The full length version of this article is available at the journal website: **www.rehva.eu** -> REHVA Journal

Technical definition for nearly zero energy buildings

REHVA launched 2013 version in cooperation with European standardization organization CEN for uniformed national implementation of EPBD recast.

REHVA has revised its nZEB technical definition, since now the only available methodology suitable for the implementation in national building codes for the primary energy indicator calculation. The 2013 version was prepared in cooperation with European standardization organization CEN and it replaces 2011 version with the intention to help the experts in the Member States to define the nearly zero energy buildings in a uniform way. 2013 version is complemented with specifications for nearby renewable energy and for the contribution of renewable energy use. A set of the system boundaries and equations are given for energy need, energy use, delivered and exported energy, primary energy and for renewable energy ratio calculation. With these definitions and energy calculation framework, primary energy indicator and renewable energy ratio can be calculated as required by the directive. Calculation principles are explained with worked examples in order to assure uniform understanding of the definitions. Full report is available at the REHVA website www.rehva.eu -> REHVA Journal.

JAREK KURNITSKI
Professor, Vice-president REHVA
Tallinn University of Technology
jarek.kurnitski@ttu.ee

Background

EPBD recast (2010/31/EU) launched nearly zero energy (nZEB) target in 2010 with the need for the Member States to define what nZEB for them exactly constitutes. REHVA experts realized the problem that various definition of nZEB may cause in Europe and established a task force to prepare technical definitions and system boundaries for energy performance calculations.

Starting point for technical definitions is the requirement of nZEB in EPBD recast formulated as buildings with **a very high energy performance** and where energy need is covered to **a very significant extent by energy from renewable sources.** Since EPBD recast does not give minimum or maximum harmonized requirements as well as details of energy performance calculation framework, it will be up to the Member States to define what "a very high energy performance" and "to a very significant extent by energy from renewable sources" for them exactly constitute.

REHVA technical definition for nearly zero energy buildings

nZEB definition shall be based on delivered and exported energy according to EPBD recast and prEN 15603:2013. The basic energy balance of the delivered and exported energy and system boundaries for the primary and renewable energy calculations, are shown in **Figure 1** and **3** (for on site and for nearby assessment), and described with detailed system boundary definitions in **Figures 4** and **5**. According to EPBD recast, all components of the energy use are mandatory except the energy use of appliances (households, elevators/escalators and outlets) which may or may not be included. With the inclusion of appliances, energy use in the buildings includes energy used for heating, cooling, ventilation, hot water, lighting and appliances.

According to **Figure 1**, for delivered electricity and thermal energy it applies:

$$E_{us,el} = \left(E_{del,el} - E_{\exp,el}\right) + E_{ren,el} \quad (1)$$

and

$$E_{us,T} = \left(E_{del,T} - E_{\exp,T}\right) + E_{ren,T} \quad (2)$$

where

E_{us} is total energy use kWh/(a);
E_{del} is delivered energy on site (kWh/a);
E_{exp} is exported energy on site (kWh/a);
E_{ren} is on site renewable energy without fuels (kWh/a);

Subscript *el* refers to electricity and *T* to thermal energy.

An example in **Figure 2** explains the use of Equation 1. An all electrical building with energy use of 100 has a PV system generating 20, from which 10 is used in the building and 10 is exported. With these values, delivered energy on site becomes: $E_{del,el} = E_{us,el} + E_{\exp,el} - E_{ren,el} = 100 + 10 - 20 = 90$.

In order to be able to take into account a new nearby renewable energy production capacity contractually linked to the building and providing the real addition of the renewable capacity to the grid or district heating or cooling mix in connection with construction/development of the building(s), the system boundary of **Figure 1** has to be extended. (If not contractually linked to the building, nearby production is calculated with primary energy factors of the network mix as shown in **Figure 1**.) To calculate delivered and exported energy nearby, the energy flows of nearby production plant contractually linked to building are to be added/subtracted to the delivered and exported energy flows on site, **Figure 3**. Prerequisite to apply this nearby assessment, is the availability of national legislation allow-

