ePANACEA

Smart European Energy Performance Assessment & Certification

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Common framework for a modular methodology

Inventory of smart and novel technologies

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HISTORY OF CHANGES

Version	Month Year	Organisation	Comments
01	November 2020	VITO	Final draft for review
02	November 2020	EFINOVATIC	Review
03	November 2020	VITO	Finalisation of deliverable

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OVERVIEW OF THE ePANACEA PROJECT

After 10 years of track record, the current EPCs schemes across the EU face several challenges which have led to not fully accomplish their initial objectives: lack of accuracy, a gap between theoretical and real consumption patterns, absence of proper protocols for inclusion of smart and novel technologies, little convergence across EU schemes, lack of trust in the market and very little user awareness related to energy efficiency.

The objective of the ePANACEA project is to develop a holistic methodology for energy performance assessment and certification of buildings that can overcome the above mentioned challenges. The vision is ePANACEA becoming a relevant instrument in the European energy transition through the building sector. ePANACEA comprises the creation of a prototype (the Smart Energy Performance Assessment Platform) making use of the most advanced techniques in dynamic and automated simulation modelling, big data analysis and machine learning, inverse modelling or the estimation of potential energy savings and economic viability check.

A relevant part of the project is to have a fluent dialogue with European policy makers, certification bodies, end-users and other stakeholders through two types of participatory actions: on the one hand a feedback loop with policy makers will be carried out through the so called Regional Exploitation Boards (REBs) covering EU-27+Norway+UK, and the dialogue with the end-users will be established by means of specific thematic workshops. Thanks to these participatory actions we will ensure that ePANACEA approach is aligned with and meets the needs of national public bodies, end-users and other stakeholders with a view to test the acceptance and to validate the methodology developed.

ePANACEA will demonstrate and validate reliability, accuracy, user-friendliness and cost-effectiveness of the methodology through 15 case studies in 5 European countries.

EXECUTIVE SUMMARY

This deliverable describes the process that has been followed in E-PANACEA Task 2.2 Inventory of smart and novel technologies. The objective of this task is to develop an inventory, containing novel, smart and innovative technologies which have an impact on the building energy performance. This inventory has mapped a number of relevant technologies, and for each a brief description was given. In addition, the potential impact on the building energy performance or on the energy system was assessed.

To this initial inventory of technologies, a process of prioritisation was applied, and together with three rounds of consultation of involved partners this has led to the selection of minimum three technologies for which in task 4.2 a methodology will be developed to assess the impact on the building energy performance (or the wider energy system) and which can be incorporated in simplified energy balance calculations of existing energy performance certification schemes.

1. INTRODUCTION

The objective of task 2.2 is to develop an inventory, containing novel, smart and innovative technologies which have an impact on the building energy performance.

In the following sections we describe the structure of the inventory and the initial long-list of technologies that were selected. This is followed by an explanation on the process of applying the prioritisation methodology – which was used to rank the selected technologies based on a set of parameters, in order to obtain a short list of technologies. From these technologies then the final selection was made for which a methodology to assess their impact on the building energy performance or the wider energy system will be developed in task 4.2.

Novel technology: technology (based on energy generation, renewable sources, storage or automatization) for enhancing the energy efficiency of the building and/or other aspects (e.g. comfort), with a low market maturity level or a limited buildings market penetration at the moment.

Smart technology: technology or a set of technologies combined (e.g. ICT technologies or physical products) that provide a smart service such as; increasing the level of controllability of the technical building systems, automatization of energy management, monitoring or data analytics, etc. With the objective of enhancing the energy efficiency in buildings and/or the optimization of demand profiles (e.g. self-consumption optimization or loads adaptation to real-time-pricing tariff).

Four partners of the E-PANACEA consortium have directly contributed to the work performed in this task and have provided input for their respective countries:

- Belgium, Flanders[1] (BE) – VITO, Task Leader
- Finland (FI) – VTT, Task contributor
- Greece (GR) – CRES, Task contributor
- Spain (ES) – CENER, Task contributor.

[1] In Belgium the EPC methodology is implemented by the regions. For this task the methodology applicable in the region of Flanders has been taken into account.

2. INVENTORY OF SMART AND NOVEL TECHNOLOGIES

The complete initial inventory includes 45 technologies which are grouped in 10 categories.

