Zukunft Bau: a summary report

Title

A study of sets of measures for constructing an energy-plus school as per various site-specific conditions and requirements for use

Background information

The European Union's Energy Performance of Buildings Directive (EPBD) stipulates that all structures built in future consume practically no energy ("nearly zero-energy buildings"). The low quantities of energy needed must be generated primarily via energy from renewable sources. Energy-plus schools do not merely meet this requirement—they exceed it. Moreover, energy-plus schools constitute important, pioneering pilot projects and will play a key role in achieving energy-policy objectives.

As part of its "Efficiency House Plus" investment programme, Germany's former Ministry of Transport, Building and Urban Development (*BMVBS* in German) defined an energy-plus standard. The *BMVBS* furthermore demonstrated in pilot projects that residential buildings can meet the energy-plus standard. No fundamental studies have been conducted on energy-plus standards for non-residential buildings.
A feasibility study should therefore be carried out to determine whether educational facilities could satisfy energy-plus requirements.

Subject of research project

The practicability of energy-plus schools was examined using theoretical calculations regarding three schools. In addition, a calculation methodology was developed and vetted. The massings of the three schools were used in calculations and the following calculation-related boundary conditions were specified: standard of insulation, building technologies, on-site electricity requirements, energy generation, and sensitivity analyses. Three heat-supply systems were studied: heat pumps, wood-pellet boilers, and district-heating systems as per a primary energy factor of 0. For the purpose of this study, electricity was generated by a rooftop photovoltaic (PV) system and by PV units integrated in the schools' façades.
In accordance with the *BMVBS* definition, calculations were performed based on standard boundary conditions such as standard climatic conditions and boundary conditions per DIN V 18599. Calculations were likewise executed as per site-specific boundary conditions – such as site-specific climatic conditions and boundary conditions. It became clear that different calculations can lead to remarkably different results. A school in Hamburg, for instance, is exposed to less sunlight than a school in Freiburg, Germany. If site-specific boundary conditions are used in calculating energy efficiency, then the school in Hamburg is less likely to meet the energy-plus standard than the Freiburg school.
In the definition of the "Efficiency House Plus" standard for the *BMVBS* programme, it is stipulated that residential buildings must generate an annual surplus of primary energy and an annual surplus of final energy. Calculations based on the three schools indicate that only one of the heat-supply systems – a heat pump, but not wood-pellet boilers or district heating – can meet the energy-plus standard based on final energy. This is because subterranean heat is not taken into account as final energy. The proposed scope of definition is consequently restricted to achievement of an annual surplus of primary energy so as to ensure a technology-neutral approach that corresponds with non-renewable resource demands. It is comparatively easy as per this approach for wood-pellet boilers or district-heating systems with low resource requirements to meet the energy-plus standard. Energy-efficient building envelopes and efficient building technologies must therefore be mandated by means of supplemental requirements.
Calculations show that all three schools could meet the energy-plus standard concerning primary energy. The more levels there are in a building, however, the worse the ratio will be between rooftop capacity for PV modules and energy requirements. Multi-level buildings

must consequently be optimized by installing PV units in façades and further enhancing the efficiency of building technologies, for example.

Depending on the building technology selected, an additional 30 to 200 euros must be invested per square metre of net floor space in order to meet the energy-plus standard. The priciest building technologies include ventilation systems and geothermal heat pumps using underground pipes.

In addition, actual energy consumption at all three schools was compared with the energy demand as stated in documents certifying compliance with Germany's Energy Saving Ordinance (*EnEV* in German). The hypothetical energy-plus standard was not used in this case, but rather the actual school facilities. The comparison between demand and consumption shows that considerably less energy than calculated was consumed for heating. The causes of this should be examined in future research projects.

A load-curve analysis was also completed. The percentage of on-site consumption of PV electricity was measured, as this is crucial for the economic efficiency of PV systems. Peak feed-in times were also assessed to estimate the impact on the public grid.

As there is a strong correlation between a school's demand for electricity and PV electricity generation, the percentage of on-site consumption exceeds that of single-family houses despite school closures for holidays. The percentage of on-site consumption at energy-plus schools is also influenced by the heat-supply system in question.

Conclusion

Schools can meet the energy-plus standard provided that they have very good insulation and efficient building technologies paired with a photovoltaic system. Heat must be generated primarily via sources of renewable energy. Viable options include geothermal energy in conjunction with a heat pump, a biomass heating system or district heating featuring a low primary energy factor. The larger a school's roof is, the larger a PV system can be with respect to the school's net floor space. In turn, a school can more readily meet the energy-plus standard. An intelligent load-management solution for energy-plus schools should be developed and implemented to minimize any negative impact of current spikes on the public power grid.

