Achieving climate neutrality in the building sector by 2050

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1 The backdrop

By 2050, carbon emissions in the EU will have to be reduced by 80 to 95 percent to reach global climate protection goals. Unlike in most other sectors, it is possible to reach a 100 percent reduction in the construction industry with justifiable expenses and technology already available today. Which developments must be promoted in terms of building envelopes, technology, neighborhood concepts, urban development, renewable energy, supply systems, and municipal and regional climate protection concepts to implement this goal on the basis of Passive House technology in construction and renovation and turn settlement structures into distributed energy suppliers? To answer these questions, studies were done on efficiency components, individual buildings, and neighborhoods designed in urban development plans. On this basis, a scenario is created for Germany that demonstrates the prerequisites for achieving climate neutrality by 2050 and, at the same time, the opportunities that can result.

2 Efficiency components

		New construction						Modernization					
		1980	**1995**	**2010**	**2020**	**2030**	**2050**	**1980**	**1995**	**2010**	**2020**	**2030**	**2050**
Wall	U [$W/(m^2K)$]	0.24	0.16	0.12	0.1	0.08	0.06	0.40	0.25	0.15	0.12	0.10	0.08
Roof	U [$W/(m^2K)$]	0.2	0.14	0.1	0.08	0.06	0.05	0.25	0.18	0.12	0.10	0.08	0.06
Floor	U [$W/(m^2K)$]	0.24	0.16	0.12	0.1	0.08	0.06	0.50	0.25	0.16	0.14	0.12	0.08
Window	Ug [$W/(m^2K)$]	1.8	0.7	0.6	0.5	0.45	0.4	2.60	1.30	0.70	0.60	0.50	0.45
	Uf [$W/(m^2K)$]	1.8	0.8	0.7	0.6	0.55	0.5	1.80	1.60	0.90	0.70	0.60	0.55
	g value	60%	50%	52%	55%	55%	58%	70%	60%	50%	52%	55%	55%
Outer door	Uw [$W/(m^2K)$]	2.6	0.85	0.75	0.6	0.4	0.3	2.6	1.5	1.2	0.75	0.6	0.4
Thermal bridges	ΔU_{WB} [$W/(m^2K)$]	0.05	0	-0.007	-0.007	-0.007	-0.007	0.1	0.05	0.03	0.025	0.020	0.015
Air-tightness	n_{50} [1/h]	1.5	0.6	0.6	0.4	0.3	0.2	3	1.5	0.6	0.5	0.4	0.35
Ventilation	Heat recovery efficiency	65%	80%	85%	90%	92%	95%			80%	85%	90%	92%
	Electric efficiency [W/m^3]	0.8	0.45	0.4	0.35	0.3	0.27			0.45	0.4	0.35	0.3

Table 1: Trends in construction standards and values for construction and modernization that are most likely able to be produced affordably in the years under review. The values are the basis for calculations in Section 3

Passive house components have been constantly improved in the last 20 years thanks to a high level of innovation. We can safely assume that this trend will continue.

Building services technology – heating, hot water supply, and process heat: A paradigm change will occur in heating system technology in the next few years. Construction on a broad scale of buildings with very high-quality building envelopes takes as its basis the standard construction of heating systems. The following aspects must be considered in the concept:

- The heating load, which will soon be far below ten W/m², makes very simple heating systems possible that must have synergitic effects with ventilation technology and hot water supply, as compact heat pumps already can. Increased investment in the building envelope is balanced out by a reduction in "classic" building services technology, although building services technology as a whole will increase in scope because of ventilation systems and renewable energy.

- Hot water supply increasingly requires more energy than heating, leading to a need to develop more efficient systems. At the same time, solar thermal, synergized with PV, should also be further developed.

- Expensive technology for heating regulation, monitoring, and billing technology will not be necessary in the future; instead, small modules will be integrated in communication technology that can be combined with maintenance technology in a cell phone format.

