40 % CO_2 saving target in the German building stock up to 2020 – integrated assessment scenarios with the Built-Environment-Analysis-Model BEAM²

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Abstract

Germany wants to bring down CO_2-emissions by 40 % across all sectors by 2020 vs. 1990. Setting the 40 % target for the building sector (which equals 90 Mt), the aim of the project is to determine whether the current measures in place are sufficient to reach climate targets in 2020. Therefore a reference scenario has been set up, which quantifies the final energy demand and emissions for heating demand, hot water and building related electricity consumptions from 1990 to 2010 for the German building stock in an ex-post literature research. For the period 2010-2020, a forecast has been developed by use of the Ecofys Built Environment Analysis Model (BEAM²). Based on a set of input parameters like floor areas, reference buildings, insulation qualities and energy supply systems, the BEAM² model was used for creating a consistent set of data including energy consumption, CO_2-emissions, running costs and investment costs of energy efficiency measures and energy supply systems of buildings. Generally the model has been developed for scenario developments, showing the potential effects of certain energy saving packages distinguished by country, climate zone, building type, size and vintage, as well as insulation level, energy carrier and energy costs.

Main result of the model calculations is the reference scenario's carbon reduction of 38 % in the building sector. Thus most probably 40 % target will be missed slightly, assuming the framework given at January 1st 2010 being unchanged till 2020 and a retrofit rate of 1.4 %. A retrofit rate of only 1.0 % till 2020 will result in a gap of approximately 9.5 Mt CO_2 in 2020 for emissions from heating and hot water in the residential and non-residential building sector (excluding industry buildings), being equivalent to 35 % carbon reduction.

Introduction

In order to assess current policies in relation to the 2020 CO_2-emission reduction targets in the building sector of -40 % related to 1990 level, Ecofys set up a reference scenario. The work on that has started in August 2010 using the Ecofys Built-Environment-Analysis-Model BEAM². This paper describes the BEAM² model in general, how it was applied in the project and what are the main messages of the scenario calculation. The conference paper is based on the draft final report of the project and our experience in developing the BEAM²-model.

In Germany a third of the final energy consumption is used in buildings. If national and international climate targets should be reached, the building sector has to contribute significantly to that path. Therefore different, independent studies have shown that the building sector is responsible for a major part of the overall emissions, but also has a huge and cost-effective final energy- and CO_2-saving potential [Wesselink, Deng 2009]. Furthermore the building sector gives optimal framework conditions for the implementation of advanced political measures.

Besides the climate-political targets, other positive effects are connected to ambitious measures for energy efficiency in the building sector, like less dependency on energy imports, lower energy costs, higher comfort and quality of living. Therefore political measures in the building sector are a multi-functional instrument to reach and sustain important social aims. Different policy measures in Germany address the building sector

