CECILIA 2050
OPTIMAL EU CLIMATE POLICY

POLICY BRIEF Nr. 3

April 2015

Development of Scenarios to 2030 and 2050

This policy brief summarises the simulation results of three models used to track the development of climate policy scenarios in the CECILIA2050 project. Together the models represent a broad methodological spectrum of economic environmental modelling. In addition, a set of building blocks for coherent instrument mixes in respect to European climate governance was developed, defining the overall research framework.

Key Conclusions

Five key conclusions can be drawn from the underlying research. A much broader picture is offered in the detailed reports, available online: http://cecilia2050.eu/publications.

- **Conclusion 1:** A carbon price alone will meet the climate targets only under restrictive assumptions
- **Conclusion 2:** A **sectoral strategy** calls for further instrument implementation to decarbonise electricity production, electrify road transport and improve the energy efficiency of buildings
- **Conclusion 3:** A **core strategy**—the sectoral strategy combined with a carbon price—is (nearly) able to meet the global "two degrees" target and the EU 80% emissions reduction target
- **Conclusion 4:** Resulting from the promotion of renewables and improvements in energy efficiency, an investment boom will be induced in the EU
- **Conclusion 5:** Climate policy will have positive effects on GDP in the EU

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Conclusion 1: A carbon price alone will meet the climate targets only under restrictive assumptions

The partial equilibrium energy system model, ETM-UCL, describes the interdependencies between the different sectors of the European energy system, assuming perfect markets and perfect foresight, through which total discounted system costs are minimised. **The simulations showed that even in this idealised picture of the European economy a very high carbon price, i.e., EUR 240 in the year 2050 (in 2010 prices), is required to meet the 80% reduction target for CO_2 emissions (in relation to 1990 levels) in the EU.** This result can only be achieved by allowing the use of technological options like CCS for fossil and biomass carriers in the power sector and for some carriers in several other ETS sectors. In the power sector, CCS on biomass (producing net negative emissions) is essential; otherwise the model does not generate the needed emissions abatement level.

Box 1: The ETM-UCL Model

The European Times Model (ETM-UCL) is a dynamic partial equilibrium energy system model with an inter-temporal objective function to minimise total discounted system costs, based on the TIMES model generator. It is a technology rich, bottom-up model with perfect foresight and covers energy flows across supply side and demand side sectors. The model comprises a total of thirty-one countries (EU28 plus Norway, Iceland and Switzerland) grouped into 11 regions along with a "global" region. Each region is modelled with supply, power generation and demand side sectors and is linked through trade in crude oil, hard coal, pipeline gas, LNG, petroleum products, biomass and electricity. The global region, however, is not characterised in the same way as the European regions and may be considered simply as a "basket of resources" from which other regions may import the above products (except electricity). Values for the exogenous variables, GDP, population and extraction prices of fossil fuels, were taken from the IEA 2012 Energy Technology Perspectives.

Source: Drummond (2014)

The main reasons for this are the ambitious target itself and the low extraction prices for fossil fuels induced by a drastic reduction in demand in the case of the "two degrees" development path. For this case the IEA 2012 Energy Technology Perspectives publication gave the following reductions in fossil fuel prices compared to the baseline: -50% (coal), -42% (crude oil) and -30% (gas).

If market imperfections are considered, a further cause for a high carbon price is given: the elasticities of substitution and the price elasticities of demand functions are low. The GINFORS model reflects these influences because all price elasticities are estimated econometrically. Of course it can never be excluded that induced innovations may raise these price elasticities in the future. Simulations with GINFORS showed that even with a much higher carbon price than realised in the ETM-UCL simulations, the emission targets are still not met with the carbon price as the only instrument.

