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SUPPORT THE DISSEMINATION AND ROLL-OUT OF THE SET OF ENERGY PERFORMANCE OF BUILDING STANDARDS DEVELOPED UNDER EC MANDATE M/480

Report on Case Study to EN ISO 52000-1 Overarching standard

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Prepared by Laurent Socal with contributions by the Project Team

Final report

Project Leader and contact point:

Mr Jaap (J.J.N.M.) Hogeling

Stichting ISSO

Weena 505, NL 3013 AL Rotterdam,
The Netherlands

PO Box 577, NL 3000 AN Rotterdam,
The Netherlands

T: Mobile: +31 65 31 61 973 |

E: j.hogeling@isso.nl

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Contents

Abbreviations and acronyms in this document:

AHU	**Air handling unit**
CEN	**European standards organization**
EN	**European standard**
EPB	**Energy Performance of Buildings**
EPBD	**Energy Performance of Buildings Directive**
EPB standard	**Standard for the calculation of energy performance of buildings, that complies with the requirements given in ISO 52000-1, CEN/TS 16628 and CEN/TS 16629 or later updates**
ISO	**International organization for standardization**
MS	**EU Member State(s)**
OFF	**Office building**
NA (/ND)	**National Annex or National Datasheet for EPB standards**
NSB	**National Standards Body of CEN and/or ISO**
PV	**Photovoltaic**
RER	**Renewable energy ratio**
TR	**Technical report (of CEN and/or ISO)**
XLS	**Spreadsheet**

1 Introduction

This document is intended to present the case studies and to discuss the contents of EN ISO 52000-1 and illustrate the effect of choices given in that standard.

This document is focused on the weighted energy and the renewable energy ratio (RER), that is on the energy performance indicators that are likely to be used for regulatory purpose.

The analysis in clause 5 gives the rationale of the selection of the case studies.

This case study assumes that the calculation of the energy flows within the building is done and monthly or hourly profiles of heat supply, heat extraction and electricity are available. Details and examples about these preceding calculations are given in the other case studies, including those on the whole building calculation (see Bibliography).

This document shows the effect of the choices concerning the parameters needed to apply this standard, such as the value of k_{exp}, the value of the weighting factors and the typical operating conditions values (e.g. amounts of energy carriers being used in the building) that one may expect according to the type of building and of generation technology used.

This case study will also consider the effect of the selection of the generation technology, which is strongly linked to the resulting energy performance in terms of weighted energy.

2 Executive summary

EN ISO 52000-1 deals with both the initial and the final part of the energy performance calculation of a building and related systems. Before proceeding with the actual calculations, spaces, thermal zones ad service areas are identified and the calculation is organised to suit the building and systems structure. At the end, the used, delivered, produced and exported energy carriers are collected and weighted to get the overall energy performance indicators. The focus of this case study is on the final electric energy balance and weighting of delivered and exported energy.

The case study starts with an analysis of the services to be provided and the required energy flows within the building. Starting from the needs, three main types of energy flows are identified within the building: heat supply, heat extraction and electricity use. Their shares influence the possible choices of the generation sub-systems. The generation subsystems use delivered energy carriers to provide heat, heat extraction and possibly electricity.

The calculation procedure defined in ISO-EN-52000-1 concerns the electricity balance and the final weighting of all energy carriers, including the determination of the RER.

The general concept of “weighting” is introduced to support the several possible energy performance indicators and also other types of indicators such as economical and polluting emissions.

The obvious influencing parameters (and national choice) are the **weighting factors**.

When there is exported energy, an additional influencing parameter (and national choice) **k_{exp}, states if to take into account exported energy**. You may include or exclude exported energy from the energy balance of the building. This choice may also introduce a reciprocal influence (potential compensation) between energy carriers and between energy import and export at different times.

Another influencing parameter is **the calculation interval**. Within a calculation interval everything is averaged: there is no strict correlation between electricity production and electricity use. On a monthly calculation interval, it looks like PV production during the day is able to supply lighting during the night. Any dynamic within the calculation interval has to be taken into account by statistical coefficients. On an hourly scale, the need for a storage or a compensation becomes explicit.

Finally, the weighting factors may be time dependent. An obvious example is cost, with peak and off-peak tariffs for electricity. Even though this is not used for rating, it is a required element of a correct cost estimation to suggest effective energy conservation measures. The variability of weighting factors of electricity during the day may soon become a relevant topic.

To demonstrate all these features and their impact, an hourly model of the energy flows within an entire building has been created to feed and stress the calculation procedure according to EN ISO 52000-1. The model is based on a mix of actual EN modules (using the demonstration spreadsheets) and simplified calculations to connect them and provide realistic time series of delivered and exported energy carriers for use within the Excel for EN ISO 52000-1.

The study shows that the choice on k_{exp} is a game changer. $k_{exp}=1$ allows compensation between exported and imported energy at different time or by different carriers. This generally allows a better (lower) energy performance than that obtained setting $k_{exp}=0$. Both solutions are used by the EU Member States (MS). This is not to say that there is a "right" or "wrong" solution, just that there are two possible ways to evaluate exported energy. That's no difference with economical accounting: when accounting an item, you may evaluate it either as its cost or as its (potential) revenue (i.e selling price). EN ISO 52000-1 makes this alternative evident and allows to make this choice in a transparent and explicit way, using the parameter k_{exp}.

The study also shows that the most suitable calculation interval is hourly. Energy carriers exchange (delivered and exported) and energy carriers weighting factors are constant (or may be reasonably considered constant) over an hourly time-span. Using a longer time interval (daily, weekly or monthly) requires averaging factors and matching factors to describe the variable energy carrier flows between the building and the surrounding world within the calculation interval.

This module is extremely simple to use and there are quite few parameters. Their impact shall be fully understood and supported by the right calculation interval.

This module covers in principle all technologies. The case study also provides a solution to integrate an electricity storage (battery) in the calculation process and demonstrates its potential effect.

3 The context of the case study

3.1 Energy use in a building

Energy is used in the buildings for two main reasons:

- "**comfort services**", that is providing adequate **comfort conditions** to people inside the building so that they can perform their intended activities;
- "**process**" use, that is supporting the **activities** performed inside the building.

EU directive EPBD and EPB standards are focused on comfort services.

Process activities within the building may influence comfort performances and energy use through heat gains. They will be mentioned when relevant.

Note Electric energy or any other energy carrier input used for process is turned into heat within the building. There may be other process flows (flue gas, ventilation air, etc.) removing or adding energy to the building (which can be a benefit or a supplementary load, depending on the season). In several cases process energy use is just electric energy turned into heat within the building. Other process uses may include domestic hot water e.g. for a hairdresser. Another example is the kitchen for a restaurant. These issues should be addressed, especially in the context of high-performance buildings.

3.2 Comfort services

The services required to provide comfort to the occupants of building are listed in table 1.

Code	Service name	Definition	Notes
H	Heating	Keeping indoor temperature above a minimum comfort value.	Typical is 20 °C Comfort temperature depend on activity and clothing of occupants and other properties.
C	Cooling	Keeping the indoor temperature below a maximum comfort value	Typical is 26 °C.
W	Domestic hot water	Providing domestic hot water for personal hygienic needs of people within the building	Domestic hot water may be used for process purposes as well. Example: hairdresser domestic hot water should be considered process. It is not needed for people living and working in to the building
V	Ventilation	Providing a minimum flow rate of outdoor air	The need is defined by the required IAQ. Ventilation may require energy use for two reasons: • air treatment: energy required to bring outdoor air at indoor comfort conditions • air flow: the energy required to bring in outdoor air and exhaust indoor air (fans), in case of mechanical ventilation
HU/DHU	Humidification and dehumidification	Keeping indoor relative humidity within a defined range	The association of temperature (heating/cooling) and humidity (humidification / dehumidification) is called “air conditioning”
L	Lighting (*)	Providing a minimum illumination in lux on work planes	
T	People transport (**)	Transporting people around the building	This may include elevators and travelators
NOTES (*) generally considered only for non-residential buildings (**) not considered in the EU directive EPBD amongst the building services but already considered by some EU Member State (MS)			

Table 1: Comfort services considered in the EPB assessment

Depending on climate and building type and use, some services may be not required. This has to be taken into account when comparing building performances.

The relative contributions of services in the overall energy performance of buildings is changing with time. In the past, for most regions in Europe, heating required the highest share of comfort related energy use. Insulation of new buildings is greatly reducing the energy required for heating whilst other services, such as domestic hot water and air conditioning, are unaffected or are even increasing because of raising comfort standards and may become dominant.

3.3 Energy flow in a building

Comfort services require provision of energy of various types.

The physical energy flow in a building is:

- from the delivery of energy carriers at the assessment boundary;
- to the use inside each space of the building;

as shown in figure 1.

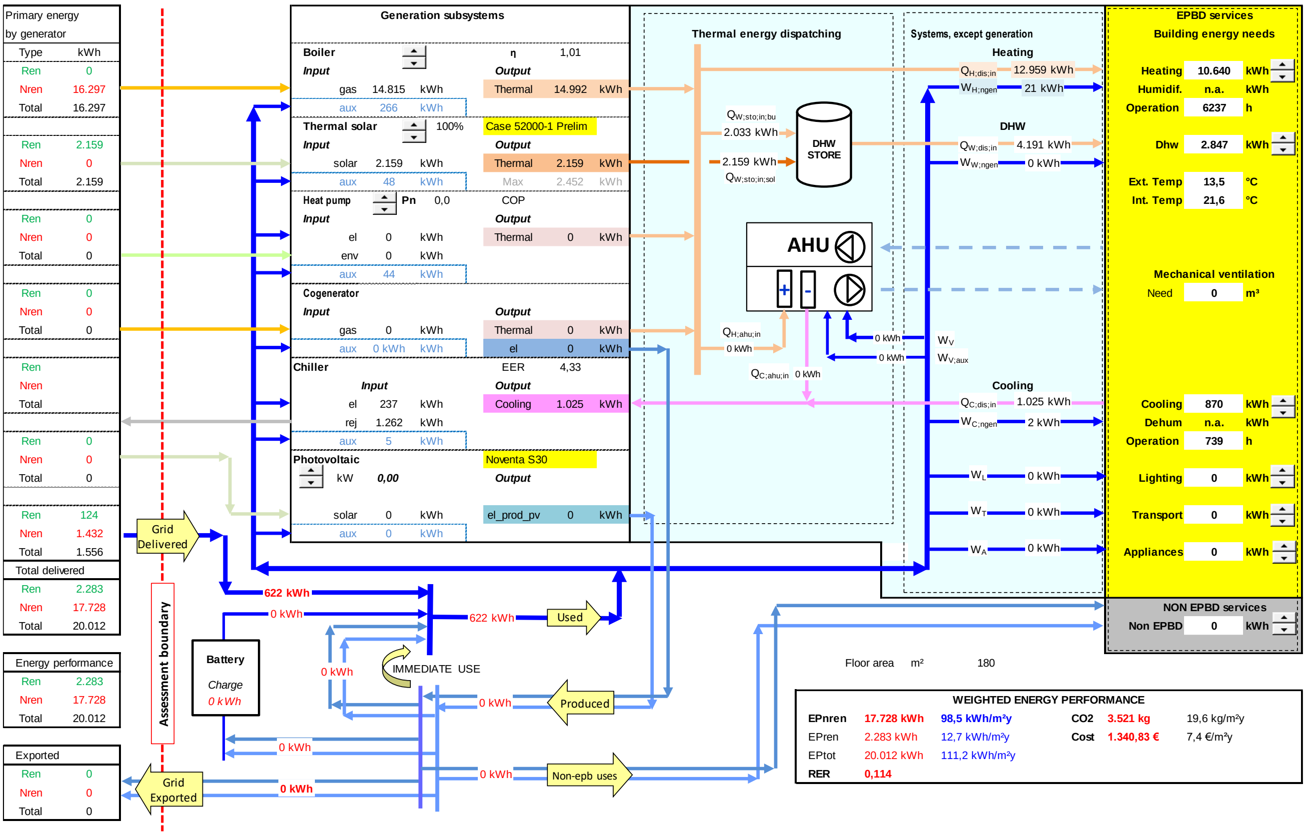


Figure 1: basic flow of energy in a building, from the assessment boundary (dashed red line on the left) to the uses (yellow box on the right)

Figure 1 is a simplified diagram which is used as an interface on the main file to demonstrate EN ISO 52000-1. It shows only one line per energy flow. It does not show the possibility to have several thermal zones or service areas in parallel.

The following main steps in the energy flow can be distinguished.

1. Energy from the various sources is delivered to the building, passing through the assessment boundary, as a set of **energy carriers**. This includes grid delivered electricity. If electricity is produced on site, there can also be a flow of exported electricity from the building to the grid.

NOTE Export may happen for heat as well, however this happens rarely and it is not explicitly considered in the equations of EN ISO 52000-1. The principle to solve this case is only described in wording.

2. Energy carriers (including electricity) are converted into either:
    a. Heat,
    b. heat extraction,
    c. and electricity

   in the "***generation***" subsystems (they should be called "transformation" sub-systems).

3. Heat, heat extraction and electricity are distributed into the building where they are used to provide the required comfort services.

Some technical systems may generate special types of services using heat, heat extraction and electricity. Example are mechanical ventilation and lighting. This is shown by the air handling unit (AHU) which is in the middle of the diagram. The AHU uses electricity for the fans to move the air and heat and heat extraction in the coils to condition air supplied to the building.

Advanced technical systems may include additional features such as heat recovery, heat exchange and/or active heat transfer (e.g. if heat and heat extraction are required simultaneously) to increase the overall efficiency, which makes the actual energy flow in a high tech building potentially more complex.

The energy performance calculation goes the other way round (from the needs to the delivered energy) with the following basic steps.

1. The requirements are defined as a set of **comfort levels** and comfort profiles. This depends mainly on the use of the building.
2. **Needs** are calculated, based on the comfort requirements. This takes into account the properties of the building envelope and of some technical systems.
   Please note that not all needs are natively an energy. Ventilation need is actually an amount of fresh, outdoor air. Energy is required then to move the air (electricity for fans) and to bring external air to indoor conditions (heat and heat extraction to adjust temperature and humidity).
3. The required **heat, heat extraction and electricity** are calculated taking into account all technical systems except generation.
4. The required amounts of **energy carriers** are calculated, taking into account the available generation sub-systems and their priorities.
5. Finally, the required energy carriers are expressed as **weighted energy** to provide the global energy performance indicators.

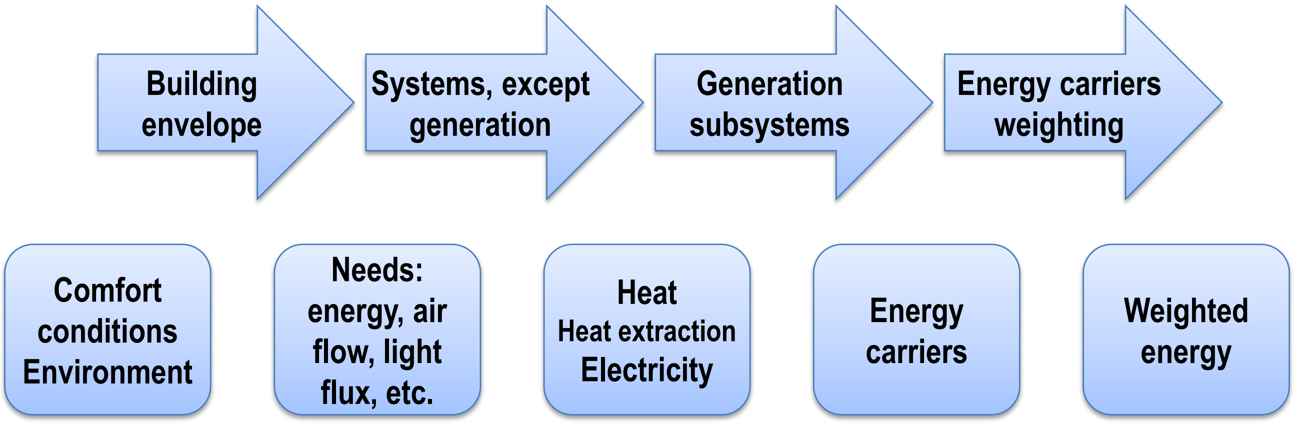


Figure 2: block diagram for the calculation of energy flow in a building

The previous scheme gives the outline of the calculation process and shows the levels at which energy amounts are:

- calculated;
- and/or measured;
- and/or used to provide indicators;
- and/or subject to legal requirements.

The following table gives an overview of energy flow characteristics at each level.

Level	Type of energy involved	Notes
Needs	Various. The native need may not be an energy amount. Reference conditions are needed to define needs (e.g. desired indoor temperature, domestic hot water temperature t the tap, etc.)	Ventilation need is natively a volume of fresh outdoor air. It becomes an energy need depending on air treatment (bringing air to indoor temperature and humidity) and air transport (fans) requirements. Strictly speaking, even heating is natively a requirement for a temperature, not an energy. Needs are regulated when they depend on technology adopted, especially for the envelope (heating and cooling need). It is no use to regulate needs when they do not depend on technological choices.
Usable energy	Heat Heat extraction Electricity Air flow Light flux	These are the energy forms that are distributed within the building. The amounts of the different types of energy cannot be summed. Usually, they are not regulated.
Delivered energy	Any energy carrier (gas, electricity, heat from district heating, etc.) which is crossing the assessment boundary.	These are the energy forms that are supplied to the building and metered. Energy carriers can be delivered (incoming through the assessment boundary) and/or exported. The amounts of the different types of energy carriers cannot be summed directly. This is seldom regulated.
Weighted energy	A common property of all energy carriers, such as primary energy contents, CO_2 emission, cost, etc.	Renewable and non-renewable primary energy are independent weighting. Precise conventions are required when energy carriers may be both imported and exported. Additional indicators are defined, such as the renewable energy ratio (RER), based on the ratio of renewable primary energy to total primary energy

Table 2: Energy flow characteristics at different levels

3.4 The role of EN ISO 52000-1

3.4.1 Introduction

There is a huge number of possible configurations for a specific building and its associated technical systems. Therefore, the EPB standards provide a set of modules that can be combined together to follow the actual structure of the calculation object.

EN ISO 52000-1 has a double role in this context:

- It is the standard that has to be considered before starting any calculation, because it defines the overall organisation of the energy balance of the building (e.g. the arrangement of modules). This includes topics such as:
  - defining the services to be taken into account

  - defining the zoning methodology
  - setting overall calculation options
  - defining the overall calculation sequence
  - …
- EN ISO 52000-1 has to be considered again at the very end of the calculation for the following tasks:
  - the overall electric energy balance, with possible inclusion of electricity storage;
  - the weighting of delivered and exported energy;
  - the calculation of partial energy performance indicators, per service or per zone.

This case study focuses on the second role of this standard and specifically on the overall electric energy balance and the weighting of delivered and exported energy. The calculation of partial energy performance indicators is straightforward and does not require any special parameter.

To test and stress EN ISO 52000-1, a simulation of the building is required to generate realistic hourly patterns of energy flows. This is shown in figure 3, which is taken from the interface of the calculation tool that has been developed for the purpose of demonstrating EN ISO 52000-1. The area enclosed by the red dashed line is the domain covered by EN ISO 52000-1.