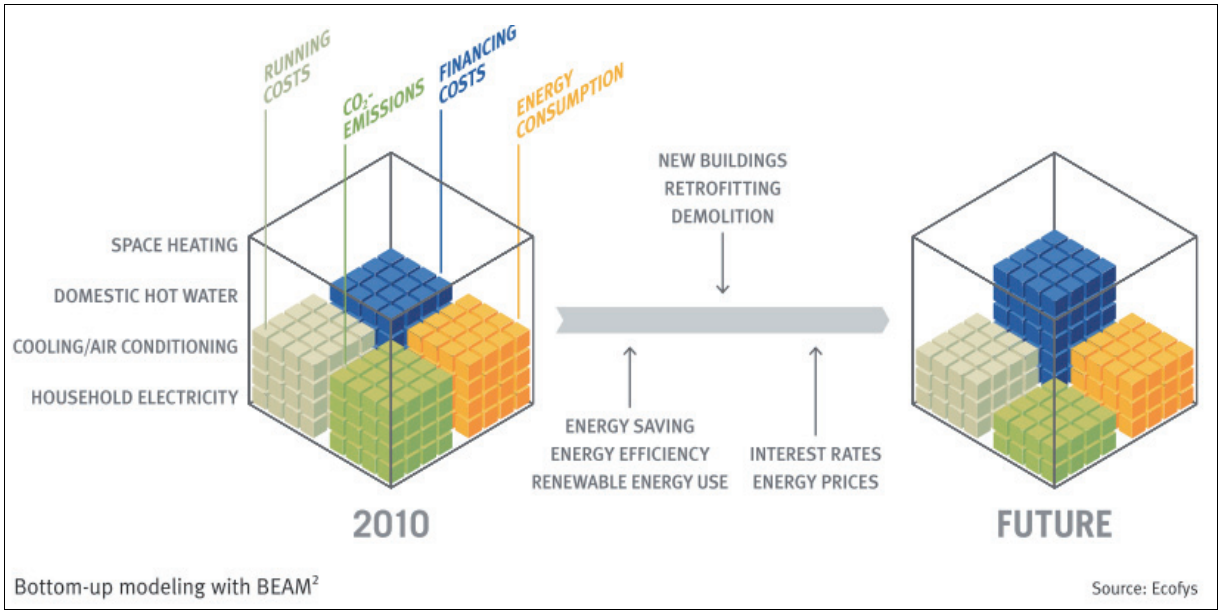


Figure 1. Calculation scheme of the BEAM²-model.

specifically, e.g. the Energy Saving Ordinance (EnEV) or the Renewable Energy Heat Law (EEWärmeG). Other measures have impact on a cross-sectoral level and their impact on the buildings sector is less clear, e.g. the use of CHP-technologies, which is used in the buildings sector and the industry. Furthermore the effects of political measures are overlapped by climate change and population development, which can't be foreseen, but have a major effect on energy demands in the future. These different boundary conditions have to be taken into account to quantify and forecast the CO_2-emission reductions in the building sector, especially when answering the question of how close we get to the -40 % CO_2-emission reduction in 2020 compared to 1990 emissions.

The aim of this research is therefore to ex-post evaluate the CO_2-emission reduction between 1990 and 2010 and to forecast/ assess this up to 2020 for already existing policy measures in a reference-scenario by considering these various impacts and boundary conditions for both residential and non-residential buildings (excluding industry).

The BEAM² model

Based on a set of input parameters like floor areas, reference buildings, insulation qualities and energy supply systems, the BEAM² model calculates a consistent set of data including energy consumption, CO_2-emissions, running costs and investment costs of energy efficiency measures and energy supply systems of buildings. For this purpose, all buildings in a building stock are classified as residential or non-residential, which are adapted to local circumstances. The model calculates the effects of measures applied to new and existing buildings, distinguished by

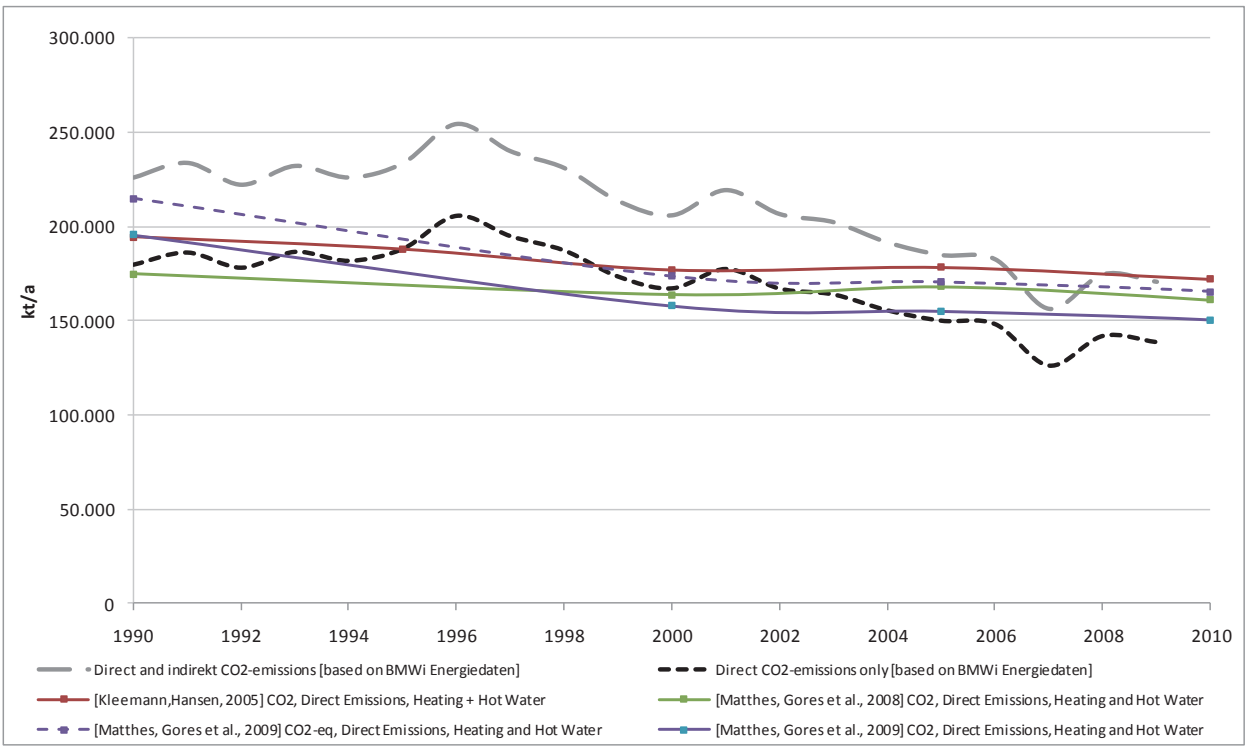
- Country
- Climate zone
- Building type and size
- Age group
- Insulation level
- Energy carrier and
- Energy costs.