- Energy and heating flows in the living area suggest that it is best to integrate kitchen technology with building services technology.

- High-efficiency buildings change supply structures at the urban development level. Monovalent electricity supply will become the standard in residential neighborhoods with single-family homes. **Electricity**: Household, operating, and auxiliary electricity must be specifically included and optimized in the planning stage. These savings can be achieved economically and provide benefits in terms of summer heat protection.

Summer heat protection and cooling: A high-quality building envelope can provide significant benefits for summer heat protection if it has undergone targeted planning for its transparent surfaces and their shading. For a sufficiently activatable building mass, summer temperatures can be kept to a comfortable level with nothing but passive measures. **Renewable energy:** Including renewable energy in building services technology and electricity supply is becoming the main task for project and construction planners.

3 Trends as shown by projects

The potential for further development until 2050 is shown using optimization plans and completed projects. For this point, calculations were either carried out using the component developments shown in Section 2 according to the Passive House Planning Packet [PHPP 2007] for characteristic buildings or current surveys were used.

Single-family, duplex, and terraced houses Passive House verification has the strictest requirements for single-family homes, since the heating demand standard is always

15 kWh/(m²a) and small buildings need the most thermal protection. An example is provided by a two-story single-family home with about 130 m² of living area.

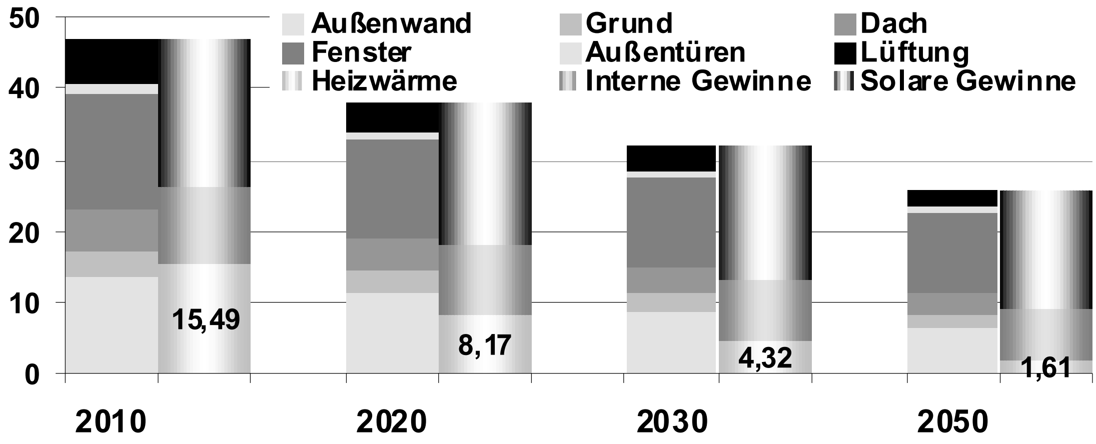


Figure 1: Passive house balance of components in Table 1 in a single-family home

Multi-family building – new building: Using the same approach as for single-family homes, trends were calculated for heating, final energy, and primary energy demand using the example of a three-story multi-family building containing 24 apartments with an average of 75 m² of living area each (see Figure 2 for results).

Multi-family building - renovation The special requirements of renovation are shown using a renovation project with the building geometry of a multi-family building. The calculation in compliance with PHPP results in demand values characteristic of Standard 2010 (see Fig. 2) with a heating demand of just over 20 kWh/(m²a), the target in the last few years for Factor 10 renovation.