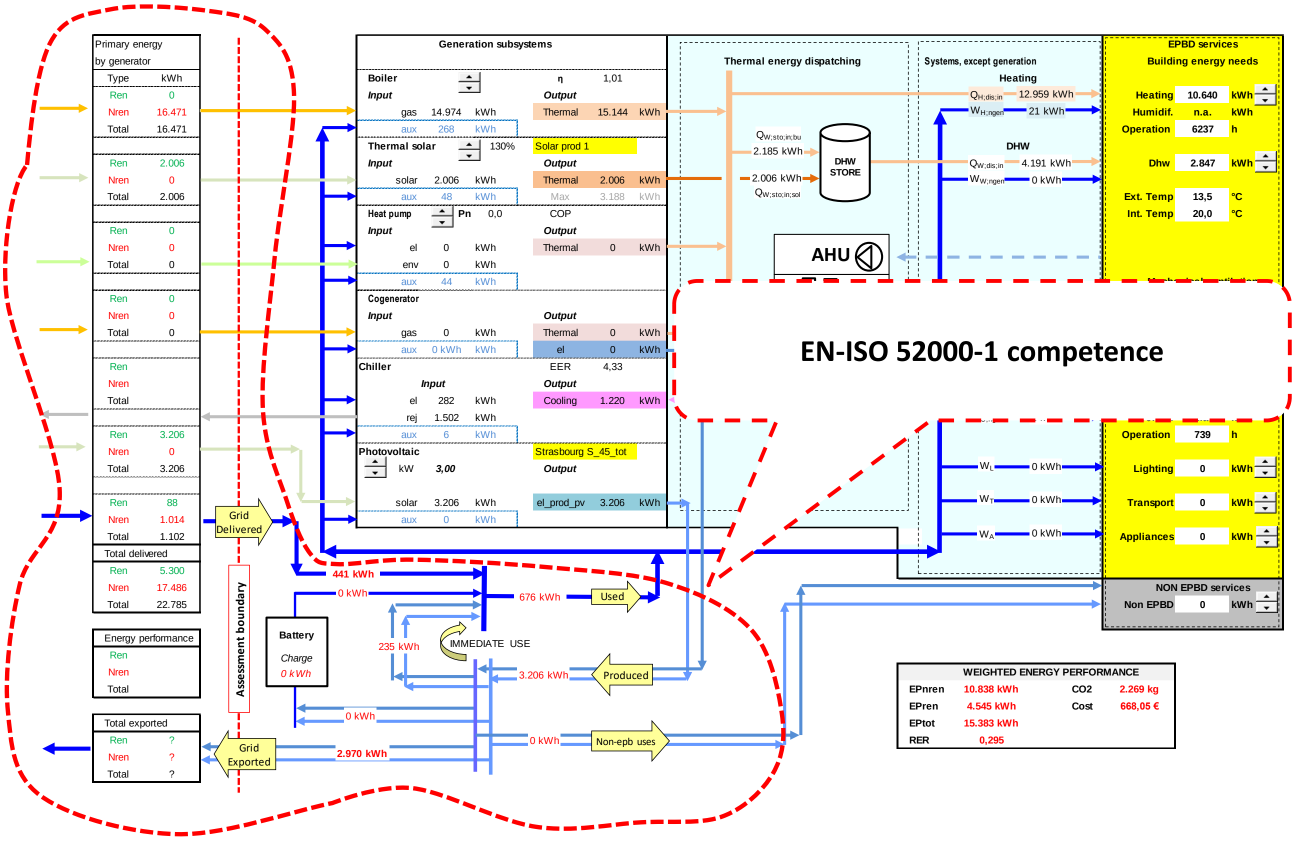


Figure 3: The competence of EN ISO 52000-1

The simulations are based on a set of hourly profiles for:

- the needs (heating, cooling, domestic hot water, etc.), calculated with EPB modules;
- climatic data.

Then the effect of technical systems is simulated with simple models and calculations that take into account:

- technical systems losses (non-generation part);
- technical systems auxiliary energy use;
- effect of storage on heat required for domestic hot water preparation;
- nominal properties of generators (boiler efficiency, heat pump COP, peak power of PV panels, etc)
- effect of operating conditions (flow temperature and climatic conditions) on boiler and heat pump performance;
- priority between generators, taking into account available power.

This is not intended to replace the regular EPB modules and their full functionality but to provide a reasonable estimation of the required delivered and exported energy carriers to get a realistic simulation of representative cases. Connecting the actual EPB modules would take a disproportionate effort compared to the achievable results for the purpose of this study.

Selected modules will be used and coupled together to demonstrate their functionality in other case studies.

3.4.2 Electric energy balance

Electricity is an energy carrier that is used throughout the building for auxiliaries but also as the main driving power of some generation devices (heat pumps, chillers, AHU fans, etc.).

Electricity can be taken from (e.g. delivered by) the grid but it can also be produced on site and even exported if the on-site production exceeds electricity use in the building. This can be done only at the end of the calculation of all electricity uses and productions and it has been therefore left as a task for EN ISO 52000-1.

This study also covers a very likely future development, the use of on-site batteries to store electric energy on site (see clause 6.8 and annex B for more details).

Figure 4 illustrates the electric energy balance in EN ISO 52000-1.

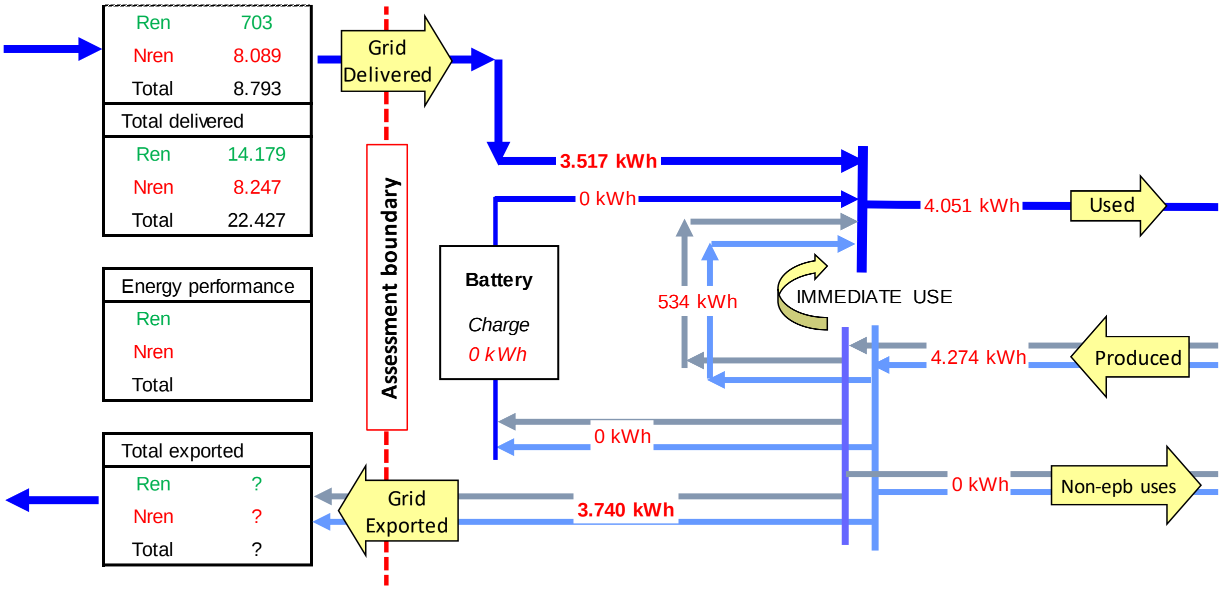


Figure 4: the electric energy balance of EN ISO 52000-1

The calculation of the building and technical systems provides, for each calculation interval, the amounts of **used electricity** and **produced electricity**.

If there is some produced electricity, coming from either PV, cogeneration or wind turbines, then it is accounted according to the following priority.

1. First for **immediate use**, up to the amount of used electricity.
2. If there is some electricity left, then it can be used to **charge the battery** (if available in the system) up to the maximum possible amount.
3. If there is still some electricity left, it can be used to satisfy **non-EPB uses** (such as plug loads or any other process load) if they are taken into account (by default non-EPB uses are not taken into account since they are out of scope of the EU directive EPBD).
4. The remaining produced electricity, if any, is considered as **exported to the grid**.

Symmetrically, the following priority is considered in selecting the electricity source to satisfy EPB uses.

1. Firstly, **on-site produced electricity** is used as much as available.
2. If more electricity is needed, it is **taken from the battery,** if the battery is available and charged.
3. If still more electricity is needed, then it is taken from the grid as **grid delivered** electricity.

EN ISO 52000-1 includes some dedicated features to fine tune the electric energy balance and reflect legal requirements in the various countries, such as:

- the possibility to use a matching factor to better identify the quota of the produced energy which is really used in the building when using the monthly method;
- the possibility to define a priority for exported energy in case of multiple on-site generators;
- the possibility to exclude specific uses of on-site produced electricity (example: no PV used for direct electric heating).

3.4.3 Weighted energy

The various energy carriers that are delivered and/or exported cannot be summed together just as a kWh amount because their use has quite different impacts per kWh on environment and costs.

Therefore, their amount shall be weighted and the following weights are explicitly supported by EN ISO 52000-1.

- **Non-renewable primary energy**, that is the amount non-renewable energy that was extracted from the sources to deliver the required energy to the building.
- **Renewable primary energy**, that is the amount of renewable energy that contributed to deliver the required energy to the building
- **Total primary energy,** the sum of renewable and non-renewable energy.
- **CO_2 emission**, that is the amount of CO_2 which is released to the atmosphere to provide the required energy to the building. This takes into account the CO_2 required to produce the delivered energy (electricity) and the CO_2 which is released when converting the energy carrier into heat (combustion of fuels) minus the CO_2 that was captured in producing the bio fuels.
- **Cost**, that is the amount of money needed to provide the required energy to the building

There are several other ways to weight delivered energy (example: according to polluting emissions). The same concepts apply to them.

This topic is straightforward until there is only delivered energy. For each delivered energy carrier, the amount of weighted energy is just the product of the delivered energy multiplied by the weighting factor for that carrier. Weighting requires much more attention when it comes to exported energy, which can be evaluated in at least in two very different ways by nature.

Weighting is the most influencing topic of EN ISO 52000-1 about energy performance and options may dramatically change the results, as shown in the following.

Selecting the appropriate generation technology allows to use the most convenient energy carriers to affect the weighted energy performance.

Requirements on weighted energy may influence or limit the choice of the generation technology.

3.5 The relation between EN ISO 52.000-1 and building and technical systems

The energy performance of a building depends on the desired indoor conditions, the external climate, the building envelope and all the technical systems (type, configuration and control options).

The impact of the parameters set in EN ISO 52000-1 is strongly connected with the type of heat generation, heat extraction and electricity production, because these choices determine the type and amount of the delivered and exported energy carriers, therefore the effect of the weighting.

As it has been highlighted in clause 3.3, the needs and the technical systems, excluding generation, first determine:

- heat supply,
- heat extraction,
- and electricity

needed for the heat distribution, cooling distribution, lighting, air handling unit, etc. as an input depending on the type of building and climate.

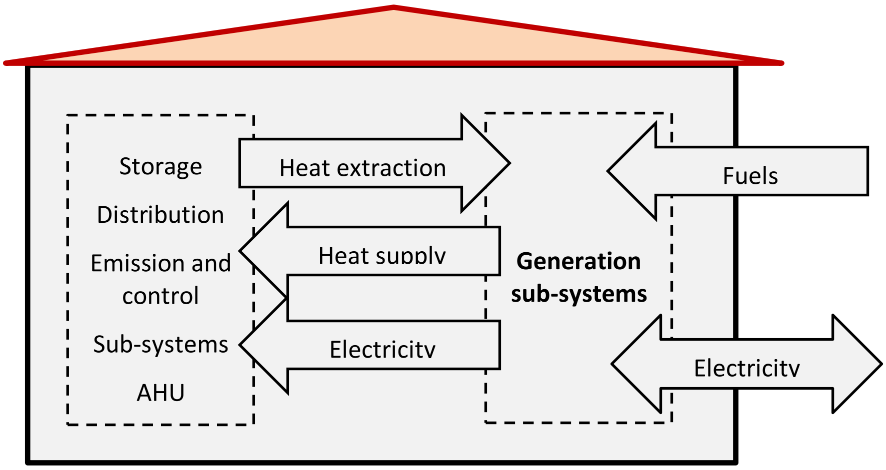


Figure 5: simplified energy flow

The choice of the generators to provide heat, heat extraction and possibly on-site electricity determines the final requirements of

- fuels;
- and electricity.

The available generation technologies are listed in the following table.

Technology	Provides	Uses as a main input	Remarks
Boiler	heat	fuel	Thermal efficiency limited by the conversion concept May use biofuels (renewable energy)
Heat pump	heat	electricity	High efficiency possible due to the transfer concept
Absorption and engine driven heat pumps	heat	fuel	High efficiency possible due to the transfer concept
Thermal solar	heat	solar radiation	Mainly for domestic hot water, cannot cover the whole year. Available only during the day and depending on climatic conditions
District heating	heat	heat	Properties depend on central generation system
Cogeneration	heat and electricity	fuel	Needs simultaneous electric and thermal load
Chiller	heat extraction	electricity	
Absorption and engine driven chiller	heat extraction	fuel	
Photovoltaic	electricity	solar radiation	Available only during the day and depending on climatic conditions
Wind turbine	electricity	wind	Availability depends on climatic conditions

Table 3: Generation technologies

Currently:

- boilers are being replaced progressively by heat pumps for heating;
- heat extraction (cooling) is mostly provided with electric chillers;
- photovoltaic is a popular generation device to produce electricity on-site from a renewable source;
- ventilation, lighting and people transport are provided using electricity;
- heating needs are being reduced by insulating the buildings;
- cooling, domestic hot water, ventilation needs cannot be influenced by the building envelope technology;
- comfort requirements concerning cooling and air conditioning are increasing.

This determines a progressive shift:

- from old buildings, where the heating need was dominating and fuel was the main energy carrier;
- to new or deeply renovated buildings where the heating need is strongly reduced and is provided with electricity driven generators, so that the main energy carrier is electricity.

Fuels cannot be produced on-site and exported, so the role of EN ISO 52000-1 in the calculation of the contribution fuels to energy performance is marginal.

Electricity can be produced on site, either with renewable sources or with fuels. This makes the electric energy balance more and more important and opens the possibility to export energy carriers. In this case the role of options specified in the EN ISO 52000-1 is paramount to determine the energy performance.

Various combinations of generation technologies will be considered and the effect of the choice of heat generation, heat extraction and electricity production will be analysed, according to the selected weighting options.

4 Coverage of the scope

4.1 Introduction

The following criteria can be used to evaluate the scope of EN ISO 52000-1:

- technologies included in the building and technical systems;
- possible electric energy distribution configurations;
- required performance indicators;
- calculation interval.

4.2 Coverage of technologies

EN ISO 52000-1 covers automatically all technologies involved in the use of energy in the building and described by underlying modules, since all of them result in an amount of delivered energy or exported energy in the form of energy carriers.

Any new energy carrier would be easily included as a new item in the tables.

Cogeneration, photovoltaic, wind turbines and more are covered.

NOTE: a technology is automatically covered by EN ISO 52000-1 as soon as a module is available for that technology.

4.3 Coverage of electric energy balance possibilities

EN ISO 52000-1 covers the case of on-site electric energy production. A balance between used and produced electricity in each calculation interval determines the grid delivered and/or exported electric energy. The case of multiple generation technologies at the same time is handled as well with priorities.

EN ISO 52000-1 doesn’t cover yet the storage of electric energy. However, this case study includes a simple proposal to handle this technology which is starting to be used. An enhanced version of the EN ISO 52000-1 spreadsheet has been used to cover this technology and the equation used are documented. This can be proposed to the responsible CEN and/or ISO working group and technical committee for inclusion.

EN ISO 52000-1 may be easily extended to cover low voltage auxiliaries, e.g. supplied directly by PV panels without AC/DC conversion and voltage shift. This is not considered in this work because it is not yet significant.

The possible use of the EN ISO 52000-1 to calculate the interaction with energy communities or local networks (“nearby”) is not described in the standard and in the accompanying technical reports. However, “step A” include all the necessary information on the exported energy to allow this calculation. See also next clause.

4.4 Coverage of performance indicators

EN ISO 52000-1 covers all the types of weighting which are currently required by the EU directive EPBD:

- non-renewable primary energy;

- renewable primary energy;
- total primary energy;
- CO_2 emissions;
- Costs.

Additional weighting criteria can be easily incorporated. The accompanying spreadsheet has been enhanced to provide simultaneously all the main weightings: primary energy, CO_2 emission and cost.

EN ISO 52000-1 covers the evaluation of both delivered and exported energy.

Two main options are provided about exported energy:

- Excluding exported energy from the energy performance of the building (k_{exp} = 0 also called “step A” or ”Option “A”)
- Including exported energy directly into the energy performance of the building (k_{exp} = 1, also called “step B” or Option “B”)

NOTE The nicknames “step A” and “step B” (and then “option A” and “option B”) originate from the fact that the calculation process always calculates first (A) the energy performance with k_{exp} =0 and then (B) the difference between the two evaluations, that is the gain in including exported energy in the energy performance of the building.

There is no “right” or “better” approach in the evaluation of exported energy. The choice between option A and option B depends on the desired meaning of the energy performance indicator. For specific applications, a specific option may be required, indeed (see the following).

EN ISO 52000-1 covers the RER calculation. There is full flexibility in defining which renewable energy components can be taken into account in the definition of this index.

EN ISO 52000-1 is scalable and may be used in the context of local grids (energy communities). For this application, “option A” shall be selected. When selecting option A, the indication of the energy available externally keeps track of the contribution of the building to the local grid, both in terms of quantity and weight of available electricity. Actually, you have to know all the contributions of all the buildings connected to the local grid to determine the right weighting factors and the total import/export of the local grid. This type of calculation may be performed by the local grid administrators.

EN ISO 52000-1 covers the allocation of weighted energy to individual services and zones within the building, to support partial performance indicators. This is demonstrated in a dedicated spreadsheet and doesn’t require any option from the user. Predefined criteria are used for the allocation of energy.

4.5 Coverage of calculation intervals

EN ISO 52000-1 can be used with any calculation interval (seasonal, monthly, weekly, etc.) even though only hourly and monthly are mentioned in the text.

If energy is only delivered to a building and the value of the weighting factor is constant (e.g. not time dependent), then any calculation interval can be used.

If either:

- there is a bidirectional interaction with the grid;
- or weighting factors are time dependent;

then the calculation interval shall be similar to the time interval for the changes of the values of the time dependent variables. If not, correction coefficients shall be introduced to take into account for dynamic effects.

The hourly calculation interval is the most appropriate for the electric energy balance, since it is reasonable to assume that the considered loads are approximately constant over one-hour intervals. Also tariffs and weighting factors depend on hourly time schedules.

If there is exported electric energy, the matching factor is provided as a means to approximate dynamic interactions with the grid for the monthly method. The use of the monthly calculation interval without a matching factor would lead to a significant distortion of results.

To analyse the impact of the calculation time interval:

- the varying input variables will be hourly profiles to take into account properly any time mismatch between on-site production and use;
- the same calculation will be performed monthly with the monthly aggregation of hourly data to demonstrate the different result obtained starting from the same input data.

5 Definition of the cases

5.1 Rationale of the selection of cases

The selection of cases shall cover

- the possible mixes of carriers and their relative amount;
- the possible profiles of use of the different carriers;
- EN ISO 52000-1 parameters options;

Taking into account the main building types, building technologies, generation technologies and climates.

As stated in clause 3, The case study has to cover different options on typical buildings to highlight the potential consequences

5.2 Building categories

Only one type of building is considered in this case study, the single-family house which represents a big share of the market.

This type of building category already allows to experiment and demonstrate all the possible cases in the application of EN ISO 52000-1.

Similar calculations are performed in more details and for the whole building in the case study about the office building.

5.3 Building technologies

5.3.1 Existing building

The typical mix of technologies for the existing buildings is the following:

- poorly insulated building envelope;
- heating with radiators;
- domestic hot water with instantaneous production or storage;
- natural ventilation, mechanical ventilation only for offices;
- split air conditioner for warm climate in the residential sector;
- fan coils (in offices);
- possibly, thermal solar for domestic hot water;
- mechanical ventilation in non-residential buildings, with low efficiency fans

Existing buildings use mostly fossil fuels and electricity for auxiliaries and special services.

5.3.2 New buildings

The typical mix of technologies for new and deeply renovated buildings is the following:

- well insulated building envelope;
- heating with low temperature emitters (embedded panels or other) for residential buildings or fan-coils for offices;
- domestic hot water with storage;
- mechanical ventilation with heat recovery and high efficiency fans;
- cooling with fan-coils for offices;
- PV on the roof.

New and deeply renovated buildings may use mostly electricity up to “full-electric” configurations.

5.3.3 Selected configuration

The most influencing factor is the electricity balance. Its variations can be explored and demonstrated on a residential building with the following configuration:

- average insulation of building envelope;
- floor heating, to allow a switch, all other conditions being equal from a boiler using fossil fuel to a heat pump using electricity;
- natural ventilation;
- possibly, thermal solar for domestic hot water;
- possibly PV production to introduce a significant on-site production in the energy balance.

This configuration allows significant amounts of electric and non-electric energy carriers.

5.4 Calculation parameters

5.4.1 Weighting factors

The default weighting factors listed in annex B of EN ISO 52000-1 are used.

Values are listed in table 6 in the following.

5.4.2 Exported energy evaluation parameters

Calculation is always performed with both Kexp= 0 and Kexp=1 since this is an impacting national choice.

The base calculation is performed with the hourly method. When relevant, calculation is repeated with the monthly method using the monthly aggregated hourly data. The monthly calculation is also repeated using no matching factor or using the default matching factor given in annex B of EN ISO 52000-1.

5.5 List of cases

The base case of this case study is the following:

- single family house, moderately insulated;
- average climate;
- the use profile generates moderate needs for cooling in summer;
- low temperature heating emitters (floor heating);
- natural ventilation;
- thermal solar that covers little more than half of domestic hot water needs.