Category	Technology	General Description
Construction	**Skylight**	Construction element allowing light to enter the building via the roof.
	Novel construction materials	Construction materials used for the building envelope (including both opaque and transparent construction elements) that have become available on the market only recently, with interesting thermal or mechanical properties.
	Dynamic glazing system	Windows can have specific thermal or physical properties. Adaptation in time of these properties could be realised by different types of interventions: mechanical, chemical, physical, etc.
Building installations	**TABS - Thermally activated building systems**	Thermally activated building systems (TABS) are radiant heating and cooling systems with pipes embedded in the building structure (slabs, walls).
	Hybrid ventilation system	System that provides a comfortable internal environment using both natural ventilation and mechanical systems, but using different features of these systems at different times of the day or season of the year. In hybrid ventilation mechanical and natural forces are combined in a two-mode system where the operating mode varies according to the season, and within individual days. Thus the active mode reflects the external environment and takes maximum advantage of ambient conditions at any point in time. The main difference between a conventional ventilation system and a hybrid system is the fact that the latter has an intelligent control system that can switch automatically between natural and mechanical modes in order to minimize energy consumption.
	Combined heating and ventilation system	Ventilation systems connected to the heating system or coordinated with the heating system.
	Natural lighting system	System collecting natural light through collectors on the outside and transporting it to the building interior where it is diffused.
	EV charging infrastructure	An interface that is capable of charging one electric vehicle at a time.

	In-building DC network	A DC-network instead of the classic AC-network for electricity distribution in the building.

Renewable energy generation and supply	**BIPV**	A Building Integrated Photovoltaic (BIPV) module is a PV module and a construction product together, designed to be a component of the building. A BIPV product is the smallest (electrically and mechanically) non-divisible photovoltaic unit in a BIPV system which retains building-related functionality. If the BIPV product is dismounted, it would have to be replaced by an appropriate construction product. A BIPV system is a photovoltaic system in which the PV modules satisfy the definition above for BIPV products. It includes the electrical components needed to connect the PV modules to external AC or DC circuits and the mechanical mounting systems needed to integrate the BIPV products into the building.
	Hydrogen panels	A panel converting sunlight and water vapour from the air directly into hydrogen gas.
	Green energy supply contract	An energy supply contract in which the supplier guarantees the delivered energy has been generated by renewable energy sources.
	Cooperant at an energy community	Through investment in an energy community a building owner can substitute local renewable energy production on his property by renewable energy produced with the energy community's generation units.
	Flexibility and aggregation market	Participate in the flexibility and aggregation market via a DSR independent aggregator according to Directive 2019/944 of the European Parliament.
	Hybrid solar panels	A solar panel that produces both thermal and electrical energy.
	Small scale wind energy production unit	A wind turbine in the range of several kW's
	Hybrid heat pump	A heat pump combined with another thermal energy production unit, such as a gas boiler, an electric heater or a solar thermal system.
	Booster heat pump	A booster heat pump allows to increase the water temperature locally, so that a low temperature heating system can be used even when some consumers (e.g. DHW supply or a single dwelling/room within a larger system) require a higher water temperature.

	Centralized heat pump	A heat pump serving multiple end consumers, for example flats in a residential apartment building. A medium temperature is used for heating and cooling, a high temperature is used for domestic hot water supply.
	Collective self-consumption (multifamily building)	A legal instrument that allows the families (or dwellings) within the same building to share a common PV installation.

Other novel energy generation and supply technologies	**4th and 5th generation district heating and/or cooling**	4GDHC (4th generation district heating and cooling) system is a smart thermal grid integrating sustainable thermal sources which supplies heat or cold to buildings thereby using a low temperature distribution system to minimize distribution heat losses. 5GDHC (5th generation district heating and cooling) system is a bidirectional smart thermal grid integrating sustainable thermal sources which supplies heat and cold through a close to ground temperature network, thereby using direct exchange of warm and cold return flows and thermal storage to balance thermal demand as much as possible. The same pipes are providing heating and cooling services simultaneously.
	Micro CHP	A micro CHP (combined heat and power) unit is able to simultaneously generate in one process thermal energy and electrical or mechanical energy and has a maximum capacity below 50 kWe.

Thermal energy storage	**Short term storage in building thermal mass**	Storage of thermal energy using the thermal mass of the building (such as walls or floor slab) over a period of hours or days.
	Short term storage in storage vessel	Storage of thermal energy using the thermal mass of a storage vessel over a period of hours or days.
	Seasonal storage in the ground	Storage of thermal energy using the thermal mass of of the ground over a period of weeks, months or a year.
	Seasonal storage in storage vessel	Storage of thermal energy using the thermal mass of a storage vessel over a period of weeks, months or a year.
	Aquifer thermal energy storage (seasonal)	An aquifer is an underground layer of water-bearing permeable rock. Aquifer thermal energy storage (ATES) allows to store and recover thermal energy by extracting and injecting groundwater from aquifers using groundwater wells.