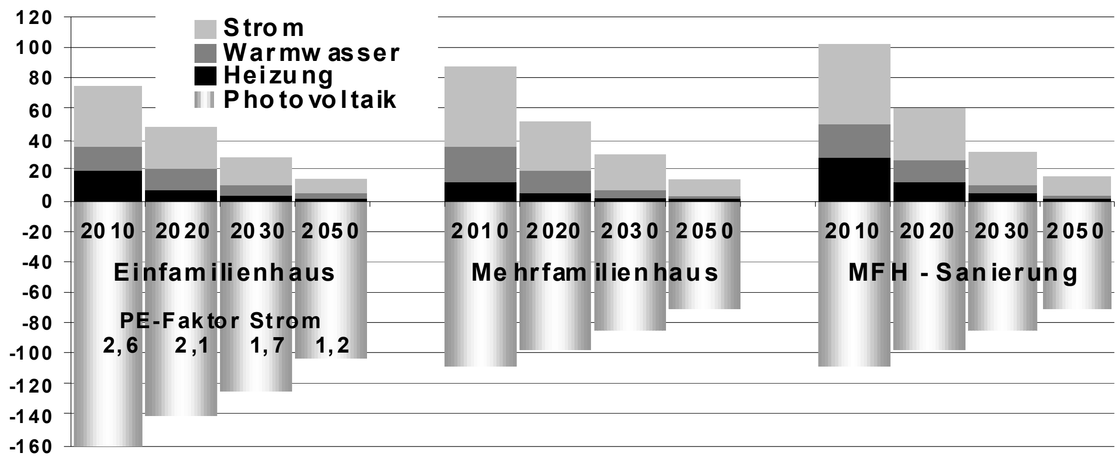


Figure 2: Optimization calculations in compliance with PHPP for a single-family home, a multi-family building, and a multi-family building renovation. Also depicted is possible yield from a photovoltaic roof array.

Non-residential building Figure 5 depicts the balance of primary energy values and an approach for substituting them with photovoltaics for three examples of non-residential buildings, each including modernization and new construction concepts and some of which are currently being built. For each concept, the PV arrays can be integrated into the building or the grounds.

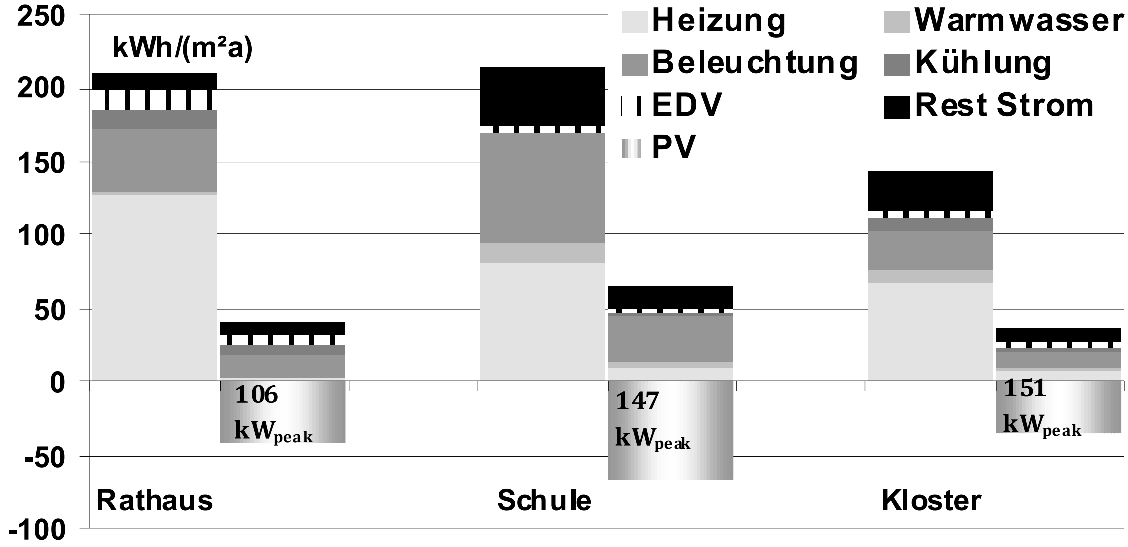


Figure 3: Renovation of a non-residential building: primary energy balance of demand values for heating, hot water, cooling, lighting, IT, and residual current before and after renovation

