Article

Nearly Zero Energy Standard for Non-Residential Buildings with high Energy Demands—An Empirical Case Study Using the State Related Properties of Bavaria

Michael Keltsch [1,*], Werner Lang [1] and Thomas Auer [2]

[1] Institute of Energy Efficient and Sustainable Design and Building, Technical University of Munich, Arcisstraße 21, 80333 Munich, Germany; jutta.bergmann@tum.de
[2] Chair of Building Technology and Climate Responsive Design, Technical University of Munich, Arcisstraße 21, 80333 Munich, Germany; klima@lrz.tum.de
* Correspondence: michael.keltsch@tum.de; Tel.: +49-89-289-23208

Abstract: The Energy Performance of Buildings Directive 2010 calls for the Nearly Zero Energy Standard for new buildings from 2021 onwards: Buildings using “almost no energy” are powered by renewable sources or energy produced by the building itself. For residential buildings, this ambitious new standard has already been reached. But for other building types this goal is still far away. The potential of these buildings to meet a Nearly Zero Energy Standard was investigated by analyzing ten case studies representing non-residential buildings with different uses. The analysis shows that the primary characteristics common to critical building types are a dense building context with a very high degree of technical installation (such as hospital, research and laboratory buildings). The large primary energy demand of these types of buildings cannot be compensated by building and property-related energy generation including off-site renewables. If the future Nearly Zero Energy Standard were to be defined with lower requirements because of this, the state related properties of Bavaria suggest that the real potential energy savings available in at least 85% of all new buildings would be insufficiently exploited. Therefore, it would be useful to instead individualize the legal energy verification process for new buildings to distinguish critical building types such as laboratories and hospitals.

Keywords: Energy Performance of Buildings Directive (EPBD 2010); nearly zero energy standard; non-residential buildings; highly technically installed buildings; energy balance

1. Introduction

Effectively reducing the energy consumption in the building sector and using renewable energies are central components of the implementation of the Paris Convention on Climate Change Agreements of December 2015. The building sector is responsible for about 40% of the total energy consumption of the EU. EU forecasts predict further expansion [1] (L153/13). Therefore, in 2010, the European Union replaced the first Energy Performance of Buildings Directive (EPBD 2010) adopted in 2002, calling upon Member States to implement the jointly formulated objectives. The directive applies extensively to the building stock. It establishes minimum required standards for renovating existing buildings and replacing individual building components.

Starting in 2021, the Nearly Zero Energy Standard (nZEB) will be required for all new buildings. From then onwards, all new buildings must guarantee “a very high energy performance (…). The nearly zero or very low amount of energy required should be covered to a very significant extent by energy from renewable sources, including energy from renewable sources produced on-site or nearby.” It is the responsibility of each member country to establish an exact definition for this standard within the framework of the European Directive [1] (Art. 2 No. 2).

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 9 January 2017 doi:10.20944/preprints201701.0030.v2

Peer-reviewed version available at Buildings 2017, 7, 25; doi:10.3390/buildings7010025

For residential buildings, fulfilling these requirements is already possible. Passive Houses and even Net Zero Energy Buildings have already been implemented and tested. As the residential building sector dominates construction activity in Germany (40.6% in 2014 [2]), many studies on future building standards have focused primarily on residential buildings [3] [4]. But what about large infrastructure projects, e.g. new hospitals, institute buildings or research laboratories? These buildings only make up a small part of the annual construction volume, but they consume multiple times the energy of other types of buildings. Figure 1 shows the share of the six most important sectors of new construction activity in 2014 [2]. For each sector, the final energy demand of the Energieeinsparverordnung 2013 (EnEV 2013) [5] reference buildings of selected usage zones was determined and compared to the demand of a typical residential zone (grey areas). Most non-residential uses have a higher energy demand than that of housing. The selected infrastructure buildings (i.e., laboratory usage) were found to have an energy demand of approximately five times that of a housing zone [own simulation]. By contrast, the average potential of renewable energies in residential buildings is sufficient to compensate the demand in the annual balance sheet (inner green sectors). Infrastructure buildings often have a lower potential because of their dense building context and higher energy demands [own qualitative estimation].

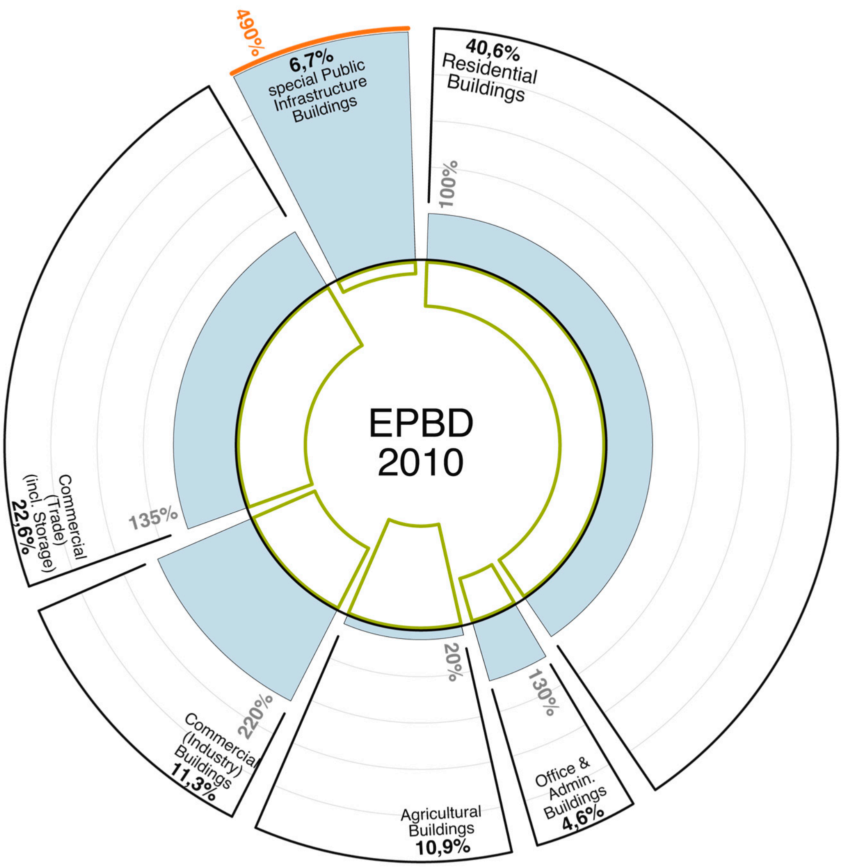

Figure 1. The new building volume in 2014 in Germany with the energy demand of each typical usage zone as well as its potential for renewable energies (own representation according to [2])

Will these critical building types be able to fulfil the requirements of the EPBD 2010 from 2021 onwards? Or – to account for these types of buildings - will the requirements be reduced for all building types to such an extent that much of the potential to reduce energy demands remains unused?

This study investigates this question by considering the properties owned by the Free State of Bavaria, to which the regulations for normal temperature buildings stipulated by the EnEV 2013 apply.