The following cases are explored:

- addition of PV and
  - $k_{exp} = 0$
  - $k_{exp} = 1$
- heat pump as a replacement of the boiler;
- heat pump and PV instead of thermal solar;
- heat pump, thermal solar and PV with
  - $k_{exp} = 0$
  - $k_{exp} = 1$
- addition of a battery.

This study is aimed to explore the following topics:

- the effect of the basic trend in generation systems, shift from boiler to heat pumping;
- the effect of on-site generation on energy performance as a function of k_{exp} and generation type;
- the effect of shifting to electric systems;
- the importance of the hourly method when dealing with exported energy.

5.5.1 Calculation cases summary

The list of the calculation cases is given in the following table 4.

Case	Heat generation	PV	Thermal solar	Kexp	Battery
1	Boiler	NO	YES	0	No
2	Boiler	YES	YES	0	No
3	Boiler	YES	YES	1	No
4	Heat pump	NO	YES	0	No
5	Heat pump	YES	NO	0	No
6	Heat pump	YES	YES	0	No
7	Heat pump	YES	YES	1	No
8	Heat pump	YES	YES	0	X kWh

Table 4: List of calculation cases

The rationale of the selection of the cases is the following

- Case1

  This is the reference configuration and represents the current basic condition of a lot of buildings. The building uses a mix of fuel and electricity.
- Case 2

  Compared to case 1, it shows the effect of PV without taking into account exported energy
- Case 3

  Compared to case 1, it shows the effect of PV if taking into account exported energy

  Compared to case 2, it shows the effect of the choice on Kexp

- Case 4

  Compared to case 1, it shows the effect of replacing a combustion boiler using fossil fuels by a heat pump. This shifts the energy carriers mix towards a full electric configuration.
- Case 5

  Compared to case 4, it shows the effect of replacing thermal solar with PV when using a heat pump
- Case 6

  Compared to case 4, it shows the effect of having both PV and thermal solar when using a heat pump
- Case 7

  Compared to case 6, it shows the effect of taking into account exported energy with PV and a heat pump
- Case 8

  Compared to case 6, it shows the effect of a battery when not taking into account exported energy

They are commented individually in the following clause 6.

5.6 Calculation tool

An enhanced version of the spreadsheet about EN ISO 52000-1 has been prepared for the case study.

An interface and a simple model of the building and technical systems calculation has been integrated to allow a quick simulation of the entire building technical systems.

The starting point are need profiles that were calculated for the test buildings with EPB modules and with a software based on EN ISO 52016-1. Hourly profiles for PV production and thermal solar producibility have been prepared with EPB modules as well.

Systems have been integrated with simple models that take into account:

- losses and auxiliary energy use of sub-systems, per service;
- efficiency of generation systems, including the influence of operating conditions;
- the effect of the presence of a storage on domestic hot water production;
- priorities between heat generators;
- sizing of a cogenerator or heat pump.

All parameters are visible in the sheet “*Base_calc_hourly*” of the spreadsheets about EN ISO 52000-1.

The calculation can be easily repeated for the hourly values and for the corresponding aggregated monthly values, to highlight the difference between monthly and hourly calculation

6 Calculation details

6.1 Case 1– Boiler - no PV - thermal solar

6.1.1 Sample building description

Data from a known building were taken. The building is a single-family house with net floor area 180 m^2.

The insulation level is rather good and thermal bridges are included in the calculation

Solar heat gains are low due to the orientation and configuration of the sample building, so the heating energy performance is average.

The heating and cooling set points are 20 °and 26°C constant according to EN 16798-1 default profile.

Climatic data are taken for a location in northern Italy. It is somewhat warmer than Strasbourg and it has been selected to have some cooling needs. This building in Strasbourg would not need any cooling.

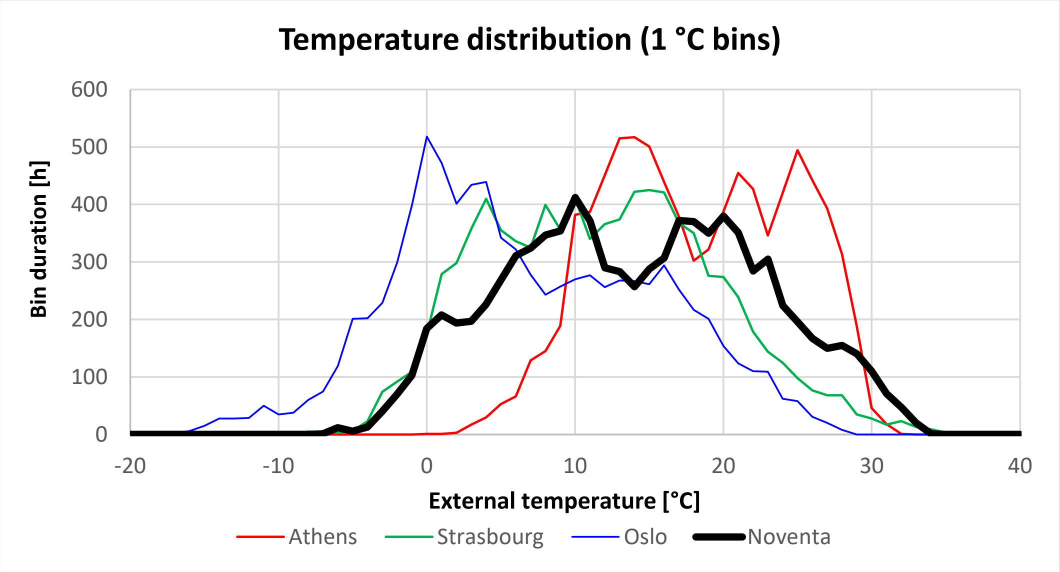


Figure 6: External temperature distribution (1°C bins) for the location, compared to reference climates. The climate used for this study is quite near to the Strasbourg climate

Heating and cooling needs have been calculated with a software based on EN ISO 52016, hourly method.

Figure 7 is the 3D view generated by the input interface of the software.

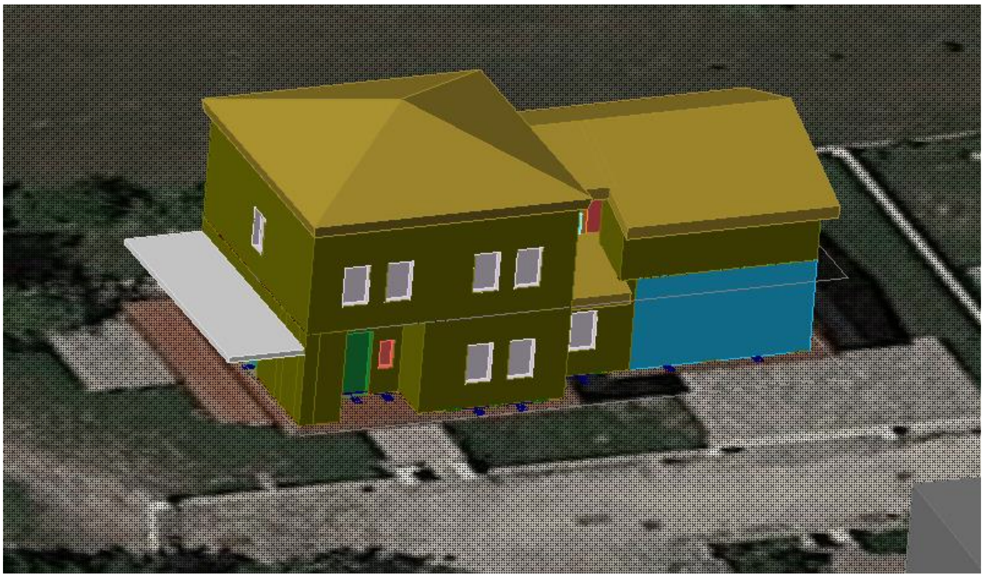


Figure 7: The sample building used to generate the hourly profiles

Use profiles are taken from EN 16798-1 default values. They are shown in figures 8 and 9.

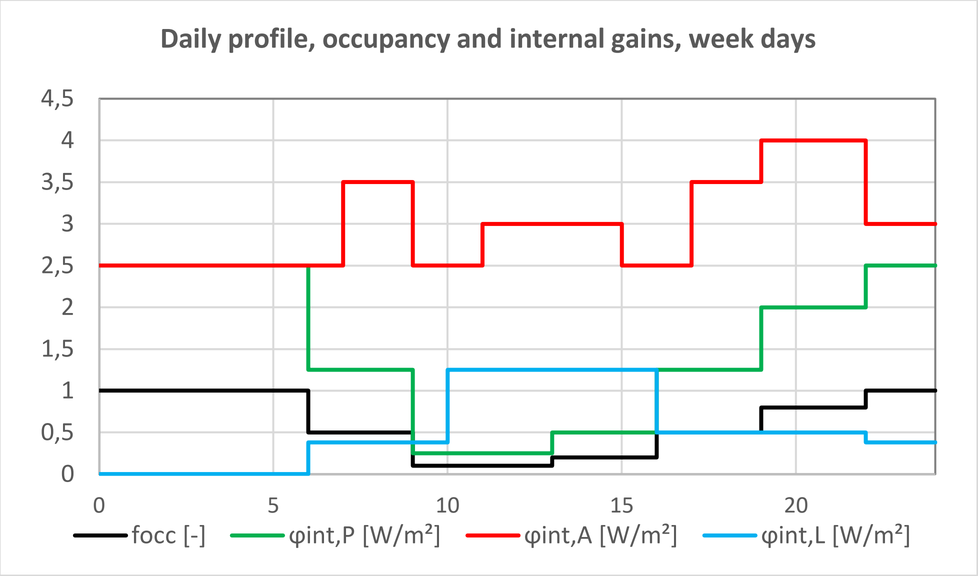


Figure 8: Daily profiles for occupancy and internal gains, single family house, week days

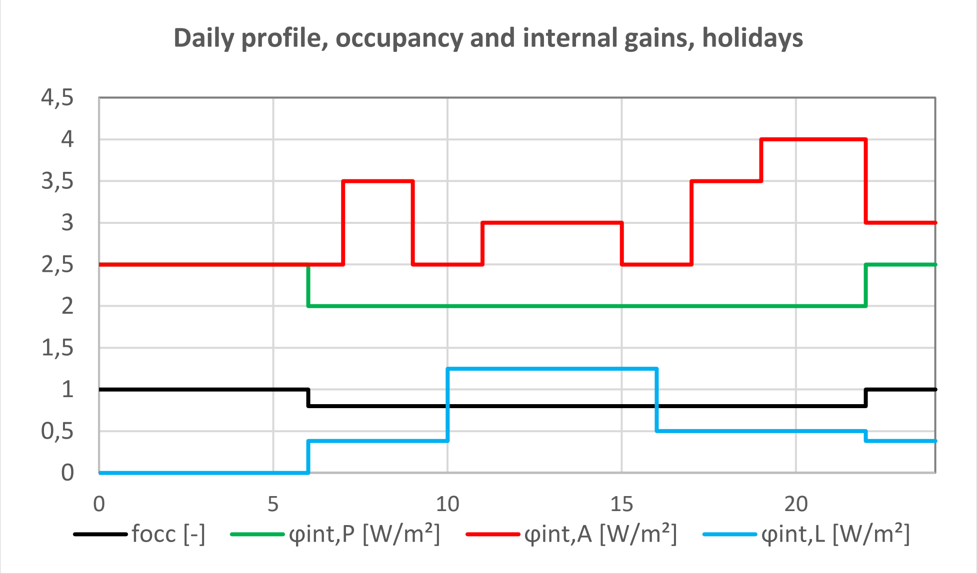


Figure 9: Daily profiles for occupancy and internal gains, single family house, holidays

Domestic hot water needs were calculated according to EN 12831-3 and XL tapping profile.

The services considered are heating, domestic hot water and cooling. Building needs are summarised in the following table 5 and graphs. The figures show the monthly values, hourly profiles and relative importance of the respective needs.

Month	**Heating needs** $Q_{H;nd}$ *kWh*	**Domestic hot water needs** $Q_{W;nd}$ *kWh*	**Cooling needs** $Q_{C;nd}$ *kWh*
January	2.552	242	0
February	1.955	218	0
March	1.424	242	0
April	606	234	0
May	12	242	0
June	0	234	228
July	0	242	419
August	0	242	216
September	0	234	7
October	486	242	0
November	1.394	234	0
December	2.212	242	0
Year	10.640 kWh 59,1 kWh/m²y	2.847 kWh 15,8 kWh/m²y	870 kWh 4,8 kWh/m²y

Table 5: Building needs for the base case, heating is clearly dominant

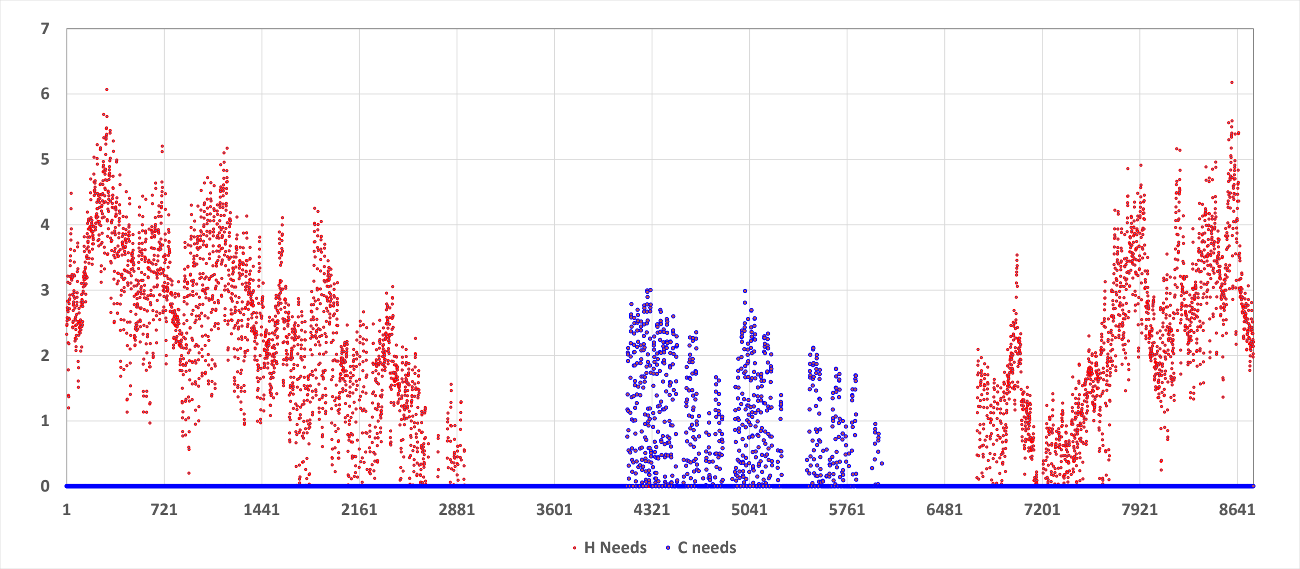


Figure 10: Hourly heating and cooling needs

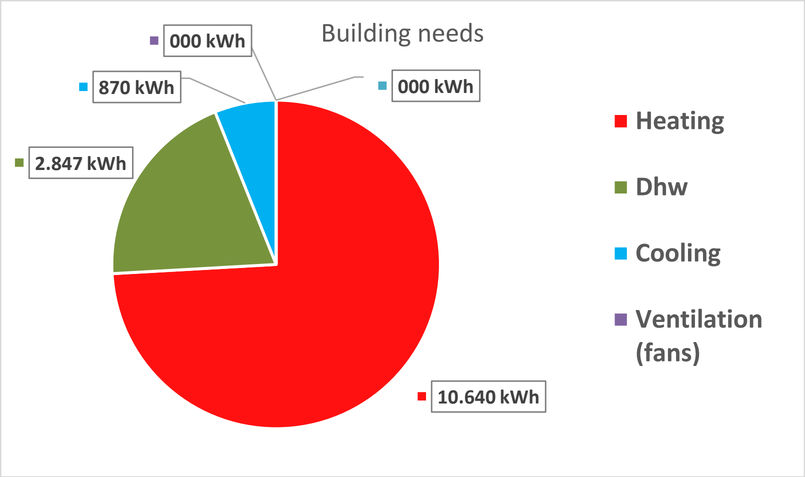


Figure 11: Relative importance of building needs

These are the typical results for a medium insulated single-family house in a temperate climate.

Heating needs are moderate but dominant, indeed.

The losses and the auxiliary energy use of technical services are taken into account by constant efficiencies, proportional auxiliaries and additional constant losses.

The following figure summarises the required output of generation systems:

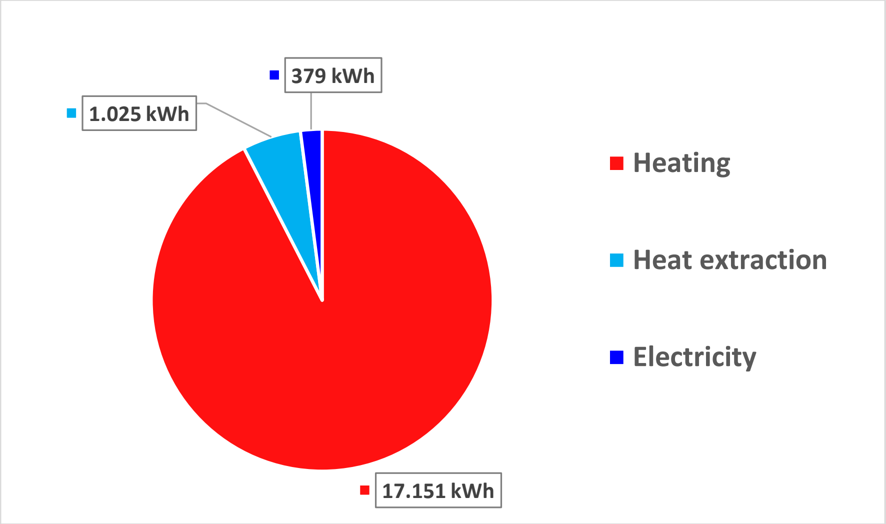


Figure 12: Total heat, heat extraction and electricity required to the generation systems

The configuration of generators has been changed in the different cases.

The weighting factors are according to the EN ISO 52000-1 default annex B. The values are reported in the following table 6. They have been considered constant.

Symbol **Unit**	f_{Pnren} *kWh/kWh*	f_{Pren} *kWh/kWh*	f_{Ptot} *kWh/kWh*	f_{CO2} kg_{co2}*/kWh*	f_{co} *€/kWh*
Energy carrier					
Natural gas	1,10	0,00	1,10	0,220	0,080
Thermal solar	0,00	1,00	1,00	0,000	0,000
Photovoltaic	0,00	1,00	1,00	0,000	0,000
Environment heat	0,00	1,00	1,00	0,000	0,000
Grid delivered electricity	2,30	0,20	2,50	0,420	0,250
Grid exported electricity	2,30	0,20	2,50	0,420	0,220

Table 6: Weighting factors used in the case study

The cost of the energy carriers in table 6 is based on common prices in an EU country (Italy).

6.1.2 Technical systems configuration options

The following 3 options have been considered.

- main generator: condensing boiler, case with heat pump with no back-up;
- PV: when included, 3 kW peak;
- Thermal solar: when included, covers about 50% of domestic hot water needs.

The contribution of photovoltaic panels (PV) and thermal solar, when available, are summarised in the following table 7 and figure 13. Thermal solar covers slightly more than 50% of the domestic hot water needs, which is a reasonable sizing to avoid overheating in summer.