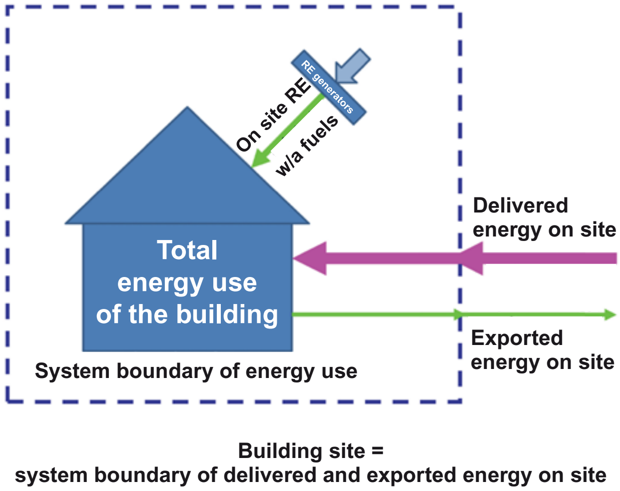


Figure 1. System boundaries for on site assessment (nearby production not linked to the building) connecting a building with on site renewable energy (RE) sources to energy networks. System boundary of energy use of building technical systems follows outer surface of the building in this simplified figure; system boundary of delivered and exported energy on site is shown with dashed line. In the case of nearby production, the nearby system boundary will be added, as shown in Figure 3.

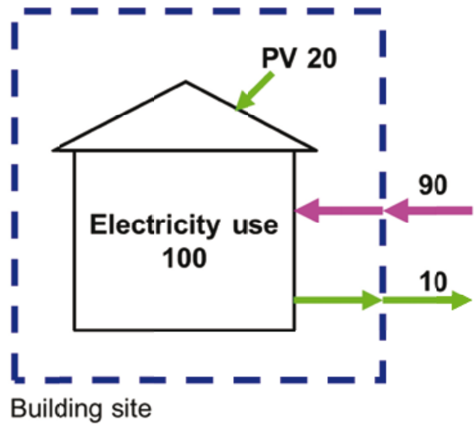


Figure 2. An example of an all electrical building explaining the use of Equations 1 and 2.

ing to allocate such new capacity to the building/development with a long term contract and assuring that the investment on that new capacity will lead to a real addition to the grid or district heating or cooling mix.

Primary energy indicator sums up all delivered and exported energy (electricity, district heat/cooling, fuels) into a single indicator. Primary energy and primary energy indicator are calculated from delivered and exported energy with national primary energy factors as:

$$E_{P,nren} = \sum_i \left(E_{del,i} f_{del,nren,i}\right) - \sum_i \left(E_{\exp,i} f_{\exp,nren,i}\right) \quad (3)$$

$$EP_P = \frac{E_{P,nren}}{A_{net}} \quad (4)$$

where

- EP_P is the primary energy indicator (kWh/(m² a));
- $E_{P,nren}$ is the non-renewable primary energy (kWh/a);
- $E_{del,i}$ is the delivered energy on site or nearby (kWh/a) for energy carrier *i*;
- $E_{exp,i}$ is the exported energy on site or nearby (kWh/a) for energy carrier *i*;
- $f_{del,nren,i}$ is the non-renewable primary energy factor (-) for the delivered energy carrier *i*;
- $f_{exp,nren,i}$ is the non-renewable primary energy factor (-) of the delivered energy compensated by the exported energy for energy carrier *i*, which is by default equal to the factor of the delivered energy, if not nationally defined in other way;
- A_{net} useful floor area (m²) calculated according to national definition.

Net zero energy building definition has an exact performance level of 0 kWh/(m² a) non renewable primary energy. The performance level of "nearly" zero energy is a subject of national decision taking into account:

- technically reasonably achievable level of primary energy use;
- how many % of the primary energy is covered by renewable sources;
- available financial incentives for renewable energy or energy efficiency measures;
- cost implications and ambition level of the definition.

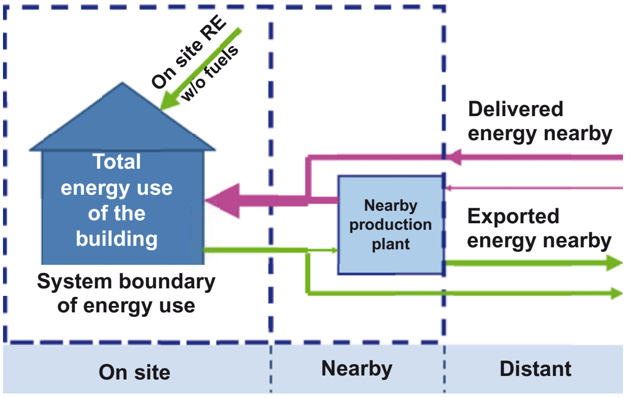


Figure 3. Nearby assessment boundary to be used in the case of nearby energy production linked contractually to the building. Compared to on site assessment boundary, delivered and exported energy flows on site are replaced by delivered and exported energy flows nearby.

