EXCESS

FleXible user-CEntric Energy poSitive houseS

Deliverable 1.1: PEB as enabler for consumer centred clean energy transition: shared definition and concept

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement N°870157.

LC-EEB-03-2019

New developments in plus energy houses (IA)

Proposal No. 870157

Title	Document Version
D1.1 PEB as enabler for consumer centred clean energy transition: shared definition and concept	1.0

Project Number	Project Acronym	Project Title
H2020-870157	EXCESS	FleXible user-CEntric Energy poSitive houseS

Contractual Delivery Date	Actual Delivery Date	Deliverable Type*-Security**
30th Apr 2020	M8 (May 2020)	R-PU

*Type: P: Prototype; R: Report; D: Demonstrator; O: Other.

**Security Class: PU: Public; PP: Restricted to other programme participants (including the Commission); RE: Restricted to a group defined by the consortium (including the Commission); CO: Confidential, only for members of the consortium (including the Commission).

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Abstract

The development of a shared definition of Positive Energy Buildings for the EXCESS project is described. Based on a literature review and through discussions, the EXCESS team decided to define PEB as "an energy efficient building that produces more energy than it uses via renewable sources, with high self-consumption rate and high energy flexibility, over a time span of one year. A high quality indoor environment is an essential element in the PEB, maintaining the comfort and wellbeing of the building occupants. The PEB is also able to integrate the future technologies like electric vehicles with the motivation to maximize the onsite consumption and also share the surplus renewable energy."

This definition and the general EXCESS objectives were compared to the EU regulations and long term visions, concluding that these are very well in line with each other. EXCESS definition and concept are especially well in line with the ideas on citizen empowerment and user comfort underlined in several of the regulations and vision documents. The documents also refer to the interaction with the grid and the (future) integration of EVs. Energy efficiency is particularly highlighted in the EU's documents, as well as the need to cover the remaining need by renewable energy.

Keywords
PEB definition, EU vision and regulations

Revision	Date	Description	Author (Organisation)
V1.0	30.04.2020	*Ready for internal review*	Mia Ala-Juusela, Hassam ur Rehman (VTT), with contributions from Mari Hukkalainen (VTT), Andreas Tuerk and Tamara Trumbic (JR) Javier Llorente (CEN), Steven Claes (VITO), Spiros, Tasos Tsitsanis and Konstantinos Latanis (S5), Erick Maas (URB)
V1.1	5.6.2020	*Edited according to internal review comments*	Mia Ala-Juusela & Hassam ur Rehman (VTT)

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement № 870157.

More information available at https://positive-energy-buildings.eu/

EXECUTIVE SUMMARY

In this deliverable, EXCESS partners assess the European dimension of EXCESS PEB residential concept proposing a common shared definition investigating complementarity and integrity with EU energy regulatory framework and with the EU long-term vision for a prosperous, modern, competitive and climate-neutral economy by 2050. The partners explored technical aspects (building in and out primary and final energy flows), social aspects (occupant engagement), indoor comfort requirements, environmental targets and the building structure aesthetical requirements. The district perspective and the positioning of the PEB in the city energy infrastructure are also taken into account. Particularly, energy /transaction schemes of produced on-site renewable energy and available on-site energy flexibility are outlined.

A common definition of PEB was developed, based on literature review and discussions among the EXCESS team. The following is the outcome of this work:

EXCESS defines a positive energy building (PEB) as an energy efficient building that produces more energy than it uses via renewable sources, with high self-consumption rate and high energy flexibility, over a time span of one year.

A high quality indoor environment is an essential element in the PEB, maintaining the comfort and well-being of the building occupants. The PEB is also able to integrate the future technologies like electric vehicles with the motivation to maximise the onsite consumption and also share the surplus renewable energy.

- EXCESS considers mainly residential buildings, while looking at the role of the building in bigger context, especially through impact to the energy networks. In the assessment of the building, the energy needs for other than residential activities, e.g. commercial or public services are excluded, while the energy use for the shared spaces is included.
- The local generation includes the energy produced at the building site, with technologies placed in/on the building or building site and technologies incorporated within the building elements.
- The energy need components considered in EXCESS are heating, cooling and electricity. Heating includes both space and water heating. Electricity includes the lighting, plug loads, ventilation and the electricity needs for the shared spaces such as lighting in common zones and elevators.
- EXCESS uses the definition of renewable energy from European RES directive, which defines it as energy from renewable non-fossil sources, e.g. wind, solar, hydro, geothermal or biomass.
- High self-consumption rate contributes to minimizing both the emissions and the negative impacts to the grid. The self-consumption rate can be increased e.g. by demand response and energy storage solutions.
- Indoor environment consists of thermal, visual and acoustic environment and indoor air quality.
- The life-cycle effects on costs and emissions should be considered in the planning and analysis of PEB.

EXCESS KPIs will include indicators on:

- Energy Perspective (energy efficiency, RES integration, CO_2 emissions reduction, air quality),
- Economic Perspective (cost of technology and measurement, energy costs reduction, revenue streams from market transactions, business models viability, return-on- investment, payback period, net present value),
- Social Perspective (user engagement, user acceptance, comfort and indoor environmental quality, energy security of supply, number of new jobs created, data security and privacy)

  and

- Technology Perspective (system interoperability, conformance with standards, ICT solutions performance, compliance of functionality to the user requirements).

In the second step, the complementarity and integrity of this definition with EU energy regulatory framework and with the EU long-term vision for a prosperous, modern, competitive and climate-neutral economy by 2050 was studied.

In general, the EXCESS PEB definition and objectives seem to be in good agreement with the regulations and targets. EXCESS definition and concept are especially well in line with the ideas on citizen empowerment and user comfort underlined in several of the regulations and vision documents. The documents also refer to the interaction with the grid and the (future) integration of EVs. Energy efficiency is particularly highlighted in the EU's documents, as well as the need to cover the remaining need by renewable energy.

One interesting finding from the development work is the lack of commonly agreed and physically sound terminology for the different energy components. The recommendation is to continue the work on harmonising the terminology for the PEB concept, also in compliance with the underlying physics.

In EXCESS, the work continues by developing the Key Performance Indicators (KPIs) for PEB based on the definition presented in this report.

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1 Introduction

1.1 Purpose of the document

The EXCESS project intends to show that it is possible to build or transform nearly-zero energy buildings into positive energy buildings, towards Energy fleXible user-CEntric poSitive houseS (EXCESS). The need for working towards this goal is based on the recognition of the fact that for reaching Europe's 2050 carbon neutrality target, it is necessary to transfer the EU building stock from being an energy waster to being highly energy efficient and an energy producer. EXCESS aims to assess the energy positivity level of building via yearly on-site energy ratio (OER) (Figure 1) and energy mismatch indicators for each energy type (heating, cooling and electricity). The KPIs will be defined at later stage of the project (in WP4). This report presents the work towards finding a common understanding of what would be considered as energy positive building in context of EXCESS project, thus setting the grounds for the KPIs. The definition is a result of a literature review and thorough discussions inside the EXCESS team.

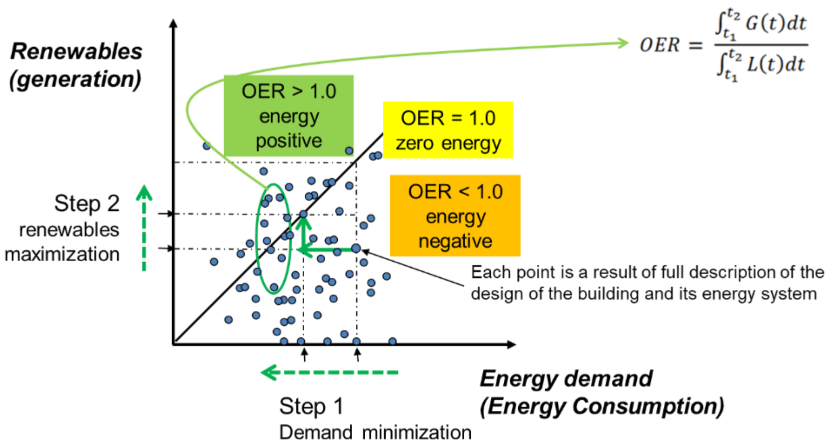

Figure 1. Conceptualisation of energy positive building (modified from Klobut et al. 2016 [1]).

In this document, the EXCESS partners assess the European dimension of EXCESS PEB residential concept by first proposing a common shared definition and then investigating its complementarity and integrity with EU energy regulatory framework (Clean Energy package [2], Energy Efficiency Directive [3], New rules for the internal market in electricity [4] and New energy performance of buildings Directive [5]) and with the EU long-term vision for a prosperous, modern, competitive and climate-neutral economy by 2050. [6]

The common definition will work as the basis for other work in the project (Figure 2), especially related to the sorting of incentives and barriers for the PEBs (in T1.4), and the supporting planning instruments of the local and regional authorities (in T1.3). Especially the development of KPIs (In T4.3) will depend on the definition of PEBs. Also, the work presented in this deliverable will contribute to the dissemination activities (in WP7), constituting the grounds for the capacity building and training on PEBs (in T7.2).

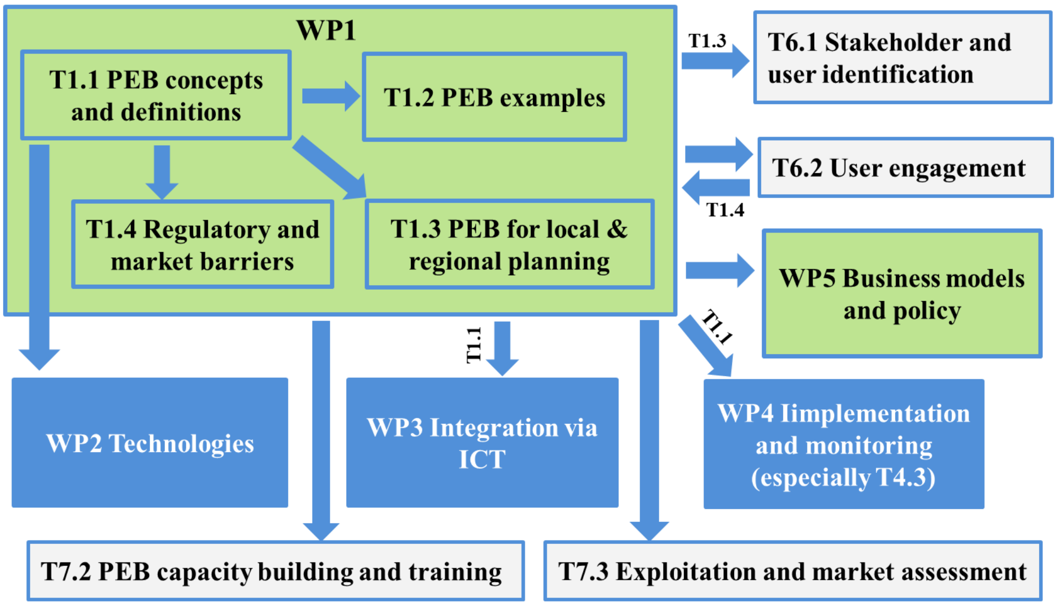

Figure 2. Relations of T1.1 to other parts of the EXCESS activities.

All EXCESS partners contributed to the development of the PEB definition. Regarding the vision and regulations, VITO and CEN explored technical aspects (building in and out primary and final energy flows), S5 the social aspects (occupant engagement), VTT the indoor comfort requirements, JR the environmental targets and URB the building structure aesthetical requirements. The district perspective and the positioning of the PEB in the city energy infrastructure were also taken into account by VTT and S5. Particularly, energy transaction schemes of produced on-site renewable energy and available on-site energy flexibility are outlined.

1.2 Scope of the document

The document describes what is meant by Positive Energy Buildings in context of EXCESS project and studies its relation to the EU regulations and visions.

1.3 Structure of the document

This deliverable presents the common definition of PEB for the EXCESS project. It first takes a look at the existing definitions of PEBs and NZEBs (Net zero enery buildings) in the literature (chapter 2), and the elements that are usually considered in these definitions. Next, (in chapter 3) it presents the work of EXCESS team in developing the concept: what issues came up in the discussions, and what aspects were considered most important to be included in the definition, based on the literature review and the partners' own opinions. Then, the final version of the PEB definition for EXCESS project is presented (in chapter 4).

