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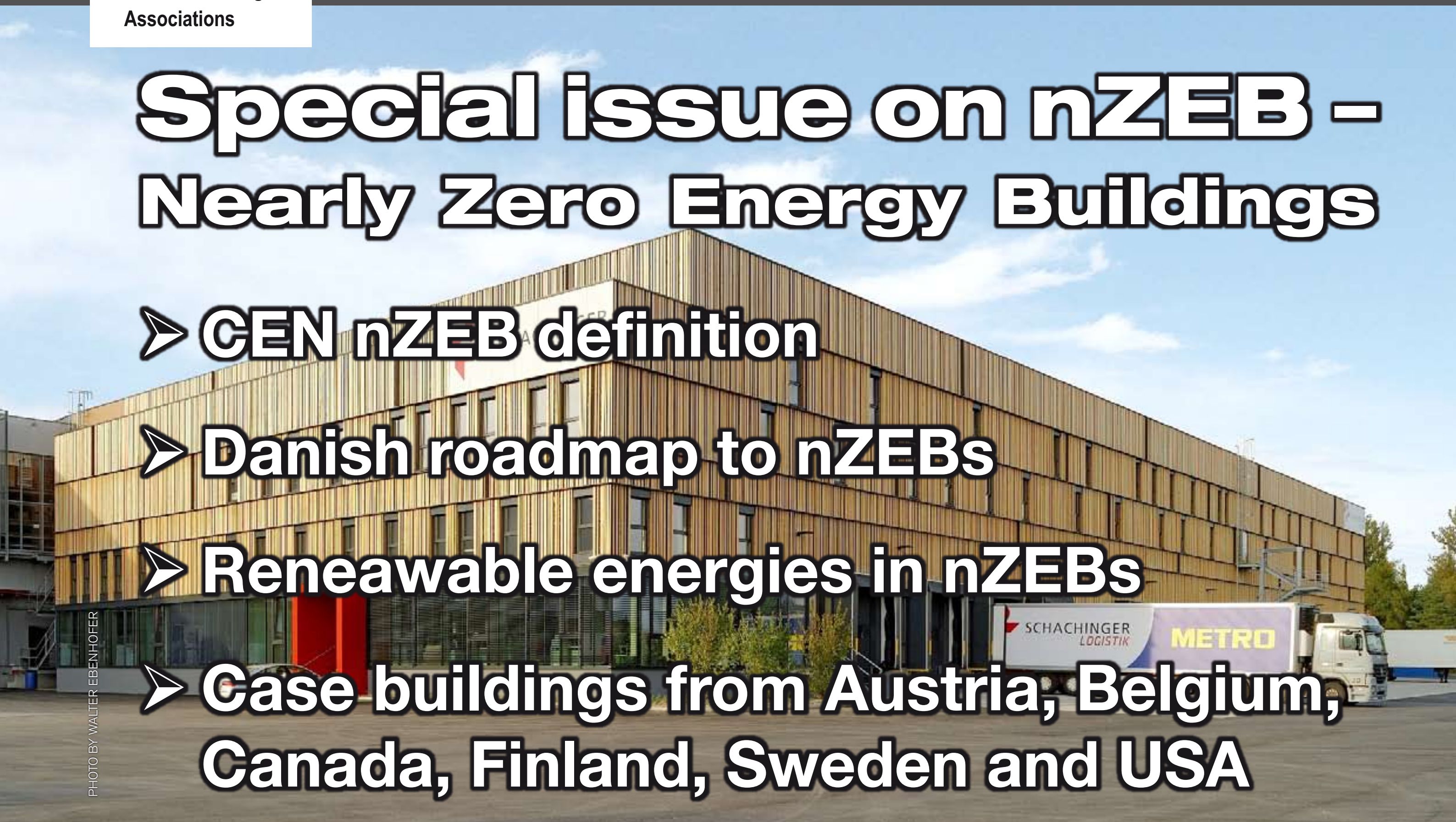

Special issue on nZEB – Nearly Zero Energy Buildings

- ➢ CEN nZEB definition
- ➢ Danish roadmap to nZEBs
- ➢ Reneawable energies in nZEBs
- ➢ Case buildings from Austria, Belgium, Canada, Finland, Sweden and USA

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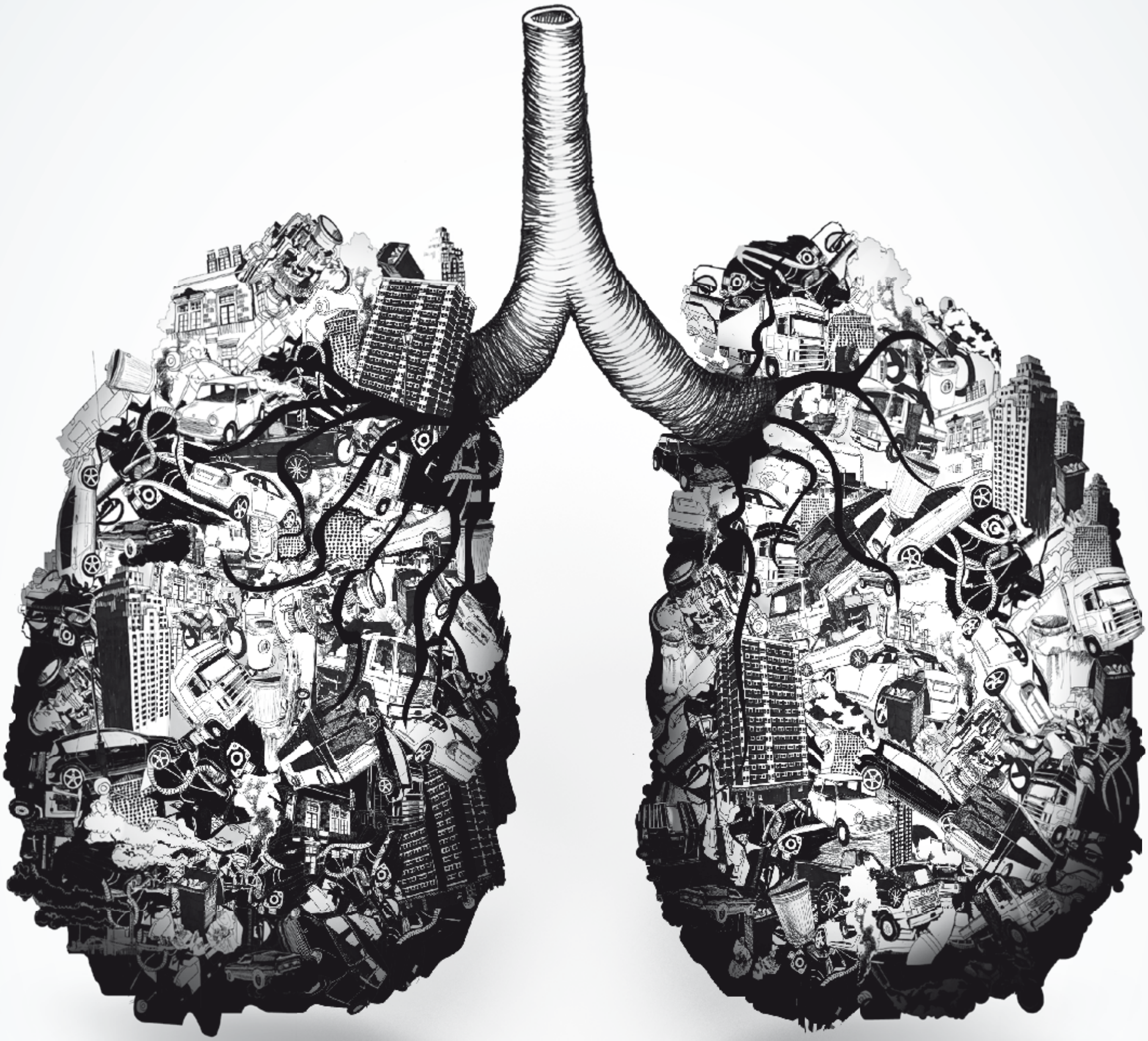

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Contents

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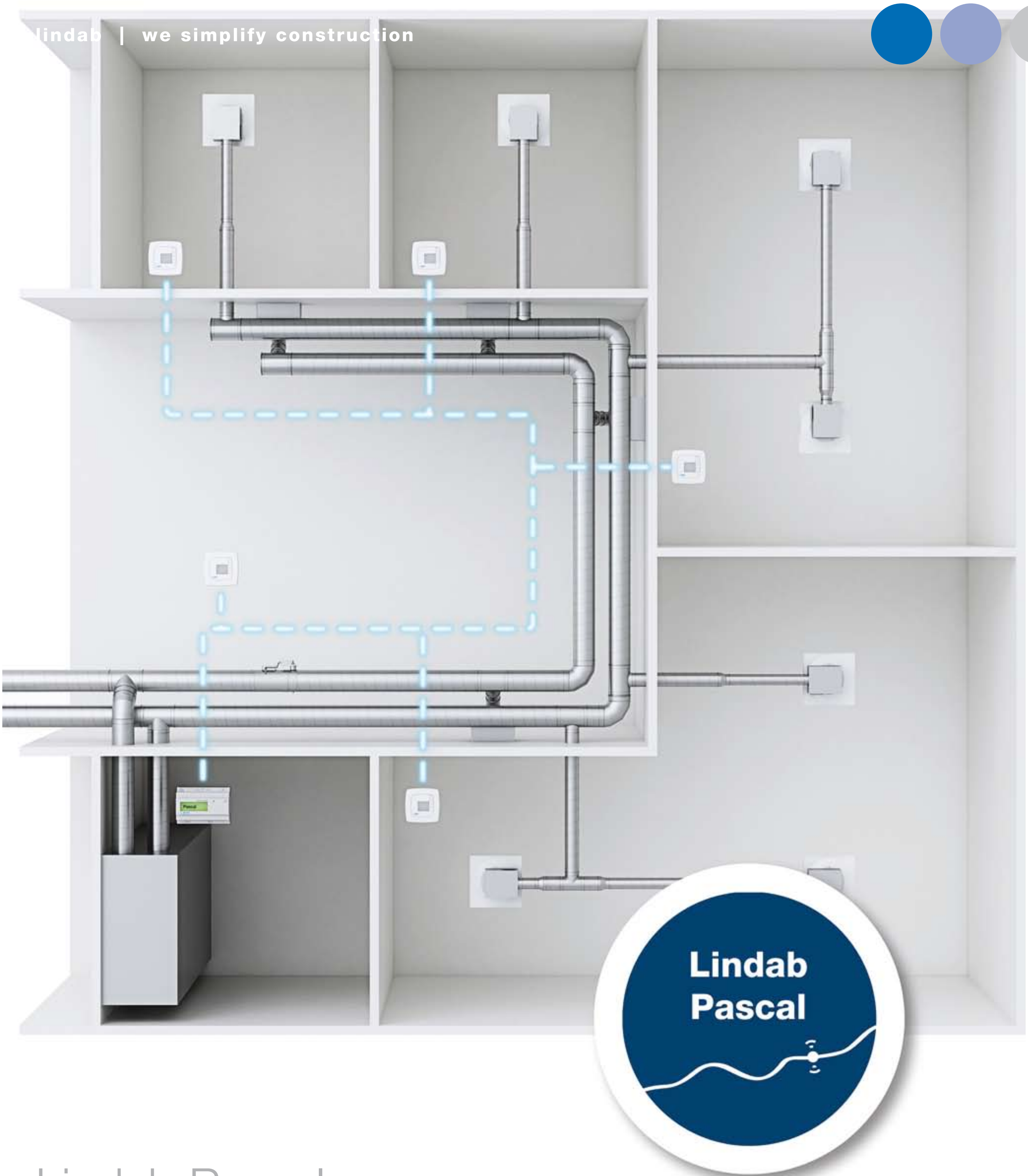

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Towards nearly Zero Energy Buildings

OLLI SEPPÄNEN
Professor
Editor-in-chief

REHVA Journal has recently published several articles on energy efficiency of buildings, particularly after 2010 when the revised Energy Performance of Buildings Directive (EPBD) was adopted. The major challenge in the directive is the requirement for all new buildings to be nearly zero energy buildings (nZEB) by 2020. The definition of how close to the zero the "nearly zero" means was left to Member States. An article in last issue showed how different the current definitions are and how difficult it is to compare the national definitions. In general it is acceptable that all Member States define the national level of energy efficiency depending on their cultural and economic background, but the basic principles should be similar regarding which energy flows are included and how the energy use is expressed. In this area REHVA has done important work which has had an influence on national definitions and European standards. Still many issues are open, like how the renewable energies are dealt with. Should the definition include only on-site energy or should the near-by or even distant sources of renewable energy be included? The debate is understandable as in many instances the investments in renewable energies are more cost effective in large scale central systems than in individual small renewable systems, however, the tradition between the use of centralised and distributed/individual systems vary between Member States. Critical in on-site production and use is how to balance the production and use, an article in this issue addresses this question.

Member States are requested to report regularly to the Commission how the Energy Related Directives are implemented. The next round of National Energy Efficiency Action Plans (NEEAP) is due in April. Some Member States are more active in implementation than others, some even fail to implement and report. A model country in the implementation and reporting has been Denmark. In this issue we publish a summary of Danish policy towards nearly zero energy.

The cases of nearly zero building in this issue show that it is possible to reach very low energy use with minor extra cost, which of course will decrease further when the technology becomes more commonly used. The cases in the issue also show that the requirements can be achieved in many building types and climatic conditions while maintaining IEQ and other attributes: Industrial building and hotel in Austria, single family house in Finland and Belgium, office building in Sweden, an article illustrates that a lot can be done also with historical buildings.

For EU the energy efficient building stock is even more important than for some other countries due to heavy dependency on imported energy. The recent crisis in Ukraine further justifies the stringent energy policy of EU where better energy efficiency of buildings plays a key role. Hopefully, the Member States understand and accept the need of the mandatory requirements for energy efficiency of buildings, even after 2030, as REHVA pointed out in its position paper published in the last issue. Even though the Energy Efficiency Directive sets a target of 3% per year to the refurbishment rate of EU buildings, it will take decades to have all buildings on the same level of energy efficiency as the new buildings.

European technology for nZEBs is advanced and has gained international attention. An article in this issue describes a successful house with European technology in Ontario, Canada. Fortunately also countries outside Europe are interested in zero energy buildings; an article in this issue describes a test house of the leading research institute, National Institute of Standards and Technology in the USA. International cooperation in this area is needed, the challenges are global and the solutions are local, however, similar technologies can be used over the national boundaries. ■

Danish plans towards Nearly Zero Energy Buildings

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Keywords: net zero energy building, nearly zero energy building, NZEB, building regulations.

The Danish Government has the target that Denmark should use 100% renewable energy in the energy and transport sectors by 2050. In March 2012 a new political ambitious Energy Agreement was reached in Denmark. This Energy Agreement is an important step towards fulfilling the 2050 target and contains a wide range of ambitious initiatives and covers the period 2012 – 2020. By 2020, the Energy Agreement will give the following main results:

- More than 35% renewable energy in final energy consumption
- Approximately 50% of electricity consumption to be supplied by wind power
- 7.6% reduction in gross energy consumption in relation to 2010
- 34% reduction in greenhouse gas emissions in relation to 1990.

Furthermore the Energy Agreement spells out the contents of a strategy for energy renovations of the existing building stock. The Strategy for energy renovation is due in 2014.

- There are several political energy ambitions in the future:
- 2030 – No more use of coal in power plants
- 2035 – All electricity and heating covered by renewable energy
- 2050 – All energy covered by renewable energy (electricity, heating, transports, industry).

Future decrease for energy use

The energy performance requirements for new buildings were implemented in their current form, i.e., the energy performance calculation method, in 2006, after the implementation of the first EPBD (Energy Performance Building Directive). These requirements included forecasts for the tightening of the EP requirements in 2010 and 2015 – approximately 25% compared with the 2006 requirements in each step. In 2009, the requirements were revised, and the EP (energy performance) requirements for new buildings were tightened by 25% in the Danish Building Regulations 2010 (BR10). In the 2010 revision, no forecast for the 2020 EP requirements was included, but the building industry requested this forecast. This led to a process of cost analysis for establishing the different levels of EP requirements. The outcome was the forecast for the EP requirements for new buildings in 2020 – i.e., the Danish nearly zero-energy building (NZEB) definition.

High oil prices making renewables attractive

Around 2000, increasing oil and natural gas prices gradually made use of wood for heating attractive for private consumers, and the share of renewable energy consequently grew considerably. This growth took place without any governmental efforts, apart from the energy tax system, which favours renewable energy. Today, 23% of the energy used for heating is renewable energy, mainly wood, with a minor share coming from heat pumps. To this comes the share of renewable energy in district heating. With approximately 40% of Danish district heating being based on renewables, the total share of renewables for heating adds up to 41%.

In order to reduce the use of oil and natural gas for space heating, the Energy Agreement states that from 2013 use of oil and natural gas will not be allowed in new buildings. For existing buildings within district heating areas and natural gas areas it will not be allowed to install new oil furnaces from 2016.

New buildings and integration of renewable energy in NZEB 2020 class

The existing BR10 sets the minimum energy requirements for all types of new buildings. These requirements relate to the energy frame and the envelope of the building. In addition to the minimum requirements, BR10 also sets the requirements for two voluntary low-energy classes: Low-energy Class 2015 and Building Class 2020 (NZEB 2020). These two classes are expected to be introduced as the minimum requirements by 2015 and 2020, respectively.

The integration of renewable energy in NZEB 2020 is taken into consideration in calculation of the primary factors. Primary energy factors will be lowered over time as RE (renewable energy) will make up a larger proportion of the energy mix. The primary energy factors in **Table 1** will be used.

Local, collective RE installations such as wind turbines, shared solar heating systems, solar photovoltaic arrays or geothermal systems are included in calculation so far as the building owner owns a share of the installation. There is requirement for thermal solar systems in large building with high domestic hot water use (above 2000 l/day).

Table 1. Primary energy conversion factors are being used in the calculation (primary/useful energy).

	2006	BR10 year 2010	Low-energy 2015	Building Class 2020
District heating	1	1	0.8	0.6
Fossil fuels	1	1	1	1
Bio fuels	1	1	1	1
Electricity	2.5	2.5	2.5	1.8

- Energy from RE installations can be subtracted when calculating the overall energy consumption, but only limited – e.g. only electricity for building operation in dwellings. There are limited subsidies for private solar panel installations. Produced energy that isn't used in the building is sold to the grid (by a low feed-in tariff). There is a maximum of 6 kW peak for single family buildings.

Energy frame

The energy frame is the maximum allowed primary energy demand for a building, including e.g. thermal bridges, solar gains, ventilation, heat recovery, cooling, lighting (non-residential buildings only), boiler and heat pump efficiency, electricity for operating the building, and sanctions for overheating. The overheating sanction is calculated on a fictive energy use, equal to the energy needed in an imaginary mechanical cooling system in order to keep the indoor temperature at 26°C. This additional energy use is included in the calculated overall energy consumption of the building.

The energy frame for the primary energy demand in new buildings has been tightened by 25% compared with the 2006 baseline Low-energy. Class 2015 introduces a 50% tightening compared with the 2006 baseline, and Building Class 2020 further tightens the energy frame by 25%, thereby reducing the allowed energy frame by 75% compared with the 2006 baseline (**Figure 1**).

The BR10 minimum energy frame requirement is:

> 52.5 + 1,650 / A [kWh/m² per year] for residential buildings, and

> 71.3 + 1,650 / A [kWh/m² per year] for non-residential buildings,

where A is the heated gross floor area.

The energy frame for the voluntary Low-energy Class 2015 is:

> 30 + 1,000 / A [kWh/m² per year] for residential buildings, and

> 41 + 1,000 / A [kWh/m² per year] for non-residential buildings.

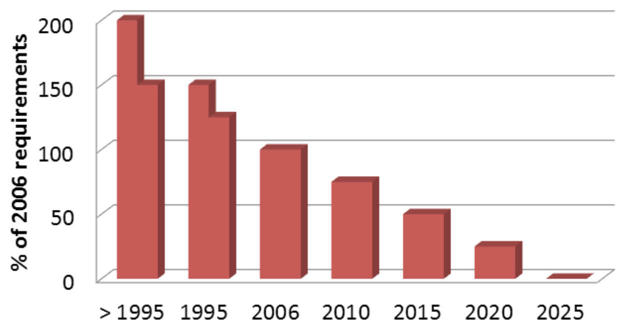

Figure 1. Development of energy use in Danish buildings by construction year, the requirements in 2006 as reference (=100%).

Figure 2. An example of a NZEB in Denmark, Green Lighthouse. It was built in less than a year in a close public/private partnership. The partners are the University of Copenhagen, VELUX, VELFAC, the Danish Building and Property Agency (UBST) and the City of Copenhagen. Green Lighthouse is located at the Faculty of Science at the University of Copenhagen and is a one-stop-shop where students can get advice on their studies, exams etc. (Photo: greenlighthouse.ku.dk)

Finally, the energy frame for the voluntary Building Class 2020 is:

20 [kWh/m² per year] for residential buildings, and
25 [kWh/m² per year] for non-residential buildings.

The building code also sets requirements for calculating the design transmission heat loss for the opaque part of the building envelope for new buildings (it fixes the temperature differential indoors-outdoors at 32°C), as well as the minimum requirements for components and installations. The minimum component requirements are primarily intended to eliminate the risk of mould growth due to cold surfaces. It is not possible to construct a building, meeting the energy frame solely by fulfilling the minimum component requirements. Both sets of requirements work in parallel with the requirements for the energy frame, and are set in order to avoid having new dwellings and/or building components and installations with a high level of renewable energy, but poor insulation. A Building Class 2020 building must be constructed so that the designed transmission loss does not exceed 3.7 W/m² of the building envelope in the case of single-storey buildings, 4.7 W/m² for two-storey buildings and 5.7 W/m² for buildings with three storeys or more.

Indoor climate in NZEB 2020 class

There are also special requirements for airtightness, windows and the thermal indoor climate in the NZEB 202 class, e.g.:

- The thermal indoor climate on sunny days must be documented through calculation for dwellings, institutions, offices, etc. in low-energy class 2015 and NZEB 2020 class
- For dwellings, a temperature of 26°C must not be exceeded for more than 100 hours per year, and a temperature of 27°C must not be exceeded for more than 25 hours per year
- In non-residential buildings the limit threshold is defined by the Danish Working Environment Authority and requests by the building owner
- NZEB 2020 class must have a glazed area of at least 15% of the floor area in habitable rooms and kitchen/family rooms if the light transmittance of the glazing is higher than 0.75. If the light transmittance is lower, the glazed area must be increased correspondingly.

As an example of a NZEB in Denmark is shown the Green Lighthouse (**Figure 2**). ■

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Nearly Zero Energy Buildings (nZEB) in the CEN draft standard

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Johann ZIRNGIBL is Head of Division in the French state owned technical and scientific building research center (CSTB). He is managing research project related to the energy performance of buildings on European and International level and is involved in setting up national energy assessment methods.

The author is Convenor of several European standardization groups (e.g. CEN TC 371/WG1, CEN TC 228/WG4) working on the CEN standards linked to the EPBD and International standardization groups (e.g. ISO TC205/WG9).

A binding roadmap and a definition of nearly zero energy buildings (nZEB) is given in the Energy Performance of Buildings Directive (EPBD). Member States are asked to report detailed application in practice of the definition and provide a roadmap towards nZEB.

Keywords: nearly zero energy building, nZEB, standard, CEN, primary energy factor, PEF, renewable energy ratio, RER.

The analysis of the applications in the Member States shows that the definitions of nZEB are varying a lot. Therefore a coherent and common definition of nZEB is needed:

- to be able to understand the content of the numerical indicator and the related requirement in the different Member States;
- to guide the industrials in the development of solutions and to give them the possibility showing the impact of the developed solution in a transparent manner at European level.

The European Commission asked CEN (mandate M480) to develop standards supporting the application of recast EPBD in the Member States. This article shows and explains the first ideas of the CEN development for a common definition of nZEB in prEN 15603.

Mandate from the European Commission for standardisation

To support the Member States in the transposition of the Directive into national application, the Commission gave mandate to CEN to work out a set of standards. CEN completed the Directive with more detailed definitions and worked out transparent and unambiguous calculation procedures. The target was to set up a common and flexible methodology allowing the Member States to take into account national, regional or local characteristics within this common methodology.

Within this common structure the Member States can set up their level of requirements according to their priorities (e.g. more focusing on the building envelope; more focusing on the total primary energy, etc.).

CEN definitions for "renewable sources", "on-site" and "nearby"

The Directive indicates that the localization of the energy sources or energy conversion to be taken into account should be 'on-site' or 'nearby' but does not define both perimeters.

The definition of on-site and nearby has an important influence on the assessment of an nZEB. As all new and refurbished building shall be nZEB's, and as some Member States intent to make the renewable energy ratio (RER) mandatory, the definition impact also the development of technologies and the choice of investments made by building owners.

In order to increase the energy performance of his building, a building owner could decide to invest not only in the building itself, but also in the 'nearby' energy source (e.g. in a biomass boiler of a district heating plant where his building is connected to). In this case, enlarging the assessment perimeter will contribute to increase the use of energy from renewable sources, make the investments more cost efficient and open new possibilities for increasing energy performance.

"On-site"

CEN defines 'on-site' as the building and the parcel of land on which the building is located. In case of building sites with multiple buildings, it is the parcel of land allocated to the assessed building. It has to be clearly stated which part of the parcel of land is allocated to which building in order to avoid double counting of energy sources (e.g. to count electricity production from PV cells on a garage several times).

The rationale for the definition of "on-site" is the unique and strong link with building.

"Nearby"

CEN defines 'nearby' as energy source which can be used only at local or district level. This definition was estimated as wake and therefore completed by having a dedicated connection, requiring specific equipment for the assessed building to be connected. The rationale for the definition of 'nearby' was the possibility to calculate a specific primary energy factor and to have still a specific link between the building and the energy source.

Renewable energy ratio (RER)

The Directive indicates that the very low amount of energy required has to be covered to a very significant extent by energy from renewable sources.

In prEN 15603 [1] CEN define the renewable energy ratio RER as the ratio of the renewable primary energy, (calculated with renewable primary conversion factors), on the total primary energy (calculated with total primary conversion factors). The renewable energy ratio *RER* can be differentiated according to the different perimeters (e.g. on-site, nearby) and the related delivered energies or energy productions.

General principles for a coherent assessment of nZEB – the CEN hurdle race

EPBD sets already two requirements to define nZEB. The use of only one requirement, e.g. the numeric indicator of primary energy use, is misleading. In prEN 15603 different requirements are combined to a coherent assessment of nearly Zero Energy Building (nZEB).

Interpreting the different requirements in EPBD, a nZEB should be a building that has a very low amount of energy required associated with a typical use of the building including energy used for heating, cooling, ventilation, hot water and lighting), taking into account:

- indoor climatic conditions;
- thermal characteristics of the building, building elements having a significant impact on the energy performance of the building envelope;
- HVAC installation, hot water supply, built-in lighting installation, optimising the energy use of technical building systems;
- active solar systems and other systems based on energy from renewable sources;
- district or block heating and cooling systems.

The very low amount of energy required by a nearly zero-energy building should be covered to a very significant extent by energy from renewable sources, including energy from renewable sources produced on-site or nearby.

A nearly zero-energy building is characterized by a numerical indicator of primary energy use expressed in kWh/m² per year.

CEN propose to combine the different requirements in a coherent assessment of nZEB. The proposed assessment methodology goes step by step 'from the needs to the overall energy performance expressed in primary energy use'. Only if the requirement of each step is reached, then the building can be qualified at the end as 'nZEB'. This approach is comparable to a hurdle race (**Figure 1**).

First requirement: the building fabric (Energy needs)

The first requirement is reflecting the performance of the building fabric characterised by the energy needs. The energy needs are based on local conditions and the designated function of the building.

They take into account:

- the quality of the building envelope (e.g. insulation, windows);
- the bioclimatic design (e.g. solar gains, natural lighting),
- the inertia, the partitioning;
  and the need to guarantee adequate indoor climatic conditions in order to avoid possible negative effects such as poor Indoor Air Quality (due to lack of ventilation).

The energy needs are calculated with EN ISO 13790 [2].

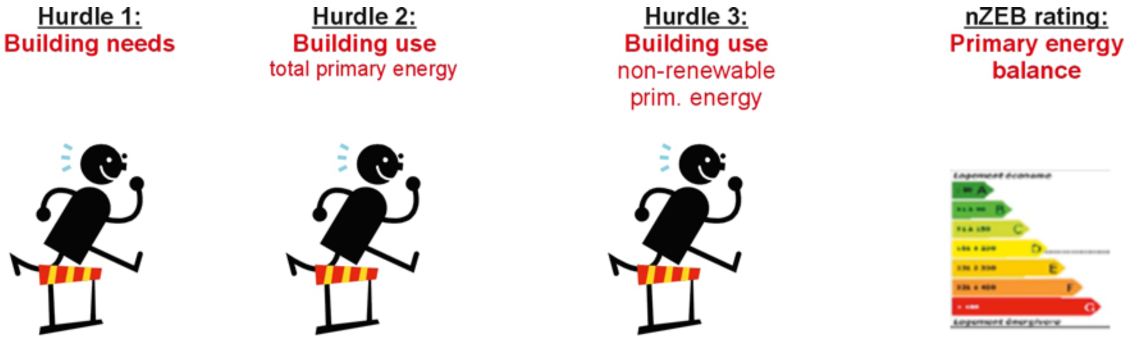

Figure 1. The CEN hurdle race towards nZEB rating.

Second requirement: The total primary energy use

The second requirement is reflecting the performance of the technical building systems (HVAC installation, domestic hot water supply, built-in lighting installation) characterized by the energy use.

Technical building systems are linked to an energy carrier (e.g. gas boiler; auxiliary consumption). To sum up the different energy carriers in a coherent way the second requirement is expressed in total primary energy.

Default values for primary energy factors are given in prEN 15603.

NOTE: Primary energy is defined as energy from renewable and non-renewable sources. The related primary energy factors (PEF) are defined as:

- non-renewable primary energy factor taking into account only non-renewable energy overheads of delivery to the point of use, excluding renewable energy overheads and primary energy components;
- renewable primary energy factor taking into account only renewable energy overheads of delivery to the point of use, excluding non-renewable energy overheads and primary energy components;
- total primary energy factor. The total PEF is the sum of the non-renewable primary energy factor and the renewable primary energy factor.

The total primary energy use is a coherent way for setting technical building system requirements because some systems (e.g. direct electrical emitters) have parts of their systems losses outside the building assessment boundary (e.g. electricity generation). The total primary energy factor takes into account the losses outside the assessment boundary.

Only energies delivered through the assessment boundary from nearby and/or distant are taken into account to link the total primary energy use with the energy counters.

The total primary energy use is calculated according to prEN 15603.

Third requirement: Non-renewable primary energy use without compensation between energy carriers

The third requirement is reflecting the contribution of energies from renewable sources (e.g. active solar systems), characterized by the non-renewable primary energy consumption.

This third requirement does not take into account:

- compensation between different energy carriers for example between gas and on-site PV production;
- the effect of exported energy.

This requirement takes into account only the energy that is used to provide on-site services (heating, ventilations, etc.)

The non-renewable primary energy use is calculated with prEN 15603.

Final nZEB rating: Numerical indicator of non-renewable primary energy use with compensation

At this stage the compensation between energy carriers and the effect of exported energy is taken into account. The numerical indicator of non-renewable primary energy is calculated with prEN 15603.

Table1. Example illustrating the CEN proposal in prEN 15603 for nZEB rating with four individual requirements.

Calculation direction			
1st requirement	**2nd requirement**	**3rd requirement**	**Final nZEB Rating**
Build. fabric	Tech. Build. systems + related energy carrier **only nearby, distant!!**	Renewable source **on-site, nearby, distant**	Compensation by exporting **on-site, nearby, distant**
Energy needs 1)	**Total primary energy use** $f_{P,tot}$ 2)	**Non-renew. Prim.Energy** $f_{P,nren}$ 2)	**Tot + nren. Prim.energy** $f_{P,nren}$, k_{exp} 3)
Heating : 60	Gas * $f_{P,tot}$: 80 * 1,05= 84	Gas* $f_{P,nren}$: 80 * 1,05= 84	Gas* $f_{P,nren}$: 80 * 1,05= 84
Cooling : 20	PV * $f_{P,tot}$: 40 * 1,00= 40	PV * $f_{P,nren}$: 40 * 0,00= 0	PV * $f_{P,nren}$: 40 * 0,00= 0
Lighting: 10	∑120 (needs+losses)		PV_{prod}. 60, k_{exp}=1 > exported: 60*1 - 40= 20
For information only: DHW: 20	NOTE: DHW added		PV_{exp} * $f_{P,nren}$: 20 *2.5=50
Result: 90	**Result: 124**	**Result: 84**	~~**nZEB rating: 34**~~
Requirement:100	**Requirement:125**	**Requirement:80**	**Requirement: 50**
fulfilled	**fulfilled**	**Not fulfilled**	**No nZEB rating**

1) Services linked to building fabric only (e.g. envelope, partition, inertia, etc)

2) Example of primary energy factors $f_{P,tot}$ = total primary energy factor , $f_{P,nren}$ = non renewable primary energy factor

3) Part of exported energy (production related!) between 0–1

Example

Table 1 illustrates the CEN hurdle race by an example. In this example there would be no nZEB rating (even if nZEB rating result is lower than requirement) because the third requirement is not passed.

Resume

The European Commission asked CEN (mandate M480) to develop standards supporting the application of EPBD in the Member States and to complete EPBD definitions where needed.

CEN completed the nZEB definition, worked out a common, clear, unambiguous assessment structure and the related standards to calculate the very low amount of energy required by nZEB. The common structure is flexible in order to take into account national, regional and regional choices.

CEN combined the definition of nZEB's and the different EPBD requirements in one assessment method (hurdle race). By following the hurdle race negative side effects (e.g. uncomfortable buildings) can be avoided.

The Member States can set level of requirements according to their priorities within this common assessment structure.

EPBD nZEB requirement is a significant contribution to EU commitments (e.g. climate change) and a huge challenge for the EU building sector. A common, unambiguous definition of nZEBs and a transparent assessment method is needed to guide and motivate EU professionals in the development of adapted solutions.

European professional needs clear, unambiguous European rules and definitions. ■

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Renewable Energy Ratio in Net Zero Energy Buildings

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The Net Zero Energy Building concept is internationally already well known. But now new discussions arise because of the actually role and use of renewable energies in Net ZEBs and according to the interaction with the public grid infrastructure as well as seasonal differences between energy generation and demand.

Keywords: Renewable Energy Ratio, RER, share of renewable energies, renewable energy supply, Net Zero Energy Building, conversion factors, weighting factors.

European and national laws ask for an increased ratio of renewable energy sources and carriers of the total energy consumption of buildings. While the Renewable Energy Directive (RED) gives only a framework for national implementations in the EU and the Erneuerbare-Energien-Wärmegesetz in Germany focuses on the partial coverage of the thermal energy demand of buildings or according compensatory measures [EEWärmeG 2012], REHVA introduces a performance indicator to calculate the actual fraction of used renewable energy sources [Kurnitski 2013]. It is named "Renewable Energy Ratio (RER)" and suggested in a similar manner in the proposal of the recast of DIN EN 15603-2013 where it is named "Share of renewable energy".