The following definitions were prepared for uniformed EPBD recast implementation:[1]

net zero energy building (net ZEB)
Non-renewable primary energy of 0 kWh/(m² a).

nearly zero energy building (nZEB)
Technically and reasonably achievable national energy use of > 0 kWh/(m² a) but no more than a national limit value of non-renewable primary energy, achieved with a combination of best practice energy efficiency measures and renewable energy technologies[2] which may or may not be cost optimal[3].

Detailed system boundaries for delivered and exported energy calculation

The set of detailed system boundaries are extended from the assessment boundary of prEN 15603:2013. As stated in EPBD recast, the positive influence of renewable energy produced on site is taken into account so that it reduces the amount of delivered energy needed and may be exported if cannot used in the building (i.e. on site production is not considered as part of delivered energy on site), **Figure 4**.

1 'reasonably achievable' means by comparison with national energy use benchmarks appropriate to the activities served by the building, or any other metric that is deemed appropriate by each EU Member State.

2 Renewable energy technologies needed in nearly zero energy buildings may or may not be cost-effective, depending on available national financial incentives.

3 The Commission has established a comparative methodology framework for calculation of cost-optimal levels (Cost optimal).

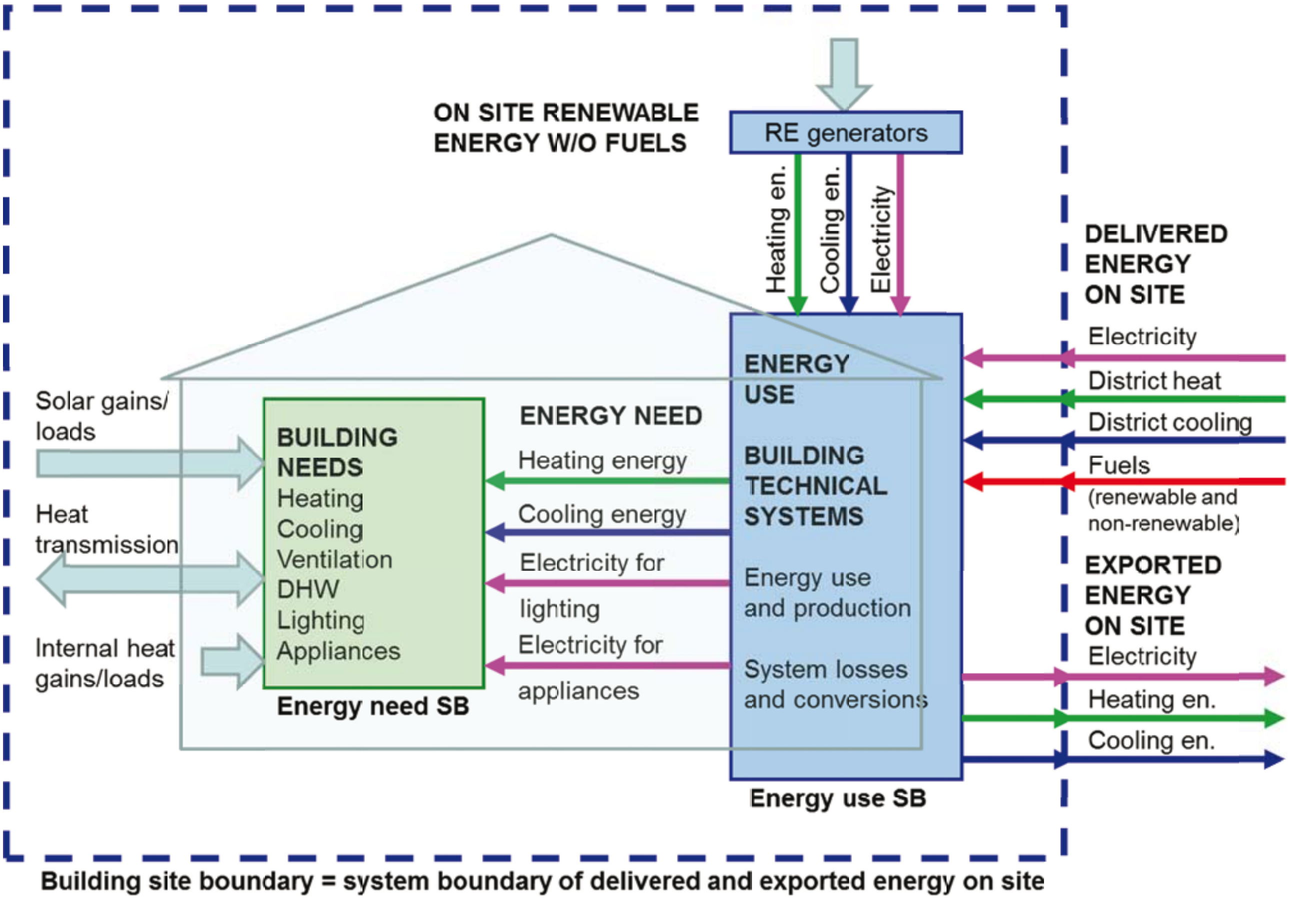


Figure 4. Three system boundaries (SB) for on site assessment (nearby production not linked to the building), for energy need, energy use and delivered and exported energy calculation. System boundary of energy use applies also for renewable energy ratio calculation with inclusion of RE from geo-, aero- and hydrothermal energy sources of heat pumps and free cooling as shown in Figure 5.