Parameters such as demolition rate, new building activity, renovation and energy-efficiency measures in retrofits are also taken into consideration. These parameters can then be adapted, focusing on the most effective and cost-efficient measures. A calculation scheme of the bottom-up BEAM²-model is given in Figure 1.

The model has beside others successfully been used for i) an investigation of the international building markets, energy demand and supply systems for a European manufacturer (2009-2010), ii) an impact assessment of the revised EPBD for the European Commission (2008) and iii) a Scenario calculation until 2050 for the building stock of the City of Hamburg (2009). The further development of the BEAM² model is the subject of the author's PhD.

Reference scenario for the German building stock

Breaking down the European 2020 targets, Germany wants to bring down the CO_2-emissions by 40 % until 2020 across all sectors. There are a couple of measures and instruments in place to reduce emissions in the building sector, most of them arranged in the Integrated Energy and Climate Program (IEKP). The reference scenario gives a path for future emissions in the German building sector up to 2020 and determines whether the current measures in place are sufficient to reach climate targets in 2020. The scenario is quantifying the final energy and emissions from 1990 to 2020 for the German building stock, taking into account heating, hot-water and building related electricity consumption. In addition some sensitivity calculations concerning climate change and population development are done.



Not climate corrected.

Figure 2. Historic development of CO_2-/ CO_{2eq}-emissions in underlying studies between 1990 and 2010.

Table 1. Historic development of CO_2-emissions for heating and hot water from [BMWi-Energiedaten 2010].

	1990	2009	`90-`10
CO_2-emissions [Mt CO_2] (Direct and indirect)	225.8	170.5	- 24 %

EX-POST EVALUATION OF POLICY-MEASURES BETWEEN 1990 AND 2010

This section covers the evaluation of policy measures between 1990 and 2010 with regard to CO_2-emission reductions. Studies are relevant which either contain scenarios for the building sector or quantify the impacts of policy measures. They have been assessed in order to indicate the relevance for the reference scenario. Hereby the following studies have been reviewed: [BMU, BMWI 2007], [BMWI 2007], [Clausnitzer, Fette et al. 2010], [Clausnitzer, Gabriel et al. 2007], [Clausnitzer, Gabriel et al. 2009], [Clausnitzer, Gabriel et al. 2008], [Doll, Eichhammer et al. 2008], [Friedrich, Becker et al. 2008], [Kirchner, Matthes 2009], [Kleemann, Hansen 2005], [Kleßmann, 2008], [Lindenberger, Bartels et al. 2006], [Mantzos, Capros et al. 2007], [Matthes, Gores et al. 2008], [Matthes, Gores et al. 2009], [Nitsch 2008], [Nitsch, Wenzel 2009], [Schlesinger, Hofer et al. 2007] and [Schulz, Bartels et al. 2005].