Offices, administration: With 5,981 m² of heated surface, the city hall of Herzogenaurach, Germany, needs a PV array of 106 kW_{peak} to reach the zero-energy standard. [Reuter, Schulze Darup 2008]

School: The secondary school in Feuchtwangen, with 5,283 m² of heated surface, would be completely balanced with 147 kW_{peak}. [Maurer, Schulze Darup 2008]

Abbey: The abbey in Plankstetten has a unique situation in terms of sustainability and calculates cost effectiveness for at least 100 years. Its wood chip heating system uses raw materials from the abbey's own resources; the PV array with 151 kW_{peak} can be integrated into the building's structure. [Schulze Darup 2009]

4 Trends in neighborhoods and cities

Results for individual buildings can be expanded for the neighborhood level and, in turn, for the sustainable design of cities and regions.

Residential park Nuremberg West: A high-quality energy concept was designed for the residential area with 1,030 living units in the southwest of Nuremberg's city center. A basic plus-energy concept can be represented based on the exemplary Factor 10 renovation implemented in the area combined with the high-quality primary-energy district heating [wbg Nürnberg 2009].

Strubergasse residential park in Salzburg: The modernization concept for this residential area with 480 living units in Salzburg includes a redensification consisting of 70 living units in the course of renovation and shows a step-by-step way toward a plus-energy balance.

The energy balance for heating, hot water, and electricity based on useful energy results in primary energy demand of 2,360 MWh/a, which is more than balanced out by a possible primary-energy photovoltaic yield of about 3,284 MWh/a [Schulze Darup 2010].

The City of Neumarkt i. d. Opf.: Because of its municipal and regional structure and a high concentration of construction firms, the city of Neumarkt will most likely achieve the status of a zero-emission city within two to three decades. A highly endowed funding program for energy efficiency and climate protection was introduced in 2009 on the basis of a climate protection report [Energieregion 2009] and a strategy study [Schulze Darup 2009-1]. Three factors are important here: high efficiency in renovations, an increase in the renovation rate from 1.6 to 3.5 percent per year starting in 2015, and successive improvement of the supply system. Climate neutrality could be reached in 2035. The remaining demand of 144.8 GWh/a can be completely covered by renewables.

Nuremberg and Munich: The climate protection objective for the City of Nuremberg includes an 80 percent reduction in carbon emissions by 2050. The current road map for climate protection [Nürnberg 2007] through 2050 is currently being updated. The City of Munich plans to reduce carbon emissions by 50 percent by 2030 and achieve climate neutrality by 2058, when the city turns 900 [München 2010].

5 Supply concepts

The calculations in Sections 2 to 4 all included a comparison with photovoltaics as a renewable “key currency” to show that balanced climate neutrality is attainable for each system, from individual projects to the neighborhood and municipal-regional joint projects. The basic goal should be a high volume of renewable energy production in urban areas. A point that makes considerable sense, however, is a regional view that includes ensuring supply security and balancing out fluctuations throughout the day and year (demand management and smart grids). Compared to the current large, central plants, these integrally connected supply systems offer a high amount of supply security and can sensibly integrate renewable energy. In this way, full renewable supply can be ensured for the mid-term [Kombikraftwerk 2008].

6 Extrapolation of results to Germany as a whole

Methodology and limits A scenario is being designed for climate neutrality in residential buildings in Germany through 2050 based on the conditions set out in Sections 2 to 4. Annual trends for the next forty years were determined using a process based on the methodology used for complete business finance plans. The following important basic assumptions for reaching an ambitious climate protection goal are **conditions for achieving climate neutrality by 2050**:

Optimized specific heating demand Since there is only **one** investment cycle for construction and modernization up to 2060, measures for the thermal building envelope must be optimized in their renovation cycles. Any building component that is suboptimally installed or modernized has a significant negative effect on the overall balance and/or must be renovated again before 2050, i.e. before its service life is over.

