The total growth rate is falling from 1.1 % in 2014 to 0.4 % in 2050. This development is accompanied by an aging process: The share of the over 65 rises and the share of the youngest group is falling.

Figure 2: Global population assumptions (totals and age groups) in 1000 persons.



Source: United Nations, 2013

Further the real world market prices in 2010 US-$ for the extraction of fossil fuels coal, gas and oil and for the extraction of ores and non- metallic minerals are exogenous variables. These prices are measured in constant dollars of the year 2010. So their **nominal** development is further driven by the GDP deflator of the USA. We take the relative fossil fuel prices from the IEA Energy Technology Perspectives (ETP) 2012 IEA, 2012. The names of the ETP scenarios indicate the warming in 2150, whereas the warming degrees which we allocated to the RCP scenarios are related to the year 2100. Schaeffer & van Vuuren, 2012,

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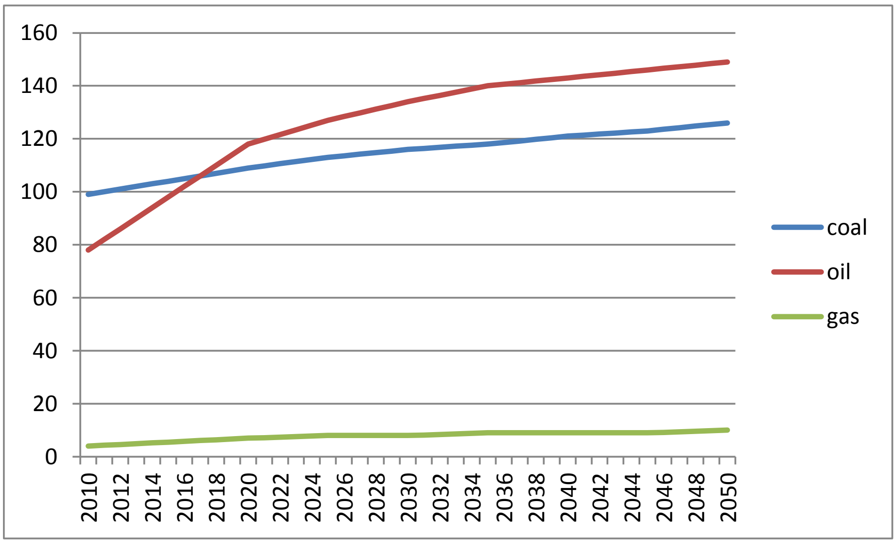
[15] United Nations, 2013

compared the ETP and the RCP scenarios. They found out that the ETP 2DS scenario corresponds closely with the RCP3-PD(2.6) concentration path and that the ETP 4DS scenario is close to the RCP 4.5, whereas the ETP 6DS has a much lower concentration path than the RCP 8.5. Insofar it makes sense to take for our baseline the IEA world market energy prices from ETP 6DS, because we expect that the concentration path that is generated by our baseline is also far lower than that of RCP 8.5. For the alternative scenarios the ETP 2DS and ETP 4DS energy prices will be appropriate.

Figure 3 shows the development of the ETP 6DS world market prices in constant US-$ for coal, oil and gas, which are taken for our baseline. Till 2050 the real coal price rises by 25 %, the real oil price doubles and the real gas price rises by 150 %. The strong dynamics for the oil and the gas price are plausible since the baseline is defined for the absence of climate policy, which implicitly means that there is a high demand for fossil fuels which for oil and gas produces a high degree of scarcity. This implies – as we will see discussing the other scenarios – that the world market extraction prices for fossil fuels in the alternative scenarios will be lower. The dimensions are for oil 2010 USD/bbl, for Coal 2010 USD/tonne and for gas 2010 USD/Mbtu.

Figure 3: World market extraction prices for coal, oil and gas in constant 2010 US-$ for the baseline scenario.



Source: IEA Energy Technology Perspectives (ETP) 2012 IEA, 2012

3.2 The results

3.2.1 GDP

GDP is an endogenous variable of GINFORS for all 38 countries and the “rest of the world” region which is consistently aggregated from value added of the 35 sectors in the respective countries (or region).

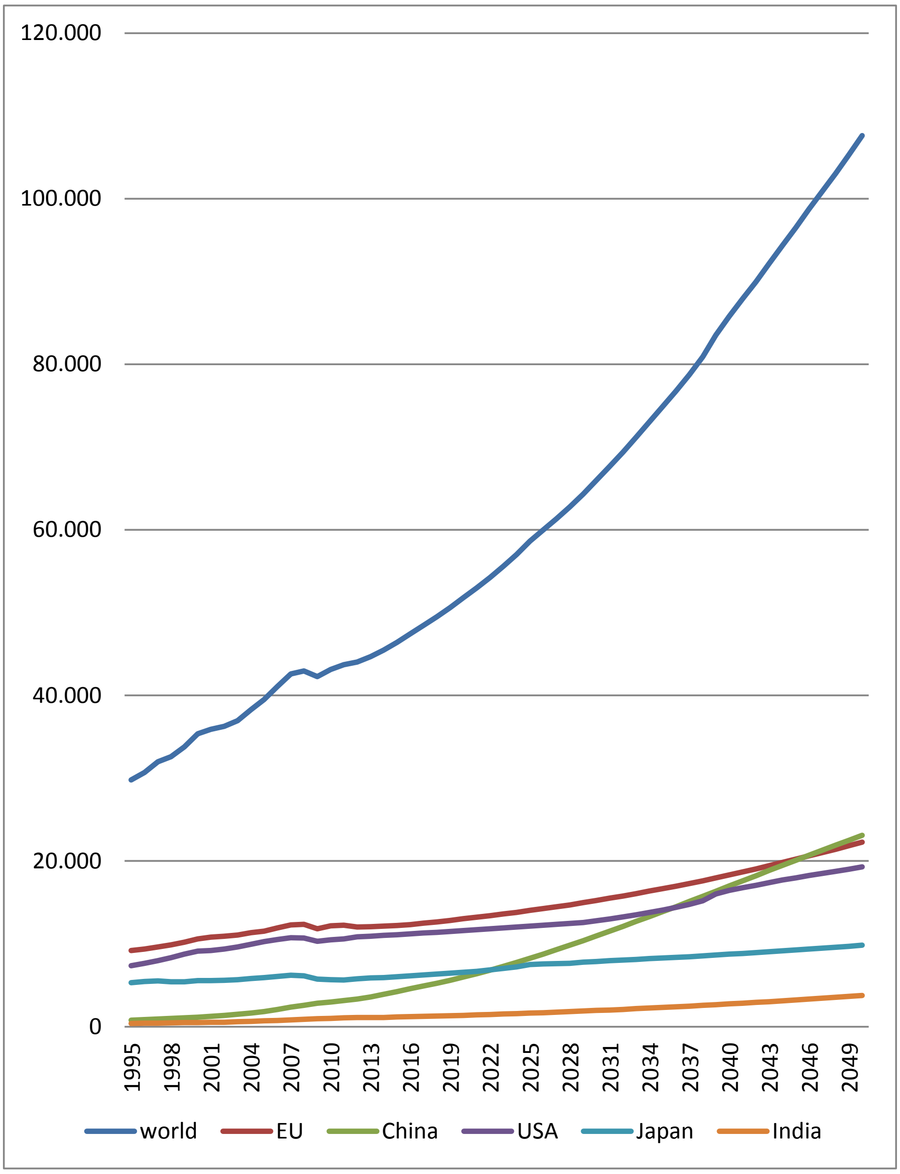
Figure 4 shows the development of GDP in constant dollars for the world economy, the EU, the three biggest economies in the world and India. The development in China dominates figure 4: In 2036 the Chinese GDP will catch the GDP of the USA and China will be the biggest economy in the world. In 2044 the Chinese economy will even pass the EU27. But of course the growth rates of the Chinese GDP will continuously fall from about 8 % in 2012 to 2.7 % in 2050. The model forecasts that the global economy will recover from the crisis and reach its long run growth path of about 2.5 % per year. The EU economy will catch 1.5 % in 2020 and will then observe slightly rising growth rates, which get to 2 % in 2050. The long run annual averages of the GDP growth rates for the period 2014 to 2050 are:

Table 1: Long run averages of annual GDP growth rates 2014 to 2050

World	2.4 %
EU27	1.7 %
China	5.1 %
USA	1.6 %
Japan	1.5 %
India	3.4 %

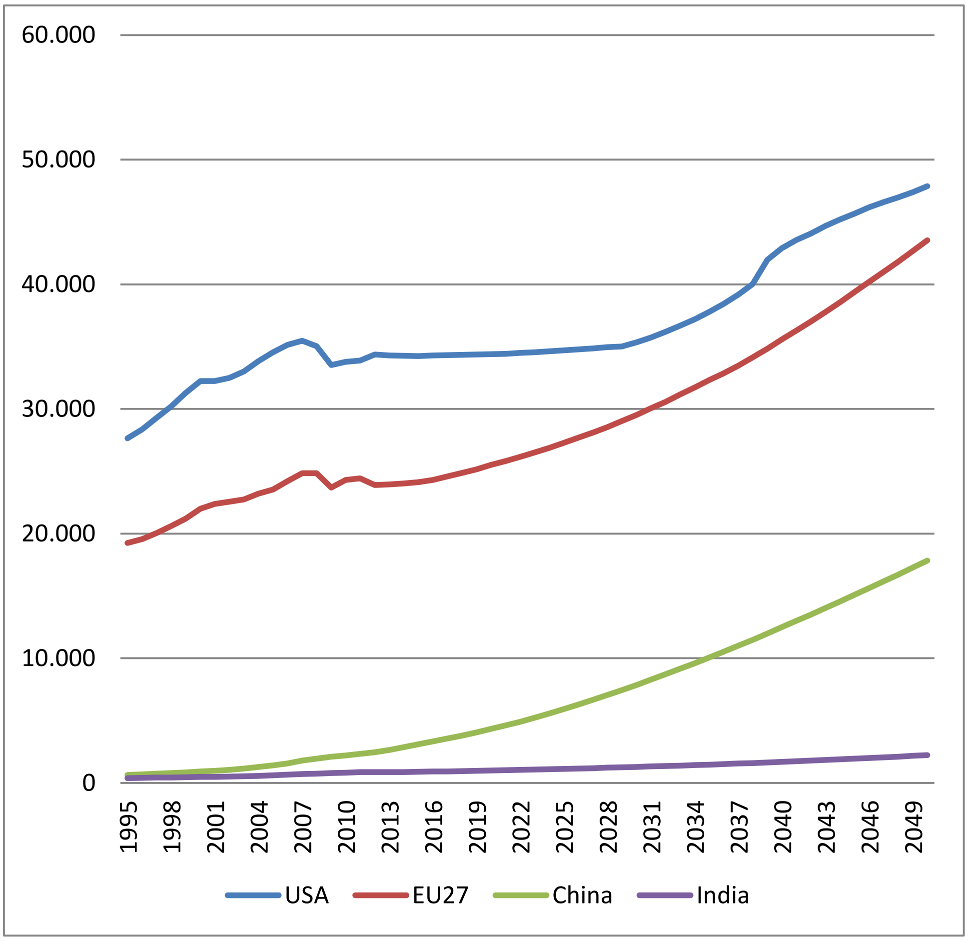
Source: GINFORS CECILIA2050

Figure 4: GDP in constant 1995 US-$ in the baseline for the world economy, the EU and selected countries. Baseline.



Source: GINFORS CECILIA2050

Figure 5: GDP per capita in constant 1995 US-$ for selected countries. Baseline.



Source: GINFORS CECILIA2050

Real GDP per capita (figure 5) will rise in all countries. EU27 will reduce its distance to USA mainly because of population growth in USA. China will have the strongest growth of per capita GDP, but there still will be a big difference to the USA and EU27. India will remain in an area of poverty.

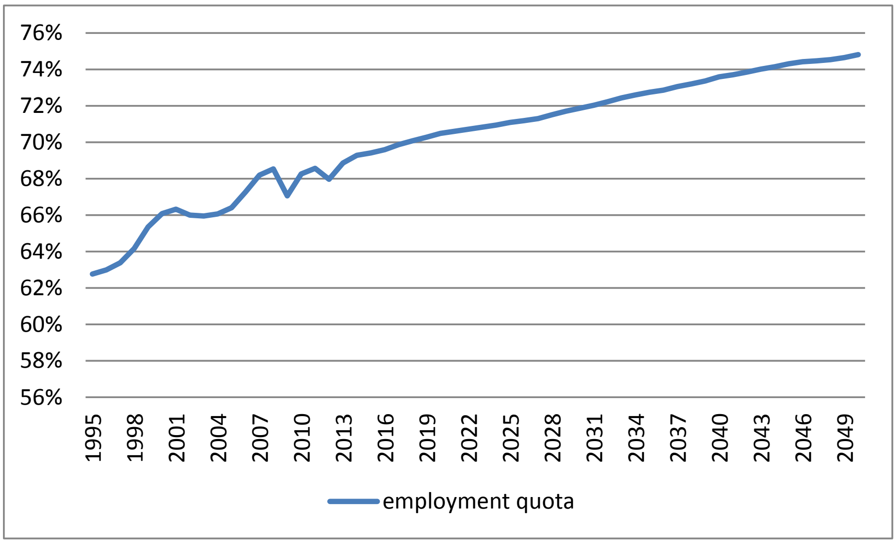
3.2.2 Employment

GINFORS calculates for 38 countries in 35 industries labour demand in the dimension of hours worked based on sectoral production and the real wage rate - both being endogenous. The step from hours worked to the number of persons employed is done by division with the hours worked per person in that industry and country. To be cautious with our estimation of employed persons we take the actual numbers of the hours worked per person as constant. To describe the situation on the labour market of a country we aggregate the sectoral employment numbers to country totals and compare them with the number of persons in the age group 15 – 65, which is not labour supply, but the maximum potential of it. We then calculate the quota between the number of persons employed and the number of persons in the age group 15-65. Figure 6 shows the aggregate of the national numbers for EU27. Actually 69 percent of the potential of the age group are employed, till 2050 this number will continuously rise up to 75 percent. Labour will be a much scarcer factor of production than today. The reason will be the demographic change, which reduces the number of persons in the age group 15-65. This feeds back into the wage determination pushing the wage rate.