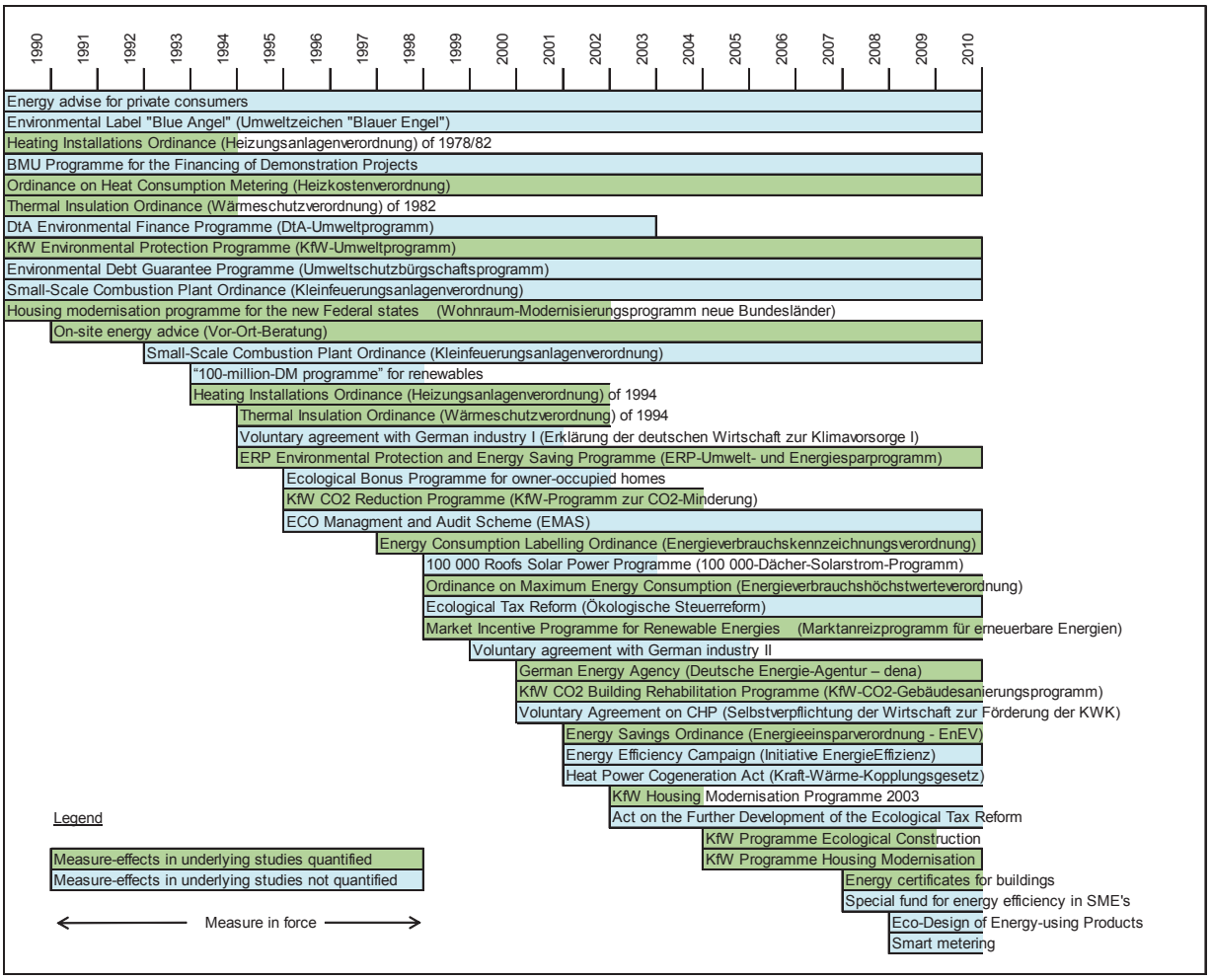
Historic development of CO_2-emissions from underlying studies