Peer-reviewed version available at Buildings 2017, 7, 25; doi:10.3390/buildings7010025

Based on the average building parameters of each category of non-residential buildings, ten case studies were selected, and their potential as Nearly Zero Energy Buildings for 2021 was analyzed. These real buildings were surveyed for geometry, components and usage zoning and were given a fictional building standard indexed to the year 2021. The calculations were carried out with the tool EnerCalC 2013 [6]. The results were discussed in the light of the objectives of the EPBD 2010 and possible requirements for new buildings from 2021 onwards.

Finally, the results of the case studies were applied to assess the risk of the properties owned by the State of Bavaria, with the aim of obtaining an estimate of how many new projects from 2021 onwards might have critical building types.

2. Property portfolio of the Free State of Bavaria

The State of Bavaria has over 10,000 built-up properties in its permanent portfolio. The portfolio ranges from simple warehouses to high-tech surgery centers, from prisons to buildings of the UNESCO World Cultural Heritage, which represent Bavaria's image worldwide [7]. Nevertheless, the real estate portfolio of a state such as Bavaria is not typically representative of the building stock in Germany. Its composition instead reflects the history of the state and the tasks assigned to federal states within the Federal system of Germany. The portfolio includes building types that can only be found within states (for example police building and court houses). However, commercial buildings are not included. The percentage of housing and accommodation buildings is smaller by far than the average German building stock. All building properties managed by the Bavarian Building Authority are grouped together in a central database (Fachdatenbank Hochbau, April 2015) [8]. The original data set contains 20,054 records of properties within Bavaria.

The data were filtered according to the following criteria: Property owned by the Free State of Bavaria, within the scope of the EnEV 2013, plausibility and completeness of the data and buildings regulated to normal temperatures. After data preprocessing, 4,401 records (buildings) remained for the evaluation.

The Bauwerkzuordnungskatalog (BZK) of the Conference of Ministers of the States, responsible for urban development, construction and housing, was used to classify the uses of these buildings. This catalogue defines building uses using a four-digit code, in which each digit represents a more detailed subdivision of building uses [9]. Only the first and second digits of this classification (depth of analysis) are largely relevant in the context of the energy analysis of non-residential buildings. Subdivisions beyond the second digit are no longer relevant for energy analysis according to DIN V 18599, since the energy demands of specific processes are not balanced [10].

The building stock of Bavaria (Figure 2) analyzed in this study consists of nearly one-third office and administrative buildings, including court and parliament buildings. This group also leads in terms of the gross floor area (GFA: 33.3%) and the gross building volume (GBV: 31.0%). Group 7000, buildings for production, storage and maintenance, and group 6000, residential and housing buildings, represent a higher percentage of the total number of buildings, but a comparatively lower percentage of the total GFA and GBV. These building types are comparatively small-scale and small-volume. Buildings for science, teaching and research, as well as for health, lie on the opposite end of the spectrum. They represent a very high percentage of the GFA and the GBV relative to the number of buildings. These buildings are disproportionately large on average. The differences within group 4000, buildings for education and culture, in terms of number, GFA and GBV are similar to groups 2000 and 3000, but not so extreme.

Peer-reviewed version available at Buildings 2017, 7, 25; doi:10.3390/buildings7010025

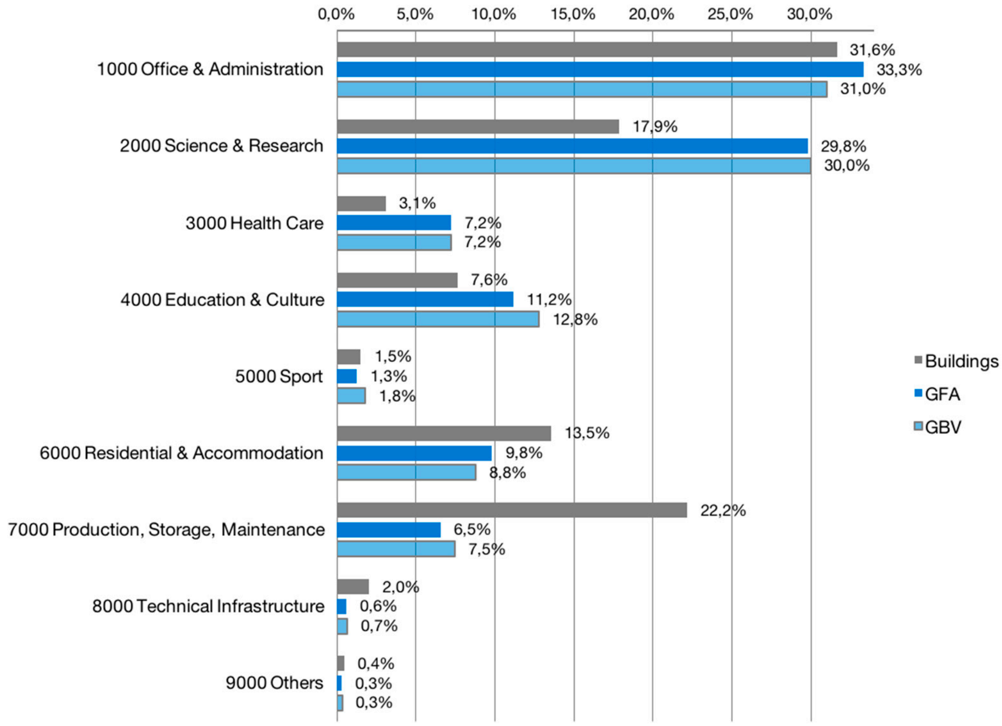

Figure 2. Percentage of building types among the building properties of the Free State of Bavaria according to the first digit of their type in the Bauwerkzuordnungskatalog (own representation according to [8])

In order to find suitable case studies for each type of building, the characteristics of GFA and number of usable floors (UF) of each category were investigated. The average values of the GFA and UF of each main category (Figure 3) served as a guide for selecting the case studies. The spread in the average values of the subcategories is shown, together with their minimum and maximum values.