Key information

Short title:	Feasibility study of energy-plus schools
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Total outlay:	102,880 euros
Share of outlay paid:	72,016 euros
Duration of project:	01 November 2013 through 15 December 2014

FIGURES

Definition Plusenergieschule	
Bilanzebene	Primärenergie
Bilanzumfang	Bedarf und Erzeugung während Nutzung (keine graue Energie) - Q_P Primärenergiebedarf Gebäude nach EnEV / DIN V 18599 - $Q_{P,N}$ Primärenergetisch bewerteter Nutzerstrombedarf - $Q_{P,prod}$ Primärenergetisch bewertete Energieerzeugung
Bilanzgrenze	Schulgebäude (incl. zugehörigen Außenanlagen) alternativ: Schulgrundstück
Bilanzzeitraum	Jahresbilanz
Bilanzwerkzeug	Bedarfsermittlung für Heizung, Trinkwarmwasser, Lüftung, Beleuchtung nach DIN V 18599 (Mehrzonenmodell) Stromerzeugung nach Methodik der DIN V 18599-9
Primärenergiefaktoren	Festlegung analog für die Schule anzuwendender EnEV Primärenergiefaktoren bei Anwendung der EnEV 2013: f_P Holz: 0,2 f_P Strombezug: 2,4 bzw. 1,8 (allg. Strommix) gemäß EnEV f_P erzeugter KWK-Strom: 2,8 (Verdrängungsstrommix) f_P erzeugter Strom aus PV und Windkraft: 2,4 bzw. 1,8 (analog allg. Strommix) f_P Fernwärme: nach Tabelle A.1 DIN V 18599-1 oder nach AGFW-Liste der veröffentlichten f_P-Bescheinigungen oder durch Berechnung von einem unabhängigen Sachverständigen nach dem Berechnungsverfahren der DIN V 18599
Bilanzbedingungen	I. Standardisierte Berechnung - Klima Bedarfsberechnung: Standardklima Deutschland nach EnEV 2013 - Klima PV-Erzeugung: Standort Potsdam - Klima Wind-Erzeugung: lokale Wetterdaten/Messungen - Nutzungsprofile gemäß Tabelle 4 DIN V 18599-10 - Nutzerstrombedarf: 8 kWh/m^2a für Grundschulen, 10 kWh/m^2a für sonstige Schulen II. Berechnung mit freien Randbedingungen (an die Schule angepasst) - Klima Bedarfsberechnung: Wetterdaten nach Region der DIN V 18599-10:2011-12 - Klima PV-Erzeugung: lokale Wetterdaten (z.B. Meteonorm) - Klima Wind-Erzeugung: lokale Wetterdaten/Messungen - Angepasste Nutzungsprofile - Angepasster Nutzerstrombedarf
Plusenergiestandard	Primärenergiejahresbilanz in kWh/m^2a bzw. kWh/a: $Q_P + Q_{P,N} – Q_{P,prod} < 0$
Nebenanforderungen	Gebäudehülle - Unterschreitung H_T' des EnEV-Referenzgebäudes um mindestens 30 % Beleuchtung - maximale Beleuchtungsleistung: 2 W/100 lx - Präsenzmelder in allen Bereichen - tageslichtabhängige Kunstlichtsteuerung in den Klassenzimmern Nutzerstrom - Erstellung eines Konzepts zur Minimierung des Nutzerstromverbrauchs Betriebsphase - Durchführung eines Monitorings Bei RLT-Anlage - Ventilatorleistung mindestens SFP 3 Bei Biomasseheizung - Einsatz regionaler Produkte aus nachhaltiger Forstwirtschaft