Box 2: The GINFORS Model

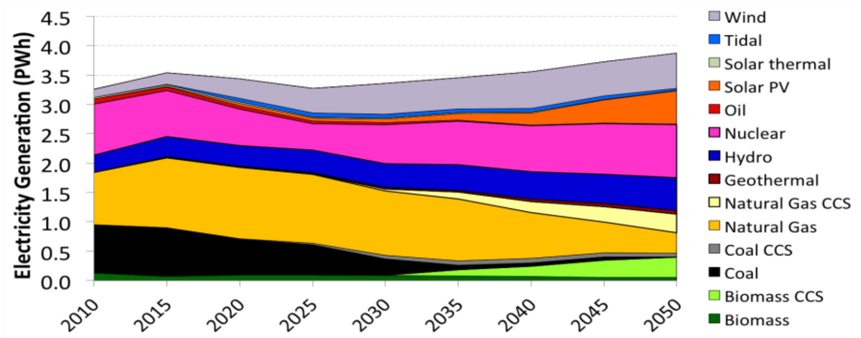
GINFORS is a global multi-county/multi-sector economic–environmental model. All countries in the EU27, all OECD countries, the BRIC countries and a "Rest of the World" region are explicitly modeled. It is a dynamic model that depicts the global economic, social and environmental relations for each country in deep product group detail (59), including the inputs of capital (fixed and intermediate), labour markets and the developments of all components of final demand depending on relative prices. The prices of all products are explained by the unit costs of the 35 sectors. The macro variables are given by explicit aggregation of the sectoral variables determining GDP as the aggregate of sectoral value added. International trade between all countries is depicted bilaterally for 59 product groups with price dependent structures. The energy intensities for heating, mobility and electricity for the use of machinery and household appliances are explained by relative prices for each of the 35 sectors and private households in each of the 39 countries. The carrier structure also depends on their price relations. All parameters of the model are estimated econometrically. Population of the different countries is exogenous and was taken from the UN medium variant forecast. The extraction prices of fossil fuels were obtained from the IEA 2012 Energy Technology Perspectives

Source: Meyer et al. (2014)

Decarbonisation of electricity production is possible through the use of three technologies: nuclear, CCS and renewables. In all simulations nuclear did not play an increasing role due to its lack of public feasibility. In the ETM-UCL model, nuclear capacity was not allowed to exceed 2010 levels, as an exogenous constraint.

The ETM-UCL simulations demonstrated (as illustrated in Figure 1, above) that **the carbon price will induce a mixture of the three technologies with substantial implementation of CCS in the power sector, particularly on biomass, producing negative emissions in the power sector by 2050 (at a CO_2 intensity of -25gCO_2/KWh).** In the other ETS sectors CCS will also be used primarily for large-scale incineration. This is also introduced by assumption in the EXIOBASE simulations.

Figure 1: Projected Electricity Generation in the EU (2010-2050) in the ETM-UCL ("Policy Success" Scenario)



Source: Solano & Drummond (2014)

The ETM-UCL model explicitly depicts individual road vehicle categories and their associated fuel consumption. The carbon price primarily induces higher engine efficiency and a general fuel substitution from gasoline to diesel in cars and from diesel to biofuels (16%) and hydrogen (49%) in heavy goods vehicles, with a small shift to electricity (7%) in light goods vehicles. The rather modest shift from fossil fuels (or high CO_2-intensity fossil fuels) produced by the ETM-UCL compared to the assumptions in the other two modelling approaches is a result of anticipated high investment costs associated with the transport sector in the ETM-UCL. Indeed, it is considered more cost effective to achieve negative CO_2 emissions in the power sector by 2050 (through the use of biomass with CCS) than to produce extensive decarbonisation in this sector. This highlights the need for instruments in the policy mix dedicated to producing innovation and cost reduction in technologies and infrastructure and preventing over-reliance on abatement in individual sectors or sub-sectors resulting from the use of a few limited technologies.

The simulations with the ETM-UCL model further describe the effects of a rising carbon price on the energy carriers and technologies employed for space and water heating in buildings.

Conclusion 2: A sectoral strategy calls for further instruments to decarbonise electricity production, electrify road transport and improve the energy efficiency of buildings

A great number of alternative policy simulations were done with the GINFORS model to meet the international climate target of reducing the effects of global warming to a maximum of two degrees. The results showed that, in addition to the carbon price, further sectoral instruments have to be installed to reach the decarbonisation of electricity production and the other ETS sectors, to electrify road transport and to improve the energy efficiency of buildings.

