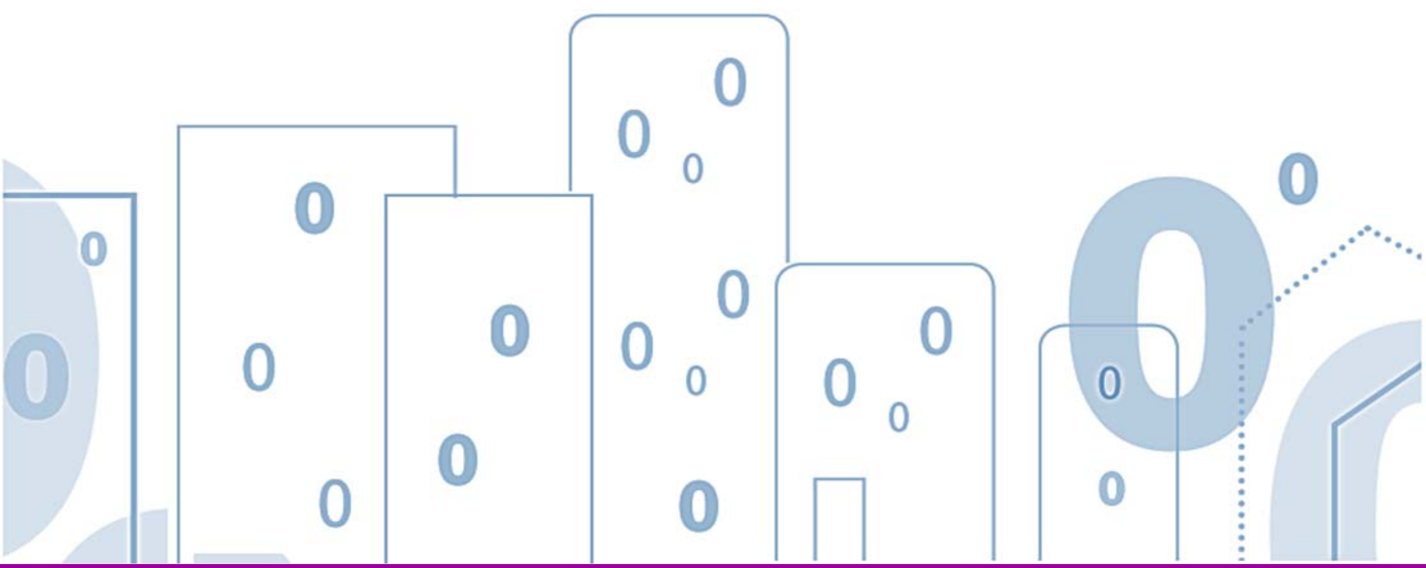
POWER HOUSE NEARLY ZERO ENERGY CHALLENGE

Co-funded by the Intelligent Energy Europe Programme of the European Union

NEARLY ZERO ENERGY HOUSING FOR COLD/CONTINENTAL CLIMATE ZONES

The nearly-Zero Energy Challenge in Cold and Continental Climates

Cost-effectiveness of nZEB in Cold / Continental Climates



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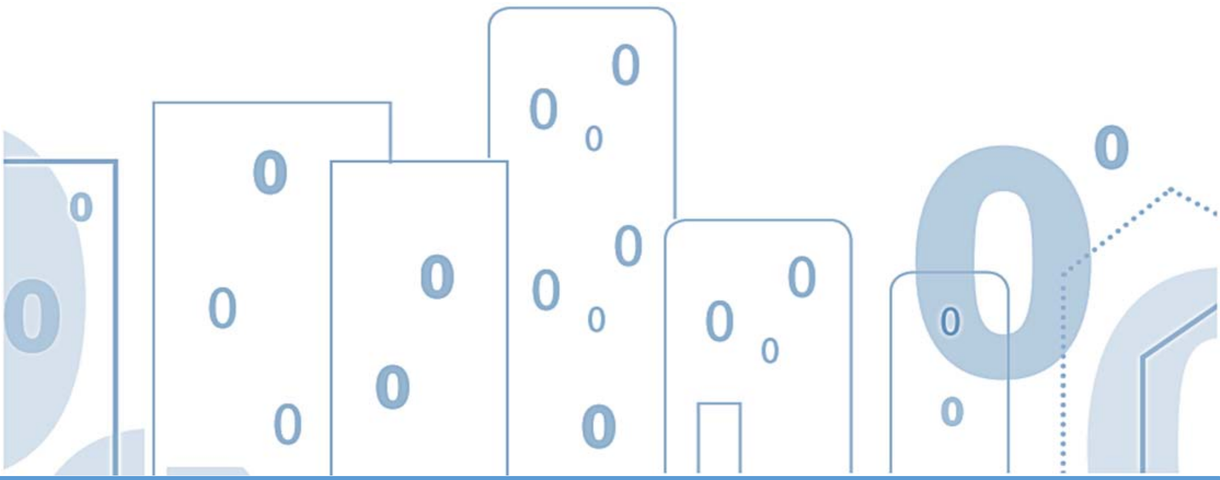

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Contents

1. Introduction

The following report is dedicated to an analysis of cost efficiency of low and very low energy residential buildings in Austria. In accordance with the task and methodology described below, this report integrates the results derived from the analysis of operating cost (see report "Operating Costs including Quality Assurance of nZEB in Cold / Continental Climates" available on the POWER HOUSE Website) with calculations for costs of construction.

The general reflections on purpose and methodology presented in the report on operating costs are thus presented here again.

In addition, other examples from Germany (only refurbishment) and France (refurbishment and new construction) are presented to provide opportunity to make comparisons with the findings of the Austrian projects.

An additional chapter (8) is dedicated to cost optimality in theory and empirical evidence derived from a broader sample of buildings in Austria. The methodology, findings and conclusions drawn from this study differ from those presented in the previous chapters. The fact of different results should be regarded as illustration for the need of further discussions on the appropriate methodology and empirical investigations.

2. Cost Efficiency in Austria: Reflections on the purpose and methodology

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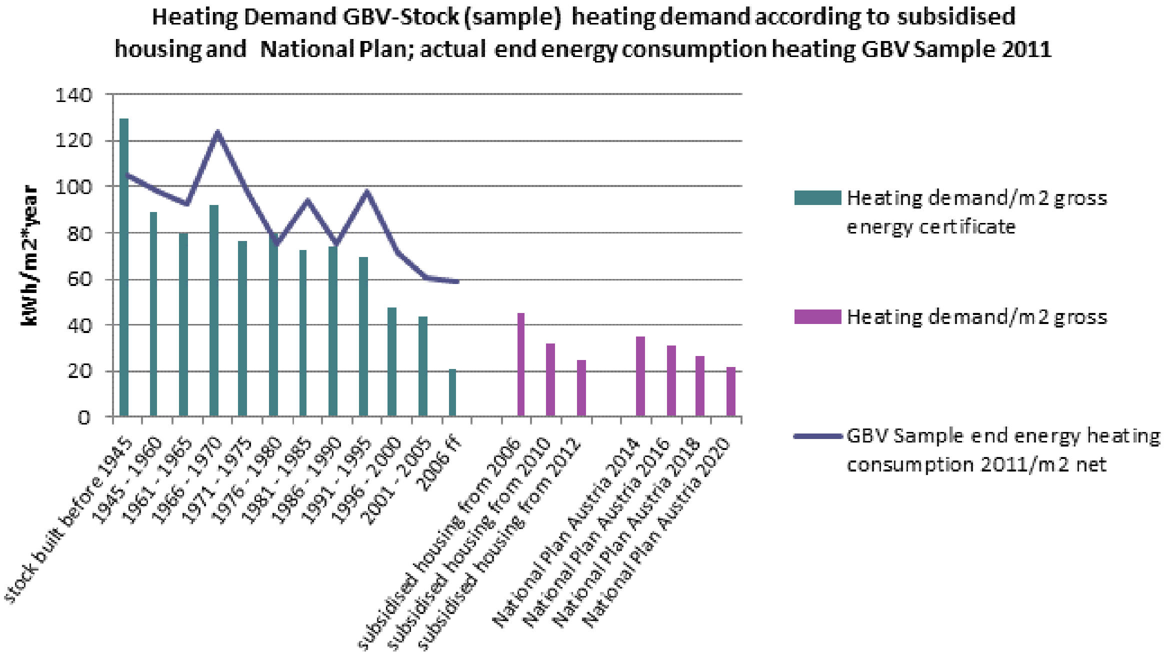
Purpose:

The purpose of the following report is an analysis of costs, cost-efficiency and usability in different types of low energy buildings to come to a definition of the spectrum of optimal energy standards in housing – more specific: in affordable housing which is meant to cover needs of broad layers of population including low-income households.

Housing providers hold a position between consumers on one side and different actors, requirements and interests on the other: housing policies, energy policies, actors in the (building) industry and financing sector. Consumers (tenants) in multi-family housing are not the direct addressees of building requirement and choice is limited since housing tends to be a scarce commodity of a long-term character. Housing providers are the intermediaries between the cost of construction, financing and energy, the necessity to provide housing of reasonable quality and the limited purchase power of their customers.

Since the problems of energy security, pollution, greenhouse gas emissions and climate change have become more evident and the building sector has become one of the focuses of policy interventions, requirements for new housing and renovation have been tightened; that can be shown at the example of the existing housing stock (rental dwellings) of limited profit providers in Austria.



The energy performance of the stock is not only indicated by the calculated standardized heating demand according the energy certificates but also by actual consumption of heating energy (end energy) to show that both data show a substantial difference. Please note that the data shown may not be interpreted as deviation in absolute terms but should be regarded in a more labelling way since the calculated heating demand refers to the gross living surface (including aisles etc.), whereas the actual consumption is expressed in Kilowatt hours per square meter usable surface (surface of dwellings only) and does include transfer losses.

Nevertheless, the range of both indicators may be compared – with the result that the actual demand shows a smoother incline than the calculated demand (that will be discussed in detail further below). The sample covers a stock of building which have not undergone energetic retrofitting to demonstrate the “historical” energy standard. However, one can assume that this standard is better than that of other buildings which have been renovated due to a less satisfying energy performance.

Nevertheless, the last years brought remarkable tightened requirements as well as a reduction in consumption. In Austria the (prospective) definition of nearly-Zero lies at about the same level as the requirements in subsidised housing from 2012 as regards the heating demand. Please note that for reasons of comparability the indicators defined in the National Plan here have been reduced; the more complex definition including primary energy demand, efficient factor and renewable energy are discussed later.

From the point of view of housing providers one crucial question remains to be answered: that for the optimal level of energy performance in relation to costs. From the data presented above it might be derived as a first finding that energy certificates cannot predict consumption – or consumption margins – perfectly. That might be caused by "pure" random behaviour differences of inhabitants. It might be also due to effects known as rebound effects which occur as consequence of technical improvements when instead of keeping the same level of comfort for less money one improves the level of comfort for the same amount of money. And there is also the possibility that new technologies used to reduce energy demand do not function properly or are not handled adequately. As regards costs, we not only have to compare operating costs (like energy and service) but also cost of construction. A better energy performance requires higher insulation, improved air tightness and above a certain tightness automatic ventilation not to disturb the effects. An addition moment is heat recovery to reduce energy consumption from external sources. These additional costs have to be taken into consideration comparing energy solutions. This moment is even reflected in the European building directive, requiring the nearly-Zero level to comply with cost efficiency.