This induces a rise of labour productivity, which means a reduction of employment. The model finds a solution of these interdependencies with a reduction of employment, which is weaker than the reduction on the supply side of the labour market. As figure 6 shows, the employment quota in EU27 rises continuously and compared with the actual situation this has to be interpreted as a tension at the labour market. This interpretation is underlined by the fact, that the hours worked per person have been held constant. If actual trends of the reduction of hours worked per person would have been assumed, the graph would have been even much steeper.

The solution of the model further shows that these effects are very different in the member states. Already the demographic movements are very different: In France there will be a stable number of persons in the age group 15-65 till 2040, which after 2040 will even rise. In Germany we will observe a continuous fall of the number of persons of this age by 25 % till 2050. Further labour demand will develop different in the Member States. This means that we might observe very different unemployment rates (including full employment) or rising labour migration inside the EU (which could eliminate these differences). Our simulations, which rest on exogenously predetermined population figures, do intend to mimic any labour market induced migration effects.

Figure 6: EU27 employment quota in EU27. Baseline.



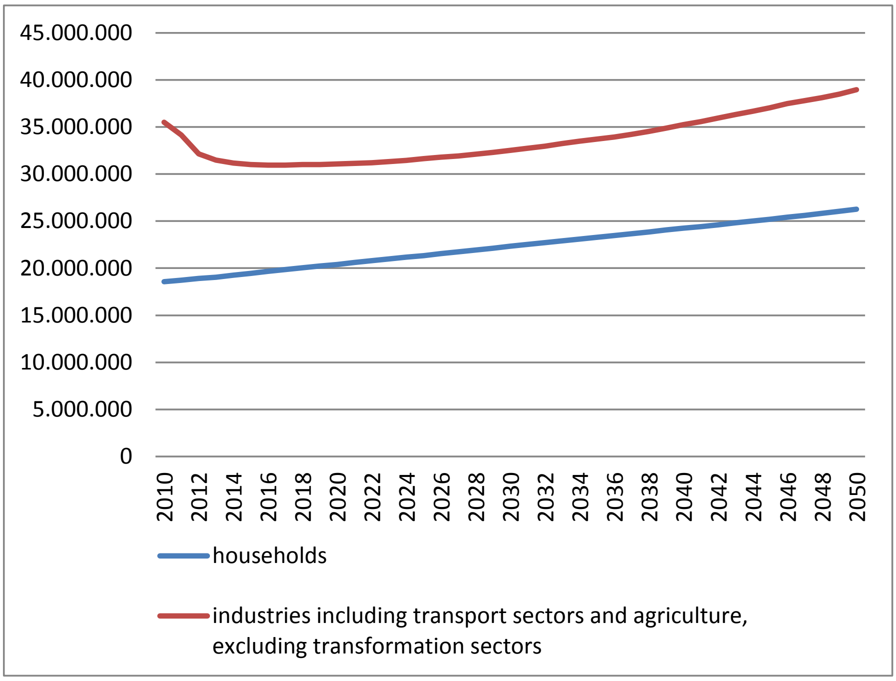
Source: GINFORS CECILIA2050

3.2.3 Public debt

Public consumption is explained by the disposable income of the government. To avoid unrealistic results for the long run development of the world economy, an adjustment mechanism has been modelled, which reduces public consumption, if a critical value of net borrowing as a percentage of GDP is reached. For EU countries this critical value is 3 %, for the non EU countries it is 5 %. All countries have falling debt ratios. Japan and the USA have outstanding figures due to their history in debt creation and the assumed weaker net borrowing restriction for the future.

3.2.4 Energy Demand

Figure 7: Final energy demand in the EU27 in TJ. Baseline.



Source: GINFORS CECILIA2050

Figure 7 shows that final energy use of total industries in EU27 breaks down in reaction to the crises, is constant from 2015 to 2025 and rises then slowly with rates that reach at the end of the period 1%. From 2015 to 2050 the average annual growth rate is 0.5 %. This gives an annual average energy productivity growth rate for industries of 1.2 %, which is lower than the historic rate of 1.9 % measured from 1995 to 2008. For households we observe a slight rise of the average annual growth rate of total final energy use from 0.6 % to 0.8 %.

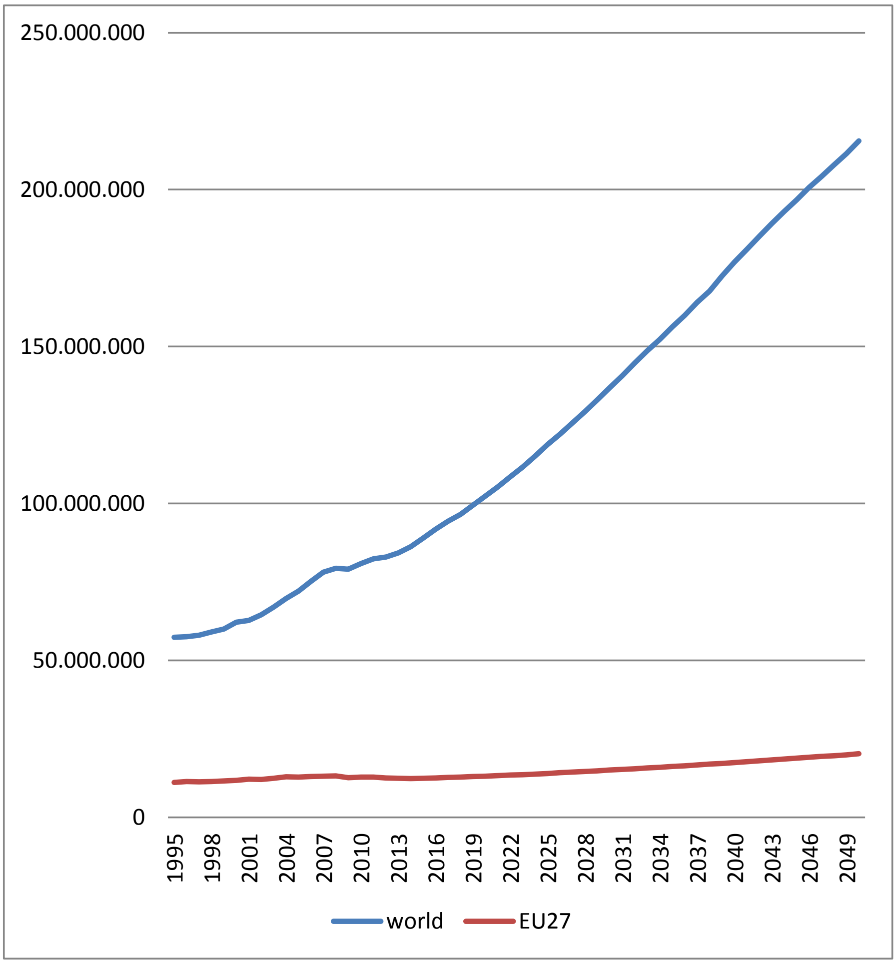
3.2.5 Electricity supply

Electricity production will globally expand with an average annual growth rate of 2.5 %, which equals the global annual growth rate of GDP. For the EU27 figure 8 further shows a development with an average annual growth rate of 1.4 % which is less than the growth rate of GDP (1.7 %).

As figure 9 shows, coal is the dominating carrier in electricity production and will expand till 2050 its share to 41.6 %. Renewables will displace gas as number two and reach 32.7 % in 2050. Gas, oil and nuclear will reduce their shares.

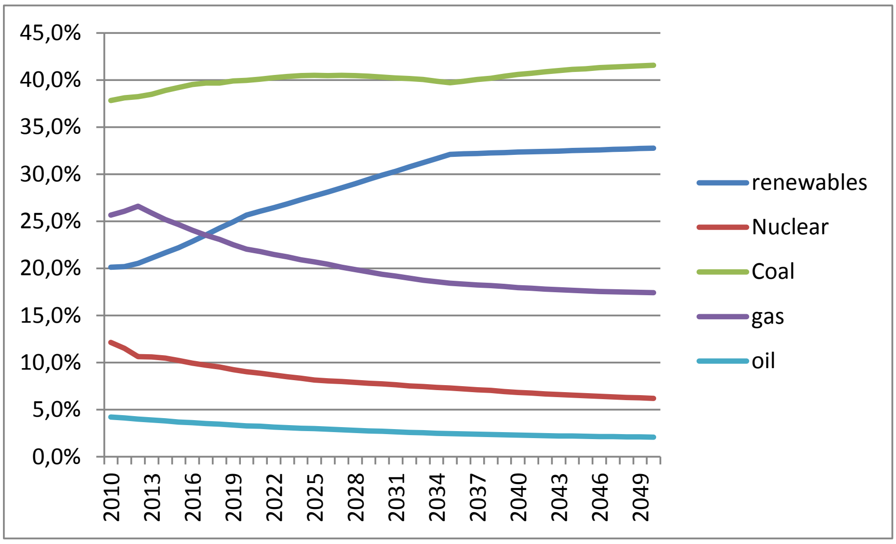
Figure 10 shows that the EU will have a different development of its structure of electricity production. At the actual margin renewables are already close to the lead. Driven by the assumptions of the EU Reference Scenario renewables will reach a share of about 50 %. Coal, Gas and nuclear are very close between 25 % and 15 % and lose shares till 2050. Oil has never played an important role in electricity production in EU27.

Figure 8: Electricity production in TJ in the world and the EU27. Baseline.



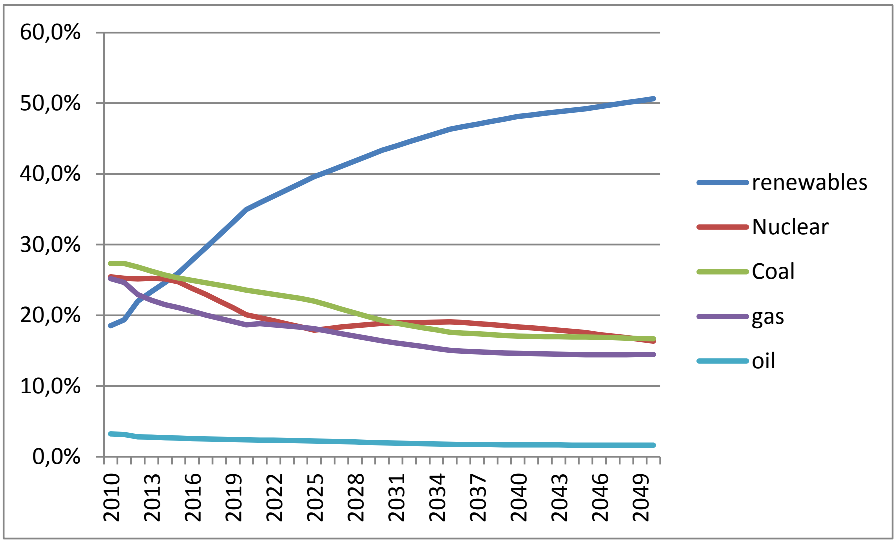
Source: GINFORS CECILIA2050

Figure 9: Global shares of energy carriers in electricity production in TJ. Baseline.



Source: GINFORS CECILIA2050

Figure 10: EU27 shares of energy carriers in electricity production in TJ. Baseline.

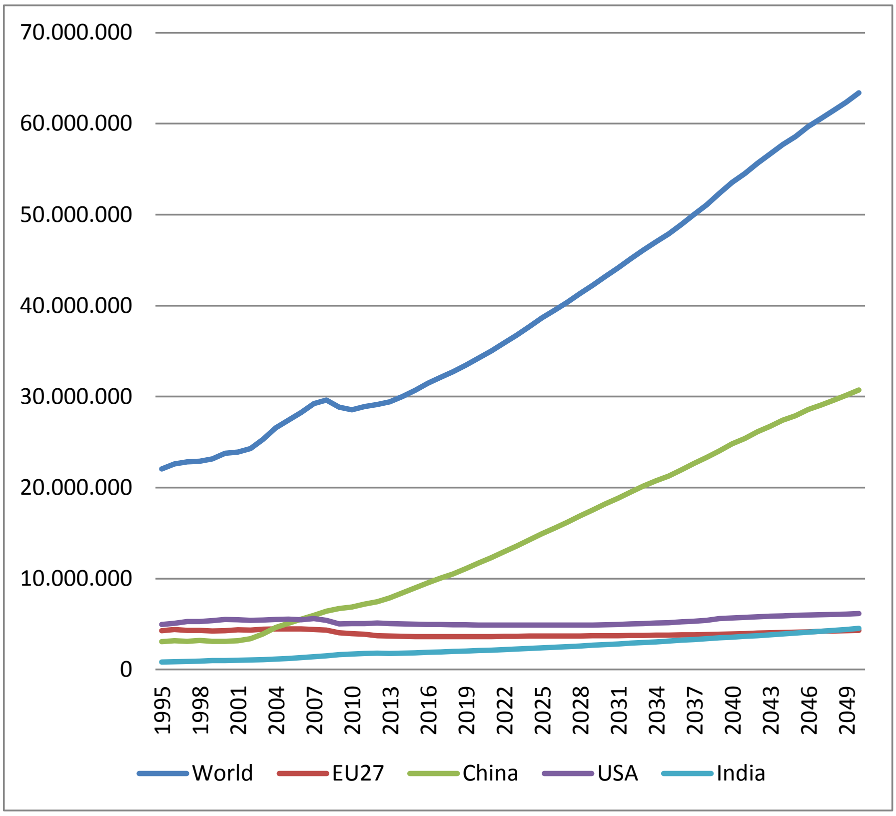


Source: GINFORS CECILIA2050

3.2.6 CO2 emissions

Figure 11 depicts the development auf CO2 emissions in the world, the EU27 and the three biggest emitting countries and gives two important insights. Globally emissions rise in the period 2015 to 2050 with an average annual growth rate of 2.0 %; compared to this development the emissions of the USA and the EU27 are rather stable. The second insight is that the two emerging economies China and India have annual average growth rates during this period of 3.5 % (China) and 2.6 % (India). China will in 2050 be responsible for nearly 50 % of global emissions and India will emit more than EU27.

Figure 11: CO2 emissions in kilo tons (global, EU27 and three biggest emitters). Baseline.



Source: GINFORS CECILIA2050

In table 2 the structure of global CO2 emissions is given for total industries including transport but excluding energy consumption of private households. Please mention that industries are defined in the classification of the national accounts. So in this context of sectoral production there is a sector "Private Households". This sector catches the production of services with employed people for households. It has nothing to do with the private households as the place where private consumption happens.