PV and thermal solar	**Required distribution input**	**Energy from solar**		**Energy from back-up**	**PV electricity production**
	$Q_{W;dis;in}$	$Q_{W;sto;in;sol}$		$Q_{W;sto;in;bu}$	$E_{del;el;t}$
	kWh	*kWh*	*%*	*kWh*	*kWh*
January	356	76	21%	281	166
February	321	111	34%	211	219
March	356	191	54%	164	325
April	344	191	55%	154	463
May	356	236	66%	119	509
June	344	233	68%	112	453
July	356	249	70%	107	553
August	356	243	68%	112	485
September	344	210	61%	134	383
October	356	214	60%	141	305
November	344	127	37%	218	171
December	356	78	22%	278	140
Year	**4.191**	**2.159**	**52%**	**2.033**	**4.175**

Table 7: Contribution of thermal solar and PV production (when available)

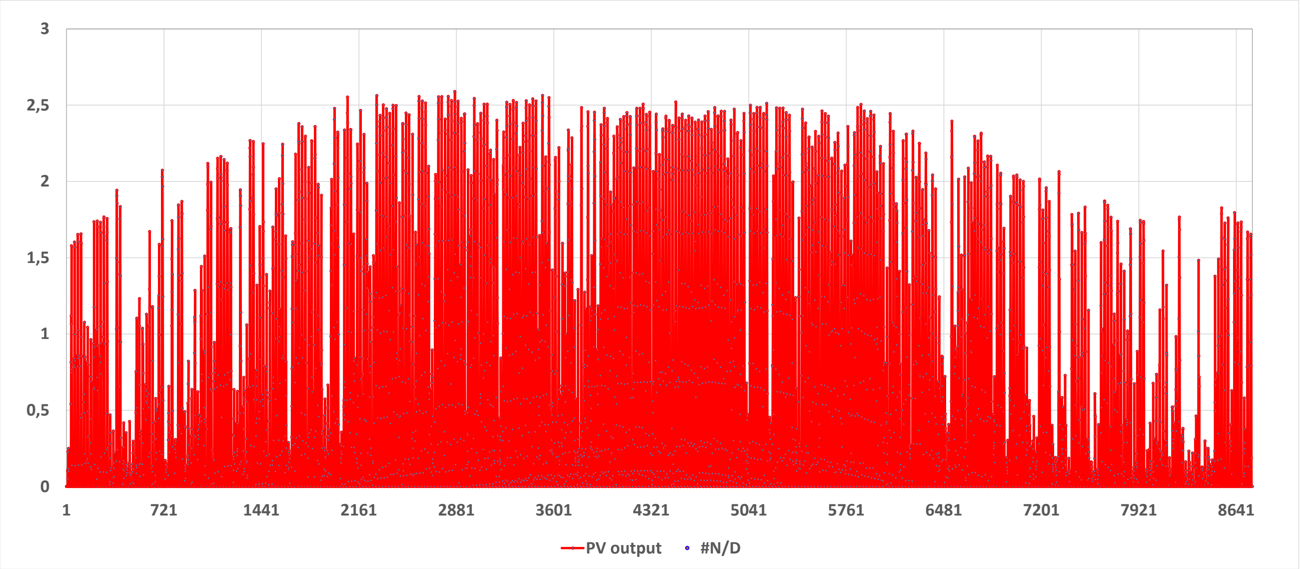


Figure 13: PV panels power output with 3 kW peak installed
This sizing is compatible with the size of the building and the available area on the roof

6.1.3 Description of the case

Case	Heat generation	PV	Thermal solar	k_{exp}	Battery	Other
1	Boiler	NO	YES	0	No	None

This is the basic case with no energy carrier export and only some thermal solar as on-site renewable energy production.

6.1.4 Calculation results

The results of the hourly calculation are given in the following tables 8 and 9.

Weighted energy performance	**Non-renewable primary energy**	**Renewable primary energy**	**Total primary energy**	**CO_2 emission**	**Cost**	**RER**
	E_{Pnren}	E_{Pren}	E_{Ptot}	CO_2	Cost	RER
	kWh	*kWh*	*kWh*	*kg CO_2*	*€*	
January	3.839	89	3.928	765	284,69	0,02
February	2.932	121	3.053	584	217,61	0,04
March	2.148	199	2.347	428	159,70	0,08
April	1.025	196	1.220	204	76,63	0,16
May	184	239	422	36	14,49	0,57
June	311	249	560	59	29,18	0,44
July	422	275	697	79	41,45	0,39
August	293	257	550	56	27,22	0,47
September	189	213	403	37	15,01	0,53
October	848	219	1.066	169	63,59	0,20
November	2.175	136	2.310	433	161,65	0,06
December	3.364	90	3.454	671	249,63	0,03
Year	**17.728**	**2.283**	**20.012**	**3.521**	**1.340,83**	**0,11**
	98,5 kWh/m^2y		**111,2 kWh/m^2y**	**19,6 kg/m^2y**	**7,4 $€/m^2y$**	

Table 8: Case 1 results: weighted energy

Electricity balance	**Electricity required for EPB uses**	**Electricity produced on-site**	**Electricity produced and used for EPB uses**	**Electricity exported to the grid**	**Grid delivered electricity, t**
	$E_{EPus;el;t}$	$E_{pr;el;t}$	$E_{pr;el;used;EPus;t}$	$E_{exp;el;grid;t}$	$E_{del;el;t}$
	kWh	*kWh*	*kWh*	*kWh*	*kWh*
January	67	0	0	0	67
February	53	0	0	0	53
March	42	0	0	0	42
April	26	0	0	0	26
May	14	0	0	0	14
June	79	0	0	0	79
July	130	0	0	0	130
August	71	0	0	0	71
September	15	0	0	0	15
October	23	0	0	0	23
November	42	0	0	0	42
December	60	0	0	0	60
Year	**622**	**0**	**0**	**0**	**622**

Table 9: Case 1 results: electricity balance

6.1.5 Discussion

There is no need to explore the case with k_{exp} = 1 because there is no exported energy. Results would be identical.

The monthly calculation gives the same results as the hourly calculation. The hourly calculation may give different results than monthly only if the weighting factors are time dependent.

The renewable energy ratio is 0,11, mostly because of the thermal solar. Grid electricity also has some renewable contents but this is marginal.

6.2 Case 2: adding PV

6.2.1 Description of the case

Case	Heat generation	PV	Thermal solar	k_{exp}	Battery	Other
2	Boiler	YES	YES	0	No	None

The PV is added to the base case 1.

6.2.2 Calculation results

The results of the hourly calculation are given in the following tables from 10 to 12.

Weighted energy performance	Non-renewable primary energy E_{Pnren} *kWh*	Renewable primary energy E_{Pren} *kWh*	Total primary energy E_{Ptot} *kWh*	CO_2 emission CO_2 *kg CO_2*	Cost Cost *€*	RER RER
January	3.790	106	3.897	756	279,45	0,03
February	2.891	136	3.026	577	213,08	0,04
March	2.109	213	2.322	421	155,46	0,09
April	995	206	1.201	199	73,46	0,17
May	164	246	410	33	12,37	0,60
June	166	300	465	32	13,39	0,64
July	192	355	547	37	16,46	0,65
August	167	301	468	33	13,56	0,64
September	170	220	390	34	12,89	0,57
October	827	226	1.053	165	61,39	0,21
November	2.145	146	2.291	428	158,41	0,06
December	3.327	103	3.430	664	245,56	0,03
Year	**16.943**	**2.556**	**19.500**	**3.377**	**1.255,47**	**0,13**
	94,1 kWh/m^2y		**108,3 kWh/m^2y**	**18,8 kg_{CO2}/m^2y**	**7,0 $€/m^2y$**	

Table 10: Case 2 results: weighted energy

Electricity balance	**Electricity required for EPB uses** $E_{EPus;el;t}$ *kWh*	**Electricity produced on-site** $E_{pr;el;t}$ *kWh*	**Electricity produced and used for EPB uses** $E_{pr;el;used;EPus;t}$ *kWh*	**Electricity exported to the grid** $E_{exp;el;grid;t}$ *kWh*	**Grid delivered electricity, t** $E_{del;el;t}$ *kWh*
January	67	166	21	146	46
February	53	219	18	201	34
March	42	325	17	308	25
April	26	463	13	451	13
May	14	509	8	500	5
June	79	453	63	390	16
July	130	553	100	453	30
August	71	485	55	430	17
September	15	383	8	375	7
October	23	305	9	296	15
November	42	171	13	158	29
December	60	140	16	124	43
Year	**622**	**4.175**	**341**	**3.833**	**281**

Table 11: Case 2 results: electricity balance

Electricity balance	**Electricity required for EPB uses**			**Electricity produced on-site**		
	Total kWh	From grid *%*	Produced *%*	*Total* kWh	Used *%*	Exported *%*
January	67	68,6%	31,4%	0	12,6%	87,4%
February	53	65,6%	34,4%	0	8,2%	91,8%
March	42	59,9%	40,1%	0	5,2%	94,8%
April	26	50,3%	49,7%	0	2,7%	97,3%
May	14	38,3%	61,7%	0	1,7%	98,3%
June	79	20,5%	79,5%	0	13,9%	86,1%
July	130	23,3%	76,7%	0	18,1%	81,9%
August	71	23,5%	76,5%	0	11,3%	88,7%
September	15	44,2%	55,8%	0	2,2%	97,8%
October	23	62,4%	37,6%	0	2,9%	97,1%
November	42	69,3%	30,7%	0	7,6%	92,4%
December	60	72,7%	27,3%	0	11,6%	88,4%
Year	**622**	**45,1%**	**54,9%**	**0**	**8,2%**	**91,8%**

Table 12: Case 2 results: electricity use and production details

6.2.3 Discussion

Results show that if k_{exp} is set to 0, adding the photovoltaic production does not influence much the performance (E_{Pnren} goes from 98,5 to 94,1 kWh/m^{2}y) because most of the input is fuel and there is no cross compensation between energy carriers.

Tables 11 and 12 show that even if the PV production is much higher than the required electricity for EPB uses, only 54,9 % of the used electricity is supplied by the PV. About half of the electricity is taken from the grid indeed. This is due to the mismatch between production and use, as shown in the figure that illustrated the first days of January.

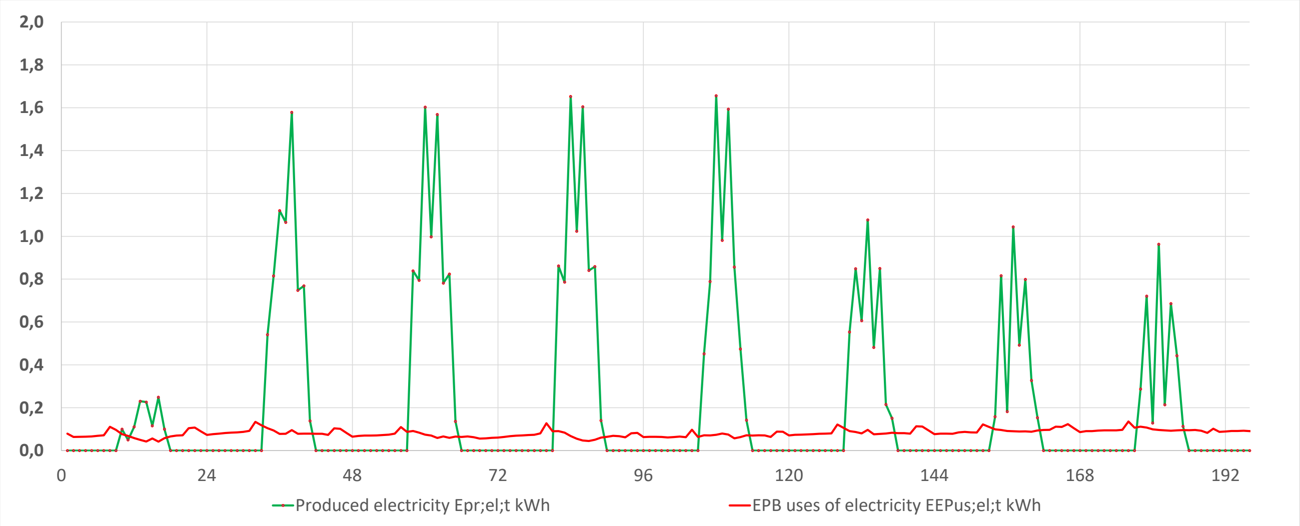


Figure 14: Mismatch between production and use. Despite the high PV production, the auxiliaries are supplied mostly by the grid

When the PV is off (night) then electricity is taken from the grid. When the PV is producing (during the day, there are little uses and the produced electricity has to be exported.

This mismatch is correctly captured by the hourly method. If this calculation is repeated with the monthly method without a matching factor, the results are shown in the following table 13. With the monthly method the mismatch between production and use is not caught. All EPB uses look like supplied by on-site production and there is no grid delivered electricity. The energy performance as non-renewable primary energy goes down from 94,1 kWh/m^{2}y to 90,5 kWh/m^{2}y.

Electricity balance	Electricity required for EPB uses $E_{EPus;el;t}$ *kWh*	Electricity produced on-site $E_{pr;el;t}$ *kWh*	Electricity produced and used for EPB uses $E_{pr;el;used;EPus;t}$ *kWh*	Electricity exported to the grid $E_{exp;el;grid;t}$ *kWh*	Grid delivered electricity, t $E_{del;el;t}$ *kWh*
January	67	166	67	100	0
February	53	219	53	167	0
March	42	325	42	283	0
April	26	463	26	438	0
May	14	509	14	495	0
June	79	453	79	374	0
July	130	553	130	423	0
August	71	485	71	414	0
September	15	383	15	368	0
October	23	305	23	282	0
November	42	171	42	129	0
December	60	140	60	81	0
Year	**622**	**4.175**	**622**	**3.552**	**0**

Table 13: Electric energy balance with the monthly method. Grid delivered electricity is always 0.

If the default matching factor is added, then the result is the following in table 14.

Electricity balance	Electricity required for EPB uses $E_{EPus;el;t}$ *kWh*	Electricity produced on-site $E_{pr;el;t}$ *kWh*	Electricity produced and used for EPB uses $E_{pr;el;used;EPus;t}$ *kWh*	Electricity exported to the grid $E_{exp;el;grid;t}$ *kWh*	Grid delivered electricity, t $E_{del;el;t}$ *kWh*
January	67	166	44	123	23
February	53	219	41	179	12
March	42	325	37	288	5
April	26	463	24	439	1
May	14	509	13	495	0
June	79	453	66	387	14
July	130	553	101	452	29
August	71	485	61	424	10
September	15	383	15	369	1
October	23	305	22	283	2
November	42	171	32	139	10
December	60	140	38	102	22
Year	**622**	**4.175**	**494**	**3.681**	**129**

Table 14: Electric energy balance with the monthly method and matching factor.

This reduces the difference but the result is not yet correct. The hourly method showed that 281 kWh shall be taken from the grid. The matching factor brought the result to 129 kWh and the monthly method failed completely to identify the mismatch. Figures are small because this is a building relying mostly on combustible fuels.

6.3 Case 3: adding PV and k_{exp} = 1

6.3.1 Description of the case

Case	Heat generation	PV	Thermal solar	k_{exp}	Battery	Other
3	Boiler	YES	YES	1,0	No	None

The value k_{exp} is set to 1.

6.3.2 Calculation results

The results of the hourly calculation are given in the following tables 15 to 17.

Weighted energy performance	Non-renewable primary energy E_{Pnren} *kWh*	Renewable primary energy E_{Pren} *kWh*	Total primary energy E_{Ptot} *kWh*	CO2 emission CO_2 *kg CO_2*	Cost Cost €	RER RER
January	3.456	223	3.678	695	247,43	0,06
February	2.428	297	2.724	492	168,78	0,11
March	1.400	460	1.859	291	87,63	0,25
April	-41	566	525	9	-25,66	1,08
May	-986	646	-341	-177	-97,68	-1,90
June	-732	612	-120	-131	-72,47	-5,09
July	-850	718	-133	-153	-83,23	-5,41
August	-822	645	-177	-148	-81,12	-3,64
September	-692	520	-172	-124	-69,55	-3,02
October	146	463	609	40	-3,78	0,76
November	1.780	273	2.053	361	123,55	0,13
December	3.042	202	3.244	612	218,27	0,06
Year	**8.127**	**5.623**	**13.750**	**1.767**	**412,16**	**0,41**
	45,1 kWh/m^2y		76,4 kWh/m^2y	9,8 kg_{CO2}/m^2y	2,3 €/m^2y	

Table 15: Case 3 results: weighted energy

Electricity balance	**Electricity required for EPB uses** $E_{EPus;el;t}$ *kWh*	**Electricity produced on-site** $E_{pr;el;t}$ *kWh*	**Electricity produced and used for EPB uses** $E_{pr;el;used;EPus;t}$ *kWh*	**Electricity exported to the grid** $E_{exp;el;grid;t}$ *kWh*	**Grid delivered electricity, t** $E_{del;el;t}$ *kWh*
January	67	166	21	146	46
February	53	219	18	201	34
March	42	325	17	308	25
April	26	463	13	451	13
May	14	509	8	500	5
June	79	453	63	390	16
July	130	553	100	453	30
August	71	485	55	430	17
September	15	383	8	375	7
October	23	305	9	296	15
November	42	171	13	158	29
December	60	140	16	124	43
Year	**622**	**4.175**	**341**	**3.833**	**281**

Table 16: Case 3 results: electricity balance

Electricity balance	**Electricity required for EPB uses**			**Electricity produced on-site**		
	Total kWh	From grid *%*	Produced *%*	*Total* kWh	Used *%*	Exported *%*
January	67	68,6%	31,4%	0	12,6%	87,4%
February	53	65,6%	34,4%	0	8,2%	91,8%
March	42	59,9%	40,1%	0	5,2%	94,8%
April	26	50,3%	49,7%	0	2,7%	97,3%
May	14	38,3%	61,7%	0	1,7%	98,3%
June	79	20,5%	79,5%	0	13,9%	86,1%
July	130	23,3%	76,7%	0	18,1%	81,9%
August	71	23,5%	76,5%	0	11,3%	88,7%
September	15	44,2%	55,8%	0	2,2%	97,8%
October	23	62,4%	37,6%	0	2,9%	97,1%
November	42	69,3%	30,7%	0	7,6%	92,4%
December	60	72,7%	27,3%	0	11,6%	88,4%
Year	**622**	**45,1%**	**54,9%**	**0**	**8,2%**	**91,8%**

Table 17: Case 3 results: electricity use and production details

6.3.3 Discussion

The comparison with cases 1 and 2 shows that the energy performance is improved (about cut by half).

Weighted energy performance	**Non-renewable primary energy**	**Total primary energy**	**CO2 emission**	**Cost**	**RER**
Case	kWh/m²y	kWh/m²y	kg_{CO2}/m^2y	€/m²y	
Case 1: K_{exp} = 0	98,5	111,2	19,6	7,4	0,11
Case 2: K_{exp} = 0	94,1	108,3	18,8	7,0	0,13
Case 3: K_{exp} = 1	45,1	76,4	9,8	2,3	0,41

Table 18: Comparison of weighted energy performance for cases 1 to 3

This effect is due to the option k_{exp}=1 in case 3, that enables to include in the energy performance the exported electricity.

This can be understood by looking at tables 8, 10 and 15.

- In tables 8 and 10 all values are positive (e,g, costs or delivered energy). The energy performance is the result of "paying" the cost for all resources used to provide the EPB services.
  The exported energy is not taken into account in the energy performance (K_{exp} = 0).
- In table 15, the rows from May to September show negative values: this is due to including in the calculation the "revenue of selling to the grid" the exported energy (that is the avoided use of resources by the grid generators), which is now taken into account into the energy performance (k_{exp} = 1) .

Table 11 and table 16 that describe the electric energy flows for cases 2 and 3 are identical. This is because these tables represent the physical flow of electricity. The difference in evaluation between case 2 and 3 is not due to a different system set-up but purely to the different accounting criteria.

With k_{exp} = 1, the monthly calculation provides exactly the same results for the energy performance as the hourly method. The results for the physical electric energy flows are not correct but this makes no difference because the exported electricity compensates exactly for the delivered electricity. This is true if the weighting factors are not time dependent. If so, the correct result would be again the hourly method with the monthly method deviating.

This example clearly shows that if k_{exp} = 1 is selected, then exported electricity may compensate the use of other resources, there is cross-compensation between energy carriers. This is maybe the most impacting parameters in the definition of the energy performance metrics.

6.4 Case 4: same as case 1 with a heat pump instead of a boiler

6.4.1 Description of the case

Case	**Heat generation**	**PV**	**Thermal solar**	**k_{exp}**	**Battery**	**Other**
4	Heat pump	NO	YES	0,0	No	None

The boiler is replaced by a heat pump.

6.4.2 Calculation results

The results of the hourly calculation are given in the following tables 19 and 20.