According to the purpose of this TaskForce, we want to concentrate on "low energy buildings" and find a way to assess their energy performance and cost optimal level. According to this purpose we have to come to a definition. It was decided to set the range of low energy buildings in between passive houses on one side and that level that provides the lowest energy demand without using an automatic ventilation system.

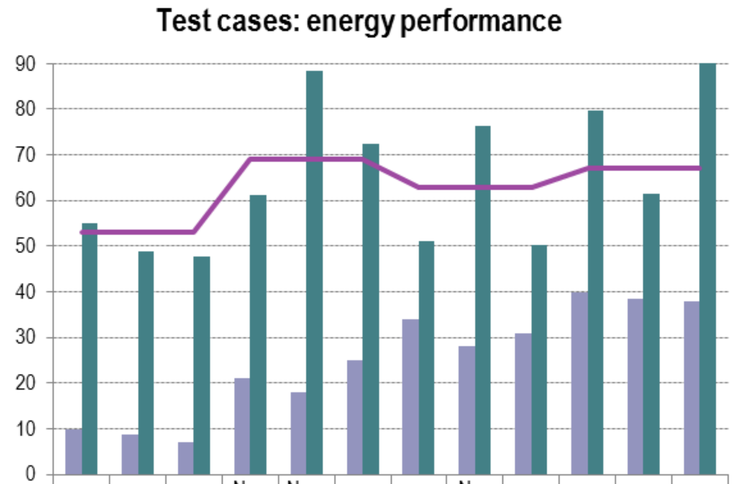
In Austria the passive house level had been in discussion to be declared as nearly-0-level, but the cost efficiency calculations have shown that this energy technology is not cost optimal when adding investment costs and operating costs for a longer period. In the federal province of Vorarlberg the passive house standard had been compulsory for subsidised rental housing for a couple of years, but that obligation was suspended – due to the fact that there were doubts concerning costs.

Methodology:

The following report is based on an inventory of 12 cases of multi-family buildings of different types of low energy buildings in Austria as it was foreseen for this TaskForce. It is crucial to discuss the implications of this methodological concept: Investigating single "test cases" (buildings) should take place in a framework of an experiment, characterised by control of all (causal) variables. It is evident that this experimental design is hard to realise for our purpose. We have to deal with operating costs which involves energy consumption of a number of different households; different heating systems with trade-offs between investment and operating costs; costs of construction are of concern when analysing the cost efficiency; those costs are influenced by a wide set of variables (discussed below).

The other option for investigation – not foreseen here – would be a broader sample of buildings. This option has been realized by the Austrian Federation of Limited Profit Housing Providers.

These 12 buildings have been selected out of a bigger sample of buildings in order to represent the “average case” identified in a broader sample – and they have not been chosen as “best practise” examples.



	New PASS 9 DW / 0,75 / West	New PASS 189 DW / 0,31 /West	Renovation Passive / 0,36	New Very Low 25 DW / 0,45 / East	New Very Low 104 DW / 0,42 / West	Renovation Very Low / 0,24	New Rather Low 6 DW / 0,46 / East	New Rather Low 37 DW / 0,30 /East	Renovation Rather Low / 0,25	New Low 21 DW / 0,53/ West	New Low 121 DW / 0,33 / East	Renovation Low 0,33
calculated Heating Demand (kWhm2GF)	10	9	7	21	18	25	34	28	31	40	38	38
Actual (measured) Heat+HotWat Consumption (kWhGF)	55	49	48	61	88	72	51	76	50	80	62	90
Average consumption per energy class of sample n = 52 projects/2.600 dwellings	53	53	53	69	69	69	63	63	63	67	67	67

Therefore, the selection has taken place with some knowledge in background – in first place knowledge as regards costs of construction. Since there are quite big differences in costs depending on the size of the building it is not advisable to compare buildings of different sizes (or ration between surface and volume) for our purpose – that could lead to wrong conclusions.

The chart above gives a description of the buildings selected; it indicates:

- the number of dwellings plus the surface/volume ratio (the lower the number the higher the building compactness);
- the location of the building (western or eastern part of Austria, that is of relevance for costs of construction;
- the energy performance of the building according to the energy certificate.

The **energy performance** as it is defined for our purposes needs some more explanation.

Before going into details it should be noted that the Austrian energy certificate until now assessed the energy performance of residential buildings according to the calculated energy demand for the components room heating, hot water production and transfer losses (end energy demand) per **square meter gross floor space** – which includes not heated areas like aisles outside the dwellings.

For our purpose, it was decided to **use only the heating energy demand** as labelling criterion. The energy demand for hot water is independent from the buildings quality, transfer losses depend on the heating system. Therefore, the heating demand refers only to the building quality, which depends on the insulation, air-tightness and way of ventilation.

- **Passive houses (PASS)**:

  According to the Austrian standard, they have a heating energy demand of max. 10 kWh/m2GFa (=gross floor space, including aisles etc), which is about 15 kWh/m2NFa (=net floor space of dwellings only). They use energy from passive sources (solar energy, waste heat) and avoid cooling by mechanical ventilation. In the original concept they were meant to get a sufficient room temperature without an extra heating source. A ventilation system in combination with a cross flow heat exchange system should replace mechanical ventilation (opening windows) and provide supply air – pre-warmed by the heat exchange in combination with e.g. brine circulation, heat pump, or other heater battery. In the original concept no other heating system should be installed. In that respect all existing passive buildings in the multi-family housing sector fail the passive house definition: It is common to install an additional heating source independent from the ventilation system, out of two reasons:

  - a comfortable temperature is not to be guaranteed without;
  - the air would be too dry.

- **Very low energy buildings:**

  These buildings have a heating energy demand between 10 and 20 kWh/m2GFa (= 15 – 27kWh/m2NFa). Automatic ventilation is required since these building are very airtight and mechanical ventilation would not be sufficient to reach a hygienic air quality.

- **Rather low energy buildings:**

  These buildings have a heating demand between 20 and 30 kWh/m2GFa (= 27 – 40kWh/m2NFa). If automatic ventilation is required is matter of discussion – dependent on the shape of the building. The test casts all have automatic ventilation. This class of buildings is close to the Austrian definition of nearly-Zero energy buildings applicable from 2020. There are not many buildings realized with this energy performance yet.

- **Low energy buildings:**

  These buildings have an heating demand between 30 and 40 kWh/m2GFa (= 40 – 53kWh/m2NFa). There is no need for automatic ventilation. That is the energy performance which was required by the housing promotion system up to 2012.

The chart also indicates the actual (measured) end energy consumption for room heating and hot water as well as the measured average level of a broader sample. That shows the range of deviance when comparing just a small number of buildings. Therefore, the passive buildings selected for our purpose are – as regards energy consumption - "better" than the sample average while the low energy buildings are "worse" than the sample average.

It also has to be mentioned that the use of renewable energy produced on site – like solar energy – has not been used as an energy label.

Finally yet importantly, it should be noted that the cases selected are no "brand new" properties since it was required to have at least two complete years of energy consumption to allow some cross checking of data.

3. The concept of Cost Optimality

To assess the cost difference between buildings of different energy performance, investment (building) costs also have to be taken into consideration.

Cost differences are expected due to different insulation standards and different equipment for air exchange. As described above "normal" low energy buildings have an average insulation of façade, roof and cellar and do not provide an automatic ventilation system. Nevertheless, in parts of the dwelling without natural air supply through windows an automatic exhaust air system is installed. Of importance is also the fact that energetic effects are not linear but have a decrease: the "second" layer of insulation does not lead to the same amount of energy saved as the first layer (compare table below).

In addition, low(est) energy buildings and passive buildings are equipped with automatic ventilation. These systems provide a permanent exhaustion and supply of air via a special system of ventilators connected to the single dwellings and the outside of the building via a net of pipes. In passive houses, these systems also have a heat exchange system to use warm exhaust air to pre-warm the supply air; also other devices may be connected for pre-warming (e.g. brine circulation or heat pumps). In addition, these buildings are better insulated than others (thicker façades and 3-glassing windows, airtightness of entrances, special constructions for balconies in order to protect façade from cold-bridges).

These components cause higher investment costs; of course there are some components which may be deducted on the other hand like the exhaust air systems in bathrooms. It was discussed above that in the original concept of the passive house an extra heating system was not designed and would also count for a deduction. However, as also discussed it turned out that a sufficient room temperature could not be obtained without extra system – at least not in all dwellings of a residential building. Moreover, the air quality as regards sufficient humidity cannot be guaranteed by heating just via the ventilation system. Nevertheless, it is possible to install a heating system with a reduced dimension.

The concept of cost optimality is also part of the European strategy towards nearly-Zero Energy Buildings. The European Directive requires low energy buildings which prove to be cost optimal in a defined way of calculation. Cost optimal is that system which has the lowest cost of investments plus running costs (energy, service etc.) in a lifecycle period of 30 years. That implies that within a certain range of low energy buildings those with the lowest level of lifetime-costs should be declared for nearly-Zero level.

Member states have to submit cost-optimality calculations based on the guidelines provides by the commission (OJE 2012/C 115/01). Austria has submitted these calculations.

The following chart shows the result for Vienna (which is one of 10 representatives of different regions/climate situations within Austria). The calculations also take different building types into consideration – while in the end the “average” cost optimal level is that which defines the nearly-Zero level for the National Plan.

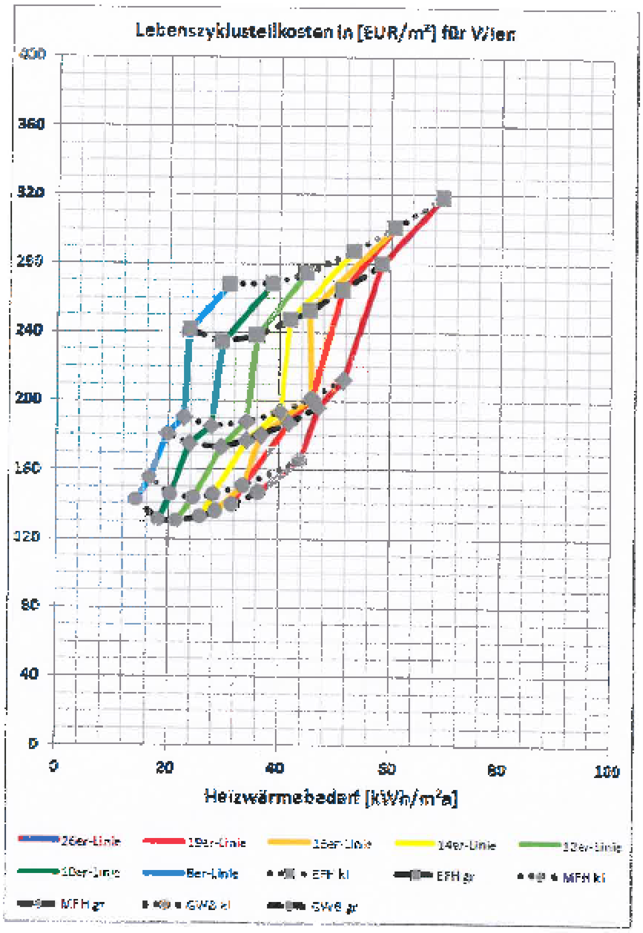


Abbildung 33: Lebenszyklusteilkosten für Wien über dem Heizwärmebedarf

What is of specific interest for our purpose is the fact that the graph shows different cost optimal levels for different building types. While for single family homes and smaller multi-family blocks (3 upper curves) the cost optimal level is the line second from left (“10er-Linie”) for the three lower curves representing bigger dwelling blocks it is the third line from left (“12-er”-Linie). In the Austrian National Plan the “10er-Linie” which is close to the actual level required for subsidised housing (20 – 30 kWh/m2(gross)a) for compact buildings, as “in average” for all types and regions that turned out to be the “dominating” level. Nevertheless, there are very small margins in costs between the different energetic types.