Table 2 documents the high concentration of total industries on the sectors electricity, transport, coke and refined petroleum, basic metals, other non-metallic minerals and chemicals. Together they have about 71 % of the industry total in 2000. In 2050 this concentration will grow up to be 85 %. Climate policy has to take electricity production, the four primary sectors and the transport sector in the focus of its activities.

Table 3 gives the analogous information for the EU. Here the sum of the sectors in question is in 2000 is 76 %, but with a higher weight for transport and a lower for electricity production. This concentration also rises till 2050, but only to 82 %.

Table 2: Structure of global CO2 emissions of industries in kilo tons. Baseline.

	World	
	2000	2050
Agriculture, Hunting, Forestry and Fishing	2,7%	1,7%
Mining and Quarrying	3,6%	2,6%
Food, Beverages and Tobacco	1,5%	1,0%
Textiles and Textile Products	0,7%	0,4%
Leather, Leather and Footwear	0,1%	0,0%
Wood and Products of Wood and Cork	0,3%	0,2%
Pulp, Paper, Paper , Printing and Publishing	1,1%	0,7%
Coke, Refined Petroleum and Nuclear Fuel	4,0%	2,2%
Chemicals and Chemical Products	4,6%	4,8%
Rubber and Plastics	1,4%	0,8%
Other Non-Metallic Mineral	6,3%	10,0%
Basic Metals and Fabricated Metal	7,4%	8,7%
Machinery, Nec	0,4%	0,6%
Electrical and Optical Equipment	0,6%	0,4%
Transport Equipment	0,5%	0,4%
Manufacturing, Nec; Recycling	0,9%	0,6%
Electricity, Gas and Water Supply	41,1%	52,3%
Construction	1,3%	1,1%
Sale, Maintenance and Repair of Motor Vehicles and Motorcycles; Retail Sale of Fuel	0,2%	0,1%
Wholesale Trade and Commission Trade, Except of Motor Vehicles and Motorcycles	0,8%	0,3%
Retail Trade, Except of Motor Vehicles and Motorcycles; Repair of Household Goods	1,3%	0,4%
Hotels and Restaurants	0,8%	0,5%
Inland Transport	4,2%	2,3%
Water Transport	2,8%	1,5%
Air Transport	3,2%	2,0%
Other Supporting and Auxiliary Transport Activities; Activities of Travel Agencies	0,6%	0,5%
Post and Telecommunications	0,4%	0,2%
Financial Intermediation	0,4%	0,2%
Real Estate Activities	0,3%	0,1%
Renting of M&Eq and Other Business Activities	1,3%	0,6%
Public Admin and Defence; Compulsory Social Security	2,4%	1,1%
Education	0,5%	0,3%
Health and Social Work	0,9%	0,5%
Other Community, Social and Personal Services	1,2%	0,8%
Private Households with Employed Persons	0,0%	0,0%

Source: GINFORS CECILIA2050

Table 3: Structure of EU27-CO2 emissions of industries in kilo tons. Baseline.

	EU	
	2000	2050
Agriculture, Hunting, Forestry and Fishing	2,9%	2,2%
Mining and Quarrying	1,8%	2,3%
Food, Beverages and Tobacco	2,5%	1,6%
Textiles and Textile Products	0,8%	0,4%
Leather, Leather and Footwear	0,1%	0,0%
Wood and Products of Wood and Cork	0,3%	0,3%
Pulp, Paper, Paper , Printing and Publishing	1,4%	1,0%
Coke, Refined Petroleum and Nuclear Fuel	4,7%	3,9%
Chemicals and Chemical Products	4,9%	5,3%
Rubber and Plastics	0,4%	0,3%
Other Non-Metallic Mineral	7,5%	10,3%
Basic Metals and Fabricated Metal	7,9%	7,4%
Machinery, Nec	0,5%	0,3%
Electrical and Optical Equipment	0,4%	0,3%
Transport Equipment	0,7%	0,5%
Manufacturing, Nec; Recycling	0,4%	0,3%
Electricity, Gas and Water Supply	39,6%	39,3%
Construction	1,8%	1,8%
Sale, Maintenance and Repair of Motor Vehicles and Motorcycles; Retail Sale of Fuel	0,6%	0,5%
Wholesale Trade and Commission Trade, Except of Motor Vehicles and Motorcycles	1,0%	0,8%
Retail Trade, Except of Motor Vehicles and Motorcycles; Repair of Household Goods	1,0%	0,7%
Hotels and Restaurants	0,5%	0,4%
Inland Transport	5,3%	4,7%
Water Transport	2,4%	3,2%
Air Transport	3,8%	7,1%
Other Supporting and Auxiliary Transport Activities; Activities of Travel Agencies	0,5%	0,5%
Post and Telecommunications	0,4%	0,4%
Financial Intermediation	0,3%	0,2%
Real Estate Activities	0,5%	0,4%
Renting of M&Eq and Other Business Activities	1,2%	1,1%
Public Admin and Defence; Compulsory Social Security	1,0%	0,5%
Education	0,6%	0,3%
Health and Social Work	0,8%	0,5%
Other Community, Social and Personal Services	1,4%	1,3%
Private Households with Employed Persons	0,0%	0,0%

Source: GINFORS CECILIA2050

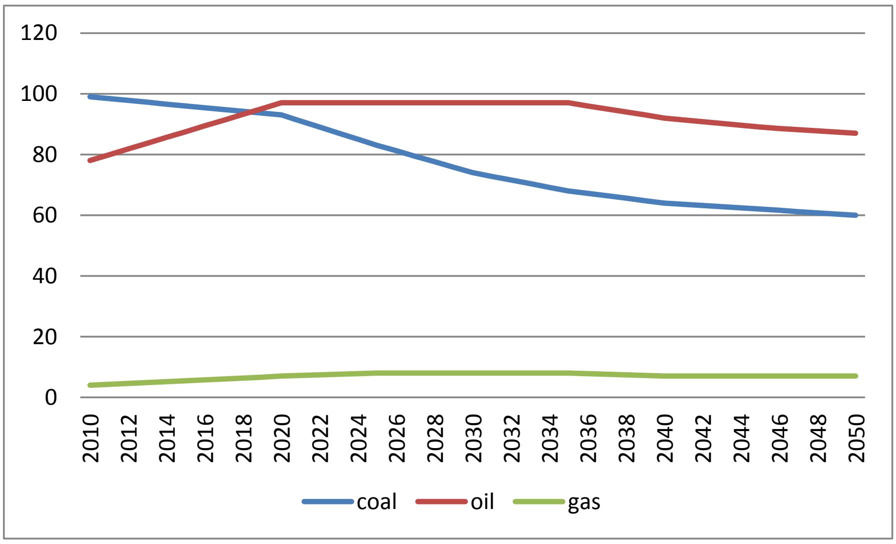
4 The alternative simulations: Assumptions and policy mixes

4.1 Global Cooperation

4.1.1 The exogenous variables

The world market extraction prices for coal, oil, gas in 2010 US-$ are now less dynamic than in the baseline, because the demand for fossil fuels is much lower than in the baseline. We take the IEA ETP 2 DS prices for fossil fuels. The dimensions are for oil 2010 USD/bbl, for Coal 2010 USD/tonne and for gas 2010 USD/Mbtu.

Figure 12: World market extraction prices for coal, oil and gas in constant 2010 US-$ for the alternative scenario 1 “global cooperation”



Source: GINFORS CECILIA2050

The Coal price is now falling till 2050 by 40% against 2010 and 52 % against the baseline in 2050. The oil price is in the scenario global cooperation in 2050 only 11% higher than in 2010, and against the baseline in 2050 it is 42 % lower. The gas price will till 2030 be the same as in the baseline and will then reduce a bit. In 2050 the gas price will be 30% lower than in the baseline. The logic for these developments is clear. In the 2 DS scenario the reduction of fossil fuel demand will be the greatest for the most carbon intensive fuel, which means that this fuel has the strongest price reductions.

4.1.2 The emission path that has to be met: RCP 2.6

Figure 1 shows that the emissions reach its maximum already in 2020 and fall then strongly till 2050 reaching a level which is about 66 % lower than the actual one. In 2050 the global target of 12.4 Gt CO2 should be reached.

4.1.3 The climate policy

A global commitment has been found to reach the 2 degrees target. This includes the installation of the following policy mix for all countries in the world:

The general instrument: Carbon price
A central element in the policy mix is the carbon price, which is implemented by the EU ETS and a second cap and trade system. This allows installing for the less carbon intensive industries a carbon price, which is twice that of the carbon intensive basic industries in the ETS system. The sectors underlying the ETS (iron and steel, coke and refined petroleum, electricity production, cement, glass, ceramics, pulp and paper) are responsible for about 50% of CO2 emissions in the EU. The allowances are given for free. The advantage of the cap and trade is that there is an incentive to reduce carbon intensity of production without endangering competitiveness. The carbon price starts at actual levels and reaches 230 € in 2010 prices at the end of the simulation period. To install a second cap and trade system is useful to allow for a different price in the other sectors of the economy which are by far less

carbon intensive than the ETS sectors. To get sensible reactions a higher price is installed here: For the second cap and trade a carbon price of 460 € will be reached in 2050. The experience of the last years with the crash of the EU ETS has shown that for the stabilization of the carbon price a flexible supply of allowances is necessary. This is also the case since the ETS is not the only instrument of climate policy. A mix of instruments with overlapping effects on all emitters makes it necessary to adjust the supply of allowances. Especially the existence of an autonomous target for renewable energies, which is followed up by specific instruments, forces this change. Further economic fluctuations destabilize the carbon price, if no such supply side management is given. Their emission reductions are of course also indirectly influenced by all other instruments of the policy mix. For example the emissions of the iron and steel sector are also indirectly influenced by the production of steel depending from car production, which may be influenced by instruments targeted on traffic.

Renewables in electricity production

Since the production costs for electricity made of renewable resources have in the past in most cases been higher than those of conventional power stations, there has been no market led incentive for investment into these technologies. Even if the renewables will be competitive one may doubt whether investors outside of the power sector will invest. Insiders of the power sector may be locked in to the old technologies for different reasons. With the introduction of subsidies several European countries successfully tried to push investment into these technologies. Two approaches can be distinguished – feed in tariffs and green certificates.

The general principle of the instrument feed in tariff is a guaranteed price for fixed periods for electricity production from renewable resources. This enables a greater number of investors like homeowners, landowners, farmers, municipalities and others to participate in this development (Couture & Gagnon, 2010). The remuneration for the investors has to be paid by the demanders of electricity, which means higher prices for electricity. There is a big variety in the concrete design of the instrument: Instead of a fixed feed in tariff a fixed premium may be paid on top of the electricity market price. Further the remuneration may be directly paid by the government and financed by a tax on electricity demand. This is not the place to discuss all variations in detail. An overview on this is given by Couture & Gagnon, 2010.

To combine the property of security for investors with a better economic efficiency the Netherlands developed a tradable quota model of “green certificates”, which has been adopted by several countries. The central idea is that the government obliges producers, distributors or demanders of electricity to hold a certain share of their electricity production, distribution or consumption in a certain time period as green electricity certificates, which are tradable. The producers of green electricity sell the certificates and the other participants of the electricity markets which have the obligation to hold the certificates can either produce the green electricity themselves or buy the equivalent certificates. For a more detailed discussion see Ringel, 2006.

We assume in our analysis that the suppliers of electricity have the obligation to produce a certain percentage by renewables. This total share of renewables is rising from its target values in 2020 to 90 % in 2050. There remains a rest of fossil fuel production that may be necessary for safety reasons. The choice of the renewable technologies is depending from the historic structures and the development of the relative unit costs of the different technologies.

This modelling approach has the advantage that its results can be interpreted either as the outcome of a quota system or as a classic feed in tariff- system with the time paths of the unit costs of the different technologies and the mark-ups of the electricity sector as the guaranteed tariffs.

The existing grids are not able to link the decentralized locations of the supply of renewable energy and the demand. Further an interregional exchange is necessary to equalize tops in the development of supply and demand. For Germany a grid development plan electricity NEP, 2013 exists which calculates for the “Energiewende” in deep detail the amount of 20 to 40 billion €, which have to be invested till 2032. We assume the medium number. Grid development plans for an expanding share of renewables do not exist for the other member states of the EU. A rough estimate can be found dividing the grid investment for Germany by the capital stock of the power sector in Germany in the year 2009, which gives 18.7 %. Assuming this relation also for the other member states a rough estimate for the necessary grid investments might be found.

E-mobility

A radical reduction of GHG emissions, local air pollution, and traffic noise can be reached by e-mobility. One aspect of e-mobility – the development of railroad services - will be positively influenced by the carbon price.

For cars the technology alternatives hydrogen, fuel cells and the battery electric cars driven by regenerative energy are given. The European Technology Platform on Smart Systems Integration and the European Road Transport Research Advisory Council clearly prefer the electric car (ERTRAC & EPoSS, 2009).

Electric cars have still some handicaps compared with the conventionally driven cars: The batteries have a limited capacity, which gives them a range of about 150 km or even less and the time for charging the batteries is rather long. Further electric cars are still more expensive than the conventional ones and investments in the infrastructure will be necessary to have charging stations for the batteries.

The limited range and the long charging times are not a problem for short distance traffic in the cities. The use for traffic between the place of work and the home and for shopping purposes might be typical for electric cars. Also short distance traffic in the cities for firms to transport goods and persons is thinkable with electric cars. The literature discusses these potentials, but comes to the result that electric cars are still not competitive.[16] EWI, 2010, p. 12 concludes that electric cars will not be competitive before 2030. If they shall play a role before 2030 either direct subsidies have to be paid, or specific regulations have to be installed (EWI, 2010, p. 13). One regulation could be to allow only “low-emission” cars in the cities for free, but all other cars with the obligation of a city tax. Further their attractiveness rises with free parking areas for electric cars and the allowance for them to use the bus tracks, as introduced already in Norway. A lot of such regulations[17] in the cities, which at the end are to the expense of the conventional car traffic, could help to press the electric car into the market before 2030. EWI, 2010, assumes that till 2050 the electric car could have a market share of about 40% of the stocks of cars in Germany, if such policies will be installed. We assume that the regulations favoring electric cars in cities are introduced in all member

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[16] A comprehensive study is given with EWI, 2010, and the literature cited there.