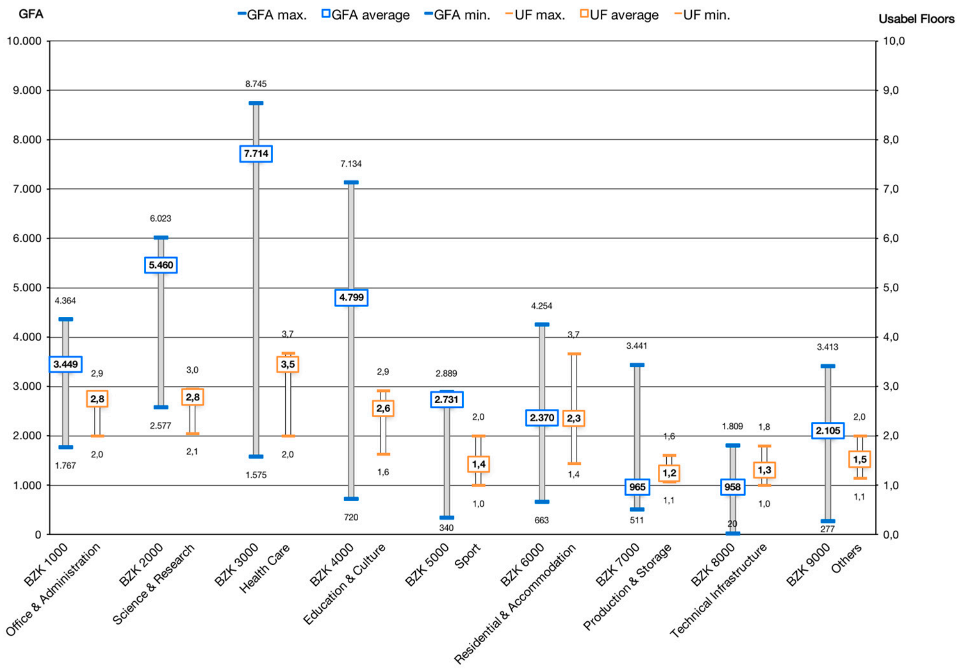

Figure 3. Empirical survey of the average values of the main categories (first digit) and spread in the subcategories (second digit), separated by gross floor area (GFA) and above-ground usable floors (UF) (own representation according to [8])

Peer-reviewed version available at *Buildings* **2017**, *7*, 25; doi:10.3390/buildings7010025

3. Case Studies

The case study buildings range from a two-storey administrative building with 1,622 m² GFA to a seven-storey research institute with 18,525 m² GFA (Table 1). As an indicator of the technical installation level, the percentage of the cost group 4 (KG 4: Building - technical installations) is listed relative to the cost of construction (cost groups 3 and 4) [11] [12]. The installation rates as measured by these cost components range from 24% for the least installed buildings to 52% for the most highly installed buildings. The use of the building is indicated by the BZK. Zoning according to DIN V 18599-10 uses between 4 and 14 different zones. The approaches of EnEV certification providers differ considerably. Many providers subdivide the building very precisely into small parts without using any of the possible simplifications. By contrast, some providers use large-scale zonation even for complex buildings.

Table 1. Overview of all case studies with the categories code by Bauwerkzuordnungskatalog (BZK), building use, number of usable floors (UF), gross floor area (GFA), gross building volume (GBV), the ratio of envelope area to volume (A/V), the percentage of window area to the envelope area, the percentage of the construction costs of technical installation to the overall construction costs (KG4/BWK) and the number of usage zones for energy performance calculation according to DIN V 18599-10

Number	BZK	Building Use	Usable Floors	GFA (m²)	GBV (m³)	A/V (m⁻¹)	Percentage Window Area	Percentage (KG4/BWK)	Number of Use Zones
01	1100	Parliament	7	5,009	16,350	0.24	39%	34%	10
02	1200	Courthouse	3	5,392	19,944	0.36	35%	30%	6
03	1340	Police Station	2.5	1,622	5,885	0.33	23%	30%	6
04	2240	University	4	5,715	23,318	0.26	24%	47%	8
05	2270	Research	3	9,978	45,185	0.30	43%	35%	9
06	2320	Research Centre	6	18,525	74,947	0.18	62%	50%	4
07	2500	Laboratory	4	5,822	24,440	0.27	29%	52%	9
08	3112	Hospital	5	9,919	41,933	0.29	54%	51%	9
09	4500	Library	4	1,982	8,429	0.51	22%	24%	7
10	4620	Museum	3.5	10,900	79,399	0.26	12%	37%	14

4. Definition of a Nearly Zero Energy Standard

This work is based on the goal of climate protection. The non-renewable primary energy demand is chosen as the main requirement of the analysis.

CO2 emissions could have been one possible alternative. However, they are less present in the energy balancing of buildings and would only represent an alternative conversion of delivered energy demands. The EPBD 2010 provides a general framework for calculating the energy performance, setting clear guidelines that comply with the German balancing standards required by EnEV and DIN V 18599. It was therefore chosen as the calculation system for this study [1] (Annex I).

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 9 January 2017 doi:10.20944/preprints201701.0030.v2

Peer-reviewed version available at Buildings 2017, 7, 25; doi:10.3390/buildings7010025

There are deviations from the above methodology in some respects. As in [4] or [13], the self-production of energy is fully calculated if it can be provided into the grid. This corresponds to all current definitions of net zero energy and net plus energy buildings. In addition, the primary energy factors are not designed asymmetrically. This means that the same primary energy factor is applied to the grid feed and supply. Indicating a political preference by weighting with various factors is excluded in this investigation. Furthermore, only unique primary factors are used for the case studies, to avoid location-related advantages. Local and district heating from cogeneration therefore always uses the same calculation factors. The overview of the definition framework (Table 2) is based on the systematics of [14]:

Table 2. Overview of the Nearly Zero Energy Standard definition framework

Criteria	**Definition**
Physical Boundary	Building site (including auxiliary buildings)
Balance Boundary	All energies according to the building operation (EPBD: heating, cooling, ventilation, domestic hot water, lightning, auxiliary power)
Renewable Energy Supply	On-Site generation including off-site renewables
Boundary Conditions	Usage profiles according to DIN V 18599-10
Weighting System	Primary energy demand (non-renewable) with symmetrical weighting of the conversion factors
Balancing Period	Calendar year (with monthly balancing)
Type of Balance	Input-Output-Balance

The EPBD 2010 (Annex I) calls for the total energy efficiency and primary energy consumption to be transparently represented. The calculation according to EnEV always outputs only one value per requirement category. Laypersons may find it difficult to understand how this value is composed. The system of net accounting uses a representation based on the demand (input) and the production (output) of energy [13]. This survey provides an easy-to-understand and transparent description of the performance of a building (Figure 4).

Peer-reviewed version available at Buildings 2017, 7, 25; doi:10.3390/buildings7010025

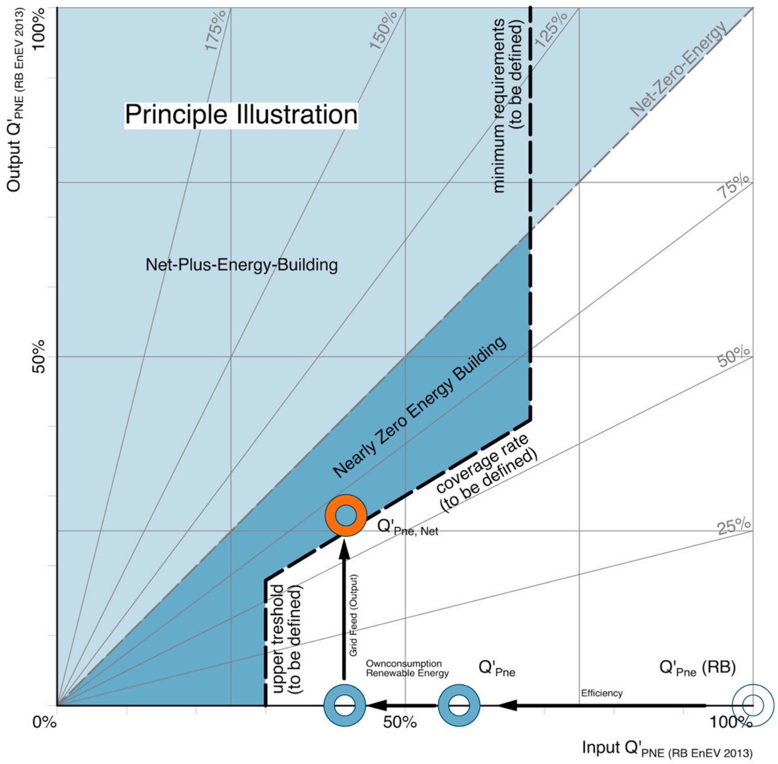

Figure 4. Illustration of the principle for the Nearly Zero Energy Standard based on the representation of an input-output balance (own representation according to [13]); The presentation is a specific requirement relative to the reference building (RB according to EnEV 2013)