The RER-concept

Both indicators determine the respective shares of renewable and non-renewable sources of the (local) energy generation, the used end energy including the environmental energy and all energy carriers. The total amount of the primary energy from renewable sources results from the difference between the total primary energy and non-renewable primary energy of all observed energy flows which cross the balance boundaries. Thus, all conversion and system losses within the balance boundary are included. Energy losses outside of the balance boundary are represented by primary energy conversion factors of the various energy carriers. Exported energy which is credited to the amount of the respective displaced primary energy carrier in the grid infrastructure equalizes energy supply. According to the EPBD the consideration of use-specific consumers like appliances or IT is optional. In the calculation of "RER" they have influence on the level of end energy demand as well as on the self-consumption respectively the amount of export of generated electricity as these shares result from a (monthly) balance of energy generation and its fictitious self-consumption (see **Table 3**). Therefore all consumers are included in this study. According to the draft from REHVA, the formula below applies for calculating the "Renewable Energy Ratio (RER)" [Kurnitski 2013b].

$$REP_p = \frac{\sum_i E_{ren,i} + \sum_i \left((f_{del,tot,i} - f_{del,nren,i}) E_{del,i} \right)}{\sum_i E_{ren,i} + \sum_i (E_{del,i} f_{del,tot,i}) - \sum_i (E_{exp,i} f_{exp,tot,i})}$$

where

RER_p is the Renewable Energy Ratio based on total primary energy

$E_{ren,i}$ is the renewable energy produced on site or nearby for energy carrier i

$E_{del,i}$ is the delivered energy for energy carrier i

$E_{exp,i}$ is the exported energy for energy carrier i

$f_{del,tot,i}$ is the total primary energy factor for the delivered energy carrier i

$f_{del,nren,i}$ is the non-renewable primary energy factor for the delivered energy carrier i

$f_{exp,tot,i}$ is the total primary energy factor of the delivered energy compensated by the exported energy for energy carrier i

The "RER" procedure follows the EPBD as a significant extent of the energy demand has to be covered by energy from renewable sources produced on-site or nearby and includes also aero-, geo-, and hydrothermal energy beside wind, solar, hydro, biomass and non-fossil gases as renewable energies. Passive heat gains (e.g. solar radiation, waste heat of internal loads) are neither included in the calculation as a distinction is made between "on-site" and "off-site" generation.

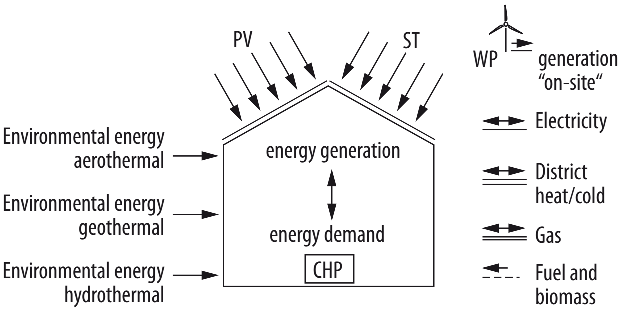

Figure 1. Representation of the calculation procedure of the Renewable Energy Ratio (RER) proposed by REHVA. The building is set as balance boundary expanded by generation and supply of renewable energy close to the building ("on-site"). The environmental energy is included. PV: photovoltaic; WP: wind power; ST: solar thermal; CHP: combined heat and power.

Methodology

In buildings with an equalized yearly energy balance on the basis of primary energy the addition of normally not balanced environmental energy should lead to high rates of renewable energy supply. Using cumulative annual values of a fully equalized primary energy balance based on monthly simulation data of energy demand and generation this is checked by a Net ZEB (Nursery "Die Sprösslinge"; detailed information in [Voss Musall 2013]) and the following six respectively twelve technology options:

1. ground source heat pump (abbreviation "HP")
2. gas-powered mini-CHP coupled with a peak load calorific boiler ("CHP")
3. biomass boiler ("Bio")
4. gas condensing boiler ("Gas")
5. district heating ("DH")
6. pellet-CHP coupled with a biomass boiler ("CHPren")

The six technology options are calculated in each case with and without solar thermal hot water heating (coverage of 60% of the DHW demand by vacuum tube collectors) and provided with the additive abbreviation "+ST". The annual balances are calculated on basis of four sets of conversion factors for primary energy which are part of current or future energy saving directives (P1 – P3, see **Table 1**) or referenced in the literature (P4, see **Table 2**):

P1: symmetrical conversion based on German DIN V 18599 – 2009
P2: asymmetrical conversion based on German DIN V 18599 – 2011
P3: symmetrical conversion based on European EN 15603 – 2008
P4: (future) quasi-dynamic weighting based on [Großklos 2013]

The two currently valid options P1 and P3 are based on static (yearly average values) and symmetric weighting

Table 1. Currently used or proposed conversion factors for primary energy in Europe and Germany.

Energy carrier	Norm	EN 15603	DIN V 18599	
	Year	2008	2009	2011*
	Set of factors	P1 [kWh_P/kWh_S]	P2 [kWh_P/kWh_S]	P3 [kWh_P/kWh_S]
Electricity (power grid)	f_{nren}	3.14	2.60	2.40**
	f_{tot}	3.31	3.00	2.80
Natural gas	f_{nren}	1.36	1.10	1.10
	f_{tot}	1.36	1.10	1.10
Oil	f_{nren}	1.35	1.10	1.10
	f_{tot}	1.35	1.10	1.10
Wood pieces / wood pellets	f_{nren}	0.09	0.20	0.20
	f_{tot}	1.09	1.20	1.20
District heat	f_{nren}	0.80***	0.70	0.70
	f_{tot}	0.80***	0.70	0.70
Environmental energy (solar energy, geothermal energy, ambient heat, etc.)	f_{nren}		0.00	0.00
	f_{tot}		1.00	1.00

* Will be used from May 2014
** In case of electricity export also the renewable share is included (factor 2.8 kWh_P/kWh_S)
*** As no factor for heating networks is specified, an average factor of known European factors is calculated
f_{nren}: Primary energy conversion factor for non-renewable energy; f_{tot}: primary energy conversion factor for non-renewable and renewable (total) energy

Table 2. Factors of the non-renewable share of the cumulative energy for P4 following [Großklos 2013] (f_{nren}) and factors of renewable and non-renewable shares (f_{tot}) according to an own adaptation.

Factor	Annual average value	Jan	Feb	Mar	Apr	Mai	Jun	Jul	Aug	Sep	Oct	Nov	Dec
f_{tot}	1.63	1.63	1.63	1.63	1.63	1.63	16.3	1.63	1.63	1.63	16.3	1.63	1.63
f_{nren}	1.23	1.30	1.29	1.25	1.22	1.15	1.17	1.20	1.19	1.22	1.27	1.30	1.21

factors. The two other options are included to make use of asymmetric (P2) and quasi-dynamic factors (P4) for electricity, while current national factors are used for all other energy carriers. These ”strategic weighting factors” may be implemented in the future in order to favour or discourage the use of specific technologies and/or energy carriers in a scenario of higher penetration of renewables in the electricity generation mix. The set of asymmetric electricity factors shown in **Table 1** includes a factor of 2.8 kWh_p/kWh_S for electricity generation/export and 2.4 kWh_p/kWh_S for demand/import. The quasi-dynamic electricity conversion factors for 2020 in **Table 2** are based on [Großklos 2013]. Because of the used scenario of high decarbonisation in Germany the values show a great seasonal variation between summer (more renewable electricity available) and winter months (more coal power used). As for P4 only factors for the non-renewable share of the cumulative energy consumption are available the required factors of the renewable and non-renewable shares (f_{tot}) are defined especially. For this purpose, it is assumed that the difference between the two values is similar in size and constant like the known annual mean values for the conversion of the German electricity in recent years, according to [DIN 18599 2009; DIN 18599 2011] und [GEMIS 2013]. A difference in the amount of 0.4 kWh_P/kWh_S can be identified and is set constantly, as fossil fuels offset fluctuating monthly renewable energy yields in the electricity grid infrastructure.

The shown factors P1 – P4 are used in the primary energy balances and the according ”RER”-calculations.

To illustrate the impact of not exactly equalized yearly primary energy balances each set of factors is additionally calculated with on the one hand a not completely equalized yearly balance following the meaning of the Swiss certificate ”Minergie-A” (the user specific electricity demand is included in the overall energy demand but not balanced by energy generation, see [Minergie 2010]) and on the other hand a positive balance. For the additional calculations only the technology options ”HP” and ”Bio+ST” are selected.

Results

The results of the ”RER” calculations correlate mainly with the respective balance result. The equalized primary energy balances on the basis of symmetrical and static weighting always have a Renewable Energy Ratio in excess of 100% (see **Figure 2**). If the balance result drifts to positive or negative, this also applies to the deviation of the Renewable Energy Ratio from the mark of 100%.

In the case that more than one energy carrier is compensated within the primary energy balance, the difference between the two related factors influences the ”RER” result quite much. This is due to the fact that the electricity import and export in the ”RER” calculation is weighted with both renewable and total shares of primary energy conversion. For the gas-based technologies ”Gas” and ”CHP” a large deviation from the mark of 100% is visible. This growth if electricity from CHP is exported to compensate the gas supply. Here, the electricity of the gas-CHP is not considered as local and renewable energy

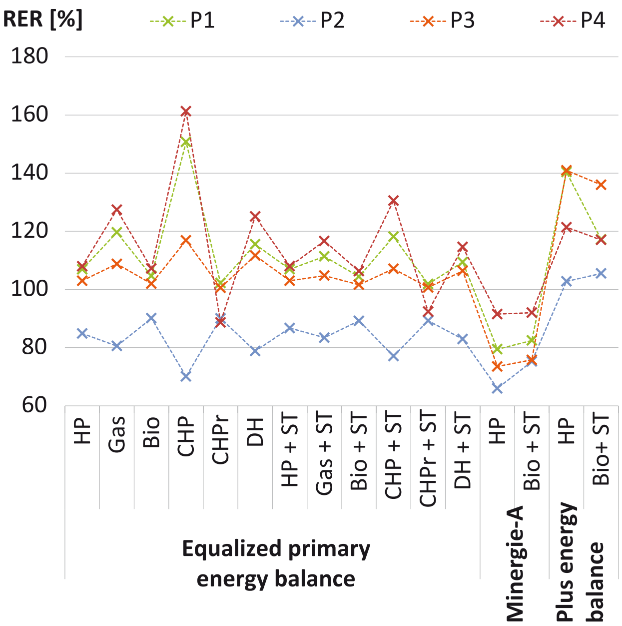

Figure 2. Representation of the Renewable Energy Ratio depending on different technology and weighting options as well as balance aims (data for P1 are given in **Table 4**).

Table 3. Breakdown of monthly and accumulated annual end energy and primary energy data for calculating "RER" for technology option "CHP+ST" and weighting factors P4 (only used energy flows are shown). The according RER is 131%.

			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual sum
Electricity demand	Auxiliary energy		0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.1	0.2	**1.3**
	Ventilation		1.0	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	**11.9**
	Lighting		0.8	0.7	0.7	0.6	0.6	0.6	0.6	0.7	0.7	0.7	0.8	0.9	**8.4**
	Appliances		0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	**7.0**
	Complete electricity		2.6	2.3	2.4	2.3	2.3	2.2	2.3	2.3	2.3	2.4	2.4	2.6	**28.6**
Fuel demand	Natural gas		9.3	5.8	3.0	1.3	0.5	0.5	0.3	0.3	1.1	2.0	5.7	9.5	**39.5**
Produced ren, energy	PV electricity	$E_{ren,el}$	1.6	3.0	3.9	5.6	6.4	6.2	6.4	5.8	4.7	3.5	1.9	1.2	**50.1**
	Solar thermal	$E_{ren,heat}$	0.3	0.5	1.1	1.6	1.6	1.4	1.6	1.6	1.3	1.0	0.4	0.1	**12.5**
Produced non ren, energy	CHP electricity	$E_{nren,el}$	3.3	2.1	1.1	0.5	0.2	0.2	0.1	0.1	0.4	0.7	2.1	3.4	**14.1**
Exported electricity	End energy	$E_{exp,el}$	2.3	2.8	2.5	3.8	4.3	4.1	4.2	3.6	2.8	1.9	1.5	1.9	**35.6**
	Weighting factors	$f_{exp,tot,el}$	1.63	1.63	1.63	1.63	1.63	1.63	1.63	1.63	1.63	1.63	1.63	1.63	
		$f_{exp,nren,el}$	1.30	1.29	1.25	1.22	1.15	1.17	1.20	1.19	1.22	1.27	1.30	1.21	
		$f_{exp,ren,el}$	0.33	0.34	0.38	0.41	0.48	0.46	0.43	0.44	0.41	0.36	0.33	0.42	
	Primary energy	$P_{exp,tot,el}$	3.8	4.5	4.1	6.2	6.9	6.7	6.8	5.8	4.5	3.1	2.4	3.1	**58.1**
		$P_{exp,ren,el}$	0.8	0.9	1.0	1.6	2.0	1.9	1.8	1.6	1.1	0.7	0.5	0.8	**14.7**
Delivered electricity	End energy	$E_{del,el}$	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**
	Weighting factors	$f_{del,tot,el}$	1.63	1.63	1.63	1.63	1.63	1.63	1.63	1.63	1.63	1.63	1.63	1.63	
		$f_{del,nren,el}$	1.30	1.29	1.25	1.22	1.15	1.17	1.20	1.19	1.22	1.27	1.30	1.21	
		$f_{del,ren,el}$	0.33	0.34	0.38	0.41	0.48	0.46	0.43	0.44	0.41	0.36	0.33	0.42	
	Primary energy	$P_{del,tot,el}$	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**
		$P_{del,ren,el}$	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**
Delivered fossil fuels	End energy	$E_{del,ff}$	9.3	5.8	3.0	1.3	0.5	0.5	0.3	0.3	1.1	2.0	5.7	9.5	**39.5**
	Weighting factors	$f_{del,tot,ff}$	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	
		$f_{del,nren,ff}$	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	
		$f_{del,ren,ff}$	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	Primary energy	$P_{del,tot,ff}$	10.2	6.4	3.3	1.5	0.5	0.6	0.4	0.4	1.2	2.2	6.3	10.4	**43.4**
		$P_{del,ren,ff}$	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**

and is therefore only used to reduce the electricity supply (by directly covered energy demands) and to increase the electricity export. Thus, the CHP-electricity is weighted with the higher weighting factors for exported electricity and reduces the overall energy consumption of the building in a significantly greater extent than it would be the case if it would be considered as not weighted but renewable electricity. The effect is smaller for P3, because the difference between the non-renewable and total share of primary energy is smaller than for P1. Also the effect is highlighted by the biomass-fired CHP_{ren} whose renewable generated electricity also reduces the electricity demand but is not weighted with any factors (see **Table 4**).

If asymmetric weighting factors are used, the "RER" is below 100%. Reason for this is that the annual primary energy balance is achieved only theoretically. Due to the asymmetric weighting and the higher conversion factor for electricity generation less (primary) energy has to be generated than actually necessary. The final energy balance is negative (even in the all-electric options less electricity is generated than consumed). The CHP options have the lowest "RER" values, as the gas supply can be met by less high electricity generation respectively weighted exports (see above). Compared with other technology options the effect is pushed by the imputation of the CHP-electricity in the primary energy balance and the lower solar power generation.

Quasi-dynamic factors usually have larger Renewable Energy Ratios. The phenomena for the fossil-heated buildings are strengthened (see **Table 3**). However, the options with biomass CHP reach ratios below 100%.

Table 4. Overview of accumulated annual values for different technology options and factor set P1 (all data except RER in kWh/m²y).

Technology option		HP	Gas	Bio	CHP	CHP ren	DH	HP + ST	Gas + ST	Bio + ST	CHP + ST	CHP ren + ST	DH + ST	HP	Bio + ST	HP	Bio + ST
Primary energy balance		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	–18.7	–18.0	14.7	12.0
End energy demand	Complete electricity	40.0	28.4	28.4	27.9	27.9	28.3	36.3	28.9	28.9	28.6	28.6	28.7	40.0	28.4	40.0	28.4
	District heat						32.6						20.1				
	Biomass			48.9		64.0				30.2		39.5			48.9		48.9
	Natural gas		33.7		64.0				20.8		39.5						
Produced ren, energy	PV electricity ($E_{ren,el}$)	40.0	42.6	32.1	32.1	10.0	37.1	36.3	37.7	31.3	31.2	17.5	34.2	33.0	24.3	45.6	35.9
	CHP electricity ($E_{ren,el}$)					22.8						14.1					
	Geothermal heat ($E_{ren,heat}$)	22.7						13.7						22.7		22.7	
	Solar thermal ($E_{ren,heat}$)							12.5	12.5	12.5	12.5	12.5	12.5		12.5		12.5
Produced non ren, energy	CHP electricity ($E_{nren,el}$)				22.8						14.1						
Exported electricity	$E_{exp,el}$	10.7	18.2	9.2	27.1	5.2	13.2	10.8	13.3	8.0	16.7	3.9	10.3	5.9	3.6	15.1	12.3
	$P_{exp,tot,el}$	32.2	54.5	27.5	81.2	15.5	39.5	32.4	39.9	24.1	50.1	11.7	30.8	17.6	10.8	45.3	36.8
	$P_{exp,ren,el}$	4.3	7.3	3.7	10.8	2.1	5.3	4.3	5.3	3.2	6.7	1.6	4.1	2.3	1.4	6.0	4.9
Delivered electricity	$E_{del,el}$	10.7	3.9	5.4	0.0	0.2	4.4	10.8	4.5	5.7	0.0	0.9	4.8	12.8	7.6	9.5	4.8
	$P_{del,tot,el}$	32.1	11.8	16.2	0.0	0.7	13.2	32.4	13.6	17.1	0.0	2.6	14.5	38.4	22.9	28.4	14.3
	$P_{del,ren,el}$	4.3	1.6	2.2	0.0	0.1	1.8	4.3	1.8	2.3	0.0	0.4	1.9	5.1	3.1	3.8	1.9
Delivered district heat	$E_{del,heat}$						32.6						20.1				
	$P_{del,tot,heat}$						22.8						14.1				
	$P_{del,ren,heat}$						0.0						0.0				
Delivered bio-mass / bio fuels	$E_{del,bio}$			48.9		64.0				30.2		39.5			48.9		48.9
	$P_{del,tot,bio}$			58.7		76.8				36.3		47.4			58.7		58.7
	$P_{del,ren,bio}$			48.9		64.0				30.2		39.5			48.9		48.9
Delivered fossil fuels	$E_{del,ff}$		33.7		64.0				20.8		39.5						
	$P_{del,tot,ff}$		37.0		70.4				22.9		43.4						
	$P_{del,ren,ff}$		0.0		0.0				0.0		0.0						
RER [%]		**107**	**120**	**105**	**151**	**102**	**116**	**107**	**111**	**104**	**118**	**102**	**109**	**79**	**82**	**140**	**117**

This is due to the very low requirement for solar electricity generation and the minimized electricity exports.

Solar thermal collectors reduce the overall end energy demand of a building and thus the weighted supply of all energy carriers respectively the necessary electricity exports. The greatest impacts are visible for those technology/energy carrier options with high primary energy conversion factors. The RER is closer to the mark of 100% when solar thermal systems are used.

Conclusions

It is shown that for Net Zero Energy Buildings no further measures are necessary to reach high fractions of renewable energy. Solely for the primary energy balances based on (future) asymmetric weighting factors additional generation is required for a full renewable coverage of the energy demand. The two calculated plus energy balances for this asymmetric weighting option indicate that for the example building a low plus of primary energy respectively an increase of PV-capacity by approximately 15% is required to achieve a "RER" of more than 100%.

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References

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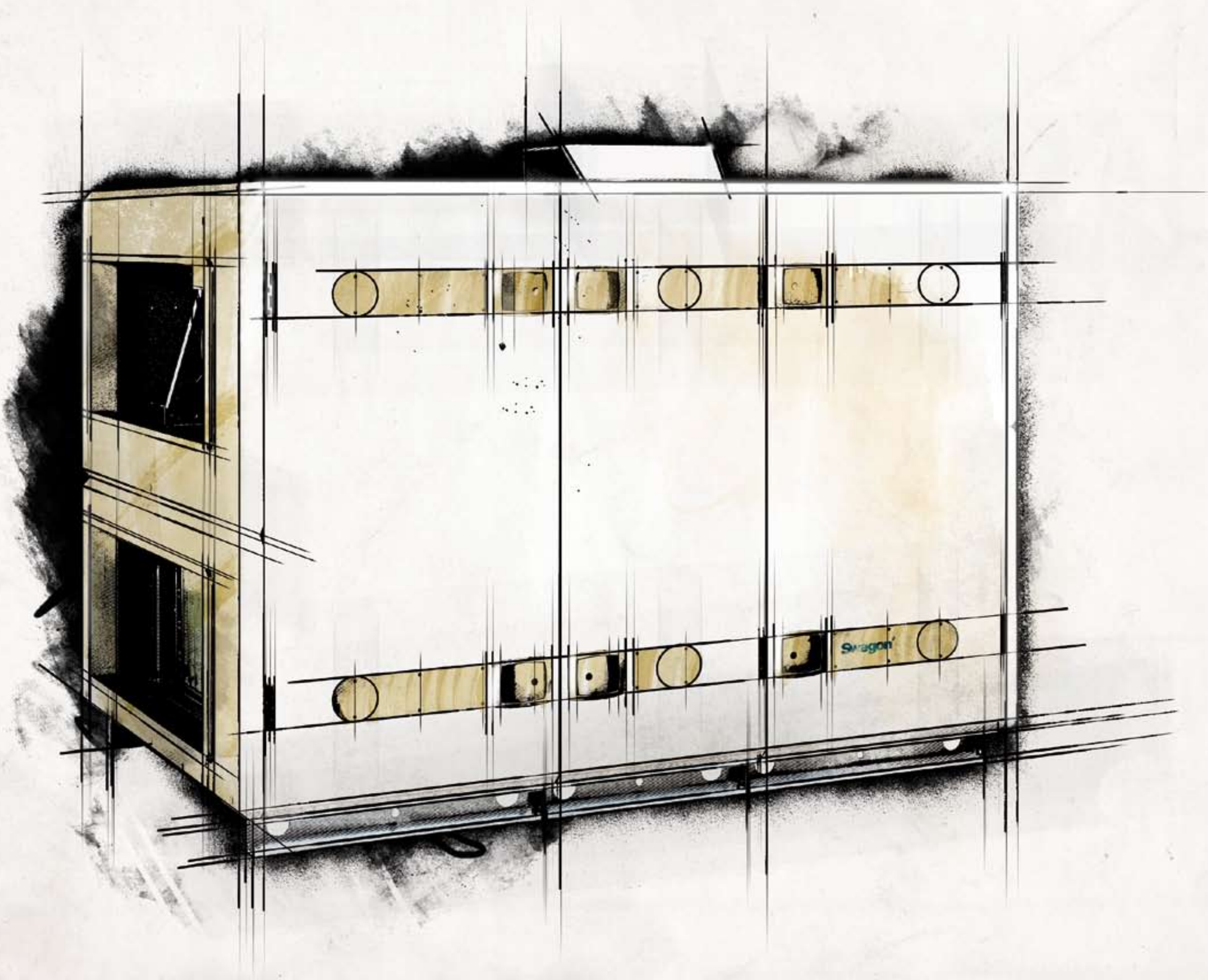

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Power demands of heating, ventilation and air conditioning components in EU Buildings

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Keywords: air conditioning, ventilation, heating, measured energy use, EU buildings. AHU, chiller, pump, hat pump.

The importance of understanding energy use at HVAC component level

A previous paper in the January 2104 REHVA Journal (Knight, 2014) proposed that detailed monitoring of energy use at HVAC component level was likely to be a key element in achieving sustained reductions in energy use in EU buildings. To use this detailed monitoring to its full potential it needs to have benchmarks against which it can be compared, and Power Demand benchmarks are a key component for identifying Energy Conservation Opportunities.

The iSERVcmb project (www.iservcmb.info) is producing what is believed to be the first public dataset of measured energy and power consumption of HVAC components operating in European Buildings. This paper presents a brief overview of a subset of this data, normalised Power Demands, to illustrate some of the forthcoming outputs from the project this summer.

The Power Demands presented here are from **measured** data obtained during the iSERVcmb project. It was taken from 1700+ HVAC systems and components drawn from across Europe, which are servicing a variety of activities and floor areas. This measured data is a key element in the HVAC system benchmarking process proposed and tested by iSERVcmb across 16 EU Member States.

With such a large dataset it is inevitable that the data covers a wide range of years, and as such will continue to be analysed at finer levels of detail before the end of iSERVcmb to explore different ways of examining the data. However, the full dataset present at the time of this paper is used to provide the largest data source possible for analysis here.

Due to the analysis work still to be completed, this paper therefore provides only an overview of the ranges of Power Demands being found in practice by HVAC Component Type normalised by Area serviced by that component. Note that this floor area is derived from the iSERV spreadsheet and is therefore much more accurate than simply relating power demand to total building floor area.

Measured Energy Use by HVAC components

The iSERVcmb process philosophy is based around physically quantifiable parameters i.e. energy, space, activity types, and HVAC system components. A HVAC component could be, for example, a fan, pump, air handling unit, cold generator, etc. There are subcomponents of these component types too e.g. different pump end uses such as primary or secondary circulation pumps.

This paper considers only the electrical energy use in the following component types, defined as:

AHU – Air Handling Unit fans and controls only, including supply, extract and combined units. No pumps, humidification, heating or cooling loads.

All-in-one unit – packaged air conditioning unit capable of heating and cooling. Includes fans, pumps, controls, compressors.

Cold Generator (Chiller) – compressors, integral heat rejection fans, integral pumps, integral controls

Heat Pump – Compressors, Outdoor unit fans, Controls, Circulation Pumps, Defrost section

Pumps – stand-alone circulation pumps including primary and secondary hot and cold pumps, condenser water pumps and Domestic Hot Water Pumps

Terminal Units – these are the fans, electrical reheat, pumps, etc that deliver the air, heating and cooling into the occupied spaces.

The benchmark ranges being proposed by iSERVcmb as the core of the iSERVcmb process, all have the measured energy or power demands as a key element. These are then normalised by the actual floor area and activity type serviced by each HVAC component. There are 7000+ combinations of HVAC sub-component and activity type benchmarks used in iSERVcmb.

This large number of potential combinations means that, despite obtaining data from over 1500 HVAC systems around the EU, the data obtained from iSERVcmb will only provide a first overview of the actual energy and power demands/m² occurring in operational HVAC components and sub-components when servicing these end use activities. It cannot be considered statistically robust yet at the level of individual activities or sub-components.

This paper presents the data from the larger sample sizes available for the electrical power demands of those HVAC component types for which we have data at the time of writing this paper. Power demands are an important indicator of component sizing and operation within buildings, and being separate from time issues allow comparison between components in buildings with very different occupancy periods.

The completion of the iSERVcmb project in May 2014 will produce additional data for HVAC components not yet published once there has been an opportunity to study it in more detail.

This short paper is only an overview of the type of data that will be produced from the iSERVcmb dataset at the end of the project. All data findings will be revisited before publication of the final project reports in July 2014, as data is still coming into the HERO database.

The data shown in the rest of this paper provides a unique insight into the range and level of normalised power demands occurring in European building services components when in operation. The data is obtained from individual meters covering periods from a few months to a few years. The majority of the data for each component covers both winter and summer periods and can therefore be considered representative of the range of demands likely for that component.

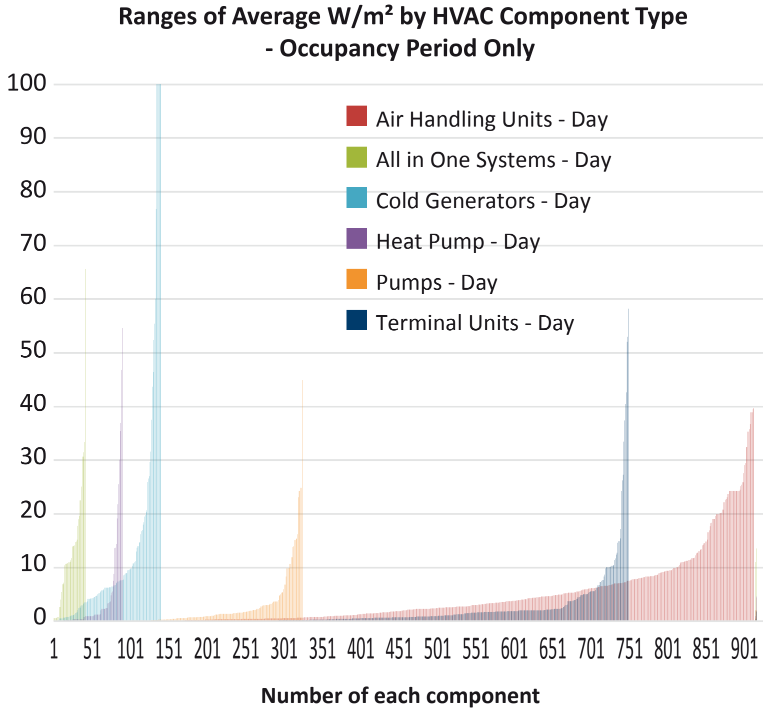

Figure 1. Ranges of Average Electrical Power Demands/m² by HVAC Component during Occupancy Period. The graphs are composed of individual component power demands but some of the individual bars are too small to be seen due to the scale of the vertical axis and the sample size.

Average Power Demands by HVAC Component Type

Figure 1 shows the range of normalised AVERAGE power demands being measured by HVAC component type in operational HVAC systems across the whole of Europe. The sample size for each component can be estimated from the X-axis, and the Y-axis is limited to 100 W/m² to enable the ranges to be seen more clearly. The largest average Cold Generator power demand recorded is 362 W/m² in a Server Room.

It is clear that there are, as might be expected, a significant range of AVERAGE power demands/m² serviced for each HVAC component type. The graph shows that Cold Generators incur the largest average power demand/m², followed by Air Handling Units, Pumps and then Terminal Units. The separate categories of All-in-One Units and Heat Pumps show similar average power demand ranges in use to Pumps and Terminal Units.

A closer examination of the data (not presented here) for the higher average consumptions shows that they tend to occur for specific activity types – underpinning the need to separate power demand ranges into activity types served, as used in the iSERVcmb process.

Maximum Power Demands by HVAC Component Type

Figure 2 shows the range of normalised MAXIMUM power demands being measured by HVAC component type. The general shape of the graph is very similar to the Average graph shown above, and the Y-axis is limited to 200 W/m² to enable the ranges to be seen more clearly.

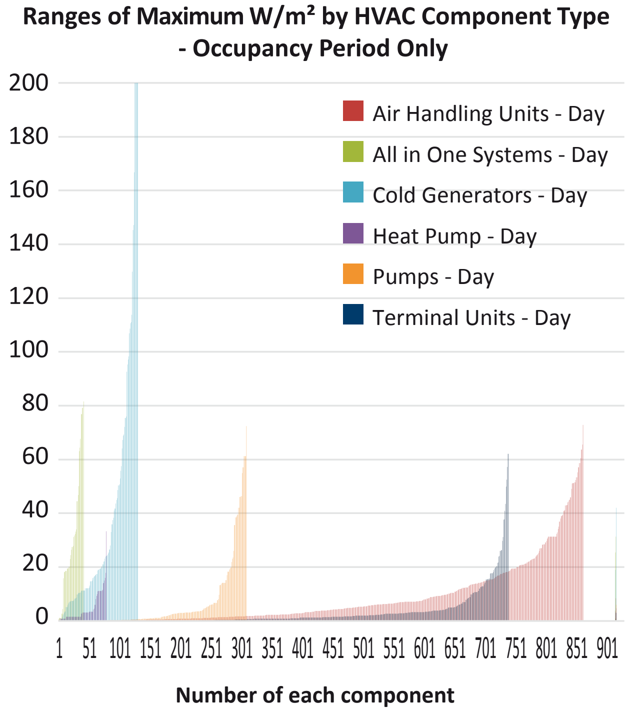

Figure 2. Ranges of Maximum Electrical Power Demands/m² by HVAC Component during Occupancy Period. The graphs are composed of individual component power demands but some of the individual bars are too small to be seen due to the scale of the vertical axis and the sample size.

What can be seen is that for all HVAC Component types other than Heat Pumps there are instances in Europe where the peak electrical demand is 50 W/m² or more at some point in the year. As with the average power demands, it appears that these peaks generally occur for significant loads such as IT server rooms.

All data will be rechecked before the project end as the detailed analysis of any large dataset obtained on real world conditions always raises questions which need to be answered to provide further confidence in the findings.

Table 1 and **Figure 3** present the **median** figures by HVAC component type for the average and maximum ranges shown in these two graphs. The median is taken, rather than the average, to reduce the influence of the extreme data values which are not considered to be typical of most HVAC component operation in buildings.

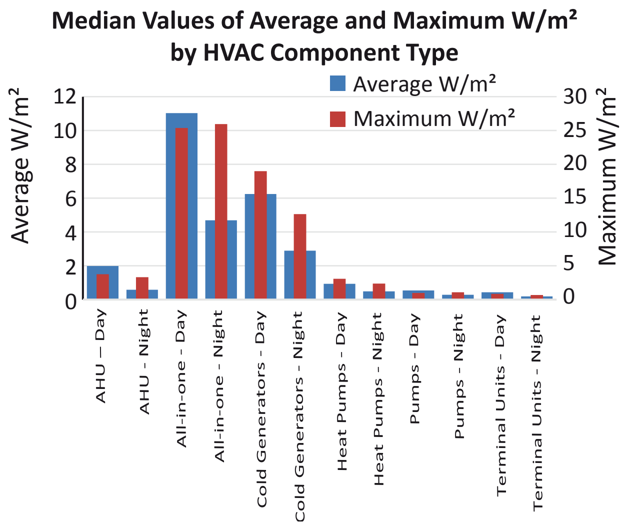

Figure 3. Median values for Day and Night Average (axis on left) and Maximum Power (axis on right) Demands/m² by HVAC Component.

Table 1. Median values for Day and Night Average and Maximum Power Demands/m² by HVAC Component.

Median values	AHU – Day	AHU – Night	All-in-one – Day	All-in-one – Night	Cold Generators – Day	Cold Generators – Night	Heat Pumps – Day	Heat Pumps – Night	Pumps – Day	Pumps – Night	Terminal Units – Day	Terminal Units – Night
Average W/m²	**1.99**	0.58	**11.03**	4.69	**6.24**	2.89	**0.94**	0.49	**0.55**	0.29	**0.43**	0.20
Maximum W/m²	**3.76**	3.33	**25.39**	25.95	**18.98**	12.63	**3.09**	2.36	**0.99**	1.09	**0.84**	0.70

Each component type is sub-divided into approximate Day (08:00 to 20:00) and Night (20:00 to 08:00) periods to examine the degree of variation between day and night, and to minimise the effect on the average figures of HVAC systems being turned off at night.

Examining the ratio of the maximum to average power demands for individual items of equipment in the HERO database shows that the median turndown ratio from peak to average power demands during the day varies from 50% for the Terminal Units, through 45% for Pumps, 44% for AHU's, 40% for All-in-one systems, down to 27% for Cold Generators and 24% for Heat Pumps.