[17] A long list is given by ERTRAC & EPoSS, 2009, p. 14.

states. This allows of course a great variety of concrete activities depending from the specific structures in the member states.
Further we assume the introduction of binding emission standards for new cars and taxation of fossil fuel burning engines, which is used for subsidies for the use of hybrid and electric cars, so that industries and households in total are not hit by this taxation. Further the use of electric cars is favoured in cities by better parking conditions, exemptions from city taxes etc.
A complex policy program has to be established using economic instruments, information instruments and regulations. With these additional instruments a share of 80 % of e-mobility shall be reached.

Of course the link from these policy assumptions to the energy structure of the land transport and private households mobility cannot be established explicitly, because the GINFORS database does not contain the needed technological information on car types, fuel consumption etc. We are only able to estimate the potential of this technology change in the sectoral, macroeconomic and global economic context. To avoid an overestimation of this potential, we assume that it does not induce effects on the level of final energy demand for mobility of the sector in question. This is a conservative assumption, because electric cars have lower final energy consumption than diesel or gasoline driven cars. So the technology change only influences the structure of final energy demand for mobility. To which extent the share of electricity rises and that of diesel and gasoline falls is depending from the intensity with which the policy instruments are implemented. GINFORS assumes that the share of electricity rises up to 80 %. Further biodiesel input of 10 % is already part of the baseline, so that for mineral oils a rest of 10 % is given in the global Cooperation scenario for mobility of households and industries. The necessary investment in charging stations could not be mentioned, so that the implicit assumption is that over the period of nearly 40 years the now not necessary reinvestment in filling stations for mineral oils and the tax revenue coming out of the taxation of oil engines corresponds with the new investments in charging stations. Our analysis does not describe the effects of a concrete action plan; it is a conservative estimation of the potential that such a technology change has.

Energy efficiency of buildings
The carbon price has a direct influence on the energy efficiency of buildings as already discussed. But it seems to be clear that on this way it will not be possible to reach the technically possible standard of energy efficiency for the whole stock of buildings.

The EU roadmap and the energy concept of the German government for 2050 give the improvement of the energy efficiency of buildings an important role (Prognos, 2013). Based on this, Prognos, 2013, modeled in deep detail for Germany a baseline and two alternative scenarios describing the effects of rising renovation rates for buildings on their energy efficiency. Based on a concrete program of the public bank KFW (Kreditanstalt für Wiederaufbau) they further calculated the necessary investment in windows, insulation of walls and heating equipment and analyzed the subsidies that may induce these investments.
In the baseline the renovation rate starts in 2011 with 1 % and reduces quickly to 0.5 % in 2050. In alternative scenario 1, which is more ambitious than alternative scenario 2, the renovation rate rises till 2021 up to 2.1 % and stays there till 2050. The difference between the renovation rate of the baseline and the renovation rate of the ambitious scenario is about 1.5 %, which coincides with the push on refurbishment, which the Fraunhofer Institute calculated for its “High Policy Intensity Scenario” to renovate all buildings in the EU till 2050 (

ECORYS & ECN, 2012, p.14). Prognos, 2013, calculates the necessary investment for Germany with 17.6 billion € in 2011, the number rises to a peak of 44.9 billion € in 2036 and reduces to 32.9 billion € in 2050, the final energy consumption for heating reduces against the baseline continuously and reaches a reduction of 43% in 2050.

The investment is induced by a credit program which includes a subsidy from the government. With this programme, KFW provides soft loans to local banks, which on-lend these funds to private homeowners, associations of homeowners and housing companies. The programme supplies a mixture of soft loans and grants. The more efficient the house becomes after the renovation, the less has to be repaid by the owner of the house. The European Commission evaluated this programme as “a good example of a national model for financing energy efficiency in buildings” (European Commission, 2013, p. 20). Prognos, 2013, p. 20 calculates over the period 2006 to 2010 an average leverage of 10 for the programme as it has been applied historically.

We adopt these figures concerning the renovation rate the leverage of the subsidies to induce the necessary investment and the improvement rate of energy efficiency of buildings to the other member states. The implicit assumption that in all member states the investment in energy efficiency of buildings via higher renovation rates has the same relative effect on final energy consumption of the building sector as in Germany is of course a rough estimate. Two arguments favour this procedure: First Germany has the biggest stock of buildings in the EU and it is situated in the centre of Europe and insofar has an average climate. Secondly in Germany the energy efficiency of buildings is already relative high so that further improvements will be more costly than in other countries. Insofar our estimates for total Europe will be rather conservative. We should not expect to overestimate the effect of the assumed policy on energy efficiency of buildings in Europe.

Dematerialization

The industry sector uses energy for mobility, heating and process heat like “cooking” steel and producing ceramics and other basic goods. In the Global Cooperation scenario the energy use for mobility will be influenced by the e-mobility program. Heating can be reduced by the program to improve the energy efficiency of buildings. The carbon price influences additionally all three uses of energy, but for process heat it is the only one. Two problems are given: First the price elasticities for energy intensity and carrier substitution are rather tight in the basic industries and secondly the relative prices for fossil fuels are very low in the scenario Global Cooperation, so that the shadow prices for energy are compared to the baseline not much higher in spite of rather high carbon prices. Therefore the climate policy instruments have been replenished by a resource policy instrument: An information program is implemented, which reduces the inefficiencies in material use in all industries, especially in small and medium sized firms. So the firms at the end of the supply chain use fewer materials, which means less steel, ceramics, chemicals etc. – products, whose production process emits much carbon.

There is bottom up information about abatement costs based on empirical research and the expertise of consulting firms. Arthur D. Little et al., 2005, Fischer et al., 2004, and Kristof et al., 2008, estimate the potential for material savings to range between 10% and 20%. Fischer et al., 2004, estimate that a 20% reduction of material cost is possible by an information and consulting program for firms with the costs of the savings of one year. So after one year firms have a permanent surplus and there is a reduction of material use which diminishes the pressure on nature – a typical win-win result. Oakdene Hollins, 2011, came to a similar result. The German official material efficiency agency demea (demea, 2010) reports that the small and medium sized firms joining their information and consulting program could on average raise their profits by 2.4 % of their respective sales.

Based on these experiences Meyer et al., 2007a, and Distelkamp et al., 2010, have presented model simulations for Germany with the model PANTA RHEI in which all input coefficients for materials (Distelkamp et al. 2010) or for materials and energy (Meyer et al., 2007a) have been reduced in manufacturing by the same amount as the costs described by Fischer et al., 2004. In the FP7 MOSUS project this has been done with the model GINFORS I in the European context (Giljum et al., 2008).

In our simulation the inputs of wood and products of wood, pulp and paper, chemicals, rubber and plastics, other non- metallic minerals, basic metals and fabricated metal products in all industries are subject of the dematerialization program.

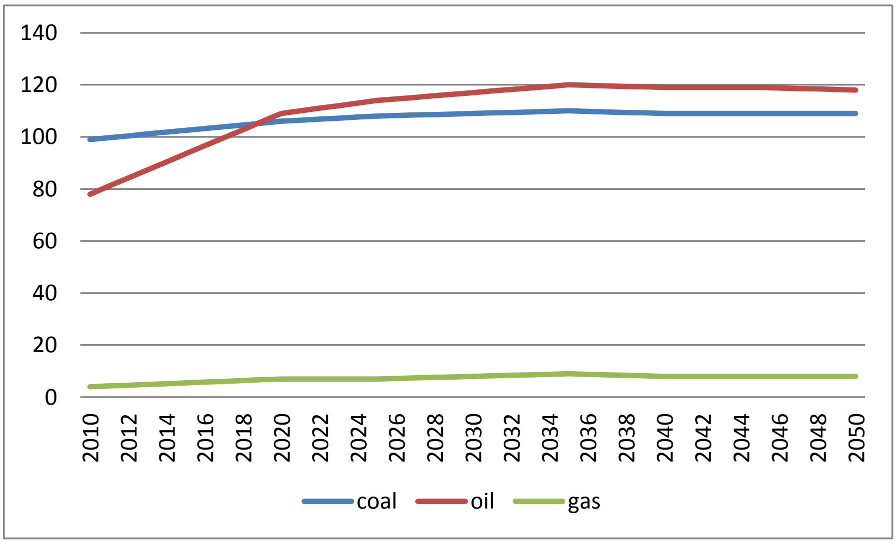
4.2 Middle of the Road

4.2.1 The exogenous variables

The development of **Population** is the same as in the baseline scenario.

The world market extraction prices for coal, oil, gas in 2010 US-$ are now less dynamic than in the baseline, but higher than in the scenario “global cooperation”, because the demand for fossil fuels is lower than in the baseline, but higher as in the scenario “global cooperation. We take the IEA ETP 4 DS prices for fossil fuels.

Figure 13: World market extraction prices for coal, oil and gas in constant 2010 US-$ for the alternative scenario 2 “middle of the road”



Source: GINFORS CECILIA2050

The dimensions are for oil 2010 USD/bbl, for Coal 2010 USD/tonne and for gas 2010 USD/Mbtu.

4.2.2 The emission path that has to be met: RCP 4.5

The global emission path is that of RCP 4.5 as depicted in figure 1. Concerning the distribution over the different countries our scenario assumes that the EU countries follow the 2 degrees target, which means that they reduce their emissions till 2050 in relation to the levels of 1990 by 80 %. For the Non-European countries this means that the rest between the European emissions and the RCP 4.5 path is to be met. We could interpret this constellation till 2050 as a delayed reaction of the Non- European countries, which may after 2050, follow the EU example. This perspective might give a motivation for EU countries to go in front although in 2050 although the 2 degrees emission path in total will probably not be met. Since our scenario assumes that there is no international agreement with only uncoordinated climate policy activities in these countries it does not make sense to allocate concrete emission paths to the different countries. On the other side it would be fair that they all meet at similar per capita emissions in 2050. For Non-European developed OECD countries (USA, Canada, Japan, Korea) absolute reductions will be necessary allowing emerging economies like Brazil, China, and India to develop with only a relative decoupling of GDP and CO2 emissions.

4.2.3 The climate policy

The EU27 countries will implement the same policy as in the “Global cooperation” scenario to reach an 80 % reduction of CO2 in relation to the 1990 numbers.

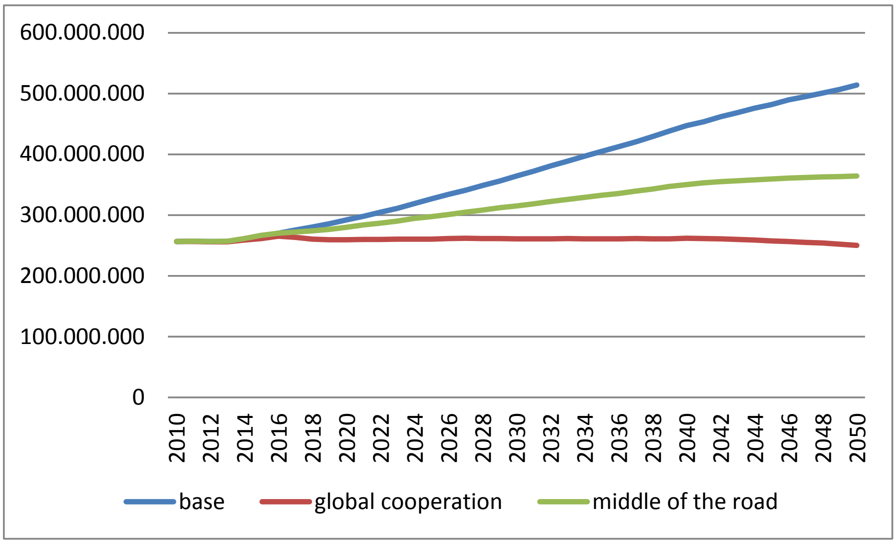
The other countries in the world may not introduce the cap and trade system. This seems to be plausible, because this instrument demands some administrative costs and the feasibility of the instrument could be problematic. On the other side the introduction of e-mobility could be interesting for the non-European countries, because the markets for cars are very strongly internationally linked so that the others might follow the European fore runners. Subsidies for the investment in buildings are not part of the climate policy of the non-European countries. Quotas for renewables in electricity production are a central part of their climate policy, but the target is only to reach a share of 70 %. The information policy for rising material efficiency will be accepted by the other countries, because the direct effect of the consulted firms is a cost reduction.

5 The Results of the Alternative Simulations

5.1 Energy Demand

Global total final energy demand of all industries will be 30 % lower in the scenario “Middle of the Road” than in the baseline (Fig. 14). Nevertheless it is still growing with an average annual growth rate of 0.8 %. In the scenario “Global Cooperation” the reduction against the baseline will be 52 % and the level will now be stabilised.

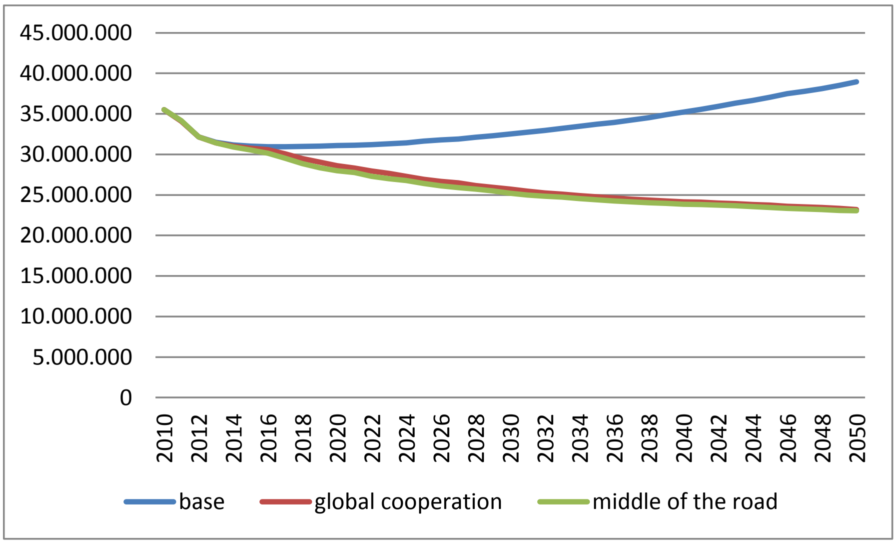
Figure 14: Final global energy demand of all industries in TJ in the three scenarios.



Source: GINFORS CECILIA2050

In the EU (fig. 15) the reduction for both scenarios is 41 %, and we observe a reduction against actual numbers of 25 %. There is no difference for both scenarios, for two reasons: First the EU 27 follows in both scenarios the same policy mix. The second is that the policy mix for the non- EU countries and also that for the EU members avoids to induce direct price- and income effects, which would infer international trade and from that side economic reactions and at the end also impacts on energy demand. We will discuss that point later in the economic context.