In the second part of the deliverable, chapters 5 and 6, the PEB definition is compared towards the EU regulations and targets, to see if the definition is well in line with these, or if there is some contradiction. Also some notices of the effect to the work in EXCESS regarding these regulations and visions are presented.

2 Existing definitions of Net Zero Energy Building or Positive energy building

This chapter first takes a look at the appearance and presentation of positive energy buildings or plus energy building (PEB) in the literature, compared also to zero energy buildings, looking at aspects that are most often taken up in the literature. Then, a framework for developing the definition is presented, based on literature. This gives grounds for developing the PEB definition for the use of EXCESS project (in the next chapter), for facilitating the assessment of which elements suggested in the literature are considered important for EXCESS, which of them not considered crucial and if there are other elements that are considered essential by the EXCESS team. In this chapter, the terminology used by the original authors is respected. It seems that the terminology used in context of the PEB or zero energy building is not fully harmonised yet and different words are used for describing the same concept (e.g. imported or delivered energy, load or demand or need).

2.1 NZEB/PEB in literature

The positive energy buildings or plus energy building (PEBs) term started to appear in the literature from 2008 onwards. Until the start of the definition work in EXCESS, more or less 50 publications were made which has the term 'Positive energy building' and almost 39 publications were made which has the term 'Plus energy buildings' as shown in Figure 3 during 2019 in Scopus [7]. The term 'Positive energy buildings' are mostly used by the journal publications from Université de Liege and Aalborg University, while the most of the publications are from France, Belgium and Canada, and the main funding bodies are located in Europe, Singapore, China, Canada and the UK. The term 'Plus energy buildings (PEBs)' are mostly used by the journal publications from Florida International University, Technische Universitat Graz and ETH Zurich, while the most of the publications are from Germany, Austria and United States of America, and the main funding bodies are Österreichische Forschungsförderungsgesellschaft, American-Scandinavian Foundation, Bundesministerium für Verkehr, Innovation und Technologies etc. [7]

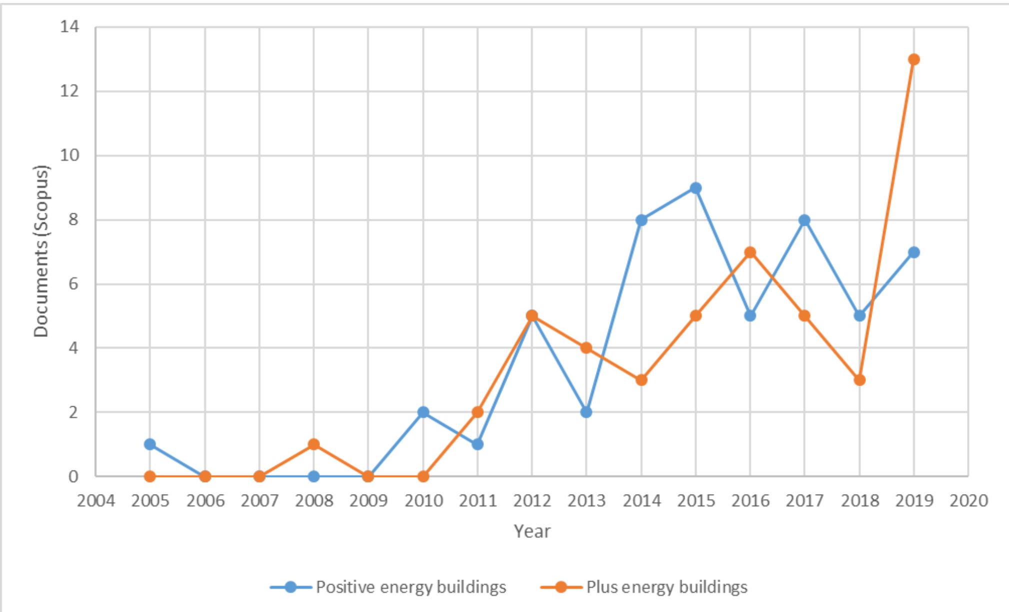

Figure 3: Terms 'Positive energy buildings' and 'Plus energy buildings' appearance in literature according to an analysis by Scopus [7].

According to the review about ZEB by Marszal *et al.*, 2011 [8], and a summary of the framework of the NetZEB in Sartori *et al.*, 2012 [9], it seems that 'Zero energy building' and 'Net zero energy building' are the terms used more widely compared to the earlier two terms for PEBs mentioned above. In addition, detailed work is carried on defining the Net and zero energy building in IEA Solar heating and cooling (SHC) Task 40/ EBC Annex 52 [10]. These two terms can provide a useful foundation to build the definition and concept of PEB.

While there is no clear concept on the PEBs, the Zero energy building (ZEB) is instead a concept relatively widely discussed in literature. This complex concept with various approaches, definitions and aspects is mentioned in different literature and discussed as described in the following, to provide the basis for net zero energy building (NZEB). The following aspects are presented as central aspects for the definition [9]:

- **Building system boundary**
  - Physical boundary specifies if the solution contains the building or neighbourhood and if the energy components are integrated at the site or somewhere else [9].
  - Balancing boundary specifies what type of energy types are used and considered in the definition[9].
- **Energy grids**

  The types of grids available for energy carriers like electricity, gas, oil, heating or cooling fluids etc. A grid can have either one way or two-way flows included. [9]
- **Energy delivered**

  The energy flowing from the grid to the building, can be specified in (kWh/y) or (kWh/m^{2}y). [9] This quantity has to be standardized as different countries have different methods to express this quantity [11].
- **Energy exported**

  The energy flowing from the building to the grid has to be specified also, either in (kWh/y) or (kWh/m^{2}y). [9]
- **Generation**

  The building's onsite energy generation per each energy carrier has to be specified in (kWh/y) or (kWh/m^{2}y). [9]
- **Demand**

  The building's energy demand per each energy carrier has to be specified in (kWh/yr) or (kWh/m^{2}yr). [9]
- **Weighting system**

  This allows changing the physical units described above into other metrics. For example, primary energy factor can be used (that includes the energy used at source to produce another form of energy carrier and may vary from one country to another). Moreover, this weighting factor can also include the political preferences. [9]

1) Weighted energy demand
   All the aggregated demand, calculated by adding together all the energy carriers multiplied by each of their weighting factor.
2) Weighted energy supply
   All the aggregated generation, calculated by adding together all the energy carriers multiplied by each of their weighting factor.

- **Energy balance**

  Energy balancing is done to balance the weighted supply and demand, over the period of a year, month or hour in most cases. In a net zero energy building (NZEB) this concept is used such that weighted supply meets or exceeds the weighted demand over a year. [9]

Figure 4 shows the concept of NZEB and the placement of the terms explained above in the concept definition of NZEB in [9]. This concept can provide a building block to build a definition of PEB presented later in this report.

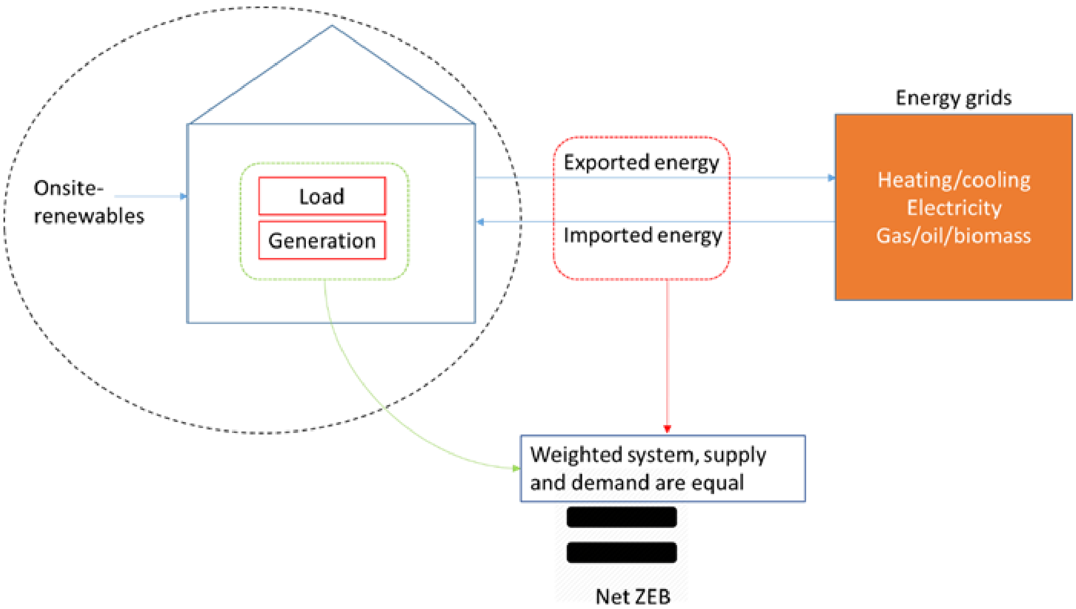

Figure 4: Net zero energy building core concept and definition. (Modified from Sartori et al. 2012 [9].)

2.2 Definition Framework of NZEB/PEB in literature

Definition framework has to be developed further in order to go beyond the core concept. There are many different aspects. These criteria and aspects are discussed in this section. In the literature, there are different options and criteria available, and the selection of the criteria would become the methodology for defining the PEB. These criteria are needed in order to provide a uniform definition of PEB based on local conditions. These local conditions can be weather, technical and policies that can be taken into account to define PEB [9]. The following presents the definition framework mainly according to the structure suggested by Sartori et al. 2012 [9], looks at other references in the literature and brings up aspects to be considered in its application to PEB. These aspects will be discussed when describing the development of the PEB definition for EXCESS project later in this document.

The main criteria to be considered can be grouped as follows:

- Boundary of the system
    - Physical boundary
    - Energy boundary
    - Boundary conditions
- Net balance
    - Balancing period
    - Type of balance
    - Energy efficiency
    - Energy supply
- Weighting system
    - Metrics
    - Symmetry
    - Time dependent accounting
- Temporary energy matching characteristics
    - Load matching
    - Grid interaction
- Measurements

2.2.1 Boundary of the system

The boundary is essential in order to identify what type of energy flows across the boundary. The boundary can be both physical boundary and balance boundary. Only the energy flows across this boundary are considered in the calculations. It needs to be considered if the definition excludes the plug loads and includes major end use loads (HVAC, lighting, water heating, etc.) or if the plug loads are also included. When making this decision, it needs to be considered that the plug loads are difficult to simulate and to include in the simulation. Moreover, it is difficult to monitor such plug-loads practically because the energy meter usually gives total energy consumption and not component vice. In order to compare the practical and simulated results it can be challenging due to such uncertainty. This needs to be considered before defining the NZEB or PEB. [9]

2.2.1.1 Physical boundary

The boundary has to be defined both if the building is single or if there is cluster of buildings. In EXCESS the focus is on the single building. The physical boundary is needed to find if the generation is 'on-site' - if the generation component is within the boundary. If the generation component is located outside the boundary, then it is called 'off-site'. Energy supply from the off-site location can be considered for calculating the balance or may be given different priorities. Lastly, it is important to mention what type of grids are available and if the grids are two way grids. If the grid is one-way then it is difficult to reach a net zero energy balance unless there is a seasonal energy storage in the building. This two-way grid allows to supply or receive energy to and from the building. These grids can be electricity, heating and cooling etc. [9]

For the physical boundary it is important to identify the ownership issue of the building and renewable energy system (RES) installations. It has to be decided if the investment of the RES can be included in the balance only if it is owned by the building owner or if it can be included also if it is owned by any other person or company. [9]

Positive energy building should have energy available on site that can be stored and also fed to the two-way grid. The energy has to be produced through renewable source that has no or limited carbon footprint.