The importance of good part-load efficiency for Cold Generators and Heat Pumps is reinforced by this data, as the Peak Demands measured do not represent the installed capacity. Previous research (Dunn, 2005) noted that installed capacity is frequently around twice the peak demand found from measurement.

Dunn also found that the systems studied operated at 8 – 44% of Installed Capacity on average, with 8 – 21% being the value for 3 of the 4 systems. Whilst we have yet to look at complete system capacities within the iSERV data, this does seem to agree with the data being obtained in iSERVcmb which, using Dunn's findings of component maximum demands generally being less than 50% of installed capacity, suggests the iSERVcmb HVAC components are operating at 14 – 25% of their installed capacity on average. This has implications for the in-use energy efficiency of such components, as efficiency has a tendency to drop off markedly below 30% of installed capacity for many HVAC components.

iSERVcmb will produce further data on the relationship between measured power demands and installed capacity for all the HVAC Component types as the data continues to be analysed.

The data also shows that, if the median figures are representative of the wider population as a whole, then the maximum normalised electrical demands occur from heating or cooling equipment (Cold Generators and All-in-one equipment) as might be expected – though the heat pumps in this sample (predominantly split systems) appear to be used in places with small loads. This is unexpected and will be checked further.

Over a full year, the median HVAC **system** in our sample (either an All-in-one system or an HVAC system composed of AHU, Pumps, Terminal Units and Cold Generators) ranges from an average electrical power demand during the day of between 9.2 to 11.0 W/m², and 4.0 to 4.7 W/m² at night, with the Cooling Demand being the major component of this average load. The median MAXIMUM demands range from 24.6 to 25.4 W/m² during the day and 17.8 to 26.0 W/m² at night.

Extrapolating this data up to a full year, implies an annual electrical energy consumption range of between 58 to 68 kWh/m² for an 'average' HVAC system in the iSERVcmb project, which compares with the 'Good Practice' 44 kWh/m² and 'Typical Practice' 91 kWh/m² measured for cooling only systems in UK Office Buildings from 2000 to 2002 (Knight,2005). As the iSERVcmb project covers all types of end use activities this figure seems to be in line with this previous study.

The iSERVcmb annual energy use figures will be further refined by the end of iSERVcmb through comparison with actual annual consumption figures for those HVAC components and systems where annual consumption data is available.

The figures presented have shown the range of measured power demands being found in practice for operational HVAC components. From a practical viewpoint these figures are too coarse for use in predicting the likely power demand ranges to be found in specific buildings, as the ranges are dependent on the end use activities being serviced in practice.

We will produce data on the ranges of power demands by component servicing given end use activities, where available, in the Final Reports from iSERVcmb.

Conclusions

This paper has shown the ranges of normalised electrical Power Demands being achieved by HVAC component type in Buildings throughout Europe. The data shows that current median **average** Power Demands figures being achieved by HVAC systems in non-residential Buildings in the EU are contributing up to about 11 W/m² of a building's total Power Demand during the average working day. The median electrical maximum Power Demands are up to 25.4 W/m². ■

References

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Energy retrofit of cultural heritage buildings

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Around a quarter of the existing building stock in Europe was built prior to the middle of the last century. Thus, historic buildings are of significant importance in reducing energy consumption and CO2 emissions. For better integrating historic buildings issues in European Union (EU) level legislation, CEN standards and voluntary retrofit certification schemes the experience and results of the FP 7 research project 3ENCULT [1] targeted the Energy Performance of Buildings Directive (EPBD) and the most important EPBD CEN standards, CEN TC 346 Conservation of Cultural Heritage and EnerPHit Certified Retrofit (PHI).

Keywords: EPBD, energy legislation, requirements, CEN TC 346, conservation, historic buildings, energy retrofit with Passive House components, EnerPHit.

Introduction

Historic buildings are the trademark of numerous European cities, town and villages and are a living symbol of Europe's rich cultural heritage and diversity. They reflect the society's identity and need to be protected. However, they show high level of energy inefficiency contribute substantially to CO_2 emissions and rising energy bills. Even more, these buildings do not offer appropriate indoor environment quality (IEQ) nor the conditions necessary for heritage collections preservation.

Within 3ENCULT a number of solutions have been developed and tested at case studies for improving the energy efficiency while conserving the heritage and guaranteeing long term structural health and preservation of historic buildings. This was possible by including all stakeholders in the design process of the energy retrofit. This base principal is reflected in the multidisciplinary consortium: it has gathered together scientists along with stakeholders from architecture, conservation, building physics and other specific technologies.

This article will present how the integration of historic buildings is assessed in relation to and recommended to be taken into consideration in: EPBD and EPBD CEN standards, then in CEN TC 346 and last but not least in the EnerPHit Certified Retrofit (PHI).

Historic buildings and EPBD

Legislation is a proven instrument to help reaching energy ambitions. The EPBD is such an instrument, put in place at a European level and influencing legislation in all Member States in respect of energy use in the build environment. Integration of historic buildings in the EPBD will be a driving force in striving towards the ambitious goals set. However, (listed) historic buildings were left out the EPBD in the first place. To realize an ambitious energy saving level in historic buildings and really have impact in Europe, integration of historic buildings in the EPBD might be a fruitful tool. This was investigated within 3ENCULT. The results of this investigation are described in the following chapters.

Some requirements in the EPBD do not exempt listed historic buildings. Large heating and air-conditioning systems need to be regularly inspected, which was judged by the multidisciplinary team of 3ENCULT as a reasonable requirement also for historic buildings. Also the EPBD requires national requirements for building systems that are replaced or upgraded. In principle this was agreed upon by the team, but with the warning that the choice, functionality and functioning of the systems should always be respectful of the building inner character and take into account the necessary thermal and hygrometric comfort that is necessary to protect the construction and present works of art (e.g. fresco's) and still be economically feasible under those conditions.

Member States may exempt listed historic buildings under certain conditions from national minimum energy performance requirements for the parts of the building envelope that are retrofitted or replaced. The team agrees that exemptions should indeed be possible. Although it seems reasonable to replace parts of the envelope by high efficiency products when they are being removed anyway, we should be aware that new elements in the façade may influence the indoor climate and that might risk the construction or possible present artefacts. On the other hand, where possible, high energy efficient products should be encouraged.

In general there was agreement among the multidisciplinary team that for transparency reasons making an energy certificate for (listed) historic buildings, as is done for all other buildings as well, is a good idea. Where the complex nature of historic buildings makes it preferable that the certificate is made by an expert who has experience with energy in historic buildings. Also it is suggested that in case of listed historic buildings a logo, including energy and (if available) heritage value figures on the certificate and an explanation warns the user that a skilled design team shall be consulted to judge the proposed measures.

Finally, it was suggested to add a requirement in the EPBD for an obligatory analysis of energy saving potentials & options in historic buildings. The idea behind such obligatory analysis is that in this way in an early phase of the renovation process of an historic building energy saving measures are at least considered. The analysis can show what measures might be fruitful from energy point of view and which don't need additional consideration.

Such an analysis assures that:

- In an early phase of the renovation process of an historic building energy saving measures are at least considered, and biases about impossibilities are taken away where possible;
- Awareness is raised about possible innovations, increasing the chance that these are considered seriously;
- A breeding ground for promotion of energy saving products for historic buildings is created.

How to achieve conservation compatible energy retrofit

The major development in the field of historic building renovation over the past few years is a new openness on the part of architects and conservators to include historic buildings in energy-efficient retrofitting.

When the first version of the EPBD came out in 2002, there was a general fear that historic buildings would be disfigured or ruined. This resulted in a quite defensive attitude and the endeavor to exclude historic buildings from any obligations. Nowadays, this has changed to a more constructive approach: they want to preserve the buildings; they want them to be used and to make them more energy efficient. Of course, this has to be done in a way that is compatible with the heritage value of a building.

Actually, a group of experts within CEN TC 346 pro-actively approaches the theme, having recognized that the initiative has to come from inside the "community". Being developed is a guidance on how to improve energy performance of historic buildings – not limited to officially protected ones, but covering a whole range of building types and ages, all buildings which are "worthy of preservation". The experts discuss, how the heritage value as well as the physical status of the building are assessed, which peculiarities historic buildings do have compared to new (or newer) ones, what this means for the determination of energy performance, how the potential of the building in all its dimension is understood and best used and finally which aspects from reversibility over cost to (life cycle) energy performance the assessment of possible interventions has to consider.

Definitely, a key factor for success identified within the group is the interdisciplinary team and the dialogue that has to shape the process from the diagnosis to the design and selection of best-suited intervention.

"EnerPHit": A voluntary standard for advanced energy retrofit

While the EPBD and its national adaptations set mandatory requirements for the energy demand of new buildings and renovations, there are also a number of additional voluntary energy standards. The Passive House standard was defined in the 1990s by the Passive House Institute in Germany. It is now widely applied to buildings all over the globe, from the mild climate of Portugal to hot and humid Shanghai or Minnesota's freezing cold winters. For all locations the Passive House standard combines very high energy efficiency with excellent user comfort at minimal life cycle costs.

In many European countries the building renovation market has gained the main market share in the recent past. However, when old buildings are renovated, it is often difficult to achieve Passive House standard. Typical reasons for this are unavoidable thermal bridges as well as a general building design, which was originally not optimized for energy efficiency. For such buildings, the Passive House Institute (PHI) introduced the EnerPHit standard in 2010. The basic principle is to modernize all relevant parts of the building with Passive House components. This way almost all advantages of the Passive House standard can be realized in retrofits, even if the heating demand is not reduced all the way down to the Passive House limit of 15 kWh/(m²a).

Figure 1. EnerPHit seal.

Typical Passive House components, which are required for EnerPHit (**Ener**gy Retro**fit** With **P**assive **H**ouse Components) retrofits in cool, temperate climates like Central Europe include an efficient heat recovery ventilation system, windows with triple glazing and insulated frames, more than 200 mm of thermal insulation and a very good air-tightness. Thermal bridge effects should be mitigated as best as possible within reason.

Further development of EnerPHit standard in the 3ENCULT project

Originally the EnerPHit standard could only be applied to retrofits of non-listed buildings in cool, temperate climates. In the 3ENCULT, the EnerPHit criteria have been developed further in order to also allow for certification of listed and historic buildings. This includes special provisions for buildings which can only be renovated with interior insulation, as is often the case in historic buildings with valuable façades. Additionally, exemptions for other parts of the building with restrictions by the cultural heritage authorities were introduced. The concept aims at improving the efficiency of each individual part of a historic building as long as this is compatible with the protection of the cultural heritage value.

Another recent development carried out within 3ENCULT is the adaptation for application in all European climates. The quality requirements for individual building components will continue to be the basis of the international EnerPHit criteria. The new component requirements for different climates were derived by means of an economic optimization process. The process was carried out for each location in a grid of climatic data sets covering all of Europe, with the aim of finding the set of component qualities with the lowest life cycle costs for an example building. 200 combinations of different ventilation, window and shading qualities were combined with different insulation levels of the opaque building envelope. The combination of components leading to the lowest sum of investment and energy costs could thus be determined using the net present value method.

The cost-optimal component set for the end-of-terrace example house (new build) used at first in the studies, resulted in a functional Passive House[1] in almost all locations. At the same time minimum requirements for thermal comfort and prevention of moisture accumulation were met. In order to test the suitability of these component qualities for refurbishments the method was also applied to several variations of another example building, a typical 3-storey Wilhelmenian-style residential building in a historic city quarter. For this building a full refurbishment with Passive House components (with remaining thermal bridges) as well as refurbishment with interior insulation was analyzed. In additional studies only one component was refurbished as could be the case in step-by-step renovations or if selected measures are not possible because of cultural heritage restrictions. The resulting cost-optimal component qualities were often even better than for the example newbuild (see **Figure 2**). This can be explained by the longer heating period in less efficient buildings. Thus an individual improved building component can save more energy over the course of a year than in a Passive House, making it even more economic to invest in better quality. However, as the effect was found not to be highly significant and depends on individual building surroundings, it is not taken into account for the general international EnerPHit component requirements, as not to overcomplicate the matter.

As different component requirements for each location in Europe would not be practical for use in general certification requirements a further step of simplification was required. Locations with similar sets of optimal component qualities were grouped into climate zones with one set of component requirements each (see **Figure 3**). A building in Oslo would for example fall into the "cold"

[1] A functional Passive House can be conditioned by solely heating or cooling the amount of fresh air, which is necessary for hygienic reasons.

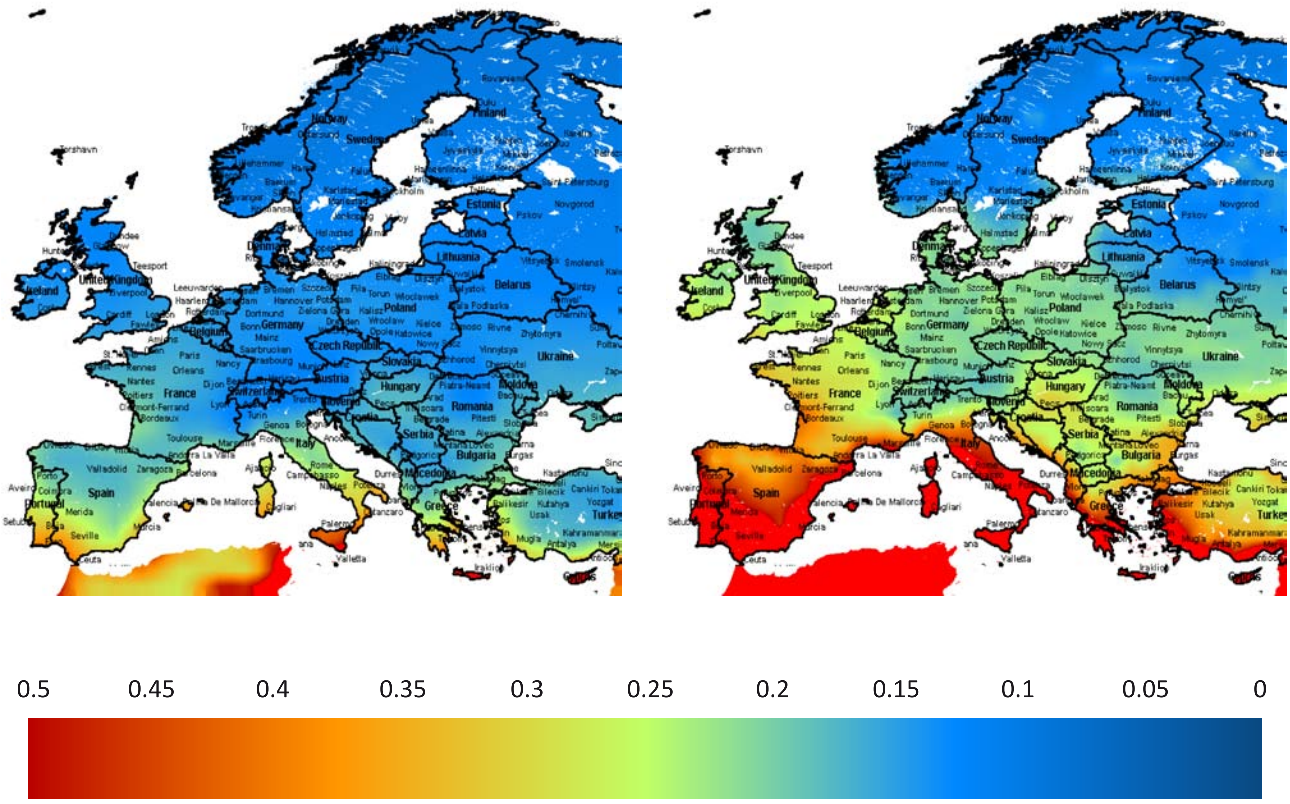

Figure 2. Cost optimal component quality (U-value) for basement ceiling insulation for a new building (left) and a historic building in which only the basement ceiling can insulated (right). In the historic building with only partial refurbishment the economic optimum is at a higher insulation thickness than for the new building.

climate zone requiring relatively ambitious measures such as quadruple-glazed windows with a well insulated frame, more than 25 cm of thermal insulation and heat recovery ventilation with a minimum efficiency of 80 %. The same building located in Lisbon ("warm" climate zone) would only need double-glazing, 6 cm of insulation and a simple extract air ventilation system without heat recovery.

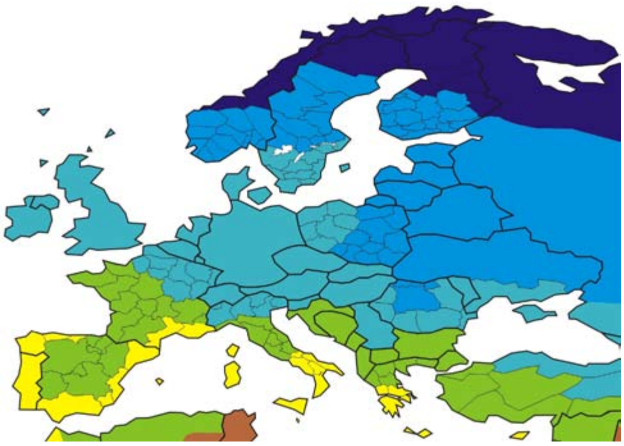

Figure 3. European climate zones map for EnerPHit requirements.

PHI plans to put the international EnerPHit criteria into effect in the second half of 2014. A draft version is planned to be published on the PHI website www.passivehouse.com in April. Certification of some pilot projects by PHI will already be possible based on this draft version.

Conclusion

3ENCULT proposes to the targeted before mentioned entities to use the experience and results of the project not as a "standard solution", but rather as a pool of possible measures and tools, along with guidelines on how to incorporate those into a historic building. ■

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[1] Efficient Energy for EU Cultural Heritage, funded within FP7, GA No. 260162, www.3encult.eu

A ZigBee based building management system for heritage

Historic buildings are a challenge in the energy refurbishment because the special character of such buildings. Thus, 3ENCULT has developed a Building Management System compliant with heritage where the restrictions of heritage have been faced. Thus, wireless monitoring and control is used in combination with passive solutions to improve energy efficiency.

Keywords: 3ENCULT, wireless sensor network, building management system, BMS, monitoring.

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The research European Project 3ENCULT [1], which is funded by the 7th Framework Programme from the European Commission, aims to establish a methodology for improving the energy efficiency and comfort conditions in European historical buildings.

In the EU-27 context, about 40% of the housing stock was built before the 60s and the other 40% between 1961 and 1990 (Buildings Performance Institute Europe 2011). Therefore, a large proportion of the building stocks are old constructions belonging to the historic heritage which presents a high level of energy consumption and low comfort conditions. Apart from the aesthetics, the heritage and other conservation issues must be borne in mind.

For those heritage values, the full range of solutions is not applicable in a historic building; therefore, the role of the ICT (Information and Communications Technologies) becomes more important. Sometimes, passive solutions such as internal insulation or a wired monitoring system do not comply with conservation concerns. Thus, in order to bridge this existing gap, the development of wireless technologies and the combination of Building Management Systems (BMS) ease the integration of energy efficiency solutions in historic buildings.

In this way, this paper presents an innovative solution utilising a wireless monitoring and control platform. Firstly, a brief state of the art is covered followed by the monitoring concepts tackling the constraints in these buildings and the wireless solutions. Secondly, the description of the Building Management System and its benefits are detailed. Finally, an example with the results achieved is described.

State of the art

Currently, there has been considerable research in heritage for both monitoring and control. An example is shown in [2] where a BMS has been developed for the improvement of the performance in the Archaeological Museum of Thessaloniki integrating multiple communication protocols for a complete management of the electric power, heating, ventilation and microclimate systems. Moreover, in the Firesense project [3] a multi-sensor network is deployed for the protection of cultural heritage areas, including wireless sensor networks.

However, these solutions are not fully compliant with the objectives of 3ENCULT because, in the first case, no wireless systems are integrated and, the second one, it is centred in fire security. Therefore, in the 3ENCULT [1] scope, a solution for the specific building requirements is needed.

Monitoring systems

In order to assess the energy behaviour of a historical building, a monitoring phase is required. This also allows an observation of the valuable basic materials and structure of buildings, so that, depending on the type and intensity of building use, an immediate threat to the valuable buildings and equipment can be detected. The monitoring can also give important information on the thermal comfort of a historical chamber [4].

The aim is therefore, by means of a suitable sensor network, to collect data of all the relevant parameters and metrics in order to characterize the energy behaviour of the building, the climate situation and comfort in the rooms, the climate-related stress on valuable surfaces, moisture and heat situation in the energy upgraded building construction and energy consumption, such as it is shown in the **Figure 1** [5]. With the evaluation of all these state variables, an evaluation of the energetic and physical behaviour of a building can be reliably evaluated. There are several reasons for implementing building monitoring. The essential task is to understand the actual condition of the building.

Heritage constraints

The possible interactions between external and indoor climate and the historical surfaces are often ignored. **Figure 2** [4][5] shows the required framework of the investigations. It is the result of an energy redevelopment whose risks appear in the near field area of valuable historical surfaces, because they are exposed to critical climate fluctuations.

A first assessment of the risk of historically significant surfaces is needed to collect data on the climatic near field conditions, e.g. by surface temperature sensors and temperature and humidity sensors in the near field of historical surfaces in sufficient numbers and distributed in the room.

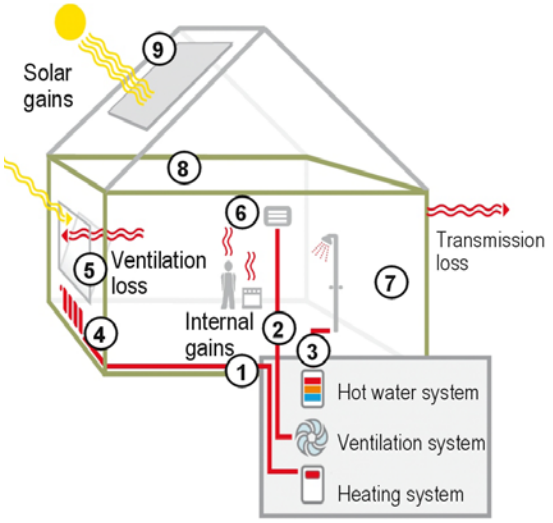
Other concerns to take into account are related to conservation issues of historical buildings such as aesthetic or conservation aspects. With regard to the aesthetics, wired sensors are forbidden in several cases because it is not possible to modify the visual aspect by making use of cables, therefore the wireless sensor network is used for solving this issue. On the other hand, conservation aspects mean it is necessary to avoid the modification of anything in, the building structure and this is sometimes a problem for the power supply of the sensors. Both concerns define a challenge which has to be faced before implementing the sensor network.

ZigBee based wireless sensor network

For bridging the aforementioned gap, agile, low-cost, ultra-low power wireless networks of sensors, which collect a huge amount of critical information from the environment, become essential tools for building automation. Such wirelessly connected microsystems are defined as Wireless Sensor Networks (WSN) and typically incorporate both sensors and communication functions.

However, the current wireless commercial systems do not provide any ability to create interoperability between new applications and pre-existing subsystems. Thus, a new flexible WSN for the real-time monitoring targeted for historical buildings needs to be designed and its performance optimized, with particular attention to the autonomy and reliability of the whole network [6]. Specific objectives can be formulated as follows:

- Physical node size of the WSN not exceeding a few cubic centimetres.
- Sensors lifetime from several years to tens of years.
- The node should be field-configurable and the WSN be modular, have dynamic deployable capabilities, and be easy extensible.
- Wireless actuators will also be considered which can reduce installation effort considerably in historical building, where existing distributed autonomous components have to work together.



1 Thermal demand general – heating system (kWh); Alternatively: temperature flow and return line
2 Power demand ventilation system – ventilation system (kWh); Flow rate – ventilation system (m³/h)
3 Flow rate – hot water system (m³/h); Temperature – hot water system (°C)
4 Thermal demand each radiator – heating system (kWh); Alternatively: temperature flow and return line
5 Contact – window open/close/tiled
6 Room clima – temperature and relative humidity (°C/%)
7 Surface temperature (°C)
8 Lighting (lux)
9 Weatherstation (Temperature, relative humidity, rain, wind, radiation)

Figure 1. Energy and comfort monitoring.

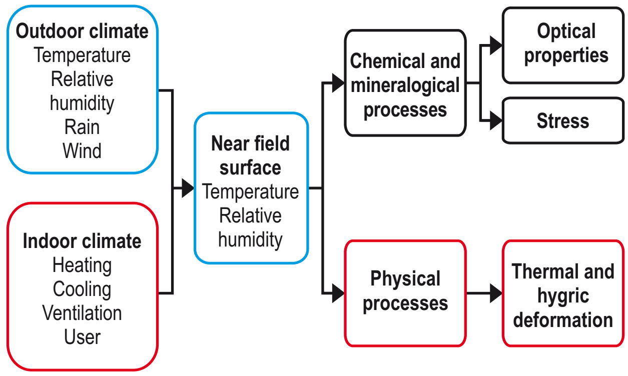


Figure 2. Framework of the monitoring concept.

Complying with these requirements, the Wispes W24TH nodes (**Figure 3**) were selected as basis of the adaptation for the sensor network. All these motes are compliant with ZigBee Pro protocol where there are three types of sensors: coordinator, router or end-device.

The core of the system is a 32bit microcontroller with a 2.4 GHz radio transceiver and 32 MHz CPU clock that permits the development of complex applications and distributed data processing [6]. The system is provided with a series of on-board sensors:

- Temperature sensor;
- Humidity sensor;
- 3-axis Accelerometer sensor;
- Ambient light sensor;
- Mox gas sensor (VOC, CO_2...).

Command-driven driver

For the communication and collection of sensed data from the sensors, a command-driven driver has been designed [6][7]. Thus, based on commands through the USB (Universal Serial Bus) interface, available on any computer, the information is compiled and stored in a persistent database. Several commands are currently implemented in the latest version of the nodes which allow the application layer to interact with the sensors in order to retrieve the information and/or configure the network. In summary, the most important commands are:

- s – Enable/disable sensor samples
- p – Change the on board sensors on/off. It means enable or disable sensor measurements in a concrete device by sending, for instance, p001100. The example deactivates the two first sensors and the last two sensors, meanwhile the two intermediate sensors are enabled.
- r – Reset the network.
- w – Set up the sleep time in the nodes. For example, sending w=600 means the sleep time in the nodes is established to 10 minutes.

Building Management System

A Building Management System (BMS) is a software high-technology computer-based system which is installed on buildings for monitoring and controlling the equipment and facilities [7][8]. Some examples for the equipment to be added in the BMS are the following:

- air handling and cooling plant systems,
- lighting,
- power systems,
- fire systems, and
- security systems.

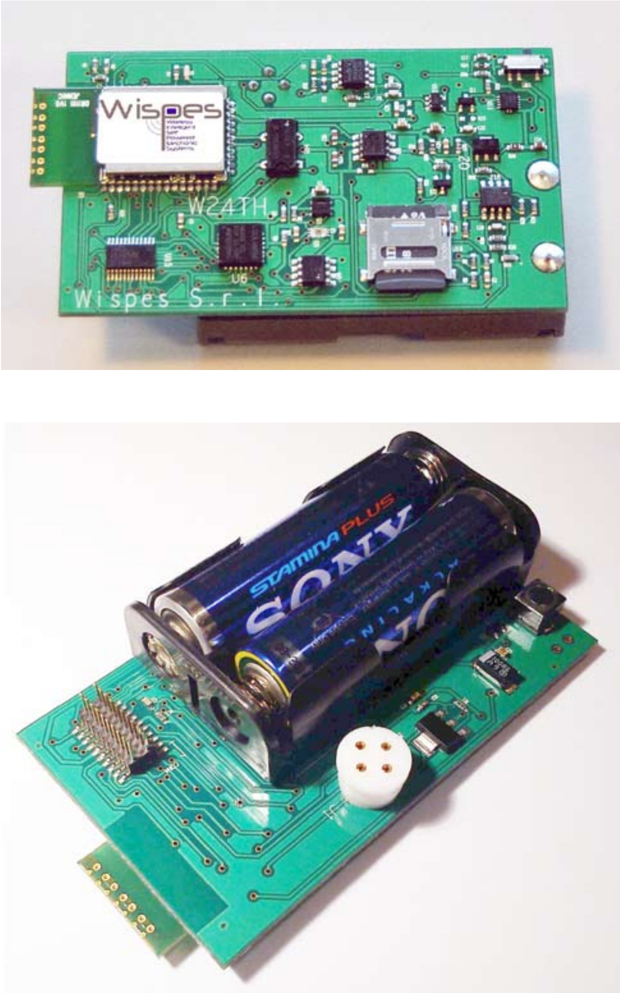


Figure 3. Wireless sensor nodes.

A BMS is a complex, multi-level, multi-objective, integrated, interrelated and complete intelligent design management information system [7][9] which mixes software and hardware.

The purpose of a Building Management System (BMS) is to automate and take control of the operations of the facilities and actuators in the most efficient way possible for the occupiers/business, within the constraints of the installed plant [8].

Architecture

The design of the BMS in the 3ENCULT context is a multi-layer Service Oriented Architecture (see **Figure 4**) based on OSGi (Open Services Gateway initiative) specification.

Thus, the architecture is set up by multiple layers so as to develop a more modular, scalable and replicable system. Lower layers represent the OSGi framework

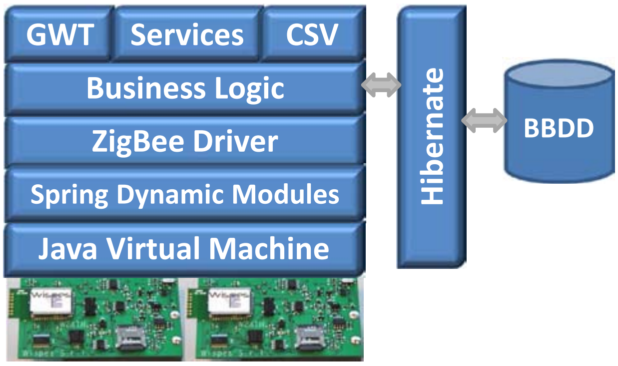


Figure 4. BMS architecture.

(Java Virtual Machine and Spring Dynamic Modules), whereas the ZigBee driver is the implementation of the communication driver described before. Finally, the Business Logic establishes the algorithms and functions for collecting data, performing internal management and rendering control algorithms, and the upper layer is related to the user services and applications.

Technologies

Within the greater novelties, the integration of new technologies is one of the most important. Thus, the main technologies are Spring Dynamic Modules, Google Web Toolkit and Hibernate. The integration of all these technologies has not been realised in the current status of BMSs. First of all, Spring Dynamic Modules provides an OSGi release 4 framework which eases the development of services by means of dependency injection property. This feature mainly manages by itself the services dependencies among services avoiding the need for taking care of these dependencies by Java code. Furthermore, Google Web Toolkit offers a framework for the implementation of Graphical User Interfaces in building and optimizing complex browser-based applications, with wide documentation. Last but not least, Hibernate brings the mapping among object-oriented programming languages and relational databases, so that the developer could manage objects in a natural way without caring the database manufacturer.

BMS Services

The upper level of the system architecture represents the user applications, which includes a set of services for the performance of the platform. These have been defined for the ZigBee sensors developed in the project, but they could be extended, if required, because of the advantages of the service-oriented design. The list of services deployed is the following [7]:

- Monitoring service: This is the fundamental service that contains the list of sensors and their measurements classified by sensor and application field.
- Lighting service: It displays the latest value related to the lighting system for each device in the network, as well as, the trend during the time slot defined by the user.
- HVAC service: Similar to lighting, it is able to show the latest values and trend for variables associated to HVAC (Temperature, relative humidity and air quality).
- Energy service: This service calculates the costs of the energy consumption, when a probe is available onto the sensors. Also, it prints the energy in order to compare consumption and costs.
- Alarms service: The alarm service allows the configuration of the set-point for raising alarms and it sends a mail to the administrator when any set-point is reneged on.
- Download data: The latest service permits the downloading of historical records of data based on user filters, in "csv" format.

Viability in historic buildings

The Building Management System and the complementary Wireless sensor network are compliant with heritage as far as they obey to the constraints and restrictions. With regard to the wireless sensor, it avoids the use of cables applying with aesthetic premises and possible structural damages in the installation. About the BMS itself, it is able to define set-points and actuate according these values so as to keep the conditions needed in the historical buildings regarding both indoor comfort conditions and energy performance. Moreover, it does not require any additional installation that could damage the building.

Performance parameters

For the evaluation of the platform, some performance parameters have been evaluated which define the capabilities of the software. Thus, the following features [7] are applicable in this case:

- Reliability: The Equinox server provides almost 100% of service working availability.
- Interoperability: Owing to the SOA, the capability of communicating services is transparent thank to the well-established interfaces.
- Scalability: SOA provides loosely-coupled services, which allows the integration of new services in the platform, increasing the number of them. About the scalability of the sensor network, the number is limited by the ZigBee sensors, as far as the BMS is able to manage large data streams.
- Replicability: The development of the BMS has been done through open software and standards, therefore, the BMS could be replicated in any other building.

Deployment in the Industrial Engineering School of Béjar, Salamanca (Spain)

During the test phase, the Industrial Engineering School of Bejar has been used, which is a case study within the project. There, a small ZigBee sensor network has been deployed (see **Figure 5**) in order to measure information in a test room in combination to the current LonWorks network so that the control algorithm could actuate directly in the system because the wireless nodes do not offer control commands until now.

The platform has been working since 28th of October 2013, when the ZigBee based network was deployed and the measurements are feeding the control algorithm in order to control the facilities of the building, improving the comfort levels in this test room, meanwhile the energy consumption has been conserved.

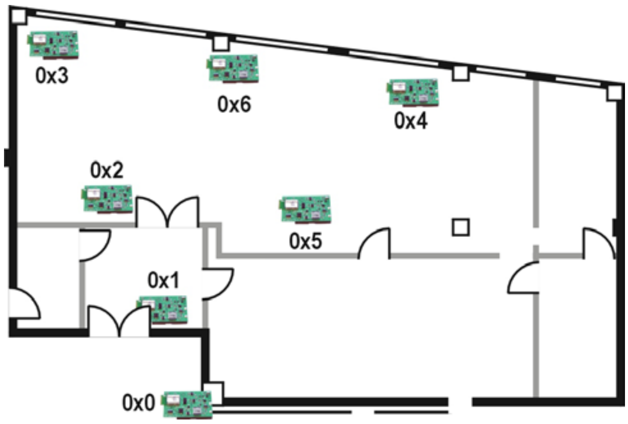


Figure 5. Sensor network in the test room.

Conclusions and future lines

The present article describes the development of a novel Building Management System compliant with historical buildings. As yet, the study of heritage is an open issue with some restrictions and constraints which are not fully covered by the current developments. Thus, the gap between the passive solutions and ICT systems can be fulfilled by integrating the presented technologies.

As open points for future development, the implementation of control commands in the sensor nodes is a key factor instead of using several systems. Last but not least, the BMS is compliant with the ZigBee based network and it is able the integration of other communication protocols, such as LonWorks, BACnet and so on. ■

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IEA Technology Roadmap for energy efficient building envelopes

The latest International Energy Agency (IEA) Technology Roadmap concerning energy efficiency in buildings was released on 18 December 2013 and focuses on Energy Efficient Building Envelopes[1][1]. The publication consists of definition and analysis of available technology, development vision for R&D and technology deployment and assessments of policy, financial and related needs.[2]

Keywords: building envelope, thermal insulation, energy efficient building, IEA.

