2 Summary

In view of dwindling fossil fuel resources and with the aim of contributing to climate protection, new models for a sustainable energy supply are currently being tested, with a focus on renewable sources of energy. In this context, the building sector with its high energy demand is in the centre of interest. While buildings so far have mainly been known as energy consumers, they can now be turned into energy producers by using modern energy generation technologies - already today. The appropriate use of regenerative sources of energy in and around buildings – like solar energy or geothermal heat, for instance – allows to turn buildings into plus-energy buildings. In the scope of the funding programme 'Model projects in the Efficiency House Plus standard' [Modellprojekte im Effizienzhaus Plus Standard] which was launched by the former German Federal Ministry of Transport, Building and Urban Affairs (BMVBS) - now German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB) - demonstration buildings will prove that this is possible. This project supports builders who raise houses that produce significantly more energy than they require. Each model project will be individually evaluated; in the scope of a research-accompanying programme, additional monitoring and analyses are included. Within this framework, BMUB has realized its own sustainable project, the so-called 'Efficiency House Plus with electro-mobility' ('Effizienzhaus Plus mit Elektromobilität') which was built in Berlin at Fasanenstrasse 87a. The other buildings are spread all over Germany with five model projects located in a Cologne prefab-house centre, at Köln-Frechen Fertighauswelt. Until December 2014, all in all 33 projects were almost finished, 27 of which are one- to two-family houses; 6 are multifamily houses including 6 up to 74 dwelling units. The present report focuses on the evaluation and the comparison of all projects with regard to their design parameters to achieve the Efficiency House Plus Standard and on the analysis of the actual building performance on the basis of the recorded data.

An Internet portal entitled 'Effizienzhaus Plus' (Efficiency House Plus), which was installed at the BMVBS website in fall 2012 is, has now been moved to the website of the research initiative 'Future of Building' (www.forschungs-initiative.de/effizienzhaus-plus/). This requires a detailed description of the project with regard to architecture, building construction, building services and energy balances in the form of a building summary/ property profile. To ensure that the requirements characterising the Efficiency House Plus standard are still complied with after the building has been occupied, all network buildings are subjected to an ongoing monitoring programme. The monitoring is designed to validate whether the occupied buildings are actually generating more energy than they need to be operated. The project partners cooperated to develop a measurement concept for the various model projects which describes the shares of the energy consumption that are to be measured.

The evaluation method for rating the Efficiency House Plus / Effizienzhaus Plus is provided by the extended EnEV-certificate as specified in the German Energy Saving Ordinance (EnEV), according to German standard DIN V 18599. To this end, the certification procedure follows the German Energy Saving Ordinance (EnEV)

according to DIN V 18599. In addition to the certificate, the characteristic values of the delivered and primary energy need for residential lighting, domestic appliances and processes must also be considered. A blanket value of 20 kWh/m²a with a maximum of 2,500 kW/a per residential unit is assumed. Taking self-generated photovoltaic (and small-scale wind power) electricity into account, which is allowed to be included according to EnEV §5, all projects are distinguished by a calculated delivered and primary energy surplus. With this, the model projects achieve the Efficiency House Plus standard. An exception was made for two projects, namely (1) for a project at Tübingen, for which - due to the compulsory connection to the local heat - an energy surplus could be verified only with regard to primary energy use, but not for delivered energy and (2) for a project at Frankfurt, which failed to reach the required performance due to a modification in the revised 2014 EnEV version. In the latter case, the definition of the efficiency house plus standard was modified by the funding body to suit the specificities. A calculation tool allowing to document the Efficiency House Plus standard was developed in the scope of this research project, which is available for free download at www.effizienzhaus-plus-rechner.de.