2.2.1.2 Balance boundary

The balance boundary is used to define the energy use in the building and what energy uses are included in the NZEB balance. In the present times, operational energy use is most often considered for the energy balance, including for instance heating, cooling, ventilation, domestic hot water, fixed lighting and plug loads, although national standards of energy performance may contain different combinations of these. Any other energy use of the component may be considered in the balance, even though they are not included in the national directives or standards. For example, electric vehicles or water treatment etc. [9]

In positive energy building the energy balance of the building could also include the embodied energy and emissions of the building materials, in the installation of renewable technologies and in the energy efficiency measures applied in the building. This would allow to consider the energy consumption and emissions of the material and components of the building and renewables installed on the building with cradle to grave approach. This would include the energy consumption and emissions of the building materials and renewables during the installation, use, maintenance and demolition [12]. Lifetime of the materials and components and their maintenance needs will affect how the building can assist in reducing the embodied energy for the whole life cycle of the building. This approach would make it more challenging to fulfil the PEB definition, especially for existing buildings.

2.2.1.3 Boundary conditions

It is important to mention the boundary conditions of the building. Therefore, it is important to specify the functionality of the building, space utilization, climate and comfort. Here, the functionality refers to the purpose and use of the building: if it is e.g. a school, office, residential or hospital building. The space utilization of the building means how the is space distributed among the building users. This can be specified by the occupancy ratio, measured in people/m^2 or energy use per person. It is important to identify the schedule of use and if the building is used in certain way when the people density is high or low at certain time. This variation in the people density can cause variation in the measured and expected data. It is important to identify also the climate and comfort conditions of the monitored building, e.g. in accordance to the national or international standards. Variation in the outdoor climate has an impact on the indoor temperature and needs to be accounted for the building. [9]

In positive energy building further studies can be carried out regarding the indoor air quality. The indoor air quality has to be based on certain standard in terms of VOCs concentration, CO_2 concentration, air flows, temperature and humidity.

2.2.2 Net energy balance

The load and generation or demand and supply have to be balanced depending on the quantities that one is interested in or that are available over a period.

2.2.2.1 Balance period
A balancing period is needed to calculate the energy balance, usually the balancing is carried out yearly or hourly. Yearly balance is mostly applied as it can include the seasonal variations. The hourly or seasonal balancing is difficult due to the timing mismatch between the supply of energy from renewable sources and demand of energy from the building [8].

2.2.2.2 Balance type
Most often primary energy is used for each energy carrier to balance the energy flow. There can be many ways to balance, i.e. it can either be a balance between imported and exported energy during the year or secondly it can be generation and load balance during the year. Each type of balance has benefits and disadvantages. The import and export balance gives detailed comparison between the energy flows. It shows the interactions between the grids, however it is difficult to obtain as it has to include the consumption profiles (on hourly or minute basis) and simulations. The load and generation balance is easier and widely used. It is integrated with the building codes that calculate the loads and only need to integrate the calculation of generation. However, this method overlooks the grid interactions.

2.2.2.3 Energy efficiency
The net zero energy building and **positive energy building** definition may include certain energy efficiency requirement. This energy efficiency requirement may be based on energy performance or on certain rules and guidelines. There may be a mixture of both criteria. The energy efficiency performance requirement means that certain level of energy demand has to be met for the building to be NZEB or PEB. This energy demand includes heating, cooling, lighting and other loads. In PEB the electric vehicle's demand can also be included in the total energy demand. The rules and guidelines criteria refer to the building properties. For instance, the building can be PEB or NZEB at certain level of envelope properties (like U-values of walls and roof, U-values of windows and air-tightness levels etc.) and energy systems (HVAC efficiency, etc.). [13]

The energy efficiency can also be defined based on cost-optimal criteria. The other way can be such that the energy demand of the building has been reduced for example by 60 % or 70 % compared to the state of the art buildings under same functionality (like schools, offices, single family house etc.)[14].

2.2.2.4 Energy supply
The renewable energy sources have to be part of the NZEB and PEB. One way is to define a minimum threshold for the share of the renewable energy that is needed to cover the building demand [15]. Another method can be such that certain priorities and hierarchy can be defined and made necessary for the renewable energy sources to be used in PEB [9]. The energy supply and sources have to be defined as 'onsite' or 'offsite' (suggested e.g. by [16] and [17]) and both the onsite location or offsite location have to be separated using boundary limits [9].

In the renewable energy supply the hierarchy could be based on four values: 1) emission-free 2) reduced transportation and conversion losses 3) available for the building's life time and 4) saleable, available and repeatable [16]. These hierarchies affect the decision process and prioritize the energy supply sources onsite. It is worth to mention that the priorities should be given to onsite renewable energy generation option and then later also to the offsite generation option [18].

2.2.3 Weighting system

The weighting system is used to convert all the energy carriers into a similar metrics. This allows to compare the effects of different energy carriers on the energy system.

2.2.3.1 Metrics

The metrics are used to define the relative value of the energy carrier and this can affect the choices made for the energy sources and renewable energy installations. There can be metrics based on site energy use, source energy use, energy cost and carbon emissions [16]. Other metrics can also be non-renewable part of the primary energy, exergy, environmental credits and political factors [16], [19], [20], [9], [17]. The choice of the metrics, especially those based on the political factor can have an impact on the decision and favour certain energy carrier or energy source. It is important to note that it is not an easy task to find the correct conversion factor of the energy carrier especially for the electrical and thermal networks. These energy carriers and their conversions depend on many factors such as: mix of the energy source, efficiency of the plants, marginal production, future values etc. Therefore, it is difficult to find the correct and absolute conversion factor. Consequently, these factors are usually based on assumptions and different analysis. In order to reduce the confusion, a political factor is proposed, which might favour certain technologies over others and may not include correct conversion factor of the primary energy to the corresponding energy carriers. Therefore, it is important to carefully adopt the metrics and conversion factors in the calculations if primary energy is used as the basis for comparison. [9]

2.2.3.2 Symmetry/Asymmetry

The import and export of the energy between the onsite grid and external grid for example heating, cooling or electricity can be weighted in symmetric or asymmetric manner. In symmetric weighting the weighting factors can be same both for import and export of energy. While in the asymmetric, the weighting factors can be different for import and export of energy. [9]

The idea behind symmetric weighting is that the exported onsite energy would compensate the equivalent generation somewhere else. The exported energy would substitute the grid energy and therefore, it would have the same weighting factor for that grid.

The idea behind the asymmetric weighting is that, energy exported and energy imported does not have same value as they may have different primary energy sources and other effects to the national energy network and market. Two situations can be assumed [9]:

a) Higher weighted factor for electricity import
   If the losses in the grid, storage and costs are included, then the imported energy can be weighted higher than the exported energy. In this scenario it is beneficial if the grid exchange is lowered and the self-consumption of the onsite renewable energy is high in the building.

b) Higher weighted factor for electricity export
   If this option is selected, then certain novel technologies can have higher energy price/benefits as metrics. For example, electricity produced by PV (with high feed-in tariff) would provide higher margin and profits compared to the cost of the imported electricity. This would ultimately benefit more on-site PV generation.

2.2.3.3 Time based factors/metrics

The weighting factors are based on certain time and location [21]. Some factors can be at the national level while some factors can be localized depending on the energy infrastructure. Usually average values are used for the period of time to avoid complications. These factors may change over the period of time and space. For instance, the district heating and cooling are localized and are calculated at the district level, while the electricity can be calculated at the larger scale. These factors need to be updated every now and then to keep the factors as close to the reality as possible because the grid infrastructure is changing with the period of time. One option to include the variability in the grid is to use sensitivity of the energy system based on different evolving weighting factors.

Some factors are changing for every seasons and hour. In the present time, when the electricity prices are on hourly bases, it is possible to use hourly emissions or primary energy factors for the calculations [22]. However, this may increase the complexity of the calculations, therefore it is advised to use monthly, average, band range or seasonal factors [9].

2.2.4 Time-based energy match

Apart from the annual energy balance for the NZEB or PEB the mismatch between the demand of the building and supply from the renewable energy sources has to be matched.

The temporary mismatch between the supply and demand has to be addressed and calculated to show the performance of the different systems. Some indicators have to be built to show, measure and compare the performance of PEBs. For instance, indicators can show what is the ratio between the load and the onsite generation and can be called as ‘load matching’. Another indicator known as ‘grid interaction’ can show the ratio between import and export of the energy from/to the grid [23],[24]. These indicators can help to make decisions and can be used for assessments and comparison of different PEBs. These indicators have to be used separately for each energy carrier. These indicators can be used when the data is available for at least for one year with hourly time resolution. [9]

2.2.4.1 Load matching

The load matching can be used to find out how much is the load and how much is the generation onsite. Simulations or calculations can be carried out without the need of knowing self-consumption. [23]

2.2.4.2 Grid interaction

The interaction between the grid and the building has to be analysed. In order to estimate the grid interaction, the import and export of the energy have to be simulated or measured. This can be used with the import/export energy balance. The grid interaction index [23] represents the standard deviation of the net export within one year, normalized by the highest absolute value. The net export is the difference between the export and import of energy between the grid and building [23]. Another way to assess the grid interaction is to measure the On-site energy fraction or matching indexes for different energy carriers [25].

2.2.4.3 Flexibility

The net zero energy building and **positive energy building** performance can also be measured using the flexibility index [24]. The flexibility can be calculated using different indicators calculated from two directions. For example, one direction of the flexibility can be calculated with export priority strategy (i.e. maximizing the export of energy): The generation from the renewable source is exported to the grid without taking into account the local building demand or any storage. The other direction of the flexibility can be calculated with the matching priority strategy (i.e. maximizing the load matching). The system is designed in a way that can promote maximum utilization of the onsite generation locally. It can consider load shifting, production control and storage as some of the possible control strategies to maximize the load match. Some other methods and indictors are also discussed in IEA EBC Annex 67 [26] to increase the flexibility. It mentions that demand response, load shifting, heat pump+tank storage combo, energy cost based demand shifting, renewable generation based demand shifting can be done to increase the flexibility and matching.

2.2.5 Measurements and validation

With the establishment of the term **positive energy building** and policy, there has to be a methodology to evaluate the energy performance of the building. These evaluations are carried out either by measurement or by calculations [27]. The design of the PEB can be done on simulation software, after which the model can be validated practically via measurements. This would assist in achieving the required targets and policies.

There can be many different ways to do the measurements and evaluate the energy performance of the building. The basic measurements and validation protocol to monitor the PEB is the energy import and export. After this, the load matching, grid interaction and flexibility indicators can be calculated. In order to measure properly, the time resolution, duration, sampling and recording time has to be decided earlier.

Another criterion to measure the performance of the PEB can be the indoor environment quality measurement. As the basic requirement of the building is to provide good indoor environment quality, this has to be monitored. [9]

The KPIs and measurement strategies in EXCESS are defined later, in WP4.

The concept of PEB and NZEB are complex in nature. It is important to mention that the validity is affected by time and boundary conditions. Things may change if the boundary condition changes, time change, or there is any variation in climate, occupancy, building use etc. Therefore, a sensitivity analysis has to be carried out, create tolerance and mention the time span.

3 Elements of PEB

3.1 Additional elements to be considered for the definition

In addition to the above mentioned aspects gathered from the literature, there are some elements that are not as such included in the definition framework in the literature, but are also often mentioned in the literature, and should be considered when developing the definition for EXCESS project.

3.1.1 Indoor environment requirements

The indoor environment requirements are not well defined in the NZEB concept, but they could be included in the PEB definition [18]. It is important to include, among others, the CO_2 concentration level, volatile organic compounds level, the good indoor temperature and airflows, efficient daylight utilization and materials with good acoustic insulation. All these factors should be included in the PEB design [18]. The user comfort level depends on the climate, tradition, culture and purpose of the building. Therefore, in a PEB the indoor environment and renewable energy availability have to be synchronized in an optimal manner. One way is to follow the national and international standards, where they exist.

3.1.2 Embodied energy

The embodied energy required for the extraction, production, transportation, construction, operation and demolition of the building elements, renewable installations and storage technologies has to be estimated as realistically as possible. In addition to that, it has to be documented in order to include the cost and embodied energy of the building in the final energy consumption. This concept is called as “cradle to grave” approach [28].

3.1.3 Emission factors

The carbon foot print of the building has to be minimized and the emissions caused by the energy needs have to be as low as possible. Moreover, the energy produced by the renewables onsite can be used to compensate the emissions related to the embodied energy of the building.