	Latent heat storage with PCM (seasonal)	Phase Changing Materials (PCM) release thermal heat at a nearly constant temperature near the specific material's phase change temperature. They have a high energy storage density within a limited operational temperature range, making them a compact storage option.
	Thermochemical storage in salt hydrates (seasonal)	Thermochemical materials (TCM) store heat by performing a chemical reaction. Salt hydrates are the most commonly used TCMs, storing thermal energy by drying the salt hydrate and storing the dry salt and water separately.

Electrical energy storage	**Domestic battery**	A fixed battery installed within a building.
	Electric vehicle battery	The battery of an electric vehicle can be used to store excess local energy production. In combination with Vehicle-to-Grid (V2G) or Vehicle-to-Building (V2B) technology, the battery can also be discharged for the energy to be used outside of the vehicle.
	Fuel cell	A fuel cell is any of a class of devices that converts the chemical energy of a fuel directly into electricity by electrochemical reactions.
	Neighbourhood battery	A shared battery which is used by several buildings in a neighbourhood.

Chemical energy storage	**Hydrogen storage**	The storage of hydrogen for later use after conversion to thermal or electrical energy.

Automation and control	**Self-regulating devices**	A self-regulating device, system, etc. is able to control its own temperature, speed, etc. and keep it at the correct level.
	BACS - Building automation and control system	Building automation and control system (BACS) means a system comprising all products, software and engineering services that can support energy-efficient, economical and safe operation of technical building systems through automatic controls and by facilitating the manual management of those technical building systems.
	DEMS - District energy management system	District energy management system (DEMS) couples the energy systems of several buildings, allowing for improved district level optimization.
	Dynamic solar shading with predictive control	With dynamic solar shading solar irradiance can be obstructed only when needed for energy efficiency or comfort reasons. Combined

		with predictive control (e.g. based on weather forecast) optimization can be improved.
	EV-charging with V2G and V2B	Electric vehicle (EV) charging in combination with vehicle-to-grid (V2G) or vehicle-to-building (V2B) technology allows bidirectional energy flow between the grid or building and the electric vehicle.

ICT systems	**Application for remote system control**	Applications for remote system control allow for a human or computer not present on-site to apply changes to the system's parameters.

Energy monitoring systems	**Building energy monitoring system**	Allows for the monitoring and collection of system and environment parameters. Often integrated in a building energy management system (BEMS).
	OBM - On board monitoring equipment	On Board Monitoring (OBM) allows to capture monitoring data of the interior climate and energy consumption of in-use buildings.
	Data analytics	The analysis of available data used to learn and minimize energy consumption.
	IOT (Internet of Things) applications, sensors, smart meters and connected devices	Hardware and software allowing for data exchange between several devices.
	Use of real time data from weather stations	Real time monitored data from wheather stations allows for improved optimization of system functioning.

Table 1: Categories and technologies

For some of the technologies a description from an existing source has been used.

Technology	**Source**	**Weblink**
TABS	Rehva, Guidebook 20 No 20	https://www.rehva.eu/eshop/preview?tx_cartbooks_preview%5Bbook%5D=41&cHash=33c5fe9e4552f750faae5e1a01ba06ce
Hybrid ventilation system	IEA-ECBCS Annex 35 “Hybrid Ventilation in New and Retrofitted Office Buildings”	https://iea-ebc.org/Data/publications/EBC_Annex_35_Principles_of_H_V.pdf

Combined heating and ventilation system	COMMISSION RECOMMENDATION (EU) 2019/1019 of 7 June 2019 on building modernization	https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32019H1019&from=EN
EV charging infrastructure	COMMISSION RECOMMENDATION (EU) 2019/1019 of 7 June 2019 on building modernization	https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32019H1019&from=EN
BIPV	IEA-PVPS T15-04: 2018	https://iea-pvps.org/wp-content/uploads/2020/02/IEA-PVPS_Task_15_Report_C0_International_definitions_of_BIPV_hrw_180823.pdf
Micro CHP	EUR-Lex	https://eur-lex.europa.eu/eli/dir/2012/27/oj
Fuel cell	Britannica	https://www.britannica.com/technology/fuel-cell

Table 2: Sources used.