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The IEA is an autonomous organisation which works to ensure reliable, affordable and clean energy for its 28 member countries and beyond. The IEA's four main areas of focus are: energy security, economic development, environmental awareness, and engagement worldwide.

In most of the world, the energy performance of building envelopes has been significantly neglected. While there has been substantial success in improving the energy efficiency of new appliances, lighting and heating and cooling equipment, many buildings are still being constructed that are leaky, have no insulation or exterior shade control, and have single-glazed clear glass windows and solarabsorbing roofs in hot climates. Given that heating and cooling account for over a third of global energy consumption in the buildings sector, optimising building envelope design should be a key part of any long-term energy reduction strategy.

Key findings and actions

Reproduced from Technology Roadmap: Energy efficient building envelopes © OECD/IEA 2013, p. 5:

- The building envelope – the parts of a building that form the primary thermal barrier between interior and exterior – plays a key role in determining levels of comfort, natural lighting and ventilations, and how much energy is required to heat and cool a building.
- The construction of new buildings offers the best opportunity to deploy passive heating and cooling designs, which make use of energy efficient building materials to minimise energy required for heating and cooling.
- Transforming typical building renovation to make way for deep reductions in energy consumption – known as deep renovation – should be a high priority.[3]

[1] This publication was prepared by the Energy Technology Policy Division of the International Energy Agency (IEA). Marc LaFrance was the lead author and coordinator for this roadmap. The IEA worked with several key organisations to host workshops including the Russian Energy Agency, Tsinghua University and the United States Department of Energy.

[2] In addition the roadmap also includes 2 annexes [2] which go into more depth on building envelope technologies and life-cycle cost analysis for energy efficient envelopes and integrated systems.

[3] Deep renovation is considered here to mean refurbishment that reduces energy consumption by 75% and limits energy consumption for heating, cooling, ventilation, hot water and lighting to 60 kWh/m/yr (GBPN, 2013). Several organisations, including EuroAce, are calling for a tripling of the current rate of renovation.

- Building envelope improvements can improve occupant comfort and the quality of life to millions of citizens, while offering significant non energy benefits such as reduced health care costs and reduced mortality of "at risk" populations.
- Air sealing – restricting the passage of air through the building envelope – is a key way of increasing energy efficiency during new construction and deep renovation.
- New office buildings should be fitted with integrated facade systems that optimise daylight while minimising energy requirements for heating, cooling, artificial lighting and peak electricity use.
- It is vital to increase global collaboration on developing more affordable zero-energy buildings, especially in cold climates.
- R&D on the following technologies will lead to greater returns on investment:
  - ➔ Highly insulated windows;
  - ➔ Advanced, high-performance, "thin" insulation;
  - ➔ Less labour-intensive air sealing, and lower-cost;
  - ➔ Validation testing;
  - ➔ Lower-cost automated dynamic shading and;
  - ➔ Glazing;

Table 1. An assessment of market saturation for high-priority building envelope components (reproduced from Technology Roadmap: Energy efficient building envelopes © OECD/IEA 2013, Table 4, p. 18, modified by author).

Market maturity/ saturation	ASEAN*	Brazil	China	European Union	India	Japa/ Korea	Mexico	Middle East	Australian / New	Russia	South Africa	United States/
Double-glazed low-e glass	O	⅄	⅄	■	⅄	O	O	⅄	O	O	O	■
Windows films	⅄	⅄	⅄	O	⅄	O	⅄	⅄	O	⅄	⅄	O
Window attachments (e.g. shutters, shades, storm panel)	O	⅄	O	■	⅄	O	⅄	O	O	⅄	O	O
Highly insulating windows (e.g. triple-glazed)		⅄	⅄	O		⅄		⅄	⅄	⅄	⅄	⅄
Typical insulation	■	O	■	■	O	■	O	■	■	■	O	■
Exterior insulation	O	⅄	O	■	O	O	⅄	O		⅄	⅄	■
Advanced insulation (e.g. aerogel, VIPs)				⅄		⅄				⅄	⅄	⅄
Air sealing	O	⅄	⅄	■	⅄	O		⅄	⅄	⅄		O
Cool roofs	⅄	⅄	⅄	O	⅄	⅄	⅄	⅄	⅄			■
BIPV/ advanced roofs	⅄	⅄		⅄	⅄	⅄			⅄	⅄	⅄	⅄

■ **Mature market** O **Established market** ⅄ **Initial market**

* ASEAN = Association of Southeast Asian Nations. Blank cells indicate that there is currently not any market presence or it is so low that it is not known to domestic experts. Some technologies may not be recommended for all climates, such as cool roofs in Russia or highly insulated windows in hot climates. Typical insulation refers to widely available products such as fibreglass and various foams with thermal conductivities higher than 0.02 watts per meter Kelvin (W/mK). VIP = vacuum-insulated panel.

- ➔ More durable and lower-cost reflective roof ;
- ➔ Materials and reflective coatings.

- To provide policy makers with the information they need, key energy efficiency indicators and benchmarks should be established for the energy consumption of multiple building types, and the market share of advanced building envelope technologies and products should be tracked.

Table 2. Cost and performance goals for building envelope technologies, 2020-30* (reproduced from Technology Roadmap: Energy efficient building envelopes © OECD/IEA 2013, Table 6, p. 25, modified by author).

Technology	Market perspectives	Performance goals	Cost targets
Typical insulation (widely available, thermal conductivity of > 0.02 W/mK)	Highly competitive market with uniform performance metrics in all regions for existing stock and new construction.	Average U-value walls and roof, cold climate ≤ 0.15 W/m²K; hot climate ≤ 0.35 W/m²K.	LCC neutral or lower at moderate energy prices.
Advanced insulation (e.g. aerogel, VIPs)	Used for very high-performance buildings in cold climates and space-constrained applications.	Thermal conductivity of ≤ 0.015 W/mk.	Material cost less 50%, installed cost competitive with typical insulation.
Air sealing	Widely applied to over 95% of world structures with heating and cooling loads.	Retrofit ≤ 3.0 ACH or 50% reduction; New ≤ 0.5 ACH with mechanical ventilation.	Validation testing reduced by 30% to 60%; 50% lower ACH in existing buildings reduced from USD 24/m² to ≤ USD 10/m².
Reflective surfaces	Applied to new roofing materials and after-market coatings for hot climates and dense urban areas.	Long-lasting SR of ≥ 0.75 for white surfaces, and SR ≥ 0.40 for coloured surfaces.	Additional installed price premiums ≤ USD 10/m².
Windows (double low-e galzing, low-conductive frames)	Minimum for global market.	Whole-window performance, U-value ≤ 1.8 W/m²K.	Price premiums from single-glazed (≤ USD 40/m²), from double clear (≤ USD 5/m²).
Highly insulating windows (e.g. tripleglazed, low-e, and lowconductive frames)	Needed for cold climates for all buildings, and mixed climates for residential.	U-value ≤ 1.1 W/m²K.	Price premiums from double low-e (≤ USD 40/m²)
Energy-plus windows in cold climates (highly insulating and dynamic solar)	Dynamic solar control for most service buildings that have glass to optimise daylight; and highly insulating and dynamic solar control for mixed and cold climates residential.	Whole-window performance, highly insulating U-value ≤ 0.6 W/mK and variable SHGC 0.08 – 0.65.	Highly insulating dynamic SHGC price premium from double low-e (≤ USD 120/m²).
Window attachments* (automatic solar control, e.g. exterior solar shades and blinds)	Priority for existing windows but also for alternative option to dynamic glass.	Ability to reduce solar heat gain almost to zero, but preferred options would have daylight features (e.g. SHGC 0.05 to 0.5) to prevent increased lighting energy.	USD 70/m²(not including control systems that can be expensive if not used for other building systems)
Window attachments (highly insulating, e.g. cellular shades, low-e films)	Predominately retrofit market but also applicable to new zeroenergy buildings.	Installed with existing windows, total performance, U-values ≤ 1.1 W/m²K.	USD 40/m².

* VIP = vacuum-insulated panel. This table is based on IEA analysis, with data taken predominantly from envelope roadmap workshop presentations. Targets have not been vetted by all regions and will vary considerably. These targets are provided as a reference or starting points so regions and countries can develop implementation plans tailored to local markets, climates and conditions. The U-values are calculated according to ISO standard. (decrease with 10% for calculating the EN standard value).

Key actions in the next ten years

To enable advanced building envelopes to be used in a wider range of climates and regions, all interested parties must make greater effort to support mechanisms that favour R&D and deployment of energy-efficient building materials.

Reproduced from Technology Roadmap: Energy efficient building envelopes © OECD/IEA 2013, p. 6:

- Policy makers must take responsibility for establishing goals for the energy efficiency of building envelopes, when new buildings are constructed and during deep renovation.
- National and local government authorities should urgently establish and enforce stringent energy codes for new buildings that identify affordable technological solutions, particularly in urban areas of developing countries with tropical or arid climates.
- It is vital to accelerate deployment of proven technologies such as insulation, air sealing, low-emissivity (low-e) windows, exterior shading or other attachments, through innovative financing mechanisms such as utility programmes, revolving funds and energy-performance contracts.
- Building energy codes should require that roof/attic insulation that meets the latest standards – including proper air and duct sealing if applicable – is installed when roofs are replaced.
- The economic, comfort and health benefits of low energy buildings need to be better communicated to the public and financial communities.

Market assessment of energy efficient building materials

Data on current market share are difficult or expensive to obtain in developed countries and are often not available in emerging markets, so the IEA has used assessment and inputs from experts worldwide to estimate three levels of market saturation: mature market (greater than 50%), established market (approximately 5% to 50%), and initial market presence (available but less than 5%) (see **Table 1**).

Cost reduction and performance goals

Establishing specific cost and performance criteria for the entire world is almost impossible because factors such as climate, occupant behaviour, construction practice and availability of resources vary widely. Key improvement metrics and goals can be established, however, that provide benchmarks for policy makers (see **Table 2**). For most regions, these criteria will be seen as aggressive, but for several advanced programmes in cold climates where energy prices are high, they may be seen as not stringent enough. Based on local conditions, more stringent criteria can easily be pursued.

Conclusions

The nature of the building envelope determines the amount of energy needed to heat and cool a building and hence needs to be optimised to keep heating and cooling loads to a minimum in accordance with LCC analysis. Lower heating and cooling requirements will also help offset envelope investments since avoided capital cost for equipment can be used to fund envelope efficiency measures. ■

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This article is based on the paper of the winner of the student competition
organised during the World Sustainable Energy Days in Wels, Austria in February 2014

Optimizing self-consumption of grid-connected PV/storage systems

An electrical storage system is mainly used to increase self-consumption of the produced photovoltaic energy, relieve the public power grid and to reduce the dependency on the grid. This article focuses on a technical simulation of a photovoltaic (PV) system linked to a storage unit and analyses its economic efficiency.

Keywords: self-consumption, photovoltaic system, electrical storage system, battery, amortisation, energy efficiency.

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Electricity is accepted as one of the driving forces for economic development around the whole world. Nowadays the human population depends on fossil fuels like oil, gas and coal for electricity production. Two major disadvantages are the depletability of these fossil resources and the resulting carbon dioxide emissions when burning them.

To reduce the energy demand and fossil fuels the following core actions need to take place in the order shown below:

- Energy savings
- Energy efficiency
- Supply of renewable energy sources

In the course of time the subsidies for private customers have been decreasing and the costs for electricity per kWh have been continuously rising. As a consequence, especially grid connected photovoltaic systems increased substantially over the past few years [1] resulting in commercial sales of energy to the distribution network if there is any surplus of PV energy. To make these systems economically viable without funding, it is necessary to use as much self-generated PV electricity [2] as possible by the directly connected consumers themselves – this factor is described by the self-consumption (SC) rate [3].

The integration of a storage system

The proper sizing and the correct configuration of the individual parts of the home power plant (load, solar yield and storage) are crucial for the cost-efficient operation [4]. In this context it is important not to oversize the storage system, because the investment costs would be enormous and subsequently the system would not be profitable.

The lifetime can be maximized by the correct operational management of the system. One important point of this consideration is the storage strategy. For the simulation a simple model has been designed:

- Energy is supplied by the PV system and there is an energy demand in the household, the energy is used by the household itself.
- If the energy produced by the PV system is higher than the currently required demand of the household, the surplus is stored.
- If more power is required than provided by the PV system at the moment, energy is taken from the battery.
- Energy is only taken from the public power grid if the demand of the household cannot be met by the storage system.
- If there is neither a demand nor a free storage capacity, the surplus is fed into the public power grid.

This model for charging and discharging the battery is not a strategy in the proper sense. Storage strategies for example take into account weather forecasts and foreseeable loads to properly manage available capacity in the storage. Furthermore the addition of a charge control, an overcharge protection and a deep discharge protection is important to increase the lifetime of the electrical storage system [5].

One of the reasons why it will be necessary to implement a storage strategy is shown in **Figure 1**. The frequency distribution of the storage state (empty of full) is recorded for each month with the associated percentage of the average state of charge. According to the simulation in January the battery is empty 81% of the time.

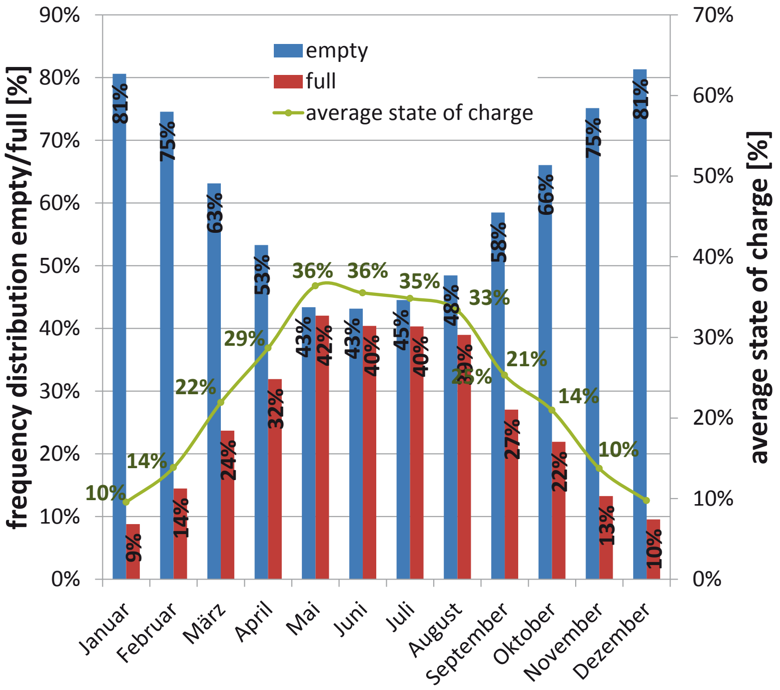

Figure 1. Frequency distribution of empty and full in a 2 kWh storage in comparison with a 5 kWp PV plant.

This means the capacity sinks to the maximum depth of discharge (DoD) and the battery just works 10% of the time in the first month of the year. Considering the months May to July the two bars are almost equal. The battery is full 40% of the time in summer because of the high solar yield and therefore the working time is also reduced.

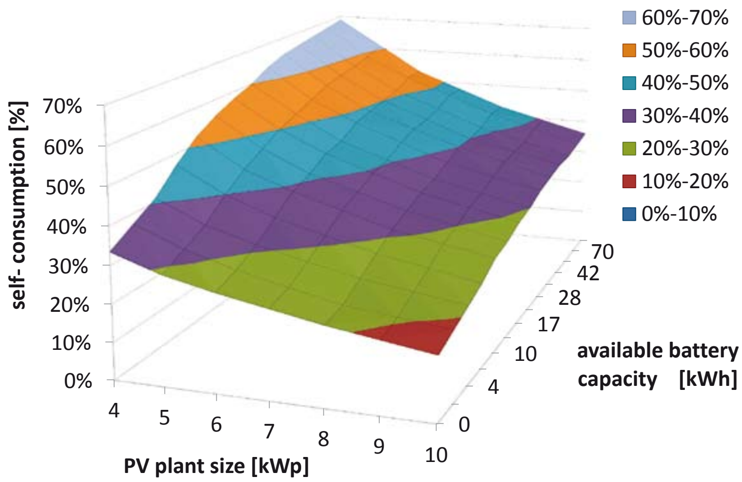

Figure 2. Self-consumption in cause of the combination of PV and storage system.

In a theoretically perfect operation the two bars would approach zero. In reality this cannot be reached: a small battery in winter is empty most of the time and full in summer. This is because of the low capacity of the battery and thus it is quickly loaded, respectively unloaded.

In comparison, a big storage system is often full and hardly empty in summer (kind of seasonal storage). This damages the battery because there is no full load cycle over a longer time.

PV/Storage Simulation

The available capacity of the battery consists of the depth of discharge, the maximum charge and the efficiency of the battery. Within the course of the simulation the charge and discharge efficiency are not taken into consideration. The cycle stability is closely linked to the life-time of a battery. This value is significant for the annual complete charge cycles. The size of the exemplary household is based on data from "STATISTIK AUSTRIA" [6] and is rounded to 4000 kWh/a.

The same principle is used to calculate the self-consumption rate with an integrated battery system. **Figure 2** shows the self-consumption rate by varying the PV plant size and the available battery capacity.

The higher the battery capacity, the greater the self-consumption rate because more surplus energy can be stored. The sum of the self-consumption rate and the amount of energy fed into the public grid and also the sum of the solar coverage rate and the energy obtained from the public grid always equals 100%.

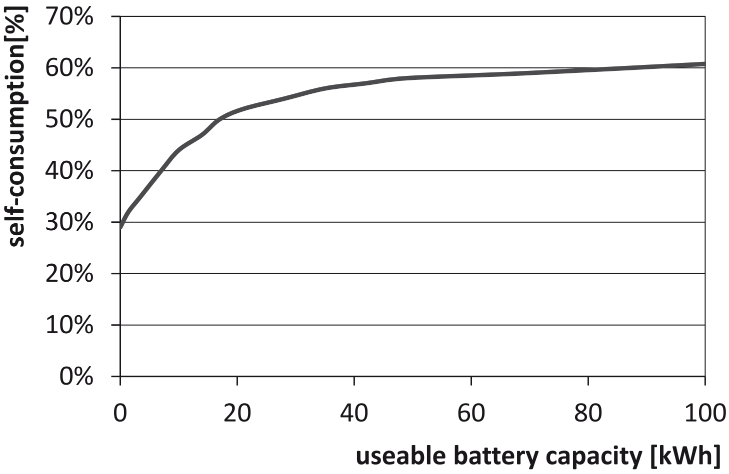

Figure 3. Self-consumption in the case of variable battery and an exemplary household (4000 kWh/a) with a 5 kWp PV.

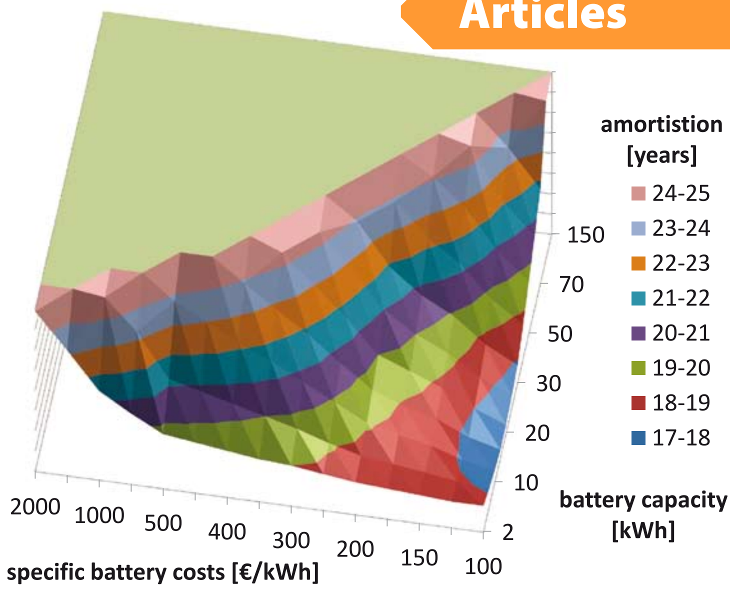

Figure 4. Amortisation of a Lithium battery in combination with 5 kWp PV and 4000 kWh/a.

It might appear that an increase in battery capacity will continuously lead a proportional increase in the self-consumption rate. However, **Figure 3** clearly shows that at a particular value the increase of the curve slows down. Therefore a supersized storage would be necessary to achieve 100% of self-consumption rate.

Pros and cons must be carefully considered when choosing the size of the electric storage system. Small batteries have the advantage of being less expensive, but on the other hand they are not able to store the midday peak energy input of a sunny day and to cover the evening demand of a household because of the low capacity.

To choose a suitable storage system all major factors need to be taken into consideration. These include the household with the specific load profile, the photovoltaic yield depending on the location, the direction of the photovoltaic modules and the efficiency of the inverter and the storage system. Only with a suitable storage system, the self-consumption rate can be increased significantly and consequently the profitability of the system is given.

In order to achieve a higher rate of self-consumption, higher storage capacities are needed. In this case the system will not be amortized in the lifespan of the PV power plant assuming of real specific costs of a battery system of at least 300 €/kWh for lead batteries and 500-1000 €/kWh for lithium batteries [7].

Economic Assessment

As basis for the economic calculation of the exemplary household a storage system with a 5 kWh useable battery capacity (including DoD and the efficiency of the system) was used. For the simulation are network costs of 22 €ct/kWh, a feed-in tariff of 5.5 €ct/kWh and an estimated 2% increase in electricity prices per year [8] assumed.

The Lithium battery with specific costs of 500 €/kWh is not amortised within 25 years. By only changing the increase in electricity prices per year to 4% the complete system is being amortized within 22 years. This means even a small change in the underlying assumptions causes a significant change in the results.

The result of the economic assessment of an electrical storage system is shown in **Figure 4**. A Lithium battery with a varying capacity between 2 and 150 kWh in combination with a PV plant size of 5 kWp and an annual electricity consumption of 4000 kWh/a is illustrated. The green area in the left corner highlights an amortisation time of more than 25 years.

This calculation does not include subsidies and new storage acquisition. In realty the storage system should be replaced every 5 to 15 years due to capacity losses depending on the storage technology and the operation of the system. This means, based on a typical 25 year lifespan of the PV system, the storage system has to be renewed three to five times.

Compared with the specific grid costs per kWh shown in **Figure 5** the electricity costs for combined PV and battery the point of intersection is reached after 24 years. This means that after 24 years the costs for the PV/storage system are as high as the sum costs over the years of the public grid. Without a battery system the point is reached after 18 years.

In conclusion the amortisation of a storage system depends on the photovoltaic plant size, the load profile of the household and the electrical storage system itself.

Conclusions

In this paper simulations to increase self-consumption with a grid-connected PV power plant are illustrated by calculation of an exemplary household. To further increase the level of self-consumption rate and the profitability of the system, the PV system can be combined with a storage system. As a result the surplus energy of the PV power plant can be stored in the battery and discharged again when energy is needed.

The battery was selected based on the following criteria:

- Depth of discharge
- Lifetime
- Self-consumption
- Investment costs
- Payback period

There are many new battery technologies under development and in the next few years the price per kWh is expected to drop significantly so that the system can be economically viable within the lifespan of the PV plant.

The mentioned parameters (self-consumption rate and solar-coverage rate) can reach 100% but major efforts will have to be made to reach this maximum and it may not be economically attractive. The aim is to find a balance between optimization of the parameters and the reduction of expenses for the system.

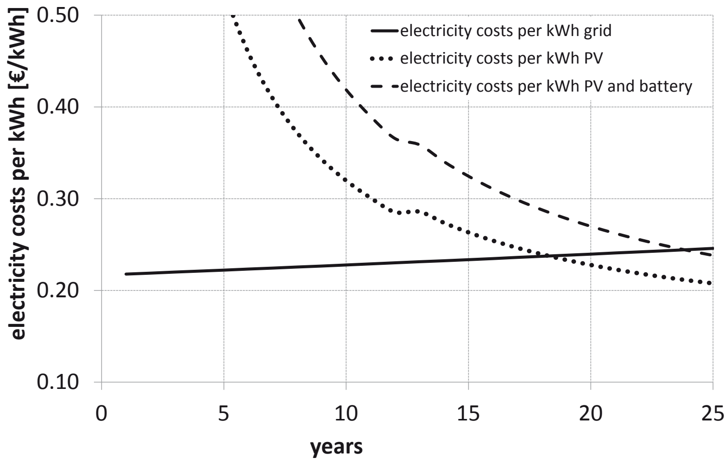

Figure 5. Electricity costs per kWh.

The actual behaviour of the user has a major influence on the self-consumption rate. An identical load profile but different annual energy consumption shifts the curve (bigger consumption means higher self-consumption). It turned out that currently an electrical storage system for households only in a few cases is economically viable and energetically appropriate.

Acknowledgements

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Excellent performance of the first active house in Canada

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The number of realized Active Houses has already proofed that it is possible to make energy efficient buildings without compromising good indoor climate and building components lowering environmental impact. Projects as Home for Life, Lichtaktivhaus, Maison Air et Lumiere shown how to design and build with the focus on people's health and well-being, furthermore by inviting the families to test the buildings and sharing their positive experiences the success of these experiments was lastly confirmed. The thorough investigation has been made to determine standard building solutions in the region and show the alternative solutions that can bring the house to higher standard.

Keywords: nZEB, nealy zero energy building, low energy building, energy efficiency, active house, daylight.

Figure 1. Great Gulf Active House in Ontario, Canada, South façade. Interior is filled with natural light.

FACTS

Builder: Great Gulf

Design:
- Superkül Inc. Architect
- Enermodal Engineering, a member of MMM Group
- Quaile Engineering
- Building Science Corporation
- Building Knowledge Canada Inc
- Enerquality verified for "Energy Star" and "Green House" certification
- "Brockport Built" Fully panelized home Ensuring precision and quality
- Danish Technological Institute
- VELUX A/S, Building Industry

Area: Lot area: 600 m^2
Ground Floor: 153 m^2
Upper Floor: 154 m^2

Location: Thorold,
Niagara Region,
Ontario, Canada

Great Gulf Active House

The Great Gulf house was built in Thorold, Ontario, a community located in the Niagara Region and roughly 90 minutes west from Toronto, this demonstration building was achieved through a collaboration involving a team of Danish architects, the award-winning Toronto architecture firm superkül, and Great Gulf, the builder committed to bringing the Active House concept to Canada. Using the design guidelines of a traditional gabled roof design and adapting them for the Active House yielded a streamlined multi-functional roof design that provided a basis for double-height spaces and opportunity for excellent daylight conditions provided by multiply windows. The house is oriented with the long roof slope and major glazing facing south to maximize the efficiency of the solar hot-water system and passive solar gain.

Two intersecting axes guide the open plan of the interior to maximize cross breezes. By removing visual barriers between living spaces, the open plan also creates the impression of a larger home. To promote the comfort of the residents, superkül ensured that each room featured exterior views without compromising privacy. The patio that aligns with the width of the living room reinforces the visually seamless extension of the interior spaces.

The Great Gulf Active House scores excellently in all of Active House categories (**Figure 2**) which is an achievement taking into account that many already popular in Europe building techniques, components – as highly efficient windows are not yet common in production home building in Canada. In addition to it, the project refers directly to the standard house meeting requirements of Canadian building code (**Table 1**) and shows the comparison between enriched version realized according to Active House principles.

Daylight

The multitude of skylights and windows create naturally light-filled spaces and minimize the need for artificial light. This occurs even in the secondary living spaces where a skylight brings light to the shared washroom between the two adjoining bedrooms, or in the Master Bathroom where three skylights are complemented by a nearby horizontal window. The Danish design team modelled extensive computer visualizations to avoid insufficient levels of natural daylight in nearly every space of the home (**Figure 3**). Their work supported the

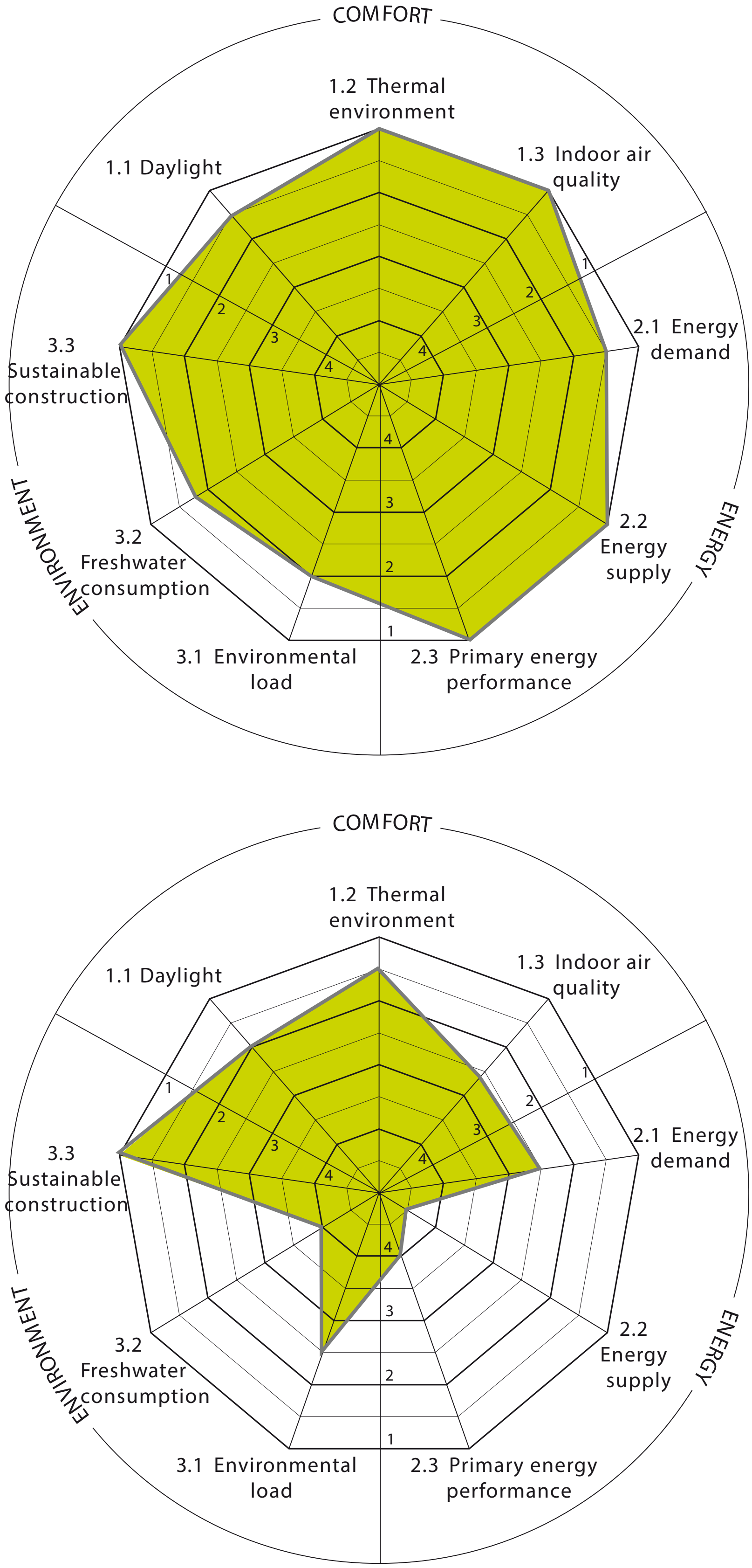


Figure 2. Active House evaluation for Great Gulf Active. House above and for standard house below (approximation), the results shown are based on calculations.

Table 1. Values show the differences in technical properties between Great Gulf Active House and standard house (the same project without 'Active' elements designed to meet the building code).

	Active house	Standard house
Windows & Energy		
Glazing (%)*	21.6%	16%
Facade windows	Triple glazed (0.97–1.19 W/(m²K))	Double glazed (< 1.6 W/(m²K))
Low/high heat gain by orientation	Yes	No
Skylights	Yes (2.29 W/(m²K))	No (< 2.8 W/(m²K))
Electric venting windows & skylights	Yes	No
Insulation		
Walls	0.17 W/(m²K)	0.26
Basement walls	0.47 (outside of wall)	0.47
Basement slab	0.75	–
Ceiling without attic	0.15	0.18
Mechanical		
Space heating AFUE *	97%	>94%
Zoned heating	Yes	No
HRV **	83%	>60%
Solar Water Heating	Yes	No
Grey Water Heat recovery	Yes	No
Cistern (toilets, irrigation)	Yes	No
Other		
Permeable driveway	Yes	No
Home Automation	Yes	No
Pre-fab panels	Yes	No
LED lighting	Yes	No
Durable, long lasting, low VOC finishes	Yes	No

*AFUE = annual fuel efficiency

** HRV =nominal efficiency of heat recovery in ventilation

architects' ability to select the most efficient sizes and the most effective locations for the skylights. The architects were able to maximize direct and indirect light, which can be reflected of walls, ceilings and the white hardwood strip flooring to help increase light reflectivity.

Thermal Comfort

The thermal environment of the Great Gulf Active House optimizes comfort and efficiency by using zoned heating, a modulating blower fan, and industry leading equipment which also ties into two HRVs (heat recovery ventilation). A modulating fan is used to deliver fresh conditioned air through the ducting system to each room, and since it can modulate down to a low speed, it can run continuously and more quietly to deliver fresh air to each room, even when heating and cooling are not being used. The house is divided in two zones by floor; in each there is centrally placed thermostat to control the desired daytime and evening temperatures, turning on the heating system or

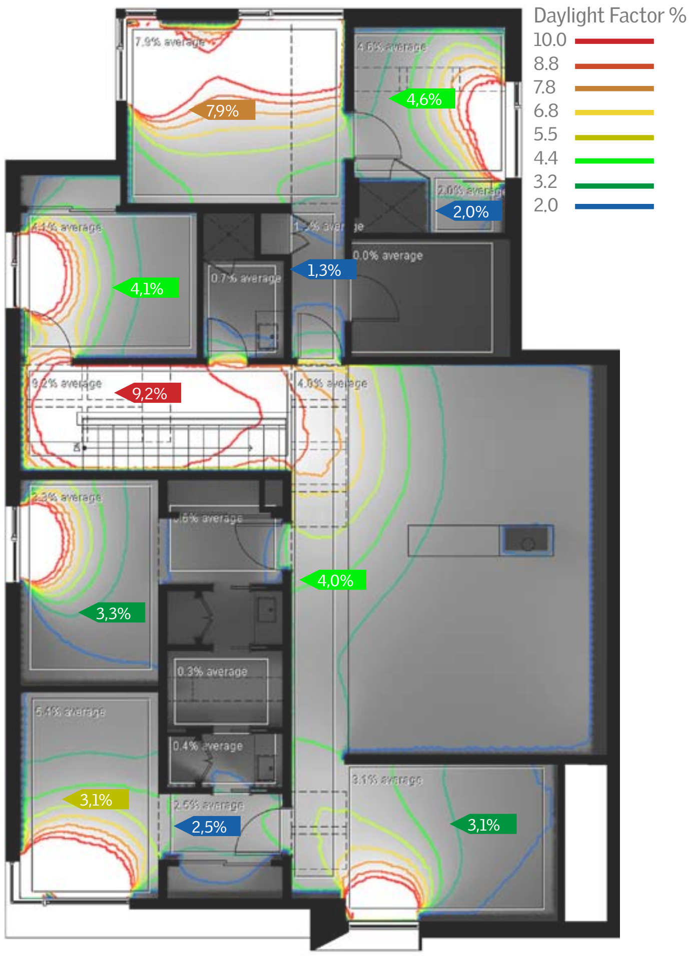


Figure 3. Daylight Analysis of the Upper floor.