3.1.4 User engagement

The user or the resident of the building should be engaged in the process of understanding the use of the building. User can be engaged in the process of controlling some of the set points in the building and also charging or using any plug loads (like electric vehicles or other items). The user should feel responsible and in control of the building because, without an easy interaction between the user and the building, the target to achieve a PEB would be difficult.

3.2 EXCESS partners’ definitions

3.2.1 Kick-off exercise

In the first general meeting, the partners were asked to list the most important things that should be included in the PEB definition. This is the list of the aspects that were most often mentioned by the partners:

- **Time span** should be mentioned, most vote for life cycle (LCA is the term mostly used in the input). Others mention one year, three years and 15 years.
- We should clarify in the definition **which energy components** are included, and potentially also the **target level**. (energy efficiency)
- Perhaps a minimum **service level** should be defined? It also seems relevant to mention the requirement of usability in terms of controls and some level of feedback or reporting in user friendly manner.
- Something needs to be mentioned about the **environmental impacts**.
- **Renewable** energy is important to be included, also a definition for what is regarded as renewables.
- **Boundaries for ”local production”** needs to be defined. One of the comments underlined that the definition needs to ”include local production of energy (not buy certificates) to compensate local pollution”.
- Something should be said about the **balance of input and output energy** or self-sufficiency. Also exergy balance was mentioned in the kick-off exercise.
- Several comments on **grid impact** (which could be understood as either the impact of the grid to the site of vice versa).
- **Cost and user engagement** were also mentioned in the kick-off exercise.

Figure 5 shows which are the important elements to be included in the PEBs definition according to the partners, while Figure 6 presents them grouped into larger themes.

Figure 5. Kick-off exercise related to important elements to be included in the PEBs by the EXCESS partners.

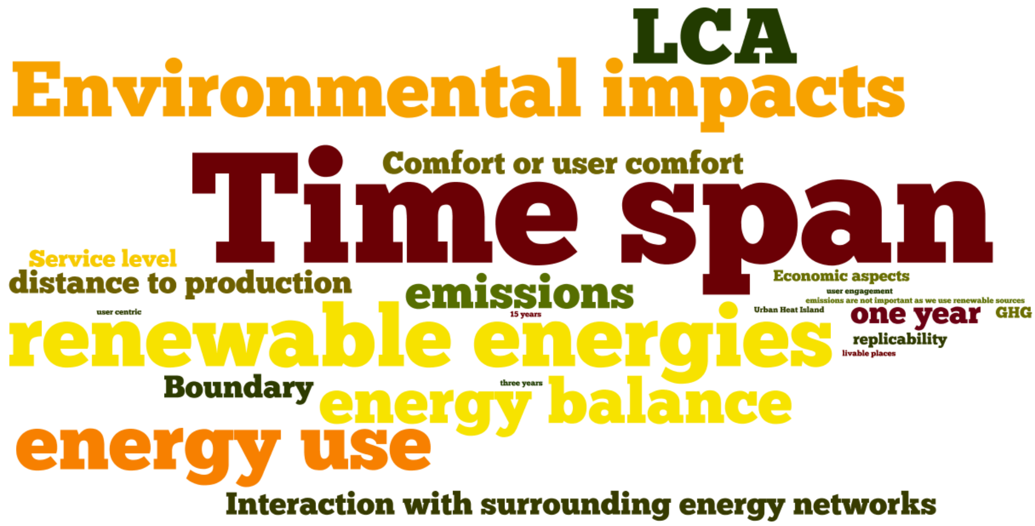

Figure 6: Kick-off exercise related to important elements to be included in the PEBs by the EXCESS partners, grouped into bigger themes.

3.2.2 National or known definitions from the partners

The EXCESS partners were also asked if they knew some national or existing PEB definitions. It seems that only in France there is an existing definition for PEB.

3.2.2.1 French definition of PEB

In France there is a legal definition from the decree:
https://www.legifrance.gouv.fr/eli/arrete/2017/4/10/LHAL1623032A/jo/texte

In the French legislation the buildings with high environmental performance need to comply with the requirements for the 1) maximum GHG emissions, and two of the following 2, 3 or 4: 2) minimum construction waste valorisation (recycling), 3) quality of building materials and ventilation system and 4) minimum amount of bio-based materials.

The law says that Positive Energy Buildings "present an energy balance less than or equal to the maximum energy balance (BEPOS max)[1], corresponding to the "Energy 3"[2] (or "Energy 4"), defined by the ministries responsible for building and energy in the "Energy-Carbon" reference

For individual home, it means that the building should not consume (thanks to the regulated calculation) more than about **95 kWh_EP/m²/yr**.

This consumption in primary energy takes into account the lighting, heating and cooling but **also specific electricity** (but neither grey energy nor energy for transportation). Final to primary energy coefficient for electricity is 2.58 at the moment in France. Surplus of PV only compensate 0,39 electrical kWh /PV kWh (after to first 10 PV kWh_EF).

No building can be Energy 3 without having made a carbon life cycle analysis.

3.2.2.2 PEB definitions by the partners

Some partners also suggested their own definitions that could be used as a starting point for the common definition. These normally included the one-year balance period and the requirement of more local renewable energy production than import of external energy.

AEA suggested that PEB is a building that, throughout its life cycle, meets all its final energy demands and exports final energy (or energy carriers) to other buildings, with a total non-renewable primary energy consumption lower than what would have been consumed without the building. (Figure 7)

- (The building has positive effects = **P**ositive **E**ffects **B**uilding).

Figure 7. AEA's suggestion for the PEB concept.

In addition, the following aspects need to be taken into account:

- The life-cycle energy consumption implies the embodied energy too.
- The PEB concept is integrated in the energy system of the region where it is built. The more efficient and renewable the regional energy system is, the more efficient and renewable has to be the building to be a PEB.
- The main target is to reduce the non-renewable primary energy consumption.
- A PEB must have a "positive effect" (its foot-print is below zero, it reduces the foot-print of the neighbourhood)

[1] http://www.batiment-energiecarbone.fr/IMG/pdf/referentiel-energie-carbone-methode-evaluation-2017-07-01.pdf
[2] http://www.batiment-energiecarbone.fr/IMG/pdf/referentiel-energie-carbone-niveau-de-performance-2016-10.pdf

CEN suggested two approaches, at national and at project level:

- National Level:
  In Spain there is no a clear definition about what a PEB is or what should be. In this sense, according with the current legislation, in residential buildings only energy consumptions from heating, cooling, ventilation and domestic hot water should be considered, referred all of them to primary non-renewable energy. In commercial buildings, lighting will have to be considered.

- Project Level:
  At project level, the energy consumption was referred to final energy consumption, and an ambitious initial approach from an outcome of a previous project, a PEB would cover from onsite RES generation the energy consumption in heating, cooling, domestic hot water, ventilation, public lighting, electric mobility, internal plugs, and common zones energy consumption. The energy from RES will be higher than the final energy consumptions referred to the previous ones.

  Referring to the balancing period, one year is the time required to do the energy balance.

4 PEB definition for EXCESS

The EXCESS team formulated the common definition of PEB starting with the core definition already presented in the DoA, and developing it further based on the literature review presented in Chapter 2, an exercise during the kick-off meeting and several iterative discussion rounds in telcos.

The core definition in the DoA stated that: ***"EXCESS defines a positive house as a building that produces more energy than they use, with high RES self- consumption rate (instead of using the grid for solving seasonal balancing issues) over a time span of one year."*** There are also other parts of the DoA with references to the aspects that could be included or addressed in the definition.

4.1 Elements to be included

EXCESS team consists of actors that are active in the field of energy efficient buildings and renewable technologies and solutions. In the kick-off meeting, the partners were asked to list the most important aspects that should be included in the definition, and a list of potential subjects were suggested as an example. After the kick-off, the partners were also asked to present the existing definitions that they know about. This input, presented above (in Chapter 3), is also taken into account in the following. In addition, a literature review was conducted (Chapter 2), based mainly on the definitions of ZEB or NZEB (Net Zero Energy Building), as no clear definitions of PEB could be found in the literature.

Based on this material, Table 1 and Figure 8 present the aspects that should be included or addressed in the PEB definition, and Table 1 indicates which of them were already mentioned in the EXCESS DoA.

Table 1. List of aspects to be included/addressed in the definition.

Suggestions in the kick-off	Partners' opinion from the exercise	Literature review NZEB	DoA
Time span	X	X	X
Energy use components	X	X	X
Something about energy use level	X	X	X
Anything about the service level (functionality, comfort,…)	X	X	X
Emissions	X		X
Type of renewables considered	X	X	X
Distance to production? = Physical boundary	X	X	X
Other items			
Building type		X	X
Balance, matching of demand and supply	X	X	X
Grid impact	X	X	X
Cost	X		X
User engagement (might be part of service level?)	X		X
Exergy balance	X	X	

In the following, the main findings of these aspects are presented based on the kick-off exercise, The DoA, the literature review and the discussions on the first draft definition. Then, a suggestion for the common definition is given. A typical discussion point was whether and how the aspect should be included in the definition, or if it is enough to take it into account when defining the KPIs (in WP4). In the following these decisions are also presented.

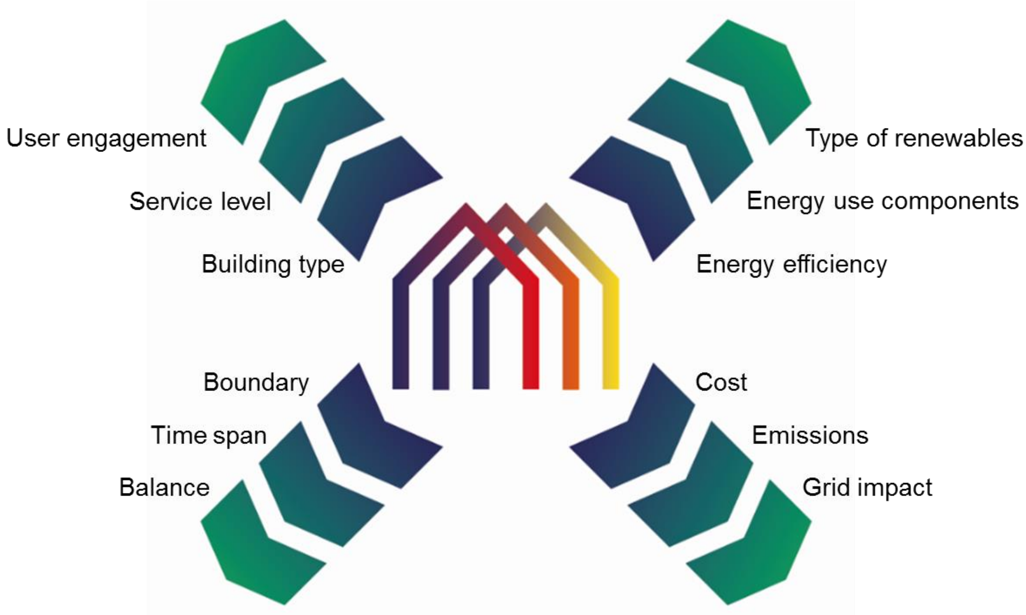

Figure 8. The elements to be included in the PEB definition, based on the kick-off exercise, partners' input & the literature review.

4.1.1 Time span

Time span was the aspect getting most mentions in the kick-off exercise. Surprisingly many of the EXCESS partners wanted to consider the whole life-cycle. Others mentioned one year, three years and 15 years as a meaningful time span for assessing the building's compliance with PEB definition. In DoA, the time span of one year is mentioned in the core definition. The literature review mentions yearly balance as the most typical balancing period, as it can include the seasonal variations. It is also underlined in the literature that apart from the annual energy balance for the (N)ZEB or PEB the mismatch between the demand of the building and supply from the renewable energy sources has to be matched. The temporary mismatch between the supply and demand has to be addressed and calculated to show the performance of the different systems. The literature suggests hourly time resolution for this performance analysis.

> It was decided to add in the definition the following explanation, in addition to the core definition stating the time span of one year: The life-cycle effects should be considered in the planning and analysis of PEB.