The ETM-UCL simulations showed that the technical option, CCS, is a substantial part of the mix needed to achieve results. However, CCS has some problematic characteristics: it raises the energy inputs and it is questionable whether the sequestered carbon will remain safely contained. The latter problem may diminish public acceptance, as is the case already observed in Germany. Given the controversial nature of CCS, the question arises: what are the consequences of excluding CCS in policy formulation?

Decarbonisation of electricity production and the other ETS sectors

To analyse this alternative the GINFORS simulations explicitly excluded CCS as a technology option. Instead, decarbonisation of electricity production was induced by rising renewable shares. It is debatable whether the carbon price will induce the large and rapid investment in renewables required due to policy uncertainty and the "lock-in" of existing installations. Therefore, feed-in-tariffs or a quota system should remain, at least in the short term, guaranteeing a market for renewables. Different instrument specifications are possible. In the case of a quota system, the type of the renewable could be determined by the market based on the unit costs of the alternatives. In addition, to avoid a destabilisation of the carbon price, supply and price management in the ETS will be necessary.

The exclusion of CCS in other ETS sectors creates a problem: it will not be possible to decarbonise their production to a large extent because even with high carbon prices, the low extraction prices (especially for coal) in relation to the relatively low price elasticities will not create high enough shadow prices to diminish the carbon intensive inputs substantially.

Box 3: The EXIOBASE model

> The EXIOBASE Input Output model distinguishes 44 trade linked countries with 129 sectors per country. The base year for the structural relations of the model is 2000. For the purpose of the study the countries have been aggregated into four regions: EU27, other High Income Countries, the BRICS and the "Rest of the World" including most African and Middle Eastern countries. Structural changes in the economy and the energy system are given by exogenous assumptions. GDP growth was taken from the OECD growth perspective, and energy efficiency improvements were forecasted by trends.

Source: De Koning et al. (2014)

This problem might be solved without the use of traditional climate policy instrumentation; the discussion on material inputs in the broader context of resource efficiency has shown that there are substantial inefficiencies in material inputs in all sectors of the economy due to market failures. This discussion will induce the implementation of resource efficiency policy instruments including consulting and information programs to reduce the coefficients of material inputs in all stages of production. In the end, demand for basic products and their production will be reduced. Such dematerialisation policies are already part of programs for the general improvement of resource efficiency targeting, primarily for metals and other minerals.

Electrification of road transport

With the decarbonisation of the power sector it makes sense to use electricity for mobility. Since fuel substitution in air transport is currently only possible between bio and fossil fuels and is restricted in water transport (gas turbine against heavy oil and diesel), achieving efficiency gains in engines is the main source of CO_2 reductions that can be reached using technical changes. Railroad traffic is to a large extent already based on electricity. However, the largest potential for CO_2 reductions rests with road transport.

EXIOBASE assumes a 95% share of plug-in hybrids and battery-electric engines for cars in 2050, whilst the GINFORS simulations assume that the fuel mix for all land transport achieves 80% electricity, 10% biofuels and 10% fossil fuels. The policy instrument mix needed to reach the exogenous targets imposed in EXIOBASE and GINFORS is not part of the modelling exercise but could include regulations and economic instruments favouring electricity and discriminating against fossil fuel based cars, such as emission standards, parking regulations and taxes on fossil fuel based cars with the resulting revenue given to subsidise investment in the infrastructure of e-mobility. In the GINFORS simulations the EU ETS is complemented by a second cap and trade system covering all non-ETS sectors. As such, transport activities of all descriptions fall under this parallel system.