The following exploration of lifetime-costs via the test cases will also be a test of cost optimality. It will bring together the analysis of operating costs and the following exploration of building costs to follow – at least to some extent – the concept of cost optimality required by the commission.

4. Costs of construction in theory and practice

The following overview summarises the components which lead to higher investment cost in lowest energy/passive buildings as reported in literature:

- Higher insulation/improved air tightness: 50 €/m2;
- 3-glassed windows: 10 - 20 €/m2;
- Ventilation system with heat recovery: 50 - 80 € /m2;
- Ventilation system with deduction of exhaust air system: 15 - 20 €/m2;
- Extra costs of planning: 15 - 20 € /m2;
- Other cost components to be deducted: smaller heating system, chimney if not required

These components add up to 100 - 150 €/m2. This is also the value mentioned in other monitoring studies; of course when a complete heating system is deducted the difference is higher in theory.

However, these should not remain the only effects to be mentioned when discussing cost optimality. There are also options and variations of insulation (façade, loft, basement), windows (double-glazing, triple glazing) to obtain different U-Values; in combination with automatic ventilation systems with or without heat exchange there is a range of options to obtain different energy performance levels. These options also imply different cost levels. The following table presents some of these options. What we also can make out from the variations: costs do not increase linear with reduced energy demand.

HWB-Anforderungen in der Praxis

Referenzgebäude 12m x 32m x 8 Geschoße ->
lc=2,94, A/V=0,34

HWB, U-Werte und Dämmstärken (Unterkonstruktion 20cm Stahlbeton) für Referenzgebäude

			HWB	Fassadendämmung		Dachdämmung		Kellerdeckendämmung		FENSTER	
		Lüftung	(kWh/m²a)	U-Wert (W/m²K)	Dämmstärke in cm	U-Wert (W/m²K)	Dämmstärke in cm	U-Wert (W/m²K)	Dämmstärke in cm		
HWB-Linie	16	ohne WRG	[illegible]	0,27	12	0,15	23	0,31	15	1,2	2-fach
HWB-Linie	14	ohne WRG	28	0,20	14	0,14	24	0,23	14	1,13	2-fach
HWB-Linie	12	ohne WRG	24	0,16	21	0,13	28	0,22	14	1,1	2-fach
HWB-Linie	10	ohne WRG	20	0,12	23	0,12	28	0,15	22	0,94	3-fach
HWB-Linie	8	ohne WRG	16	0,10	40	0,09	30	0,14	24	0,76	3-fach*
HWB-Linie	14	mit WRG	28	0,32	10	0,18	19	0,37	8	1,36	2-fach
HWB-Linie	12	mit WRG	24	0,27	12	0,17	20	0,32	9	1,29	2-fach
HWB-Linie	10	mit WRG	20	0,23	14	0,15	23	0,27	[illegible]	1,2	2-fach
HWB-Linie	8	mit WRG	16	0,15	18	0,14	24	0,23	14	1,1	3-fach

* mit gedämmtem Rahmen

Walter Hüttler: [illegible] Konferenz Salzburg, 16. Apr. 2013
e7 Energie Markt Analyse GmbH
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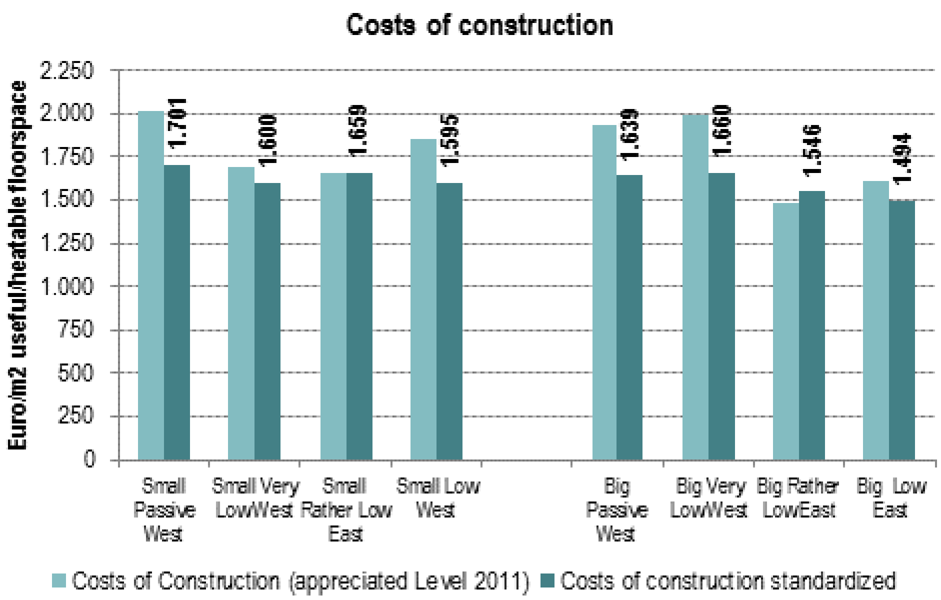
For the test, we took the eight low energy residential buildings new built between 2007 and 2010. For all of them costs of construction were provided. Nevertheless, some calculations had to be undertaken to bring those costs on a comparable level:

- The actual prices were appreciated to the level 2011 with the index of construction costs;
- The costs of garages were deducted;
- As well as costs of solar systems;
- A correction for the average size of dwellings was applied;
- And costs were standardized by a regional price factor.

There is another relevant fact which has to be taken into consideration when inspecting differenced in construction costs: Cost of construction depend to a good deal on size of buildings; smaller buildings with same standards of large ones have higher costs. For our purpose we did not standardize the observed costs but split the test cases into two groups – one consisting of small buildings and one of larger ones.

The result is shown in the following chart:



Inspecting the standardized costs of construction one finds the mentioned differences in costs according to the size of the buildings as well as according to the energetic performance. The size (density) of the buildings causes a difference of up to 110 €/m2. The difference between the passive house and the low energy building within small buildings is 106 €/m2 (6,7 percent) and within large buildings 145 €/m2 (9,7 percent). That corresponds quite well to the range mentioned before.

Also of interest it the margin between the low energy buildings and rather low energy buildings – the latter correspond to the actual definition of nearly-Zero Energy Buildings according the National Plan. The difference in construction costs is about 50 - 70 €/m2, both for small and large buildings.

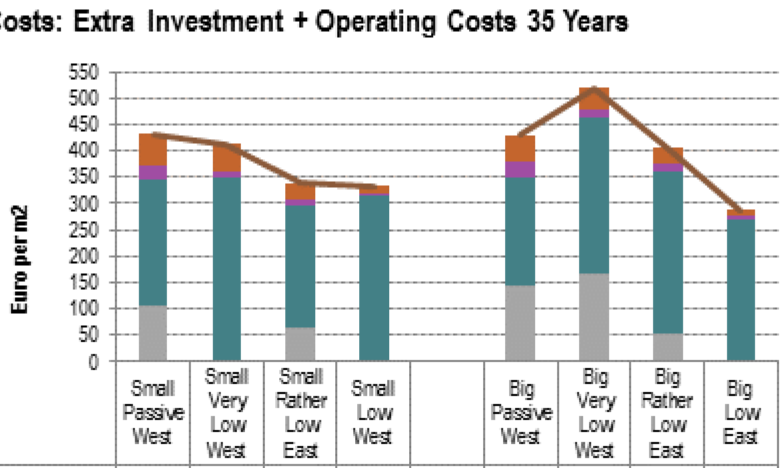
4.1 Total costs New Construction

To conclude our investigation we bring together operating costs and investments. For this purpose we follow in some respect the European requirements of cost optimality calculation.

Instead if calculating with energy-related investment costs we take the observed cost margins in contrast to the low energy building ("extra costs"). Energy costs are added for a period of 35 years (expected lifetime of the building parts) with an assumed real price increase of 1,5 percent per year. To offset the differences caused by different energy sources etc. we do not take the prices reported for the single project but identical ones.

Since we have no clear data base for additional costs for extra efforts of housing administration as well as maintenance costs we leave aside these components.

The result is presented with the following chart:



	Small Passive West	Small Very Low West	Small Rather Low East	Small Low West	Big Passive West	Big Very Low West	Big Rather Low East	Big Low East
Service Ventilation	59	50	29	13	50	42	29	13
Energy Ventilation, real price increase 1,5% p.a.	29	15	15	7	29	15	15	7
Energy Heating + Hot Water, real price increase 1,5% p.a.	237	342	230	313	206	296	308	268
extra costs of construction	106	5	64	0	145	166	52	0
TOTAL	431	412	338	333	430	518	404	288

Also for the horizon of 35 years the low energy buildings have the best cost balance – the lower energy costs cannot compensate the extra investments plus service costs. For small buildings the cost savings in the low energy building in contrast to the passive house is about 100 Euro per square meter in 35 years; that would account for about 200 Euro per dwelling and year. For the large buildings the saved amount in low energy buildings in contrast to passive house is about 140 Euro per square meter in 35 years; that would account to 280 Euro per dwelling and year.

Also of interest is the margin between low energy buildings and rather low energy buildings (the nearly-Zero Buildings according to the National Plan): There is a margin but it is comparably low in small buildings, while in large buildings there is a clear advantage for the low energy building.

So we have to conclude that the nearly-Zero Energy Building of the National Plan does not correspond to the cost optimal type in big (compact) buildings while for smaller buildings there is rather correspondence. The calculations of the National Plan seem to be proved as they also have different levels of cost optimality for smaller and bigger buildings.

Nevertheless one point of interest needs further discussion: The National Plan in Austria leaves room for compensation a less insulated/airtight building by the use of renewable energy produced on site. That would correspond to the low energy building represented by two of our test cases equipped with solar panels. This range of choice is favourable on one hand. On the other hand, it has to be mentioned that cost efficiency of solar panels is not proved yet. Moreover, it seems that not every residential building is suited to be equipped with solar panels - due to its situation or unfavourable relation of roof space to number of dwellings (large buildings).

4.2 Conclusions New Construction

According to our findings the “normal” low energy buildings is the cost optimal type of nearly-Zero Energy Buildings. Thus, we have to state a deviance from the National Plan in Austria which defines “rather low energy buildings” which need – at least in majority – an automatic ventilation system as Nearly-0-Energy buildings.

From the point of view of Limited-Profit-Providers which have to provide affordable housing it would be necessary to reflect the strategy of the National Plan, also if this plan provides an alternative to the “rather low energy building” via the installation of solar systems. Moreover, it takes some more time to observe existing buildings since it shows that the ventilation systems in residential buildings need very careful planning and construction. We do not know all effects of these systems up to now and have not been confronted with all relevant costs – e.g. for cleaning and checking the hygienic status.