The reference value is always the non-renewable primary energy demand (Q'_{PNE}) of the reference building according to EnEV (100%). The value of Q'_{PNE} represents the overall efficiency of the building's performance. This value is reduced by the increasing the building's self-consumption of renewable energies (lower input value on the x-axis). The output (y-value) is increased by increasing the energy supplied to the grid. If the output exceeds the value of the input (angle bisector), the building meets the net zero energy standard. Since meeting this standard is not required for low-energy buildings, a lower degree of coverage (allowing the energy demand to be compensated by grid feed) could provide a definition for Nearly Zero Energy Buildings. The purpose of the case studies is to analyze this option.

An upper limit for the inputs of new buildings must be chosen in order to define minimum standards for energy efficiency that take into account the buildings' consumption of the renewable energy produced by their own systems. A high threshold for energy efficiency (Figure 4 dashed line) above which no feed-in is necessary should also be discussed for buildings that do not have the possibility to generate energy on-site (for example dense, shaded city centers).

5. Analysis Method

5.1.Tool EnerCalC

It is doubtful that the existing EnEV balance sheets of the case studies are comparable. They were developed by different creators using different software with very different approaches. [15] shows that simply using different commercial software creates considerable differences in the calculation results. A new unique calculation following a unique framework is necessary in order to be able to make comparable qualitative statements in the analysis of the case studies.

The calculation tool EnerCalC 2013 is therefore used. In his dissertation, Markus Lichtmeß developed simplified approaches based on the accounting method of DIN V 18599 at the Bergische Universität Wuppertal in the field of the physics of buildings. EnerCalC is designed to simplify the extremely complex surface area of zones and the associated thermal heat transfer surfaces without having to dispense with the advantages of multi-zone models in non-residential buildings. Since the validation of EnerCalC did not use a statistically reliable method [16], the tool was compared to commercially available software before the study on three of the case studies. This comparison found an average deviation of 3.3%, and a maximum deviation of 7.9%. For the qualitative assessment, it is important to analyze all of the considered case studies using the same tool.

5.2 Assumed Nearly Zero Energy Standard 2021 (nZEB 2021)

Buildings can no longer be considered as isolated systems. The study [17] considers two main characteristics that directly relate to future new buildings, taking into account the conversion of the energy production and network infrastructure:

- Reduction of energy demands by consistently exploiting all efficiency potentials,
- Change of heat supply: away from chemically bound energy to electrically operated heat pumps (primarily geothermal heat pumps).

Against this background, a future building standard is indicated for 2021 (Table 3), and then applied to the real case studies for analysis. Passive measures for reducing the demand are preferable to active efficiency measures [18]. An accepted standard for 2021 cannot replace individual building planning and should only make a qualitative statement.

Without a considerable advance in technology, no heat transfer coefficient (U-value) below 0.08 to 0.1 W/m²K will become commercially viable for outdoor components in the foreseeable future [19]. This would not make sense given our commercially available insulation materials when taking a holistic view of the life cycle. The energy required to produce large quantities of insulation with a U-value of e.g. 0.15 W/m²K to 0.1 W/m²K would no longer be beneficial relative to the energy saved during the operation of the building [20]. For transparent parts of the building envelope, triple-glazed glazing is customary. High-quality window constructions already achieve U_W-values of 0.70 W/m²K. To simplify the analysis, the window geometries were not recalculated individually. The U_W-value was assumed to be uniform.

The technical conditioning of the usage zones was taken from the actual execution of the case studies. For the technical systems, a highly efficient state-of-the-art building standard was chosen.

Different types of renewable energies are also listed in Table 3. The available roof area (class 1 according to [21]) of the case studies was used for the scope of the usable radiation energy. The electrically operated geothermal heat pump was selected because of reasons mentioned above, and associated with an evaporation of all market-based heaters relative to their primary energy requirements and their availability at all locations.

The details of the assumed Nearly Zero Energy Standard can be found in Table 3.

Peer-reviewed version available at *Buildings* **2017**, *7*, 25; doi:10.3390/buildings7010025

Table 3. Assumed Nearly Zero Energy Standard for 2021

	Component / System	Attribute	Definition for assumed Nearly Zero Energy Standard 2021
Efficiency Building Envelope	Opaque envelope comp.	U-Value	0.15 W/(m²K)
	Transparent envelope components	U-Value	0.70 W/(m²K) with Ug= 0,5 W/(m²K); U_f = 0,7 W/(m²K); Ψ = 0.045 W/mK
		g-Value	0.50
	Heat bridging coefficient	Δ UWB	0.01 W/(m²K)
	Building impermeability	n50 / q50	0.6 1/h
Efficiency Building Technology	Lighting	Techn. System	Self-ballasted fluorescent tube light
	Lighting control	Techn. System	Often presence detector & constant lighting settings sometimes zone-dependent
	Ventilation	Techn. System	as case study
	Recovery coefficient	ηt	0.75
	Cooling	Techn. System	as case study
	Coolers	Techn. System	Water cooled compressor (efficient)
	Cold transfer	Techn. System	Large area components
	Heat transfer	Techn. System	Large area components, PI-Regulation
Use of Renewable Energy	Heating	Techn. System	Brine/water heat pump (DIN V 18599-5)
	Solar heating	Techn. System	Flat collectors optimized for heat support and hot water usage
	Photovoltaic	Techn. System	crystalline cells, horizontally mounted; area by potential class 1

6. Results

In order to fully credit the renewable energy sources generated by the building itself / on-site in the future, it would make sense to give a clear presentation of the power supply (input) and the feed-in (output) of the building. Therefore, a two-dimensional representation of the input-output balance is used in the discussion of the total building performance, since it allows the relationships between energy inputs and outputs to be clarified.

When considering the overview of all data series of the ten case studies (Figure 5), differences between the individual results can be recognized. The greater the distance between the right data

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 9 January 2017 doi:10.20944/preprints201701.0030.v2

Peer-reviewed version available at Buildings 2017, 7, 25; doi:10.3390/buildings7010025

point (reference building according to EnEV) and the left data point (nZEB 2021) of a row with respect to the x-axis, the higher the absolute reduction of the specific primary energy demand (Δx).