Improvement of the energy efficiency of buildings

The building sector suffers from very strong market failures concerning the necessary improvement of the energy efficiency of buildings. In the future a carbon price might help, but it will not do the work alone. According to the ETM-UCL model, the building and residential sector sees a 36% reduction in CO_2 emissions delivered chiefly by increases in end use product efficiency, some space heating electrification and the use of heat pumps

In the EXIOBASE and the GINFORS simulations it is assumed that the carbon price influences the carrier mix and the efficiency of the heating system. In the GINFORS simulations, however, the stronger influence on energy intensity for heating in the industry sector and households comes from a subsidy for investment in windows, the insulation of walls and heating equipment. The policy reaches a renovation rate of buildings of 2.3% per year till 2050. The relations between the subsidy, the investment and the effect on energy efficiency are based on the experience with a specific program that KfW developed for Germany. The reduction in energy intensity of heating against the baseline is 55% by 2050.

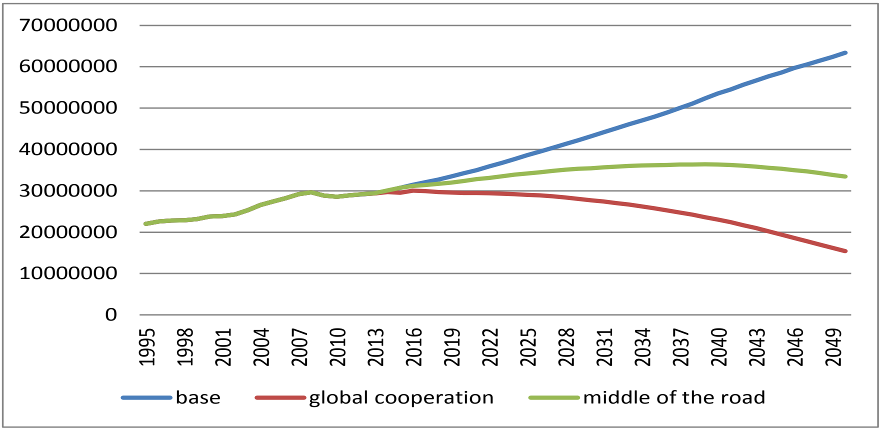
Conclusion 3: A core strategy—the sectoral strategy combined with a carbon price—is (nearly) able to meet the global “two degrees” target and the European 80% emissions reduction target

Next a core strategy—a carbon price combined with the decarbonisation of process heat especially in the power sector, electrification of land transport and improvements in the energy efficiency of buildings—was proposed and analysed in the GINFORS simulations. Two alternative scenarios were calculated, which differ concerning the international alignment of climate policy:

- For the **“Global Cooperation” scenario,** the policies discussed are introduced globally per a global climate agreement. The renewable quota in power generation reaches 90% in 2050, the share of electricity inputs in total energy inputs of road transport rises up to 80%, and the renovation rate of buildings is pushed till 2050 to 2.3%. The carbon price for the ETS sectors rises to EUR 230 by 2050 and to EUR 460 in the non ETS sectors.

- In the **"Middle of the Road" scenario,** the EU countries follow the same policy path as in the "Global Cooperation" scenario, but the Non-European countries do not introduce the carbon price, raise the renewables quota to only 70% in 2050 and do not introduce a program for the improvement of energy efficiency in buildings. They follow the EU in realising e-mobility, but of course the effects are smaller because electricity is not produced entirely from renewables.

Figure 2: World CO_2 emissions from 1995 to 2050 in kilo tons in the three scenarios.