Figure 2 shows the historic CO_2-emission paths between 1990 and 2010 for four studies, which comprehend a scenario that reflects the status-quo of the implemented policy measures quite well. These are the scenario by [Kleemann, Hansen 2005], the scenario by [Matthes, Gores et al. 2008] and the scenario by [Matthes, Gores et al. 2009]. Furthermore it contains the direct and indirect CO_2-emission scenarios calculated from the [BMWi-Energiedaten 2010], which are published by the Federal Ministry of Economics and Technology. Direct emissions are emitted by an on-site heating system in a building (e.g. a boiler), while indirect emissions by definition are from electricity and district heat, where an upstream conversion process is in place.

It becomes obvious that the difference between direct plus indirect emissions vs. direct emissions for 1990 both from [BMWi-Energiedaten 2010] is about 50 Mt CO_2. Reason for that is that different definitions are used (direct plus indirect or direct emissions only). The "Direct and indirect emissions" development from the "BMWi Energiedaten" is taken as the baseline (see Table 1), because it is based on the same final energy data as the BEAM² model is calibrated with. Between 1990 and 2009 24 % reductions (55.3 Mt) have been achieved of the 40 % target.

Identification of policy measures for the Reference Scenario

In Figure 3 all policy measures being relevant for the building sector are listed which have been put into force between 1990 and 1st of January 2010. They are split-up by measures which are today covered by the IEKP and those outside the IEKP. Overlapping effects of measures are subtracted where ever possible, based on the information give in the studies.



Source: Mure II database.

Figure 3. CO_2-mitigating measures in the German building sector between 1990 and 2010 in chronological order.

When looking at Figure 3 it becomes obvious, that not all policy measures between 1990 and 2010 are quantified. Since a quantification afterwards is not the purpose of this study, no mitigation potential can be given. Reasons can be combined effects or missing methods.

Quantification of CO_2-emission reductions per measure

Evaluating all the policy measures leads the CO_2-emission reduction potentials given in Table 2. Hereby measures are often grouped in the studies. Since the overall reduction between 1990 and 2010 is, based on the "BMWi-Energiedaten"-scenario, approximately 24 %, further actions are needed in order to reach the -40 % target in 2020.

The mitigation potentials per measure from implementation until 2010 (effect in that year against a BAU where the measure wouldn`t be in place) are given in Table 2. They are summarized based on the evaluated studies, see footnotes.

EX-ANTE EVALUATION OF POLICY-MEASURES UP TO 2020 USING THE BEAM² MODEL

The above described calculation model BEAM² has been used to calculate impacts for the national policy measures already in force until January 1st 2010 for the period 2010-2020, not taking into account any additional measures. Mid-term targets from the EPBD (e.g. nearly zero energy buildings) are not taken into account, because they are not yet implemented in national law. Future revisions of the Energy Saving Ordinance (EnEV) are also not accounted for.

Input data for modelling

Status-quo in the building stock

Reference buildings are used in the BEAM² model in order to cover different house types. For the residential sector we used a typical single-family house, a semi-detached house, one small and one large multi-family building. The non-residential sector is much more inhomogeneous and therefore described by four reference buildings as well, in spite of the fact that there is much less data available: A typical office- and education building, a trade- and retail-building, a hospital/retirement home and a hotel/ restaurant. In total eight reference buildings with different geometries.

Modelling the quality of building envelopes is been done by using age-groups. We distinguish five age groups: Built before 1948, between 1949 and 1978, between 1979 and 1994, between 1995 and 2009 and built after 2009. Hereby buildings already renovated are taken into account accordingly, using a database set up recently by IWU, [Diefenbach et al. 2011].

Table 2. Quantification of CO_2-emission reductions in 2010 [Mt CO_2/a].