Figure 1: definition energy-plus schools

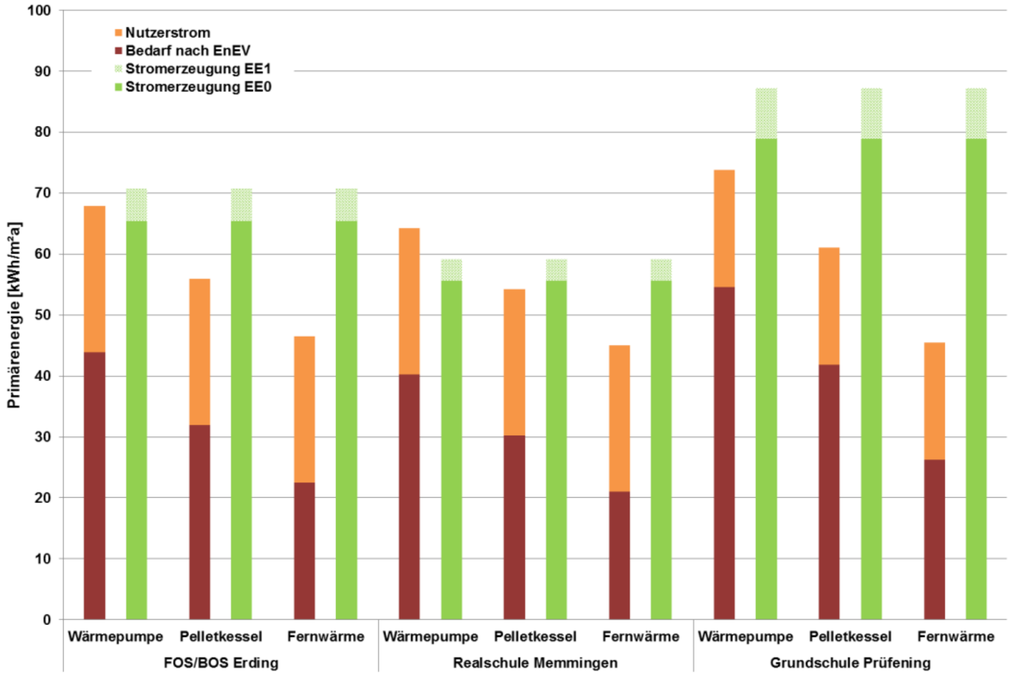

Figure 2: PE_Basis.tif

Underline: primary energy on standard boundary conditions

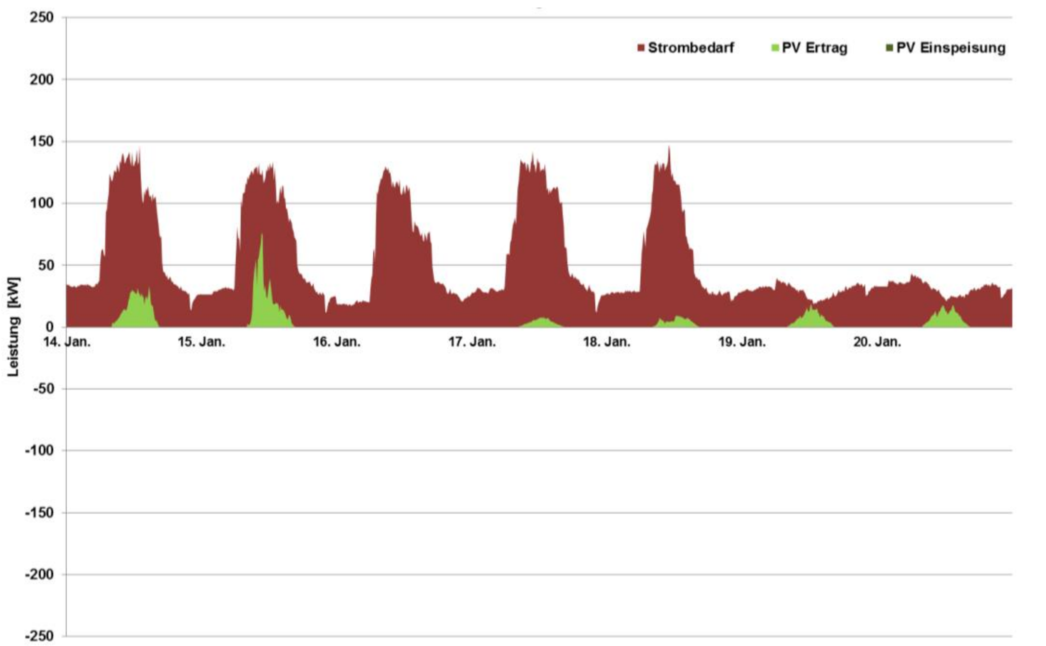

Figure 3: Last_Winter.tif

Underline: load-curve analysis – week in winter (type: heat pump + ventilation system)

