



By ENCI-LowCarb Project (2009-12) supported by the EU 7th Framework Program



The Model REMIND-D and Low-Carbon Scenarios for Germany

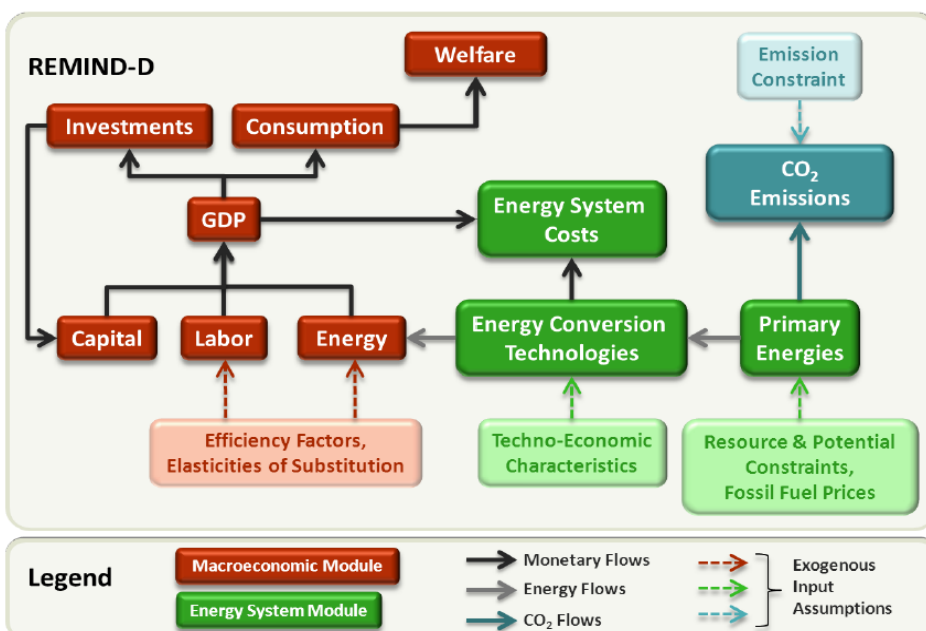
Traditionally, energy-economy models for energy scenarios have been either top-down, macro-economic models or bottom-up engineering models. Both concepts have their specific strengths and weaknesses. Basically, they analyze different aspects of the energy economy. The REMIND models, developed at the Potsdam Institute for Climate Impact Research, are hybrid models that integrate a detailed bottom-up energy system into a top-down representation of the macro economy. Such models are known as hard-linked hybrid models. For the current project, the REMIND-D model was developed to represent Germany, based on the global REMIND-R model.

The macro-economic module is a neoclassical growth model based on a production function. GDP is produced by aggregating the production factors capital, labor and energy. The production factor energy is subdivided into the final energy demands of the industry and of the residential & commercial sector, as well as the energy service demand of the transport sector. The model maximizes the welfare, *i.e.*, the intertemporal sum of logarithmic per capita consumption. CO₂ emission reductions are enforced

with an emission budget over the optimization period. Constraints, including emission budgets, always lead to net mitigation costs in optimization models. These are expressed in the model output as discounted GDP losses over the scenario period. Thus, with this model, scenarios with forced emission reductions will always result in net costs.

The energy system module in REMIND-D converts primary energy to secondary and final energies as well as to energy services in the transport sector. It includes, for example, power plants that convert coal or solar irradiation to electricity, which is demanded by the macroeconomic module. Inputs include renewable energy potentials, price forecasts for fossil fuels, investment costs, and operating costs as well as efficiencies of energy conversion technologies and of transport vehicles. With the input data used, the model's baseline scenario will lead to about 40% CO₂ reductions by 2050, relative to 1990.

The REMIND-D model was used to develop a series of three scenarios, all leading to 85% reduction of CO₂ emissions from fossil fuel combustion relative to 1990.



Overview of the REMIND-D model with physical and monetary flows. Source: Schmid, Bauer & Knopf, 2012

(http://www.feem.it/use_rfiles/attach/20122211_032394NDL2012-009.pdf).

ENCI-LowCarb project partners

RAC-France (Coordinator) Climate Action Network – France att. Meike Fink, www.rac-f.org
 Germanwatch att. Jan Burck, www.germanwatch.org INFORSE-Europe att. Gunnar Olesen www.inforse.org/europe
 CIRED - Centre International de Recherche sur l'Environnement et le Développement att. Sandrine Mathy www.centre-cired.fr
 PIK Potsdam Institute for Climate Impact Research att. Brigitte Knopf www.pik-potsdam.de

The Three Low-Carbon Scenarios for Germany

Civil society and stakeholders from the transport and energy sectors were involved in the definition of boundary conditions for the model. They also evaluated the scenarios in a participatory approach.