Weighted energy performance	**Non-renewable primary energy** E_{Pnren} *kWh*	**Renewable primary energy** E_{Pren} *kWh*	**Total primary energy** E_{Ptot} *kWh*	**CO_2 emission** CO_2 *kg CO_2*	**Cost** Cost *€*	**RER** RER
January	2.130	2.717	4.847	390	228,84	0,56
February	1.502	2.194	3.695	275	162,34	0,59
March	963	1.774	2.737	176	104,50	0,65
April	440	946	1.386	80	47,80	0,68
May	111	344	454	20	12,03	0,76
June	246	338	584	45	26,71	0,58
July	358	360	719	65	38,92	0,50
August	228	346	574	42	24,79	0,60
September	121	317	438	22	13,19	0,72
October	368	834	1.202	67	39,96	0,69
November	1.053	1.694	2.747	192	114,06	0,62
December	1.759	2.436	4.195	322	189,14	0,58
Year	**9.277**	**14.300**	**23.577**	**1.697**	**1.002,28**	**0,61**
	51,5 kWh/m²y		**131,0 kWh/m²y**	**9,4 kg_{CO2}/m^2y**	**5,6 €/m²y**	

Table 19: Case 4 results: weighted energy

Electricity balance	**Electricity required for EPB uses** $E_{EPus;el;t}$ *kWh*	**Electricity produced on-site** $E_{pr;el;t}$ *kWh*	**Electricity produced and used for EPB uses** $E_{pr;el;used;EPus;t}$ *kWh*	**Electricity exported to the grid** $E_{exp;el;grid;t}$ *kWh*	**Grid delivered electricity, t** $E_{del;el;t}$ *kWh*
January	894	0	0	0	894
February	642	0	0	0	642
March	417	0	0	0	417
April	191	0	0	0	191
May	48	0	0	0	48
June	107	0	0	0	107
July	156	0	0	0	156
August	99	0	0	0	99
September	53	0	0	0	53
October	160	0	0	0	160
November	453	0	0	0	453
December	740	0	0	0	740
Year	**3.960**	**0**	**0**	**0**	**3.960**

Table 20: Case 4 results: electricity balance

6.4.3 Discussion

The comparison with case 1 shows that the energy performance is improved because a more efficient generation device is used. The building and all its technical systems, except the generation devices, are all the same.

Weighted energy performance	**Non-renewable primary energy**	**Total primary energy**	**CO_2 emission**	**Cost**	**RER**
Case	kWh/m^2y	kWh/m^2y	kg_{CO2}/m^2y	€/m^2y	
Case 1: k_{exp} = 0	98,5	111,2	19,6	7,4	0,11
Case 4: k_{exp} = 0	51,5	131,0	9,4	5,6	0,61

Table 21: Comparison of weighted energy performance for cases 1 and 4

The heat pump is completely fed by the grid, there is no local electricity production.

The gain in non-renewable primary energy performance is due to the higher efficiency of the heat pump compared to a boiler.

The total primary energy increases because the energy flow from the cold source is included as well.

The CO_2 emission is reduced because of the better efficiency of the system.

The RER is boosted from 0,11 to 0,61 because the energy flow from the cold source of the heat pump is included as well.

There is no exported energy, so the parameter k_{exp} has no influence on this case and the monthly method gives exactly the same results (if weighting factors are constant, e.g. not time dependent).

6.5 Case 5: same as case 4 with PV and no thermal solar

6.5.1 Description of the case

Case	**Heat generation**	**PV**	**Thermal solar**	**k_{exp}**	**Battery**	**Other**
5	Heat pump	YES	NO	0,0	No	None

The thermal solar is replaced by PV to supply the heat pump.

6.5.2 Calculation results

The results of the hourly calculation are given in the following tables 22 to 24

Weighted energy performance	**Non-renewable primary energy** E_{Pnren} *kWh*	**Renewable primary energy** E_{Pren} *kWh*	**Total primary energy** E_{Ptot} *kWh*	**CO$_2$ emission** CO$_2$ *kg CO$_2$*	**Cost** Cost *€*	**RER** RER
January	1.899	2.792	4.691	348	203,41	0,60
February	1.300	2.259	3.560	238	140,12	0,63
March	871	1.807	2.678	159	94,42	0,67
April	410	956	1.366	75	44,55	0,70
May	178	321	499	32	19,34	0,64
June	174	363	537	32	18,87	0,68
July	207	414	621	38	22,49	0,67
August	189	361	550	35	20,58	0,66
September	195	291	486	36	21,16	0,60
October	410	821	1.231	75	44,56	0,67
November	972	1.720	2.692	178	105,19	0,64
December	1.609	2.484	4.093	295	172,50	0,61
Year	**8.413**	**14.590**	**23.003**	**1.540**	**907,19**	**0,63**
	46,7 kWh/m^{2}y		**127,8 kWh/m^{2}y**	**8,6 kg$_{CO2}$/m^{2}y**	**5,0 €/m^{2}y**	

Table 22: Case 5 results: weighted energy

Electricity balance	**Electricity required for EPB uses** $E_{EPus;el;t}$ *kWh*	**Electricity produced on-site** $E_{pr;el;t}$ *kWh*	**Electricity produced and used for EPB uses** $E_{pr;el;used;EPus;t}$ *kWh*	**Electricity exported to the grid** $E_{exp;el;grid;t}$ *kWh*	**Grid delivered electricity, t** $E_{del;el;t}$ *kWh*
January	921	166	131	35	789
February	681	219	130	89	551
March	482	325	106	219	376
April	250	463	71	392	178
May	111	509	34	475	77
June	162	453	86	367	75
July	212	553	122	431	90
August	158	485	75	410	82
September	110	383	25	358	85
October	226	305	48	257	178
November	495	171	78	93	417
December	767	140	96	45	671
Year	**4.573**	**4.175**	**1.003**	**3.172**	**3.570**

Table 23: Case 5 results: electricity balance

Electricity balance	**Electricity required for EPB uses**			**Electricity produced on-site**		
	Total kWh	From grid *%*	Produced *%*	*Total* kWh	Used *%*	Exported *%*
January	921	85,8%	14,2%	0	78,7%	21,3%
February	681	80,9%	19,1%	0	59,4%	40,6%
March	482	78,0%	22,0%	0	32,6%	67,4%
April	250	71,4%	28,6%	0	15,4%	84,6%
May	111	69,8%	30,2%	0	6,6%	93,4%
June	162	46,7%	53,3%	0	19,0%	81,0%
July	212	42,5%	57,5%	0	22,0%	78,0%
August	158	52,2%	47,8%	0	15,5%	84,5%
September	110	77,0%	23,0%	0	6,6%	93,4%
October	226	78,8%	21,2%	0	15,7%	84,3%
November	495	84,2%	15,8%	0	45,6%	54,4%
December	767	87,5%	12,5%	0	68,1%	31,9%
Year	**4.573**	**78,1%**	**21,9%**	**0**	**24,0%**	**76,0%**

Table 24: Case 5 results: details on electricity balance

6.5.3 Discussion

The comparison with case 4 shows that the use of photovoltaic panels to supply a heat pump to produce domestic hot water can provide better results than a thermal solar system. The only difference between case 5 and 4 is that the thermal solar has been removed and replaced by some photovoltaic panels.

Weighted energy performance	**Non-renewable primary energy**	**Total primary energy**	**CO_2 emission**	**Cost**	**RER**
Case	kWh/m^2y	kWh/m^2y	kg_{CO2}/m^2y	$€/m^2y$	
Case 4: K_{exp} = 0	51,5	131,0	9,4	5,6	0,61
Case 5: K_{exp} = 0	46,7	127,8	8,6	5,0	0,63
Case 5: K_{exp} = 0 monthly	30,8	117,4	5,6	3,3	0,74

Table 25: Comparison of weighted energy performance for cases 4, 5 and 5 monthly

Since the exported energy is not included in the energy performance of the building (k_{exp}=0), the amount of exported energy shall be calculated correctly with the hourly method. The monthly method without matching factor introduces a severe mistake, like in case 2. Tables 26 and 27 show this difference when compared to tables 23 and 24. The quota of produced electricity that is used on site goes

- from 1003 kWh covering 21,9% of EPB uses
- to 2250 kWh covering 49,2% of EPB uses.

The matching factor could reduce the error of the monthly method but only partly.

Electricity balance	**Electricity required for EPB uses** $E_{EPus;el;t}$ *kWh*	**Electricity produced on-site** $E_{pr;el;t}$ *kWh*	**Electricity produced and used for EPB uses** $E_{pr;el;used;EPus;t}$ *kWh*	**Electricity exported to the grid** $E_{exp;el;grid;t}$ *kWh*	**Grid delivered electricity, t** $E_{del;el;t}$ *kWh*
January	921	166	166	0	754
February	681	219	219	0	462
March	482	325	325	0	157
April	250	463	250	214	0
May	111	509	111	398	0
June	162	453	162	292	0
July	212	553	212	341	0
August	158	485	158	327	0
September	110	383	110	273	0
October	226	305	226	79	0
November	495	171	171	0	324
December	767	140	140	0	626
Year	**4.573**	**4.175**	**2.250**	**1.924**	**2.322**

Table 26: Case 5 results: electricity balance with the monthly method

Electricity balance	Electricity required for EPB uses			Electricity produced on-site		
	Total kWh	From grid *%*	Produced *%*	*Total* kWh	Used *%*	Exported *%*
January	921	81,9%	18,1%	0	100,0%	0,0%
February	681	67,8%	32,2%	0	100,0%	0,0%
March	482	32,5%	67,5%	0	100,0%	0,0%
April	250	0,0%	100,0%	0	53,9%	46,1%
May	111	0,0%	100,0%	0	21,8%	78,2%
June	162	0,0%	100,0%	0	35,7%	64,3%
July	212	0,0%	100,0%	0	38,3%	61,7%
August	158	0,0%	100,0%	0	32,5%	67,5%
September	110	0,0%	100,0%	0	28,7%	71,3%
October	226	0,0%	100,0%	0	74,1%	25,9%
November	495	65,4%	34,6%	0	100,0%	0,0%
December	767	81,7%	18,3%	0	100,0%	0,0%
Year	**4.573**	50,8%	49,2%	**0**	53,9%	46,1%

Table 27: Case 5 results: electricity balance details with the monthly method

6.6 Case 6: same as case 4 with PV and thermal solar

6.6.1 Description of the case

Case	Heat generation	PV	Thermal solar	Kexp	Battery	Other
6	Heat pump	YES	YES	0,0	No	None

The thermal solar and the PV are both available.

6.6.2 Calculation results

The results of the hourly calculation are given in the following tables 28 to 30.

Weighted energy performance	Non-renewable primary energy E_{Pnren} *kWh*	Renewable primary energy E_{Pren} *kWh*	Total primary energy E_{Ptot} *kWh*	CO_2 emission CO_2 *kg CO_2*	Cost Cost *€*	RER RER
January	1.835	2.819	4.655	336	196,84	0,61
February	1.216	2.293	3.509	222	131,31	0,65
March	741	1.852	2.592	135	80,37	0,71
April	306	992	1.298	56	33,26	0,76
May	70	358	428	13	7,64	0,84
June	84	394	478	15	9,12	0,82
July	113	446	559	21	12,25	0,80
August	92	394	485	17	9,95	0,81
September	95	326	420	17	10,28	0,78
October	285	863	1.148	52	31,00	0,75
November	890	1.751	2.640	163	96,34	0,66
December	1.546	2.510	4.056	283	166,01	0,62
Year	**7.272**	**14.997**	**22.269**	**1.331**	**784,37**	**0,67**
	40,4 kWh/m²y		**123,7 kWh/m²y**	**7,4 kg_{CO2}/m^2y**	**4,4 €/m²y**	

Table 28: Case 6 results: weighted energy

Electricity balance	**Electricity required for EPB uses** $E_{EPus;el;t}$ *kWh*	**Electricity produced on-site** $E_{pr;el;t}$ *kWh*	**Electricity produced and used for EPB uses** $E_{pr;el;used;EPus;t}$ *kWh*	**Electricity exported to the grid** $E_{exp;el;grid;t}$ *kWh*	**Grid delivered electricity, t** $E_{del;el;t}$ *kWh*
January	894	166	128	38	766
February	642	219	124	95	518
March	417	325	97	229	320
April	191	463	58	405	133
May	48	509	18	491	31
June	107	453	70	383	36
July	156	553	107	446	49
August	99	485	59	426	40
September	53	383	12	372	41
October	160	305	36	269	124
November	453	171	71	101	382
December	740	140	93	48	648
Year	**3.960**	**4.175**	**872**	**3.303**	**3.088**

Table 29: Case 6 results: electricity balance

Electricity balance	**Electricity required for EPB uses**			**Electricity produced on-site**		
	Total kWh	From grid *%*	Produced *%*	*Total* kWh	Used *%*	Exported *%*
January	894	85,7%	14,3%	166	76,9%	23,1%
February	642	80,7%	19,3%	219	56,6%	43,4%
March	417	76,8%	23,2%	325	29,7%	70,3%
April	191	69,6%	30,4%	463	12,6%	87,4%
May	48	63,5%	36,5%	509	3,5%	96,5%
June	107	34,2%	65,8%	453	15,5%	84,5%
July	156	31,5%	68,5%	553	19,3%	80,7%
August	99	40,1%	59,9%	485	12,2%	87,8%
September	53	78,0%	22,0%	383	3,0%	97,0%
October	160	77,6%	22,4%	305	11,7%	88,3%
November	453	84,4%	15,6%	171	41,3%	58,7%
December	740	87,5%	12,5%	140	65,9%	34,1%
Year	**3.960**	**78,0%**	**22,0%**	**4.175**	**20,9%**	**79,1%**

Table 30: Case 6 results: details on electricity balance

6.6.3 Discussion

The comparison with case 4 and 5 shows the effect of using thermal solar, photovoltaic or both in a system with a heat pump.

Weighted energy performance	**Non-renewable primary energy**	**Total primary energy**	**CO_2 emission**	**Cost**	**RER**
Case	kWh/m^2y	kWh/m^2y	kg/m^2y	$€/m^2y$	
Case 4: TS only	51,5	131,0	9,4	5,6	0,61
Case 5: PV only	46,7	127,8	8,6	5,0	0,63
Case 6: TS and PV	40,4	123,7,4	7,4	4,4	0,67

Table 31: Comparison of weighted energy performance for cases 4 to 6

Similar consideration as with case 5 hold for the monthly method, since k_{exp}=0 and it is critical to identify correctly the quota of produced electricity which is also used on-site.

6.7 Case 7: same as case 6 with k_{exp}=1

6.7.1 Description of the case

Case	**Heat generation**	**PV**	**Thermal solar**	**Kexp**	**Battery**	**Other**
7	Heat pump	YES	YES	1,0	No	None

The thermal solar and the PV are both available. k_{exp} is set to 1,0

6.7.2 Calculation results

The results of the hourly calculation are given in the following tables.

Weighted energy performance	**Non-renewable primary energy** E_{Pnren} *kWh*	**Renewable primary energy** E_{Pren} *kWh*	**Total primary energy** E_{Ptot} *kWh*	**CO_2 emission** CO_2 *kg CO_2*	**Cost** Cost €	**RER** RER
January	1.747	2.850	4.597	320	188,38	0,62
February	997	2.369	3.366	182	110,33	0,70
March	215	2.035	2.249	39	30,05	0,90
April	-626	1.316	691	-114	-55,85	1,91
May	-1.059	751	-309	-193	-100,41	-2,43
June	-797	701	-97	-146	-75,15	-7,25
July	-914	803	-111	-167	-85,96	-7,23
August	-887	734	-153	-162	-83,70	-4,80
September	-760	623	-137	-139	-71,47	-4,55
October	-334	1.078	744	-61	-28,23	1,45
November	659	1.831	2.490	120	74,22	0,74
December	1.436	2.548	3.984	263	155,49	0,64
Year	**-325**	**17.639**	**17.315**	**-56**	**57,70**	**1,02**
	-1,8 kWh/m^2y		**96,2 kWh/m^2y**	**-0,3 kg_{CO2}/m^2y**	**0,3 $€/m^2y$**	

Table 32: Case 7 results: weighted energy

Electricity balance	**Electricity required for EPB uses** $E_{EPus;el;t}$ *kWh*	**Electricity produced on-site** $E_{pr;el;t}$ *kWh*	**Electricity produced and used for EPB uses** $E_{pr;el;used;EPus;t}$ *kWh*	**Electricity exported to the grid** $E_{exp;el;grid;t}$ *kWh*	**Grid delivered electricity, t** $E_{del;el;t}$ *kWh*
January	894	166	128	38	766
February	642	219	124	95	518
March	417	325	97	229	320
April	191	463	58	405	133
May	48	509	18	491	31
June	107	453	70	383	36
July	156	553	107	446	49
August	99	485	59	426	40
September	53	383	12	372	41
October	160	305	36	269	124
November	453	171	71	101	382
December	740	140	93	48	648
Year	**3.960**	**4.175**	**872**	**3.303**	**3.088**

Table 33: Case 7 results: electricity balance

Electricity balance	**Electricity required for EPB uses**			**Electricity produced on-site**		
	Total kWh	From grid *%*	Produced *%*	*Total* kWh	Used *%*	Exported *%*
January	894	85,7%	14,3%	166	76,9%	23,1%
February	642	80,7%	19,3%	219	56,6%	43,4%
March	417	76,8%	23,2%	325	29,7%	70,3%
April	191	69,6%	30,4%	463	12,6%	87,4%
May	48	63,5%	36,5%	509	3,5%	96,5%
June	107	34,2%	65,8%	453	15,5%	84,5%
July	156	31,5%	68,5%	553	19,3%	80,7%
August	99	40,1%	59,9%	485	12,2%	87,8%
September	53	78,0%	22,0%	383	3,0%	97,0%
October	160	77,6%	22,4%	305	11,7%	88,3%
November	453	84,4%	15,6%	171	41,3%	58,7%
December	740	87,5%	12,5%	140	65,9%	34,1%
Year	**3.960**	**78,0%**	**22,0%**	**4.175**	**20,9%**	**79,1%**

Table 34: Case 7 results: details on electricity balance

6.7.3 Discussion

There is no change in the physical energy balance. The only change is in the evaluation parameters, e.g. inclusion of exported energy into the energy performance of the building.

This discussion is the same as that for case 3 compared to 2.

Weighted energy performance	**Non-renewable primary energy**	**Total primary energy**	**CO_2 emission**	**Cost**	**RER**
Case	kWh/m^2y	kWh/m^2y	kg_{CO2}/m^2y	€/m^2y	
Case 6: k_{exp} = 0	40,4	123,7,4	7,4	4,4	0,67
Case 7: k_{exp} = 1	-1,8	96,2	-0,3	0,3	1,02

Table 35: Comparison of weighted energy performance for cases 6 and 7

This table shows the effect of the inclusion of exported energy into the energy performance of a building when the amount of produces energy is high: the energy performance will assume negative numbers and the RER can be higher than 1.

The negative energy performance means that if the exported energy is included in the energy performance of the building, it appears that the operation of this building reduces the overall use of renewable primary energy of the world and reduces the overall CO_2 emissions in the world (these are pure operation data). This implies the assumption that exporting energy will replace the use of non-renewable primary energy and the emission of CO_2 of the grid generators.

The RER higher than 1 means that the useful renewable energy exceeds the energy need of the building, which is the case since the whole need is satisfied by renewable energy from photovoltaic and the excess is exported (therefore the negative energy performance).

Again, with k_{exp} = 1 and constant weighting factors, the monthly calculation provides the same results.

6.8 Case 8: same as case 6 with battery

6.8.1 Description of the case

Case	**Heat generation**	**PV**	**Thermal solar**	**k_{exp}**	**Battery**	**Other**
8	Heat pump	YES	YES	0,0	No	Battery 5 kWh

The thermal solar and the PV are both available. Kexp is set to 0,0. A battery with 5 kWh capacity is included.

6.8.2 Calculation results

The results of the hourly calculation are given in the following tables 36 to 38.