Renewable energy ratio (RER) calculation

In order to calculate the share of renewable energy use, renewable energy ratio RER, all renewable energy sources have to be accounted for. These include solar thermal, solar electricity, wind and hydro electricity, renewable energy captured from ambient heat sources by heat pumps and free cooling, renewable fuels and off site renewable energy. Ambient heat sources of heat pumps and free cooling are to be included to the renewable energy use system boundary, because in RER calculation, heat pumps and free cooling are not only taken into account with delivered energy calculation based on COP, but also by the extracted energy from ambient heat sources. Renewable energy use system boundary is shown in **Figure 5**.

The renewable energy ratio is calculated relative to all energy use in the building, in terms of total primary energy. It is taken into account that exported energy compensates delivered energy. By default, it is considered that the exported energy compensates the grid mix or in the case of thermal energy, the district heating or cooling network mix. For on-site and nearby renewable energy the total primary energy factor is 1.0 and the non-renewable primary energy factor is 0. Total primary energy based RER equation is the following:

$$RER_P = \frac{\sum_i E_{ren,i} + \sum_i \left(\left(f_{del,tot,i} - f_{del,nren,i}\right) E_{del,i}\right)}{\sum_i E_{ren,i} + \sum_i \left(E_{del,i} f_{del,tot,i}\right) - \sum_i \left(E_{\exp,i} f_{\exp,tot,i}\right)} \tag{5}$$

where

RER_P is the renewable energy ratio based on the total primary energy,

$E_{ren,i}$ is the renewable energy produced on site or nearby for energy carrier *i*, kWh/a;

$f_{del,tot,i}$ is the total primary energy factor (-) for the delivered energy carrier *i*;