Daylight factor

The daylighting performance of the Great Gulf Active House has been measured using the daylight factor (DF) as the performance indicator. The daylight factor is a common and easy to- use measure for the available amount of daylight in a room. It expresses the percentage of daylight available inside, on a work plane, compared to the amount of daylight available outside the building under known overcast sky conditions.

The higher the DF, the more daylight is available in the room. Rooms with an average DF of 2% or more are considered daylit. A room will appear strongly daylit when the average DF is above 5%. The daylight factor analysis has been performed using computer simulation software Daylight Visualizer.

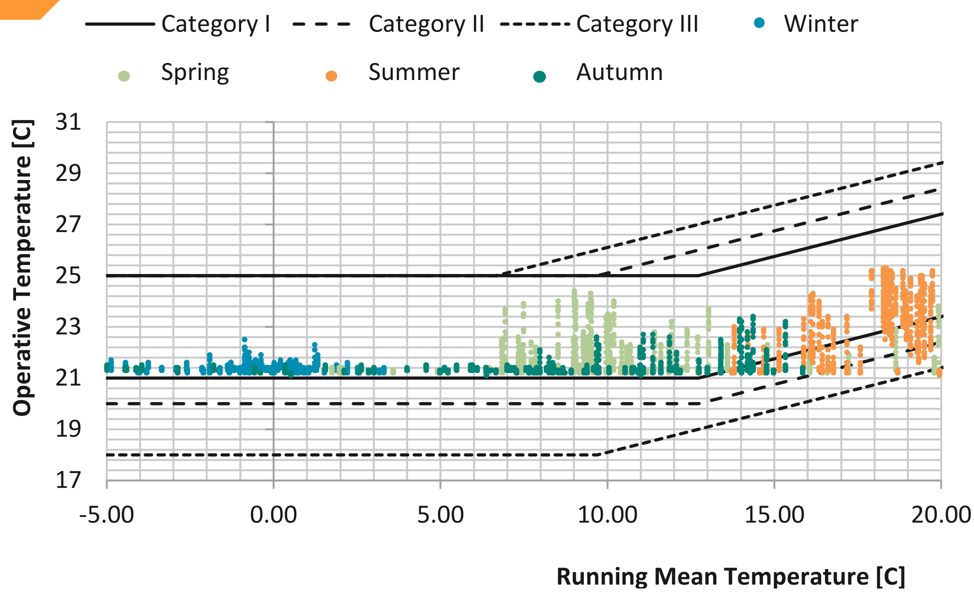


Figure 4. Indoor temperatures in the master bedroom plotted against running mean outdoor temperature for each hour of the year including Active House requirements. The dots are coloured to represent a season. The results shown are based on calculations.

air conditioner as needed on that floor. The duct work is insulated and sealed to ensure enough conditioned fresh air reaches each room. The benefits of a dual-zoned system allows occupants to heat their bedrooms at night while lowering the temperature of unused living spaces. The control-system that leads to the results is based on the assumption that the open motorized windows will provide adequate cooling until the indoor temperature reaches 24°C. If the temperature exceeds 25°C, the mechanical cooling will be activated and the windows closed.

The thermal environment in the building scores 1 (**Figure 4**). The score is a result of the combination of natural ventilation, the possibility of mechanical cooling on warm days and zoned heating during cold days.

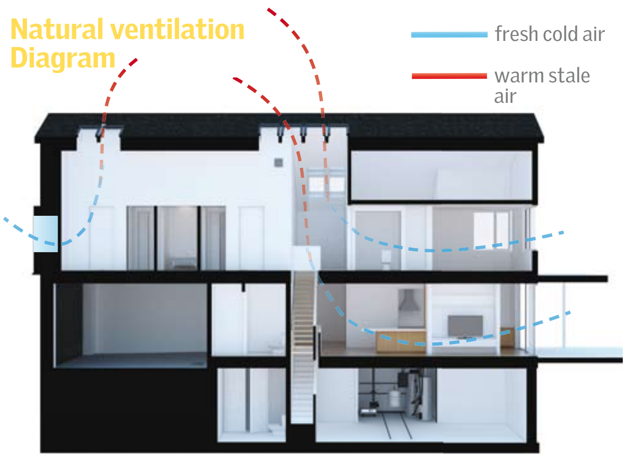


Figure 5. Openable motorized skylight windows can be used for ventilation and free cooling.

Indoor air quality

The high indoor air quality and energy efficiency is assured by hybrid ventilation that contributes to providing an excellent indoor air quality with score 1 (500 ppm above the outdoor CO_2 concentration). Natural ventilation is encouraged by a dual-zone HVAC system connected to a Somfy Tahoma Smart House system that uses sensors to automate the windows, blinds and 14 skylights to open and close in response to the interior temperature and air quality. Openable, motorized windows provide cooling below 24°C, above the control system switches mechanical ventilation on (**Figure 5**).

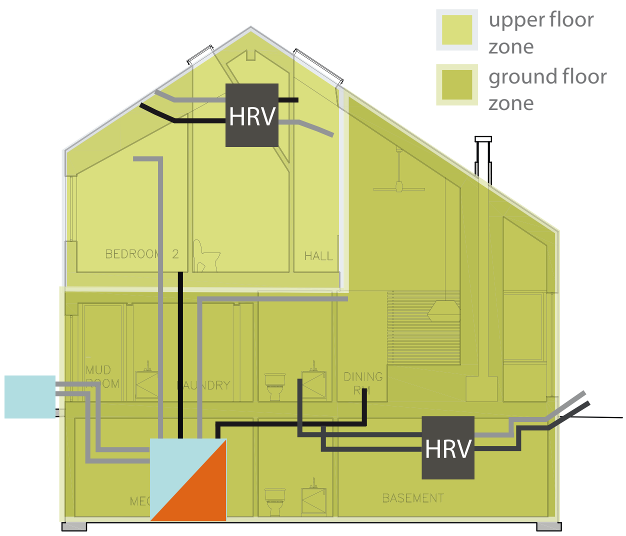


Figure 6. Two zones mechanical heating/ventilation system providing ventilation to each room separately.

The mechanical ventilation with two heat recovery ventilation, HRV units supply the house with fresh air through the furnace intake (**Figure 6**). Fresh air is pre-conditioned by one of two HRVs in the home. An HRV is a heat exchanger that uses the warm air being exhausted from the home to pre-heat outside winter air coming in. Likewise, in the summer the HRV can pre-cool fresh air coming into the home which reduces the energy needed to heat and cool the home while providing ample amounts of fresh air to all rooms. A second HRV is located in the conditioned attic near the master bedroom and ensures each bedroom has ample amounts of fresh air, important for a good night's sleep. The air change rates and the volume of the house along with many other parameters have been accounted for.

Energy performance

Great Gulf Active House boasts fully integrated systems designed to optimize natural lighting and air quality while reducing its dependency on non-renewable energy sources. House annual energy demand is very low, **Figure** 7 (1,5 according to Active House specification what indicates ≤ of 50 kWh/m²) what is result of a design strategy utilizing natural energy resources like solar gain, natural ventilation, efficient technical equipment, heat recovery, a well-insulated and air tight building envelope and fenestration with a low U-values. The compactness achieved by building in two storeys with a finished basement also has a good effect on the energy performance. The grey water heat recovery unit captures heat from showers and baths and preheats incoming cold water which helps to reduce the energy demand for the domestic hot water. The energy supply is a combination of heat from the solar thermal panels and renewable gas from Bullfrog Power, the heat supply is considered as being 100% renewable. The electricity is also supplied by Bullfrog Power which comes in 100% from renewable sources. The score of the energy supply and primary energy performance is 1.

Environmental performance

Waste Water Heat Recovery

RenewABILITY Energy's Power-Pipe is a heat exchanger that is comprised of standard plumbing components: copper fresh water coils wrapped very tightly around an inner Type "DWV" copper drainpipe. As fresh water flows up the multiple fresh water coils, warm to hot drainwater flows down the inside wall of the drainpipe as a falling film. This counter-flow design maximizes the amount of energy that can be recovered from the drainwater while minimizing pressure loss. The Power-Pipe is a

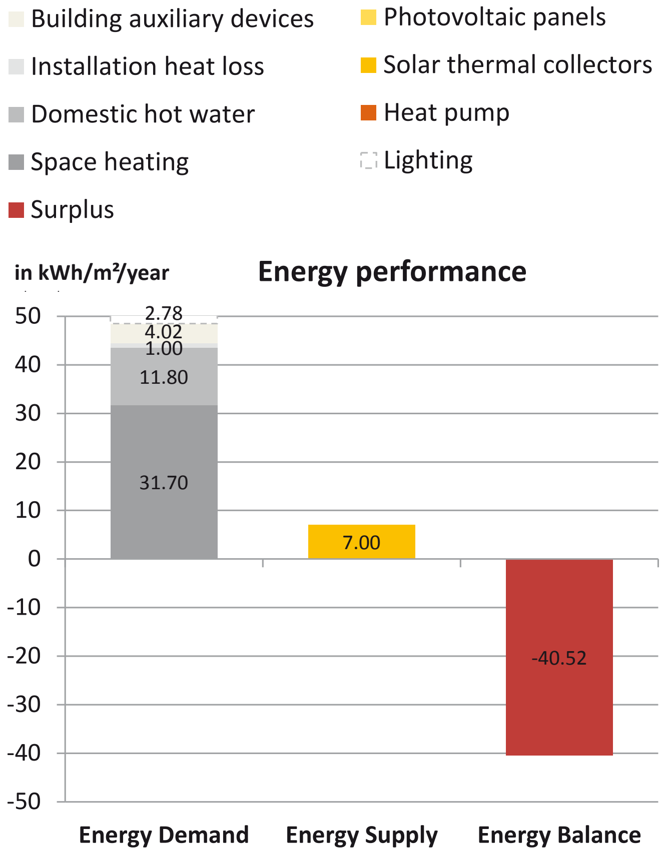


Figure 7. Annual energy balance of the Great Gulf Active House.

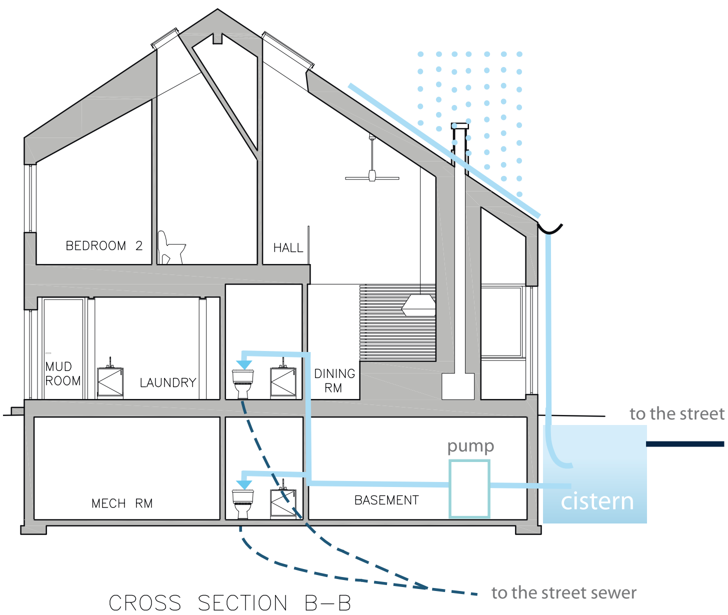


Figure 8. Water management system in the Great Gulf Active House.

Active House components: energy

- R-35 2LB closed cell spray foam insulation on all exterior 2 x 6 walls equipped with Icynene. Excel III R-1.5 exterior wall sheathing/ air barrier system
- Hybrid windows/ patio doors strategically orientated to provide high solar heat gain
- All supply and return ducts sealed and insulated to minimize heat loss
- 2 VanEE heat recovery ventilators to better provide conditioned air to all areas of house
- Somfy Tahoma Smart House Automation system to provide control of windows/skylights/ blinds
- LED light fixtures throughout to provide low electrical consumption as per Designer Specifications
- VELUX Operable solar powered ventilated Skylights strategically placed to provide an abundance of light
- Two south facing VELUX CLI U12 4000 collectors
- Water Heat Recovery

Active House components: comfort

- Dual zoned mechanical system with 97% efficient high efficiency variable speed furnace: Lennox and 19 SEER air conditioner providing a balanced distribution of air on all floors
- Somfy Tahoma Smart House Automation system to provide control of windows/skylights/ blinds
- Somfy system to provide automated control for operation of windows and skylights
- VELUX Operable solar powered ventilated Skylights strategically placed to provide an abundance of light
- Automated roller sun shades throughout to control sun and prevent from solar overheating
- Modulating fan to deliver fresh conditioned air to each room

Environment

- Upgraded low-flow plumbing fixtures
- Graff Rainwater Cistern utilizing rainwater collected from roof and ground to supplement municipal water in the operation of all toilets and the outside irrigation system
- Bullfrog Power supplying 100% renewable energy to both natural gas and hydro grids for total energy
- VELUX solar hot water collectors utilizing the sun to heat municipal water minimizing the natural gas usage
- "Brockport built" ensures that there is minimal waste during on-site assembly reducing the carbon footprint from removal of waste from site
- Eco Paver Permeable Driveway interlock system to better control surface rainwater runoff into local storm systems

passive energy saving device. It has no moving parts, it's self-cleaning and will require no maintenance.

Water management

A cistern and rain water collection system was installed to reduce the need for municipal water when watering the lawn or using the low-flush toilets. The system captures rain from the roof and lawn close to the house. The water is pumped from the weeping tile into the cistern. A saving potential of 35% has been calculated, based on the annual rainfall in Ontario combined with the area of the roof and the number of people in the house.

Construction

The climate and environmental in Great Gulf Active House features represent higher upfront costs for the consumer but are worthwhile investments, becoming increasingly commonplace as both energy and water costs rise. The use of innovative construction method/ prefabrication of building components as exterior walls, roof and floor systems contributed to low environmental impact of the house. The method reduces material waste and energy usage. Moreover it reduces risks of onsite accidents during the construction process, improves the accuracy and quality of construction and makes the building increasingly affordable to future homeowners. Automated premanufacturing allows the house to be erected in only one week. The wood frame panels are a more sustainable alternative to the typical steel structure.

Maintenance

The clean aesthetic of Great Gulf Active House's modernist architectural shape provides the foundation for maximum human comfort with the goal of reducing maintenance and operating costs. Even minor or imperceptible features such as interior and exterior LED lighting systems, permeable driveway surfaces, native plant species or cedar window frames help minimize maintenance costs.

Conclusion

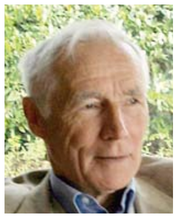
The architectural intentions that define the Great Gulf Active prototype have enabled the architects, investor, and product manufacturers, opportunities to measure and study the Active House's performance, improve upon it, and then implement the necessary modifications before building next generation of homes. From Great Gulf's perspective, the value of offering various levels "comfort packages," or levels of energy efficiency, climate and environmental controls to the consumer will certainly shift the conversation from granite countertops to human comfort and wellbeing. ■

Performance of a nearly Zero House in Belgium

Case study in the frame of IEA ECB annex 58 Research Program







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This case study aims in identifying the best way of verifying the actual performances of a very well insulated building exposed to very significant solar heat gains.

Keywords: nearly zero energy building, nZEB, net zero energy building NZEB, house, energy efficiency.

The method considered is combining measurements with computer simulation; it has already been tested in the frame of the previous IEA ECB annex 53 project "Total Energy Use in Buildings: Analysis & Evaluation Methods": the measured consumption of a dwelling was compared with the simulated consumption on different time bases. The new idea consisted in using the measured indoor temperatures as input data in the simulation.

Satisfactory results were obtained, but this was a relatively "easy" case: a poorly insulated building with negligible solar heat gains and direct electric heating.

The passive house considered in the present case study might be much more difficult to characterize: solar heat gain plays an important role and, even during the so-called "heating season", the net space heating demand is, most of the time of the same order of magnitude as other power demands (sanitary hot water, appliances and lighting).

"Passive" verifications based on a recording of indoor temperatures and energy consumptions without interference with current life of building occupants might require too long periods of observation and produce too inaccurate results.

"Active" verifications will be therefore also considered: they will consist in analyzing the building response to some artificial variation of heating power thanks to some "co-heating" equipment.

The house

The house is built in a very open environment; it's South oriented, with large glazing area on that side (**Figure 1**). Other façades (**Figure 2**) are much less open to sunshine. According to Passive House Planning Package (PHPP) description, the building has the following characteristics:

- Internal volume: 894 m³
- Reference heated floor area: 232 m²
- Windows: 44 m² (with 31 m² South oriented), triple glazing, U=1 W/m²K
- Opaque walls: 244 m², U=0.12 W/m²K
- Roof: 174 m² U=0.1 W/m²K

This gives, for the whole envelope, a total area of 583 m² and an average U value of 0.174 W/m²K. According to the pressure test result, the infiltration is of the order of 0.32 1/h at 50 Pa of overpressure. Per unit of floor area, the nominal heating power and the yearly heating demands are supposed to be equal to 9 W/m² and 14 kWh/m² if the whole house is heated.

Figure 1. South-West corner.

Figure 2. North-West corner.

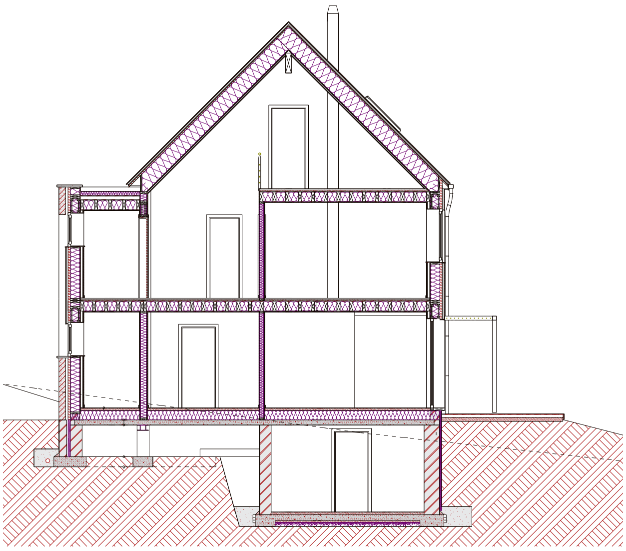

Figure 3. Vertical North-South cross section.

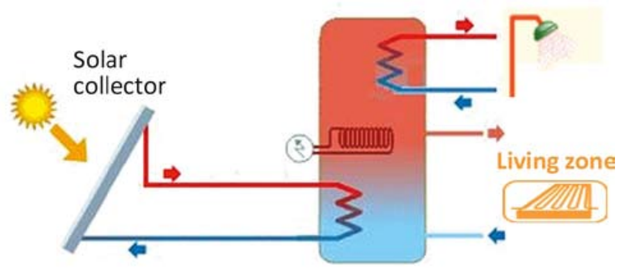

Figure 4. Boiler equipped with electric resistance and solar thermal collectors, supplying heat to the living zone heating floor and providing domestic hot water.

Energy systems

The large South-oriented glazing is protected from outside by motorized blinds.

The house is ventilated thanks to a dual-duct mechanical system with fresh air pre-heating through both ground-connected heat exchanger and air/air recovery (effectiveness estimated to 65%).

The house ground floor is equipped with a water floor heating system.

Electric floor heating is used in both bath rooms (installed powers: 250 and 150 W in the large and small bath rooms respectively).

The office room of the second floor is occasionally heated by an electrical convector.

Ground floor space heating and sanitary hot water systems are supplied from a common hot water tank heated by an electrical resistance of 4 kW and by 4 m² of evacuated tubes solar collectors installed on the roof.

The solar heat exchanger, the electrical resistance and the (space and sanitary) heat use connections are located at the bottom, at the middle and at the upper part of the tank, respectively (**Figure 4**).

The electrical resistance is controlled in such a way to maintain a temperature of 55°C in the upper part of the water tank. 22.5 m² of PV collectors are also installed on the roof; their nominal power is of the order of 4500 W. They are expected to produce a total of the order of 4200 to 4800 kWh/year.

Control strategy

In order to reduce the overheating risk in the living room, external blinds openings are automatically adjusted every half hour according to the indoor temperature, provided the heating system and the indoor lighting are switched OFF.

The mechanical ventilation is sized for a nominal air flow rate of 350 m³/h. Electric fan provides thee rotation speeds. Occupants usually impose the middle rotation speed corresponding to 45% flow rate reduction factor.

The outdoor air is supplied through 8 outlets (**Figure 5**):

- Ground floor: 3 in the living room
- First floor: 1 in each of the three sleeping room and 1 in the office room

- Second floor: 1 in the west room

Extractions are realized through 9 inlets:

- Ground floor: 2 in the kitchen, 1 in the toilet and 1 in the technical room
- First floor: 1 in each of the two bath rooms, 1 in the washing room and 1 in the toilet
- Second floor: 1 in the east room.

In nominal conditions, the air should be distributed as follows:

- Ground floor: supply 150 m³/h, extraction 130 m³/h
- First floor: supply 200 m³/h, extraction of 185 m³/h
- Second floor: supply and extraction of about 35 m³/h

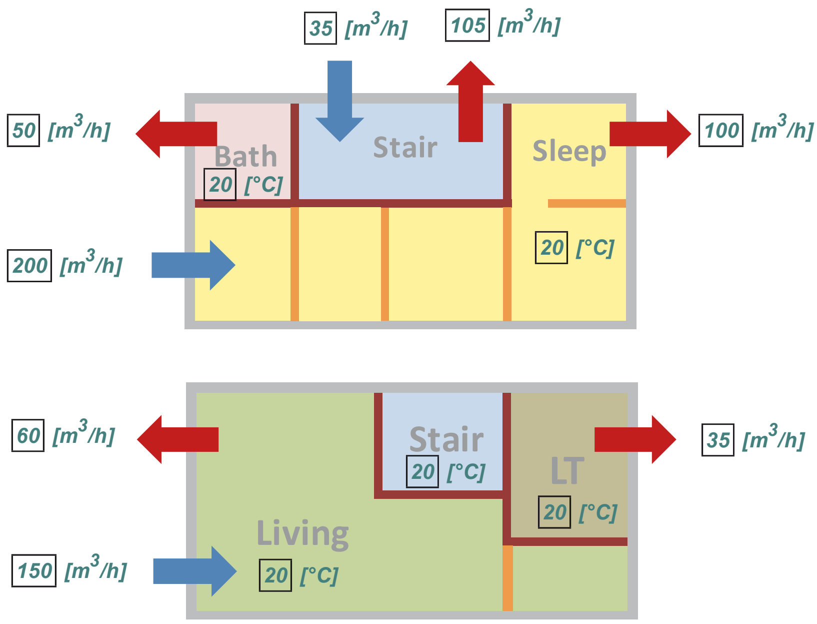

Figure 5. Simplified scheme of the house floor building zones with nominal outdoor air flows.

In winter time, the water temperature of the floor heating system is usually maintained between 28 and 30°C.

The building is occupied by a four people family (two parents and two children). All of them are out (for work and school) during week days. The hot water consumption is estimated to 200 l and 7 kWh per day. This heat demand is almost completely covered by the solar system in summer time.

Measured and estimated consumptions

Electrical consumption was manually recorded on a two year period (**Figure 6**). It corresponds to the integration of the total electricity consumption of the building. Negative slopes along this curve corresponds to time periods during which the PV collectors are producing more electricity than required and sending back energy to the network.

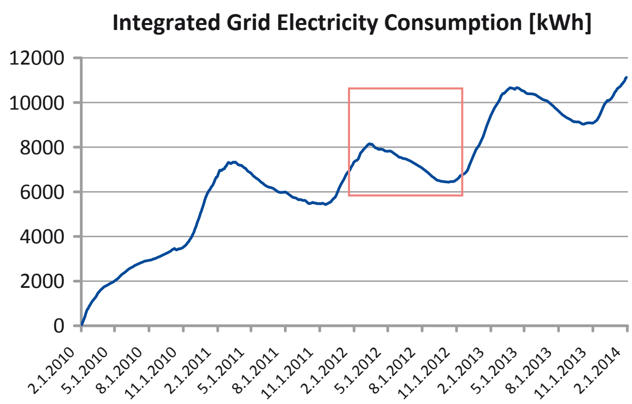

Figure 6. Integrated total electricity consumption (electricity counter).

The total electricity consumption and the PV cell production recorded from 1st January to 31st December 2012 are plotted on **Figure** 7. The difference is provided by the grid.

The corresponding measured electricity consumptions devoted to the boiler, bath rooms electric floor heating and fans are plotted in **Figure 8**. The electricity consumptions devoted to other uses (lighting, appliances and pumps) are deduced from the energy balance.

The "fans" curve corresponds to the consumption of the fans of the mechanical ventilation system. This consumption (173 kWh/yr) is marginal (it's even null in some periods during which the ventilation was not operational).

An energy balance of the measured electricity consumption is provided in **Figure 9**.

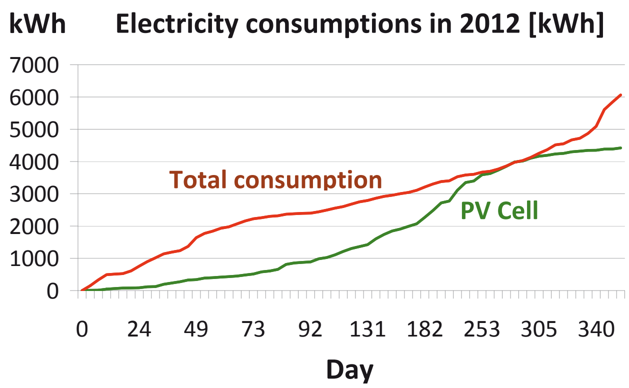

Figure 7. Measured total electricity consumption W_{total} and PV cell production W_{PV} for a year.

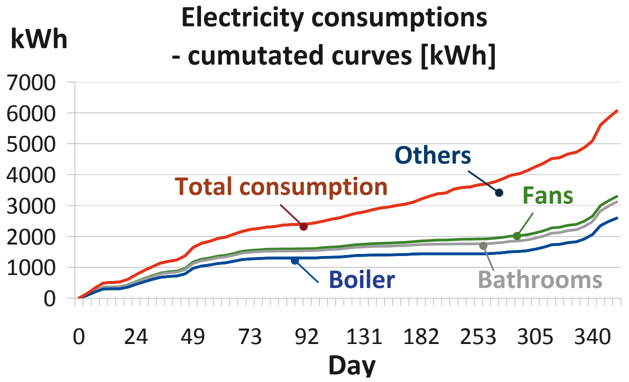

Figure 8. Measured total electricity consumption including the boiler resistance for space heating and DHW, the electric floor heating in the bathrooms, the fans and the other uses (lighting, appliances and pumps) for year 2012 (cumulated curves).

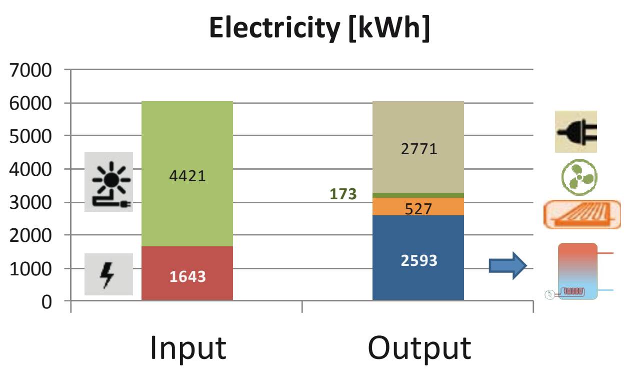

Figure 9. Breakdown of electricity consumptions for year 2012.

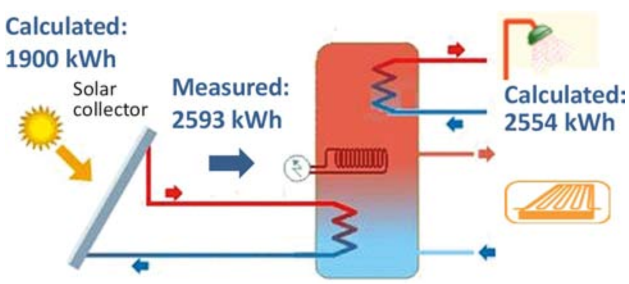

Figure 10. Energy balance of the boiler for year 2012.

If not taking the lighting and appliances consumptions, this house can be considered as a "nearly zero energy building": the thermal and PV collectors are roughly covering the whole (space and sanitary water) yearly heating demand.

Space heating and sanitary hot water consumptions provided by the boiler are not actually distinguished in these records (only the total is actually measured). **Figure 10** provides a balance of the boiler energy inputs (solar thermal collectors, electric resistance) and outputs (domestic hot water production and floor heating in the living zone).

The sanitary hot water consumption (2554 kWh) on Figure 10 corresponds to an extrapolation from records having been taken before the installation of the solar system (7 kWh per day). The production of the solar thermal collector is expected to reach 2000 kWh per year. The heating demand of the living zone computed through a dynamic simulation with EES solver, on the basis of 2012 weather data, reaches 513 kWh. It seems to be strongly underestimated. This is probably due to a stack effect occurring in the staircase that provides heat from the living zone to the upstairs.

Conclusion

The analysis of measured electricity consumptions in this passive house inhabited by occupants who are very motivated for energy saving purposes shows, that the house can be considered as a "nearly zero energy building": the thermal and PV collectors are roughly covering the whole (space and sanitary water) yearly heating demand. They do not cover the whole lighting and appliances consumptions.

It is difficult to provide an accurate energy balance of the house on the basis of the available data, as the effective heat production of the solar thermal collectors is not recorded. Heat production of the solar thermal collectors should be measured in order to provide a complete balance of the system.

Dynamic simulation of the building provided with a floor heating systems at the ground floor seems to underestimate the ground floor heating demand, probably because of a stack effect occurring in the staircase and providing heat from the living zone to the upstairs.

Acknowledgments

The support of the Walloon Region of Belgium to the work described in this project is gratefully acknowledged. ■

A net Zero Energy Building in Finland

Buildings and the whole built environment are in a key role when societies are mitigating climate change and adapting to its consequences. The building sector can significantly reduce energy use by incorporating energy-efficient strategies into the design, construction, and operation of buildings. In addition building sector can further reduce dependence on fossil fuel derived energy by increasing use of on-site and off-site renewable energy sources.



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Keywords: net zero energy building, nZEB, low energy building, energy use, solar heating.

A net zero energy building refers to a building where the amount of energy provided by on-site renewable energy sources is equal to the amount of energy used by the building in a year. A net zero energy building bases on a very low-energy building concept to minimise the energy demand. The low energy demand defines the design of the building integrated renewable energy production systems.

A zero energy house in Finnish climate

The building was designed based on architecture competition organised by Saint-Gobain ISOVER in co-operation with Finnish Association of Architects SAFA, Rakennuslehti Building and construction magazine, VTT Finnish Technical Reseach Centre and WWF World Wide Fund for Nature. The competition was big and all together 81 proposals were achieved. The selection of the winning proposal was hard due to many very good solutions. The winning proposal was named as BLOK and it was designed by architects Tiina Antinoja ja Olli Metso from Muuan Studio (http://www.muuan.fi/).

Figure 1. The architecture of the building.

The building was built on a housing exhibition located in southern Finland (latitude 60). Due to the schedule of the housing exhibition area, the process had rather tight schedule and good co-operation was needed between various design teams from the project. The core of the design of the building was to develop an attractive home which is suitable for typical family living preferences.

The cornerstone in design was to first minimise the energy demand for heating, cooling and electricity use, and then to cover the energy use by building integrated energy production at the yearly balance level. The main heating source was ground source heat pump but also solar heat can serve a share of heating use. In addition the building was equipped with a fire place capable to store some heat in its massive structures. The space heating was distributed with a floor heating maximising the use of solar heat (low exergy system).

The ground source heat pump efficiency SPF (seasonal) was 3.5 for space heating and 2.5 for domestic hot water heating. The solar thermal collector system was faced towards south with an angle of 15–30 degree from horizontal and the collector surfaces area was 6 m².

The surface area of the photovoltaic system was 80 m². Also the PV system was installed in the southern façade of the roof at the same angle as the solar thermal collectors. The PV system consists of 72 CIS-type thin film modules. The system is has 3 inverters each rated for 3 kW power.

The structures were designed for high thermal resistance, corresponding very low energy building structures in Finnish climate. The U-values of the structures are shown in **Table 1**. The window solar heat transmission factor (g-value) was 0.49 except for the west façade 0.34. The air tightness of the envelope at 50 Pa was 0.4 m³/m²h (measured value).

Table 1. U-values of the structures.

Structure	U-value (W/m²K)
Exterior wall	0.09
Roof	0.06
Base floor	0.09
Window	0.75
Door	0.6–0.75

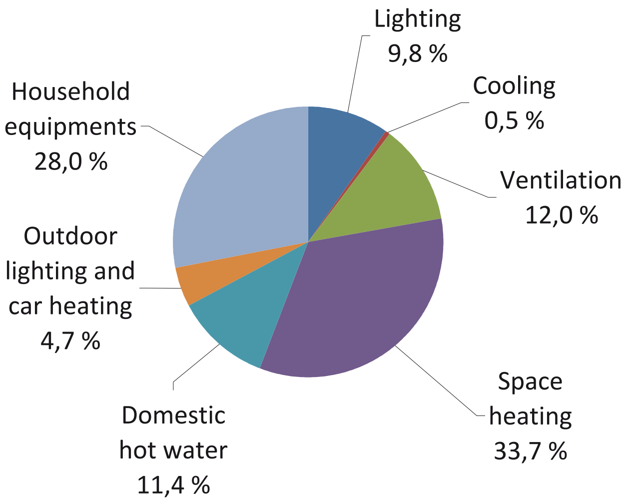

Figure 2. The electric energy consumption of the building.

Calculated energy consumption

In the design phase calculations it was assumed that the building is occupied by four persons and that their domestic water use is 120 dm³/person, day. It was also assumed that 40% of the domestic water use is hot water, thus 48 dm³/person, day. The ventilation was calculated according to the Finnish building code (0.5 ach) corresponding a 72 dm³/s fresh air flow. The efficiency of the heat recovery unit in the ventilation system was designed for 80% and the set point temperature for heat exchange surface freezing was –10°C, corresponding the yearly heat recovery efficiency rate of 76% for the ventilation system. The surface temperature for the floor heating with clinker surfaces was assumed to be 26°C for comfort reasons, other spaces were controlled by the room temperature. Lighting is assumed to be LED and all household equipment is assumed to have the best energy label classification A++.