For each technology several indicators were included:

- Impact (low/medium/high)
- Most appropriate building typology (newbuilt/renovation, residential/non-residential, small-large)
- Feasibility to integrate in building performance assessment (low/medium/high)
- Technology Maturity Level (low/high according to Technology Readiness Level - TRL)
- Relevance for energy policy in targeted countries (low/medium/high)
- Presence in current EPC schemes (Yes/No)

Impact low/medium/high		**Most appropriate building typology**	**Feasibility to integrate in building performance assessment**				**Technology maturity (TRL)**		**Relevance for energy policy in targeted countries (low/medium/high)**				**Presence in current EPC schemes**			
Building energy performance	Impact on the energy system		BE (FI)	FI	GR	SP	Low	High	BE	FI	GR	SP	BE	FI	GR	SP

Table3: Example structure of the indicators (simplified).

<u>Indicators on impact:</u>

<u>Impact on building energy performance</u>

Possible values are: low/medium/high.

Evaluation is based on a combination of desk research for each of the technologies complemented with use of high level of experience and expertise of the involved partners, with building energy consumption and smart technologies.

The following rationale was implemented:

- **Low impact** for technologies which do not decrease the energy consumption of a building (e.g. EV charging infrastructure; short term storage)
- **Medium impact** for technologies affecting only to a limited extent an energy vector compared with default technology which is present anyway.

  For example: natural lighting system (more daylighting) will only partially influence the overall energy consumption for lighting.

  For example: seasonal (long term) thermal energy storage will not decrease demand for heating and cooling, but will have an impact on how efficient the demand is supplied.
- **High impact** for technologies that will substantially decrease the overall energy consumption (such as renewable energy production, novel construction materials or dynamic solar shading) or for technologies that have major impact on the efficiency of energy supply, either through efficient supply and/or production (such as a hybrid heat pump), either through smart control (such as BACS).

<u>Impact on the energy system</u>

Possible values are: low/medium/high

Evaluation is based on the possibility of offering flexibility to the grid on the one hand and the additional stress/uncertainty from the technology on the grid on the other hand. Some examples are given below.

- **Low impact**: Construction components will not provide any flexibility and will mainly limit the energy consumption.
- **Medium impact**: TABS have a high thermal inertia, hybrid heat pumps can switch energy vector. These technologies can offer some (limited) flexibility to the grid. Long term storage will balance seasonal variations in energy demand from the grid, but will not be able to provide short term flexibility in order to avoid peaks. Booster heat pumps will put additional stress on the energy system, but only influence a small energy vector (i.e. domestic hot water) or a fraction of a large energy vector (i.e. heating for a limited number of rooms).
- **High impact**: short term thermal energy storage and electrical energy storage can offer considerable flexibility to the energy system. Local renewable energy generation can have major impact on the grid. These are therefore valid examples of technologies with a high impact on the energy system.

Most appropriate building typology

Possible values are:

- Residential; Non-residential
- Small; Large (small residential is for example a single family dwelling, large residential is a multifamily dwelling; small non-residential is smaller than 500m²)
- New-built; Retrofitted
- All (in case there is no specific preference)

A general reading guideline:

- When 'New-built' is the value provided, this means 'all new-built, large and small, residential and non-residential buildings'.

Feasibility to integrate in building energy performance assessment

Possible values are: low/medium/high.

For each of the countries, the respective partners involved in the E-PANACEA have provided their assessment on how feasible it is to integrate the specific technology in the country's existing building energy performance assessment. Besides the feasibility to integrate the technology form a technical point of view, also legislative aspects have been taken into account.

Technology maturity

Possible values are 1 to 9, expressing the Technology Readiness Level (TRL)[2]. A range has been provided.

The higher value within the range of TRL-levels assigned to a specific technology is indicating what is the most advanced state of the technology that has been identified so far. A high maximum TRL level therefore doesn't mean the technology already has a high market maturity level or an extensive buildings market penetration at the moment. It rather means the technology has been proven at least once to be able to reach this maximum TRL level. This, combined with the fact that all the technologies included in the inventory are novel, smart and/or innovative, we prefer to select technologies with an average higher TRL level, as they will have more impact on the medium term. (See section **Error! Reference source not found.**for more information on how the TRL l evel has been taken into account in the prioritization methodology.)

Relevance for energy policy in targeted countries

Possible values are: low/medium/high.

For each of the countries, the respective partners involved in the E-PANACEA have provided their assessment on the relevance for the energy policy in their country.

Presence in current EPC schemes

Possible values are: yes/no.

[2] https://ec.europa.eu/research/participants/data/ref/h2020/wp/2014_2015/annexes/h2020-wp1415-annex-g-trl_en.pdf

For each of the countries, the respective partners involved in the E-PANACEA have indicated whether the technology is already included in the EPC schemes that exist in their country.

Besides the description and the indicators, for each technology the inventory includes the calculation of the prioritization score. (See section **Error! Reference source not found.**for more information on the prioritisation methodology.)