Weighted energy performance	**Non-renewable primary energy** E_{Pnren} *kWh*	**Renewable primary energy** E_{Pren} *kWh*	**Total primary energy** E_{Ptot} *kWh*	**CO_2 emission** CO_2 *kg CO_2*	**Cost** Cost *€*	**RER** RER
January	1.765	2.852	4.616	324	189,18	0,62
February	1.054	2.367	3.421	193	113,68	0,69
March	477	1.979	2.456	87	51,67	0,81
April	43	1.111	1.154	8	4,64	0,96
May	0	393	393	0	0,00	1,00
June	0	430	430	0	0,00	1,00
July	4	496	501	1	0,48	0,99
August	1	439	440	0	0,15	1,00
September	0	369	369	0	0,00	1,00
October	87	951	1.038	16	9,44	0,92
November	733	1.821	2.554	134	79,32	0,71
December	1.459	2.550	4.009	267	156,55	0,64
Year	**5.623**	**15.760**	**21.382**	**1.030**	**605,10**	**0,74**
	31,2 kWh/m^2y		**118,8 kWh/m^2y**	**5,7 kg_{CO2}/m^2y**	**3,4 $€/m^2y$**	

Table 36: Case 8 results: weighted energy

Electricity balance	**Electricity required for EPB uses** $E_{EPus;el;t}$ *kWh*	**Electricity produced on-site** $E_{pr;el;t}$ *kWh*	**Electricity produced and used for EPB uses** $E_{pr;el;used;EPus;t}$ *kWh*	**Electricity used for battery loading** $E_{bat;el;in}$ *kWh*	**Electricity exported to the grid** $E_{exp;el;grid;t}$ *kWh*	**Contribution by battery** $E_{EPus;el;bat}$ *kWh*	**Grid delivered electricity, t** $E_{del;el;t}$ *kWh*
January	894	166	128	38	0	31	735
February	642	219	124	88	7	71	448
March	417	325	97	150	78	115	206
April	191	463	58	142	263	114	19
May	48	509	18	41	450	31	0
June	107	453	70	44	339	36	0
July	156	553	107	60	386	47	2
August	99	485	59	53	373	39	1
September	53	383	12	52	320	41	0
October	160	305	36	105	164	86	38
November	453	171	71	84	16	68	314
December	740	140	93	48	0	38	610
Year	**3.960**	**4.175**	**872**	**906**	**2.397**	**717**	**2.371**

Table 37: Case 8 results: electricity balance

Electricity balance	**Electricity required for EPB uses**				**Electricity produced on-site**			
	Total kWh	From grid *%*	Battery *%*	Produced *%*	*Total* kWh	Used *%*	Battery *%*	Exported *%*
January	894	82,3%	3,4%	14,3%	166	76,9%	23,1%	0,0%
February	642	69,7%	11,0%	19,3%	219	56,6%	40,3%	3,1%
March	417	49,3%	27,5%	23,2%	325	29,7%	46,2%	24,1%
April	191	9,7%	59,9%	30,4%	463	12,6%	30,7%	56,8%
May	48	**0,0%**	63,5%	36,5%	509	3,5%	8,2%	88,4%
June	107	**0,0%**	34,2%	65,8%	453	15,5%	9,6%	74,8%
July	156	1,2%	30,3%	68,5%	553	19,3%	10,9%	69,9%
August	99	0,6%	39,5%	59,9%	485	12,2%	10,8%	76,9%
September	53	0,0%	78,0%	22,0%	383	3,0%	13,5%	83,5%
October	160	23,5%	54,0%	22,4%	305	11,7%	34,5%	53,7%
November	453	69,3%	15,0%	15,6%	171	41,3%	49,0%	9,6%
December	740	82,4%	5,1%	12,5%	140	65,9%	34,1%	0,0%
Year	**3.960**	**59,9%**	**18,1%**	**22,0%**	**4.175**	**20,9%**	**21,7%**	**57,4%**

Table 38: Case 8 results: details on electricity balance

6.8.3 Discussion

This case shall be compared with case 6.

Weighted energy performance	**Non-renewable primary energy**	**Total primary energy**	**CO_2 emission**	**Cost**	**RER**
Case	kWh/m^2y	kWh/m^2y	kg_{CO2}/m^2y	€/m^2y	
Case 6: no battery	40,4	123,7	7,4	4,4	0,67
Case 8: with battery	31,2	118,8	5,7	3,4	0,74

Table 39: Comparison of weighted energy performance for cases 6 and 7

The battery improves the energy performance because it allows to use in the building energy that has been produced at another time. This is detected only if k_{exp} is set to 0.

Table 30 shows that for case 6 without the battery

- 78% of the required electricity is taken from the grid
- 20,9% of the produced electricity is used on site, the rest is exported

Table 38 shows that for case 6 without the battery

- Only 59,9 % of the required electricity is taken from the grid
- 42,6 % of the produced electricity is used on site, either immediately (20,9, as in case 6) or at another time because stored in the battery (21,7%)

Table 38 also shows that in May, June and September no electricity is taken from the grid.

The battery allows to reduce the interaction on the grid. This can be calculated only with the hourly method.

If the weighting factors are constant (e..g. not time dependent) and the same for delivered and exported energy, the effect of the presence of the battery is detected only with the option $k_{exp} = 0$. Selecting $k_{exp} = 1$ makes the grid an infinite and perfect battery (no power limit, efficiency = 1) because delivered and exported energy at any time cancel each other since the weighting factors are the same anytime.

This is not true if the weighting factors are time dependent.

6.9 Summary of cases

The following tables 40 to 42 present a quick summary of all calculation results.

For ease of understanding, the table is divided in

- a section for calculations with $k_{exp} = 0$
- a second section for calculations with $k_{exp} = 1$
- specific sections for dedicated comparisons

A key is provided in the first table.

Case #	**Calc**	**Gen**	**PV**	**TS**	**K**	**Bat**	E_{Pnren} kWh/m^{2}y	E_{Ptot} kWh/m^{2}y	CO_2 kg$_{CO2}$/m^{2}y	**Cost** €/m^{2}y	**RER** -
1	h	Boil	No	Yes	0,0	No	98,5	111,2	19,6	7,4	0,11
2	h	Boil	Yes	Yes	0,0	No	94,1	108,3	18,8	7,0	0,13
2	*m*	*Boil*	*Yes*	*Yes*	*0,0*	*No*	*90,5*	*106,0*	*18,1*	*6,6*	*0,15*
2	*m-m*	*Boil*	*Yes*	*Yes*	*0,0*	*No*	*92,2*	*107,1*	*18,4*	*6,8*	*0,14*
4	h	HP	No	Yes	0,0	No	51,5	131,0	9,4	5,6	0,61
5	h	HP	Yes	No	0,0	No	46,7	127,8	8,6	5,0	0,63
5	*m*	*HP*	*Yes*	*No*	*0,0*	*No*	*30,8*	*117,4*	*5,6*	*3,3*	*0,74*
5	*m-m*	*HP*	*Yes*	*No*	*0,0*	*No*	*40,4*	*123,7*	*7,4*	*4,4*	*0,67*
6	h	HP	Yes	Yes	0,0	No	40,4	123,7	7,4	4,4	0,67
8	h	HP	Yes	Yes	0,0	Yes	31,2	118,1	5,7	3,4	0,74

Key

- Case#	Case number
- Calc	Calculation type h = hourly m = monthly m-m monthly with matching factor
- Gen	Generator type, Boil = boiler HP = Heat pump
- PV	Photovoltaic Yes/No (3 kW)
- TS	Thermal solar Yes/No (52% coverage of domestic hot water)
- K	Value of K_{exp} 0,0/1,0
- Bat	Battery Yes/No (5 kWh)

Table 40: Summary of cases, calculation with $k_{exp}=0$

This table shows the results for $k_{exp}=0$, that is excluding the exported energy from the energy performance of the building. The energy performance of the building depends exclusively on energy used to provide the required EPB services within the building. The energy performance of the building doesn't benefit exporting the excess of on-site energy production.

The table shows clearly that with this choice non-renewable primary energy, CO_2 emission and cost reflect the progressive influence of:

- the efficiency of generation device (boiler to heat pump);
- the availability of renewable sources (thermal solar and photovoltaic);
- the ability to actually use the on-site production in the building itself (by adding a battery).

This study has no case on the building but it is obvious that a reduction of needs would be detected as well.

For the option k_{exp}=0, the hourly calculation is required. The monthly calculation interval cannot evaluate the dynamic interaction between the building and the grid (see cases 2 and 5). The matching factor can only partly compensate and would depend on the electricity use and production patterns.

Case **#**	**Calc**	**Gen**	**PV**	**TS**	**K**	**Bat**	**E_{Pnren}** kWh/m²y	**E_{Ptot}** kWh/m²y	**CO_2** kg_{CO2}/m²y	**Cost** €/m²y	**RER** -
3	h	Boil	Yes	Yes	1,0	No	45,1	76,4	9,8	2,3	0,41
7	h	HP	Yes	Yes	1,0	No	-1,8	96,2	-0,3	0,3	1,02

Table 41: Summary of cases, calculation with k_{exp}=1

This table shows the results for k_{exp}=1, that is including the exported energy into the energy performance of the building. The energy performance of the building benefits of exporting the excess of on-site energy production.

The table shows clearly that with this choice non-renewable primary energy, CO_2 emission and cost reflect the progressive influence of

- the efficiency of generation device (boiler to heat pump)
- the availability of renewable sources (thermal solar and photovoltaic);
- the exported energy amount.

The following table shows clearly the effect on including exported energy into the energy performance of the building.

Case **#**	**Calc**	**Gen**	**PV**	**TS**	**K**	**Bat**	**E_{Pnren}** kWh/m²y	**E_{Ptot}** kWh/m²y	**CO_2** kg_{CO2}/m²y	**Cost** €/m²y	**RER** -
2	h	Boil	Yes	Yes	0,0	No	94,1	108,3	18,8	7,0	0,13
3	h	Boil	Yes	Yes	1,0	No	45,1	76,4	9,8	2,3	0,41
6	h	HP	Yes	Yes	0,0	No	40,4	123,7	7,4	4,4	0,67
7	h	HP	Yes	Yes	1,0	No	-1,8	96,2	-0,3	0,3	1,02

Table 42: Summary of case 1, comparison of identical cases with k_{exp}=0 and k_{exp}=1

Choosing k_{exp}=1 the energy performance increases due to the exported energy. This happens also across energy carriers. From case 2 to 3, following the installation of PV panels, the building is still using a non-renewable source for heating but this is compensated by the renewable electricity exported to the grid.

With this option, a poor quality of building envelope and/or efficiency of a generation device can be masked in the energy performance of a building by the exported energy. A second indicator (e.g. building needs) is required to correctly understand the reason for the performance of the building.

For the option k_{exp}=1, the hourly calculation is not required until weighting factors are not time dependent and the same for delivered and exported energy. The grid acts as an infinite and perfect battery (no power limit, efficiency = 1) because delivered and exported energy at any time cancel each other since the weighting factors are the same anytime. So, this option doesn't detect the presence of a battery.

With the option k_{exp}=1, when the amount of produces energy is high the energy performance may become a negative number and the RER can be higher than 1 and even negative. This is correct and coherent with the definition.

The negative energy performance means that since the exported energy is included in the energy performance of the building, it appears that the operation of this building reduces the overall use of renewable primary energy of the world and reduces the overall CO_2 emissions in the world (these are pure operation data, not LCA). This implies the assumption that exporting energy will replace the use of non-renewable primary energy and the emission of CO_2 of the grid generators.

The RER higher than 1 means that the useful renewable energy exceeds the energy need of the building, which is the case since the whole need is satisfied by renewable energy from photovoltaic and the excess is exported (therefore the negative energy performance).

7 Analysis

7.1 Completeness

EN ISO 52000-1 supports all energy weighting options currently used by EU member states, including the choices on exported energy.

EN ISO 52000-1 already covers time-dependent weighting factors, which have not been yet adopted in the EU Member States for EPBD regulatory purpose.

There is no module in the set of EPB standards about batteries (electricity storage).

The standard would be complete if the battery is included. The proposed (and demonstrated) simple amendments to the spreadsheet satisfy this requirement. It can be easily refined with further control options, such as time schedules to change the priority between the interaction with the battery rather than with the grid (i.e. use stored energy or grid delivered as well as charge the battery or export to the grid).

7.2 Functionality

This standard provides adequate indicators to highlight the features of the system, based on the mix of delivered and exported energy carriers.

However, no single indicator will tell everything about the energy performance of a building. To get a complete picture of the energy performance of a building, the indicators defined by EN ISO 52000-1 should be complemented by other partial performance indicators, such as energy needs and comfort indicators which are already defined in other modules of the EPB standards.

7.3 Sensitivity

The obvious influencing parameters are the weighting factors.

Other influencing factors are:

- k_{exp}, which determines if the contribution by exported energy is included in the energy performance of the building. Anytime there is exported energy, this can be a game changing parameter.
- Matching factors, only for the monthly method, to take into account the effect of the simultaneity (or not) of energy production and use.

7.4 Usability

The standard is extremely easy to use.

The input parameters are a limited number and well defined.

This standard makes explicit choices that were embedded in the national calculation methodologies .

8 Conclusions and recommendations

k_{exp} is a game changer. $k_{exp}=1$ allows compensation between exported and imported energy at different time or by different carriers. This generally allows a better (lower) energy performance than that obtained setting $k_{exp}=0$. This is not to say that there is a “right” or “wrong” solution, just that there are two possible ways to evaluate exported energy. That’s no difference with economical accounting: when selling an item, you may take into account either the cost or the revenue. EN ISO 52000-1 makes this alternative evident and allows to make this choice in a transparent way.

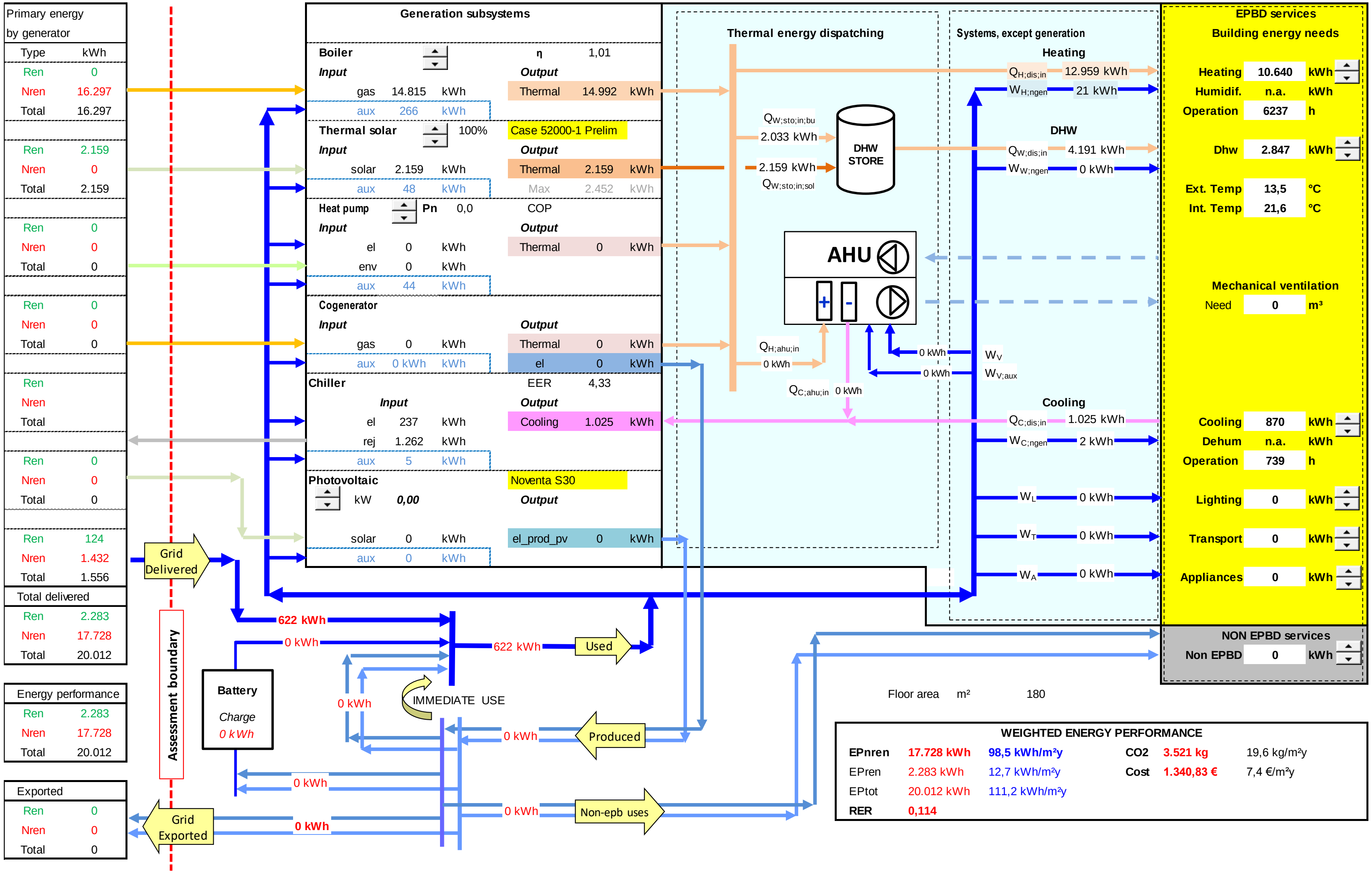
The result also shows that the hourly calculation interval is appropriate when considering a bidirectional interaction between the grid and the building.

The calculation of the battery should be included. A possible set of equations is suggested in the accompanying spreadsheet.

Annex A

Yearly energy balance diagrams of the calculated cases

In the following pages there are screen shots of the yearly balance for each calculated case, taken from the respective spreadsheets.



Primary energy by generator	
Type	kWh
Ren	0
Nren	16.297
Total	16.297
Ren	2.159
Nren	0
Total	2.159
Ren	0
Nren	0
Total	0
Ren	0
Nren	0
Total	0
Ren	
Nren	
Total	
Ren	0
Nren	0
Total	0
Ren	124
Nren	1.432
Total	1.556
Total delivered	
Ren	2.283
Nren	17.728
Total	20.012

Energy performance	
Ren	2.283
Nren	17.728
Total	20.012

Exported	
Ren	0
Nren	0
Total	0

EPBD services

Building energy needs

Heating	10.640	kWh
Humidif.	n.a.	kWh
Operation	6237	h
Dhw	2.847	kWh
Ext. Temp	13,5	°C
Int. Temp	21,6	°C

Mechanical ventilation

Need	0	m³

Cooling	870	kWh
Dehum	n.a.	kWh
Operation	739	h
Lighting	0	kWh
Transport	0	kWh
Appliances	0	kWh