> The time span needed for the KPIs is left for the KPI discussion in WP4.

4.1.2 Energy use components

In the kick-off exercise it became clear that we should clarify in the definition which energy components are included, and potentially also the target level. The DoA lists the energy types in connection of the indicators: heating, cooling and electricity, and further indicates that heating includes space and water heating. When referring to emissions, the energy types are further tied to the needs of residential buildings.

Literature review reveals that in the present times, operational energy use is usually considered for the energy balance - for instance, heating, cooling, ventilation, domestic hot water, fixed lighting and plug loads. Any other energy use of the component may be considered in the balance, even though they are not included in the national directives or standards. For example, electric vehicles or water treatment etc. The energy balance of the building could also be broadened to include the embodied energy and emissions of the building material, technical installation of renewables or installation of the energy efficiency measures in the buildings. This would allow to consider the energy consumption of the material and components of the buildings and renewables installed on the building with cradle to grave approach. This was considered by the EXCESS team as quite a hard condition for e.g. renovated buildings, so it was decided to not include it as a requirement, but rather a recommendation.

> It was decided to add in the definition the following explanation: The energy need components considered in EXCESS are heating, cooling and electricity. Heating includes both space and water heating. After the first draft, it was also decided to include a list of the electricity components: lighting, plug loads, ventilation and the electricity needs for the shared spaces such as lighting in common zones and elevators.

(However, the discussion of the plug loads still continues at the time of writing of this deliverable, in connection of the development of the KPIs. This is mainly related to the difficulties to measure the plug loads when the building's PEB qualification is to be validated through measurements, but also the difficulties to affect the user behaviour through design choices. This is however one of the main goals of EXCESS: to create user-centric positive energy houses, where the user is engaged in the energy efficient behaviour and maximum utilisation of demand response to support high self-sufficiency.)

> The embodied energy was covered by the further explanation on life-cycle effects presented above.

4.1.3 Energy use level

In the kick-off exercise the target level for energy use was mentioned as one important aspect to be included in the definition. Literature review also mentions the need to specify the building's energy demand per each energy carrier. The DoA also states that energy efficiency would be included in the indicators.

> It was suggested that the energy efficiency requirement would be mentioned in the core definition, but leave the definition of what is considered as energy efficient building to the KPIs.

4.1.4 Service level

Service level could include aspects like functionality or comfort. In the kick-off exercise it was discussed if a minimum service level should be defined. It also seems relevant to mention the requirement of usability in terms of controls and some level of feedback or reporting in user friendly manner. In DoA these aspects are mentioned in connection of the indicators, e.g. air quality, user acceptance, comfort and indoor environmental quality, energy security of supply. In addition, the DoA takes clear position on the user comfort, stating that "User comfort is a primary objective and may not be compromised." Also indoor environment is mentioned as one of the important impacts: "**Improved indoor environment** leading to higher rate of users' satisfaction based on their demand and behaviour." Literature review findings suggest that in positive energy building further study can be carried out on the indoor air quality (VOCs concentration, CO_2 concentration, air flows and temperature).

> It was decided to mention the requirement of high quality indoor environment in the core definition, but leave the definition of user engagement and user acceptance to the KPIs.

4.1.5 Emissions

In the kick-off it was a clear agreement that something needs to be mentioned about the environmental impacts. But discussion is needed on the KPIs: Which emissions should be included? GHG expressed as CO_2 equivalent? In the DoA emissions are mentioned in several places, mainly CO_2 emissions, but also GHG and air pollutants (CO, NO_x, Nanoparticle, Non-combustible hydrocarbon) are mentioned, related to the expected impacts. This means that these emissions are highly relevant for the KPI development.

> It was decided that the emissions will be mentioned in the core definition but leave the definition of the types of emissions to the KPIs.

4.1.6 Type of renewables considered

In the kick-off exercise it was concluded that some reference to renewables is important to be included, and it already is included in the core definition, but maybe it should be defined what is understood as renewables. In the DoA the concept of local RES-based solution is mentioned, that brings together a variety of carbon-friendly technologies, spanning solar, PVT, wind and geothermal energy. Later it was also discussed that we should use a definition of the European RES directive for the renewables.

The literature review clearly states that the renewable energy sources have to be part of the (N)ZEB and PEB. In addition, a minimum threshold is suggested for the share of the renewable that is needed to cover the building demand [10]. Another method suggested in the literature is to use a set of priorities and hierarchy for the renewable energy sources to be used in PEB. This hierarchy could be based on four values: 1) emission-free 2) reduced transportation and conversion losses 3) available for the building's life time and 4) saleable, available and repeatable [11]. It is worth to mention that the priorities should be given to onsite renewable energy generation option and then later to the imported energy option [12].

> It was decided to define the renewables based on the European RES directive, but also mention the most relevant sources for EXCESS: "e.g. wind, solar, hydro, geothermal or biomass".

4.1.7 Distance to production = Physical boundary

The kick-off exercise concluded that the boundaries for "local production" needs to be defined. One of the comments underlined that the definition needs to "include local production of energy (not buy certificates) to compensate local pollution". The DoA only refers to "local RES-based solution" that brings together a variety of carbon-friendly technologies, spanning solar, PVT, wind and geothermal energy,… In the literature it is suggested that the boundary of the system should include physical boundary, energy boundary or boundary conditions. Physical boundary should express if the solution contains the building, or neighbourhoods and if the energy components are integrated at the site or somewhere else [4].

> It was decided to add the following explanation to the definition: The local generation includes the energy produced at the building site (the lot). It was later added that the technologies can be placed in/on the building or building site or incorporated within the building elements.

4.1.8 Building type

In the kick-off exercise the building type was not discussed, probably the participants assumed that we are discussing residential buildings, as all the demos are in residential buildings. Also the DoA mentions residential buildings or residential sector several times, especially in the impact section. Literature review concluded that it is important to specify the functionality of the building, space utilization, climate and comfort. Here the functionality means the purpose and use of the building, e.g. school, office, residential or hospital building.

> It was suggested to add the following explanation to the definition: "EXCESS limits the consideration to residential building sector, while looking at the role of the building in bigger context, especially through impact to the energy networks."

4.1.9 Balance, matching of demand and supply

In the kick-off exercise it was concluded that something should be said about the balance of input and output energy or self-sufficiency. Also exergy balance was mentioned in the kick-off exercise. The balance requirement is already mentioned in the core definition in DoA: "EXCESS defines a positive house as a building that produces more energy than they use, with high RES self-consumption rate … " and also the need to match the energy demand and supply at building level is stated in the DoA. Literature discusses the matching of demand and supply in the weighing factor definition, which would allow to compare the different inputs and outputs of energy.

> It was decided to state the positive balance requirement in the core definition but leave the discussion on the weighting factors and primary or other energy or exergy to the KPI definition.

4.1.10 Grid impact and impact to the grid

In the kick-off exercise there were several comments on grid impact, so it was clear that this should be addressed in the definition. The literature review also refers to the exchange with the grid, mentioning the need to list the types of energy carriers and the impact to the indicators coming from the different standardization methods in the countries. It is also noted that in PEB, the existence of two-way grid is a prerequisite. The core definition in the DoA also underlines the effects to the grid, as it mentions that a PEB should not use the grid for solving seasonal balancing issues.

> This aspect is already addressed in the definition as it is, and should be included. In further discussion it was moved to the further explanations.

4.1.11 Cost

Cost was also mentioned in the kick-off exercise, and it is also mentioned as part of the indicators in DoA. The DoA lists cost indicators from different perspectives, e.g. cost of technology and measurement, energy costs reduction, revenue streams from market transactions, return-on-investment, payback period, net present value. DoA also underlines the need to identify cost-optimal levels as a combination of current and innovative technologies estimating costs also as service life costs (not only investments).

> This will be taken into account in the definition by the following statement in the additional explanations: "The life-cycle effects on costs and emissions should be considered in the planning and analysis of PEB."

4.1.12 User engagement

This aspect came up in the kick-off exercise, and it was mentioned that this could be considered as part of the service level. This aspect is also mentioned in the DoA, as part of the indicators:

- Social Perspective (**user engagement, user acceptance,** comfort and indoor environmental quality, energy security of supply, number of new jobs created, data security and privacy)
- Technology Perspective (system interoperability, conformance with standards, ICT solutions performance, **compliance of functionality to the user requirements**).

> It was decided to leave the definition of user engagement and user acceptance to the KPIs. The core definition only mentions the requirement to maintain the user comfort and well-being.

4.2 Further discussion

After an initial agreement on the definition some further points to be taken into account were raised by the partners. Many of them were related to the discussions on the KPIs, which will be part of WP4.

- It was noted that the discussion on how one year is defined for measuring the PEB's performance should be part of the KPI discussion. Also, it should be discussed in KPIs what if the building complies with PEB in one year according to measurements, but not for next two years, e.g. as result of the weather conditions.
- Life cycle requirement is more difficult to achieve for an existing building, which has already used a lot of energy before its transfer to PEB. How to handle this is also part of KPI discussion. Life cycle = construction + use + demolition
- There seemed to be general agreement that energy use of public spaces should also be included in the balance, like public lighting and elevators. And also that only residential uses should be included and at this stage the EVs are not yet included. It might also be a source of energy in the future.
- The definition of residential buildings was also discussed. A couple of definitions for residential buildings can be found in the literature. One of them [29] says that: "Residential building is a multi-residential space contained in a single structure where dwellers may rent or own their residences." and another one from OECD [30]: "A building should be regarded as residential building when more than half of the floor area is used for dwelling purposes. Other buildings should be regarded as non-residential. Two types of residential buildings can be distinguished:
    - houses (ground-oriented residential buildings): comprising all types of houses (detached, semi- detached, terraced houses, houses built in a row, etc.) each dwelling of which has its own entrance directly from the ground surface;
    - other residential buildings: comprising all residential buildings other than ground-oriented residential buildings as defined above."
- In the Spanish case with commercial activities on the ground floor, we could stick to the definition, which excludes other than residential uses, but we could make an additional analysis which includes the commercial spaces, and analyse e.g. how the demand could be covered by renewables in this case.
- In the KPIs we could define different levels of PEBs, e.g.
    - Supply operational energy (basic)
    - Includes EV charging (very good PEB)
    - Level depending on time balance: balance over year or hourly balance
- Energy can be provided by third-party, as long as it is generated on site.

- For the renewables, we concluded that it would not be relevant to make an own definition but neither it would not be good to have in the definition a reference to an external document, so we made a compromise by referring to RES directive and listing some of the relevant renewable sources for our project. In the directive, the definition of renewable energy is the following: "'energy from renewable sources' or 'renewable energy' means energy from renewable non-fossil sources, namely wind, solar (solar thermal and solar photovoltaic) and geothermal energy, ambient energy, tide, wave and other ocean energy, hydropower, biomass, landfill gas, sewage treatment plant gas, and biogas;" so, some of these are not very relevant for EXCESS cases (e.g. ocean, landfill gas, sewage treatment plant gas).
- High self-sufficiency is different from/more than self-consumption, but together with the requirement of producing more than using with high self-consumption is more or less the same as self-sufficiency
    - hourly self-consumption should be discussed in KPIs
    - self-sufficiency level should be part of the KPIs
- Costs (also life cycle costs) should be discussed when defining the KPIs.

4.3 PEB definition for EXCESS

The process described above led to a common definition of Positive Energy Buildings (PEBs) for EXCESS project, consisting of a core definition, clarifications of the terminology and the description of the KPIs:

> EXCESS defines a positive energy building (PEB) as an energy efficient building that produces more energy than it uses via renewable sources, with high self- consumption rate and high energy flexibility, over a time span of one year.
>
> A high quality indoor environment is an essential element in the PEB, maintaining the comfort and well-being of the building occupants. The PEB is also able to integrate the future technologies like electric vehicles with the motivation to maximise the onsite consumption and also share the surplus renewable energy.