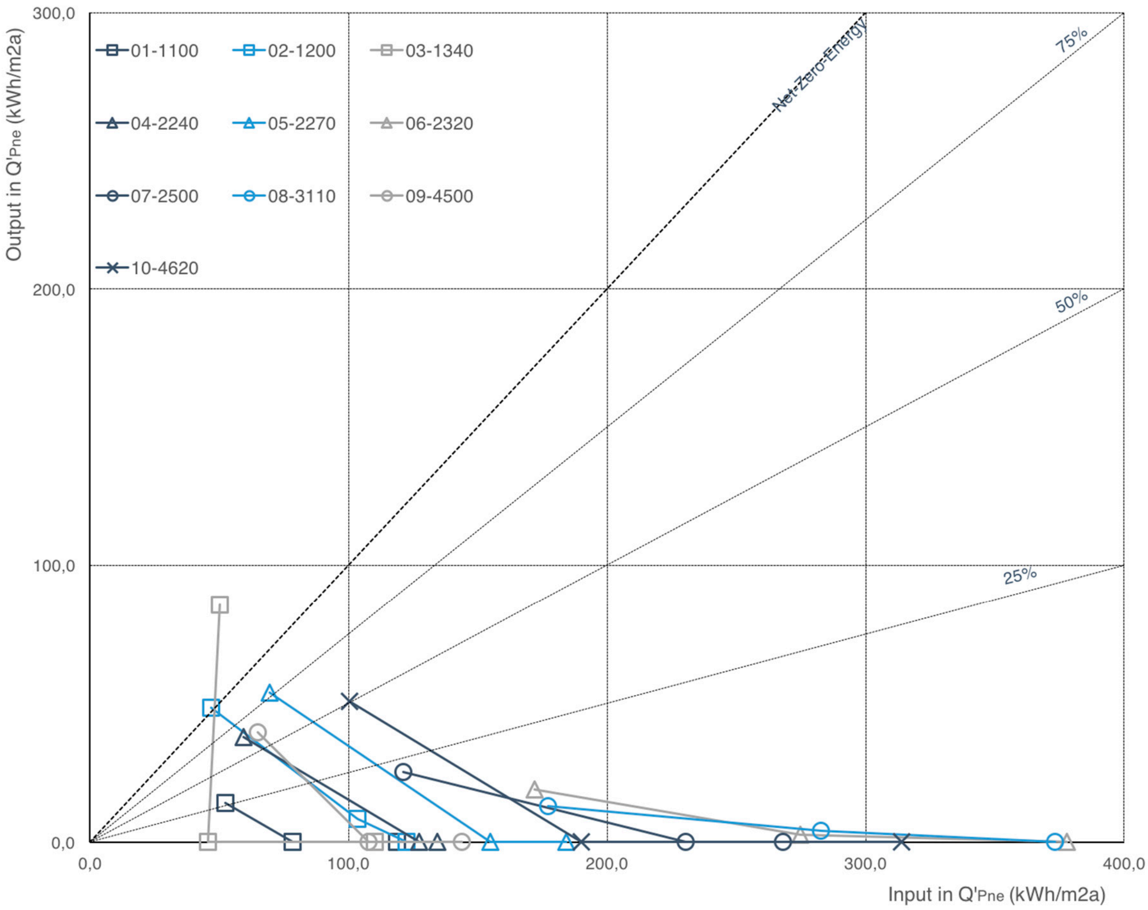

Figure 5. The results of all case studies - input-output balance (Q`P (kWh/m²a)) of the energy standard's reference building according to EnEV (right data point), standard case study (middle data point) and standard nZEB 2021 (left data point);

The highest absolute demand reductions in the specific primary energy demand tended to be achieved by the buildings whose reference design had high demand (often buildings with a high degree of technical installation) and large volumes. The three best results were:

- 10-4620 (museum building) Δx = 213.6 kWh/m²a
- 06-2320 (research centre) Δx = 205.8 kWh/m²a
- 08-3110 (hospital) Δx = 196.1 kWh/m²a

The lowest reduction was:

- 03-1340 (office / administration building) Δx = 59.9 kWh/m²a

The y-value indicates the grid feed (input). It should be noted that this is not the absolute power generation of the PV systems, but only the ratio of the grid feed to the generated electricity. The generated electricity is primarily used to reduce the energy consumption of the building itself and deducted using the monthly balance sheet method. The best results are:

- 03-1340 (office / administration building) y = 85.8 kWh/m²a
- 05-2270 (institute building) y = 54.0 kWh/m²a
- 10-4620 (museum building) y = 50.9 kWh/m²a
- 02-1200 (office / administration building) y = 48.6 kWh/m²a

All the case studies with good input results have in common that they have a roofing plan that is well-suited for solar energy. In addition, their buildings have between two and three utility floors

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 9 January 2017 doi:10.20944/preprints201701.0030.v2

Peer-reviewed version available at Buildings 2017, 7, 25; doi:10.3390/buildings7010025

(case study 10 has four storeys). Case study 03 also uses an auxiliary building for solar energy, which results in a comparatively high feed-in value.

When considering the input-output balance, three of the ten case studies do not reach the 25% coverage rate:

- 08-3110 (hospital) 7% coverage rate
- 06-2320 (research centre) 11% coverage rate
- 07-2500 (laboratory building) 21% coverage rate

Seven buildings reach more than 25%:

- 01-1100 (office / administration building) 27% coverage rate

Six buildings reach more than 50%:

- 10-4620 (museum building) 51% coverage rate
- 09-4500 (library building) 61% coverage rate
- 04-2240 (institute building) 64% coverage rate

Three buildings reach over 75%:

- 05-2270 (institute building) 78% coverage rate

Two buildings should be seen as net zero or net plus energy buildings:

- 02-1200 (office / administration building) 104% coverage rate
- 03-1300 (office / administration building) 171% coverage rate

Under the foundational conditions of the study, it seems unrealistic to achieve a net zero-energy balance for all new buildings from 2021, as only two out of the ten case studies meet this standard.

Energy from renewable sources does not only affect the grid feed (output) in the balance sheet. Geothermal energy, solar thermal energy and PV also reduce the non-renewable primary energy demand. The requirement of the EU directive is therefore fulfilled by combining the two parameters of non-renewable primary energy supply and grid feed of renewable energies (two-dimensional balancing space, see point 7).

The relative specific primary energy demand of each building type is considered relative to the corresponding reference building (= 100%) (Figure 6). This is the reference building method for the energy evaluation of new buildings according to EnEV. This shows that all case studies produce less than 55% of the demand of the reference buildings. The worst-case study here reaches 48%. In three of the case studies, the production falls below 40% of the reference requirement (twice 32% and 38%). The production of the majority of buildings is between 40% and 50% (44% - 48%).

Since simplifications and generalizations were made in the analysis, the potential for reducing the demand and optimizing the energy generation of individual examples has not yet been exhausted.

It is reasonable to expect that producing 40% of the specific primary energy demand (non-renewable) could even be exceeded without major effort, with the aid of regional primary energy factors (for example district heating with cogeneration and waste incineration). Hopefully this will not lead to a leak in building efficiency quality in order to exploit the economic optimum. To address this issue, it is necessary to discuss which additional requirements should be placed on the specific primary energy demands (for example, a limitation on the end energy requirement according to [4]).