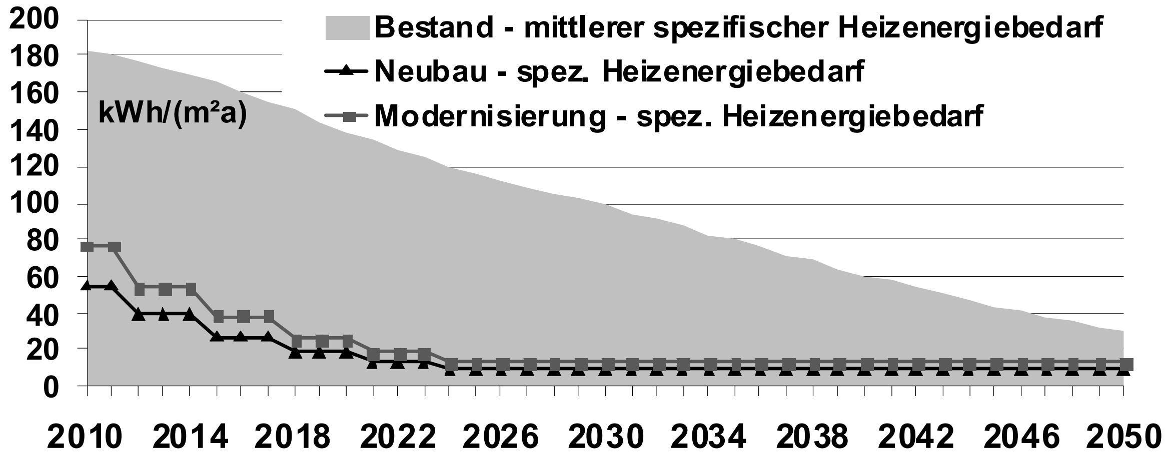
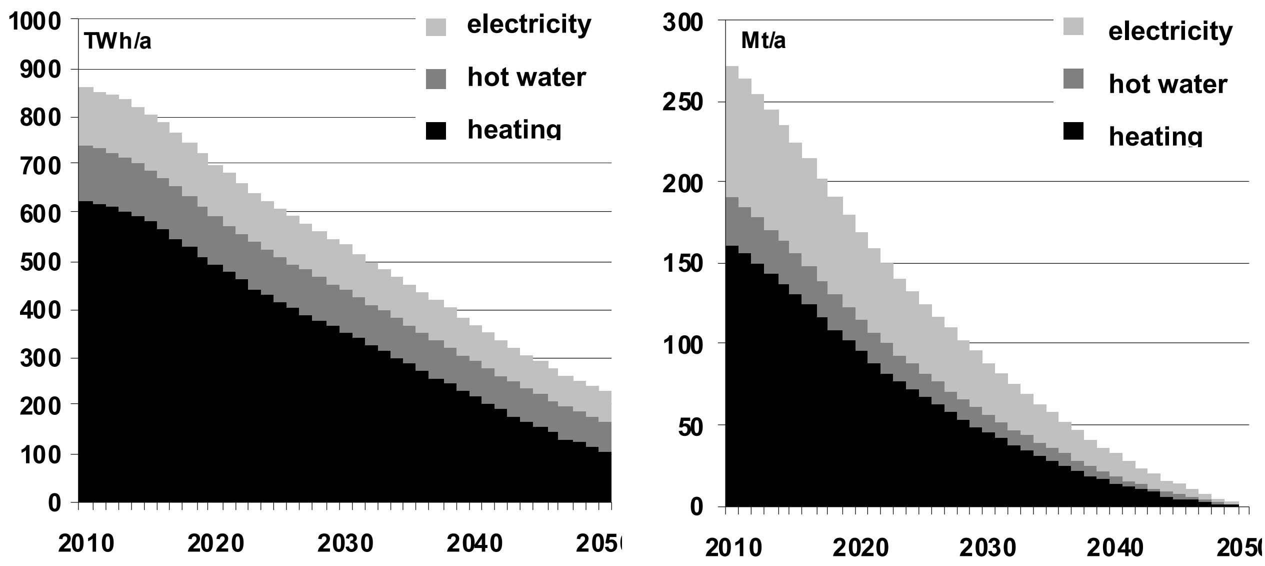