- EXCESS considers mainly residential buildings, while looking at the role of the building in bigger context, especially through impact to the energy networks. In the assessment of the building, the energy needs for other than residential activities, e.g. commercial or public services are excluded, while the energy use for the shared spaces is included.
- The local generation includes the energy produced at the building site, with technologies placed in/on the building or building site and technologies incorporated within the building elements.
- The energy need components considered in EXCESS are heating, cooling and electricity. Heating includes both space and water heating. Electricity includes the lighting, plug loads, ventilation and the electricity needs for the shared spaces such as lighting in common zones and elevators.
- EXCESS uses the definition of renewable energy from European RES directive, which defines it as energy from renewable non-fossil sources, e.g. wind, solar, hydro, geothermal or biomass.

- High self-consumption rate contributes to minimising both the emissions and the negative impacts to the grid. The self-consumption rate can be increased e.g. by demand response and energy storage solutions.
- Indoor environment consists of thermal, visual and acoustic environment and indoor air quality.
- The life-cycle effects on costs based on EPBD definition of 'cost-optimal level' and emissions should be considered in the planning and analysis of PEB.

EXCESS KPIs will include indicators on:

- Energy Perspective (energy efficiency, RES integration, CO_2 emissions reduction, air quality),
- Economic Perspective (cost of technology and measurement, energy costs reduction, revenue streams from market transactions, business models viability, return-on- investment, payback period, net present value),[3]
- Social Perspective (user engagement, user acceptance, comfort and indoor environmental quality, energy security of supply, number of new jobs created, data security and privacy)

  and
- Technology Perspective (system interoperability, conformance with standards, ICT solutions performance, compliance of functionality to the user requirements).

5 Comparison towards EU energy regulatory framework

5.1 Overview

The EXCESS partners compared the PEB definition towards the EU regulatory framework, especially regarding specific aspects that are central for EXCESS project. In Table 2 below, a general overview of the appearance of these aspects in the regulatory documents are presented, and in the following subchapters the relevance and comparison results are presented, after a short summary presenting the main content of the documentation.

In this work, the EXCESS partners assessed the European dimension of EXCESS PEB residential concept, investigating complementarity and integrity with EU energy regulatory framework: Energy Performance of Buildings Directive [31] and [5], Energy Efficiency Directive [3], Clean Energy Package [2] and New rules for the internal market in electricity [4].

The European Commission has recognized the crucial role the building sector plays for achieving the EU's energy and environmental goals. It has also been noticed that at the same time, better and more energy efficient buildings improve the quality of citizens' life while bringing additional benefits to the economy and the society. Therefore, to boost energy performance of buildings, the EU has established a legislative framework that includes the Energy Performance of Buildings Directive (EPBD; 2010/31/EU) [31] and the Energy Efficiency Directive (EED; 2012/27/EU) [3]. Together, the directives promote policies that will help

[3]) The 'cost-optimal level' based on the EPBD definition can be further estimated, here the cost optimal level means the energy performance level which leads to the lowest cost during the estimated economic lifecycle.

- achieve a highly energy efficient and decarbonised building stock by 2050
- create a stable environment for investment decisions
- enable consumers and businesses to make more informed choices to save energy and money

All of these goals are very relevant and in line with EXCESS PEB definition and general objectives in EXCESS project.

Both directives were amended as part of the Clean energy for all Europeans package [2], in 2018 and 2019. In particular, the Directive amending the Energy Performance of Buildings Directive (2018/844/EU) [5] introduces new elements and sends a strong political signal on the EU's commitment to modernise the building sector in light of technological improvements and increase building renovations.

In this work, VITO and CEN explored technical aspects (building in and out primary and final energy flows), S5 the social aspects (occupant engagement), VTT the indoor comfort requirements, JR the environmental targets and URB the building structure aesthetical requirements. The district perspective and the positioning of the PEB in the city energy infrastructure were also taken into account by VTT and S5. Particularly, energy transaction schemes of produced on-site renewable energy and available on-site energy flexibility were outlined.

Table 2: Appearance of the analysed items in the regulatory framework

Document	Technical	Social	Indoor comfort	Environmental	Aestethical	District
Clean energy package	X	X	X	X	-	X
Energy Efficiency Directive	X	X	X	X	-	X
Electricity market rules	X	X	-	-	-	X
Energy Performance Directive	X	X	X	X	-	X

5.2 Clean Energy package

5.2.1 Summary of the Clean Energy Package

The Council of ministers of the European Union (EU) adopted four new pieces of legislation on 22nd May 2019 that redesign the EU energy market for future. EU has been the leader to promote clean energy. Since 2009 ambitious energy and climate targets were set for 2020 (20 % greenhouse gas emission reduction, 20 % increase in efficiency and 20 % increase renewable energy). After 10 years, the EU in general is on the track to achieve these targets, showing that GDP can be increased while reducing the emissions. In 2015 when the Paris agreement was signed, the EU planned to move further ahead and reduce the greenhouse gas emissions by 40 % till 2030. In order to tackle this challenge and to lead the global energy transition, the EU Commission proposed in 2016 a set of new and ambitious rules known as 'Clean energy package for all Europeans'. The plan is to address the 5 dimensions with this new package which are: 1) Energy security, 2) Internal energy market, 3) Energy efficiency, 4) Decarbonisation of the economy, and 5) Research and innovation [2]. It has following five elements [32]:

1) Energy efficiency: the revamped directive on energy efficiency sets a new, higher target of energy use for 2030 of 32.5 %, and the new Energy performance of buildings directive maximises the energy saving potential of smarter and greener buildings.
2) More renewable: an ambitious new target of at least 32% in renewable energy by 2030
3) A better governance of the Energy Union: A new energy rulebook under which each Member State drafts National Energy and Climate Plans (NECPs) for 2021-2030 setting out how to achieve their energy union targets, and in particular the 2030 targets on energy efficiency and renewable energy. These draft NECPs are currently being analysed by the Commission, with country-specific recommendations to be issued before the end of June
4) More rights to consumers: the new rules make it easier for individuals to produce, store or sell their own energy, and strengthen consumer rights with more transparency on bills, and greater choice flexibility.
5) A smarter and more efficient electricity market: the new laws will increase security of supply by helping integrate renewables into the grid and manage risks, and by improving cross-border cooperation.

5.2.2 Comparison towards EXCESS definition of PEB and the objectives in EXCESS

Upon review of the document, both the objectives of EXCESS project and the provided definition of PEBs are found to be clearly aligned with the Clean Energy package rulebook, as provided by the EC. The PEB definition as defined above is broadly similar to the strategy initiatives outlined in this document. For each of the three main goals (energy efficiency, renewable energy and a fair deal for consumers) of the European clean energy transition, parallels are highlighted in the next paragraphs.

Regarding energy efficiency, both the definition and the document start from an energy efficient building. The document states: “the cheapest and cleanest energy is energy that does not need to be produced”, however this statement remains quite simplistic and depends on the boundary conditions of the case at hand. E.g. further investments in energy efficiency could prove to be more costly compared to installing renewable sources. Moreover the document indicates that energy efficiency will have the additional benefit that by actively managing demand to optimize energy consumption, the costs for consumers will be reduced and the import of energy will be lower. This observation can be linked with the emphasis the EXCESS PEB definition puts on the fact that PEBs are interconnected and need to be able to communicate with the grid through smart appliances. The definition has the advantage that it explicitly focuses on both aspects as they are not necessarily linked. Flexibility is an important aspect and hence deserves to be mentioned individually.

In this document the overall target for the share of renewable energy consumed in the EU is 27% of renewable energy in the generation mix by 2030. It is stated that electricity will play a major role in the transition towards a clean energy system resulting in a more variable supply based on wind and solar power. Hence the electricity market has to allow shorter term trading to cope with the necessities of variable generation, and flexibility from both supply and demand side should be rewarded. This aspect is also incorporated in the EXCESS definition of PEB. Moreover, other sources of renewable energy such as district heating, - cooling and bioenergy are also promoted. Hence the same definition of renewable energy mix is used in both instances.

Considering the social aspect as identified within the document and more specifically the consumers (such as building occupants) engagement, the provided definition of PEBs fulfils one of the three main goals of the Clean Energy package, which is to offer a fair deal for consumers. The document proposes regulatory changes to support a reform of the energy market towards empowering consumers, enabling them to undertake an active role towards self-control of energy costs. These changes are meant also to support self-generation and storage, enabling consumers to share/ sell back to the market as energy cooperatives.

Being fully aligned with the proposals of the Clean Energy package, within EXCESS project building occupants are placed at the centre of all offered optimization processes. Based on the novel service functionalities (e.g. continuous monitoring of generation/ demand, deployment of novel control concepts to maximize self-consumption based on the inherent flexibility of specific residential loads and energy behaviours) and the integrated technological systems (PVT balcony, Multifunctional Facade element, Power-to-Heat flexible thermal storage, etc.) to be provided through EXCESS, building occupants are being supported with tools towards maximising their self-consumption and self-generation rate. This approach is, furthermore, extended to the district side, with EXCESS solutions enabling self-consumption maximization at the community level, through optimal balancing of demand and generation and the deployment of human-centric demand side management concepts and strategies (facilitated by flexibility trading and remuneration mechanisms), while at the same time increasing their awareness on energy consumption and flexibility capacity.

An additional overlap is achieved by the focus on maintaining and increasing the comfort and well-being of the building occupants. This can be achieved by integrating renewables, storage, digital technologies and link the buildings with transport systems. As mobility is responsible for an important share of CO_2 emissions, electric transport will be encouraged. In this sense, for new residential buildings, and residential buildings under major renovations that have more than 10 parking space, there is an obligation to include the installation of ducting infrastructure, namely conduits for electric cables, for every parking space to enable the installation, at a later stage, of recharging points for electric vehicles.

Finally, the Commission proposes to reform the energy market to empower consumers and enable them to be more in control of their choices when it comes to energy. For businesses, this translates into greater competitiveness. For citizens, it means better information, possibilities to become more active on the energy market and be more in control of their energy costs. The most efficient way to achieve this is to provide the consumers with better information about their energy consumption and their costs. The proposals will entitle consumers to smart meters, clear bills and easier switching conditions. The proposals will also make it cheaper to switch through the elimination of termination fees. Certified comparison tools will provide consumers with reliable information about the offers available to them. The proposals will provide for more reliable energy performance certificates with a 'smartness' indicator. New smart technologies will make it possible for consumers – if they chose to do so – to control and actively manage their energy consumption while improving their comfort. These changes will make it easier for households and businesses to become more involved in the energy system and respond to price signals. This also necessitates the removal of wholesale and retail price caps, while ensuring the full and appropriate protection of vulnerable household consumers. The link with energy poverty is not incorporated in the current definition and only mentioned as a KPI. It may be necessary in the future to increase its importance.

Regarding the comfort issues, the Clean energy package expects additional benefits such as improved air quality and protection from external noise provided by energy efficient windows. It is noted in the material that although space cooling still accounts for a rather limited proportion of energy consumption, it has been growing fast in some countries, while the number of cooling degree-days almost doubled in 2017 compared to 2014. Energy efficiency improvement measures also have a positive impact on air quality, as more energy efficient buildings contribute to reducing the demand for heating fuels, including solid heating fuels. Energy efficiency measures therefore contribute to improving indoor and outdoor air quality and help achieve, in a cost effective manner, the objectives of the Union's air quality policy, as established in particular by Directive (EU) 2016/2284 of the European Parliament and of the Council.

5.3 Energy Efficiency Directive

5.3.1 Summary of the Energy Efficiency Directive EED (2012) and its amendment (2018)

The 2012 Energy Efficiency Directive (2012/27/EU) [3] is part of the Clean Energy package and it establishes a set of binding measures to help the EU reach its targets for 20 % energy savings target by 2020. It was updated in 2018 with the new amending Directive on Energy Efficiency (2018/2002) [33] by extending the policy framework to 2030 with an energy efficiency target of at least 32.5 %. The amendment has a clause for a possible upwards revision by 2023. The energy savings should be done through improving energy efficiency throughout the full energy chain, including energy generation, transmission, distribution and end-use consumption. The directive will benefit the environment, improve air quality and public health, reduce greenhouse gas emissions, improve energy security by reducing dependence on energy imports from outside the Union, cut energy costs for households and companies, help alleviate energy poverty, and lead to increased competitiveness, more jobs and increased economic activity throughout the economy, thus improving citizens' quality of life. Each EU country was required to set their own indicative national energy efficiency targets and publish national energy efficiency action plans (NEEAPs) every three years, as well as integrated 10-year national energy and climate plans (NECPs).