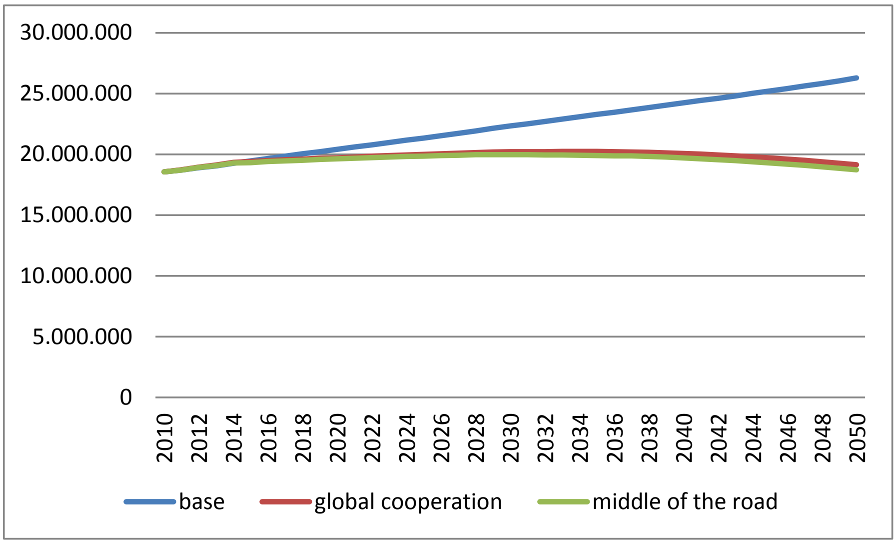
Figure 15: Total final energy demand of all industries in the EU27 in TJ in the three scenarios.



Source: GINFORS CECILIA2050

Households' final energy demand (Figure 16) is reduced by about 35 % against the baseline because the energy efficiency of heating has been improved by 55 %. This stabilizes more or less till 2050 final energy demand of households.

Figure 16: Final energy demand of EU27-households' in TJ in the three scenarios.



Source: GINFORS CECILIA2050

Table 4 gives an overview on households' structural change of energy demand. The carriers needed for heating (natural gas, light fuel oil and hard coal and derivatives) are all reduced by the efficiency program for heating. Since heating is only one part of total final energy demand of households, the reductions of the shares of total energy demand of households are smaller than the reductions of the energy intensity of heating. So natural gas for example has 22.6 % in the scenario "Global Cooperation" and 32.4 % in the baseline. The number in the alternative scenario is 70 % of the number in the baseline. The reduction is here 30%. Further deviations are given because the model calculates on the lever of the Member States, which have different energy intensities and also structures of energy carriers. So the aggregated result for EU27 also depends from the weight that the countries have concerning heating in the EU27.

The deviations of the shares of the carriers diesel, gasoline and electricity from the baseline are influenced by the e-mobility program. Here we have also to mention that a 90 % reduction of energy inputs for mobility means a less reduction in relation to total demand. Further also here the structural effect has to be mentioned.

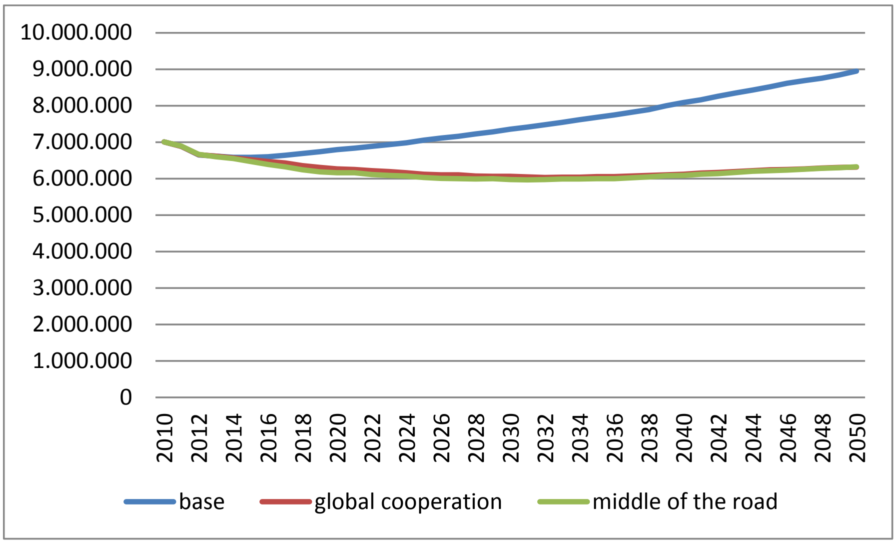
Figure 17 describes the development of final energy demand of the transport sector. Since the e-mobility program has no effects on the energy intensity of the transport sector, the observed reductions of the alternative scenarios against the baseline of 30 % must have another background. First there is the influence of the carbon price, which reduces transport demand. But because the e-mobility program reduces the carbon content of the transport services, this effect should become weaker in time. The explanation is that with rising time the dematerialization program gets a stronger influence since a rising number of firms is participating. Since dematerialization means less transport services for materials we have a rising reduction of transport services and insofar permanent reduction of final energy demand of the transport sector.

Table 4: Structure of EU27-households' energy demand in the three scenarios.

	2050		
	base	global cooperation	middle of the road
Hard coal and derivatives	2,5%	1,8%	1,8%
Lignite and derivatives	0,2%	0,2%	0,1%
Coke	0,1%	0,1%	0,1%
Crude oil, NGL and feedstocks	0,0%	0,0%	0,0%
Diesel oil for road transport	11,9%	2,9%	2,8%
Motor gasoline	11,2%	2,9%	2,9%
Jet fuel (kerosene and gasoline)	0,0%	0,0%	0,0%
Light Fuel oil	7,4%	5,4%	5,3%
Heavy fuel oil	0,2%	0,2%	0,2%
Naphta	0,0%	0,0%	0,0%
Other petroleum products	3,5%	2,5%	2,5%
Natural gas	32,4%	22,6%	22,9%
Derived gas	0,1%	0,1%	0,1%
Industrial and municipal waste	0,0%	0,0%	0,0%
Biogasoline also including hydrated ethanol	0,4%	0,6%	0,6%
Biodiesel	0,5%	0,7%	0,7%
Other combustible renewables	7,9%	5,7%	5,7%
Electricity	16,0%	50,5%	50,4%
Heat	5,6%	4,0%	4,0%

Source: GINFORS CECILIA2050

Figure 17: Final energy demand of EU27 transport sectors in TJ in the three scenarios.



Source: GINFORS CECILIA2050

The transport sector is an aggregate of the land transport sector, water transport and the air transport sector. First it astonishes that in the baseline electricity demand rises up to a share of 28 % the road transport sector.

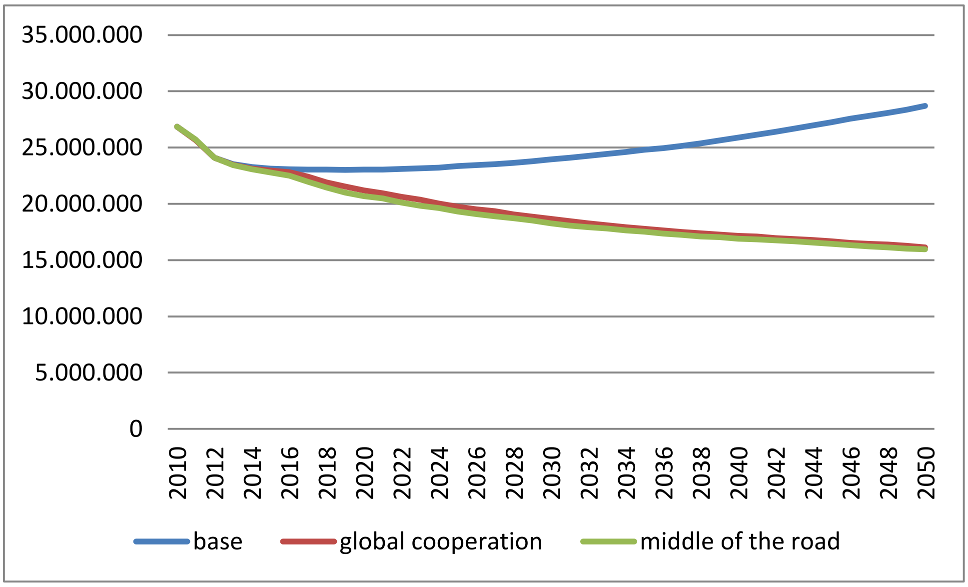
Table 5: Structure of EU27-transport sectors' final energy demand in the scenarios.

	2050		
	base	global cooperation	middle of the road
Hard coal and derivatives	0,0%	0,0%	0,0%
Lignite and derivatives	0,0%	0,0%	0,0%
Coke	0,0%	0,0%	0,0%
Crude oil, NGL and feedstocks	0,0%	0,0%	0,0%
Diesel oil for road transport	17,5%	4,8%	4,8%
Motor gasoline	0,2%	0,2%	0,2%
Jet fuel (kerosene and gasoline)	29,7%	32,0%	31,9%
Light Fuel oil	5,2%	2,0%	2,0%
Heavy fuel oil	13,5%	5,8%	5,7%
Naphta	0,0%	0,0%	0,0%
Other petroleum products	1,1%	0,5%	0,5%
Natural gas	0,7%	0,3%	0,3%
Derived gas	0,0%	0,0%	0,0%
Industrial and municipal waste	0,0%	0,0%	0,0%
Biogasoline also including hydrated ethanol	0,0%	0,0%	0,0%
Biodiesel	3,4%	4,2%	4,2%
Other combustible renewables	0,0%	0,0%	0,0%
Electricity	28,8%	50,2%	50,3%
Heat	0,0%	0,0%	0,0%

Source: GINFORS CECILIA2050

Final energy demand in the industry sector without transport is reduced against the baseline in the alternative scenarios by 45 %. The strong reduction is induced by all instruments which are part of the policy mix. First the carbon prices reduces fossil fuels in general, further the e-mobility program reduces the demand for diesel and gasoline pushing the demand for electricity, and the program for heating efficiency diminishes the input of natural gas and light fuel oil and other petroleum products, and last not least the dematerialization program reduces the production of the industries with high fossil fuel inputs (basic metals, non-metallic- minerals, chemicals etc.) and favours industries investment goods industries and service sectors, which are using to a large extend electricity. So the strong rise of electricity in the alternative scenarios against the baseline documented in table 6 is the result of many different effects: There is carrier substitution (e-mobility, carbon price), there is a reduction of a certain type of energy demand (heating) and there is a change in the structure of the economy favouring sectors that use electricity for the power of machines and reducing the production of sectors, which use fossil fuels for process heat.

Figure 18: Final energy demand of EU27 industry sectors (excl. transport sectors) in TJ in the three scenarios.



Source: GINFORS CECILIA2050

Table 6: Structure of EU27-industries' final energy demand in the three scenarios (excl. transport sectors).

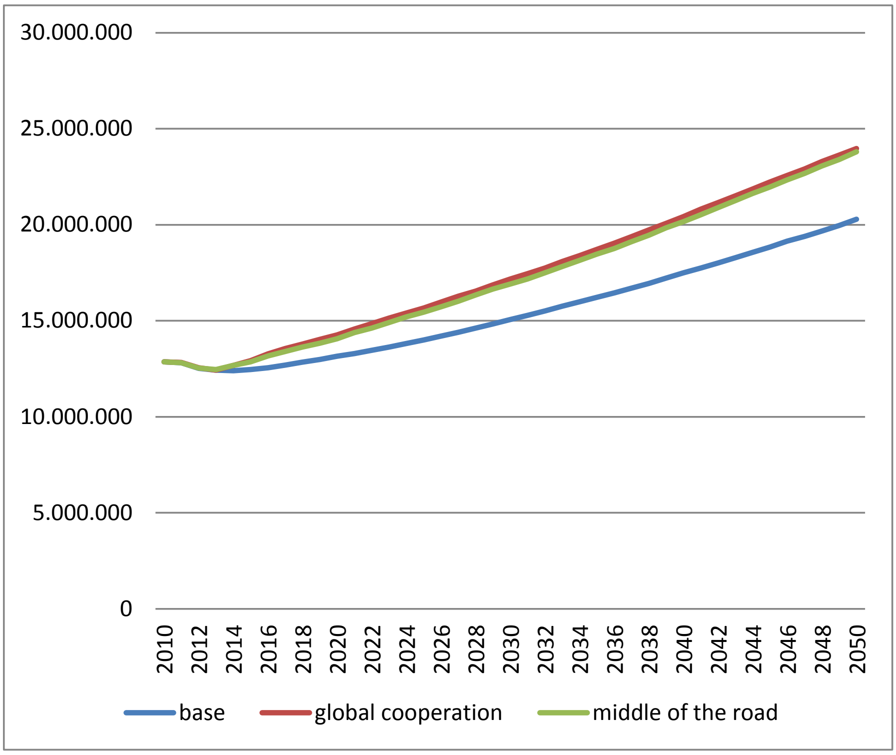
	2050		
	base	global cooperation	middle of the road
Hard coal and derivatives	4,7%	1,7%	2,2%
Lignite and derivatives	2,9%	0,5%	0,9%
Coke	1,7%	0,7%	0,9%
Crude oil, NGL and feedstocks	0,0%	0,0%	0,0%
Diesel oil for road transport	6,5%	2,8%	2,9%
Motor gasoline	1,1%	0,5%	0,5%
Jet fuel (kerosene and gasoline)	0,0%	0,0%	0,0%
Light Fuel oil	4,6%	3,0%	3,0%
Heavy fuel oil	2,8%	1,9%	1,9%
Naphta	8,2%	4,5%	4,4%
Other petroleum products	9,8%	5,6%	5,6%
Natural gas	12,4%	11,3%	9,7%
Derived gas	0,7%	0,4%	0,4%
Industrial and municipal waste	1,1%	0,9%	0,9%
Biogasoline also including hydrated ethanol	0,2%	0,2%	0,2%
Biodiesel	0,6%	0,9%	1,0%
Other combustible renewables	3,2%	2,6%	2,6%
Electricity	36,1%	60,1%	60,9%
Heat	3,6%	2,3%	2,1%

Source: GINFORS CECILIA2050

5.2 Electricity Supply

Electricity production of EU27 would in the alternative scenarios in 2050 be about 18 % higher than in the baseline. The main reason is the substitution effect of e-mobility.