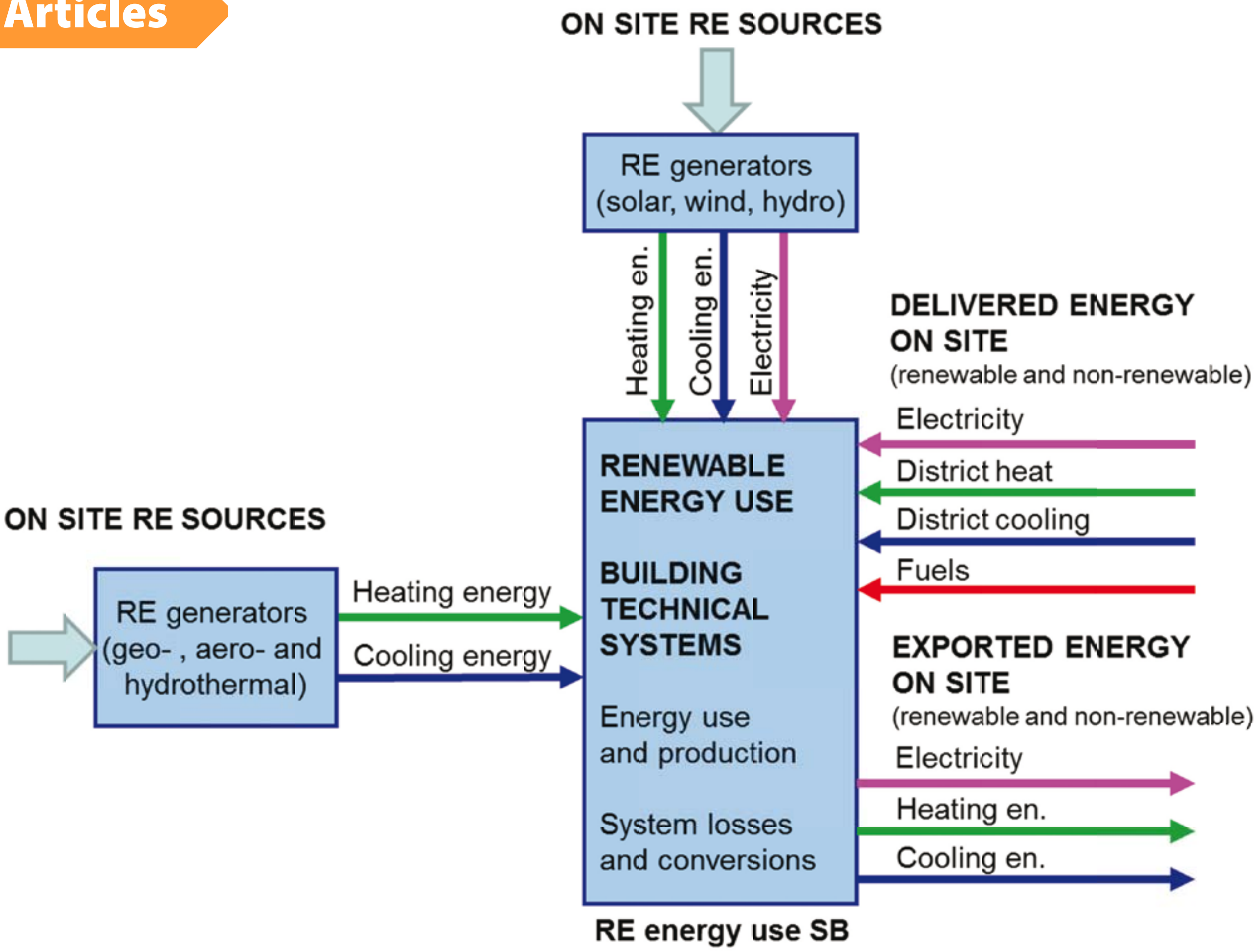


Figure 5. Renewable energy use system boundary for renewable energy ratio RER calculation. In addition to energy flows shown in Figure 4, renewable thermal energy from ambient heat pump and free cooling sources (heat exchangers) is accounted.

$f_{del,nren,i}$ 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;*

$E_{del,i}$ is the delivered energy on site or nearby for energy carrier *i*, kWh/a;

$E_{exp,i}$ is the exported energy on site or nearby for energy carrier *i*, kWh/a.