Following the first stakeholder dialogues, three scenarios were developed:

- The 'Continuation' scenario, which enforced the developments that were deemed likely by stakeholders in the transport and electricity sectors
- The 'Paradigm Shift' scenario, which included the developments that were perceived as desirable by the majority of the stakeholders.
- The 'Paradigm Shift +' scenario, which additionally allowed for the deployment of several technological mitigation options, that stakeholders judged as undesirable or discussed controversially. This included liquid biofuels as well as carbon capture and storage (CCS).

The model results indicate that the 'Continuation' scenario leads to a carbon lock-in, where the majority of the cumulative CO₂ emissions by 2050 are used for road transport and coal-power plants. This lock-in and the CO₂ reduction requirements combined to slow down economic growth with a cumulative GDP loss of 3.5% until 2050, leading to undesired effects for society. One such undesired effect is that personal transport is forced to decrease from 13000 person-km (p-km) per year today to 9000 p-km in 2050. This renders ambitious domestic mitigation extremely challenging.

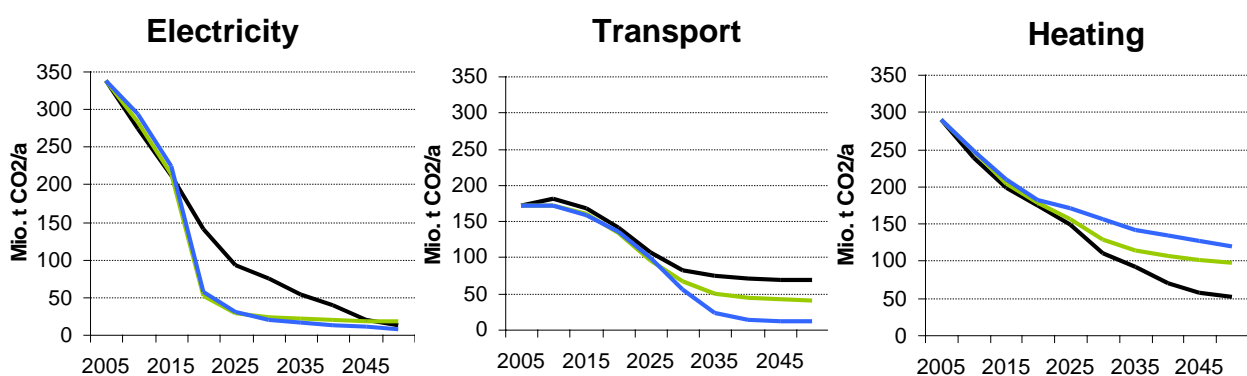
Moving to the 'Paradigm Shift' scenario, where the renewable energy growth rates increase, the cumulative GDP losses are reduced to 1.4%. As an example, in this scenario the personal, motorized transport is reduced from 13,000 p-km today to 11,000 p-km in 2050, and additionally it is assumed that the gap is filled by non-motorized transport, e.g. bicycling or walking.

In the 'Paradigm Shift +' scenario, the mitigation costs decrease further to 0.8% cumulative GDP losses, a minor decrease from the 'Paradigm Shift'. The small economic difference between these two scenarios suggests that the choice of the contested technologies can be left to further analysis of their viability.

In conclusion, the scenarios show that the scenario with the development that stakeholders find likely will lead to carbon lock-ins that makes the transition to a low-carbon society expensive and politically difficult. Choosing a scenario that is perceived as desirable but not likely by most stakeholders, however, can achieve the transition at lower economic costs.

Source: Schmid, E, and Knopf, B, 2012, 'Ambitious Mitigation Scenarios for Germany: A Participatory Approach', submitted to Energy Policy and available via the project websites.

More information: The materials of the ENCI-LowCarb Project will be available from the website www.lowcarbon-societies.eu. The reports and articles from the German and French scenario development processes will be available on the website www.enci-lowcarb.eu



Sectoral emissions of the three scenarios with an ambitious mitigation budget that leads to 85% CO₂ emission reduction by 2050, relative to 1990, in all cases.

Notice the carbon lock-in in the electricity and transport sector of the 'continuation' scenario, leading to strong reduction pressure in the heat sector.

— "Continuation"
— "Paradigm Shift"
— "Paradigm Shift + "

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