Austria is seen as a forerunner in the construction of lowest energy/passive houses. To this fact, it has to be added that Austria also is a forerunner with regard of subsidies for this building type. Most of the passive houses have been realized with public financial support. That underpins the fact that this building type is not cost optimal.

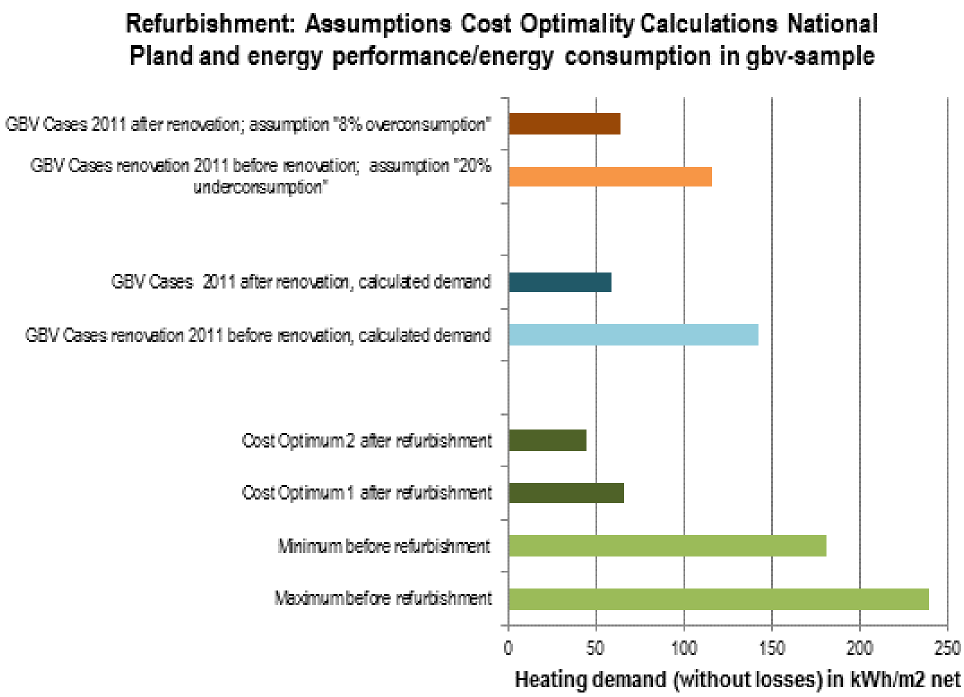
With regard to primary energy consumption and greenhouse gas emissions, it is to state that lowest energy/passive buildings do not have a considerable advantage. Electricity used for the auxiliary devices has high primary energy factors as well as high greenhouse gas emissions. There remains only a small advantage of passive houses if any.

Therefore, it is up also to the European Union to decide about the future of nearly-Zero Energy Strategy. Maybe a little less progress in regulation to give room for more investigations will bring better results with respect to people and environment.

5. Costs of refurbishment in theory and practice

Since the tests cases cover only four cases of refurbished project for which the energetic costs of refurbishment could not be identified and energy consumption before refurbishment was not available due to individual heating systems, a detailed analysis like done for new constructions is not possible.

However, from a broader sample some conclusions may be drawn: Inspection of non-refurbished buildings built before 1980 show that actual energy consumption is about 20% below the predicted amount (Austrian sample of 29 buildings/1.100 dwellings); in addition, it turns out that GBV-cases refurbished in the last years have a much better energy performance than assumed in the Cost-Optimality calculations. Under these circumstances, it is evident that a reality check of cost optimality for refurbishment cannot be executed.



As regards cost efficiency of refurbishment: The costs of energetic refurbishment for buildings/dwellings 35-40 years after construction amount to 170 – 190 Euro/m2 (in small buildings more than € 200. (VAT has been deducted according to Austrian VAT-regime).

These costs comprise insulation of walls, loft and cellar as well as replacement of windows ("simple renovation). The actual reduction in energy savings ranges between 40 and 50 kWh/m2 and year. These savings cannot compensate the costs of refurbishment within a period of 15 years (which is the typical maturity of a loan for refurbishment in older buildings) given the actual energy prices and an average real increase of 1,5% p.a. Compensation would only be possible within a longer period and a reduction of costs for components which would have been done without energetic improvement (simple renovation of façade, new windows in same quality as replaced ones).

It also has to be noted that energy is not the only issue of refurbishment. "Complicated" older buildings of very poor quality have higher refurbishment costs up to 1.000 €/m2 - this includes building-in of elevators, upgrading of dwellings, elimination of architectural barriers etc. Accessibility, comfort and aesthetic positively affect the overall performance of the refurbished building which is the base of its future value – in terms of meeting housing demand and economic soundness.

Additional information also may be obtained from test-cases in Germany (see Chapter 6.2 Refurbishment in Germany).

6. Experiences and lessons learnt from France and Germany

6.1 New built and refurbished (Very) Low Energy Buildings in France

France has very ambitious energy targets which require all features mentioned above: thick insulation, automatic ventilation, renewable energy.

A recent study by USH has monitored 13 cases of new built and refurbished projects. The task was to analyse functioning of building components, handling by residents and the comparison between predicted (calculated) and actual (measured) energy consumption.

The results were similar to those in Austria: in very low energy buildings actual consumption is above the predicted level (in total for heating, hot water production, auxiliary devices, cooling and lightening by factor 3). Accordingly, the costs for energy are higher than the calculated level.

This observation is followed by a detailed analysis of reasons. A number of dysfunctions is discovered – such as insufficient insulation, thermal bridges, dimensions of heating and imperfect building materials. Sensitivity of systems is also a matter when it comes to handling by residents.

The conclusions are that these complex and sensitive systems need special attendance – beginning with the building industry and building materials. Conception and planning is also of importance since insulation, technical systems and regulation for heating and ventilation need optimisation to show efficient results and smooth handling. For solar plants, the optimal dimensions have to be identified. The buildings process also needs special care since perfect installations are a required.

The results of the study also prove that monitoring of the new building technologies in use is essential. Otherwise, improvement of planning and building would not be possible.

6.2 Refurbishment in Germany

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The German housing industry follows a strategy for implementing energy transition. A part of the strategy aims at the building itself, see components 1–4 in Fig. 1.

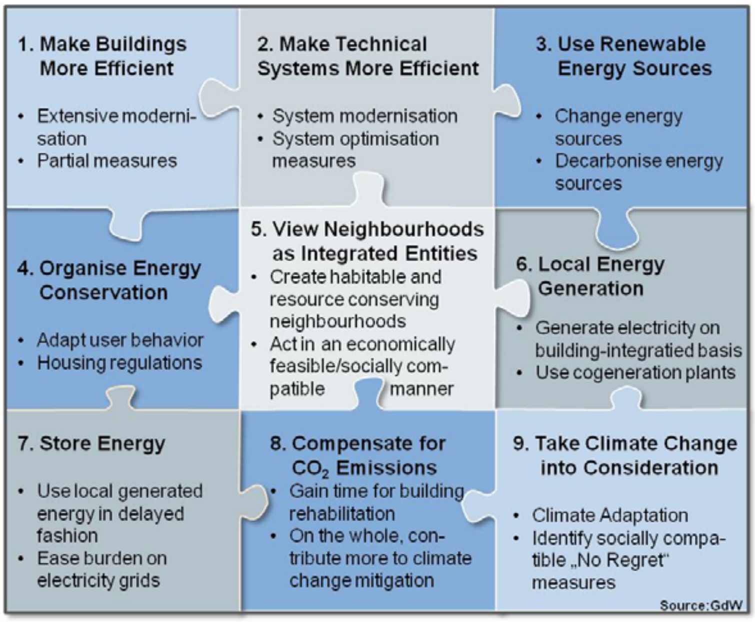

Fig. 1: Elements of the expanded energy and climate protection strategy. See: GdW Position "Strategy of the Housing Industry for Implementing Energy Transition", www.gdw.de.

The housing industry can currently save up to 20 % of the energy consumption of buildings with comparatively little in the way of financial means, i.e. an order of magnitude of EUR 10 EUR/m². This has been demonstrated by the ALFA® Projects[1] of member associations. See also: http://panel.hiveproject.net/building-chart.php?f=12&v=m&a=n&m=i&b=111

Reductions in the use of fossil fuels of up to 50 % and more can also be realised with the allocation of very high levels of funding involving several hundred EUR/m². (In other cases, very little energy can be saved through high levels of investments.) However, possibilities of saving larger volumes of energy with manageable investment levels are wholly lacking. In

[1] ALFA® Allianz für Anlageneffizienz (Plant Efficiency Alliance), Projects in the Federal Länder Berlin/Brandenburg (ALFA), Hamburg (ALFA North), Mecklenburg-Western Pomerania, Schleswig-Holstein, Thuringia (ALFA Thuringia)

this context, energy savings must consequently also lead to savings in energy costs, see Fig. 2.

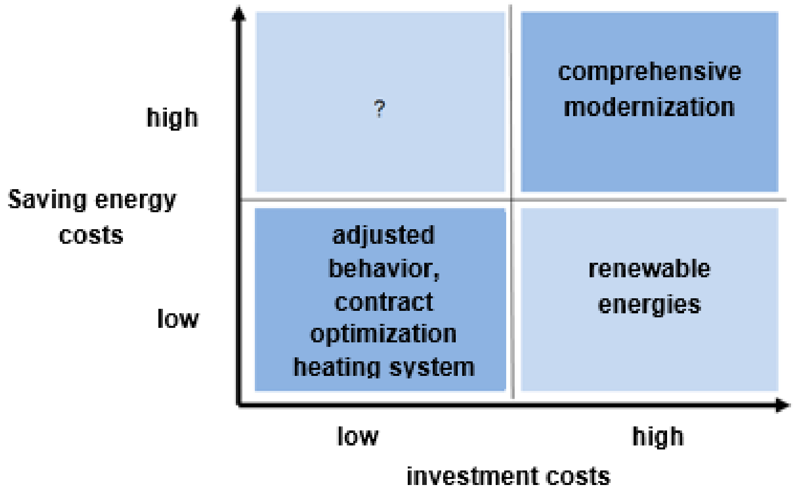

Fig. 2: Fields of action for saving energy and energy costs

A study[2] has given an overview over current energy use, net rent and gross rent for the buildings, depending on energy source and renovation status, see Fig. 3.