NON EPBD services

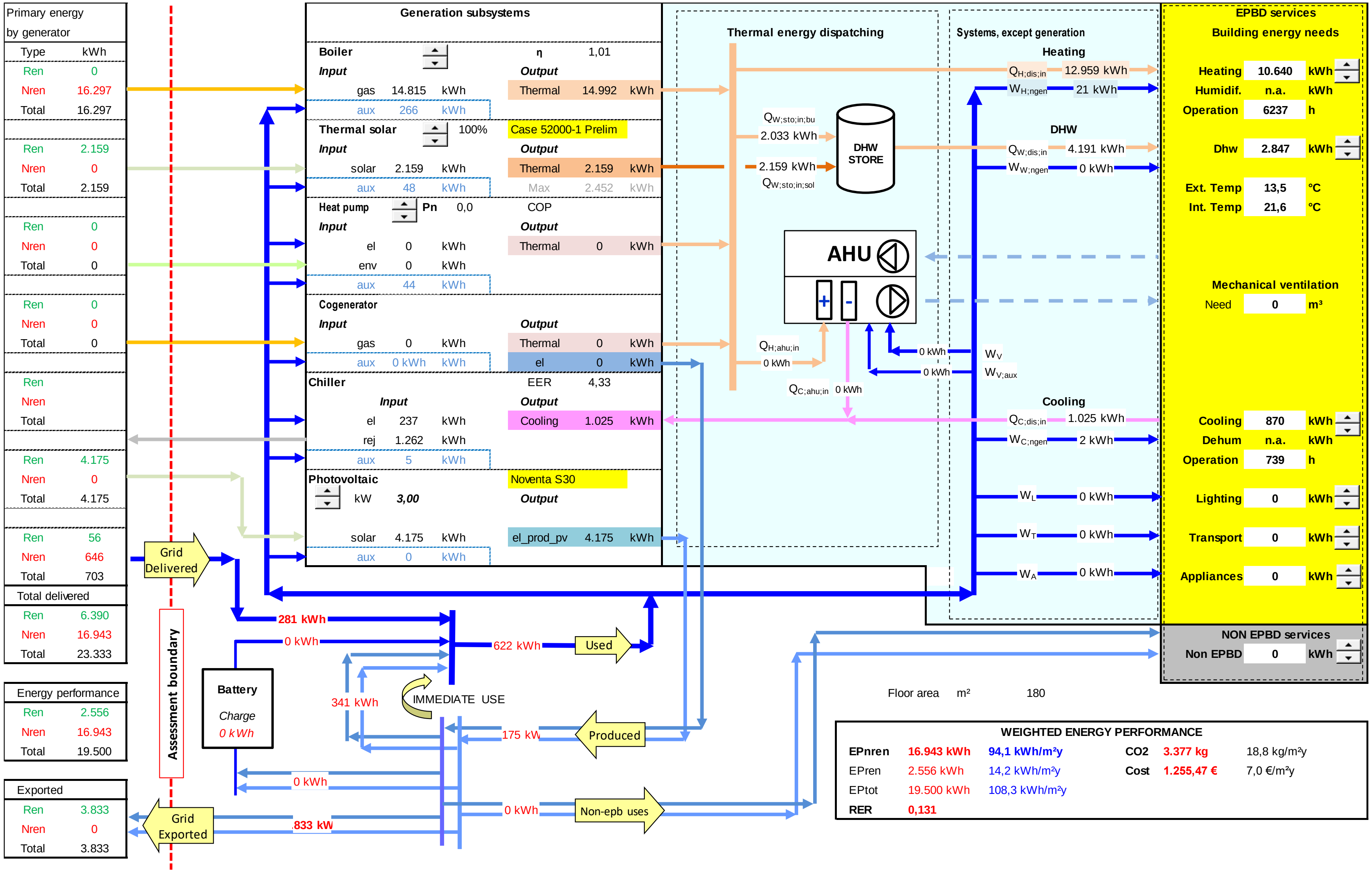
Non EPBD	0	kWh

Floor area m² 180

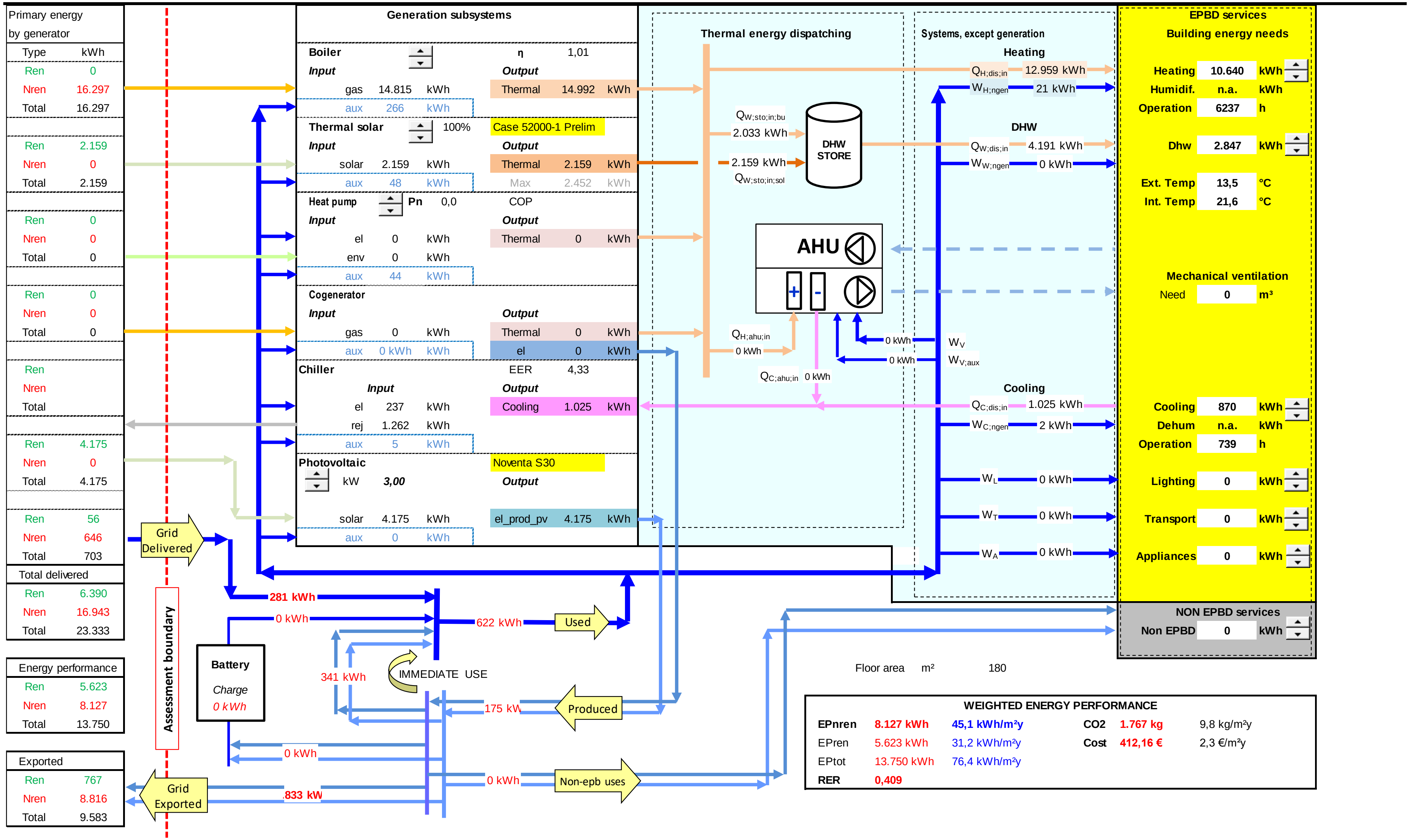
WEIGHTED ENERGY PERFORMANCE

EPnren	17.728 kWh	98,5 kWh/m²y	CO2	3.521 kg	19,6 kg/m²y
EPren	2.283 kWh	12,7 kWh/m²y	Cost	1.340,83 €	7,4 €/m²y
EPtot	20.012 kWh	111,2 kWh/m²y			
RER	0,114				

Case 1: Boiler, thermal solar, no photovoltaic, Kexp = 0



Case 2: Boiler, thermal solar, ***photovoltaic****, Kexp = 0*



Primary energy by generator

Type	kWh
Ren	0
Nren	16.297
Total	16.297
Ren	2.159
Nren	0
Total	2.159
Ren	0
Nren	0
Total	0
Ren	0
Nren	0
Total	0
Ren	
Nren	
Total	
Ren	4.175
Nren	0
Total	4.175
Ren	56
Nren	646
Total	703

Total delivered

Ren	6.390
Nren	16.943
Total	23.333

Energy performance

Ren	5.623
Nren	8.127
Total	13.750

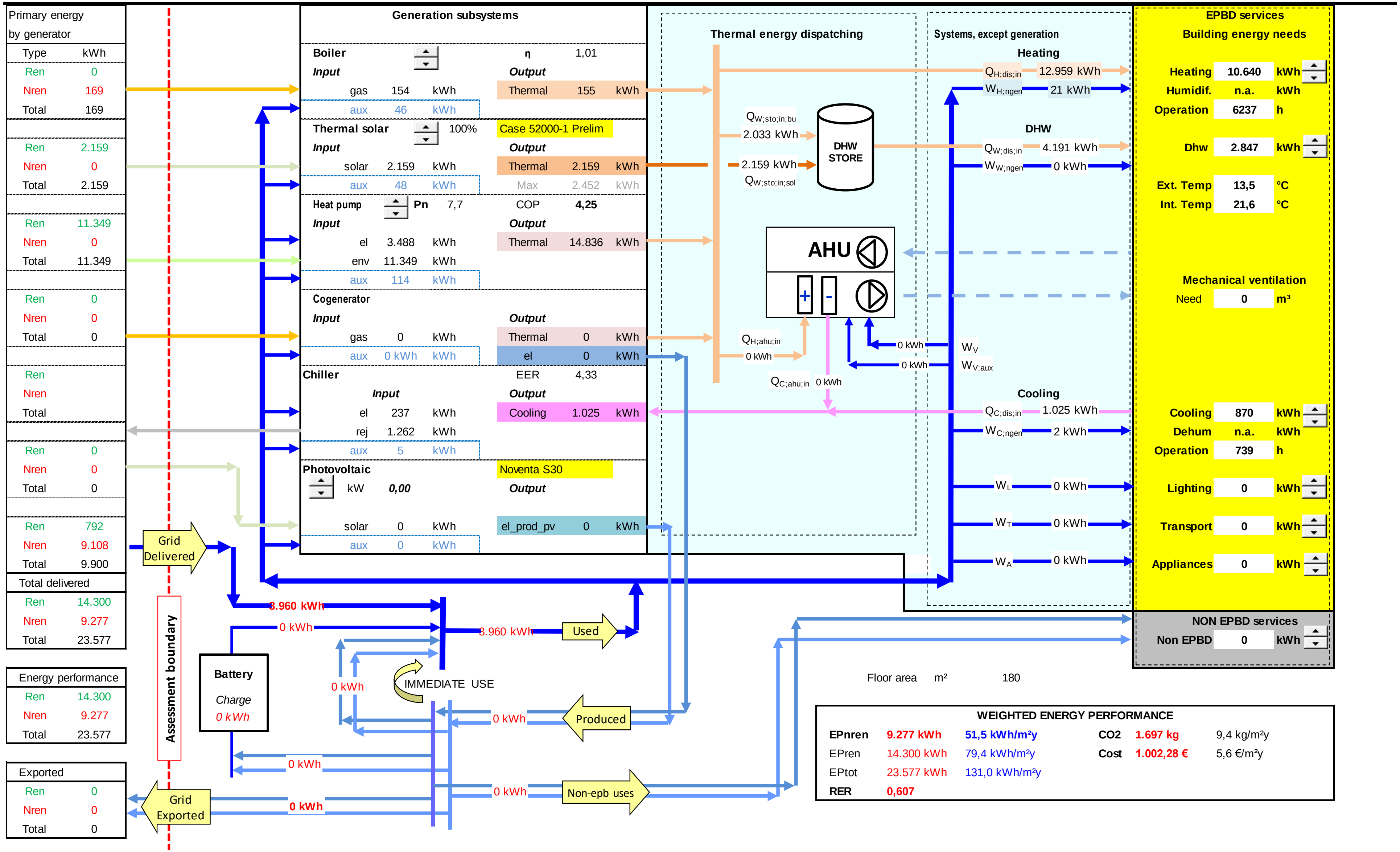
Exported

Ren	767
Nren	8.816
Total	9.583

WEIGHTED ENERGY PERFORMANCE

EPnren	8.127 kWh	45,1 kWh/m²y	CO2	1.767 kg	9,8 kg/m²y
EPren	5.623 kWh	31,2 kWh/m²y	Cost	412,16 €	2,3 €/m²y
EPtot	13.750 kWh	76,4 kWh/m²y			
RER	0,409				

Case 3: Boiler, thermal solar, photovoltaic, ***Kexp = 1***



Primary energy by generator

Type	kWh
Ren	0
Nren	169
Total	169
Ren	2.159
Nren	0
Total	2.159
Ren	11.349
Nren	0
Total	11.349
Ren	0
Nren	0
Total	0
Ren	
Nren	
Total	
Ren	0
Nren	0
Total	0
Ren	792
Nren	9.108
Total	9.900

Total delivered

Ren	14.300
Nren	9.277
Total	23.577

Energy performance

Ren	14.300
Nren	9.277
Total	23.577

Exported

Ren	0
Nren	0
Total	0

Generation subsystems

Boiler η 1,01

Input			Output		
gas	154	kWh	Thermal	155	kWh
aux	46	kWh			

Thermal solar 100% Case 52000-1 Prelim

Input			Output		
solar	2.159	kWh	Thermal	2.159	kWh
aux	48	kWh	Max	2.452	kWh

Heat pump Pn 7,7 COP 4,25

Input			Output		
el	3.488	kWh	Thermal	14.836	kWh
env	11.349	kWh			
aux	114	kWh			

Cogenerator

Input			Output		
gas	0	kWh	Thermal	0	kWh
aux	0 kWh	kWh	el	0	kWh

Chiller EER 4,33

Input			Output		
el	237	kWh	Cooling	1.025	kWh
rej	1.262	kWh			
aux	5	kWh			

Photovoltaic Noventa S30

kW *0,00*

			Output		
solar	0	kWh	el_prod_pv	0	kWh
aux	0	kWh			

Thermal energy dispatching

Systems, except generation

EPBD services

Building energy needs

Heating	10.640	kWh
Humidif.	n.a.	kWh
Operation	6237	h
Dhw	2.847	kWh
Ext. Temp	13,5	°C
Int. Temp	21,6	°C

Mechanical ventilation

Need	0	m³
Cooling	870	kWh
Dehum	n.a.	kWh
Operation	739	h
Lighting	0	kWh
Transport	0	kWh
Appliances	0	kWh

NON EPBD services

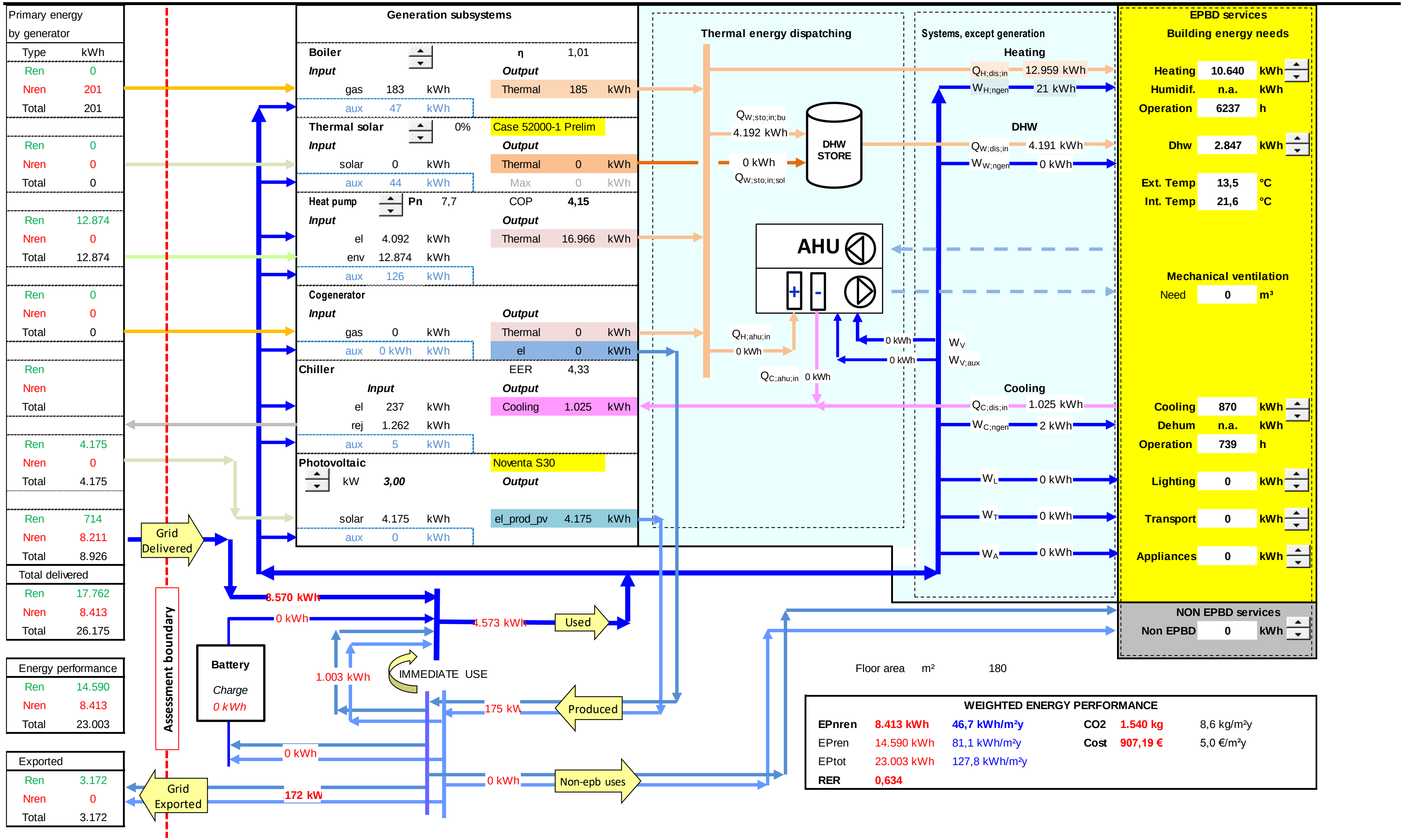
Non EPBD 0 kWh

Floor area m² 180

WEIGHTED ENERGY PERFORMANCE

EPnren	9.277 kWh	51,5 kWh/m²y	CO2	1.697 kg	9,4 kg/m²y
EPren	14.300 kWh	79,4 kWh/m²y	Cost	1.002,28 €	5,6 €/m²y
EPtot	23.577 kWh	131,0 kWh/m²y			
RER	0,607				

Case 4: ***Heat pump****, thermal solar, no photovoltaic, Kexp = 0*



Primary energy by generator

Type	kWh
Ren	0
Nren	201
Total	201
Ren	0
Nren	0
Total	0
Ren	12.874
Nren	0
Total	12.874
Ren	0
Nren	0
Total	0
Ren	
Nren	
Total	
Ren	4.175
Nren	0
Total	4.175
Ren	714
Nren	8.211
Total	8.926
Total delivered	
Ren	17.762
Nren	8.413
Total	26.175

Energy performance	
Ren	14.590
Nren	8.413
Total	23.003

Exported	
Ren	3.172
Nren	0
Total	3.172

Generation subsystems

Boiler η 1,01
Input gas 183 kWh; aux 47 kWh
Output Thermal 185 kWh

Thermal solar 0% Case 52000-1 Prelim
Input solar 0 kWh; aux 44 kWh
Output Thermal 0 kWh; Max 0 kWh

Heat pump Pn 7,7 COP 4,15
Input el 4.092 kWh; env 12.874 kWh; aux 126 kWh
Output Thermal 16.966 kWh

Cogenerator
Input gas 0 kWh; aux 0 kWh kWh
Output Thermal 0 kWh; el 0 kWh

Chiller EER 4,33
Input el 237 kWh; rej 1.262 kWh; aux 5 kWh
Output Cooling 1.025 kWh

Photovoltaic Noventa S30
kW *3,00*
Output solar 4.175 kWh; aux 0 kWh
el_prod_pv 4.175 kWh

EPBD services
Building energy needs

Heating	10.640	kWh
Humidif.	n.a.	kWh
Operation	6237	h
Dhw	2.847	kWh
Ext. Temp	13,5	°C
Int. Temp	21,6	°C
Mechanical ventilation Need	0	m³
Cooling	870	kWh
Dehum	n.a.	kWh
Operation	739	h
Lighting	0	kWh
Transport	0	kWh
Appliances	0	kWh

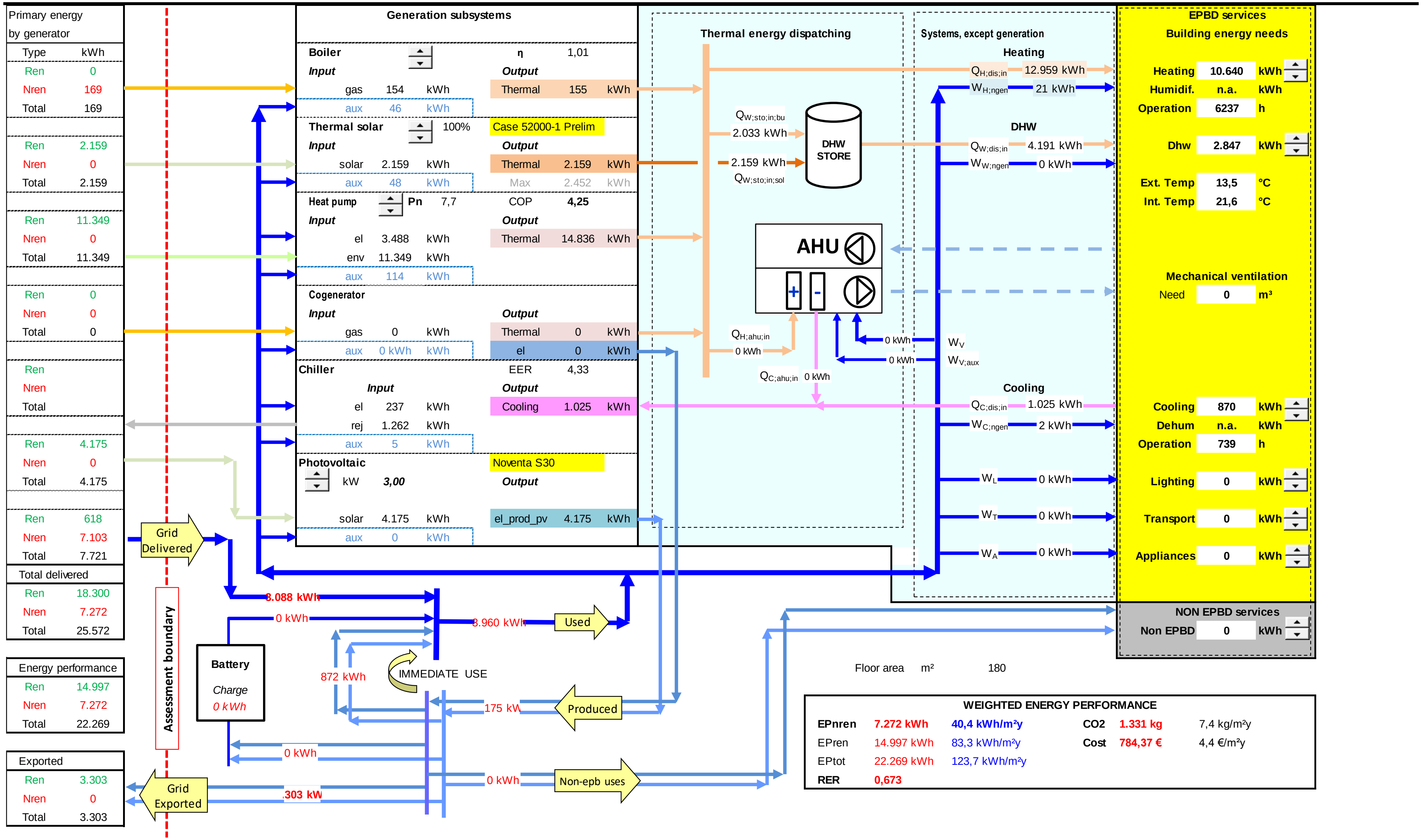
NON EPBD services
Non EPBD 0 kWh

Floor area m² 180

WEIGHTED ENERGY PERFORMANCE

EPnren	8.413 kWh	46,7 kWh/m²y	CO2	1.540 kg	8,6 kg/m²y
EPren	14.590 kWh	81,1 kWh/m²y	Cost	907,19 €	5,0 €/m²y
EPtot	23.003 kWh	127,8 kWh/m²y			
RER	0,634				