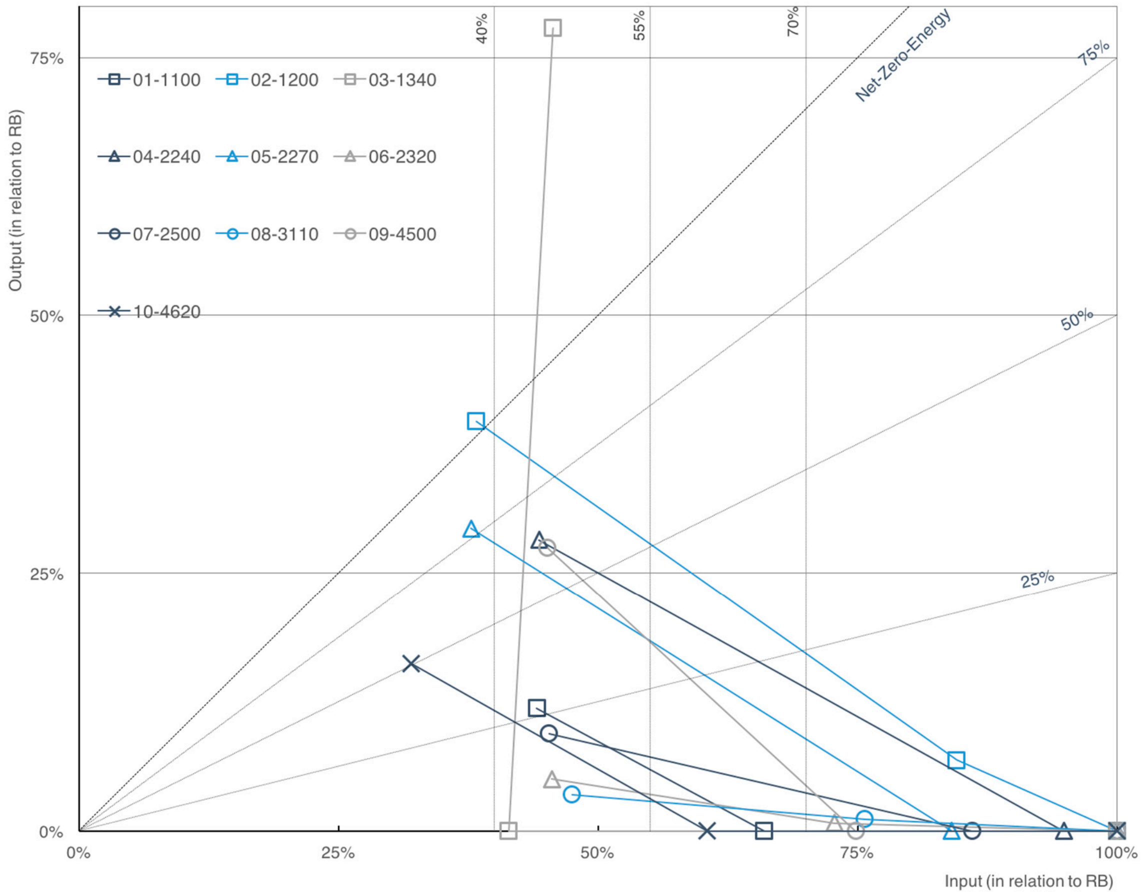

Figure 6. The result of all case studies - input-output balance (Q`P (kWh/m²a)) as a percentage of the reference building (RG = 100%) in the energy standard's reference building according to EnEV (right data point), standard case study (middle data point) and standard nZEB 2021 (left data point);

7. Discussion

7.1 Target area for a Nearly Zero Energy Standard 2021

The results of this analysis can be used to propose a target range for a Nearly Zero Energy Standard for 2021. This proposal should consider the findings of state-of-the-art research and should also integrate the results of studies of different types of non-residential buildings. The following points are important:

- The one-dimensional view of energy demands, as currently stipulated by the EnEV, only allows energy-negative buildings to be balanced.
- The net balance of energy supply (input) and grid export (output) is a survey that allows a transition from energy-negative to energy-positive buildings (two-dimensional target range).
- The self-consumption of renewable generated electricity varies greatly depending on the building type. This affects the overall result of the input-output balance in the direction of the x-axis as well as in the direction of the y-axis. Building types with high energy demands use their own consumption to reduce their demand, whereas building types with lower energy demands feed more energy into the grid.

It would therefore be useful to define the target area for Nearly Zero Energy Buildings in terms of these two parameters. The following represents an attempt to propose a draft requirement based on the above analysis: One possible Nearly Zero Energy Standard could be establishing by defining a two-dimensional target area (nZEB 2021) in the input-output diagram (Figure 7) as follows. The permissible x-values (input non-renewable primary energy demand) are defined as 40% to 55% of the reference building, depending on the output coverage level. Forty percent was chosen as the lower threshold for the input, since it is an ambitious value for buildings with low feed-in (coverage

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 9 January 2017 doi:10.20944/preprints201701.0030.v2

Peer-reviewed version available at Buildings 2017, 7, 25; doi:10.3390/buildings7010025

0-25%). This target is particularly accessible if more energy sources with high renewable shares are used (environmental heat, wood pellets, etc.) [22].
One study even proposes this standard as the main requirement for the primary energy requirement of new buildings from 2021 onwards for all building types, even without awarding credit for potential grid feed [4].
A percentage of 55% of the non-renewable primary energy requirement of the reference building is taken as the minimum standard for the input, since all building types in the above study far exceeded this value. Even critical building types with high degrees of installation and a high number of usable floors surpassed this standard. This criterion is thus chosen as the minimum efficiency standard, even for buildings that fall in the net plus energy range. This minimum standard guarantees that new buildings must achieve a minimum efficiency level. The principle that avoiding energy demand is preferable to regenerative cover should also apply to future net plus energy houses [23]. Between the thresholds of 40% and 55% of the primary energy demand relative to the reference building, the requirement is graded uniformly in steps of 25%, depending on the coverage ratio.

Buildings with input-output values located to the left of the requirement level (blue area) should be defined as Nearly Zero Energy Buildings.