The EED as amended extends the energy savings obligation to the period from 1 January 2021 to 31 December 2030 and beyond (subject to review by the Commission). In each year of the 2021-2030 obligation period and beyond, Member States must achieve cumulative end-use energy savings equivalent to new savings of 0.8 % of final energy consumption in the period and beyond [34].

5.3.2 Comparison towards EXCESS definition of PEB and the objectives in EXCESS

The definition of the EXCESS project corresponds well with the suggested pathway forward set out in the European legislation regarding energy efficiency and decarbonisation of the building stock.

It however remains important to keep in mind the significance of energy flexibility and the relationship of a positive energy building with the grid as clearly mentioned in the amendment of 2018. This reduces a potential negative impact on the grid as also mentioned in the definition. Nothing specific was mentioned regarding the self-consumption rate. Although, smart electricity meters are mentioned as a potential tool to improve the energy efficiency in the EU and raise consumer awareness. This can be related to other smart solutions mentioned in other documents (Smart Readiness Indicator).

Within the amended EED (2018) we identified the requirement expressed by the EC to undertake a series of actions to reduce energy consumption towards meeting EU climate and energy targets. Among the various good practice examples provided within the document, increasing consumers' awareness through the use of smart metering and adoption of comprehensive billing is found to be in alignment with the scope of the EXCESS project and PEBs definition.

Building occupants (i.e. consumers) engagement and acceptance is found to be key within EXCESS towards achieving a positive energy equilibrium at the building and district side (through fine-grained strategies for minimising energy wastes and optimizing energy use). One of the ways to achieve this is through better information provision (real-time and highly granular). In EXCESS, it is envisaged to trigger the increase of awareness and better understanding of the building occupants (i.e. consumers) around energy and flexibility through the provision of appropriate monitoring and analytics mechanisms. Such mechanisms will utilize smart metering and sub-metering information and data coming from the building and its systems and will provide real-time (personalized) snapshots of energy performance, energy balance and flexibility capacity of building residents, while revealing outliers and non-optimal consumption points that can further trigger recommendations and (most importantly) control optimization strategies for increased energy savings and optimal utilization of flexibility.

5.4 New rules for the internal market in electricity

5.4.1 Summary of the Common Rules for the Internal Market for Electricity Directive

On 16th March 2019 the European Parliament adopted the new Electricity market Directive (2019/944), which was finally approved by the Council on 22nd May 2019 [4]. The new electricity market directive marks a fundamental change from a centralized to a decentralized energy system. The directive puts the energy consumer at the centre. All consumers should have the opportunity to participate directly in the energy market by adopting their energy consumption in response to market conditions. All consumers should be able to benefit from directly participating in the market, in particular by adjusting their consumption according to market signals and, in return, benefiting from lower electricity prices or other incentive payments. Consumers should have the possibility of participating in all forms of demand response. All customer groups (industrial, commercial and households) should have access to the electricity markets to trade their flexibility and self-generated electricity. Customers should be allowed to make full use of the advantages of aggregation of production and supply over larger regions and benefit from cross-border competition. Market participants engaged in aggregation are likely to play an important role as intermediaries between customer groups and the market. Member States should be free to choose the appropriate implementation model and approach to governance for independent aggregation while respecting the general principles set out in the directive.

5.4.2 Comparison towards EXCESS definition of PEB and the objectives in EXCESS

Following the "New rules for the internal market in electricity", the EXCESS project puts consumers at the heart of the energy market. Through the innovative functionalities offered by EXCESS, building occupants (i.e. consumers) are enabled to participate in energy/ flexibility transactions being supported by EXCESS technology advancements, thus providing further means to successfully manage the energy transition in a cost-effective way. On the way to empower building occupants, EXCESS solutions provide occupants with the means to get engaged in flexibility trading (at the local level) in a conceivable and transparent manner and benefit from the utilization of this flexibility, both in the frame of self-consumption increase (reducing energy flows from the grid and respective costs) and in the frame of providing ancillary services to network operators (offering flexibility and being remunerated for its activation), in close collaboration and under specific agreements and contracts with Aggregators. Further engagement can be achieved by enabling consumers to choose freely switch between service providers (aggregators or even energy suppliers) through appropriate interoperability mechanisms that will ensure smooth data flows and satisfaction of integration requirements between heterogeneous systems. Another aspect that supports such freedom to choose on the consumer/ prosumer side, relies on the fact that through EXCESS, they become owners and have better control over their data, thus being able to evaluate alternative offerings and take informed decisions on how and with whom they can optimally share this data, for the realization of ambitious energy and economic targets.

Other than the aspects mentioned above, the document does not address the other dimensions focused on in this comparison. E.g. the new electricity market directive has no specific aims regarding GHG emission reductions, it does not mention the indoor comfort or aesthetics.

5.5 New energy performance of buildings Directive

5.5.1 Summary of the New Energy Performance of Buildings Directive

The Energy Performance of Buildings Directive (2010/31/EU) [31] required the Commission to carry out a review in the light of the experience gained and progress made during the application of that Directive, and, if necessary, to make proposals. The outcome of the review indicated that a series of amendments are required to strengthen the current provisions of Directive 2010/31/EU.

The basis for the EPBD is the recognition of the fact that “achievement of the Union’s energy and climate goals is linked to the Union’s efforts to renovate its building stock by giving priority to energy efficiency, making use of the ‘energy efficiency first’ principle as well as considering deployment of renewables.”[5]

The Directive urges the Member States to develop national renovation strategies in order to achieve a highly energy efficient and decarbonised building stock and to ensure that the long-term renovation strategies deliver the necessary progress towards the transformation of existing buildings into nearly zero-energy buildings. In particular, an increase in deep renovations is expected. In order to facilitate the progress towards these targets, the Directive states that the Member States should provide clear guidelines and outline measurable, targeted actions. The Directive also underlines the importance of promoting equal access to financing. For supporting the necessary improvements in their national rental stock, the Directive suggests Member States to apply requirements for a certain level of energy performance for rental properties.

The New EPBD assumes that the efforts to increase the energy performance of buildings would contribute actively to the Union’s energy independence and, furthermore, have great potential to create jobs in the Union. It is also seen as one potential action to alleviate energy poverty. The 2009 World Health Organisation guidelines are also referred to concerning indoor air quality, claiming that better performing buildings provide higher comfort levels and well-being for their occupants and improve health.

The New EPBD also notes that the renovation actions should not be limited to the building envelope, but to also include the “all relevant elements and technical systems in a building, such as passive elements that participate in passive techniques aiming to reduce the energy needs for heating or cooling, the energy use for lighting and for ventilation and hence improve thermal and visual comfort”. But it also underlines the use of solutions based on nature (such as well-planned street vegetation, green roofs and walls providing insulation and shade to buildings), which would contribute to reducing energy demand by limiting the need for heating and cooling and thus improving a building's energy performance.

Digitalisation of buildings is also addressed in the New EPBD. It encourages the use of smart readiness indicator to measure the capacity of buildings to use information and communication technologies to adapt the operation of buildings to the needs of the occupants and the grid and to improve the energy efficiency and overall performance of buildings. The smart readiness indicator should also raise awareness amongst building owners and occupants of the value behind building automation and electronic monitoring of technical building systems and should give confidence to occupants about the actual savings of those new enhanced-functionalities.

The directive also gives guidelines for preparing to EV charging, and mentions the future role of buildings in decarbonising the transport sector through EV charging. In this context, the need for holistic and coherent urban planning is mentioned.

The New EPBD underlines the importance to ensure quality of renovation works, equipment and material, and the use of independent control systems for energy performance certificates. Inspections of heating, air-conditioning and ventilation systems should give information of the performance of these systems in conditions closer to real-life situation.

The New EPBD recommends to update the general framework for the calculation of the energy performance of buildings and to encourage the improved performance of the building envelope in order to make sure appropriate implementation of the Directive takes place.

5.5.2 Comparison towards EXCESS definition of PEB and the objectives in EXCESS

With regard to social aspects, the EXCESS project is found to be clearly aligned with the new EPBD mainly addressing the requirements for efficiently tackling energy poverty. The EXCESS solutions are expected to significantly contribute to the tackling of the energy poverty problem, directly during the project, but also indirectly through the definition of a targeted exploitation strategy, prioritizing on the engagement of this part of the population in the involved Member States and (progressively) beyond.

Another important social aspect addressed by EXCESS and relates to the prosperity of the society, the deployment of EXCESS solutions is intended to enhance security of supply, through the promotion of local/ self-generation through the use of RES and consequently self-consumption, thus reducing reliance on energy imports (carried out mainly for heating purposes).

On the flexibility trading side, the introduced solutions and mechanisms in the EXCESS project will be characterized by high transparency provisions in any transactions performed between consumers and aggregators (in the frame of flexibility activation for demand response purposes) thus further increasing trust of consumers in such new business contexts and facilitating their engagement into the concept introduced by EXCESS.

The EXCESS solutions are also found to be supportive to the scope of the EPBD, in respect to enhancing occupants' comfort (thermal and visual) conditions. By taking into consideration all technical systems and relevant elements of a building (rather than only the elements forming the building envelope), EXCESS solutions are intended to improve the overall building performance by reducing the current energy needs for heating, cooling, lighting and ventilation without compromising human comfort in the indoor environment, while totally respecting non-negotiable requirements for high indoor air quality and health-preserving/ liveable buildings.

Another topic found to be in alignment with the objectives of EXCESS is focusing on the Smart Readiness Indicator of buildings as adopted by the EC in the new EPBD. Through the EXCESS evaluation framework, the project aims to rate the smart readiness of buildings while also promoting the use of smart devices and advanced ranking of energy consumers according to the Smart Readiness Indicator.

With regards to environmental aspects the new EPBD see the decarbonisation of buildings as critical to meet the 2050 EU emissions targets. Innovation and new technology also make it possible for buildings to support the overall decarbonisation of the economy, including the transport sector. The new EPBD mentions that for example buildings can be leveraged for the development of the infrastructure necessary for the smart charging of electric vehicles. This is in line with the EXCESS solutions that see buildings a nucleus for a broader penetration of renewables and the decarbonisation of the energy system.

Combined with an increased share of renewable electricity production, electric vehicles produce fewer carbon emissions resulting in better air quality. Electric vehicles constitute an important component of a clean energy transition based on energy efficiency measures, alternative fuels, renewable energy and innovative solutions for the management of energy flexibility.

With regard to the building stock, this document focusses on how to achieve a decarbonisation for new buildings as well as renovation strategies for existing buildings, which guides both towards nearly zero energy buildings. This will be achieved by giving priority to energy efficiency as well as the deployment of renewables and introducing smart technologies in the building stock. This approach combines the three main pillars: energy efficiency, development of integrated renewables and flexibility combined with smartness as suggested in the EXCESS definition.

The definition of technical building systems, which was updated in June 2018, comprises: technical equipment for space heating, space cooling, ventilation, hot water, lighting, building automation and control, on-site electricity generation. Building automation & control is further specified as: all products, software and services that can support energy efficient, economical and safe operation. Annex 1 of the document provides a general framework for the calculation of energy performance of buildings. The energy performance of a building shall be determined on the basis of calculated or actual energy use and shall reflect typical energy use for space heating, space cooling, domestic hot water, ventilation, built-in lighting and other technical building systems. This results in a numeric indicator of primary energy use in kWh/(m^2.y) for the purpose of both energy performance certification and compliance with minimum energy performance requirements. The methodology applied for the determination of the energy performance of a building shall be transparent and open to innovation. Additionally, member states may define additional numeric indicators of total, non-renewable and renewable primary energy use, and of greenhouse gas emissions produced in kgCO_2eq/(m^2.y). Finally, the positive influence of the following aspects shall, where relevant in the calculation, be taken into account: local solar exposure conditions, active solar systems and other heating and electricity systems based on energy from renewable sources, electricity generated by cogeneration, district or block heating and cooling systems and natural lighting.