Case 5: Heat pump, ***no thermal solar***, ***photovoltaic****, Kexp = 0*



Primary energy by generator

Type	kWh
Ren	0
Nren	169
Total	169
Ren	2.159
Nren	0
Total	2.159
Ren	11.349
Nren	0
Total	11.349
Ren	0
Nren	0
Total	0
Ren	
Nren	
Total	
Ren	4.175
Nren	0
Total	4.175
Ren	618
Nren	7.103
Total	7.721

Total delivered

Ren	18.300
Nren	7.272
Total	25.572

Energy performance

Ren	14.997
Nren	7.272
Total	22.269

Exported

Ren	3.303
Nren	0
Total	3.303

Generation subsystems

Boiler				η	1,01		
Input				*Output*			
	gas	154	kWh	Thermal	155	kWh	
	aux	46	kWh				
Thermal solar	100%			Case 52000-1 Prelim			
Input				*Output*			
	solar	2.159	kWh	Thermal	2.159	kWh	
	aux	48	kWh	Max	2.452	kWh	
Heat pump	Pn	7,7		COP	4,25		
Input				*Output*			
	el	3.488	kWh	Thermal	14.836	kWh	
	env	11.349	kWh				
	aux	114	kWh				
Cogenerator							
Input				*Output*			
	gas	0	kWh	Thermal	0	kWh	
	aux	0 kWh	kWh	el	0	kWh	
Chiller				EER	4,33		
Input				*Output*			
	el	237	kWh	Cooling	1.025	kWh	
	rej	1.262	kWh				
	aux	5	kWh				
Photovoltaic				Noventa S30			
	kW	*3,00*		*Output*			
	solar	4.175	kWh	el_prod_pv	4.175	kWh	
	aux	0	kWh				

Systems, except generation

Heating		
$Q_{H;dis;in}$	12.959 kWh	
$W_{H;ngen}$	21 kWh	
DHW		
$Q_{W;dis;in}$	4.191 kWh	
$W_{W;ngen}$	0 kWh	
Cooling		
$Q_{C;dis;in}$	1.025 kWh	
$W_{C;ngen}$	2 kWh	
W_L	0 kWh	
W_T	0 kWh	
W_A	0 kWh	

EPBD services

Building energy needs

Heating	**10.640**	**kWh**
Humidif.	**n.a.**	**kWh**
Operation	**6237**	**h**
Dhw	**2.847**	**kWh**
Ext. Temp	**13,5**	**°C**
Int. Temp	**21,6**	**°C**
Mechanical ventilation		
Need	**0**	**m³**
Cooling	**870**	**kWh**
Dehum	**n.a.**	**kWh**
Operation	**739**	**h**
Lighting	**0**	**kWh**
Transport	**0**	**kWh**
Appliances	**0**	**kWh**

NON EPBD services

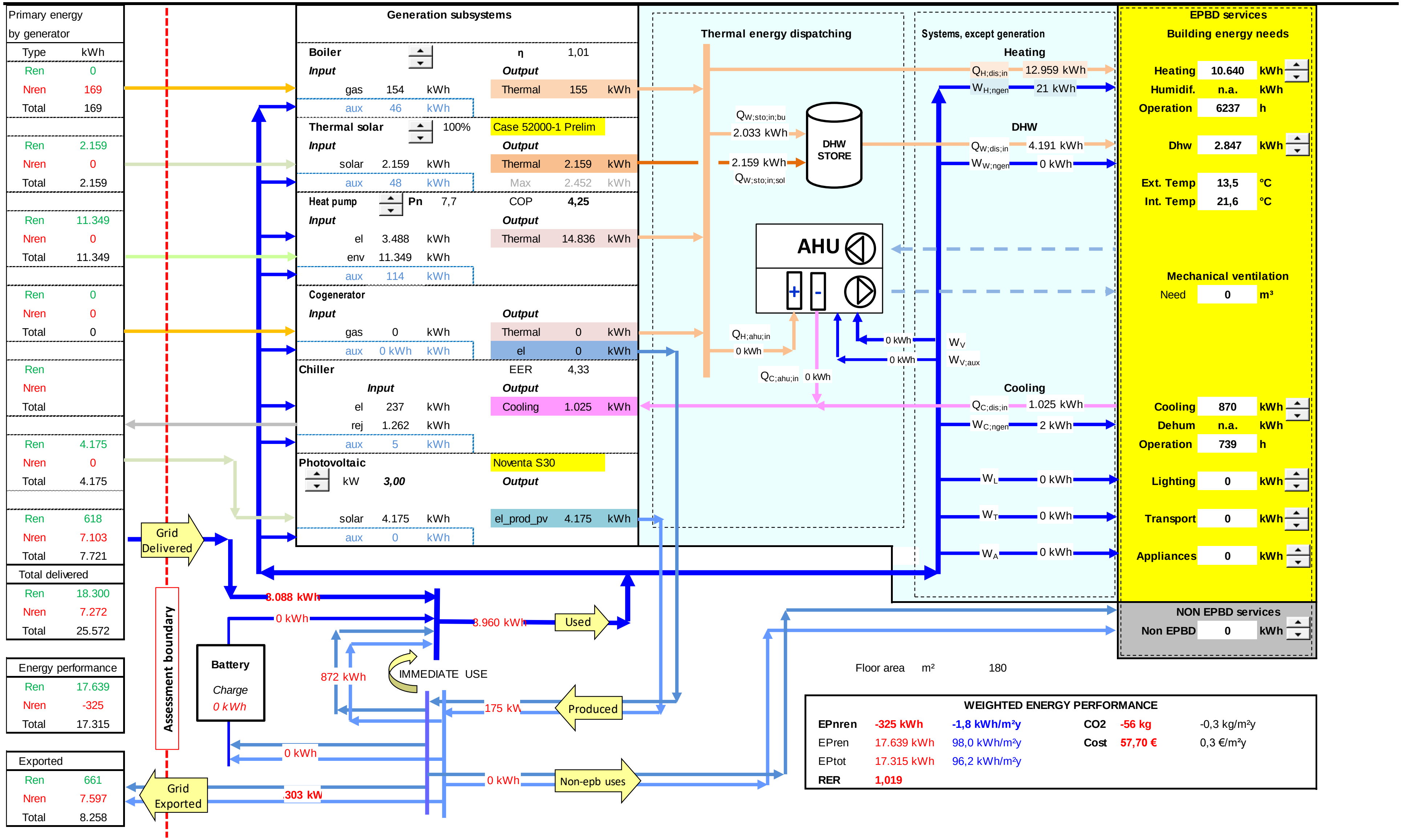
Non EPBD	**0**	**kWh**

Floor area m² 180

WEIGHTED ENERGY PERFORMANCE

EPnren	**7.272 kWh**	**40,4 kWh/m²y**	**CO2**	**1.331 kg**	7,4 kg/m²y
EPren	14.997 kWh	83,3 kWh/m²y	**Cost**	**784,37 €**	4,4 €/m²y
EPtot	22.269 kWh	123,7 kWh/m²y			
RER	**0,673**				

*Case 6: Heat pump, **thermal solar**, photovoltaic, Kexp = 0*



Primary energy by generator

Type	kWh
Ren	0
Nren	169
Total	169
Ren	2.159
Nren	0
Total	2.159
Ren	11.349
Nren	0
Total	11.349
Ren	0
Nren	0
Total	0
Ren	
Nren	
Total	
Ren	4.175
Nren	0
Total	4.175
Ren	618
Nren	7.103
Total	7.721

Total delivered	
Ren	18.300
Nren	7.272
Total	25.572

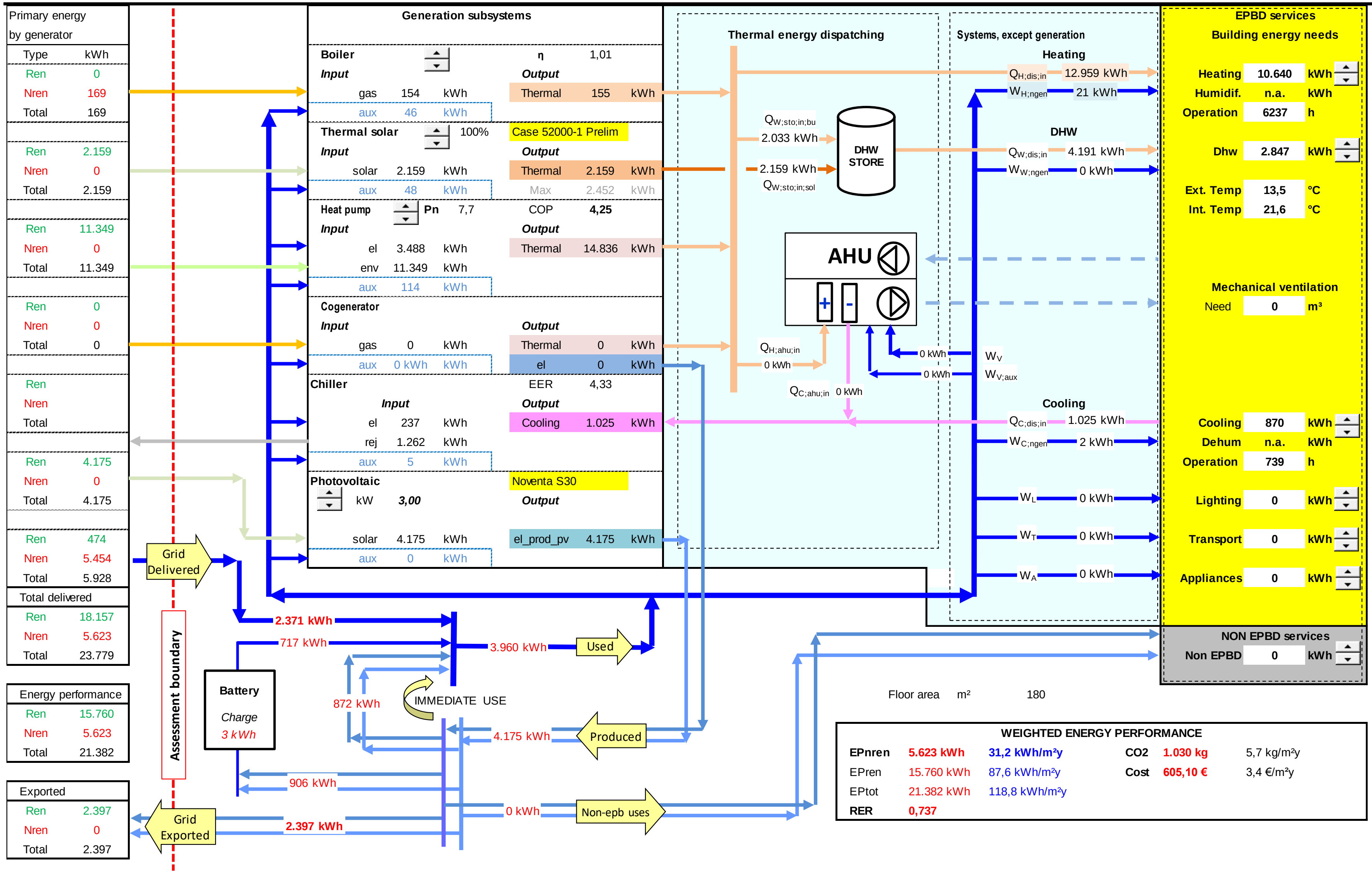
Energy performance	
Ren	17.639
Nren	-325
Total	17.315

Exported	
Ren	661
Nren	7.597
Total	8.258

WEIGHTED ENERGY PERFORMANCE

EPnren	-325 kWh	-1,8 kWh/m²y	CO2	-56 kg	-0,3 kg/m²y
EPren	17.639 kWh	98,0 kWh/m²y	Cost	57,70 €	0,3 €/m²y
EPtot	17.315 kWh	96,2 kWh/m²y			
RER	1,019				

Case 7: Heat pump, thermal solar, photovoltaic, ***Kexp = 1***



Primary energy by generator

Type	kWh
Ren	0
Nren	169
Total	169
Ren	2.159
Nren	0
Total	2.159
Ren	11.349
Nren	0
Total	11.349
Ren	0
Nren	0
Total	0
Ren	
Nren	
Total	
Ren	4.175
Nren	0
Total	4.175
Ren	474
Nren	5.454
Total	5.928

Total delivered

Ren	18.157
Nren	5.623
Total	23.779

Energy performance

Ren	15.760
Nren	5.623
Total	21.382

Exported

Ren	2.397
Nren	0
Total	2.397

Generation subsystems

Boiler				η	1,01		
Input				*Output*			
gas	154	kWh		Thermal	155	kWh	
aux	46	kWh					
Thermal solar		100%		Case 52000-1 Prelim			
Input				*Output*			
solar	2.159	kWh		Thermal	2.159	kWh	
aux	48	kWh		Max	2.452	kWh	
Heat pump	Pn	7,7		COP	4,25		
Input				*Output*			
el	3.488	kWh		Thermal	14.836	kWh	
env	11.349	kWh					
aux	114	kWh					
Cogenerator							
Input				*Output*			
gas	0	kWh		Thermal	0	kWh	
aux	0 kWh	kWh		el	0	kWh	
Chiller				EER	4,33		
Input				*Output*			
el	237	kWh		Cooling	1.025	kWh	
rej	1.262	kWh					
aux	5	kWh					
Photovoltaic				Noventa S30			
kW	*3,00*			*Output*			
solar	4.175	kWh		el_prod_pv	4.175	kWh	
aux	0	kWh					

Thermal energy dispatching

Systems, except generation

Heating		
$Q_{H;dis;in}$	12.959 kWh	
$W_{H;ngen}$	21 kWh	
DHW		
$Q_{W;dis;in}$	4.191 kWh	
$W_{W;ngen}$	0 kWh	
Cooling		
$Q_{C;dis;in}$	1.025 kWh	
$W_{C;ngen}$	2 kWh	
W_L	0 kWh	
W_T	0 kWh	
W_A	0 kWh	

EPBD services

Building energy needs

Heating	10.640	kWh
Humidif.	n.a.	kWh
Operation	6237	h
Dhw	2.847	kWh
Ext. Temp	13,5	°C
Int. Temp	21,6	°C

Mechanical ventilation

Need	0	m³

Cooling	870	kWh
Dehum	n.a.	kWh
Operation	739	h
Lighting	0	kWh
Transport	0	kWh
Appliances	0	kWh

NON EPBD services

Non EPBD	0	kWh

Floor area m² 180

WEIGHTED ENERGY PERFORMANCE

EPnren	5.623 kWh	31,2 kWh/m²y	**CO2**	1.030 kg	5,7 kg/m²y
EPren	15.760 kWh	87,6 kWh/m²y	**Cost**	605,10 €	3,4 €/m²y
EPtot	21.382 kWh	118,8 kWh/m²y			
RER	0,737				

Case 8: Heat pump, thermal solar, photovoltaic, ***Kexp = 0, battery***

Annex B

Electricity storage model (battery)

B.1 Introduction

Electricity storage has been added because it is an emerging technology and the implementation should be at overarching level.

B.2 Model used

The following assumptions were made when modelling the electricity storage (battery).

- Capacity of the battery is expressed in terms of available energy output.
- The efficiency of the load-unload cycle is taken into account in the loading phase.
- A separate maximum power is taken into account for the loading and un-loading phases.

The logics applied uses the following priorities:

- If on-site production exceeds on-site use, priority to battery charge with respect to electricity export
- If on-site production doesn't meet on-site use, priority to battery use with respect to importing grid electricity

No time-of-day strategy is taken into account.

Annex C

List of calculation files

The following calculation files are annexed in the case study package:

- EN_ISO_52000-1_01_boil_PVno_TSyes_K0_ hourly.xlsm
- EN_ISO_52000-1_01_boil_PVno_TSyes_K0_ monthly.xlsm
- EN_ISO_52000-1_02_boil_PVyes_TSyes_K0_ hourly.xlsm
- EN_ISO_52000-1_02_boil_PVyes_TSyes_K0_ monthly - match.xlsm
- EN_ISO_52000-1_02_boil_PVyes_TSyes_K0_ monthly - no match.xlsm
- EN_ISO_52000-1_03_boil_PVyes_TSyes_K1_ hourly.xlsm
- EN_ISO_52000-1_03_boil_PVyes_TSyes_K1_ monthly - match.xlsm
- EN_ISO_52000-1_03_boil_PVyes_TSyes_K1_ monthly - no match.xlsm
- EN_ISO_52000-1_04_hp_PVno_TSyes_K0_ hourly.xlsm
- EN_ISO_52000-1_04_hp_PVno_TSyes_K0_ monthly no match.xlsm
- EN_ISO_52000-1_05_hp_PVyes_TSno_K0_ hourly.xlsm
- EN_ISO_52000-1_05_hp_PVyes_TSno_K0_ monthly - match.xlsm
- EN_ISO_52000-1_05_hp_PVyes_TSno_K0_ monthly - no match.xlsm
- EN_ISO_52000-1_06_hp_PVyes_TSyes_K0_ hourly.xlsm
- EN_ISO_52000-1_07_hp_PVyes_TSyes_K1_ hourly.xlsm
- EN_ISO_52000-1_08_hp_PVyes_TSyes_K0_B5_ hourly.xlsm

File name template:

EN_ISO_52000-1_**NN_gen**_PV**yn**_TS**yn**_**Kx_calc**.xlsm

NN ID number of the case

gen type of generator

- **boil**: boiler
- **hp**: heat pump

PVyn presence of PV panels

- **PVyes** Photovoltaic panels
- **PVno** No photovoltaic panels

TSyn presence of solar collectors

- **PVyes** Solar collectors
- **PVno** No solar collectors

Kx k_{exp} option

- **K1** $k_{exp} = 1,0$
- **K0** $k_{exp} = 0,0$

Bx Battery, x kWh capacity

calc type of calculation

- **hourly** hourly
- **monthly** monthly, with or without matching factor

Bibliography

[1] (EN) ISO 52000-1:2017, *Energy performance of buildings — Overarching EPB assessment — Part 1: General framework and procedures*

[2] (CEN) ISO/TR 52000-2:2017, *Energy performance of buildings — Overarching EPB assessment — Part 2: Explanation and justification of ISO 52000-1*

[3] ENERC32017-437-SI2-785.185, Case study on EN ISO 52000-1, Overarching standard, simplified spreadsheets, October 31, 2021

[4] ENERC32017-437-SI2-785.185, Case study on EN ISO 52010-1, Climatic data
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[5] ENERC32017-437-SI2-785.185, Case study on EN 15316-1, Heating and domestic hot water systems, general part, October 31, 2021

[6] ENERC32017-437-SI2-785.185, Case study on EN 15316-4-2, Heat pumps
October 31, 2021

[7] ENERC32017-437-SI2-785.185, Case study on EN ISO 52016-1, Heating and cooling needs and internal temperatures
October 31, 2021

[8] ENERC32017-437-SI2-785.185, Case study on EN ISO 52016-1, Annex F, Solar shading reduction factors
October 31, 2021

[9] ENERC32017-437-SI2-785.185, Case study on EN 16798-1, Conditions of use
October 31, 2021

[10] ENERC32017-437-SI2-785.185, Case study on EN 16798-7, Natural ventilation
October 31, 2021

[11] ENERC32017-437-SI2-785.185, Case study on EN 16798-7 and EN 16798-5-1, Mechanical ventilation
October 31, 2021

[12] ENERC32017-437-SI2-785.185, Case study on Single-family House
October 31, 2021

[13] ENERC32017-437-SI2-785.185, Case study on Multi-family House
October 31, 2021

[14] ENERC32017-437-SI2-785.185, Case study on Office building
October 31, 2021

Please check the EPB Center website for the most recent versions of these case study reports

Link: EPB Center support documents

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