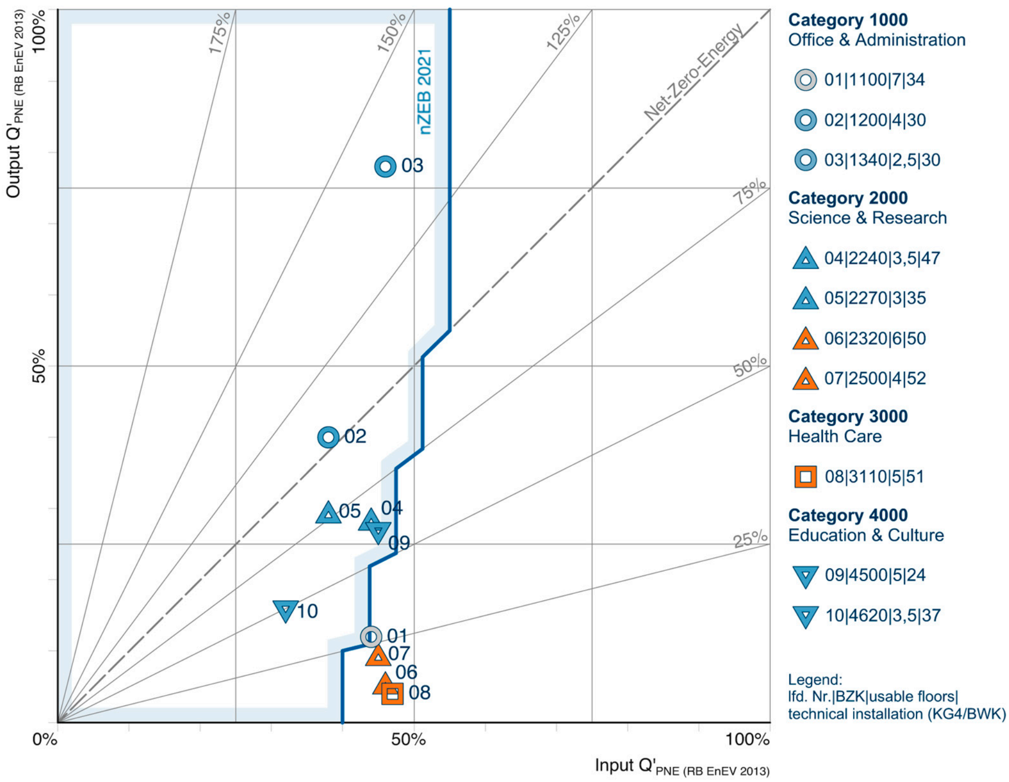

Figure 7. Input-output balance ($Q`_{Pne}$ (kWh/m²a)) relative to reference building (RB = 100%) - Summary of case studies for standard nZEB 2021

If this definition is applied to the results of all ten case studies, seven out of ten would reach this level. Case studies 04 and 09 do not reach the 40% limit, but compensate for the higher energy demand by means of grid feed. It is thus possible to compensate in part for the energy demand by producing renewable energy. This approach is more open to technological innovation in new buildings from 2021 onward. In case of larger sanitizations of buildings, this type of balancing allows the lower efficiency potential of existing buildings to be compensated by producing energy within the building.

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 9 January 2017 doi:10.20944/preprints201701.0030.v2

Peer-reviewed version available at *Buildings* **2017**, *7*, 25; doi:10.3390/buildings7010025

The three projects (06, 07 and 08) that do not achieve this nZEB level have in common the fact that they have of a very high degree of technical installation, at over 50%, and the fact that they have four or more usable floors.

7.2 Risk assessment for the property portfolio of the Free State of Bavaria

By taking the degree of technical installation and the number of usable floors as criteria for assessing the criticality of the building portfolio of the Free State of Bavaria, an empirical assessment of the number of critical buildings can be made. Neither the selection of the criteria nor the evaluation fulfil the scientific standards of a statistical study. Nevertheless, this estimate is an indicator of the number of possible new buildings from 2021 onwards that will not be able to achieve the proposed performance requirements.
By considering the number of buildings of each type as a reference for building activity, an estimate can be established for the number of new buildings from 2021 that should be assessed as challenging and critical with respect to the proposed Nearly Zero Energy Standard. This approach requires a consistent life span for all types of buildings and their replacement by equivalent new buildings.

Based on the case studies, boundaries were drawn for uncritical attributes (+), attributes requiring individual case evaluations (0) and critical attributes (-) in order to determine the number of buildings in each of these categories. The results from Table 4 are shown in Figure 8. The data for the degree of technical installation are taken from [11] and [12].

Table 4. Data analysis (number of buildings) of the property portfolio of the Free State of Bavaria using the criteria degree of technical installation (KG4 / BWK) and number of usable (above-ground) floors differentiated into uncritical (+), neutral (0) and critical (-) attributes (data from [8])

BZK	Technical Installation (KG4/BWK)	Usable Floors ≤ 3 (+)	Usable Floors = 4-5 (0)	Usable Floors ≥ 6 (-)
1000	20.0% (+)	1126	211	55
2100	25.0% (+)	87	16	10
2210	28.0% (+)	152	60	17
2220	27.0% (+)	30	4	0
2230	33.0% (+)	13	2	2
2240	33.0% (+)	57	36	7
2250	36.0% (0)	19	5	3
2260	39.0% (0)	32	9	2
2270	28.0% (+)	0	0	0
2280	41.0% (-)	57	29	1
2310	44.0% (-)	35	3	0
2320	52.0% (-)	1	0	0
2400	49.0% (-)	54	7	1
2500	52.0% (-)	30	5	0
3100	50.0% (-)	59	38	10
3200	40.0% (-)	5	0	0
other 3000	30.0% (+)	18	5	0
4000	26.0% (+)	273	51	11
5000	21.0% (+)	66	0	0
6000	25.2% (+)	510	73	13
7000	25.5% (+)	971	4	1

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 9 January 2017 doi:10.20944/preprints201701.0030.v2

Peer-reviewed version available at Buildings 2017, 7, 25; doi:10.3390/buildings7010025

Figure 8 shows the results: According to this evaluation, 86.8% of the new buildings from 2021 onwards would be uncritical and implementable with regard to the above-mentioned Nearly Zero Energy Standard. 8.4% of new buildings would be considered challenging, 2.3% critical or very critical. This also includes all three case studies (06, 07 and 08) that did not reach the defined minimum energy standard.

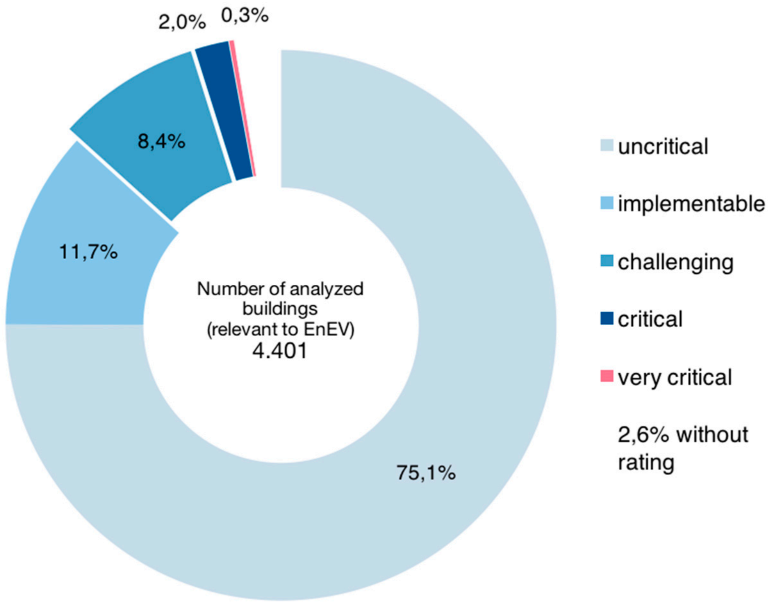

Figure 8. Risk assessment with the criteria of degree of technical installation and usable floors using the example of the FDH of the Free State of Bavaria [8]

8. Outlook

By 2050, the building stock should be almost climate-neutral [5]. At this point in time, most new buildings will still be in operation. They have to meet the requirement as early as 2021. If the standard for 2021 is defined in such a way that all building types can achieve it, much of the potential for climate protection would be left unused due to few types of critical buildings. This "lowest common denominator" approach certainly does not lead towards achieving the goal in 2050.