Calculation example

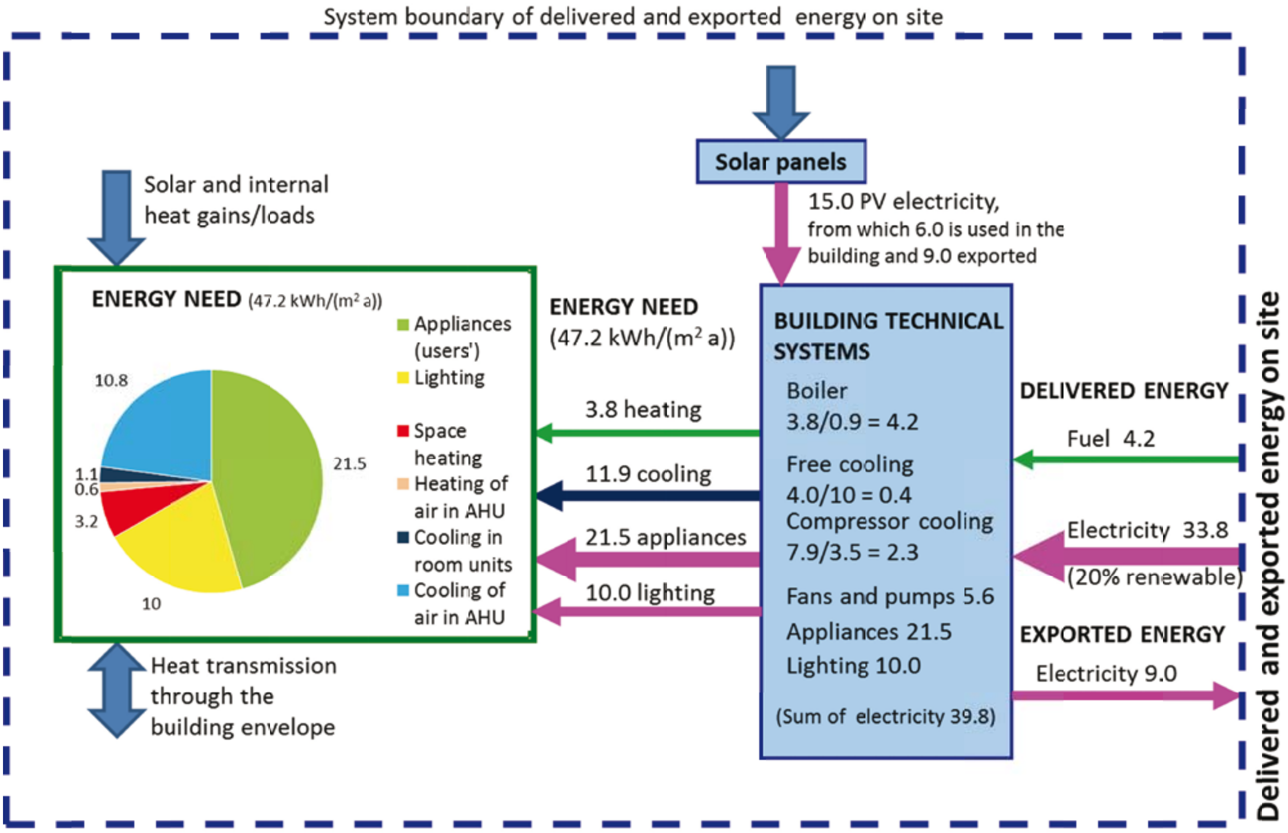
Consider an office building located in Paris with following annual energy needs (all values are specific values in kWh/(m² a)):

- 3.8 kWh/(m² a) energy need for heating (space heating, supply air heating and DHW)
- 11.9 kWh/(m² a) energy need for cooling
- 21.5 kWh/(m² a) electricity for appliances
- 10.0 kWh/(m² a) electricity for lighting

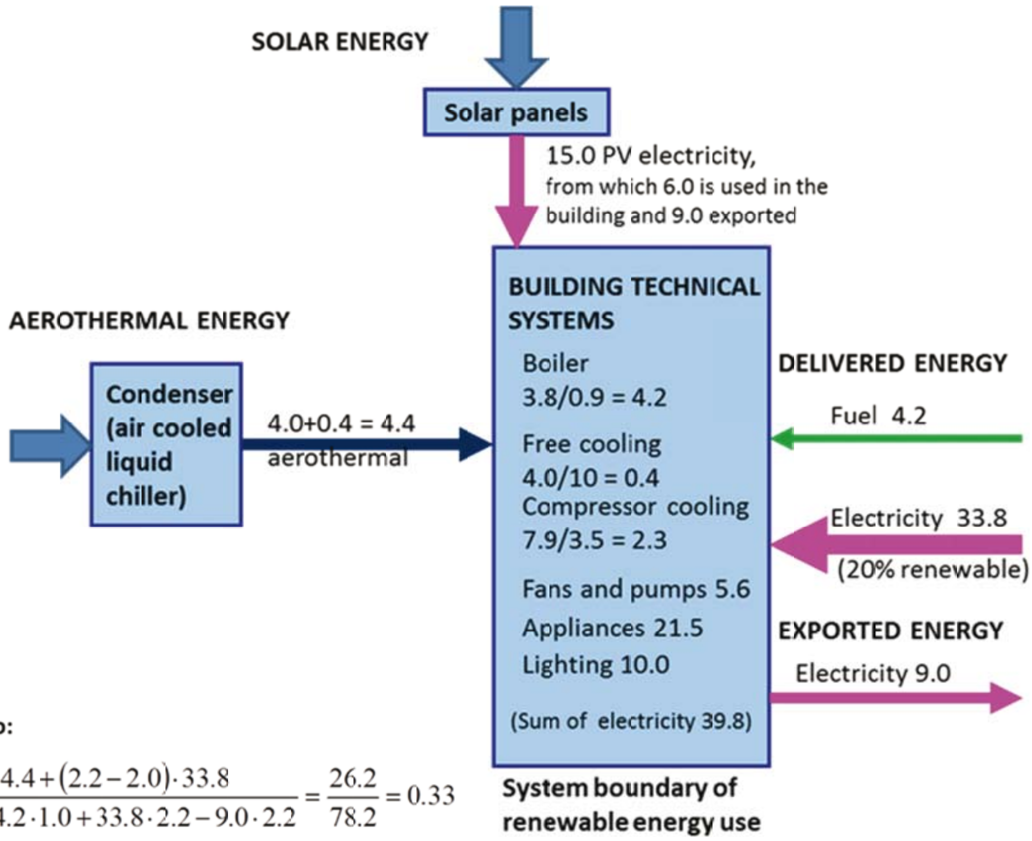
Breakdown of the energy need is shown in **Figure 6**.