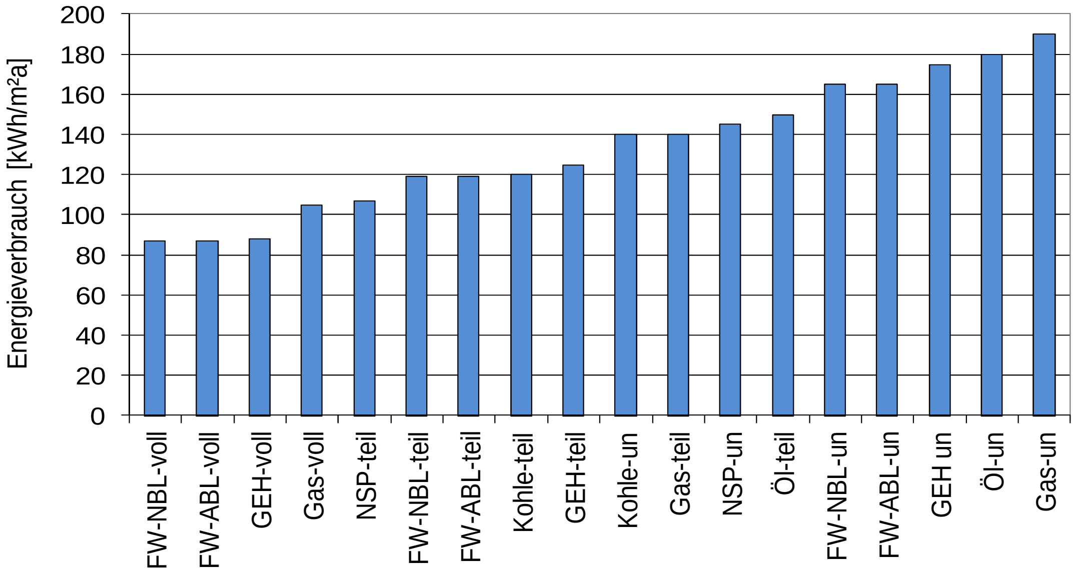

Fig. 3: Energy use in kWh/m²a (m² living area, net)

FW – district heating, GEH – gas boiler in dwelling, Gas – gas boiler in building, Kohle – coal, NSP – electrical heating, storage for electricity in nights, ÖL – oil, voll – comprehensively energetically modernized, teil – partially energetically modernized, un – not energetically modernized, ABL – old federal states, NBL – new federal states, former GDR

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[2] See Vogler, Ingrid: Analysis of medium- and long-term effects of different energy-saving strategies by housing companies for housing costs , http://nbn-resolving.de/urn:nbn:de:hebis:34-2014120146575

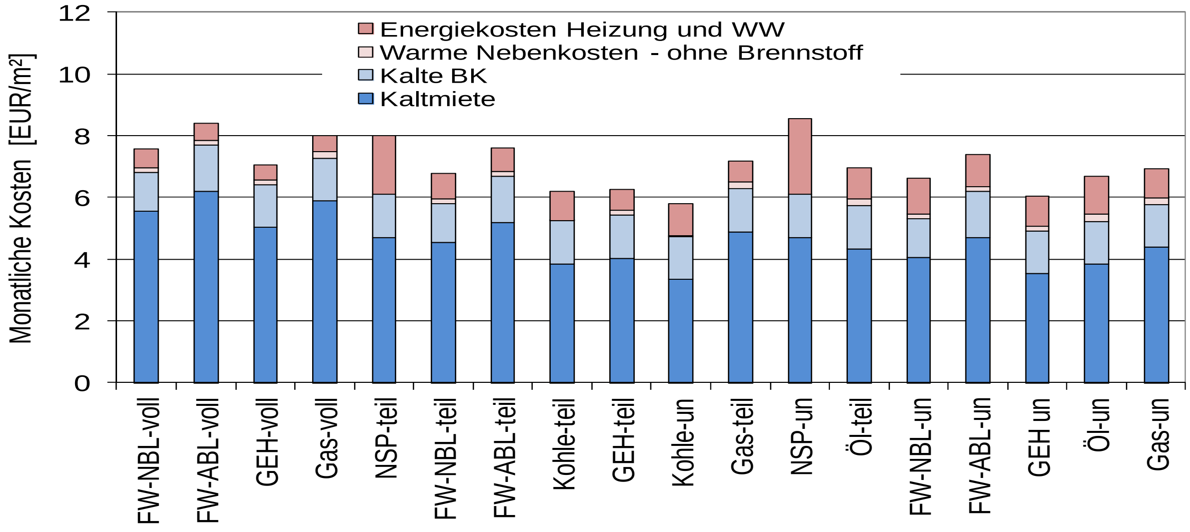

Fig. 4: Monthly gross rent per m² living area Kaltmiete – net rent, kalte BK – cold running costs, Warme BK – ohne Brennstoff – running costs for heating and hot water without energy (that means for submetering, maintenance, chimney sweep and so on), Energiekosten Heizung und Warmwasser - running costs for heating and hot water, FW – district heating, GEH – gas boiler in dwelling, Gas – gas boiler in building, Kohle – coal, NSP – electrical heating, storage for electricity in nights, ÖL – oil, voll – comprehensively energetically modernized, teil – partially energetically modernized, un – not energetically modernized, ABL – old federal states, NBL – new federal states, former GDR

The study also analyzed practical energy savings, see Fig. 5.

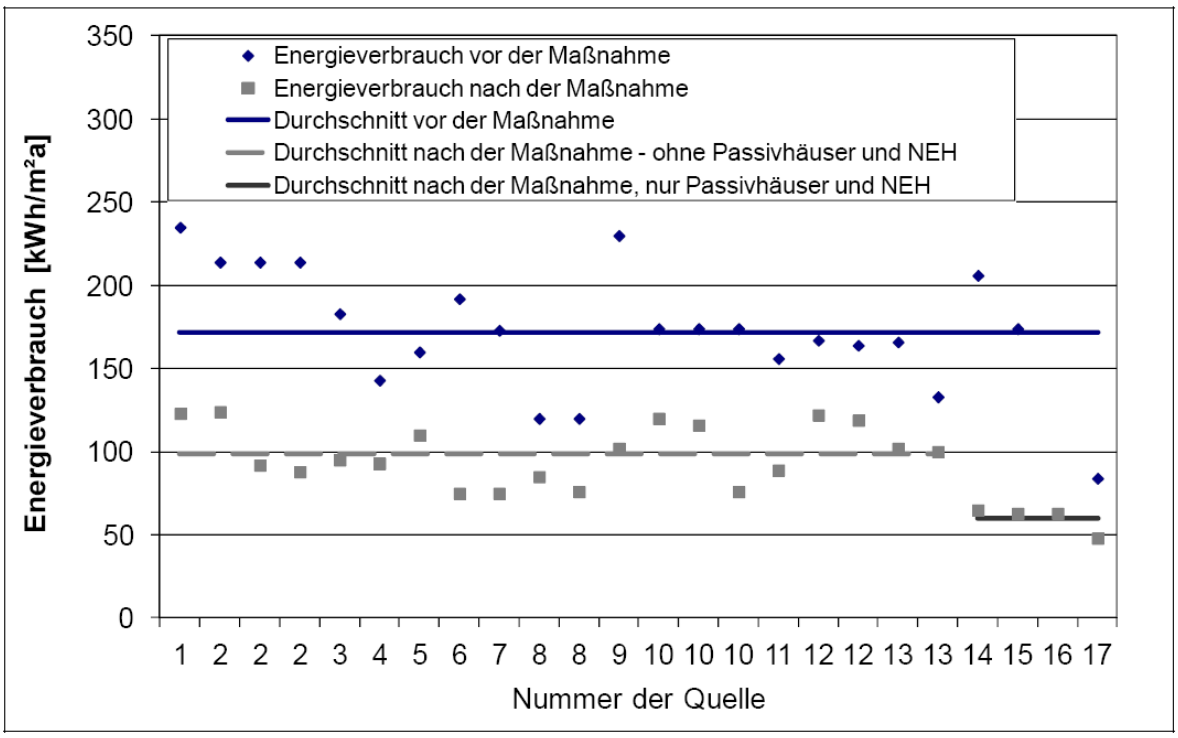

Fig. 5: Energy use before and after energetic modernization for 17 cases. Case 14-17 passive houses

A practical example for renovating a passive house can be given by the housing company WBG - Wohnungsbaugesellschaft mbH Weißwasser. They modernized a prefabricated quarter into various energetic standards, see Fig. 6.

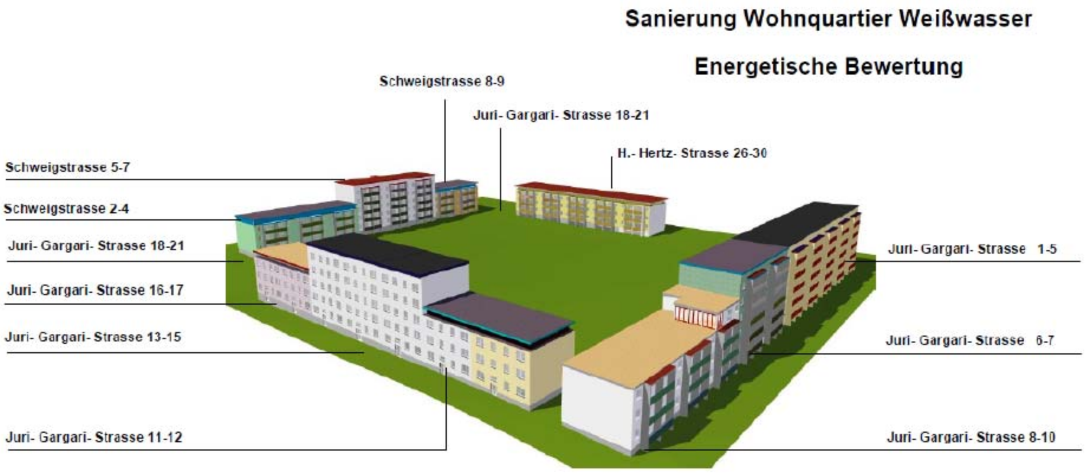

Fig. 6: Overview over the prefabricated quarter

The results are displayed in Fig. 7.

Adress	**Energetic standard**	**Renovation osts**	**Energy use before**	**Energy use (demand) after**	**Increasing net rent**	**Decreasing heating costs**
		EUR/m²	kWh/m²a	kWh/m²a	EUR/m² year	EUR/m² year
J.- Gagarin Str. 1 -10 91dwellings	KfW 130	280	105	75,4 (66,9)	10,32	3,26
J.-Gagarin-Str. 11 - 17	KfW 85	376	110,7	72,9 (60,5)	11,70	4,14
Schweigstraße 2-9	KfW 70	444	106,4	58 (51,5)	15,84	4,51
H.-Hertz-Str. 26 - 30	Passive house	637	106,9	42,1 (33,7)	22,44	5,32

It has also to be mentioned that the calculated demand before renovation had been substantial higher than the actual consumption (168kWh/m2 calculated demand vs. 105 – 110 actual consumption).

In conclusion the housing company gave two recommendations:

- An economy for the tenant is not achievable by energy price increases of less than 7%;
- The most economical variant for the housing company is a renovation with the standard KfW 85/130.

7. Conclusions

Cost-effectiveness in new housing projects:

In new housing projects, extra costs of construction for very low energy buildings and passive houses for additional/extra insulation and ventilation with heat exchange add up to 6,7% for small buildings and 9,7% for large (compact) buildings, and cannot be compensated by the energy savings in the long run. Between Very low energy vs. Passive buildings differences in consumption are very small; we should take cost implications into consideration when defining the optimal level of nearly-Zero Energy Buildings. Austrian housing associations are in favour of “simple“ low energy buildings without the need for an automatic ventilation due to cost reasons and handling of technical systems.

Cost-effectiveness in refurbishment projects:

Average costs for energy-efficiency measures amount to 180 €/m2 (VAT has been deducted according to Austrian VAT-regime). These costs cannot be compensated with actual energy savings of 40-50 kWh/m2 within a period of 15-30 years, unless a cost reduction is calculated for components that would have been replaced anyway and/or subsidies are granted.