Figure 19: Electricity supply in the EU27 in TJ in the three scenarios.



Source: GINFORS CECILIA2050

Especially biogas, hydroelectric and wind power raise their shares, whereas nuclear and fossil fuels lose (table 7).

Table 7: Structure of electricity supply in the EU27 in the three scenarios.

	2050		
	base	global cooperation	middle of the road
Biogas	10,6%	19,4%	19,4%
Hydroelectric	12,5%	25,0%	25,2%
Geothermal	3,6%	6,0%	6,0%
Photovoltaic	4,8%	7,1%	7,1%
Solarthermal heat	3,1%	5,4%	5,3%
Solarthermal electricity	0,0%	0,1%	0,1%
Wind power	16,0%	26,9%	26,8%
Nuclear	16,3%	5,7%	5,7%
Coal	16,7%	0,0%	0,0%
Gas	14,5%	4,1%	4,1%
Oil	1,7%	0,0%	0,0%

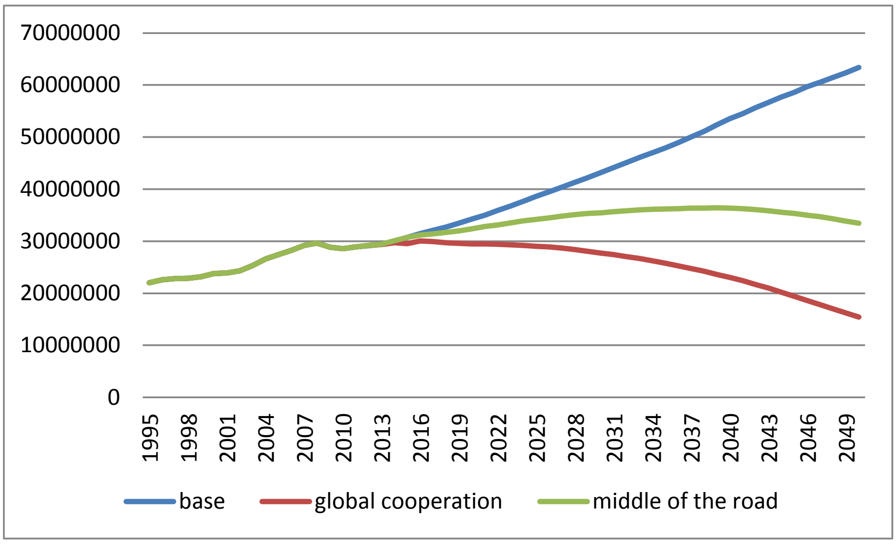
Source: GINFORS CECILIA2050

5.3 CO2 Emissions

Strong effects on carrier substitution and total energy intensity are the results of the evaluated policy mix as we have seen. Figure 20 now shows what this means in terms of CO2 emissions. In the “Global Cooperation” scenario 15.4 Gt are reached in 2050, which is 3 Gt

more than RCP 2.6 demands. Of course this is a not negligible difference, but it can hardly be argued that this has drastic ecologic implications.
The scenario “Middle of the Road” reaches 33.4 Gt CO2 emissions – a number that is much deeper than 41.4 Gt of the RCP 4.5 target.

Figure 20: CO2 emissions in the world in kilo tons in the three scenarios.



Source: GINFORS CECILIA2050

Table 8 presents the structure of global CO2 emissions for the three scenarios and shows that the power sector has in “Global Cooperation” the strongest reductions against the baseline. The scenario “Middle of the Road” has fewer reductions in the power sector as follows directly from the scenario parameterization.

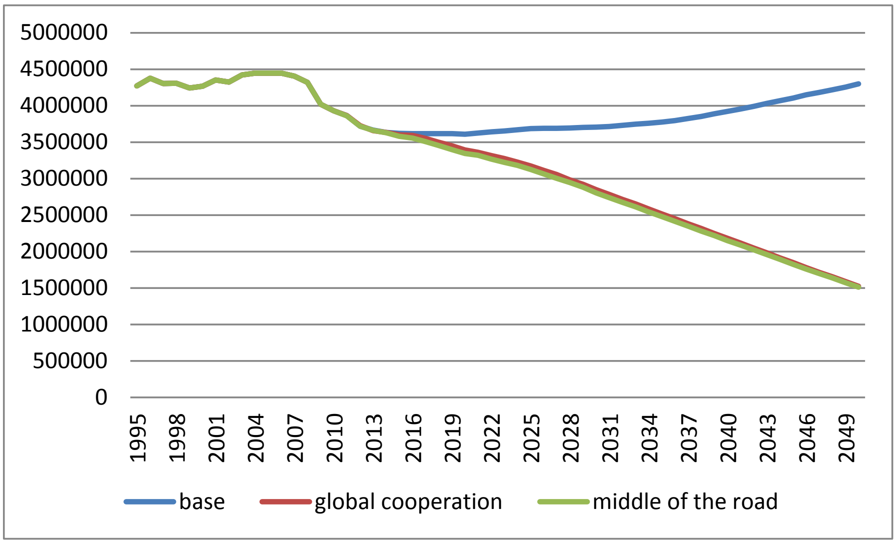
Table 8: Structure of CO2 emissions in the world in the three scenarios.

	2050		
	BASE	GLOBAL COOPERATION	MIDDLE OF THE ROAD
households	12,4%	23,7%	16,3%
agriculture	1,5%	2,0%	2,0%
power sector	46,9%	11,0%	35,3%
transport	5,2%	10,5%	7,2%
industries	34,0%	52,8%	39,2%

Source: GINFORS CECILIA2050

In the EU (fig. 21) the alternative scenarios reach 1.5 Gt CO2 emissions in 2050. This is more than the target of the Commission - a reduction of 80 % in relation to the 1990 emissions – would allow. The deviation in terms of the reduction target is about 10 %.

Figure 21: CO2 emissions in the EU27 in kilo tons in the three scenarios.



Source: GINFORS CECILIA2050

The structure of the emissions in the three scenarios in table 9 shows that the impact of the program on the power sector is the strongest, whereas in the transport sector the smallest relative reduction is achieved, which lets the share rise relative strong. The reason is that here only the land transport is met by e-mobility and carbon price impacts. Water transport and air transport are only under the carbon cap, but here the possibilities of substitution are restricted. Also the industries reduce their emissions less than the average. The impact on household emissions meets with the heating program is more or less at the average.

Table 9: Structure of CO2 emissions in the EU27 in the three scenarios.

	2050		
	BASE	GLOBAL COOPERATION	MIDDLE OF THE ROAD
households	28,8%	32,5%	32,1%
agriculture	1,7%	1,6%	1,6%
power sector	29,1%	11,4%	11,4%
transport	11,1%	15,4%	15,6%
industries	29,3%	39,1%	39,2%

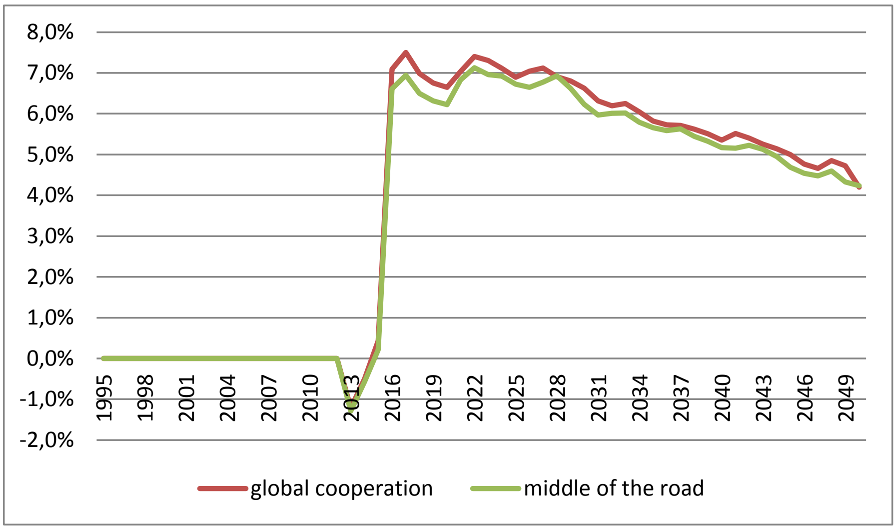
Source: GINFORS CECILIA2050

5.4 The Structure of the Economy

5.4.1 Gross fixed capital formation

Figure 22 presents the percentage deviations of gross fixed capital formation in constant 1995 US-$ in the scenarios “Global Cooperation” and “Middle of the Road” from the baseline. This impact is a result of the investments in renewables and grids and of the program for the improvement of the energy efficiency of heating. In “Global Cooperation” the deviations are a bit higher, because via international trade positive impacts are transferred from the investments in renewables in countries outside the EU. This effect is not very strong, because in the non EU countries there is no additional investment in heating installations. The deviations reduce over time, because the program has also this time profile.

Figure 22: Gross fixed capital formation in the EU27 (constant US-$). Baseline deviations in percent.



Source: GINFORS CECILIA2050

5.4.2 The sectoral structure of the economy

The effect of the policy mix on the structure of production is depicted in table 10 for Germany and in table 11 for Italy as examples. For Germany we observe for the carbon intensive basic industries pulp and paper, chemicals, rubber and plastics, other non-metallic-minerals and basic metals reductions of their shares compared with the baseline. These industries are hit by the dematerialization program. The investment goods industries machinery, electrical and optical equipment, transport equipment and construction are favoured by the dematerialization program and the investment for renewables and heating installations. The coke and refined petroleum industry suffers from the reduction of mineral oil demand, whereas electricity, gas and water supply has advantages from the extended use of electricity.

Table 10: Sectoral structure of gross production in constant prices in Germany in the three scenarios.

	2050		
	base	global cooperation	middle of the road
Agriculture, Hunting, Forestry and Fishing	0,9%	1,0%	1,0%
Mining and Quarrying	0,1%	0,1%	0,1%
Food, Beverages and Tobacco	1,8%	2,0%	2,0%
Textiles and Textile Products	0,7%	0,8%	0,8%
Leather, Leather and Footwear	0,1%	0,2%	0,2%
Wood and Products of Wood and Cork	0,7%	0,5%	0,5%
Pulp, Paper, Paper , Printing and Publishing	2,5%	2,0%	2,0%
Coke, Refined Petroleum and Nuclear Fuel	0,4%	0,3%	0,3%
Chemicals and Chemical Products	3,5%	2,9%	2,9%
Rubber and Plastics	1,7%	1,3%	1,3%
Other Non-Metallic Mineral	0,8%	0,6%	0,6%
Basic Metals and Fabricated Metal	4,4%	2,9%	2,9%
Machinery, Nec	4,2%	4,3%	4,3%
Electrical and Optical Equipment	5,4%	5,8%	5,5%
Transport Equipment	6,6%	7,3%	7,3%
Manufacturing, Nec; Recycling	0,9%	0,9%	0,9%
Electricity, Gas and Water Supply	2,3%	2,5%	2,5%
Construction	5,1%	6,2%	6,2%
Sale, Maintenance and Repair of Motor Vehicles and Motorcycles; Retail Sale of Fuel	0,9%	1,0%	1,0%
Wholesale Trade and Commission Trade, Except of Motor Vehicles and Motorcycles	5,2%	4,5%	4,5%
Retail Trade, Except of Motor Vehicles and Motorcycles; Repair of Household Goods	3,3%	2,7%	2,9%
Hotels and Restaurants	1,3%	1,4%	1,4%
Inland Transport	1,3%	1,3%	1,3%
Water Transport	1,4%	1,4%	1,4%
Air Transport	0,6%	0,7%	0,7%
Other Supporting and Auxiliary Transport Activities; Activities of Travel Agencies	2,2%	2,1%	2,2%
Post and Telecommunications	3,1%	3,1%	3,2%
Financial Intermediation	5,9%	6,2%	6,2%
Real Estate Activities	7,1%	7,3%	7,4%
Renting of M&Eq and Other Business Activities	11,3%	11,3%	11,3%
Public Admin and Defence; Compulsory Social Security	3,6%	4,0%	4,0%
Education	1,6%	1,8%	1,8%
Health and Social Work	5,4%	5,9%	5,9%
Other Community, Social and Personal Services	3,5%	3,7%	3,7%
Private Households with Employed Persons	0,1%	0,1%	0,1%

Source: GINFORS CECILIA2050

The same impacts can be studied for the Italian economy in table 13.

Table 11: Sectoral structure of gross production in constant prices in Italy in the three scenarios.