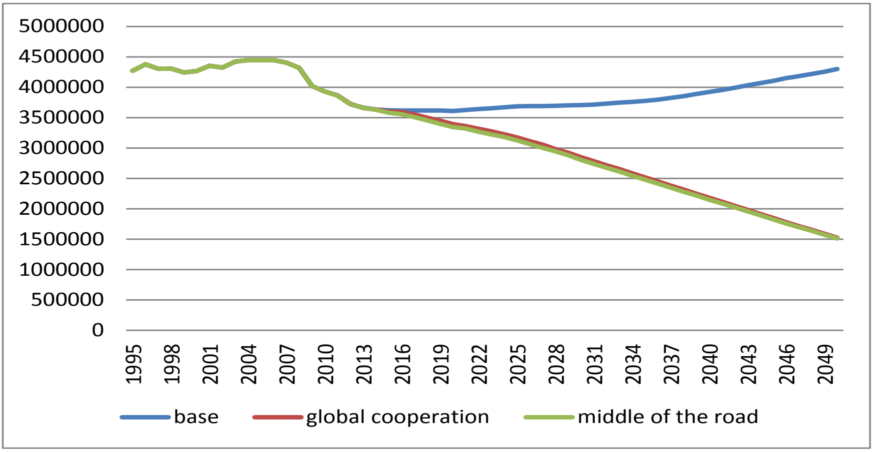


Source: Meyer et al. 2014

Figure 2 shows the development of CO_2 emissions in the world by 2050 for the baseline and the alternative scenarios. In the "Global Cooperation" scenario a level of 15.4 $GtCO_2$ is reached in 2050, 3 $GtCO_2$ more than RCP 2.6 demands. These 3 $GtCO_2$ are less than the reductions achieved during the last four years of the simulation phase. So, if the program is prolonged, the target would be met in 2053 or 2054. Whilst this is not a negligible difference, it is unlikely to be significant in the long term. The "Middle of the Road" scenario reaches 33.4 $GtCO_2$ emissions—a value much lower than the 42.4 $GtCO_2$ required by the RCP 4.5 target.

Figure 3 shows CO_2 emissions in the EU27 for the three scenarios. In the EU the alternative scenarios reach 1.5 $GtCO_2$ emissions in 2050. This is more than the target of the Commission—a reduction of at least 80% in relation to the 1990 emissions—allows. The deviation in terms of the reduction target is about 10%.

Figure 3: CO_2 emissions in the EU27 in kilo tons in the three scenarios.



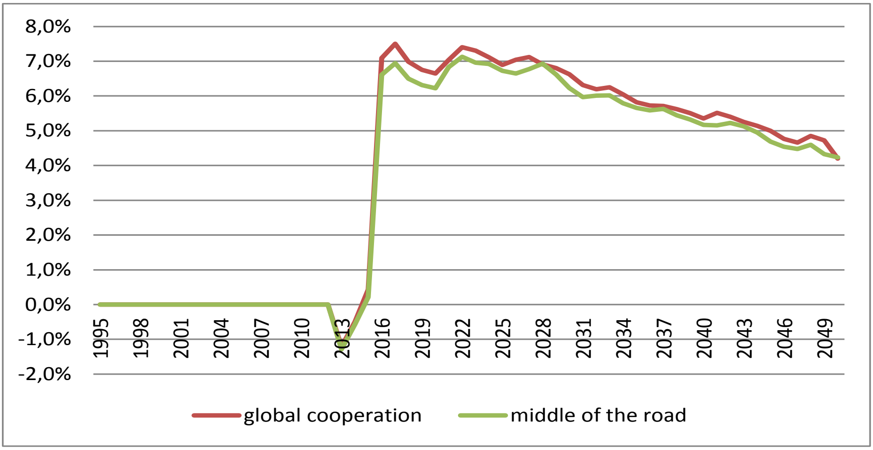
Source: Meyer et al. 2014.

Conclusion 4: Resulting from the promotion of renewables and improvements in energy efficiency, an investment boom will be induced in the EU

Figure 4 presents the percentage deviations from the baseline of gross fixed capital formation in constant 1995 dollars in the "Global Cooperation" and "Middle of the Road" scenarios. This impact is a result of investments in renewables and grids as well as in improvements in the energy efficiency of heating. In the "Global Cooperation" scenario the deviations are a bit higher because positive impacts are transferred from the investments in renewables in countries outside the EU via international trade. This effect is not very strong, however, because there is no additional investment in heating installations outside of the EU. The deviations reduce over time because the program also has a time profile.

Of course the strong rise at the beginning of the simulation phase seems to be unrealistic. A less steep development is more plausible. Furthermore, it has to be mentioned that the figure includes not only the direct effects of investment in grids, renewables and the stock of buildings but also the induced indirect investments. Such indirect investments will be induced for example in the chemical industry to raise the capacity for insulation material and in the metal industry, where the capacity has to be higher because of the demand for grids.