The average costs of refurbishment for buildings/dwellings 35-40 years after construction is of 250 €/m2; “complicated” older buildings of very poor quality have higher refurbishment costs up to 1.000 €/m2 (this include building-in of elevators, upgrading of dwellings, elimination of architectural barriers etc.). That demonstrates that energy quality is not the only aspect of refurbishment, since other elements such as accessibility, comfort and aesthetic positively affect the overall performance of the refurbished building.

8. Cost optimality in theory and praxis – affordable housing through cost optimal building standards?

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8.1 Cost optimality: Legal and methodical background

The recast of the Energy Performance of Buildings Directive (EPBD) introduced, in Article 9, "nearly Zero -Energy Buildings" (nZEB) as a future requirement to be implemented from 2019 onwards for public buildings and from 2021 onwards for all new buildings. The EPBD defines a nearly zero energy building as follows: A nearly zero energy building is a "building that has a very high energy performance […]. The nearly zero or very low amount of energy required should to a very significant extent be covered by energy from renewable sources, including renewable energy produced on-site or nearby."[3]

Acknowledging the variety in building culture and climate throughout the EU, the EPBD does not prescribe a uniform approach for implementing nZE Buildings and neither does it describe a calculation methodology for the energy balance. To add flexibility, it requires Member States to draw up specifically designed national plans for increasing the number of nZE Buildings reflecting national, regional or local conditions. The national plans will have to translate the concept of nZE Buildings into practical and applicable measures and definitions to steadily increase the number of nZE Buildings.[4]

Furthermore, the EU Directive requires that the cost optimum over the life cycle of buildings is taken into account when requirements for the energy performance of buildings are established. National minimum standards should be set by the Member States based on the cost optimum for construction costs and operational costs. Therefore, the European Commission has submitted the regulation No. 244/2012 in accordance with the objective clause of the EPBD in March 2012. Within the scope of this EU regulation, the methodological approach for the analysis of cost optimality of requirement levels is determined bindingly.[5]

The cost optimality principle acts as a bridge between the standard energy performance – as it is usual on today's markets – and the intended goal of reaching nearly zero energy buildings by 2020 (at least for new construction). In this sense the period between now and

[3] EU Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings (EPBD)

[4] BPIE (2011) Principles for Nearly Zero Energy Buildings – Paving the way for effective implementation of policy requirements.

[5] COMMISSION DELEGATED REGULATION (EU) No 244/2012 of 16 January 2012 supplementing Directive 2010/31/EU of the European Parliament and of the Council on the energy performance of buildings by establishing a comparative methodology framework for calculating cost-optimal levels of minimum energy performance requirements for buildings and building elements.

2020 can be interpreted as a "transition period" during which the markets are forced to adapt and to apply a life-cycle cost perspective instead of the usual construction cost perspective.[6]

It has to be stressed, however, that the cost optimality principle as defined in the EPBD offers high degrees of freedom when it comes to applying it in the building regulations. Although the EU regulation on cost optimality provides uniform regulations in some respects – e.g. concerning included cost elements, calculation algorithms and analysis period – it allows room for national stipulations in many key areas, such as:

- Definition of the reference building related to important assumption such as size, form, compactness, share of window areas etc.,
- Selection of variants (packages of measures) which are assessed,
- construction costs (and most important construction cost differences for different qualities),
- maintenance costs of relevant building elements and related inflation rates,
- the assumed (technical resp. economical) life-time of building elements,
- discount rates,
- starting level of energy prices,
- energy price trends (although the regulation includes a recommendation to use the "official" EU forecast member states are allowed to use other forecasts for their assessments).

According to a survey done in the frame of the EPBD concerted action in 2011 (before the EU regulation was submitted in March 2012) most of the member states intended to follow a microeconomic approach instead of or together with a macroeconomic approach (which would mainly include GHG emissions as externalities).[7] Up to now, the number of available cost-optimal calculations for different reference buildings according to the EU regulation is quite limited, although considerable work has been done during the last years in developing the application of life-cost-analysis in building practice.

Among the first countries with cost-optimal calculations available for residential buildings there were Estonia[8] and Austria[9][10]. The first comparative study with practical examples of

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[6] LEUTGÖB K, PAGLIANO L, ZAHGHERI P (2013): Cost optimality – Brake or accelerator on the way towards nearly zero energy buildings. Proceedings eceee 2013.

[7] Cost-optimal levels for energy performance requirements - The Concerted Action's input to the Framework Methodology. April 2011.

[8] KURNITSKI J, SAARI A, VUOLLE M (2011): *Cost optimal and nZEB energy performance levels for buildings. Sitra, the Finnish Innovation Fund, Aalto University and Equa Simulation Finland Oy.*

[9] BEDNAR T, NEUSSER M, DESEYVE C. (2012): *Studie zur Analyse der österreichischen Anforderungen an die Gesamtenergieeffizienz*

cost-optimal calculations for Austria, Germany and Poland was carried out by BPIE in cooperation with The Danish Building Research Institute (SBi), the German Institut Wohnen und Umwelt (IWU) and e7 Energie Markt Analyse (Austria).[11] Although these countries had not announced officially their nZEB definitions, within the cost-optimal calculation performed in this study, packages of measures leading to very low energy buildings have taken into consideration (primary energy demand between 30 and 70 kWh/m².a). The results of this study show, that the difference between actual and cost-optimal energy performance is between 10 and 20% in Austria and Germany, according to different assumptions on input factors and heating systems, whereas there is still a "very big gap" between current requirements and cost-optimal levels in Poland.

8.2 nZE Buildings in a total cost perspective – the case of Austria

A crucial question regarding the cost-efficiency of nZE buildings is whether calculated energy demand and cost assumptions are corresponding with measured energy consumption and real cost data from buildings in use. Up to now there is little empirical evidence to answer this question on a broad basis, even in those countries where a considerable number of nZE is already realized. If any, it is mostly data for single objects, primarily focusing on measured energy consumption. Even worse is a reliable data basis when it comes to real costs: so called "additional investment costs" for nZE buildings depend on the actual building standard in the respective country and the availability of cost competitive building components like triple glazing windows. Costs for energy consumption, maintenance and replacement costs are further the crucial elements when it comes to the question of life-cycle-costs.

Regarding the question of actual energy consumption compared to theoretical consumption, it is documented for a sample of 200.000 cases in the Netherlands that there is a considerable difference in both directions, due to the fact that "in very bad performing dwellings the energy use is not as high as expected due to a lower comfort level (behavior) and in very high classified dwellings not as low as expected due to lacking performances of the buildings and services (building control) and the rebound effect (behavior)".[12] Earlier and fundamental research regarding the rebound effect was already published by Haas and

von Gebäuden in Bezug auf das kostenoptimale Niveau. Technical University Vienna.

[10] LEUTGÖB K, JÖRG B, RAMMERSTORFER J, AMANN C, HOFER G (2012): *Analyse des kostenoptimalen Anforderungsniveaus für Wohnungsneubauten. e7 Energie Markt Analyse GmbH, Wien.* http://www.e-sieben.at/de/download/CostOpt_WOHN_Endbericht.pdf

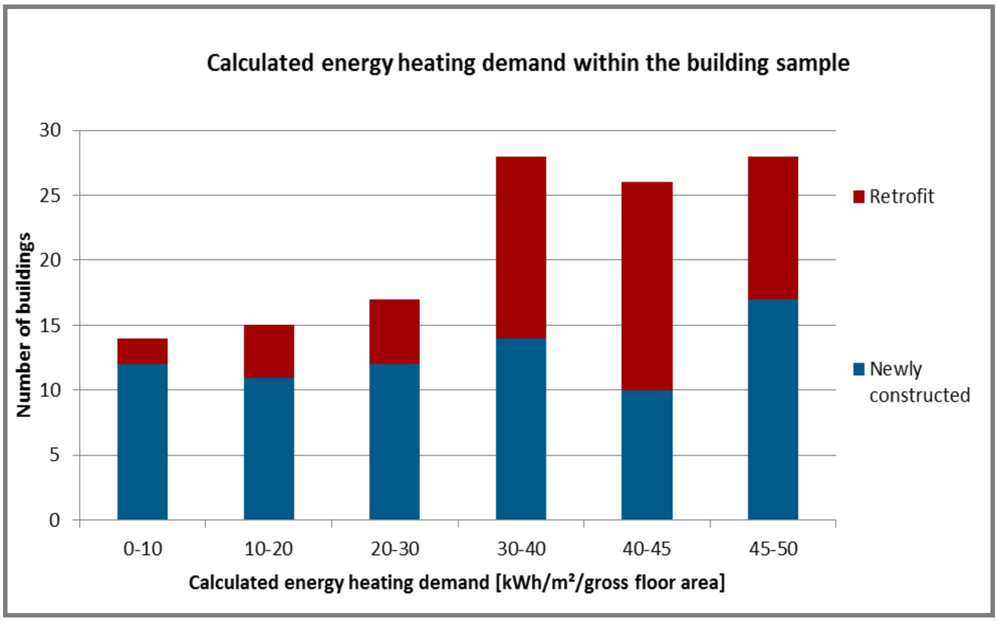
[11] ATANASIU B, KOULOUMPI I, THOMSEN KE, AGGERHOLM S, ENSELING A, LOGA T, LEUTGÖB K, RAMMERSTORFER J, WITCZAK K (2013): *Implementing the cost-optimal methodology in EU countries – Lessons learned from three case studies. Buildings Performance Institute Europe (BPIE), Brussels.*

[12] VISSCHER H, MAJCEN D, ITARD L (2012): *Effectiveness of energy performance certification for the existing housing stock. RICS COBRA 2012, Las Vegas, USA, p 130-148.*

Biermayr (2000)[13] based on a sample of 12 thermally retrofitted buildings in Austria and Berkhout et al (2000).[14]

A considerable number of nZE demonstration projects is well documented in the R&D program "Building of Tomorrow" in Austria. However, the evaluations of these buildings focus on energy consumption and give little or no indication on running costs or life-cycle-costs.[15][16] Therefore, in 2011 the Austrian Federation of Limited-Profit Housing Associations (gbv) together with e7 launched a broad survey in order to collect energy consumption AND cost data from innovative multi-family-residential buildings. The aim of this study was to analyze the cost-effectiveness of nZE buildings compared to "normal" low energy buildings.[17]

The following figure 1 shows the distribution of energy heating demand categories within the sample of 128 buildings from the survey carried out. The major part of the buildings within the sample were built between 2006 and 2010, thus securing that consumption data and actual data on running costs are available at least for 2-3 years.



[13] HAAS R, BIERMAYR P (2000): *The rebound effect for space heating. Empirical evidence from Austria. Energy policy 28/6, June 2000, p 403-410.*

[14] BERKHOUT PHG, MUSKENS JC, VELTHUIJSEN JW (2000): *Defining the rebound effect. Energy policy, 28/6, June 2000, p 425-432.*

[15] *Innovative Buildings in Austria – Austrian demonstration buildings and flagship projects within the research programme "Building of tomorrow"* http://download.nachhaltigwirtschaften.at/hdz_pdf/innovative_gebaeude_in_oesterreich_2012_technical_guide.pdf.

[16] TREBERSPURG M, SMUTNY R (2009): *Nachhaltigkeitsmonitoring ausgewählter Passivhäuser in Wien.* http://www.wohnbauforschung.at/de/Projekt_Namap.htm.