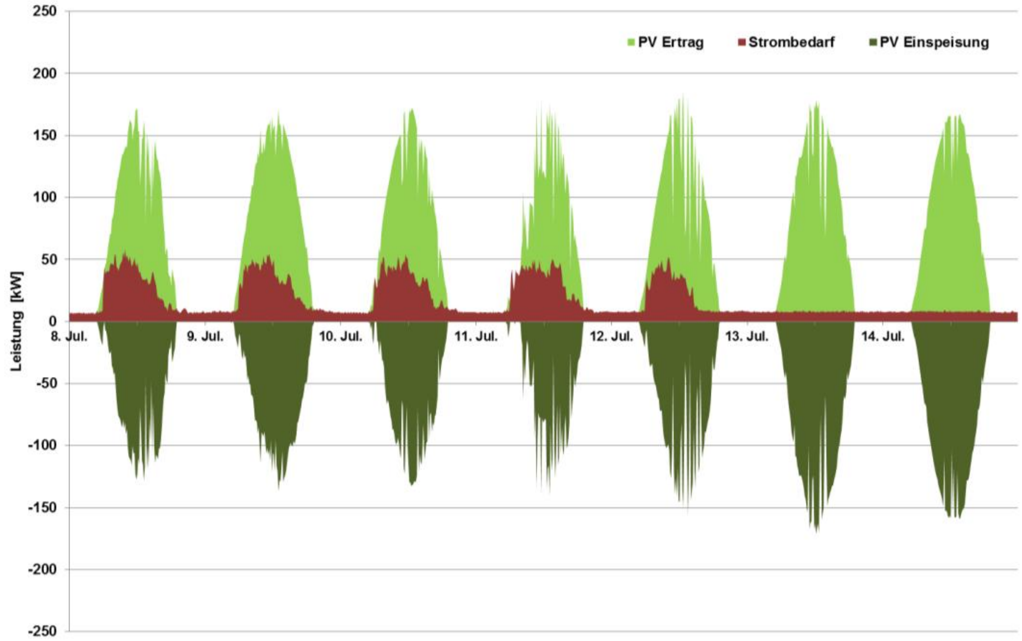

Figure 4: Last_Sommer.tif

Underline: load-curve analysis – week in summer (type: heat pump + ventilation system)

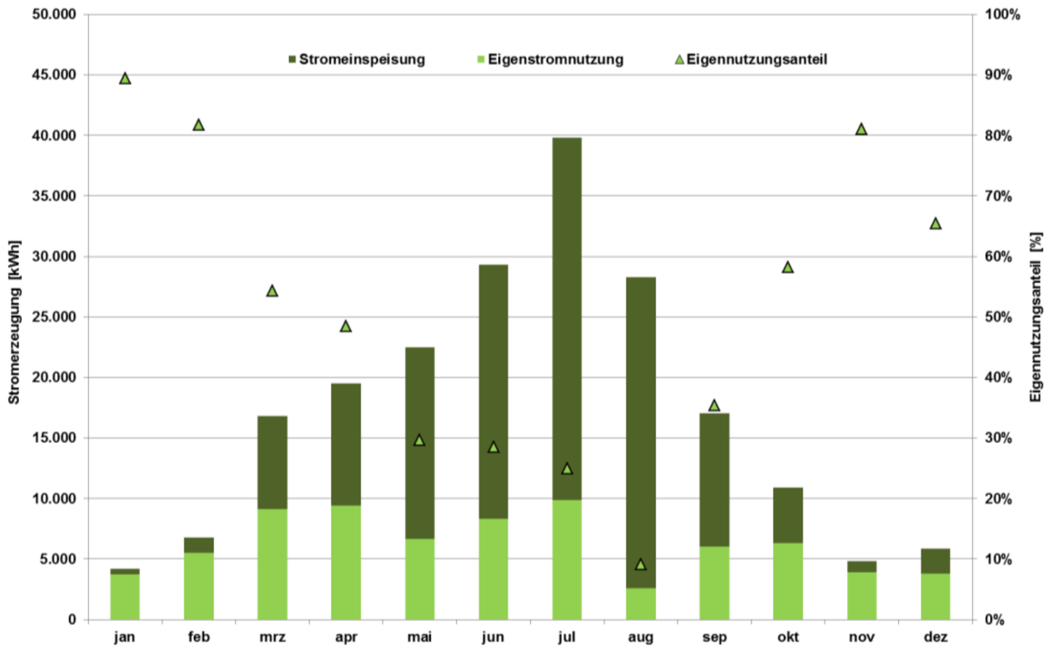

Figure 5: Last_Monat.tif

Underline: Monthly load-curve analysis - generated photovoltaic electricity (type: heat pump + ventilation system)