Figure 4: Gross fixed capital formation in the EU27 in constant dollars. Deviations from the baseline shown as percentages.



Source: Meyer et al. 2014.

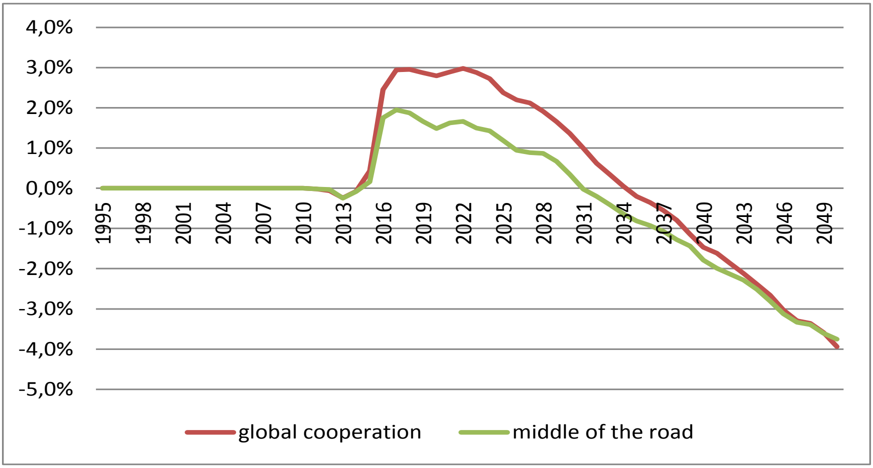
Conclusion 5: Climate policy will have positive effects on GDP in the EU

The investment boom induced will end in the early 2030s. After this point negative deviations from the baseline will occur. However, over the whole period the sum of the deviations is net positive in the "Global Cooperation" scenario, and if a time preference is assumed, the positive effect becomes more pronounced.

The economic implications for GDP are mainly triggered by two effects: investment in renewables, grids and the energy efficiency of buildings on the one side and a dematerialisation program on the other.

The investments represent a direct goods demand and insofar enlarge the circular flow of income inducing further demand effects, which raises GDP. On the other side, capital costs rise, which means higher prices and indirectly less demand. The direct demand effect is related to the level of investment and thus stable over time, but the capital cost effect is related to the stock of capital and therefore it grows.

Figure 5: GDP in the EU27 in constant dollars. Deviations from the baseline shown as percentages.



Source: Meyer et al. 2014.

The interplay of both explains how at first strong positive deviations from the baseline are observed, which later decrease over time and finally become negative. Compared with the baseline, dematerialisation has stronger effects on costs and prices for sectors at the end of the supply chain in the BRIC countries than in Europe. This occurs because the BRIC countries show less material efficiency in the baseline than European countries.

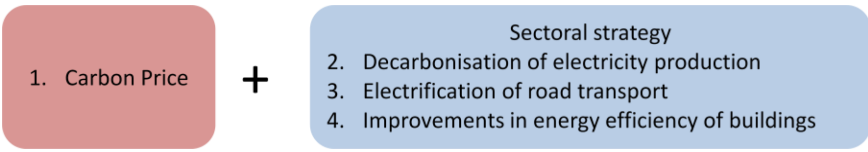
In the “Middle of the Road” scenario a similar time profile can be observed for the deviations of GDP from the baseline as in the “Global Cooperation” scenario, but the positive deviations in the first period are lower. The reason for this is because investment in Non-European countries is lower in this scenario than in the “Global Cooperation” scenario, which in turn reduces exports from Europe to Non-European countries. Further, the capital costs are lower in the

Non-European countries, which reduces the competitiveness of the EU. Regardless, the decrease in GDP in this scenario is very low.