The building has a gas boiler for heating with seasonal efficiency of 90%. For the cooling, free cooling from boreholes (about 1/3 of the need) is used and the rest is covered with mechanical cooling. For borehole cooling, seasonal energy efficiency ratio of 10 is used and for mechanical cooling 3.5. To simplify the calculation, emission and distribution losses of the heating and cooling systems are neglected in this example. Ventilation system with specific fan power of 1.2 kW/(m³/s) and the circulation pump of the heating system will use 5.6 kWh/(m² a) electricity. There is installed a solar PV system providing 15.0 kWh/(m² a), from which 6.0 is utilized in the building and 9.0 is exported to the grid.

Energy calculation results are shown in **Figure 6**, in the building technical systems box. Gas boiler with 90% efficiency results in 4.2 kWh/(m² a) fuel energy. Electricity use of the cooling system is calculated with seasonal energy efficiency ratios 10 and 3.5 respectively. Electricity use



Primary energy: $EP_P = 4.2 \cdot 1.0 + 33.8 \cdot 2.0 - 9.0 \cdot 2.0 = 53.8 \frac{kWh}{m^2 a}$



Renewable energy ratio:

$$RER_P = \frac{15.0 + 4.4 + (2.2 - 2.0) \cdot 33.8}{15.0 + 4.4 + 4.2 \cdot 1.0 + 33.8 \cdot 2.2 - 9.0 \cdot 2.2} = \frac{26.2}{78.2} = 0.33$$

Figure 6. Calculation example of the energy flows in nZEB office building.

Figure 7. Some nZEB office buildings are calculated and reported according to REHVA definition that makes it possible to compare the results. See in Journal 3/2011, 2/2012 and 5/2012 for these buildings from France, the Netherlands, Switzerland, Finland.

of free cooling, mechanical cooling, ventilation, lighting and appliances is 39.8 kWh/(m² a). Solar electricity of 6.0 kWh/(m² a) used in the building reduces the delivered electricity to 33.8 kWh/(m² a). The rest of PV electricity, 9.0 kWh/(m² a) is exported. The delivered fuel energy (caloric value of delivered natural gas) is 4.2 kWh/(m² a).

In this example, it is considered that 20% of the grid electricity is from renewable sources with the non-renewable primary energy factor of 0 and the total primary energy factor of 1.0. For the rest of 80% of the grid electricity the total and non-renewable primary energy factor of 2.5 is used. Therefore, the non-renewable primary energy factor of the grid mix is $0 \cdot 0.2 + 2.5 \cdot 0.8 = 2.0$ and the total primary energy factor is $1.0 \cdot 0.2 + 2.5 \cdot 0.8 = 2.2$. It is assumed that exported electricity compensates the grid mix.

Acknowledgment

REHVA nZEB Task Force and CEN EPBD project group members are greatly acknowledged for this work: Francis Allard, Derrick Braham, Dick van Dijk, Jacquelyn Fox, Jonas Gräslund, Per Heiselberg, Frank Hovorka, Risto Kosonen, Jean Lebrun, Zoltán Magyar, Livio Mazzarella, Ivo Martinac, Vojislav Novakovic, Jorma Railio, Olli Seppänen, Igor Sartori, Johann Zirngibl, Michael Schmidt, Maija Virta, Karsten Voss, Åsa Wahlström. ■