The calculated delivered energy was 8 200 kWh yearly corresponding 53 kWh/-living-m². Roughly 60% of the energy is used for heating and ventilation. The ventilation includes the electric energy used for fans. The heating and cooling energy consumption corresponds to 20 kWh/m² yearly which corresponds 39 kWh/m² yearly energy demand for heating and cooling. The cooling system was integrated to the ventilation system to cool the supply air. The cooling demand was covered by the bore hole energy during the summer period.

The calculated electricity production from the installed PV system is 8 200 kWh yearly, **Figure 3**. Evidently the major share of the production comes during summer months. This leads obviously to a high imbalance at yearly bases. During summer months the excess electricity is sold to the grid operator.

The solar thermal production was estimated by using Finnish National Solar calculation method (Aurinkoopas 2012), and the calculated production was 1 900 kWh corresponding 335 kWh/m² of collector surface. The produced solar heat covers roughly 45% of the yearly domestic hot water consumption.

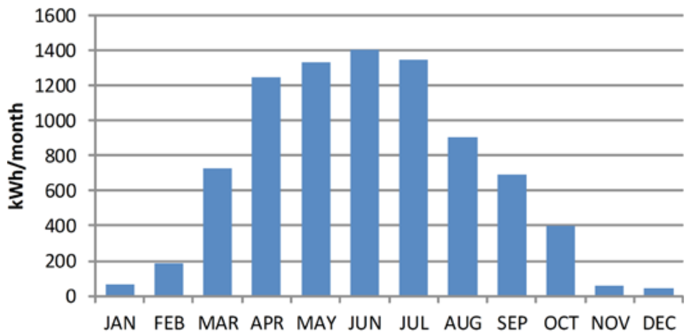

Figure 3. Calculated solar electricity production. The calculation is based on Soleras. (http://www.soleras.fi/)

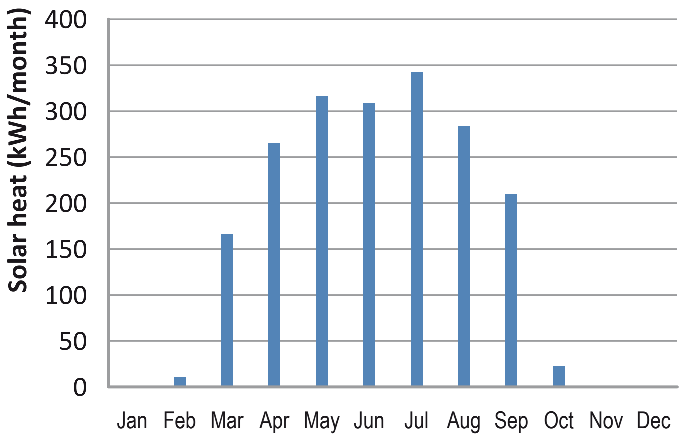

Figure 4. Calculated solar heat production.

The building performance is monitored at detail level. The first preliminary results are showing a promising results and further analyse is carried out currently to see the holistic picture about the building performance in real use. ■

Väla Gård - a Net Zero Office Building in Sweden

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Väla Gård is the Skanska Group's greenest office project to date and the first to achieve the Deep Green level according to Skanska's Color Palette™. It is also the only Net ZEB office in Sweden so far. Väla Gård is thoroughly followed-up by measurements for optimising and controlling the performance. This paper presents Väla Gård and Skanska's experiences so far with developing, designing, constructing and using a high performance net zero energy office.

Keywords: Net Zero Energy Building, Low Energy Buildings, Deep Green Buildings, Load Matching, Photo Voltaic, PV, Office Building.

Net Zero Energy Buildings, Net ZEBs, is one of many necessary measures for climate change mitigation as they may reduce the energy consumption in the building sector. The number of low-energy buildings has increased significantly over the past years in Sweden (Wahlström, Jagemar, Filipsson, & Heincke, 2011) and Europe. However, renewable energy such as PV-panels has until recently constituted a substantial initial cost for building projects, a fact that can explain that up to this date only one Net ZEB office has been constructed in Sweden, i.e. Väla Gård. Hence there is a need for sharing the experiences gained so far.

As a part of Skanska's commitment to reduce the environmental impact of the built environment, Skanska has defined and embarked on its Journey to Deep Green™. Skanska has developed an internal tool for environmental performance, the Color Palette. It is the strategic framework and communication tool for Skanska's green business development, that has been developed to measure and guide the company's performance on this journey towards Deep Green. Deep Green is defined by 6 zeros that relate to the priority opportunities for reduction of the environmental impact of our projects. These zeros are:

- Net Zero Primary Energy
- Near Zero Carbon in construction
- Zero waste to landfill
- Zero hazardous materials
- Zero unsustainable materials
- Net zero water for buildings

A Deep Green project must achieve three of the following six objectives: net zero primary energy, zero waste, zero unsustainable materials, zero hazardous materials, near zero embodied carbon and net zero water. Väla Gård achieved zero energy, zero waste and zero hazardous materials. The project also achieved LEED Platinum, the highest LEED score in Europe and the third highest in the world to date. LEED is a U.S. Green Building Council (USGBC) certification system for sustainable and energy efficient buildings. Väla Gård is the Skanska Group's greenest office project to date and is the first to achieve the Deep Green level according to Skanska's Color Palette™.

To create and construct a well functioning Net ZEB that is connected with an existing grid, it is important to consider the interaction with the grid. Hence, Net ZEBs have the dual role of being producers and consumers of energy, at all times.

The design may be evaluated by using quantitative indicators to describe load matching (LM) and grid interaction (GI). Load match refers to how the local energy supply compares with the building load and grid interaction refers to the energy exchange between the

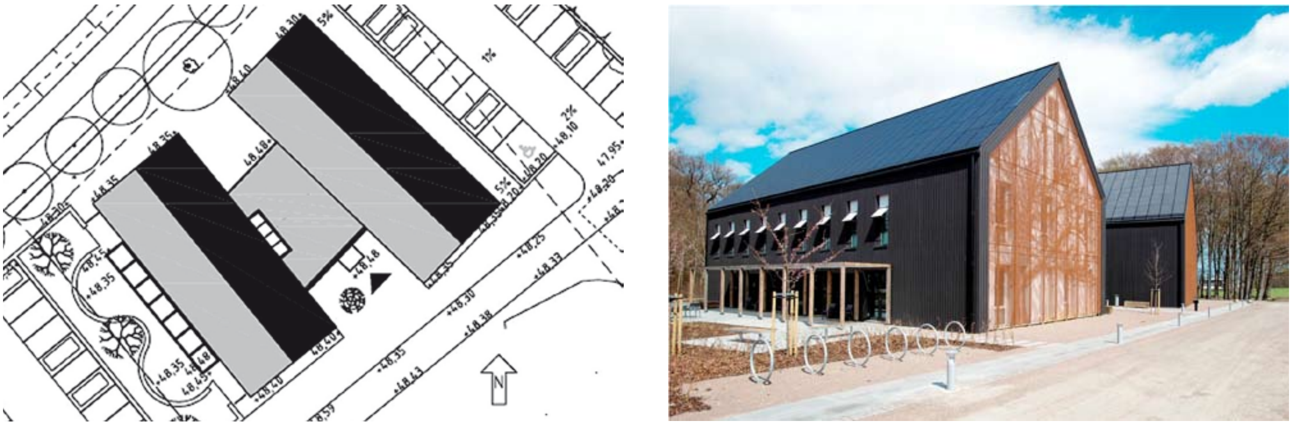

Figure 1. Left: Orientation of building. Right: Photo taken from the south. The overall design concept for energy efficiency follows the passive house design principle with a highly insulated and airtight building envelope and a balanced ventilation system with high heat recovery. Heat is produced by a geothermal heat pump and free-cooling is extracted from the bore holes during summer. Roof sides facing south west are equipped with PV panels. A summary of the building constructions is presented in ***Table 1***.

building and the grid. Further description and discussion may bee found in (Voss et al., 2010), (Salom et al., 2011), (Sartori et al., 2012), (Berggren et al., 2012) and (Salom et al., 2014).

Within this article electricity use is divided into two categories, according to definitions in the Swedish building regulations:

- Property energy
  Energy for heating, cooling, hot water and electricity for building services necessary for the use of the building (permanently installed lighting of common spaces, pumps, fans, etc.)
- Operational energy
  Energy for computers, copiers, TVs, refrigerators/freezers, lighting, etc.

The building and the building process

Väla Gård is a two-story office building in the outskirts of Helsingborg, Sweden. The project started in 2011, when Skanska Sweden started to plan and design an office building. The development consists of two three-level main buildings with double pitched roofs, connected by a smaller building with a flat roof, see **Figure 1**.

Skanska had a good opportunity to construct something really green as we had control of the whole building process being the developer, contractor, HVAC contractor and end-user, and having the specialists needed in-house. The architect was not from Skanska but won the job in competition, where the green ideas were important measures. The project could easily set, understand, share and agree upon the tough environ-

Table 1. Summary of building elements for Väla Gård.

Building element	Summary of construction	U-value (W/m²K)
Slab on ground	Concrete slab; 350 mm EPS	0.08
Exterior walls	Concrete walls; 200 mm Graphite EPS + 95 mm mineral wool	0.11
Double pitched roof	Glulam beam constructions; 520 mm mineral wool	0.08
Flat roof	Corrugated steel plate; 350 mm EPS + 20 mm mineral wool	0.10
Windows	Triple glazed lowE windows with argon filling	0.90
Glazed entrance	Triple glazed lowE windows with argon filling	1.00

mental and energy related goals, and this was used as a guiding light from the early phases until the user phase. The energy specialists had for instance the possibility to take part of the process early, make early calculations and give advice on the architectural design and other early choices. This has had a substantial effect on the energy performance. For example, the architect chose to design solar shading made of perforated Corten steel as a result of a dialogue about reducing the need for cooling. Concrete frame was chosen for increased air tightness and moisture control during construction.

Except for the net zero energy performance, Väla Gård is LEED-certified in Platinum with one of the world's highest score of 105 points. The extra investment for the technology, specialist support and work during production is about 3.4 million SEK or 2 050 SEK/m² (230 Euro/m²) compared to a house that is designed and built to just fulfil the national code. The estimated annual energy cost savings is 150 000 SEK or 17 000 Euro.

HVAC system and renewable energy

A detailed description and discussions about the building and its HVAC systems can be found in (Kempe 2013).

Ground source Heat Pump System

Heating and domestic hot water is produced by a ground source heat pump system with four variable speed heat pumps. The heat pumps are sized to produce more than the estimated peak load for the fully developed area with a total of four buildings, whereof Väla Gård office building is the first one.

Ventilation systems

The ventilation systems consist of air handling unit with a DCV (Demand Controlled Ventilation) system per building body, which is controlled by the presence, temperature and CO_2 in the conference rooms. The ventilation operation times are Mon- Fri 6–18. An example on the DCV air flow variations: 10 l/s with no one present, 25–50 l/s at presence, controlled by temperature and CO_2. The DCV system is controlled by the "Super Wise" and communicates with the air handling unit control, to optimize the duct pressure in the supply and extract air ducts and thus become more energy efficient. SFP for the AHU's has been very low during the winter, around 0.7 kW/(m³/s).

By separating the set points for heating and cooling with 2°C, the risk of simultaneous heating and cooling in the office is reduced.

Heating systems

Each of the two main building bodies has its own radiator system with a radiator shunt group in the AHU room. The radiator valves in the rooms are electrically controlled from the master air supply devices, which is part of the Super Wise system that controls the DCV-system.

Figure 2. The AHU in southern building body, LA1, with supply air duct in the bottom left of the picture with heating coil closest to the ventilation unit and then cooling coil. LA2 in the northern building body is similar.

Cooling systems

If there is a cooling demand in a room the air flow increases with cooled air in the room. If the supply air temperature is too high the cooling coil lowers the supply air temperature using free cooling from the bore holes in the ground source heat systems.

Operational electricity (Plug loads)

The lighting system consists of energy efficient light fixtures, which can be dimmed and controlled by presence and daylight. To minimize tenant electricity (reducing standby losses), the main part of the electrical outlets, plug loads, are turned off when the alarm is switched on. Furthermore, all appliances are at least A-rated. Refrigerator and Freezer is A++.

The photovoltaic system

Väla Gård photovoltaic plant has received The Swedish Solar Prize 2013 and Skåne Solar Award 2013. **Figure 3** shows two images: photovoltaic panel assembly in May 2012 and inverters in the AHU room.

Overall, it is mounted 288 solar modules of type Naps Saana 245 W with 5 inverters from SMA. Peak power for PV systems is 70 kWp and the calculated yearly power generation of 64,000 kWh.

Figure 3. Installation of photovoltaic modules on Building B (North Building) and inverters in the AHU room.

Theory

As mentioned in (Sartori et al., 2012) it is important to define and describe a Net ZEB in a transparent way, making it comparable with others. In **Table 2**, a summary of the Swedish definition of Net ZEB is presented (SCNH, 2012), following the framework presented in (Sartori et al., 2012).

The definition of Net ZEB in Skanskas Color Palette in general follows the Swedish definition. The main differences are the requirement for energy efficiency and LMGI. The requirement for energy efficiency is that the energy demand must be 25% lower compared to Swedish building regulations.

The LMGI-requirement is that LM should be calculated and presented. No specific level for LM is defined. Relevant terms, used in LMGI analysis are presented in **Figure 4**.

In all analyzes in this article, no weighting factors are applied. Hence, the building is an all electric building.

The temporal match between load and generation, LM, is investigated using the *load match index*, which describes the ratio of on-site power generation and load. The definition is described in **Equation 1**. When energy is fed into the grid, the load match index is 100%. Regarding the load match index, a high index is preferable if a high on-site coverage of the energy demand is desired.

To assess the interaction between the building and the electricity grid, the grid interaction, GI, is investigated. The grid interaction is based on the ratio between the net metering (e.g. exported - delivered energy) compared to the maximum exported - delivered energy over a given time period, as shown in **Equation 2**. The load match index and grid interaction may be calculated for different time intervals, e.g. hourly, daily, weekly, monthly and by year.

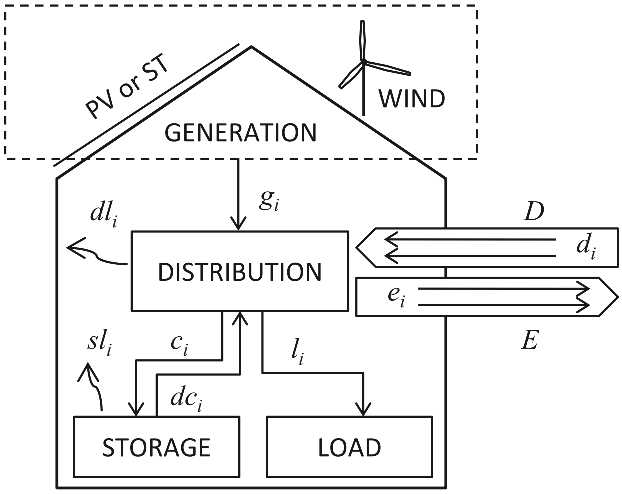

Figure 4. Schematic presentation of energy flows addressed in this article.

The average stress on the grid is investigated by calculating the grid interaction index. This is defined as the standard deviation of the grid interaction over the year, as shown in **Equation 3**. In this article the grid interaction index is not used as data does not cover a full year.

$$f_{load,i,T} = \min\left[1, \frac{g_i}{l_i}\right] \quad \textbf{Equation 1}$$

$$f_{grid,i,T} = \frac{(e_i - d_i)}{\max[e_i, d_i]} \quad \textbf{Equation 2}$$

$$f_{grid,year,T} = \mathrm{STD}(f_{grid,i,T}) \quad \textbf{Equation 3}$$

Measurements and data management

The Väla Gård control computer collects data to its OPC-server each minute from the installations systems and their meters, sensors etc. The data is sent to an external database in case the values have changed. This has several advantages; it saves memory, transmission capacity, but also creates a freedom in the evaluation, i.e. data time steps for analysis (1 minute, 5 minutes or hourly values).

Table 2. Summary of Swedish Net ZEB definition

Criteria	Swedish definition
Physical boundary	In accordance to the Swedish building regulations. Hence, in general, the physical boundary is the building itself.
Balance boundary	Energy used for heating, cooling and dehumidification, ventilation and humidification, hot water and permanently installed lighting of common spaces and utility rooms are included in the balance. Other services are not included in the balance (e.g. computers, copiers, TVs etc.).
Boundary conditions	Set point for heating (+21°C) and internal heat gains is defined.
Weighting system	Weighted energy is used, with static and symmetric weighting factors.
Balancing period	1 year.
Type of balance	Balance is calculated based on import/export.
Energy efficiency	Fulfilment of Swedish Passive house criterion.
Measurement and verification	To enable verification of the energy performance, energy metering must be separated into heat and electricity.

Currently, the detailed logging consists of 300 signals. There are increased indoor climate measurements in 17 rooms, 4 rooms per floor and the building body and the foyer, whereof 5 conference rooms. These increased measurements are room temperature, supply air temperature, CO_2, RH, supply air flow, presence, lighting control as well as control signal to radiators. There are also 19 signals per air handling unit, air flow, duct pressure, temperatures, and control signals to the fans, valves and heat exchangers, and 18 energy meters (electricity and heat), 18 air flows in the DCV systems, etc. and a lot of signals from the ground source heat pump system.

The measuring system was taken into use in spring 2013. From mid-February the building energies, was measured. The electricity meters for the PV-panels were taken into use April 26th and the tenant electricity meter was taken into use May 1st.

To get a prognosis of the annual energy profile, calculations were carried out for the six weeks between March 17th and the end of April, see **Figure 5**. PV-calculations have been carried out with PV Sol Expert and corrected hourly for actual solar radiation. An average operational energy profile measured in May was also used to fill the gap March 17th – April 30th.

Results and discussion

In **Figure 5**, the measured energy profile is displayed The PV-panels give almost no energy in the end of January 2014, due to the almost complete lack of sunshine.

In **Figure 6**, results from simulations are presented together with results from measurements. The wider columns represent the measured data and the narrow bars the results from simulation. The results from the measurements have not been normalized for disparities between outdoor climate and user profile, set in the simulation.

As can be seen, the total energy use (solar energy used directly + imported energy) are in general lower than simulated. Less solar energy is used on site compared to simulated and more energy is exported than expected. The performance of the PV panels is close to expected. The simulated electricity generation during the period is 35 323 kWh, which may be compared to measured electricity generation: 35 546 kWh. Hence, the main reason for the lower solar energy used on site and higher exported solar energy is most likely due to that the energy use is lower than expected.

In **Figure 7**, the load match is analyzed, both on hourly basis and on weekly basis. Load match is presented both including and excluding operational energy.

The analysis clearly shows the complexity of the interaction between the load and generation. There are, except for a short period in January, periods every day where the load match is 100% and 0%. Analyzing the load match on a weekly basis, shows that the generation from the PV panels may cover the load from the building throughout the summer until somewhere in October/November,

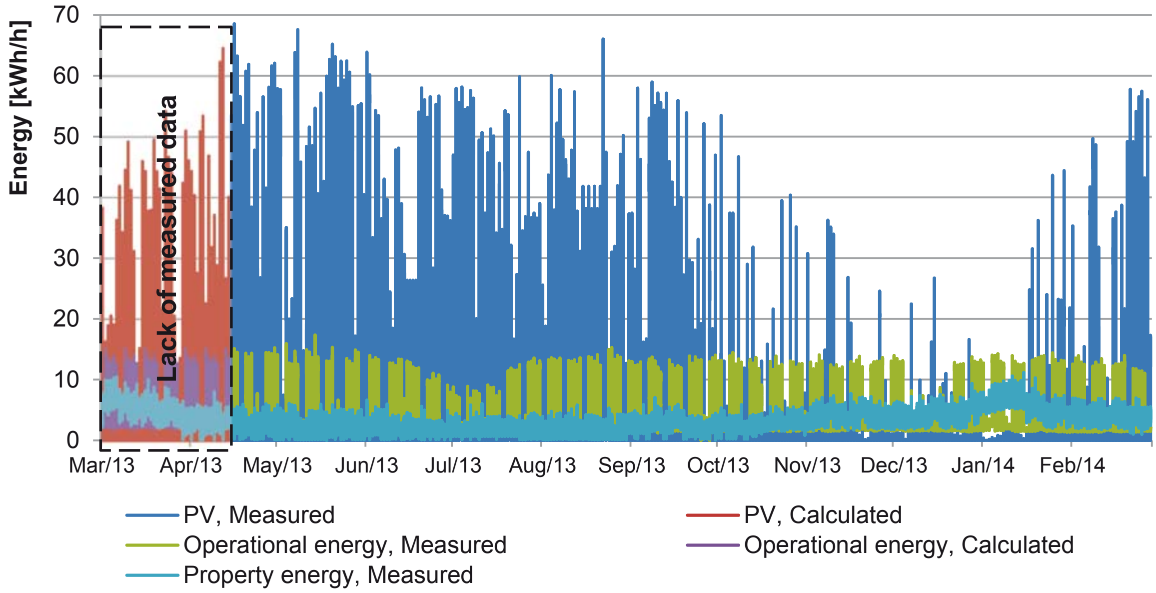

Figure 5. PV, operational and building energy [kWh/h]. Measured data for building energy: 17 March 2013 – 16 March 2014. Measured data for PV and operational energy: 1 May 2013 – 16 March 2014. Simulated data for PV and operational energy to fill-in the gap: 17 March to 1 May 2013.

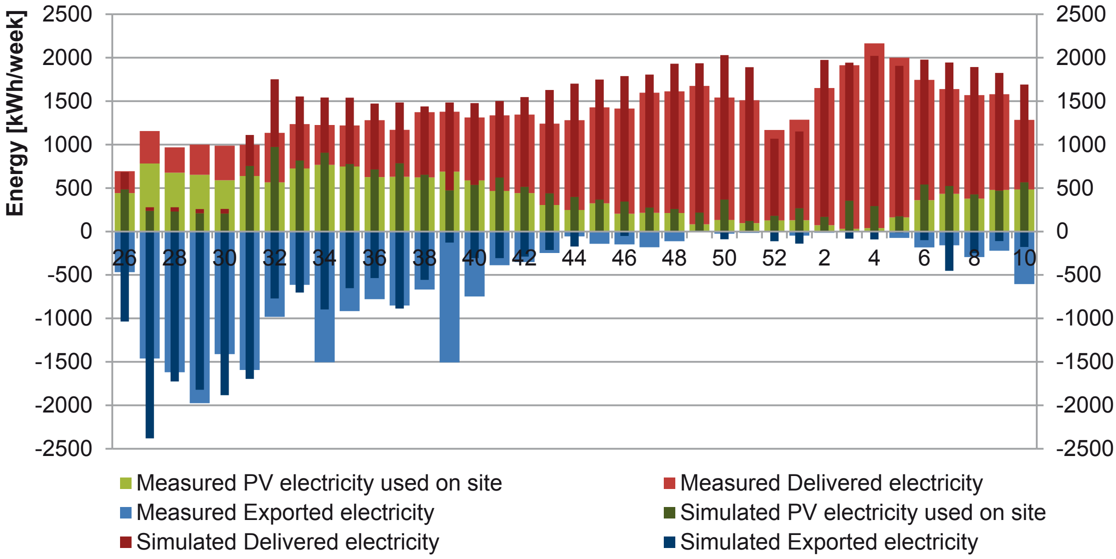

Figure 6. Results from simulation and measurement.

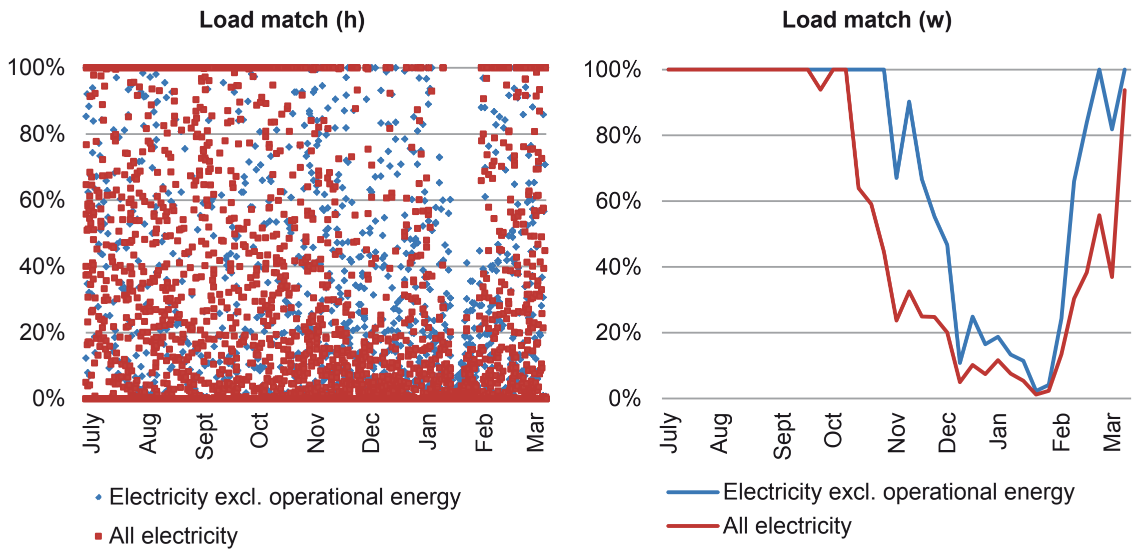

Figure 7. The load match i.e. the percentage of on-site power generation compared to energy load [%] for measured data (1 May 2013 – 16 March 2014).

Table 3. Prognosis of annual power generation and energy use. Measured data for building energy: 17 March 2013 – 16 March 2014. Measured data for PV and operational energy: 1 May 2013 – 16 March 2014. Fill-in simulated data for PV and operational energy: 17 March to 1 May 2013.

	PV	Building	Tenant
kWh	66 678	29 222	44 447
kWh/Atemp	38.10	16.70	25.40

depending on whether operational energy is included or not. The differences between the load match, whether operational energy is included or not, are rather small.

In **Figure 8**, representative/characteristic weeks for summer and winter are shown. The generated electricity from PV panels and energy use during the same period is presented in **Table 4**. The load match for the corresponding period is presented in **Figure 9**.

As can be seen, during summer the building would easily be able to cover its own load by electricity from PV panels if a one-day energy storage would be used/

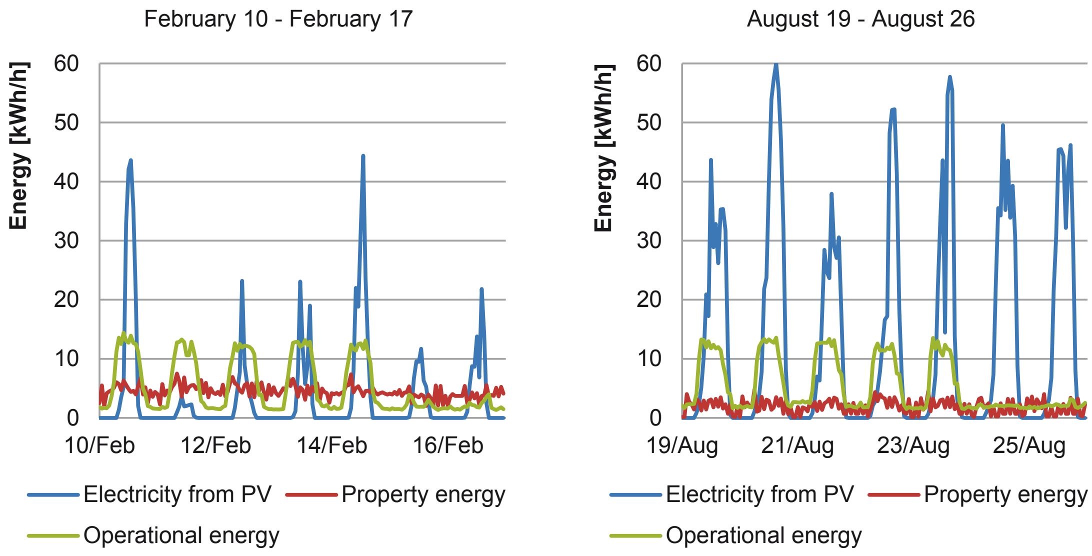

Figure 8. Representative weeks for winter profile (20140210-20140217) and summer profile (20130819-20130826) for PV, operational and building energy [kWh/h]

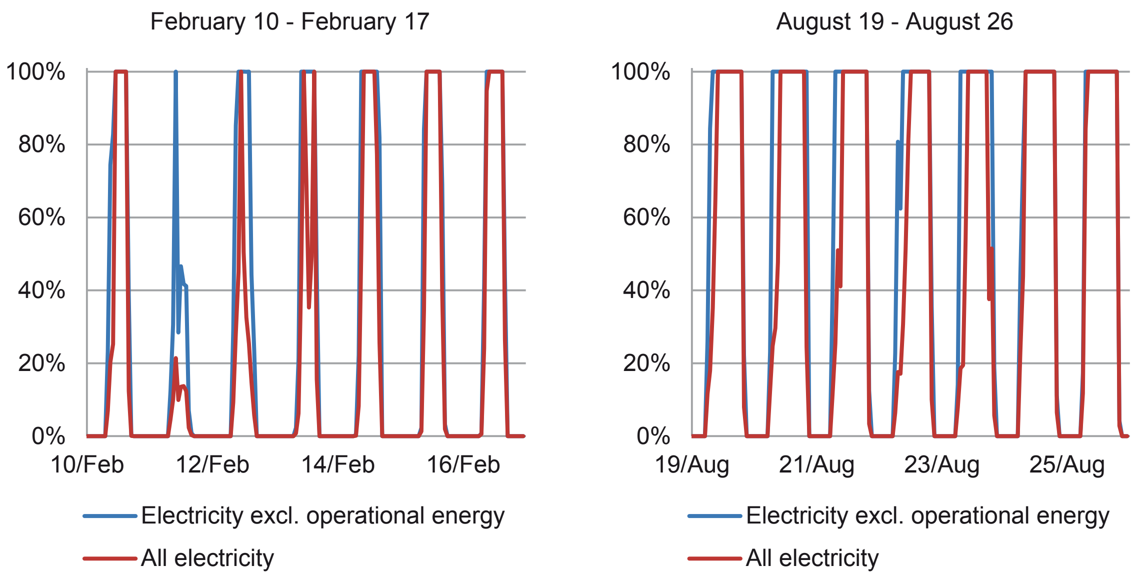

Figure 9. The load match of two representative weeks, in winter (20140210-20140217) and summer (20130819-20130826) i.e. the ratio of on-site power generation and energy load, where full ratio means full coverage of energy load with generated energy.

implemented. During winter there is a need to import electricity. However, even during winter electricity is exported.

Analysing the load match, the load match is during noon 100% both during a representative winter day and summer day. However, the period of 100% load match is shorter during winter.

Analysing the grid interaction, as shown in **Figure 10**, the complexity of the interaction between import and

Table 4. Representative weeks for winter (20140210-20140217) and summer (20130819-20130826) showing energy generation, energy loads and energy balance [kWh].

Period	Generated electricity, PV panels (kWh)	All energy excluding operational energy (kWh)	Operational energy (kWh)	Balance (kWh)
Feb 10 – Feb 17	644	752	895	–1 003
Aug 19 – Aug 26	2 277	318	907	1 052

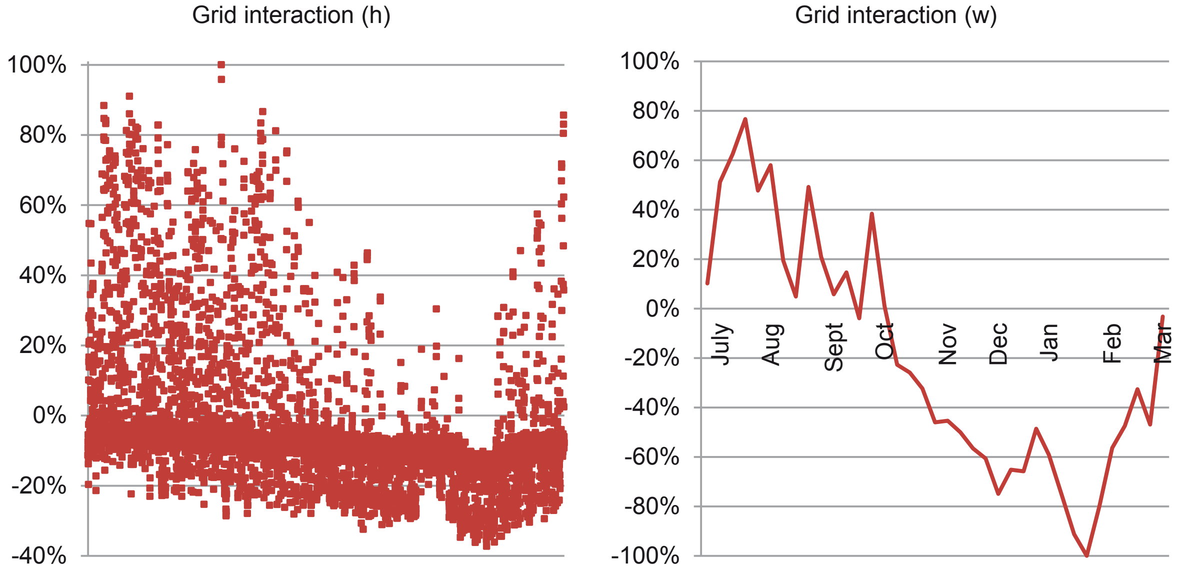

Figure 10. Grid interaction on an hourly and weekly basis.

export is shown. Electricity is imported and exported several times a day. Analysing the grid interaction on a weekly basis shows that the stress to the grid could be lower and more predictable if a one-week energy storage could be used/implemented.

The prognosed energy performance indicate a very good match between simulated and measured data and that Väla Gård performs well, resulting in a net ZEB performance including operational energy.

From an economic point of view, the investment is paid back within the guaranteed life span of the PV-panels, even with a rate of return for the investment of 7% (net rate). With very varying prices on electricity and changing conditions for exporting and selling electricity it is not possible to give a precise prediction of the net value-based break-even of the investment. However, it can be noted that with a net-metering system in Sweden, Väla Gård would have been an even better investment.

Lessons learned from the project are the importance of early involvement from energy experts and an overall energy plan for implementation, control, follow-up and optimisation. Meetings with the facility manager to check the energy status is essential for finding faulty components etc. From an economic point of view, Väla Gård is good business for Skanska, resulting in lower rental cost compared to our old office in Helsingborg. It has raised the awareness of Net ZEB buildings, giving us experiences and inspiration to develop and construct other Deep Green buildings. It is also an excellent reference building for showing our customers what Skanska wants and foresees in the future.

Acknowledgements

The Väla Gård project received financial support from LÅGAN – Sweden's program for buildings with very low energy use, for evaluating the energy system and indoor environment for the first few years of operation. ■

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Figure 1. The first neZEH selected showcase: the Boutiquehotel Stadthalle in Vienna.

An existing best practice of nearly Zero Energy Hotel

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The paper presents the design concept and the energy consumptions of one of the few nearly zero energy city hotels in Europe, the Boutiquehotel Stadthalle in Vienna. The provided information resulted from meetings and questionnaires to the hotel, which was interviewed as best practice in the neZEH project.

Keywords: neZEH, nZEB, hotel, refurbishment project, sustainable design.