Regarding primary energy and how to calculate it, “The calculation of primary energy shall be based on primary energy factors or weighting factors per energy carrier, which may be based on national, regional or local annual, and possibly also seasonal or monthly, weighted averages or on more specific information made available for individual district systems”. In these calculations, plug loads and other applications such as electrical vehicles are not incorporated. By also including plug loads the suggested PEB definition in EXCESS is more complete and provides a more realistic assessment of the entire electricity consumption of the building and its occupants.

In annex IA, the smart readiness indicator is introduced and its added value for communication, smartness and user interactions is elaborated. Three functionalities relating to the building and its technical building systems are focussed on: the energy performance of the building and the ability to guarantee a smooth transition towards the sole use of renewable energy sources. Secondly, the document focusses again on a healthy indoor climate and how SRI can contribute to it. The final emphasis relates to flexibility of the electricity demand of the building and its relation with the grid. Active and passive as well as implicit and explicit demand response will become more important in the future. All these aspects require a sufficient interoperability between systems such as smart meters, building automation and control systems, built-in home appliances, self-regulating devices for the regulation of indoor air temperature within the building and indoor air quality sensors and ventilations.

The above mentioned technical aspects follow the same approach as the EXCESS definition, regarding smartness of buildings. A PEB will be a smart building that allows for a lot of flexibility regarding its energy use and is easily adaptable and able to incorporate future technological evolutions.

6 Comparison towards EU long-term vision

The EXCESS partners compared the PEB definition to the EU long term vision, especially regarding specific aspects that are central for EXCESS project. In Table 3 below, a general overview of the appearance of these aspects in the vision documents are presented, and in the following subchapters the relevance and comparison results are presented.

In this work, the EXCESS partners assessed the European dimension of EXCESS PEB residential concept, investigating complementarity and integrity with the EU long-term vision for a prosperous, modern, competitive and climate-neutral economy by 2050 [6]. In addition, a comparison was made towards the Green Deal communication, published in December 2019 [35], after the start of EXCESS project.

VITO and CEN explored technical aspects (building in and out primary and final energy flows), SUITE-5 the social aspects (occupant engagement), VTT the indoor comfort requirements, JR the environmental targets and Urbatelier the building structure aesthetical requirements. The district perspective and the positioning of the PEB in the city energy infrastructure were also taken into account by VTT and SUITE-5. Particularly, energy transaction schemes of produced on-site renewable energy and available on-site energy flexibility were outlined.

Table 3: Appearance of the analysed items in the vision and target material.

Document	Technical	Social	Indoor comfort	Environmental	Aestethical	District
Clean planet package	X	X	-	X	-	X
EU Green Deal	X	X	-	X	-	X

6.1 Clean planet for all Europeans

6.1.1 Summary of the Clean Planet for All Europeans communication

Recognising the Climate Change concerns of the European citizens and the urgency to protect the planet, the European Commission has developed a strategy to answer these concerns and take action.

The aim of this long-term strategy is to confirm Europe's commitment to lead in global climate action and to present a vision that can lead to achieving net-zero greenhouse gas emissions by 2050 through a socially-fair transition in a cost-efficient manner. It underlines the opportunities that this transformation offers to European citizens and its economy, whilst identifying challenges ahead. The proposed Strategy does not intend to launch new policies, nor does the European Commission intend to revise 2030 targets [36]. Combined, the climate and energy policies already set by the Commission will deliver on the EU's contribution under the Paris Agreement to reduce emissions by at least 40% by 2030 compared to 1990, but this is, however, not sufficient for the EU to contribute to the Paris Agreement's temperature goals. Instead, this would require the EU to achieve greenhouse gas emissions neutrality by 2050. [6]

6.1.2 Comparison towards EXCESS definition of PEB and the objectives in EXCESS

Upon review of the EU's strategic long-term vision, as identified in the "Clean planet for all" document, the EXCESS project and PEB definition is found to be aligned with the solutions provided.

Following EU's strategy for maximising the deployment of RES, EXCESS will provide consumers with the appropriate technologies and solutions to further increase the affordability of RES (optimize payback periods for such investments) via self-generation and self-consumption, but also through energy and flexibility trading, thus contributing to EU's target for decarbonisation of the energy supply and shift from fossil fuels to RES. In addition, EXCESS aims at enhancing consumers' knowledge of their flexibility (through provision of flexibility analytics) and enable them to be engaged in flexibility trading either directly in markets or through aggregators.

6.2 EU Green deal

6.2.1 Summary of the Green Deal

The EU Green Deal, aiming Europe to become first climate-neutral continent by 2050, was unveiled on 9 December 2019 as a growth strategy or a roadmap for achieving a sustainable European economy [35]. Unlike the Clean Planet for All, EU Green Deal goes beyond climate and energy issues and addresses broader sustainability aspects such as reducing environmental pollution, protecting biodiversity and using resources efficiently. More specifically, it touches upon on the following policy areas: clean energy, sustainable industry, buildings and renovation, sustainable mobility, biodiversity, agriculture, pollution elimination and climate action. The EU Green Deal will consistently use all policy mechanism to deliver this transformation: sectoral strategies and plans, regulations and standards, investments and innovations, national reforms, stakeholder dialogues and international cooperation.

6.2.2 Comparison towards EXCESS definition of PEB and the objectives in EXCESS

Based on the currently available Green Deal Communication, PEB definition and concept is aligned with the EU's long-term goals. The announcement of a new Climate Law aiming at zero emissions by 2050, and tightening targets for 2030, as well as the announced building 'renovation wave', consideration of extending the ETS emission trading systems to the building sector, while simultaneously asking for smart integration of renewables in all sectors could help to promote PEB as a 'new approach' to buildings renovation, along with currently prevailing nZEB concept, considered to be most cost-effective solution for buildings transformation. However, EU Green Deal also indicates that buildings should follow circular economy principles, be digitalised and climate-proof, and EXCESS PEB concepts could take that into account if they are to adapt to future market demands.

In the section discussing building and renovating in an energy and resource efficient way, the Green Deal document focuses on the role of the built environment. The Commission states the following initiatives and will launch actual proposals by the end of 2020: 1) Emissions from buildings could be included in European emissions trading, as part of broader efforts to ensure that the relative prices of different energy sources provide the right signals for energy efficiency. 2) Secondly, the Commission suggests an open platform bringing together the buildings and construction sector, architects and engineers and local authorities to address the barriers to renovation. 3) This initiative will also include innovative financing schemes under InvestEU. These could target housing associations or energy service companies that could roll out renovation including through energy performance contracting. Here, also the district perspective is mentioned, as it is suggested that renovation efforts should be organised into larger blocks to benefit from better financing conditions and economies of scale.

7 Conclusions

In the work described in this document, a common definition of Positive Energy Buildings was developed by the EXCESS team. Based on a literature review and thorough discussions inside the EXCESS team, the following was considered to present a common view of the meaning of Positive Energy Buildings (PEB):

> EXCESS defines a positive energy building (PEB) as an energy efficient building that produces more energy than it uses via renewable sources, with high self- consumption rate and high energy flexibility, over a time span of one year.
>
> A high quality indoor environment is an essential element in the PEB, maintaining the comfort and well-being of the building occupants. The PEB is also able to integrate the future technologies like electric vehicles with the motivation to maximise the onsite consumption and also share the surplus renewable energy.

The core definition was supported with clarifications on the terminology and the different components of PEB definition. The definition will also be supported by the KPIs developed later in EXCESS project.

In the comparison towards EU regulations and visions, a good agreement and no specific contradiction was found between the EXCESS PEB definition and the EXCESS approach in general. So it can be concluded that EXCESS definition and work plan is well in line with EU energy regulatory framework and with the EU long-term vision for a prosperous, modern, competitive and climate-neutral economy by 2050.

EXCESS definition and concept are especially well in line with the ideas on citizen empowerment and user comfort underlined in several of the regulations and vision documents. The documents also refer to the interaction with the grid and the (future) integration of EVs. Energy efficiency is particularly highlighted in the EU's documents, as well as the need to cover the remaining need by renewable energy.

One interesting finding that was made during the PEB definition exercise was that the terminology used for describing and defining the NZEB or PEB concepts is not yet fully harmonised, and there seems to be no common agreement of what should be used for describing the different energy components in the balance. Different terminology can be used even inside the same source. This is why in this document, the use of the terminology is also not harmonised, as it was decided to use the terms in accordance with the original source. Therefore, also in chapter 3, the same components are named differently even inside one paragraph, as part of the text is referring to the literature review. Here is clearly place for further work for the PEB community. As an example, load is often used in the literature as the concept to define what amount of energy is required for the different activities on the site during e.g. one year, measured in kWh/y. However, traditionally, load is an instantaneous quantity, power that is used by a certain electrical element, measured in Watts. It is a bit confusing to use this as the description of an amount of energy. The better words to describe this amount (calculated as the integral or sum of the instantaneous loads) are energy demand or energy need. Energy use is also often applied to describe this entity, and this is also done in EXCESS PEB definition (due to the choices made in the preparation phase), but this collides with the ideas of basic physics, the first law of thermodynamics, which states that energy can't be used or produced in a closed system. In this sense, the term "production" should be replaced e.g. by "conversion" and "use" should be replaced by "demand" or "need" as described earlier.

There are also needs to describe the energy components at different stages of the chain, based on the boundaries. One effort towards this is made e.g. in the European guidelines for calculating the energy performance of buildings (Figure 9) [37], but this still e.g. includes the "energy use" term. This work on the terminology is however beyond the scope of EXCESS project, and could not be finalised in the time that was available for the definition work. The discussion should, and will no doubt continue, both inside the EXCESS team as inside the PEB community.

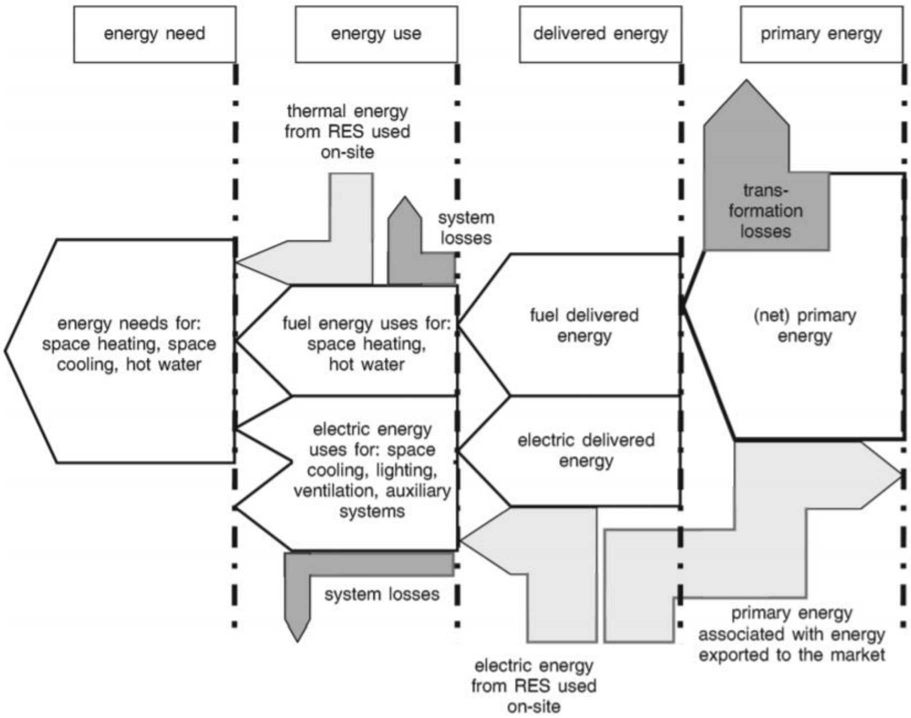

Figure 9. Terminology used in the calculation of energy performance of buildings.[37]

In next phases of the EXCESS project, the definition will be used to define the KPIs, and as discussion base towards different stakeholders regarding the possibilities to promote PEBs and the different challenges and opportunities related to this. It has even been agreed among the EXCESS team that the definition itself can still be adapted if we notice some very crucial needs for that during the EXCESS work. Especially the plug load is something that can induce needs for change, as well as the harmonisation of the terminology.

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