Energy Saving Ordinance (EnEV)[1)]	1,75	Market Incentive Program Solar[1)]	0,56
Renewable Energy Heat Law (EEWärmeG)[1)]	0,31	Market Incentive Program Biomass[1)]	0,82
KfW Energy Efficient Retrofits[1)]	3,00	Market Incentive Program Heat Pumps[1)]	0,10
KfW Energy Efficient New Buildings[1)]	0,40	Non-residential Measures[2)]	2,00
Social Housing[1)]	0,04	Replacement of Electrical Heating Systems[3)]	1,50
Energy Performance Certificates & Advise[1)]	0,18	Retrofit of Federal Buildings[3)]	0,11
Urban Redevelopment Eastern Germany[1),4)]	0,00	Modernization of Social Infrastructure[3)]	0,32

Comment: Overall effects of measures, not additional potential against previous year. Sources: [1)] [Matthes, Gores 2008], [2)] [Kleemann, Hansen 2005], [3)] [Doll, Eichhammer 2008]. [4)] Urban Redevelopment Eastern Germany: Until 2030 an effect of 0.2 Mt is expected.

Table 3. Retrofit- and new-building rates.

	Residential buildings		Non-residential buildings	
	Retrofit	New building	Retrofit	New building
Energy Saving Ordinance 2009 (EnEV09) (Taking into account an energy-related retrofit efficiency of 70% for insulation measures)	1.20% (+/- 0.4%)	0.42%	1.40% (+/- 0.4%)	0.70%
KfW building-retrofit program	0.20%	-	-	-
KfW Energy efficiency new building program	-	0.28%	-	-
Total	1.40% (+/- 0.4%)	0.70%	1.40% (+/- 0.4%)	0.70%

Primary- and CO_2-emission factors

The heated floor areas per reference building and age group are assigned afterwards. With 33 % of all floor area in the residential and non-residential sector there is a concentration of single-family houses. Multi-family houses account for 25 %, while trade and retail covers 16 % and office- and education 13 %.

Different mixes of heating systems are defined per reference building and age group, considering ventilation- and solar-thermal systems as well.

Retrofit-, new building- and demolition- programs

Table 3 gives an overview of the retrofit- and new-building rates. The demolition rates from national statistics are 0.10 % for residential- und 0.35 % for non-residential buildings, [Destatis 2010].

The primary-energy factors are 2.6 for electricity, 1.1 for gas and oil, 1.0 for district heat and 0.2 for biomass, source [DIN-V-18599]. Emission factors are 550 g/kWh for electricity, 260 g/kWh for oil, 210 g kWh for gas, 180 g/kWh for district heat and 0 g/kWh for biomass, [Bettgenhäuser, Boermans 2010].

The heating systems applied in retrofits and new buildings are mostly gas-condensing boilers and heat-pumps, but it`s always depending on the ambition level (EnEV or KfW) and the age group.

Intersection in 2010

The BEAM² model is calibrated with final energy data from "BMWi-Energiedaten" in 2010. As consequence the CO_2-emissions don't have a break in 2010, see Figure 4.