The system for proving compliance with fire protection standards in new buildings could serve as an example in the energy sector: For the majority of new buildings, the building regulations of the States of Germany stipulate general rules that can be used to achieve and demonstrate compliance with the protection objective. For special types of buildings, whose use requires special measures beyond the general rules, an expert elaborates an individualized concept for structural fire protection.

Individual Climate Protection Balance Sheet for Critical Types of Buildings

If this approach is applied to the energy verification process in the future, the EnEV regulations could cover the majority of new buildings. The energy performance of new buildings with critical attributes would be calculated by specialist designers according to a fixed list of criteria. In this case, the protection target definitions would have to be established based on the climate protection measures necessary to achieve the overall goals.

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 9 January 2017 doi:10.20944/preprints201701.0030.v2

Peer-reviewed version available at *Buildings* **2017**, *7*, 25; doi:10.3390/buildings7010025

Acknowledgments

This work was supported by the German Research Foundation (DFG) and the Technical University of Munich (TUM) in the framework of the Open Access Publishing Program.

Thanks to the Bavarian Ministry of the Interior, for Building and Transport for providing the anonymized data of the state related properties.

Special thanks to John Anderson for the proofreading of the English grammar and to the two anonymous reviewers and the academic editor for their comments.

Conflicts of Interest

The authors declare no conflict of interest.

References

1. Europäische Union. Richtlinie 2010/31/EU des Europäischen Parlaments und des Rates vom 19. Mai 2010 über die Gesamtenergieeffizienz von Gebäuden (Neufassung). 2010.
2. Statistisches Bundesamt. Statistisches Jahrbuch 2014. Statistisches Bundesamt: Wiesbaden, 2014.
3. Erhorn, H.; Bermann, A. Wege zum Effizienzhaus Plus. Bundesministerium für Umwelt, Naturschutz, Bau und Reaktorsicherheit: Berlin, 2014.
4. Bundesministerium für Verkehr Bau und Stadtentwicklung (Hrsg.). Untersuchung zur Novellierung der EU-Gebäudenergieeffizienzrichtlinie (EPBD). Identifikation und Analyse von Hemmnissen beim Neubau von hocheffizienten (Niedrigstenergie-)Gebäuden und Entwicklung eines Konzepts zur Marktdurchdringung bis 2020; 2012.
5. Bundesrepublik Deutschland. Energieeinsparverordnung vom 24. Juli 2007 (BGBl. I S. 1519), die durch Artikel 326 der Verordnung vom 31.August 2015 (BGBl. I S. 1474) geändert worden ist. Bundesgesetzblatt S. I 3951 2013.
6. Lichtmeß, M. EnerCalC, vereinfachte Energiebilanzen nach DIN V 18599. EnOB: Onlineveröffentlichung EnOB-Plattform Energieoptimiertes Bauen: 2010.
7. Oberste Baubehörde im Bayerischen Staatsministerium des Innern, für Bau und Verkehr. 7. Jahresbericht der Staatsbauverwaltung 2014; München, 2015.
8. Oberste Baubehörde im Bayerischen Staatsministerium des Innern, für Bau und Verkehr. Fachdatenbank Hochbau; Stand 21.04.2015. München, 2014.
9. Bauministerkonferenz (ARGEBAU). Bauwerkzuordnungskatalog; 2010.
10. Leibniz-Institut für ökologische Raumentwicklung; Ingenieurbüro Ralph Petereit. Typologie und Bestand beheizter Nichtwohngebäude in Deutschland. BMVBS-Online-Publikation 2010, 16/2011.
11. Baukosteninformationszentrum Deutscher Architektenkammern. BKI Baukosten 2016 Neubau. Baukosteninformationszentrum Deutscher Architektenkammern: Stuttgart, 2016.
12. Bauministerkonferenz (ARGEBAU). Kostenrichtwerte für Hochschulgebäude; 2012.
13. Voss, K.; Musall, E. Nullenergiegebäude: Internationale Projekte zum klimaneutralen Wohnen und Arbeiten. 1. Aufl. ed.; de Gruyter: Berlin, 2011; Vol. 1.
14. Sartori, I.; Napolitano, A.; Voss, K. Net zero energy buildings: A consistent definition framework. Energy and Buildings 2012, 48, 220-232.
15. Bundesministerium für Verkehr Bau und Stadtentwicklung (Hrsg.). Marktuntersuchung und Evaluierung zum Energieausweis-System für Nichtwohngebäude und Entwicklung geeigneter Vereinfachungen für die Energieausweiserstellung. BMVBS-Online-Publikation 2012, 09/2012.
16. Lichtmeß, M. Vereinfachungen für die energetische Bewertung von Gebäuden. Dissertation, Bergische Universität Wuppertal, Fachbereich D-Architektur, 2010.
17. Lüking, R.-M.; Hauser, G. Die thermische Konditionierung von Gebäuden im Kontext eines zukünftigen Energieversorgungssystems: Studie des Fraunhofer-instituts für Bauphysik. Fraunhofer-IRB-Verl.: Stuttgart, 2011.
18. Rodriguez-Urbinas, E.; Rodriguez, S.; Voss, K.; Todorovic, M. Energy efficiency evaluation of zero energy houses. Energy and Buildings 2014, 83, 23-35.
19. Beuth Hochschule; ifeu Institut. Dämmbarkeit des deutschen Gebäudebestandes. Berlin, 2015.

Peer-reviewed version available at *Buildings* **2017**, *7*, 25; doi:10.3390/buildings7010025

20. prognos; ifeu; IWU. Hintergrundpapier zur Energieeffizienzstrategie Gebäude - erstellt im Rahmen der wissenschaftlichen Begleitforschung zur Erarbeitung einer Energieeffizienzstrategie Gebäude. Berlin, Heidelberg, Darmstadt, 2015.
21. Quaschning, V. Systemtechnik einer klimaverträglichen Elektrizitätsversorgung in Deutschland für das 21. Jahrhundert. VDI-Verl.: Düsseldorf, 2000.
22. Biswenger, C. Einsatzfähigkeit erneuerbarer Energiequellen zur Bedarfsdeckung von Niedrigstenergiegebäuden in Süddeutschland. Masterarbeit (unveröffentlicht), Technische Universität München, München, 2014.
23. Lüking, R.-M.; Hauser, G. Plusenergiehäuser : Technische und ökonomische Grundlagen. Fraunhofer Verl.: Stuttgart, 2012.