Figure 4: Specific heating energy demand for new buildings and modernization projects within the scenario and the resulting average heating energy demand for all buildings

Modernization and new construction volumes In the last few years, the annual new construction rate relative to already constructed buildings has been 0.6 percent. This figure was used through 2015 in the model calculation; it was dropped to 0.5 percent after that and then 0.4 starting in 2040, with a decreasing overall volume. The demolition rate is set at 0.2 percent until 2015 and 0.3 percent after that. As required by demographics, the demolition rate is 0.4 percent starting in 2025 and grows to 0.6 percent by 2036. The basic modernization rate is set at 1.7 percent and increases to as much as 3.2 percent in 2014 to 2025.

Investment volumes and economic effects Additional investments in this sector amount to about 40 billion euros annually in the key years of 2014 to 2020. About 25 percent of this increased amount can be invested to induce this process in the form of financial support because of such effects as income from value-added tax, money saved on programs for the unemployed, and a higher inflow from social security and other taxes. This potential for funding is about ten times more than the funds given out by the KfW Group over the last few years. To provide an initial incentive, a nationwide funding program with a total annual volume of five billion euros is required that would then grow to as much as ten billion euros of economically neutral funding from 2015 to 2020. These investments help to induce a high regional level of added value, replace energy imports, improve foreign trade figures, and ensure long-term, high-quality jobs.



Figures 7 and 8: Trends for final energy demand (left) and carbon emissions in the residential sector

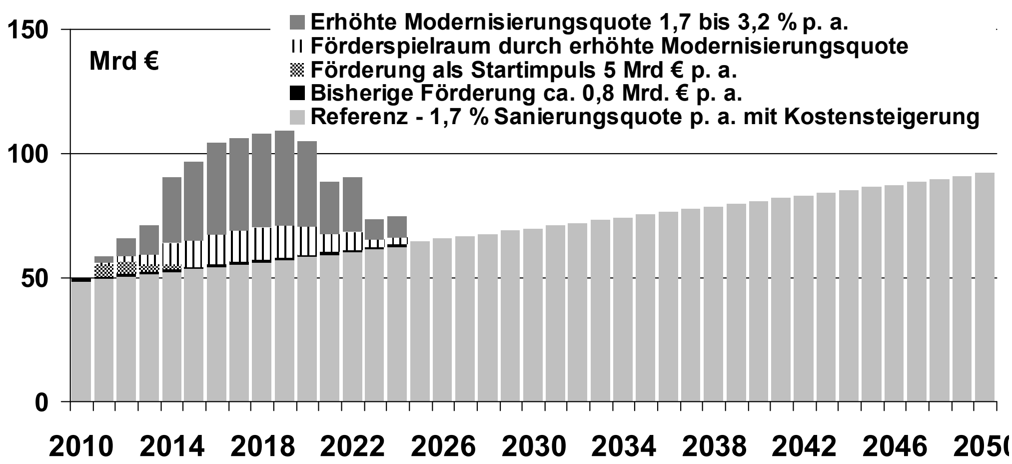


Figure 9: Investment volumes, increasing by about 40 billion euros each year because of a modernization rate increase from 1.7 to 3.2 percent.

Conclusions Climate protection measures in the construction sector are almost entirely win-win strategies. Contrary to the construction industry's traditionally more conservative mindset, this added economic value can especially be achieved by providing short-term incentives and promptly introducing market-ready climate protection technologies and components on a large scale. With quick, broad implementation, German industry can hold on to its leading position in efficiency technology and renewable energy. Prompt, sustainable action is simultaneously a requirement and an opportunity at both the regional and the national levels.

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