Showcasing existing best practices of nearly Zero Energy Hotels is one of the activities undertaken by REHVA as a partner of the IEE founded project neZEH*. Aim of this task is to provide hoteliers with the direct evidence that the

* **Nearly Zero Energy Hotels (neZEH)** is a 3-years long project supported by the Intelligent Energy Europe (IEE) program started in April 2013, involving a consortium of 7 European Countries (Croatia, France, Greece, Italy, Romania, Spain, Sweden) and 10 partners. The project aims at accelerating the refurbishment rate of existing buildings into nZEB in the hospitality sector and promoting the front runners. Focusing particularly on the SME hotels. http://www.nezeh.eu/

nearly zero energy level is an achievable and profitable target for hotels.

To show to potential pilot project's initiators a complete overview of the best practices refurbishment process, information concerning both the economic and technical features are asked to the showcases, structured as a questionnaire for the technical and quantitative questions and as an interview for economical and qualitative aspects.

The first hotel selected as a showcase was the Boutiquehotel Stadthalle in Vienna (**Figure 1**) and the derived information are reported in the following paper. In this hotel the nZEB level is reached in the newly built "passive building", which became the world's first example of nearly zero energy city hotel.

The Hotel

Boutiquehotel Stadthalle is a three star hotel in Vienna, which became the first city hotel with a nearly zero energy balance thanks to its manager's strong commitment to environmental issues. The whole structure is formed by an apartment building of the beginning of 19^{th} century and a newly built passive building. The hotel renovation process began in 2001, when Michaela Reitterer, current owner and manager, bought the 19^{th} century hotel building and started to refurbish it. To comply with Ms Reitterer higher goals, in 2009, new works started to couple the renovated existing building with the new passive house, a nearly zero energy building, which was completed by the beginning of 2010. The additional building's installed technologies allowed it to reach a nearly zero energy balance.

The hotel has 79 guestrooms in total, 41 in the old building and 38 in the passive house, and does not offer extra facilities apart from a lounge bar. In accordance with what was defined as "typical energy use of a hotel" in the neZEH project, the latter aspect allows to consider all the energy consumptions of the Boutiquehotel Stadthalle in the nearly zero energy balance.

Table 1 displays the main data about the hotel.

The energy system

Different energy systems are installed in the "old" building and the passive house. While the refurbished 19^{th} century building mainly uses district heating and has no cooling and active ventilation systems, the new section is equipped with a groundwater heat pump for heating and cooling, used for the concrete core activation, and with controlled air room ventilation (only ventilation, no air conditioning).

An in-house well serves as cooling source and provides groundwater to the heat pump, powered by a 13 kWpeak photovoltaic system (93 m^2). In addition, 130 m^2 of solar thermal panels are used to produce domestic hot water for the whole hotel, as well as to pre-heat the fresh air through the ventilation system, which achieves over 90% heat recovery, as conceptually schematized in **Figure 2**.

Table 1. Hotel's main information.

Name	Boutiquehotel Stadthalle
Location	Hackengasse 20, Wien
Type of hotel	Urban
Owner	Michaela Reitterer
Floor area	2.271 m^2
Floors	4 (existing building) – 5 (passive house)
Guest rooms area	1.316 m^2
Guest rooms	79 (41 in existing building + 38 in passive house)
Guest beds	156
Offered facilities	Lounge bar
Total refurbishment costs	5.200.000 € approx.
Refurbishment cost	2.290 €/m^2 approx.

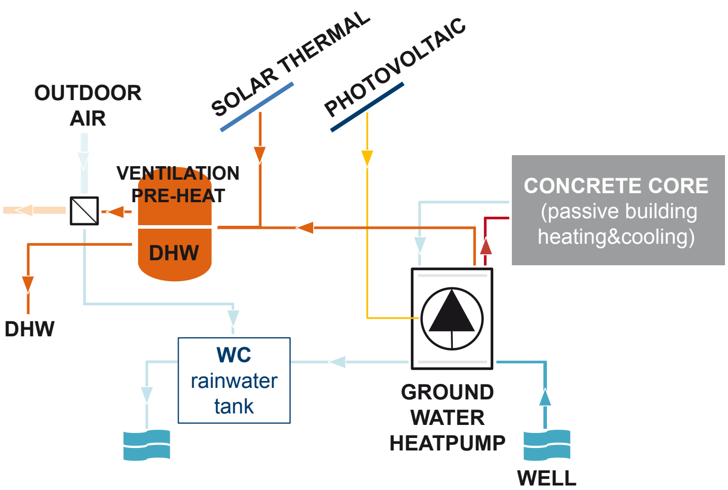

Figure 2. Conceptual scheme of the heating&cooling system and of the domestic hot water production.

The electricity needs for auxiliary systems, appliances and lighting not covered by the PV plant are currently supplied by the electricity grid, but 3 wind turbines are waiting for the permission of authorities for being installed on the building roof.

The hotel energy system is summarized in **Figure 3**.

The building plants are managed by a Building Automation and Control System (BACS): programmable automation controllers help maintaining the right balance between guest comfort and energy savings by monitoring and enabling the regulation of heating and ventilation based on actual demand or pre-defined schedules. The system also controls and monitors the concrete core activation, water heating, the solar panel system, buffer management and the groundwater heat pump.

The energy consumptions

The amount of measured delivered energy in the past three years by the Boutiquehotel Stadthalle is reported in **Table 2.**

To obtain primary energy, the proper primary energy factors are applied to the average yearly heat and electricity consumptions. The European non-renewable primary energy factors set by the latest version of standard FprEN15603:2014 are used: 1.30 for district heating, 2.30 for grid electricity. The obtained primary energy performance for the whole hotel (existing building and passive building) is shown in **Table 3**. The energy factor for the passive building, taking only electricity from the energy grid, is derived by applying a factor taking into account the different dimensions (number of rooms) of the old and the new constructions. With these premises, the calculated primary

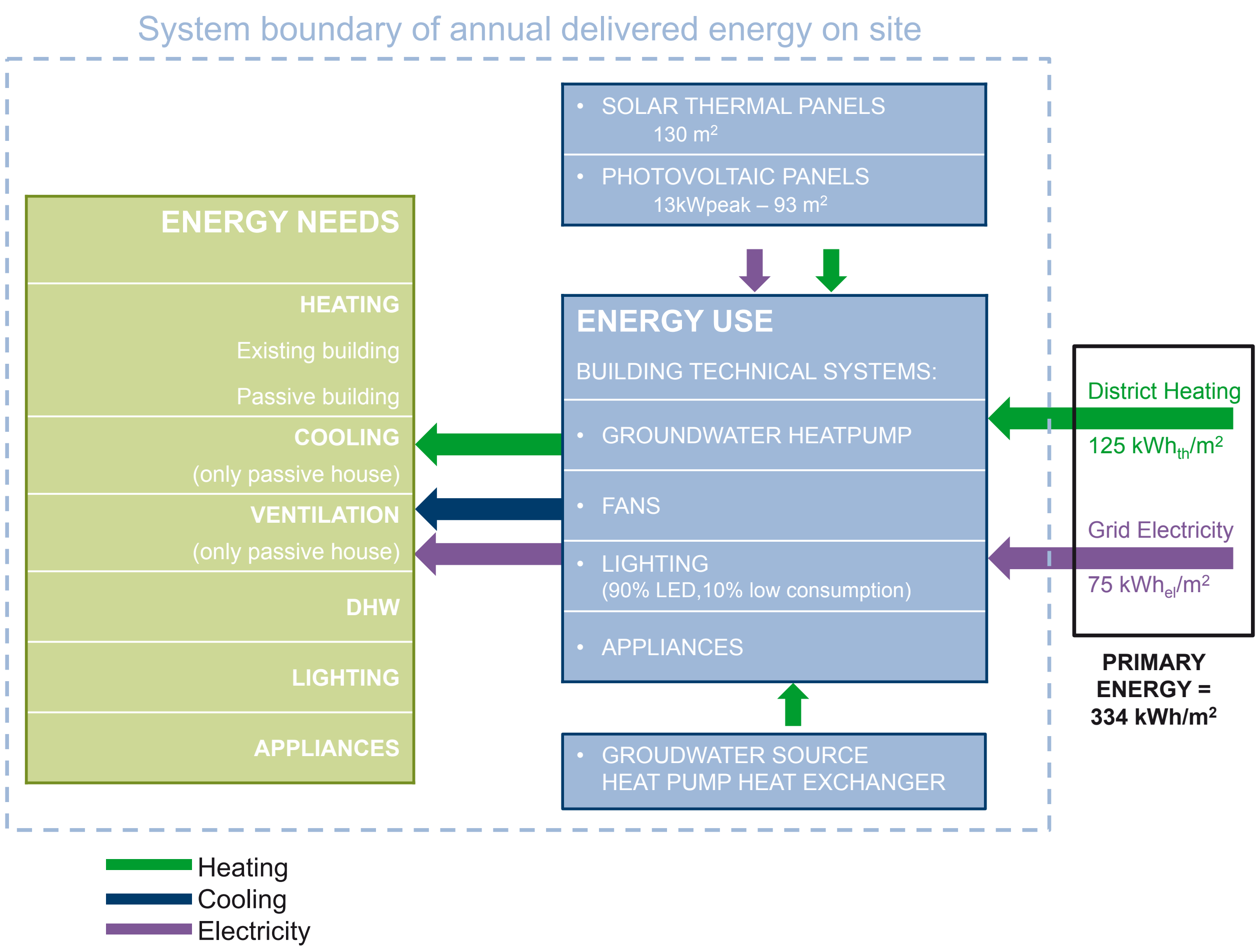

Figure 3. Scheme of the Boutiquehotel Stadthalle energy system.

Table 2. Energy delivered to the building in 2010, 2011, 2012.

		Amount of energy use				Type of energy use									
		Total (0*+P**)		0*	P**	Heating		Ventilation		DHW		Lighting		Appliances	
Source	Year	kWh_{th}	kWh_{el}	%	%	0*	P**	0*	P**	0*	P**	0*	P**	0*	P**
District heating	2010	301.700		100 approx.	0 approx.	x				x					
	2011	263.100				x				x					
	2012	287.300				x				x					
Electricity grid	2010		170.200	65 approx.	35 approx.		x		x			x	x	x	x
	2011		159.500				x		x			x	x	x	x
	2012		177.100				x		x			x	x	x	x

*0 = old building **P= passive building

Table 3. Primary energy factor calculation for Boutiquehotel Stadthalle.

	Average yearly consumption		Non-renewable primary energy factor	Primary energy		Primary energy for heating, cooling, domestic hot water, HVAC aux, lighting	
				Whole hotel	Passive building	Whole hotel	Passive building
Source	kWh	kWh/m^2	–	kWh/m^2y		kWh/m^2y	
District Heating	284.033	125	1.3	163	0	163	
Grid Electricity	168.933	74	2.3	171	124	155	108
			Total	**334**	**124**	**318**	**108**

energy consumption of the passive building only is approximately 124 kWh/m²y.

The gap in primary energy factors obtained for the whole building and for the passive building only reflects the different level of retrofit actions undertaken. In the passive house, where the goal set from the very beginning of the design phase was the zero-energy balance, the primary energy use including energy uses for heating, cooling, domestic hot water, HVAC aux and lighting, 108 kWh/m²y, is in line with the reference value defined in the context of the neZEH project for Western Europe countries (zone 3 in **Table 4**), presented in REHVA Journal January issue. The primary energy use for the listed energy uses was derived by reducing the total primary energy of the appliances contribution (7 kWh/m² weighted by the primary energy factor).

Other sustainable features

The energy systems of the hotel are only part of the sustainable strategy adopted by the hotel, which strives to contribute to lower the environmental impact of the tourism business by implementing a wide range of measures.

Lighting. In order to reduce the hotel lighting power use, the 90% of the light sources are LED and the remaining 10% are low consumption bulbs. Moreover, lighting is automatically controlled by sensors in public spaces, while in guest rooms lighting is governed by the room badge presence in the dedicated fold.

Water. Water saving measures were undertaken from the very beginning of the renovation process, in 2001, when cisterns were installed to store rainwater and use it for toilets and the garden. Additional water savings methods were implemented in the new passive building, in which also the cold well-water is used instead of the rainwater to flush toilets.

Food. Despite being breakfast the only meal served at the hotel, the food policy undertaken by the hotel plays an important role in the holistic green vision of the hotel manager: the products served are either local or organic, or both local and organic.

Table 4. Summary of the requirements for nearly zero energy hotels in Europe proposed by neZEH.

Zone	EP [kWh/m^2*y]	Energy uses
Zone 1	55	Heating, cooling, domestic hot water, HVAC aux, lighting
Zone 2	60	
Zone 3	95	
Zone 4	115	

Transport. In the effort of promoting the use of low emissions means of transport, the hotel provides a 10% discount to guests coming by train or bike, a free bicicle garage and free of charge recharge for guests' electric vehicles.

Education. Accordingly with the strong motivation and environmental concerns of the hotel manager, the education of guests is among the main goals pursued. The hotel provides to guests an example of how it is possible to have a zero energy building by informing them directly in their rooms: green points with explanation of the adopted green solutions are placed next to the corresponding point of use. Moreover, to check the indoor environmental quality level in a nZEB, "test sleeping" are arranged for interested parties in the passive house. Beside the education for guests, training courses are organized for staff members.

Waste management. A strict waste prevention (e.g. biodegradable cleaning supplies) and separation policy is implemented in the hotel and recycled fabrics are used in guestrooms.

Certifications. The hotel obtained the EU-Ecolabel certification in 2007, before the construction of the new passive building. Together with a few other hotels in German speaking countries, it is now founder of the Sleep Green Hotels network.

The economical side

Investment. Achieving the nZEB status took a significant financial effort: a reckoning of the investment costs, provided by the hotel manager and owner during the interview, highlighted that the total cost of the intervention from 2008 to 2010 exceeded 5 million euros. The first measures undertaken for achieving energy efficiency in the existing building accounted for more than 1 million euros, while the second part of the project, the passive house, cost approximately 4.2 million euros.

In this case, however, it must be highlighted that the consistent investment is not merely related to the energy retrofit, but also to the additional costs entailed by providing a sustainable and high quality indoor environment to guests (e.g. factors related to the hotel interior design).

Because of the financial crash of 2008, the extension of the hotel with the construction of the passive house did not receive any finance from Austrian banks except the furniture which was by the Austrian Tourism bank. The renovation was financed through a lease–back scheme according to which the hotel is going to be purchased back by the manager/owner.

Benefits. Despite the considerable risk assumed, the manager's choices were successful. Even if the Return of Investment was not a considered economic index by Ms. Reitterer, whose main purpose was to put in practice her green believes, her commitment proved to be not only a way to reduce the hotel operation costs, but also a choice appreciated by the market. Even if not providing figures, the manager affirmed that the return of investment came back faster than expected. In fact reaching the nZEB status, complementary with the other green actions engaged, entailed on the one side a lot of free visibility and media exposure, and on the other side opened the doors to a completely new target of guests and to a special market sector, enabling the hotel to keep both high room rates and high and constant occupancy rates (average yearly occupancy rate of 82% in 2012).

Conclusions

Achieving the nearly zero energy status in the Boutiquehotel Stadthalle was a result obtained by its manager and owner when the recast of the Energy Performance of Buildings Directive was not even in place. It required strong motivation and consistent economical efforts, very far from the cost-optimal level of energy requirements nowadays suggested by the EBPD recast. Nevertheless it proved to be a successful strategy, both in terms of achieved energy performance and of market appreciation. The Hotel Stadthalle became the first example of nearly zero energy urban hotel, with a primary energy factor of 108 kWh/m²y in the passive building, which is in line with the preliminary benchmarks for hotels primary energy use defined by the neZEH project. ■

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High performance logistics centre in upper Austria

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The Austrian company Schachinger Logistik's new logistics park in Hörsching, Upper Austria, is one of Europe's most sustainable high-bay warehouses. The 11,790 m² wood construction, called "Lighthouse 1" (LT1), complies with passive building standards. Planned and implemented by Poppe*Prehal Architekten in a time span of only one year, the project has already received various awards.

Keywords: Nearly Zero Energy Building, passive building, logistics, new build, Upper Austria, wood construction, industrial building.

High thermal quality and energy efficiency lowered the building's energy demand by 60% compared to some of Schachinger's other standing infrastructure. The project's overall investment of around 9 million Euro represents only 6% additional costs over conventionally-built similar buildings. By making building ecology, energy efficiency, job quality and cost savings equal planning pillars throughout the whole project, LT1 has become an ecological and economic flagship project in the logistics industry.

Main entrance of the office wing and delivery area.

Since its inauguration in September 2013, the logistic park has been in full function – serving as a central warehouse for Metro Österreich (Cash and Carry Wholesale), Schachinger's cooperation partner.

About Schachinger

Founded in 1939, *Schachinger Logistik*'s is an Austrian family-owned business with headquarters in Hörsching, Upper Austria. The company owns a fleet of 100 transportation vehicles and an aggregate of 400,000 m² of floor area, 200,000 m² of which are storage area.

Schachinger has an annual turnover of around 181 million Euro and employs over 500 people throughout its 15 locations in Austria, Hungary, Czech Republic, Slovenia and Croatia. The LT1 project was an initiative of Max Schachinger, one of the company's managing directors.

Project objectives and pillars

Maximum use of environment-friendly materials, high functionality and high energy efficiency were main objectives of the LT1 project. The goals were achieved through a combination of environmentally-friendly building materials, state-of-the-art technologies and the consideration of building biology principles.

Ecological building materials

Life-cycle cost analysis was made an integrated part of the project. Already in the preliminary planning phase, the project leaders worked with a specialist to define minimal requirements of all building materials that could be used in the construction. These requirements were included in all of the project's tenders. They were also considered in the selection for the professionals and companies that worked on the project. Furthermore, particular attention was paid to the choice of energy mix that would support LT1's operations.

Process efficiency

Assuring high functionality and minimising the building's future operational costs were main focal points. Applied measures include: maximum use of the building's height, optimal shelf height for palletted merchandise, aisle and corridor width tailored to individual purposes, minimised transportation distance between the loading docks and storage shelves, and the construction of an intermediate level/mezzanine to permit co-packing.

Energy efficiency

Achieving very high energy efficiency was considered as equally important as assuring smooth business operations. Storing food in logistic halls requires specific climatic conditions, namely in this case, 14–18°C and 40–60% relative humidity. The merchandise often arrives at different temperatures than that at which it is stored – resulting in significant extra heating or cooling demands. The building's design and the choice of materials and technical systems needed to maintain these parameters in spite of the location's daily product turnover of around 400 tonnes. This represented an important challenge for the architects.

LT1, which complies with passive building standards, has an energy performance indicator for heating (heating energy demand) of 8.9 kWh/m² (office wing). This was achieved through a combination of high thermal properties of the building envelope and efficient energy systems.

Interior of the warehouse with a detailed view of the wood structure.

East façade with its barcode-like appearance.

A 400 kWp roof-top photovoltaic-system will be installed in 2014. This will permit on-site generation of around 65% of the building's 510 MWh yearly electricity consumption. Purchased eco-electricity will supply the remaining 35% of the electricity demand – resulting in 100% coverage of the electricity demand through renewable sources.

Architectural design

Building characteristics

The total construction covers 11,790 m². The 9,440 m² and 14 m high warehouse can store around 20,000 pallets. It is accompanied by a 1,490 m² assembly/distribution area. The climate in the warehouse is maintained between 14–18° C and 40–60% relative humity. The building also houses 860 m² of office space in its 3-storey office wing.

The entire project, including the conceptual exterior design, is the work of the Upper Austrian architectural company Poppe*Prehal (www.poppeprehal.at). One of the building's destinctive features is the outer fassade's barcode-like appearance – representing how barcodes are an essential part in the logistics process.

Main structure and building shell

Wood construction was chosen for wood's carbon-neutral characteristics. Untreated wood from indigenous species (spruce and silver fir) and low-carbon cement were used. The flooring has Cradle-to-Cradle® certification. The laminated timber flat roof with massive wood supports is insulated with 28 cm of mineral wool. A water-tight finishing was achieved with an EPDM foil. Outer walls were erected in lightweight timber construction and contain 24 cm of mineral wool. All windows consist of high-quality triple-glazed windows with wood-aluminium frame. As shown in the **Table 1**, U-values greatly superior to those required by Upper Austrian building regulations were achieved. Inflatable door seals at the docking stations also enabled to reach a very high airtightness (blower-door results exceed minimal requirement by 30%).

Technical systems

Cooling is partly achieved by taking advantage of natural ventilation. When outdoor conditions are suitable, the controlled ventilation automatically switches to free-cooling. The remaining cooling demand is covered through cold supplied from the groundwater by means of a heat pump (~ 70%) and free-cooling circuit (~ 30%). The free-cooling circuit permits the direct use of the already cold groundwater.

Heating demand is supplied by two ground water source heat pumps. Heat is distributed to the ambient air through trench heaters in the office wing and recirculating air heaters in the storage area.

Heat and moisture recovery through a rotary heat exchanger increases the building's overall energy efficiency and regulates the indoor air parameters – helping to prevent dryness in winter. Periodic activation of ceiling fans in the warehouse move the air and prevent temperature layering.

The building's indoor lighting system (office wing and storage hall) is mostly equiped with daylight- and demand-controlled LED lamps. The use of LED-technology helps minimise the building's cooling demand. Windows are equipped with automatic blinds.

Interior finishing

The company's vision of an environmentally and worker friendly construction did not stop at the building shell and technical systems. The interior installations and design were also thought out for their energy efficiency and user friendliness. All working stations were designed according to ergonomic and EPD (Environmental Product Declarations) criteria. The height-adjustable tables and stools were purchased from regional producers. Numerous windows permit employees to enjoy the surrounding landscape and follow natural day-lighting phases, the interior colour-scheme follows Feng Shui design and waterless and CO_2-neutral-produced urinals were installed in the washrooms.

Table 1. U-values of LT1 and, in comparison, the minimum legal building requirements. (Oö. Bautechnikverordung 2013)

	U-Value [W/m²K]	
	LT1	**Legal building requirements**
Exterior walls – warehouse	0.14	0.35
Exterior walls – office wing	0.185	0.35
Roof – office wing	0.141	0.20
Windows – office wing	0.84	1.70

Energy savings and investments cost

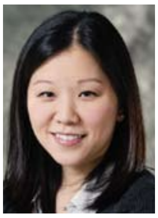
The construction and design of LT1 permits significant energy- and CO_2-savings. Its energy demand (prorated to building area) lays 60% below that of Schachinger's conventionally-built building in Stockerau (built in 2008). The new building is also completely supplied by renewable energy sources. Overall, this represents a saving of approximately 400 tonnes of CO_2 per year.

Overall investment cost, including planning, construction and interior installations amounted to around 9 million Euro. In spite of the building's extensive NZEB measures, this represents only 6% additional costs (when compared to the construction costs of Schachinger's most recent conventional building with similar layout).

Conclusion

LT1 has become an ecological and economic flagship project in the logistics industry. It demonstrates that high energy-efficiency is achievable in large-scale industrial construction. Requiring only 6% higher investments costs than a similar conventional construction, this project is an example of how long term energy and CO_2 savings can be ensured with little additional investment costs. The project was awarded, among others, the 2014 Upper Austrian Energie-Star – the Upper Austrian award for sustainable energy projects. ■

Indoor air quality specifications for a net zero energy research home



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Net Zero Energy Research Test Facility (NZERTF) at NIST.

A Net Zero Energy Residential Test Facility (NZERTF) has been constructed at the National Institute of Standards and Technology in Gaithersburg, Maryland. The facility is currently being used to demonstrate that a home similar in size, aesthetics, and amenities to those in the surrounding communities can generate as much energy as it consumes on an annual basis, while meeting the needs of a family of four. The facility will subsequently serve as a test bed to facilitate the development and improvement of methods of test and performance metrics for existing and future energy efficiency technologies (1).

The energy goals of the NZERTF are addressed by a combination of a well-insulated and airtight building envelope, efficient heating and cooling equipment, and the use of solar thermal and PV systems. In addition, ventilation and indoor air quality (IAQ) issues were addressed in the design of the building through a balanced mechanical ventilation system with heat recovery and detailed specifications for low-emitting building materials. A measurement program has been implemented to verify that the IAQ and ventilation goals are being achieved. These measurements include envelope airtightness, ventilation system airflow rates, thermal comfort, and the concentrations of volatile organic compounds (VOC) including aldehydes. This article describes the design of the building, with a focus on the ventilation and IAQ requirements, and discusses the measurements to verify that the ventilation and IAQ goals are being achieved.

The NZERTF is located just outside of Washington DC, which has a climate characterized by hot and humid summers and mild winters. The mean temperatures in January and July are 2.2 °C and 26.7 °C respectively. The house itself is unoccupied and unfurnished, but it is configured to contain a family of four with devices to simulate their heat and moisture output as well as the operation of lights, appliances and typical plug loads. Note that airborne contaminants emitted by the occupants, such as carbon dioxide and particles, are not simulated.

The NZERTF was designed and constructed with the following objectives: (1) demonstrate net-zero energy over one year in a home that is typical for the surrounding community; (2) provide high-quality field measurements to validate and improve models of building energy use, equipment performance and other environmental attributes; (3) serve as a test bed for measuring the performance of building components and systems; and, (4) improve laboratory test procedures for these components and systems to better predict whole building performance. The design principles for the facility were established early in the project and are as follows:

- building enclosure to minimize heat loss/gain
- locate all heating/cooling equipment within the conditioned space
- use energy efficient appliances and space-conditioning equipment
- design the house as a system, not as a collection of individual components
- meet energy requirements with renewables
- provide good IAQ.

It is the last principle, design for good IAQ, which is covered in this article.

As the building community pushes for buildings that use less energy and have reduced environmental impact, it is important to bear in mind that buildings are built for the occupants to live, work, learn and conduct other activities. Reducing energy use, to the detriment of the indoor environment, detracts from the real purpose of a building. Also, reduced productivity and higher health care expenses typically cost more than the savings from reduced energy use (2).

In order to provide a high-quality indoor environment within the NZERTF, two fundamental principles were employed: "Build tight, ventilation right" and contaminant source control. The first principle was pursued by constructing the building with a tight exterior envelope. While this approach is not new, particularly in northern Europe, the U.S. is still catching up with the latest airtightness construction practice (3). The goal for this house was that it be extremely airtight, for a U.S. home, through the use of a continuous air barrier system. Detailed specifications for the air barrier were developed by the design team with a goal that it have an air change rate of less than 1 air change per hour at 50 Pa as measured with a whole house pressurization test. The design team worked closely with the contractors to make sure they understood this goal and the envelope construction details required to make it happen. As part of this effort, quality control pressurization tests were performed during construction as shown in **Figure 1**.

In order to ventilate right, the house was designed to comply with ASHRAE Standard 62.2-2010 (4). For this house, Standard 62.2 requires an outdoor air ventilation rate of 37 L/s as well as 25 L/s of continuous exhaust in each bathroom and 50 L/s of intermittent exhaust capacity in the kitchen. The whole house ventilation rate was provided with a heat recovery ventilator (HRV) that supplied air to the bedrooms and first floor living area and exhausted it from the bathrooms. The HRV does not provide for humidity transfer between the incoming and outgoing airstreams in order to better control the indoor humidity. The space conditioning system employs MERV 9 particle filters rated per ASHRAE Standard 52.2 (5), though Standard 62.2 only requires MERV 6 filters. In addition, the house was built to be resistant to radon entry consistent with local building codes.

In order to address the IAQ goals for the house, detailed specifications were developed for the materials used in its construction. These included limits on the VOC content of adhesives and sealants, attaching the interior wall board with mechanical fasteners instead of adhesives, requiring VOC emissions reports for insulation, and not allowing any added urea formaldehyde in the building materials. In addition, any substitutions suggested by the contractor were reviewed for their acceptability in terms of IAQ impacts.

Figure 1. NZERTF prepared for a quality control airtightness test (Note that windows openings are covered to measure tightness of only the opaque portions of the building envelope).

These design goals and specifications were intended to provide a well-ventilated indoor environment with low contaminant levels (1). However, it is well known that design intent is not always realized in practice once a building is constructed and in operation. Therefore, a series of measurements are being performed in the house to verify its actual performance. These measurements include envelope airtightness, ventilation rates, thermal comfort, radon and VOC levels. Envelope airtightness was measured using a whole house pressurization test, which resulted in a value of about 0.6 air changes per hour at a pressure difference of 50 Pa. This is below the value in the house's design specifications and is very tight for U.S. homes.

Airflows are being measured in the HRV by performing air speed traverses with a hot wire anemometer in the four airstreams of the device: incoming outdoor air, supply air to the space, return air from the space, and exhaust air to the outdoors. Due to limitations in the ability to set the HRV fan speeds and flow rates, the actual airflow rate is roughly 47 L/s, which is about 20% higher than the minimum requirement based on ASHRAE Standard 62.2. This flow rate has been measured approximately monthly since the house first became operational in late 2012. It was found that the airflow rate become significantly lower over time due to the clogging of the HRV filters with outdoor pollen and other substances. Since that time, the airflows are being measured weekly and the filter cleanliness is being closely monitored to avoid airflow reductions. It is important to note that such frequent monitoring of HRV operation in this research facility is unlikely to occur in an actual residence, leading to questions on how well such a device would perform in a more typical home.

Thermal comfort conditions are monitored in several rooms in the house to verify that the heating and cooling system is providing a thermally acceptable environment relative to the criteria in ASHRAE Standard 55 (6). This evaluation involves the measurement of dry-bulb temperature, relative humidity and radiant temperature using a gray globe as shown in **Figure 2**. These values are converted to predicted percentage dissatisfied (PPD) and predicted mean vote (PMV) and compared with the following criteria: PPD < 10% and –0.5 < PMV <+0.5.

Radon concentrations have been measured over 3 to 5 days on four different occasions in 2013 to cover different seasons of the year. The measurements were made in the basement and on the first and second floors. All of the results were less than 37 Bq/m³ in the living space, while the concentrations were on average below 82 Bq/m³ in the basement. The level in the U.S., above which some remedial action is recommended, is 148 Bq/m³ in occupied spaces in homes (7).

VOC and aldehyde concentrations are being measured on an approximately monthly basis in the house to assess the impacts of the low-emissions material specifications. These measurements started in May 2013, with one-hour samples in the kitchen on the first floor, the second floor hallway and outdoors. The VOCs are sampled on Tenax sorption tubes with 6 L sample volumes and analyzed using a gas chromatograph/mass spectrometer. Aldehydes are sampled using DNPH cartridges with 60 L sample volumes and analysis with a high-pressure liquid chromatograph. These results are still being analyzed, but it appears that some of the compounds have emission rates that increase with increasing outdoor temperature.

This research effort shows the importance of airtightness, ventilation and IAQ in achieving high-performance, net zero energy buildings and demonstrates a detailed approach to achieving those performance goals. Future activities on the ventilation and IAQ performance of the NZERTF include a continuation of the monthly VOC and aldehyde sampling through the summer of 2014 to better understand the impacts of elevated temperatures on emissions. These results will be studied to understand which materials are associated with the emissions. In addition, the low-emitting material specifications used in the house will be converted into a format that will allow their use in other projects. A multizone building airflow model of the house was created in CONTAM (8). The model will be validated using tracer gas experiments in the facility and used to understand the impacts of different ventilation strategies and contaminant sources on IAQ and energy use. ■

Figure 2. Test stand for measurement of thermal comfort parameters.

References

Please see the complete list of references of the article in the html-version at **www.rehva.eu** -> REHVA Journal

NIST

Founded in 1901, the National Institute of Standards and Technology (NIST) is a non-regulatory federal agency within the U.S. Department of Commerce. NIST's mission is to promote U.S. innovation and industrial competitiveness by advancing measurement science, standards, and technology in ways that enhance economic security and improve our quality of life. NIST employs about 3,000 scientists, engineers, technicians, and support and administrative personnel. NIST also hosts about 2,700 associates from academia, industry, and other government agencies, who collaborate with NIST staff and access user facilities. More information on NIST can be found at www.nist.gov.

World Sustainable Energy Days (WSED) awarded to young researchers

The World Sustainable Energy Days (WSED), one of Europe's largest annual conferences in this field, offered a unique combination of events on sustainable energy. The 2014 conference, which was held from 26 – 28 February in Wels/Austria, attracted more than 750 participants from 59 countries.

The WSED next – a subconference for young researchers

The conference **WSED next** offered a platform for presenting the work of young researchers and professionals as well as for interaction with experts and decision makers from industry and institutions. "**Young Researchers Awards**" were given.

The **WSED next** conference 2014 offered:

- oral and poster presentations, presenting the work of around 60 young researchers in the fields of biomass and energy efficiency from over 30 countries
- the awards for the "Best Young Researcher in Biomass" and the "Best Young Researcher in Energy Efficiency" were presented
- the conference gave networking opportunities with experts and decision makers from industry and institutions

Based on a call for papers, young researchers from all over the world submitted their work in the fields of energy efficiency and biomass – the conference's two main topics. A scientific committee consisting of over 40 experts selected around 60 papers submitted by young researchers from more than 30 countries for oral and poster presentations. The papers were presented in two sessions – one on biomass and one on energy efficiency.

The winner of Energy Efficiecy cetergory of the competition Ms Theresa Wohlmuth, Alpine Energie (with cetrificate) and from left Mr Rudi Anschober, Regional Minister for Energy, Ms hristiane Egger, conference director and Mr Gerhard Dell, energy commissioner of Upper Austria and director of OÖ Energiesparverband. The shortened version of the winning paper is published on page 37.

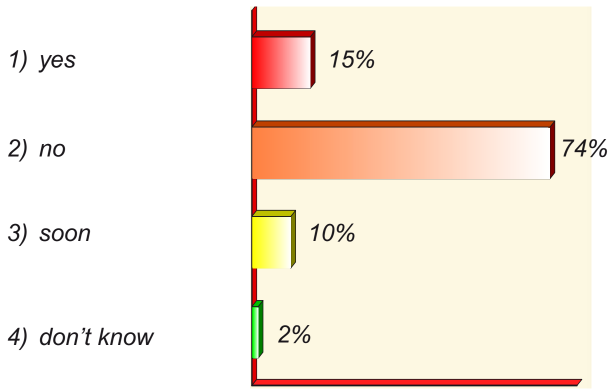
The prize was awarded to two very deserving young researchers – one in each of the main fields: biomass (Satu Lantiainen, University of Missouri) and energy efficiency (Theresa Wohlmuth, Alpine Energie).