Final Remarks

The simulations showed that a **core strategy** consisting of four elements has the potential to reach Europe's climate targets without economic risks (Figure 6). **A robust carbon price must be combined with a sectoral strategy that decarbonises electricity production, electrifies road transport and improves the energy efficiency of buildings.**

Figure 6: The core strategy



Concerning the decarbonisation of the power sector, three technologies can achieve this result: nuclear, CCS and renewables. In the GINFORS alternative policy simulations, nuclear followed the baseline level taken from the EU reference scenario and IEA 2012 country nuclear profiles due to a lack of public feasibility. In the ETM-UCL simulations the level of nuclear power was held constant. In the case of CCS such a clear judgement concerning public feasibility cannot be given. There are some who expect dangerous side effects to accompany the application of CCS. However, others disregard the potential hazards or are convinced that further research will avoid these problems. To this end we need a discussion about the acceptance of CCS in the EU, and if the expectation of severe risks cannot be eliminated, we need a policy decision. Our simulations showed that the targets may be met with (ETM-UCL and EXIOBASE) or without (GINFORS) CCS. If CCS is excluded, subsidies for renewable energies might be necessary to avoid the "lock-in" of existing fossil fuel installations. In the GINFORS simulations a quota for the total renewables was introduced leaving the choice of the type of technology open to the market depending on the relation of unit costs.

The electrification of road transport has a lot of potential for the decarbonisation of the transport sector (EXIOBASE and GINFORS). How this potential will be used concerning a concrete policy mix that favours "clean" technologies and discriminates against cars run on fossil fuels is an open question, but it could be shown that the choice of the vehicle technologies will still be open to the market.

Illustrated in Figure 6, the EXIOBASE and the GINFORS simulations clearly demonstrated that a partial core strategy consisting only of (1) an economy wide carbon price accompanied by (2) the decarbonisation of the power sector and (3) the electrification of road transport is not able to meet the targets. The simulations illustrated that a fourth element is needed to close the gap, i.e., (4) improvements in the energy efficiency of buildings. Of course this does not mean that other pathways might not also be successful. For instance, additional findings of the GINFORS analysis showed that an information campaign focused on the dematerialisation of production would likely curb emissions in the industrial sector, also helping to close the gap.

These economic models revealed that a combination of an economy wide carbon price with the sectoral strategy described above has the potential to reach the climate targets. The exact combination of economic instruments or regulations and their concrete formulation to push e-mobility, the inputs of renewables in the power sector and the renovation rate of buildings in combination with an economy wide carbon price must be considered in future research.

Further Reading

De Koning, Arjan; Huppes, Gjalt; Deetman, Sebastiaan. 2014. Scenarios for 2050 for a 2-degrees world. Using a four regions trade linked IO-model with high sector detail. Leiden, Institute of Environmental Sciences (CML) Leiden University.

Drummond, Paul. 2014. Scenarios for a Low-Carbon Europe for 2050. WP3 Deliverable 3.4. London: University College London.

Huppes, Gjalt; Huele, Ruben. 2014. Building Blocks for Climate Policy Instrumentation aligned to Governance Story lines and Scenarios. WP3 Deliverable 3.3. Leiden, Institute of Environmental Sciences (CML) Leiden University.

Meyer, Bernd; Meyer, Mark; Distelkamp, Martin, 2014. Macroeconomic routes to 2050. WP3 Deliverable 3.2. Osnabrück, Gesellschaft für Wirtschaftliche Strukturforschung.

Solano, Baltazar; Drummond, Paul. 2014. Techno-Economic Scenarios for Reaching Europe's Long-Term Climate Targets Using the European TIMES Model (ETM-UCL) to Model Energy System Development in the EU. WP3 Deliverable 3.1. London, University College London.