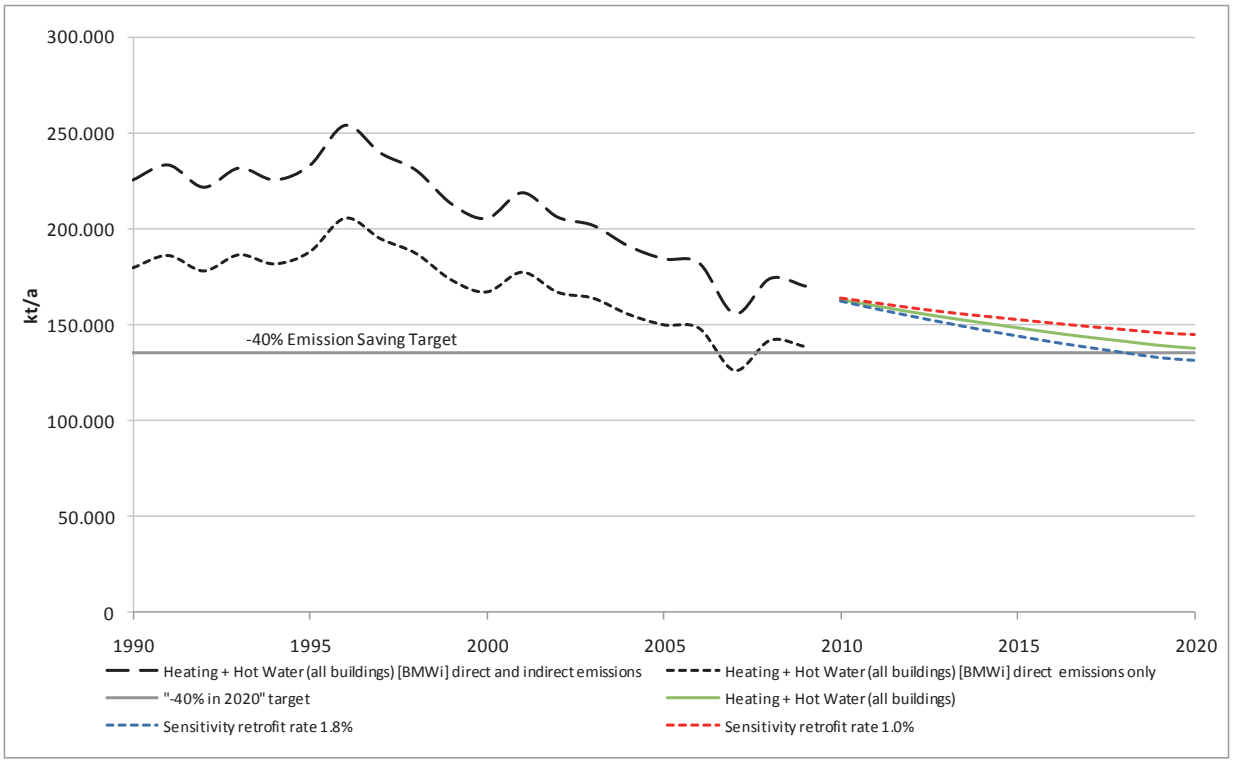
Implementation of policy-measures

The following packages of measures are analysed in order to give a realistic scenario.

- *KfW Building retrofit program:* Retrofits of existing buildings better than required by the energy saving ordinance (compare Table 3), using the KfW85-definition (Primary energy consumption less than 85 % and average transmission losses less than 100 % compared to new building standard according to the Energy Saving Ordinance).
- *Renewable energy heat law (EEWärmeG):* Obligatory for new buildings (Either renewable energy technology or advanced thermal performance)
- *Market incentive program (MAP):* Promotion of solar-thermal collectors, heat-pumps and biomass boilers in new and existing buildings.
- *KfW Energy efficient building program:* New buildings with higher energy performance than required by law (compare Table 3), using the KfW55-definition (Primary energy consumption less than 55 % and average transmission losses less than 70 % compared to new building standard according to the Energy Saving Ordinance).
- *Energy saving ordinance 2009 (EnEV):* Covers all reminding measures that are not explicitly covered by the packages above.

Scenario up to 2020

Figure 4 gives the full scenario from 1990 to 2020. The period 1990-2010 is based on the above mentioned literature evaluation, while the forecast from 2010-2020 results from the BEAM² model calculation.



For 2010-2020, three scenarios with different retrofit-rates (1.0%, 1.4% and 1.8%) are calculated, resulting in different emission paths. Not climate corrected.

Figure 4. CO_2-mitigating potential for heating and hot water in residential and non-residential buildings up to 2010 from study evaluation and forecast until 2020.

Conclusion

It becomes obvious, that the 40 % emission reduction target in 2020 will be slightly missed for the 1.4 % retrofit rate and not be reached for the 1.0 % retrofit rate scenarios under the political framework given at January 1st 2010.

Further research in the field of policy measures is needed in order to close the gap between the scenario and target level. Furthermore fast action in order to close that gap in 2020 should absolutely consider the national 2050 target of lowering CO_2-emissions by at least 80 % compared to 1990 as well. The EU-target for the building sector is a reduction of 88 %-91 % until 2050. In the mid-term it is not useful to e.g. just increase the retrofit rate and not the retrofit standard. These shallow retrofitted buildings would endanger the 2050 target, because fast but not ambitious action locks in economic potentials for a renovation-cycle of 30-40 years. Since the participation of the buildings sector to climate targets is usually higher than for other sectors (because of volume and profitability), this is even more important, see [Wesselink, Deng 2009].

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