[17] HÜTTLER W, RAMMERSTORFER J, TUDIWER D (2014): *InnoCost – Cost-effectiveness of innovative multi-family-residential buildings in Austria. e7 Energie Markt Analyse GmbH, Wien. Final report within the R&D program „Building of tomorrow", Vienna.*

Fig. 1: Calculated energy heating demand in the Austrian multi-family residential building sample (Source Hüttler, Rammerstorfer, Tudiwer, 2014)

The focus of this project was on multi-family-residential buildings with (calculated) heating energy demand lower than 50 kWh/m².a, covering the range from low-energy buildings to lowest-energy buildings to passive-house standard.[18] Energy consumption data were provided by the housing associations for at least two or three years for each building. Results derived from a broad sample of about 60 buildings indicate that the measured energy consumption for heating in NZE-buildings is in reality significantly lower than in low-energy-buildings. However, data show also a broad variance of real consumption data of about factor three within each group (appr. 15-50 kWh/m².a passive-house / 20-70 lowest-energy / 30-90 low-energy-buildings). Therefore, it could be quite misleading to draw far-ranging conclusions from single objects or a small sample of (selected) buildings.

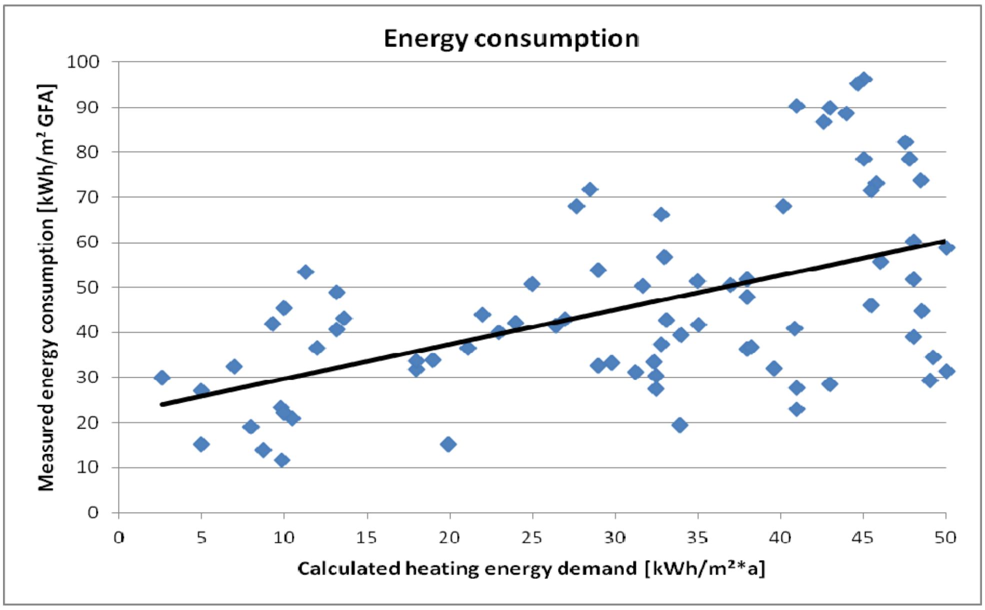


Fig. 2: Energy consumption for heating vs. calculated heating energy demand in nZE multi-family-residential buildings (Source Hüttler, Rammerstorfer, Tudiwer, 2014)

Costs for energy consumption for heating are easily available only for those buildings with central heating systems. Furthermore it has to be differentiated between heating and hot water. Maintenance costs were becoming an increasingly important issue mainly due to

[18] According to heating energy demand: passive house < 10 kWh/m²a (gross floor area!), lowest energy < appr. 25-30 kWh/m²a (depending on compactness of the building) low energy standard < 40-50 kWh/m²a.

mechanical ventilation systems, which are a crucial element of the passive-house-concept but also more and more frequently installed in lowest-energy buildings due to air-tight construction.

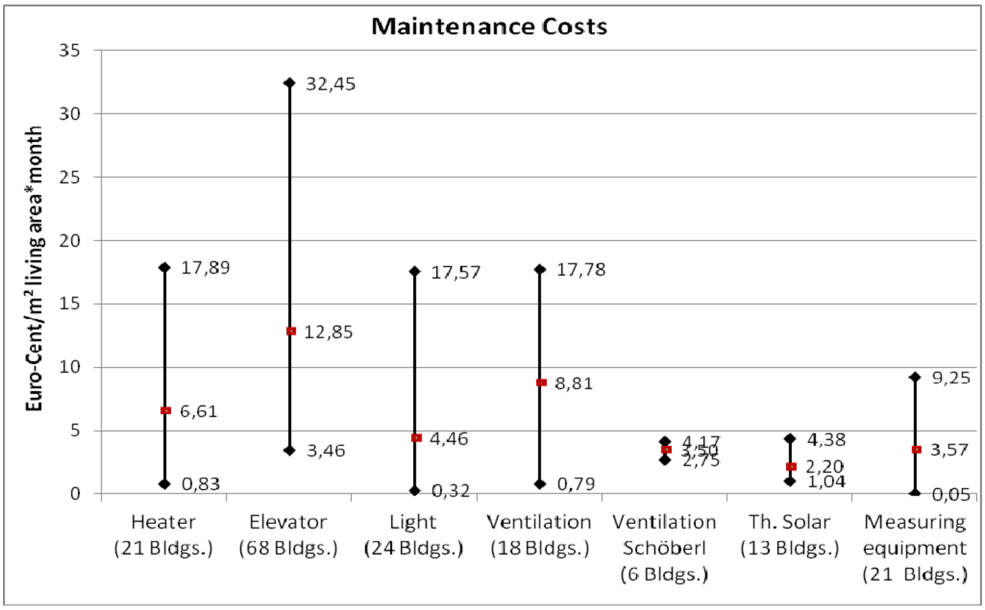


Fig. 3: Maintenance costs in nZE multi-family-residential buildings (Source Hüttler, Rammerstorfer, Tudiwer, 2014)

Not surprisingly there can also be observed a broad variety of maintenance costs in practice. Maintenance costs for ventilation systems range from 0,8 till 18 ct/m².month with an average of about 9 ct/m²m.month, depending mainly on the system (central or decentralized ventilation, frequency of filter exchange, quality of filters and adequate contracts with external maintenance contractors. Best practice studies for a limited number of 6 buildings show that the maintenance costs for central mechanical ventilation systems can be limited to a range from 3 to 4 ct/m².month, whereas decentralized ventilation systems result in maintenance costs of 10 ct/m².month on average.[19]

Buildings with ventilation systems trend to have higher maintenance costs compared to buildings without ventilation systems. Consequently, lower energy costs for heating which can observed in lowest-energy and passive-house-buildings are tending to be partly compensated by higher costs for maintenance.

[19] SCHÖBERL H (2011): *Wartungskosten Minus - Reduktion der Wartungskosten von Lüftungsanlagen in Plus-Energiehäusern. Final report within the R&D program „Building of tomorrow“, Vienna.*

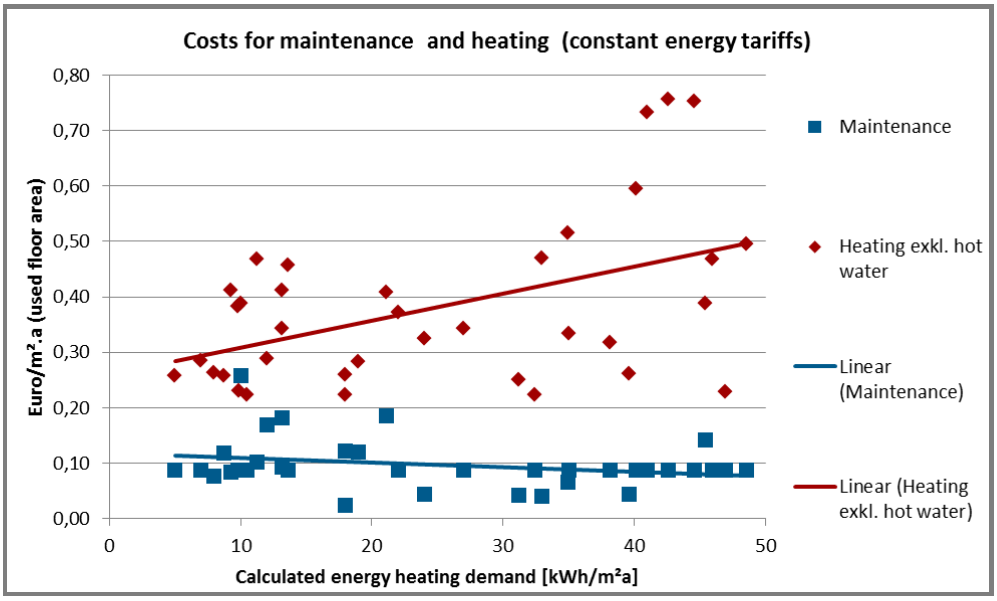


Fig. 4: Energy costs for heating and maintenance costs in nZE multi-family-residential buildings (Source Hüttler, Rammerstorfer, Tudiwer, 2014)

Specific investment costs (€/m² used floor area) are depending on different factors: most important of them the size of a building, since small and less compact buildings have significantly higher specific costs than large and very compact buildings. Further cost components which influence the comparability of building costs are the number of elevators and if there is an underground garage for each dwelling or not. Furthermore regional differences in building cost levels can be generally observed. So one has to be very careful when it comes to comparison of investment costs with regard to different energy standards.

The following graph shows a sample of 40 nZE buildings with (calculated) energy heating demand lower than 50 kWh/m².a. Whereas the specific investment costs for individual buildings vary considerably due to factors mentioned above (regional cost differences etc.) the trend line results in additional specific costs for passive-house buildings of about 100 €/m² compared to low-energy standard (which is mandatory in Austria since 2012). A more detailed analysis show, that the additional costs for passive-house standard seems to be significantly lower for large and compact buildings (appr. 40-80 €/m²) compared to additional costs for small and less com pact buildings (appr. 120-200 €/m²).[20]

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[20] Eva Bauer, Austrian Federation of Limited-Profit Housing Associations (gbv), January 2013.

One has to mention that the economic ratio of the passive-house according to the (initially) strictly reduced concept based on the idea that additional investment costs for the improved building shell and mechanical ventilation are partly compensated since there is no need for a conventional heating system. This has been successfully proven in practice for a number of buildings but it turned out that in practice (at least in Austria) most of the multi-family-passive houses are built with mechanical ventilation AND a more or less conventional heating system. Decoupling heating and ventilation allows lower air-change rates and reduces the risk of unhealthy dry air indoor conditions during the winter and is therefore state of the art in passive-house technology. Consequently, to have both mechanical ventilation AND a conventional heating system is questioning the initial idea of cost-effective passive-houses.