More information: www.next.wsed.at

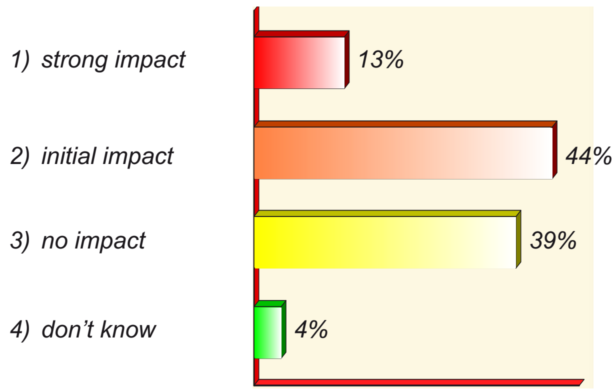
The responses of the participants of the WSED to some questions related to energy efficiency of buildings and nZEBs

An interesting online survey with immediate results was performed during the WSED main conference sessions. The participants were asked to respond to some simple questions related to the energy efficiency of buildings with an individual remote voting device. The results were displayed without delay on the screen:

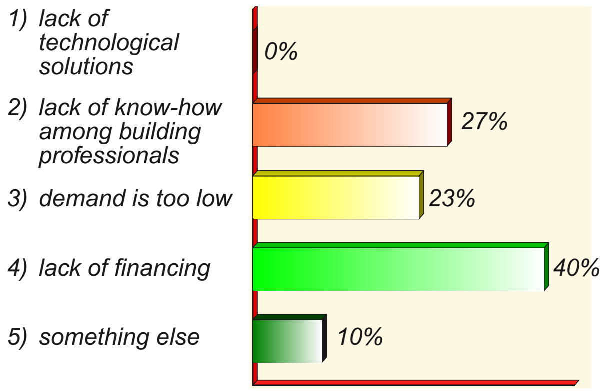
Do you live in an NZEB?



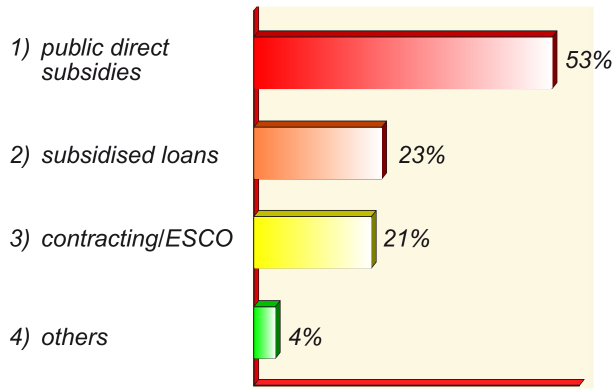
In your country, does building energy certification have an impact on the real estate market?



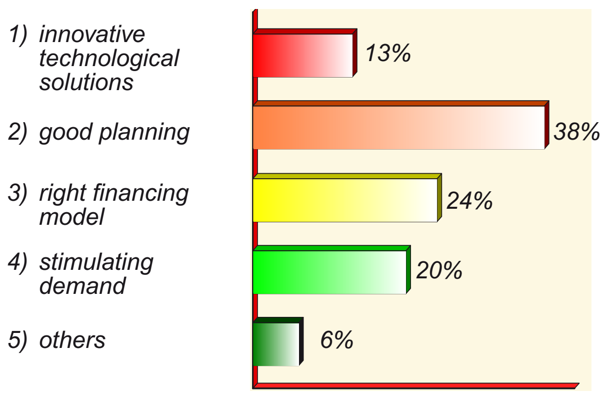
What is currently the biggest barrier for more NZEBs?



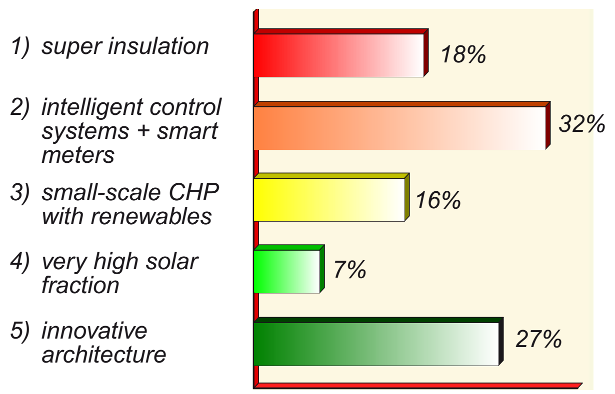
For you, which economic incentive is the most effective for NZEB?



For you, what is the most important success factor for NZEBs?



Which technical solution do you consider the most interesting for NZEBs?



REHVA Seminar during Aqua-Therm Prague

REHVA organized a seminar on Technical Seminar on 'Technologies for nZEB' at Aqua-Therm Prague exhibition on 5 March 2014. This seminar was well attended and received.

REHVA's President, Karel Kabele from CTU in Prague made a presentation on IEQ and high energy performance buildings. Jarek Kurnitski from Tallinn University of Technology and REHVA Vice-President talked about the nZEB definition in Europe. Zoltan Magyar from Budapest University of Technology explained how continuous monitoring could improve the energy saving of HVAC systems. The seminar concluded with the presentation of EN 15603 and other 2nd generation of EPBD standards as a firm basis for the nZEB definition by Jaap Hogeling from ISSO and Chair of CEN TC 371.

Speakers of the REHVA seminar at Aqua-Therm in Prague (Kabele, Kurnitski, Hogeling and Magyar).

REHVA - AICARR Seminar at MOSTRA CONVEGNO

This year during the Mostra Convegno 2014 exhibition, REHVA organised in collaboration with AiCARR a seminar on 'Towards nearly zero retrofitted buildings', prepared and distributed a special issue of the REHVA European HVAC Journal.

The topic of designing and constructing nearly zero energy buildings has been firstly addressed to new buildings. Nevertheless, the big challenge for the European Countries is to focus in increasing the energy performance of the existing building stock.

As highlighted by several European projects and researches, the energy properties of buildings are really poor and high potentials of energy savings can be achieved by energy renovation actions.

In this scenario, it is important to analyses which are the real strategies to develop and the proper technologies to set for retrofitting existing building up to the target of "nearly zero energy", taking into account the suitable trade-off between energy and economical goals as introduced by the "cost optimality approach".

Livio Mozzarella made an excellent summary of the NZEN and nZEB conceptions focusing on implementation Mediterranean Countries.

Livio de Santoli the president of AiCARR from April 1st, 2014 opened the seminar at Mostra Concegno.

AiCARR president-elect, prof Livio de Santoli welcomed all the seminar participants. Prof Livo Mazzarella presented the nZEB concept and the implementation in the Mediterranean Countries. Stefano Corgnati talked about retrofitted for nZEB, challenge between energy and economic targets. Dr Zoltan Magyar discussed about the energy retrofitting of panel residential buildings for nearly zero energy buildings in Hungary. Dr Ioan Dobosi presented the status of implementation of the European Directives for Energy Efficiency in Romania. He also presented some technical solutions for transforming an existing residential building into a nearly zero energy building (nZEB). Mr Fabrizio presented some case studies on the role of energy simulation towards nZEB. The Seminar ended with the presentation of the certification of multi-energy systems by Mr Ball from Eurovent Certita Certification.

Association of Building Services Engineers from Romania – AIIR

AIIR is one of the most important professional associations in Romania, with great expertise in the fields of building services engineering, energy efficiency and renewable energy and professional training.

ASSOCIATION OF BUILDING SERVICES ENGINEERS FROM ROMANIA - AIIR represents the interests of more than 1100 engineers in the field of plumbing, heating, ventilation, air conditioning, electric and natural gas, working in education, research, design, implementation and operation.

The main focus of AIIR is creating the organizational framework for association members, in order to achieve measures, concepts and actions that lead to the development, improvement and increased intake of building services specialists to assure the life and work of people.

Founded in 1990, AIIR has edited with Artecno Publisher a Building Services Manual, which was reissued in 2010 under the title "Technical Encyclopaedia for Building Services". Technical Encyclopaedia for Building Services is the result of a collective work of 68 Romanian professionals and experts in building services.

Romanian Technical Encyclopaedia for Building Services.

Also, AIIR coordinates the magazine "Instalatorul" since 1993. AIIR members receive a free subscription to the magazine.

CONFERENCES

AIIR with its 5 subsidiaries organized 150 conferences, of which 30 with international participation. AIIR organized 48 national conferences in Sinaia, Banat Branch organized 22 conferences, Transilvania Branch– 33, Moldova Branch – 23, Valahia Branch together with The Faculty for Building Services Engineers organized 18 and The Romanian Energy Auditors Chamber within AIIR organized 5.

Within the 150 conferences 187 volumes were published, with conferences proceedings which totalled over 8500 papers.

TRAINING COURSES

AIIR has trained more than 2000 specialists in energy efficiency, RES use and experts in building services.

CERTIFICATION

AIIR together with other professional associations have initiated a project in order to authorize specialists and companies in the field of building services engineers.

AFFILIATION

Romania is represented in REHVA since 1985. AIIR is affiliated to REHVA since 1995 as a partner with The Romanian Refrigeration Association (AGFR) and The Romanian Refrigeration and Cryogenics Association (AFCR) which are associated to AIIR.

Affiliation with international professional organisations.

Mr Dusan Petras participated as REHVA President in the XIVth Building Services Conference in Timisoara, organised by Banat Branch in 2005 and was a part of the awards jury of REHVA Student Competition.

Within the 41st National Conference on Building Services, which took place in Sinaia, during 20-22 October 2006, Prof. Olli Seppänen participated as REHVA President with a paper which was presented in the Conference and published in the Conference Proceeding.

Also, REHVA Presidents in 2008 and 2013, Prof. Francis ALLARD and Prof. Karel Kabele, participated in the 43rd and 48th National Conference on Building Services with a presentation on energy performance of buildings.

Romania organised until now two REHVA Annual Meetings. The first was organised by AGFR in Sinaia, in 1995. The 56th REHVA Annual

Meeting, in 2012, was organised by AIIR and AGFR, in Timisoara simultaneous with the 21st Conference of the Banat Branch, which had more than 200 participants from 25 countries, such as USA, China, Japan and India.

AIIR participated in REHVA Student Competitions from its first edition in 2005, in Lausanne within Clima 2005 Congress and in 2010 in Antalya, Turkey and in 2013, within Clima 2013 Congress in Prague, Czech Republic.

ASHRAE Danube Chapter was founded in 2005, within the 15th Conference of Banat Branch, in Timisoara, in the presence of ASHRAE Acting President, Mr Ronald Vallort. The following countries are part of this ASHRAE Danube Chapter: Hungary, Bulgaria, Serbia, Montenegro, Croatia, Slovakia and Czech Republic.

PRESIDENT **LIVIU DUMITRESCU**
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Energy efficiency through transparent system monitoring wih Belimo Energy Valve

The Belimo products "Energy Valve" and the room controller "CR24-B1" were the protagonists of a Macedonian pilot project in Skopje for the determination of the energy efficiency of buildings. The experimental set-up at the Institute of Forestry was able to demonstrate that, with the implementation of meaningful renovation measures, the consumption of primary energy could be reduced by 20 percent by the year 2020 in comparison with the expectations projected for 2007 – as outlined by the 2012/27/EU Directive. Thanks to the Belimo Energy Valve™ also the current energy consumption values and the optimisation potential of the system are known at all times.

Initial situation

In addition to forestry subjects, the Institute at the "St. Cyril and Methodius" University also performs research on aspects of environmental and energy efficiency. In the case of this pilot project, the intention was to investigate potential heating energy savings in the Institute's own building. The basis for the experimental set-up was the international standard ISO 50001:2011, which describes systems and processes for improving energy efficiency.

Project requirements

Two points were defined as conditions:

- Energy consumption can be analysed and regulated in accordance with work conditions (working hours, working days, room temperature etc.).
- The energy consumption of the current month is known at all times, in contrast to the retrospective invoice data of the operator.

Belimo solution

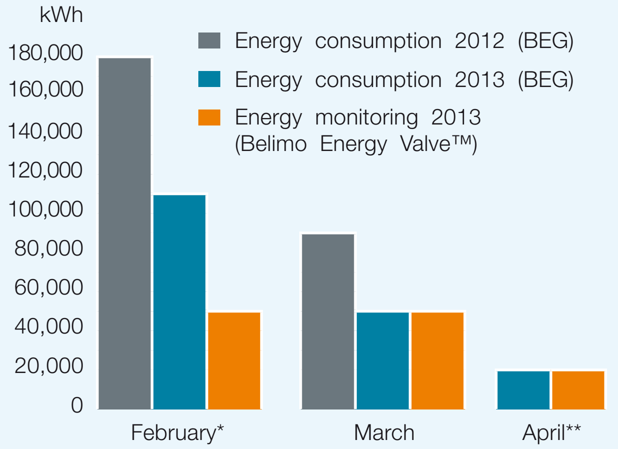
These customer requirements correspond exactly to the features of the Belimo Energy Valve™. It measures, regulates, balances and saves all measurement values. Because a web server is integrated in the valve actuator, the data can be viewed and analysed for a period of 13 months through any Internet connection with the Belimo Energy Valve™ Tool. The 2-way control valve that was previously used in the primary part of the heat supply facility was therefore replaced with the Belimo Energy Valve™ in the DN65 dimension. The valve is controlled with a room controller CR24-B1 (master controller with PI response) that is installed in a reference room. The nominal room temperature of 21°C was lowered to 16°C on weekdays after 3 pm and on weekends. From 7th February to the end of April 2013, the Energy Valve then used sensors to continuously measure, balance and control the flow and temperature values in the supply and return lines. Thanks to this transparent energy monitoring, it was possible to analyse where and in which amounts the energy in the heating system was being used. The optimisation potential was quickly determined: the available energy can be used according to actual requirements and energy consumption can be reduced significantly.

Customer benefit

The optimisation of the heating periods and temperatures with the aid of the Belimo Energy Valve™ led to energy savings of ≥ 30%, as could be seen on the invoices of the local heating supplier (Balkan Energy Group BEG).

- The specifications of the EU Directive 2012/27/EU were fulfilled.
- The customer has transparent energy consumption values at his disposal at all times and can project budgeting for the coming heating season.
- Installation of the Belimo Energy Valve™ and the room controller CR-24-B is possible with a manageable technical outlay.

After three months, the evaluation of the energy consumption values revealed considerably improved economic efficiency for the converted heating system:



* The clear imbalance between these consumption values is probably due to the fact that the actual energy consumption in January 2013 was not recorded. The energy supplier had charged a flat-rate amount for this period and then corrected it once again in February 2013.

** BEG values not yet available at the end of the experiment.

Customer satisfaction

After the heating period was over, the experimental results achieved with the Energy Valve at the Institute of Forestry were analysed and presented to university management. The expectations of the responsible officials were thereby greatly exceeded. Vice-Rector Prof. Dr. Nikola Vasilevski emphasised that the use of modern, energy efficient technologies was of great value for his facility. It is for that reason that he would like not only to continue cooperation with BELIMO Automation AG in this area but also to extend it further. Based on this pilot project, the budgeting of a project is now being planned that involves the equipping of all 22 Institutes with Belimo Energy Valves™.

VDI- Guidelines published March 2014

D VDI 4710/4 "Meteorological data for the building services; t,x correlations and wind statistics for 122 European cities"

This standard allows to specify design points (summer and winter) for air temperature, water vapour content, and enthalpy, to be used in the calculation of heating, ventilating and air-conditioning (HVAC) systems in Europe, and can serve as a basis for the analysis of annual energy consumption according to the individual-frequency method. In addition to information regarding the correlations between the air temperature and the water vapour content, a wind statistic including wind speeds and wind directions is provided for each station, thus delivering insight into any non-standard heat transfer conditions to be expected. At the suggestion of REHVA, a compilation of data from 122 stations in Europe, allowing the same processing quality in the vicinity of the stations as for the German stations, is presented here on the basis of the same time period as for Germany (1991 to 2005). For these 122 European stations, the same procedure and basic analysis have been chosen. It is a harmonised proposal which, although surely not meeting all national procedures of system design, provides a good synopsis of the respective climatic situation.

VDI 6002/1 "Solar heating for potable water; Basic principles; System technology and application in residential buildings"

This standard deals with solar-powered potable-water heating. It may be reasonable for technical as well as economic reasons to supply solar heat to a second consumer from a single collector area. This is the case, e.g., for room heating, room-air cooling, or swimming-pool heating for indoor pools. The standard focuses on solar systems for multi-family homes with collector surface areas of up to 20 sq m. However, the statements made can be applied by analogy to single-family and two-family homes. Where special considerations are required for such small systems, this is pointed out. In addition to planning and dimensioning criteria, guidance is given regarding systems technology and the selection of components and any particularities of solar technology.

VDI 6002/2 "Solar heating for potable water; Application in students accommodations, senior citizens' residences, hospitals, swimming baths and camping sites"

This standard deals with solar thermal potable-water heating systems. As a supplement to VDI 6002 Part 1, this standard gives consideration to the particular requirements applying to solar thermal systems for non-residential buildings. Case studies are described for student's halls of residence, homes for the elderly, hospitals, indoor swimming pools and camping sites. Detailed consideration is given to demand profiles on which the planning of solar thermal systems is based.

VDI 6022/4.1 "Ventilation and indoor-air quality; Qualification of personnel for hygiene checkings, hygiene inspections, and assessment of indoor air quality; Certificate of competence in Category A and Category B"

This standard complements the standard VDI 6022 Part 4 with a simplified method for the declaration of the qualification in categories A and B according to VDI 6022. The standard regulates the entry requirements and the issuing of the "air hygiene" VDI pass introduced with VDI 6022 Part 4.

D VDI 6210/1 "Demolition of civil constructions and technical facilities"

The standard defines the procedures and assessment criteria for the planning and execution of demolitions of civil constructions and technical facilities for all involved personnel. It applies to the demolition of stationary and non-stationary variable structural and technical systems. The standard describes the planning, implementation and follow-up of such work as well as retrieving, deployment, (interim) storage, treatment and handling of the accumulating materials and waste. It does not include the requirements imposed on the reuse of resulting materials or the recycling or the disposal of waste.

VDI 7001 "Communication and public participation in planning and building of infrastructure projects; Standards for work stages of engineers"

Infrastructure projects always create a lot of public discussion and protest. How may the involved players and the engineers be able to achieve common solutions for the planned infrastructure projects in the next decades? In consideration of the work stages of engineers the standard gives references for communication and public participation in planning and building of infrastructure projects.

D = Draft Guideline

REHVA has a memorandum of understanding with China Committee of HVAC and Indian Society of Heating, Refrigerating and Air Conditioning Engineers (ISHRAE). The MoU encourages the exchange of information and articles.

The leading magazine for HVAC industry in China

The Journal of HV&AC is a key resource for designers, specifiers, installers and users of heating, ventilating and air conditioning equipment and systems in China. It enjoys a huge readership of near 20,000 subscribers and a pass-along rate of 3.9 readers per issue – making it the best-read HVAC magazine in China.

Established in 1971 and published monthly in Beijing on the 15th of each month, the Journal of HV&AC is the only magazine in the sector which is officially under the supervision of the Ministry of Housing and Urban-Rural Development of the People's Republic of China. It is jointly sponsored by such a few powerful organizations as Asia-Pacific Institute of Construction Sci-tech Information, China Architecture Design & Research Group and HVAC Committee of the Chinese Architectural Society.

The magazine has won several awards for the quality of its content, including the China National Top Award for Magazine 2005, China's Top 100 Newspapers and Periodicals (2013), and a title of "Core Magazine in Chinese Construction Field".

The goal of the magazine is to provide its professional readers with "novel, practical, accurate and concise" information and literatures to promote the flow of information about new technologies and their applications. The magazine has been included in several databases. **The articles have English abstracts**.

Readers Who Design and Install Systems

A readership breakdown of the Journal shows that more than half of them are involved in the system design and installation. Many of the readers are engineers or technicians who design advanced HVAC systems or install them in commercial, industrial and residential buildings. There is a smaller fraction of the readers involved in the daily operation of these systems and in research and education.

The Journal of HV&AC reports on a range of topics related to this trade, including:

- Development in research
- General and specific introduction of national and international standards and regulations
- Technical information for designers
- Engineering example reports
- R&D in products and materials
- Operation management
- Construction methods

Contact Information:
E-mail: hvac@cadg.cn
www.hvacjournal.cn
www.ehvacr.com

In addition, the Journal of HV&AC has some special columns according to the hot spots of this trade in recent years, i.e. Expo building, airport building, culture building, industrial building, railway building, data center air conditioning design, engineering test, urban rail transportation HVAC, temperature and humidity independent control, energy storage technology, public building energy efficiency, heat metering retrofit, HVAC design of hospitals, simulation analysis application, optimal design of stadium and gymnasium, evaporative cooling air conditioning technology, building energy analysis, green buildings, HVAC automatic control, environment control of scientific laboratory, heating in high altitude zone, heating in hot summer and cold winter zone, energy efficiency reformation of existing buildings, indoor air quality, etc.

Top HVAC Journal from India "Air Conditioning and Refrigeration Journal"

Air Conditioning and Refrigeration Journal is a bi-monthly published by the Indian Society of Heating, Refrigerating and Air Conditioning Engineers (ISHRAE). It is circulated complimentary to all members of the Society, which number about 10,000. First published in 1998, it is presently in its 17th year of publication. It is the most widely circulated and respected magazine in India in the field of HVAC&R due to its content. It is the only magazine in India which features original application-oriented articles written by experts in various domains of HVAC&R. Its readership comprises ISHRAE members who are individuals: engineers from the field, partners in consultancy firms, contractors, manufacturers, users, etc. based in 39 Chapters of ISHRAE throughout India. In addition, there are several hundred subscribers, mainly libraries of engineering colleges.

The Journal has two regular supplements that are published with alternate issues:

Cold Chain contains material on the rapidly growing cold chain industry in India, and is published along with the March-April, July-August and November-December issues of the Journal. It is now in its fifth year of publication.

AC&R Service Installation Maintenance, now in its second year of publication, contains material relevant to field activities. It is published along with the January-February, May-June and September-October issues of the Journal.

Articles published in the Journal and its supplements are application oriented, on topics of interest to HVAC&R professionals in India. They are generally between 2500 and 4000 words long, supported by good diagrams and high resolution photos wherever the text requires. Commercial bias in favour of any brand is avoided. The articles are generally original, or at least not published in India earlier. Articles may be sent to the Technical Editor for evaluation and publication.

Contact Information:
E-mail: journal@ishrae.in
www.ishrae.in

Send information of your event to Ms Cynthia Despradel cd@rehva.eu

Events in 2014 - 2015

Conferences and seminars 2014

April 10–13	2014 Windsor conference-Counting the Cost of Comfort in a Changing World	Windsor, United Kingdom	http://nceub.org.uk
April 25–26	18th International Passive House Conference	Aachen, Germany	www.passivhaustagung.de
April 28–29	2014 Euroheat & Power Annual Conference and 60th anniversary	Brussels, Belgium	www.euroheat.org/2014EHPac
April 30	REHVA Annual Conference	Dusseldorf, Germany	www.rehva.eu
May 8–10	TTMD XI. International HVAC+R Technology Symposium 2014	İstanbul, Turkey	www.ttmd.org.tr/sempozyum2014
May 13–15	11th IEA Heat Pump Conference 2014	Montreal, Canada	http://goo.gl/ouuVDI
May 20	7th EHPA European Heat Pump Forum	Berlin, Germany	http://forum.ehpa.org/
May 21–22	National conference Air Conditioning and Ventilation	Prague, Czech Republic	www.kvcr.cz
June 5–6	International Conference "Energy Performance of Buildings"	Bucharest, Romania	www.rcepb.ro
June 17–19	BREEAM International New Construction 2013 Assessor Training Course	Bucharest, Romania	www.aiiro.ro
June 23–24	Building Simulation and Optimization BSO14	London, United Kingdom	www.bso14.org
June 23–27	Sustainable Energy Week EU Sustainable Energy Week	Brussels, Belgium	www.eusew.eu
June 28–July 2	ASHRAE 2014 Annual Conference	Seattle, WA, USA	http://ashraem.confex.com/ashraem/s14/cfp.cgi
July 1–3	Alternative energy Sources	Kromeriz, Czech Republic	www.azecr.cz
July 7–12	Indoor Air 2014	University of Hong Kong	www.indoorair2014.org
September 7–9	14th International Symposium on District Heating and Cooling	Stockholm, Sweden	http://svenskfjarrvarme.se/dhc14
September 10–12	ASHRAE/IBPSA-USA Building Simulation Conference	Atlanta, GA, USA	http://ashraem.confex.com/ashraem/emc14/cfp.cgi
September 10–12	Building Services Summer School	Czech Republic	tzb.fsv.cvut.cz
September 21–24	Licht 2014 – Den Haag Holland	The Netherlands	www.licht2014.nl
September 24–25	35th AIVC Conference – 4th TightVent Conference – 2nd venticool Conference	Poznań, Poland	www.aivc.org
October 15–17	The 49th National Conference on Building Services	Sinaia, Romania	www.aiiro.ro
October 19–22	Roomvent 2014	Sao Paulo, Brazil	www.roomvent2014.com.br
October 28–29	9th International ENERGY FORUM on Advanced Building Skins	Bressanone, Italy	www.energy-forum.com/fr.html
October 29-31	XXXI ABOK conference and exhibition "Moscow - Energy Efficient City"	Moscow, Russia	http://events.abok.ru/meeg
October 29-31	CCHVAC 2014 conference	Tianjin, China	
December 3–5	45 HVAC&R International Congress	Belgrade, Serbia	www.kgh-kongres.org
December 10–12	9th International Conference on System Simulation in Buildings – SSB2014	Liege, Belgium	www.ssb2014.ulg.ac.be

Exhibitions 2014

May 7–10	ISK – SODEX 2014	Istanbul, Turkey	www.hmsf.com
May 13–15	ISH China & CIHE	Beijing, China	www.ishc-cihe.com
October 1–3	Finnbuild 2014	Helsinki, Finland	www.finnbuild.fi
October 14–16	Chillventa 2014	Nuremberg, Germany	www.chillventa.de/en/

Conferences and seminars 2015

February 25–27	World Sustainable Energy Days 2015	Wels, Austria	www.wsed.at
April 16–18	International Conference Ammonia and CO2 Refrigeration Technologies	Republic of Macedonia	
May 6–8	Advanced HVAC and Natural Gas Technologies	Riga, Latvia	
May 7–9	REHVA Annual Conference	Riga, Latvia	www.lsgutis.lv/
October 20–23	Cold Climate HVAC	Dalian, China	www.coldclimate2015.org

Exhibitions 2015

May 7–10	ISK – SODEX 2014	Istanbul, Turkey	www.hmsf.com
May 13–15	ISH China & CIHE	Beijing, China	www.ishc-cihe.com
October 1–3	Finnbuild 2014	Helsinki, Finland	www.finnbuild.fi
October 14–16	Chillventa 2014	Nuremberg, Germany	www.chillventa.de/en/

Conferences and seminars 2016

May 22–25	12th REHVA World Conference – CLIMA 2016	Aalborg, Denmark	www.clima2016.org

International conference – "Advanced HVAC & Natural Gas Technology"

Radisson BLU Hotel Latvija Conference Centre, Riga, Latvia May 6-8, 2015

TOPICS

Energy efficient Cooling systems
- Indirect and direct adiabatic cooling;
- Innovations in field of direct expansion systems;
- Hydronic cooling systems;
- Environmentally friendly Refrigerants;
- Natural resources for cooling of the buildings;
- Absorption cooling systems;

Advanced Heating and Ventilation systems
- Heat recovery;
- Natural ventilation;
- Heating systems operation and maintenance specifics;
- Centralized heating systems;
- Indoor air quality and thermal comfort;

Sustainable buildings
- Integration of renewables;
- Rain water and Potable Water reuse;
- Green buildings;
- Retrofitting of existing building stock;
- Sustainable building materials;

Efficient and clean Natural Gas technologies
- Efficient and clean natural gas technologies for energy generation transportation and distribution;
- Increasing the energy efficiency of natural gas applications in environmental protection. Urban innovations on the base of natural gas;
- Natural Gas advanced technologies;
- Role of the Natural Gas transmission and distribution operators in the liberalized energy market;

ABSTRACT SUBMISSION

Abstract (4000 characters including spaces) should be submitted to **www.hvacriga2015.eu** by June 1st, 2014

More information: www.hvacriga2015.eu

e-mail: elina.purviske@btgroup.lv

Organized by:

LSGŪTIS · RTU · WORLD ENERGY COUNCIL

Endorsed by:

ASHRAE · REHVA

RoomVent 2014

October 19–22, 2014, Sao Paulo, Brazil

The 13th SCANVAC Conference RoomVent 2014 will be held in Sao Paulo, Brazil, on October 19–22, 2014. The main theme of the next RoomVent is "New ventilation strategies with base in active and passive technology in building and for comfort in airplane".

The topics of the scientific and technical sessions cover:

- Indoor Air Quality and Human Comfort
- Ventilation and Air Conditioning in Green Buildings
- Innovative strategies and components for ventilation and air conditioning systems
- Computer based design methods applied to Room Ventilation
- Airflow inside buildings and case studies
- Smoke and Contaminant Movement
- IAQ in Vehicles

Organisers:

IPT – Institute for Technological Research
USP – São Paulo University
State University of North Fluminense – Rio de Janeiro
Federal University of Minas Gerais – Belo Horizonte

Technical visits will be arranged during the Conference.

More information: www.roomvent2014.com

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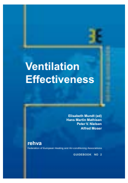
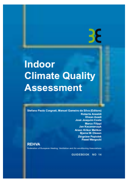
REHVA GUIDEBOOKS

REHVA Guidebooks are written by teams of European experts

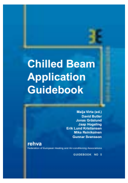
REHVA
Federation of European Heating, Ventilation and Air Conditioning Associations



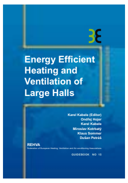
Ventilation Effectiveness. Improving the ventilation effectiveness allows the indoor air quality to be significantly enhanced without the need for higher air changes in the building, thereby avoiding the higher costs and energy consumption associated with increasing the ventilation rates. This Guidebook provides easy-to-understand descriptions of the indices used to measure the performance of a ventilation system and which indices to use in different cases.



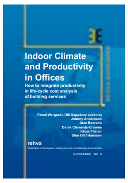
Indoor Climate Quality Assessment. This Guidebook gives building professionals a useful support in the practical measurements and monitoring of the indoor climate in buildings. Wireless technologies for measurement and monitoring have allowed enlarging significantly number of possible applications, especially in existing buildings. The Guidebook illustrates with several cases the instrumentation.



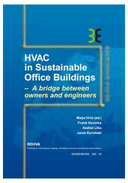
Chilled Beam Cooling. Chilled beam systems are primarily used for cooling and ventilation in spaces, which appreciate good indoor environmental quality and individual space control. Active chilled beams are connected to the ventilation ductwork, high temperature cold water, and when desired, low temperature hot water system. Primary air supply induces room air to be recirculated through the heat exchanger of the chilled beam. In order to cool or heat the room either cold or warm water is cycled through the heat exchanger.



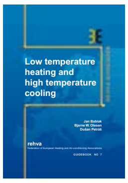
Energy Efficient Heating and Ventilation of Large Halls. This Guidebook is focused on modern methods for design, control and operation of energy efficient heating systems in large spaces and industrial halls. The book deals with thermal comfort, light and dark gas radiant heaters, panel radiant heating, floor heating and industrial air heating systems. Various heating systems are illustrated with case studies. Design principles, methods and modelling tools are presented for various systems.



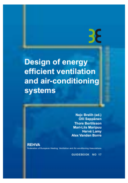
Indoor Climate and Productivity in Offices. This Guidebook shows how to quantify the effects of indoor environment on office work and also how to include these effects in the calculation of building costs. Such calculations have not been performed previously, because very little data has been available. The quantitative relationships presented in this Guidebook can be used to calculate the costs and benefits of running and operating the building.



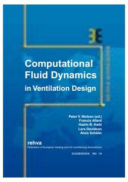
HVAC in Sustainable Office Buildings – ***A bridge between owners and engineers.*** This Guidebook discusses the interaction of sustainability and heating, ventilation and air–conditioning. HVAC technologies used in sustainable buildings are described. This book also provides a list of questions to be asked in various phrases of building's life time. Different case studies of sustainable office buildings are presented.



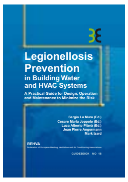
Low Temperature Heating And High Temperature Cooling. This Guidebook describes the systems that use water as heat-carrier and when the heat exchange within the conditioned space is more than 50% radiant. Embedded systems insulated from the main building structure (floor, wall and ceiling) are used in all types of buildings and work with heat carriers at low temperatures for heating and relatively high temperature for cooling.



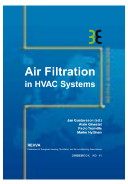
Design of energy efficient ventilation and air-conditioning systems. This Guidebook covers numerous system components of ventilation and air-conditioning systems and shows how they can be improved by applying the latest technology products. Special attention is paid to details, which are often overlooked in the daily design practice, resulting in poor performance of high quality products once they are installed in the building system.



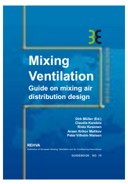
Computational Fluid Dynamics in Ventilation Design. CFD-calculations have been rapidly developed to a powerful tool for the analysis of air pollution distribution in various spaces. However, the user of CFD-calculation should be aware of the basic principles of calculations and specifically the boundary conditions. Computational Fluid Dynamics (CFD) – in Ventilation Design models is written by a working group of highly qualified international experts representing research, consulting and design.



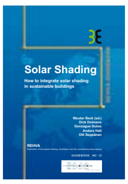
Legionellosis Prevention in Building Water and HVAC Systems. This Guidebook is a practical guide for design, operation and maintenance to minimize the risk of legionellosis in building water and HVAC systems. It is divided into several themes such as: Air conditioning of the air (by water – humidification), Production of hot water for washing (fundamentally but not only hot water for washing) and Evaporative cooling tower.



Air Filtration in HVAC Systems. This Guidebook will help the designer and user to understand the background and criteria for air filtration, how to select air filters and avoid problems associated with hygienic and other conditions at operation of air filters. The selection of air filters is based on external conditions such as levels of existing pollutants, indoor air quality and energy efficiency requirements.

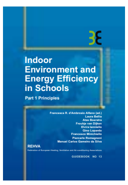


Mixing Ventilation. In this Guidebook most of the known and used in practice methods for achieving mixing air distribution are discussed. Mixing ventilation has been applied to many different spaces providing fresh air and thermal comfort to the occupants. Today, a design engineer can choose from large selection of air diffusers and exhaust openings.



Solar Shading – ***How to integrate solar shading in sustainable buildings.*** Solar Shading Guidebook gives a solid background on the physics of solar radiation and its behaviour in window with solar shading systems. Major focus of the Guidebook is on the effect of solar shading in the use of energy for cooling, heating and lighting. The book gives also practical guidance for selection, installation and operation of solar shading as well as future trends in integration of HVAC-systems with solar control.

Advanced system design and operation of GEOTABS buildings. This Guidebook provides comprehensive information on GEOTABS systems. It is intended to support building owners, architects and engineers in an early design stage showing how GEOTABS can be integrated into their building concepts. It also gives many helpful advices from experienced engineers that have designed, built and run GEOTABS systems.



Indoor Environment and Energy Efficiency in Schools – ***Part 1 Principles.*** School buildings represent a significant part of the building stock and also a noteworthy part of the total energy use. Indoor and Energy Efficiency in Schools Guidebook describes the optimal design and operation of schools with respect to low energy cost and performance of the students. It focuses particularly on energy efficient systems for a healthy indoor environment.

REHVA nZEB Report. In this REHVA Report in cooperation with CEN, technical definitions and energy calculation principles for nearly zero energy buildings required in the implementation of the Energy performance of buildings directive recast are presented. This 2013 revision replaces 2011 version. These technical definitions and specifications were prepared in the level of detail to be suitable for the implementation in national building codes.

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