	2050		
	base	global cooperation	middle of the road
Agriculture, Hunting, Forestry and Fishing	2,5%	2,4%	2,6%
Mining and Quarrying	0,3%	0,2%	0,2%
Food, Beverages and Tobacco	5,6%	6,0%	6,1%
Textiles and Textile Products	3,4%	3,1%	3,1%
Leather, Leather and Footwear	1,1%	1,1%	1,1%
Wood and Products of Wood and Cork	0,5%	0,4%	0,4%
Pulp, Paper, Paper , Printing and Publishing	1,9%	1,6%	1,5%
Coke, Refined Petroleum and Nuclear Fuel	0,3%	0,1%	0,1%
Chemicals and Chemical Products	3,3%	2,7%	2,8%
Rubber and Plastics	1,0%	0,8%	0,8%
Other Non-Metallic Mineral	1,1%	0,8%	0,8%
Basic Metals and Fabricated Metal	3,5%	2,8%	2,8%
Machinery, Nec	3,5%	4,0%	4,0%
Electrical and Optical Equipment	1,6%	1,9%	1,9%
Transport Equipment	2,1%	2,5%	2,5%
Manufacturing, Nec; Recycling	1,6%	1,9%	1,9%
Electricity, Gas and Water Supply	1,8%	1,9%	1,9%
Construction	5,5%	6,5%	6,5%
Sale, Maintenance and Repair of Motor Vehicles and Motorcycles; Retail Sale of Fuel	2,2%	2,3%	2,3%
Wholesale Trade and Commission Trade, Except of Motor Vehicles and Motorcycles	5,9%	5,6%	5,5%
Retail Trade, Except of Motor Vehicles and Motorcycles; Repair of Household Goods	3,9%	3,7%	3,6%
Hotels and Restaurants	4,7%	4,7%	4,8%
Inland Transport	3,7%	3,2%	3,4%
Water Transport	0,2%	0,3%	0,3%
Air Transport	0,3%	0,3%	0,3%
Other Supporting and Auxiliary Transport Activities; Activities of Travel Agencies	1,7%	1,7%	1,7%
Post and Telecommunications	3,1%	3,1%	3,1%
Financial Intermediation	4,9%	5,0%	5,0%
Real Estate Activities	6,0%	6,3%	6,3%
Renting of M&Eq and Other Business Activities	7,1%	7,2%	6,9%
Public Admin and Defence; Compulsory Social Security	4,9%	5,0%	5,0%
Education	2,1%	2,1%	2,1%
Health and Social Work	5,0%	5,2%	5,2%
Other Community, Social and Personal Services	3,3%	3,4%	3,3%
Private Households with Employed Persons	0,4%	0,4%	0,4%

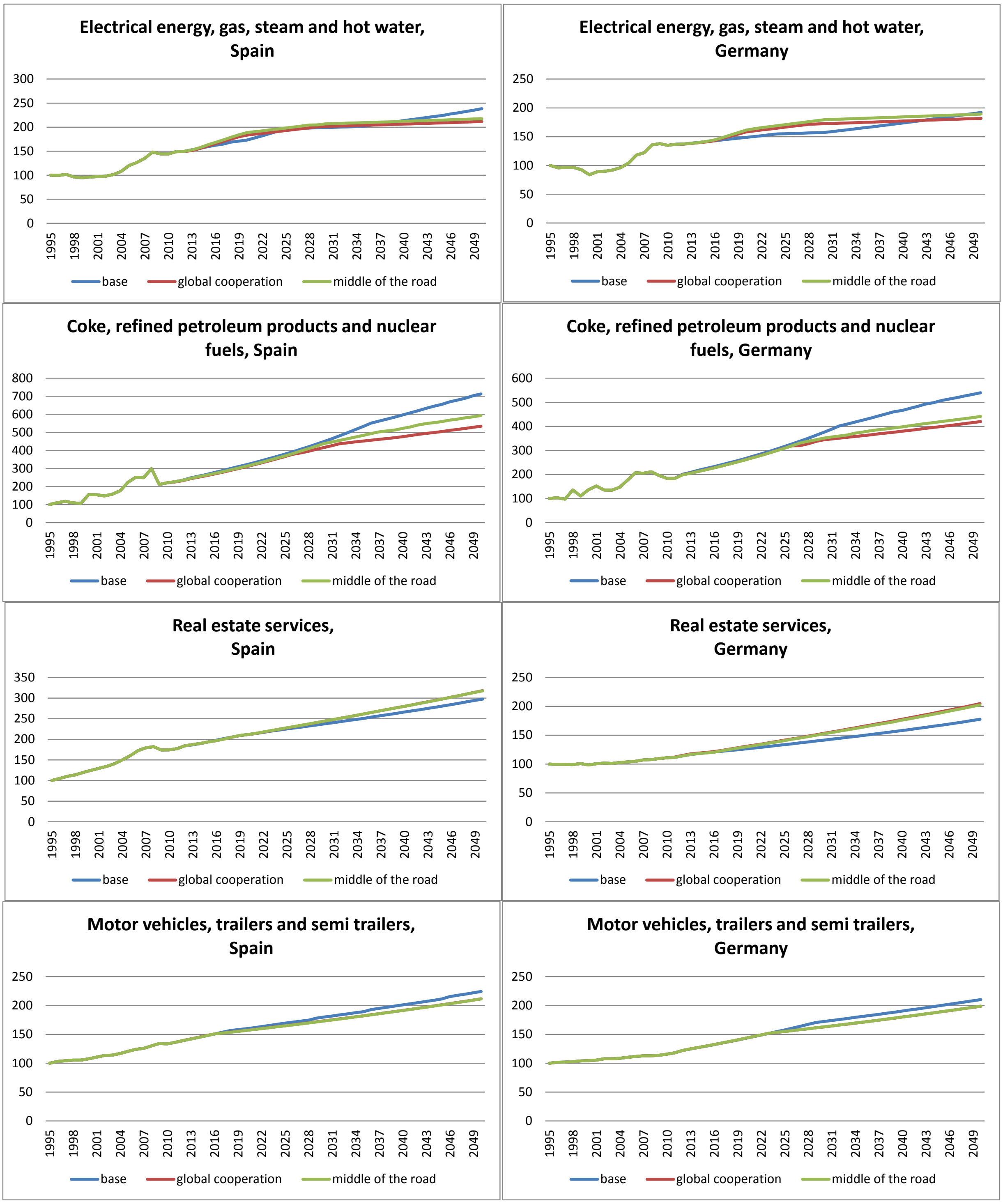
Source: GINFORS CECILIA2050

5.5 Prices

In comparison with the baseline the policy mix induces a substitution of intermediate inputs (energy) by capital inputs (renewables in electricity production, investment in energy efficiency of heating). Inside the intermediate inputs there is further a substitution of fossil fuels by electricity (e-mobility). Figure 23 shows the development of prices in the three scenarios for Spain and Germany. In the first years the price for electricity is higher in the alternative scenarios than in the baseline. In the later years the falling costs for the new installations of renewables in the alternative scenarios and the rising costs for fossil fuels in the baseline turns this: At the end electricity is cheaper in the alternative scenarios than in the baseline.

For mineral oil and coke products the prices are lower than in the baseline from the beginning of the period, because the dominating input price of crude oil is lower in the alternative scenarios.

Figure 23: Price indices for selected goods in Spain and Germany in the three scenarios.

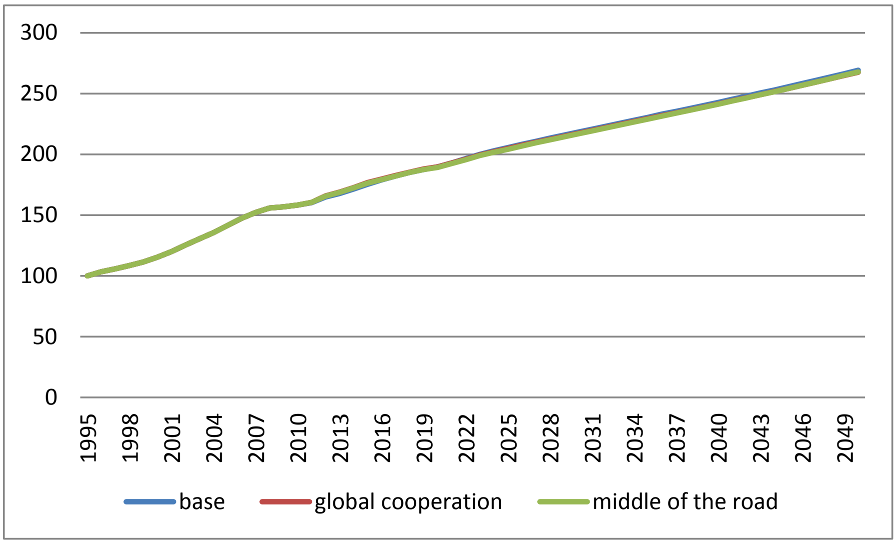


Source: GINFORS CECILIA2050

The prices for real estate services rise, because the capital costs for the investment of energy efficiency for heating are additional to the baseline situation.
In the case of investment goods like motor vehicles the prices are lower than in the baseline as a consequence of the dematerialization program which improves the efficiency of car production.

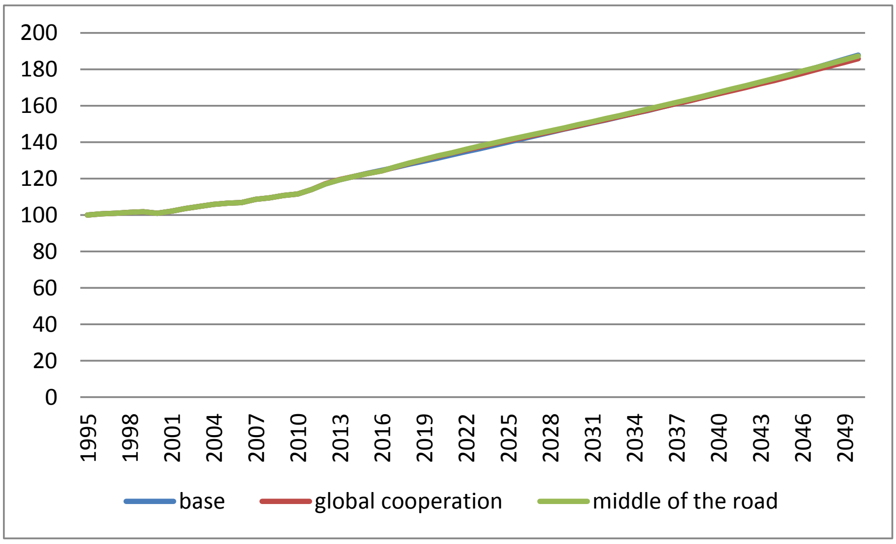
The total effects on price aggregates like the GDP deflator are negligible as figures 24 and 25 show.

Figure 24: GDP deflator for Spain in the three scenarios.



Source: GINFORS CECILIA2050

Figure 25: GDP deflator for Germany in the three scenarios.



Source: GINFORS CECILIA2050

5.6 GDP

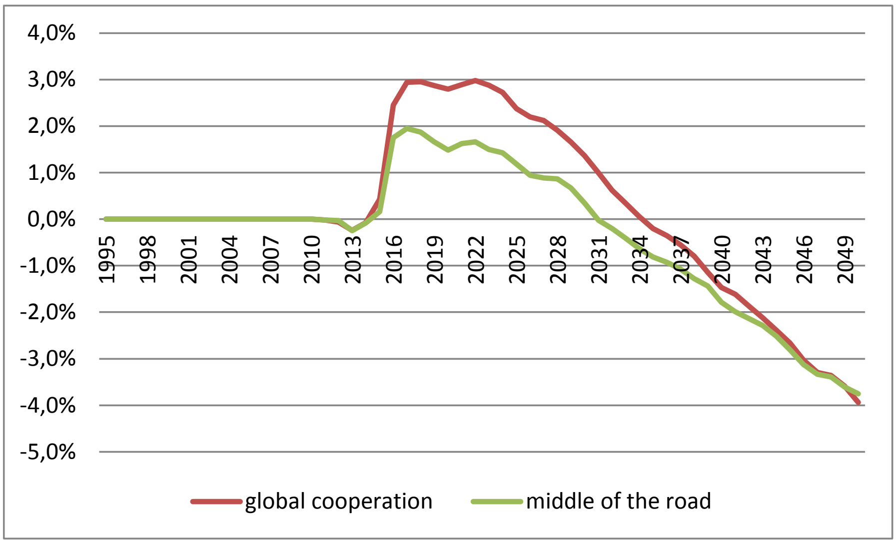
As we just have seen, the macroeconomic price effects do not play a role. The economic implications for GDP are mainly triggered by two effects: Investments for renewables, grids and the energy efficiency of buildings on the one side and the dematerialization program.

In EU27 investments rise in both alternative scenarios against the baseline as already described. Summarized over the whole period from 2015 to 2050 investment expenditure exceed their respective baseline values in both scenarios by about 7.4 trillion US-$ in constant prices. This has two effects on the economy: First, the circular flow of income is triggered which rises GDP. Secondly, capital costs are increased which tends to feed into higher prices which reduce GDP. The net effect of investment is clearly positive for GDP.

The dematerialization program has the following economic implication: The firms at the end of the supply chain improve their economic efficiency, which means directly higher value added. Further an indirect effect is induced: Lower costs tend to dampen price dynamics, to enforce competitiveness and to stimulate demand, production and further rising value added. For the basic industries at the bottom of the supply chain demand, production and value added fall. What is the net effect for the whole economy? The strength of the positive effect of the firms at the end of the supply chain is depending from the indirect effect on competitiveness. In former studies we discussed this instrument for a single region (EU27)[18] or country (Germany). Then of course the effect on competitiveness is positive and the total effect on GDP also. But if – as in our case - this instrument is implemented globally, the competitiveness effect is reduced and can even be negative for the EU27, if in the other countries the material input coefficients are higher than in the EU. Already the reduction of the competitiveness effect can mean that the net effect of dematerialization for GDP can be negative, which is the case in our simulations.

Since the positive investment effect is stronger in the first twenty years of the period and further the negative dematerialization effect is rising because from year to year the number of improved firms rises, we watch first positive impacts and after 2035 negative impacts. But the total effect is very small. Summing up all deviations from the baseline over the period 2015 to 2050 for the global cooperation scenario gives nearly zero. The percentage deviation from the baseline is in 2050 for the global cooperation - 4 percent. This means a reduction of the average annual growth rate of 0.1 % from 1.7 % in the baseline to 1.6 % in the scenario global cooperation.

Figure 26: EU27-GDP (constant US-$). Baseline deviations in percent.



Source: GINFORS CECILIA2050

5.7 Employment

The discussion of the effects on the structure of the economy has shown that the losers and winners of the policy mix can easily be addressed. The basic industries including coak and mineral oil production belong to the losers, whereas electricity production, investment industries and service industries belong to the winners. Does this mean that we have already the key to answer the employment question?

The impact on employment is determined by two effects: The first is the development of demand and production of the sector, the second the movement of its real wage rate. Both

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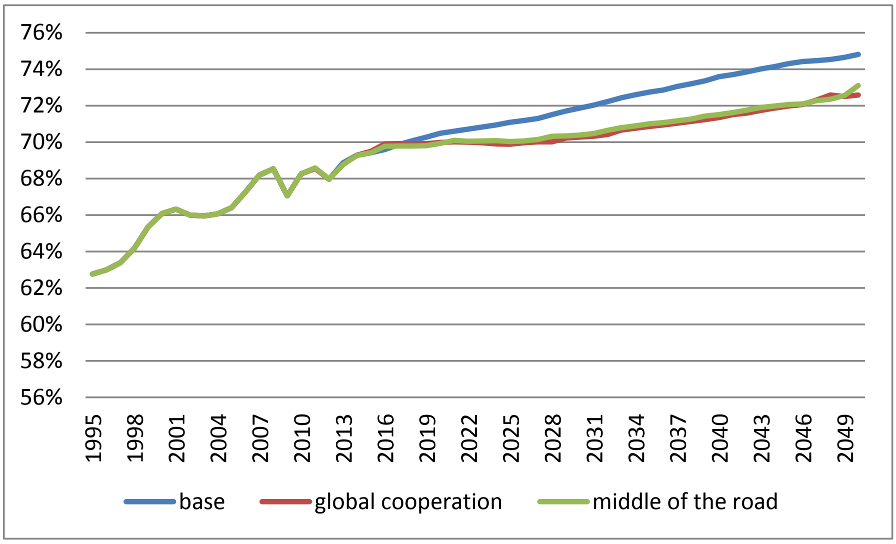
[18] See Meyer, 2012.

variables are endogenous to the sector and the country in question. A fall of production – as in the case of the basic industries as impact of the dematerialization program – does not necessarily mean that employment reduces with the same amount. The real wage rate depends on labour productivity of the sector, so that this elasticity and the elasticity of labour demand in respect to the real wage rate decides on the reaction of employment. This argumentation holds also in the opposite direction. In other words: There are no simple rules that tell us how the system will react on the policy mix.
The total effect on employed persons aggregated over all industries and all Member States of EU27 is given in figure 27 as a percentage of the number of persons in the age group 15-65.