Research Background

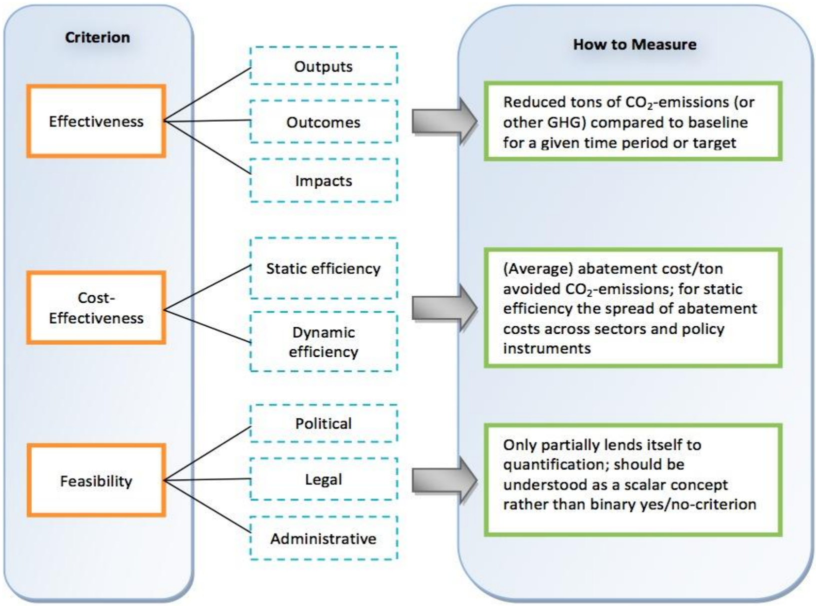
The results described in this policy brief were taken from five research papers: Solano and Drummond (2014) simulated techno- economic scenarios for reaching Europe's long term climate targets with the European Times model ETM-UCL, De Koning et al. (2014) calculated scenarios for 2050 for a 2- degrees world with the multiregional input-output model, EXIOBASE and Meyer et al. (2014) estimated the macroeconomic routes to 2050 with the global multicountry/multisector macro-econometric model, GINFORS. An overview of the three simulation studies with a special focus on sectoral effects can be found in Drummond (2014). The building blocks for coherent policy mixes consistent with governance concepts were developed by Huppes and Huele (2014). Scenarios for international climate policy instruments were proposed by Zelljadt (2014).

This policy brief was written by Bernd Meyer and edited by Paul Drummond, Matthias Duwe and Nick Evans.

The CECILIA2050 concept of Optimality

In economics 'optimality' is generally understood to be the most favourable relationship between an outcome and the resources necessary to achieve it and the outcome itself. If the outcome itself is not predefined, an assessment of optimality would determine the level of both the outcome and resource input, as would occur in a cost-benefit analysis. In determining the optimality of EU climate policy, however, the output is already given in the form of the EU's short and long-term GHG emission reduction targets. Optimality therefore becomes a discussion of achieving these targets with the least cost to society. Such a task is not straightforward. Finding the 'least-cost' pathway to meeting these targets involves inherent uncertainty and a long-term view; many technological, organisational, social or other changes required to decarbonise are still yet to be identified and developed. The capacity to absorb any changes must also be considered; public acceptance, economic and social impacts and the legal and procedural requirements of existing, expanded or new policy instruments must be considered. As such, the CECILIA2050 project has developed a broad definition of 'optimality' that extends beyond the purely economic concept and considers real-world constraints.

Figure: Broad Definition of 'Optimality' – Key Criteria



A comprehensive literature review determined that no universally agreed upon set of criteria exists for judging the optimality of a policy instrument or mix of instruments, however there is broad overlap between different approaches. Criteria may be broadly arranged into three categories and subcategories, as in the figure above.

The CECILIA2050 project has been set up as a three-year research project, funded by the European Union's 7th Framework Programme for Research. Running until August 2015, it brings together ten leading research institutions from eight EU countries to assess the performance of the existing climate policy mix, and to map pathways towards future climate policy instrumentation for the European Union, with a prime focus on economic instruments.

CEILIA2050 Policy Briefs – this policy brief is part of a series that discusses the results of the CECILIA2050 project. Here, we focus on the results of the third Work Package, in which the building blocks for a coherent future EU climate policy mix were developed using forward-looking scenarios calculated by three different models. An overview of the three simulation studies then focused on sectoral impacts.

All underlying reports can be accessed at: www.cecilia2050.eu.

The research leading to these results has received funding from the European Union Seventh Framework Programme (FP7/2007-2013) under Grant Agreement no. 308680 for the research project CECILIA2050.