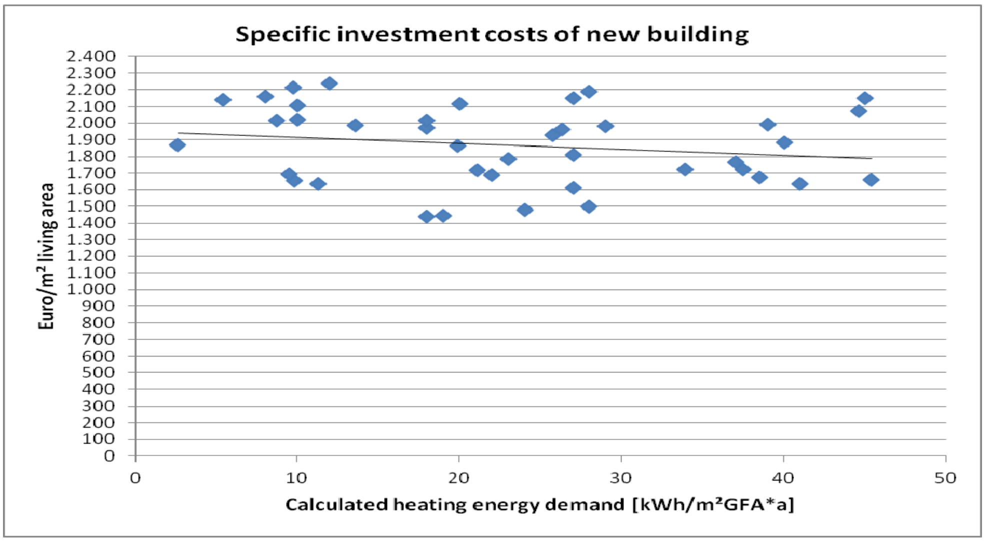


Fig. 5: Specific investment costs for nZE multi-family-residential buildings depending on the energy standard (Source Hüttler, Rammerstorfer, Tudiwer, 2014)

Finally, putting together the data on running costs and investment costs in a simplified total cost calculation over 20 years (net present value, without reinvestments for technical installation and without declining-balance, 3% energy cost increase per year) the results show that lower costs for energy heating do not compensate the higher investment costs for passive-house standard in general. At least for the specific situation in Austria it seems, that lowest-energy standard (energy heating demand about 20-30 kWh/m².a) turns out to be the range for cost-optimal building standards.

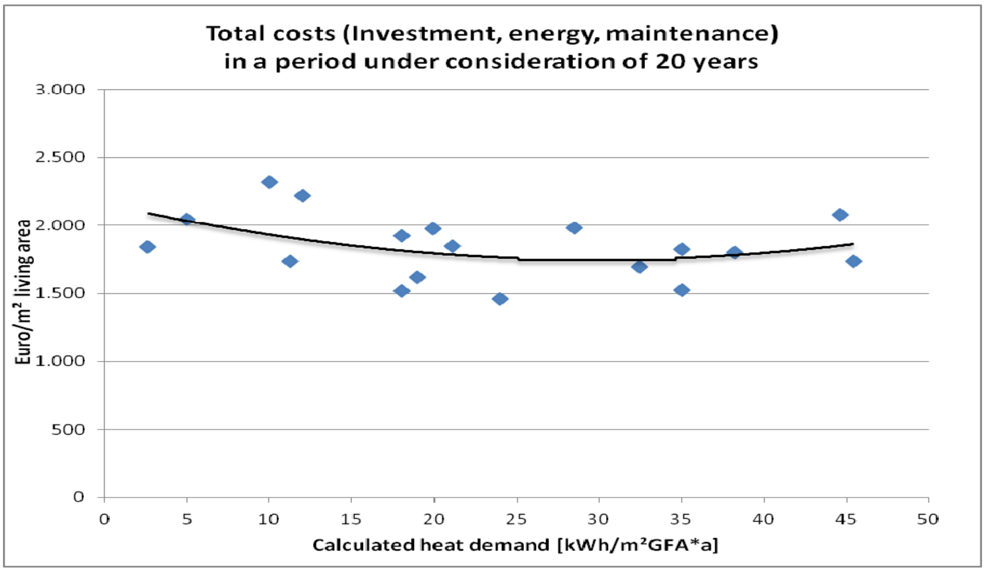
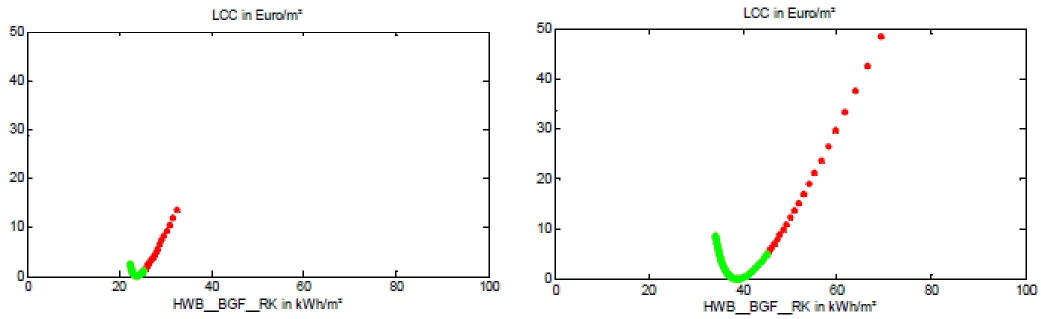


Fig. 6: Total costs (investment, energy, maintenance) in nZE multi-family-residential buildings depending on the energy standard (simplified calculation without reinvestments for technical installation, 3% energy cost increase per year) (Source Hüttler, Rammerstorfer, Tudiwer, 2014)

Approximately, this is quite in line with theoretical calculations on cost-optimal building standards for multi-family-residential buildings in 2012[21]. Results from different organizations based on three different data sets lead to comparable results.

The results of Bednar et al. from the Technical University Vienna was made for two different reference buildings and show an "cost-optimal" heating energy demand of about 20 kWh/m².a for large residential buildings (80 dwelling) whereas the "cost-optimal" heating energy demand for a small residential buildings (6 dwellings) is about 40 kWh/m².a.



[21] BEDNAR et al. (2012) and LEUTGÖB et al. (2012) see above references [7] and [8].

Fig. 7: Cost-optimal building standards for multi-family-residential buildings: large (80 dwellings) left and small building (6 dwelings) right graph. The y-axis describes the global cost difference between the different standards in €/m² (Source Bednar et al., 2012)

Cost-optimality calculations for a residential building with 30 dwellings done by e7 show a cost-optimum range between 20 and 30 kWh/m².a (heating energy demand) (Fig. 8). This is in line as well with the cost-curve derived from our empirical data (Fig. 6) and with the calculations of the Technical University Vienna (Fig. 7).

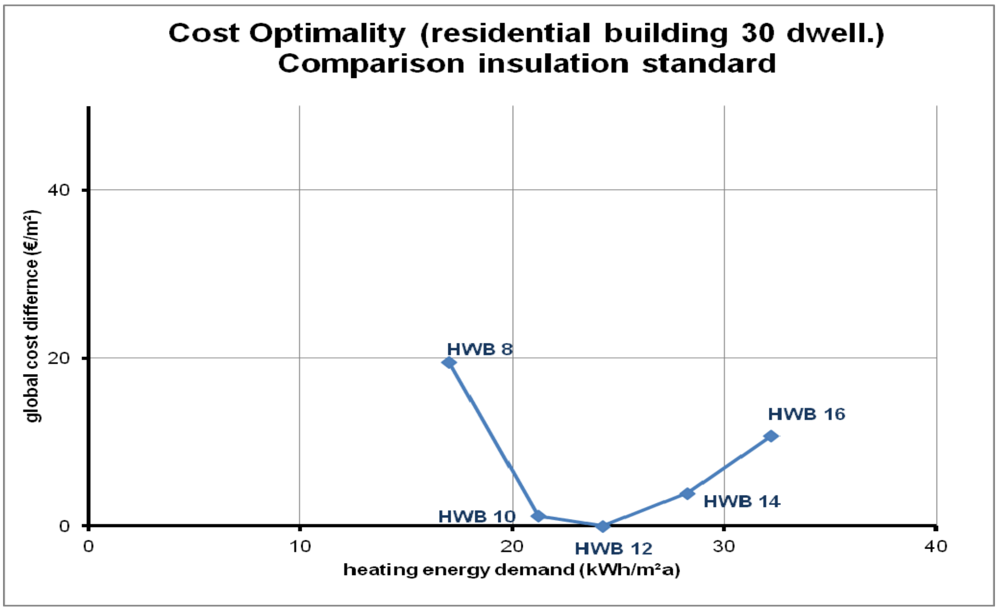


Fig. 8: Cost-optimal levels for multi-family-residential buildings (30 dwellings). The y-axis describes the global cost difference between the different standards in €/m² (Source Leutgöb and Rammerstorfer, 2013)

Based on these calculations it is obvious that the passive-house standard seems actually not to be the cost-optimum for residential buildings. One of the main reasons, why a considerable number of passive-house buildings in Austria were realized during the last years is financial incentives integrated in the housing subsidy schemes of the federal regions. For example, the additional subsidy for building a residential passive-house is 120 €/m² in Tyrol. Consequently, the housing association “Neue Heimat Tirol” is able to offer dwellings in passive-house standard at the same rent conditions as usual low-energy buildings for their tenants.[22]

8.3 Conclusions

Based on both theoretical calculation and the analysis of evidence based cost and consumption data from buildings already in use for 3 to 5 years a plausible range for cost-optimal building standards could be identified for Austria. The combination of different approaches carried out independently seems to be a promising way to define nZE buildings based on cost-optimal levels. Furthermore, this reflects only the sheer economic perspective, not including other important parameters like living comfort or practical usability. The results of this analysis may be applied in general to other countries, results in details are very country specific. Therefore, theoretical calculations and analysis based on real data from practice have to be done for each country.

Innovative building standards can only be cost efficient if the proposed heating demand levels are reached in practice and if maintenance of the building technology is provided at optimal cost. The compliance of energy consumption with energy demand levels depends on several parameters, which are: Validity of the calculation, quality assurance over the whole planning, construction and commissioning process as well as user behaviour.

Due to the significant scattering of data it is questionable to draw general conclusions for the profitability of building standards on the basis of data of individual objects.

For a further propagation of innovative building concepts additional impulses for quality assurance over the whole planning, construction and commissioning process as well as during operation are necessary. A moderate tightening of the current minimum energy performance requirements with respect to the 202020 goals is feasible also from the economic point of view. Affordable solutions for a continuous and standardised energy consumption and cost monitoring systems are an important aspect of quality assurance.

The results are a guide to define which incentive systems will facilitate the further propagation of innovative building standards best. Future incentive systems should be strongly oriented on quality assurance and should require continuous energy monitoring systems as a mandatory element for the eligibility for funding.

The analysis contains data of existing innovative buildings with an age of 5 to 10 years, which belong to the “first generation” of low-energy and nearly zero-energy buildings. In the meantime additional know-how was gathered and technological development, especially with respect to cost-efficient solutions, has taken place. Therefore an ongoing data analysis with data from new buildings is essential.

[22] SPISS E (2012): The Tyrolean path in social housing: from low-energy to passive housing. Neue Heimat Tirol. Symposium: CECODHAS Housing Europe meets Solar Decathlon Europe 2012 - 26 September 2012, Madrid, Spain.

Quality assurance plays a key role for the propagation of innovative technologies. The central tool of quality assurance is a detailed energy consumption and cost monitoring.

Research and development activities should therefore focus on standardised and affordable monitoring solutions on the one hand. On the other hand detailed energy consumption and cost monitoring systems together with an economic assessment should be applied in future pilot- and demonstration projects.

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