Most model projects built have a compact form, featuring energy optimised building constructions. The mean building net area A_N acc. to EnEV of the single/ dual-family houses is equal to 284 m². Compared to an average living space of 135 m² in single/ dual family homes in Germany, the mean living space of 200 m² is relatively large. In the dwelling units of the multi-family apartment houses, the living space ranges from 40 m² to 100 m², which is also rather large compared with the German average of 67 m². Due to the high-quality thermal envelope components, the overall transmission heat loss H'_T of all buildings varies between 0.13 W/(m²K) and 0.40 W/(m²K), which means it is on average by 50 % better than specified in the EnEV requirements. With this, the mean energy performance of the building envelope ranges between the KfW levels of subsidy (efficiency houses 40 and 70) with a focus towards KfW efficiency house 55.

Heat generation and DHW heating is mainly supplied by electrically driven heat pumps, which use different heat sources. In 57 % of the projects an electrochemical storage system is available: with a gross storage capacity of 3.5 kWh to 40 kWh in single-family homes and up to 250 kWh for a multi-family building. Solar electricity for the buildings is mainly generated using photovoltaic modules made of monocrystalline solar cells, which are installed as roof-top solutions or fitted as in-roof installations. About 25 % of the projects are provided with additional photovoltaic modules, which are integrated into the vertical building façades. To achieve Efficiency House Plus standard in single to dual family homes, a PV area of about 0.48 m² is required for every square metre of living space. For multi-family houses, an average area of 0.34 m² photovoltaic modules per m² living space should be available.

Every building will be monitored for a period of two years. During this phase, the amounts of supplied energy and the volumes of energy that are fed into the grid from the building will be continuously recorded. Besides, indoor and outdoor climate conditions and user-specific consumptions will be measured. The measured data prove that the measured yields of the photovoltaic systems are in good agreement with the predicted data, apart from a few minor exceptions. For buildings without electricity storage facility the degree of self-use of PV-generated electricity during the 2-year monitoring phase is 28 % on average, which can be raised up to 60 % for buildings using energy storages. Depending on the dimensions of the PV-systems, the degree of self-sufficiency (i.e. the ratio of the self-used PV electricity to the total electricity requirement of the building) amounts to an average of about 36 % in buildings without electricity storage facilities. When using a battery, this degree can be increased by 50 % on average. On the basis of these measured data, which were partially characterized by extensive downtime of the batteries, it is however not possible to derive any generally valid dimensioning parameters for PV-electricity storage devices.

The final energy consumption (delivered energy use) of most of all buildings is higher than predicted. This is associated with increased consumption due to inefficiencies when running the building services systems for supply of space heating, DHW and ventilation on the one hand and additional consumption for domestic electricity and lighting on the other. In 2013, additional consumption was 46 % on average; on account of building optimization and favourable climatic conditions, it could be reduced to 23 % in 2014. Regarding the general approach underlying the Efficiency House Plus Standard it is recommended to increase the final energy demand for lighting, domestic appliances and domestic processes by some 20 % to 25 kWh/m²a and to raise the maximum limit for each household to 3,500 kWh/a.

In 4 projects, the final energy surplus of the buildings (which results from the difference between the PV-yield and the final energy consumption) was still negative after the first year of measurements. With the exception of one project, these buildings could establish a positive balance in the second year of measurements (following optimization of building services systems and measurement equipment) to achieve the Efficiency House Plus Standard. The predicted values were achieved (and surpassed) only by one building, for all other buildings the surplus turned out to be less than expected. In view of this experience, 10 -20 % of overdimensioning should be considered when designing the layout of the photovoltaic system, to compensate for suboptimal building performance.

It was found that minimum monitoring in an adjustment phase of about 2 years is necessary to achieve the Efficiency House Plus Standard. Equally important is that project partners communicate early in the process, that measurement sensors are carefully maintained, and measured data are meticulously managed during the monitoring phase.

Regarding the costs of the individual projects, information was more or less detailed. An analysis of the currently concluded projects suggests gross costs for cost groups KG 300 and KG 400 in an order of 1,100 €/m² $_{UFA}$ and 2,000 €/m² $_{UFA}$.