Figure 27: The development of the number of working persons as a percentage of the number of persons of the age group 15 – 65 in EU27 in the three scenarios.



Source: GINFORS CECILIA2050

The employment quota is slightly lower in the alternative scenarios than in the baseline, which means that the negative effects induced by the impacts of dematerialization on basic industries have dominated the positive effects coming from investment industries and service sectors. Further we have to mention that the employment quota is much higher than at the actual margin. So this result can also be interpreted as normalization in relation to the extreme tension at the labour market in the baseline.

6 Conclusions

The simulations with GINFORS have shown that it is not easy to reach the targets, but it seems to be possible with the chosen policy mix. What we could not achieve are the very quick reductions of emissions after 2020. In our scenario a more continuous development has been found. But we start earlier and remain till 2030 below RCP 2.6.
A policy mix has been developed, which forces renewables in electricity production by feed-in-tariffs or quotas for renewables and presses e-mobility by regulations into the markets. The second big use of energy – heating of buildings – is reduced by subsidies for the investment in the energy efficiency of buildings. Further improvements of the energy intensity of heating and its carrier mix in the industry sector shall be reached by a second cap

and trade system for the non ETS sectors, which allows introducing here higher carbon prices than in the ETS. The ETS system primarily has to decarbonize process heat that is needed for the energy intensive basic industries covering the ETS. The simulations have shown that the carbon price is not able to play its role sufficiently. Two reasons could be found: For process heat price elasticities of the energy intensity and the elasticities of substitution between the energy carriers are rather low. Secondly: Somehow climate policy is a victim of its success. The higher the reductions of fossil fuel demand, the lower are the prices for fossil fuels and the higher is the carbon price to raise the shadow price to reach a further reduction of demand. In other words: The higher the carbon price the lower is the price of fossil fuels. Of course in our simulations the prices for fossil fuels have been exogenous, but the just described process is the reason for the following problem: It could be realized that in the average of country and sector more than halve of the rise of the carbon price was needed to compensate the low fossil fuel prices in comparison to the baseline.

Therefore during the simulation phase it became clear that with that policy mix the 2 DS target would not have been met with reasonable carbon prices. It further was clear that the problem was the carbon needed for process heat in the basic industries. The solution of the problem was an instrument of resource policy: The information program to improve material efficiency in the industry, which means that less material like metals, ceramics, chemicals etc. would be used and produced, which of course reduces carbon.

This is a first step in the direction of integrating resource policy and climate policy. Of course other instruments of dematerialization could be useful in the climate policy context. One further example is the recycling of metals and non- metallic minerals. Recycling in steel production for example means a reduction of coke inputs (basic oxygen furnace (BOF) technology) and a rise of electricity inputs (electric arc furnace (EAF) technology). Further research has to identify the potential of this approach.

We restricted our policy options renouncing on CCS and the use of biomass for energetic purposes (the decision of the EU for 10 % biodiesel was mentioned). From the resource point of view CCS is problematic, because the use of the resource rises. Further it may be questioned whether CO2 remains for thousands of years under the surface. The use of biomass induces scarcity of land use for feed and food. But biomass made of seaweed could be an attractive technology, because it would not restrict agricultural land use. Future research could implement this into GINFORS when there will be more information about this technology.

One lesson learned from the simulations with GINFORS is that this policy mix will induce during the next decades a strong push on investment. The total sum from 2015 to 2050 will be 7.4 trillion $ in real terms for EU27 additionally to the number of the baseline. This will only happen, if the investors have no doubt about the long run perspectives of climate policy. So we need soon a very clear long run commitment.

The simulations have shown further that the technology change induced by the assumed policy mix in the investment dominated first phase till 2035 will create higher GDP values than in the baseline. This will help for acceptance of the policy. After 2035 remaining capital costs and the costs of dematerialization will lower a bit the growth rates. But in total the sum of deviations is zero. A win-win situation is given, if a time preference is assumed.

The results of the scenario “Middle of the Road” are also remarkable, because they show that with a less active climate policy in the non-European countries (no carbon price, no investments in energy efficiency of buildings, less intensive push on renewables) CO2 emissions of 33 Gt can be reached in 2050, which is far below the RCP 4.5 number of 41.4 Gt. This offers perspectives for another policy option: To start from this seems to be promising because the assumed instruments of this scenario (less intensive push on renewables, e-mobility, and information for dematerialization) could be accepted for a broader community as for example the G20 countries. If this policy mix would be enlarged by sectoral agreements like recycling in the metals industry or substitution of oil engines by gas turbines in water transport, the reductions of emissions could be much deeper.

The general result is that the targets can be reached with conventional technologies. We do not have to wait till the big techno-jump solves our problems. But what we need is time to do in 35 years all the marginal steps from year to year that are described in the paper.

7 References

Almon, C. (1991). The Inforum approach to interindustry modeling. *Economic Systems Research*, 3(1), 1–8.

Arthur D. Little, Fh-ISI, & Wuppertal Institut (2005). *Studie zur Konzeption eines Programms für die Steigerung der Materialeffizienz in mittelständischen Unternehmen: Abschlussbericht*.

Barker, T., Lutz, C., Meyer, B., & Pollitt, H. (2011). Models for projecting the impacts of ETR. In P. Ekins & S. Speck (Eds.), *Environmental Tax Reform (ETR): A Policy for Green Growth*, Creating Sustainable Growth in Europe Series (pp. 175–203). New York: Oxford University Press.

Bowen, A. (2011). The case for carbon pricing. *Grantham Research Institute on Climate Change and the Environment and the Centre for Climate Change Economics and Policy at the London School of Economics and Political Science: Policy brief*, December 2011.

Clarke, L. E., Edmonds, J. A., Jacoby, H. D., Pitcher, H. M., Reilly, J. M., & Richels, R. G. (2007). Scenarios of greenhouse gas emissions and atmospheric concentrations. Sub-report 2.1A of Synthesis and Assessment Product 2.1 by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research. Department of Energy, Office of Biological and Environmental Research, Washington, 7 DC., USA.

Couture, T. & Gagnon, Y. (2010). An analysis of feed-in tariff remuneration models: Implications for renewable energy investment. *Energy Policy*, 38(2), 955–965.

Deetman, S., Hof, A. F., & van Vuuren, D. P. (2014). Deep CO_2 emission reductions in a global bottom-up model approach. *Climate Policy*, 15 May 2014.

demea (2010). Deutsche materialeffizienzagentur. vermat. kennziffern, basis: 451 verifizierte potenzialanalysen. ergebnis der bisherigen potenzialanalysen. www.demea.de/dateien/standardfolien/demea-10-05-10-web-version-standardfolien.pps.

Dietzenbacher, E., Los, B., Stehrer, R., Timmer, M., & de Vries, G. (2013). The construction of World Input-Output Tables in the WIOD Project. *Economic Systems Research*, 25(1), 71–98.

Distelkamp, M., Meyer, B., & Meyer, M. (2010). Quantitative and qualitative effects of a forced resource efficiency strategy: Executive summary. ResourceEfficiency Paper 5.4. Summary Report of Task 5 within the framework of the "Material Efficiency and Resource Conservation" (MaRess) Project.

ECORYS & ECN (2012). The energy efficiency investment potential for the building environment: Two approaches. Client: Directorate General for Energy of the European Commission. Rotterdam. 7 November 2012.

EEA (2013). Towards a green economy in Europe: EU environmental policy targets and objectives 2010-2050. *European Environment Agency: EEA Report*, 8/2013.

ERTRAC & EPoSS (2009). The electrification approach to urban mobility and transport. Strategy Paper, Version 5.0, 24.01.2009, European Road Transport Research Advisory Council, European Technology Platform on Smart Systems Integration.

European Commission (2013). *EU energy, transport and GHG emissions: Trends to 2050: Reference Scenario 2013*.

EWI (2010). Potenziale der Elektromobilität bis 2050: Eine szenarienbasierte Analyse der Wirtschaftlichkeit, Umweltauswirkungen und Systemintegration. Endbericht, Juni 2010, Energiewirtschaftliches Institut an der Universität zu Köln.

Fischer, H., Lichtblau, K., Meyer, B., & Scheelhaase, J. (2004). Wachstums- und Beschäftigungsimpulse rentabler Materialeinsparungen. *Wirtschaftsdienst*, 4, 247–254.

Giljum, S., Behrens, A., Hinterberger, F., Lutz, C., & Meyer, B. (2008). Modelling scenarios towards a sustainable use of natural resources in Europe. *Environmental Science & Policy*, 11(3), 204–216.

Giljum, S., Hinterberger, F., Lutz, C., & Meyer, B. (2009). Accounting and modelling global resource use. In S. Suh (Ed.), *Handbook of Input-Output Economics in Industrial Ecology*, volume 23 of *Eco-Efficiency in Industry and Science* (pp. 139–160). Springer Netherlands.

Huppes, G. & Huele, R. (2014). Building blocks for climate policy instrumentation aligned to governance story lines and scenarios. Deliverable 3.3, Task 3.5 of the CECILIA2050 Project. http://cecilia2050.eu/.

IEA (2012). *Energy Technology Perspectives 2012: Pathways to a Clean Energy System*. Paris: OECD/IEA.

Kristof, K., Lemken, T., Roser, A., & Ott, V. (2008). Untersuchung der Wirksamkeit des Programms zur Verbesserung der Materialeffizienz: Endbericht. Im Auftrag des Bundesministeriums für Wirtschaft und Technologie (AZ I D 4 – 02 08 15).

Meyer, B. (2012). Macroeconomic modelling of sustainable development and the links between the economy and the environment: Final Report to the EU Commission. *GWS Research Report*, 2012(1).

Meyer, B., Distelkamp, M., & Wolter, M. I. (2007a). Material efficiency and economic-environmental sustainability. Results of simulations for Germany with the model PANTA RHEI. *Ecological Economics*, 63(1), 192–200.

Meyer, B., Lutz, C., Schnur, P., & Zika, G. (2007b). National economic policy simulations with global interdependencies: A sensitivity analysis for Germany. *Economic Systems Research*, 19(1), 37–55.

Meyer, B. & Uno, K. (1999). COMPASS - Ein globales Energie-Wirtschaftsmodell. *ifo-Studien*, 45, 703–718.

Oakdene Hollins (2011). The further benefits of business resource efficiency. March 2011 - Final report. A research report completed for the Department for Environment, Food and Rural Affairs. London.

Prognos (2013). Ermittlung der Wachstumswirkungen der KfW-Programme zum Energieeffizienten Bauen und Sanieren. 08.03.2013, Berlin, Basel.

Riahi, K., Grübler, A., & Nakicenovica, N. (2007). Scenarios of long-term socio-economic and environmental development under climate stabilization. *Technological Forecasting and Social Change*, 74(7), 887–935.

Riahi, K. & Nakicenovic, N. (2007). Greenhouse gases - Integrated assessment. *Technological Forecasting and Social Change*, Special Issue 74(7).

Ringel, M. (2006). Fostering the use of renewable energies in the European Union: the race between feed-in tariffs and green certificates. *Renewable Energy*, 31(1), 1–17.

Schaeffer, M. & van Vuuren, D. (2012). Evaluation of IEA ETP 2012 emission scenarios. *Climate Analytics Working Paper*, 2012(1).

Smith, S. J. & Wigley, T. M. L. (2006). Multi-gas forcing stabilization with the MiniCAM. *Energy Journal*, Special Issue 3, 373–391.

Stern, N. (2007). *The Economics of Climate Change: The Stern Review*. Cambridge University Press.

United Nations (2013). World Population Prospects: The 2012 Revision, key findings and advance tables. *UN Department of Economic and Social Affairs, Population Division: Working Paper*, ESA/P/WP.227.

Uno, K., Ed. (2002). *Economy-Energy-Environment Simulation: Beyond the Kyoto Protocol*, volume 20 of *Economy & Environment*. Springer Netherlands.

van Vuuren, D. P., den Elzen, M. G. J., Lucas, P. L., Eickhout, B., Strengers, B. J., van Ruijven, B., Wonink, S., & van Houdt, R. (2007). Stabilizing greenhouse gas concentrations at low levels: An assessment of reduction strategies and costs. *Climatic Change*, 81(2), 119–159.

van Vuuren, D. P., Eickhout, B., Lucas, P. L., & den Elzen, M. G. J. (2006). Long-term multi-gas scenarios to stabilise radiative forcing - Exploring costs and benefits within an integrated assessment framework. Multigas mitigation and climate policy. *The Energy Journal Special Issue*.

Wiebe, K. S., Bruckner, M., Giljum, S., & Lutz, C. (2012). Calculating energy-related CO_2 emissions embodied in international trade using a global Input-Output Model. *Economic Systems Research*, 24(2), 113–139.

Wiedmann, T., Lenzen, M., Turner, K., & Barrett, J. (2007). Examining the global environmental impact of regional consumption activities – Part 2: Review of Input-Output Models for the assessment of environmental impacts embodied in trade. *Ecological Economics*, 61(1), 15 – 26.

Wise, M., Calvin, K., Thomson, A., Clarke, L., Bond-Lamberty, B., Sands, R., Smith, S. J., Janetos, A., & Edmonds, J. (2009). Implications of limiting CO2 concentrations for land use and energy. *Science*, 324(5931), 1183–1186.

Zelljadt, L. (2014). Scenarios for international climate policy instruments. Task 5.1 of the CECILIA2050 Project. http://cecilia2050.eu/.