3. PRIORITISATION METHODOLOGY

A prioritisation methodology is developed in order to make an assessment of which technologies are most suited to be used further in the E-PANACEA project, namely for the task 4.2 whereby a methodology will be developed to assess the impact on the building energy performance (or the wider energy system) that can be incorporated in simplified energy balance calculations of existing energy performance certification schemes.

The prioritisation methodology makes use of two steps:

1. Ranking of technologies

For each technology a score is calculated based on three indicators:

- **the relevance** of the technology for the energy policy in the targeted countries
- **the impact** of the technology on the building energy performance and on the energy system
- **the maturity** of the technology

This is based on the logic that the selected technologies for which a methodology will be developed to assess the impact on the building energy performance (or the wider energy system) should be sufficiently relevant for energy policy, should preferably have a high impact on the building energy performance and/or the energy system, and should be sufficiently mature to have impact in the medium term.

Each indicator has a certain weight in the calculation of the final score:

- Relevance 40%
- Impact 40%
- Maturity 20%

To assign numeric scores, the qualitative assessments 'low', 'medium' and 'high' are translated to scores:

- Low 0
- Medium 0,5
- High 1

The relevance is calculated using the weighted average of the country scores.

For impact, 20 percent point of the score is based on the impact of the technology on the building energy performance and 20 percent point is based on the impact of the technology on the energy system.

The score for project maturity is calculated as the average of TRL-range (average of the lower and upper limit of the TRL-range) divided by nine (maximum TRL level).

The result of this calculation is a score between 0 and 1, which allows ranking the technologies from higher to lower scores.

2. Sanity checks

Besides the calculation of a quantitative score, **three sanity checks** are applied before selecting the technologies that will be used further in the E-PANACEA project:

Feasibility to integrate in building energy performance assessment:

- ✓ Technologies that are considered impossible to integrate in building energy performance assessment are not withheld.

- ✓ On the other hand, the integration should be sufficiently innovative.

Presence in current EPC schemes:

- ✓ Technologies which are already present in most countries don't have to be withheld, because they don't need a methodology to be integrated in EPC schemes any more.

Most appropriate building typology:

- ✓ A wide applicability of the technology is desired.

4. TECHNOLOGY SELECTION PROCESS

This section describes the process which has been followed to select to the technologies that will be further used in the E-PANACEA project. Four partners where involved in the process: VITO (lead), CENER, CRES and VTT (Contributors), based on on-line consultation moments to discuss the selection of technologies in detail.

- **First Round of Consultation**

In the first round of consultation, a draft version of the inventory was sent to all contributing partners. The partners were asked to provide feedback on the technologies and the type of indicators used, as well as to provide input for the indicators for their respective countries.

- **Second Round of Consultation**

After the partners had provided their first feedback and input, a meeting was held to discuss the current status of the inventory, including the newly added technologies resulting from the partners feedback and any missing information. The prioritisation methodology was explained and a number of specific questions where discussed. Also the first results of the ranking where presented.

- **Third Round of Consultation**

After the two rounds of consultations, several new technologies where added to the inventory. The partners were asked to review and fill in the data for their respective countries. A meeting was set-up to discuss the final ranking and select at least three technologies that will be used further in the E-PANACEA project (i.e. Task 4.2).

Prior to the meeting, the complete inventory – including the scores for the ranking – was send to the partners. During this meeting five final technologies were selected (as shown below).

N°	Cat.	Tech	Feasibility	Overall	Relevance	BE (FL)	FI	GR	ES	Impact	Impact Building	Impact Energy System	Maturity
1	RE	**Collective self-consumption**	**M/M/L/H**	**0,82**	**0,63**	0,5	0,5	0,5	1	**1,00**	1	1	**0,83**
2	RE	**Centralised heat pump**	**H/M/M/H**	**0,79**	**0,75**	1	0,5	0,5	1	**0,75**	1	0,5	**0,94**
3	EES	**Electric vehicle battery (combined with EV charging infrastructure)**	**M/M/L/H**	**0,78**	**0,88**	1	0,5	1	1	**0,75**	0,5	1	**0,67**
3	EES	**Domestic battery**	**M/L/L/H**	**0,78**	**0,75**	1	0	1	1	**0,75**	0,5	1	**0,89**
4	A&C	**BACS - Building automation and control system**	**H/M/M/M**	**0,74**	**0,88**	1	0,5	0,5	1	**0,75**	1	0,5	**0,89**
4	BI	**EV charging infrastructure (combined with EV battery)**	**M/M/L/H**	**0,74**	**0,88**	1	1	0,5	1	**0,50**	0	1	**0,94**
4	RE	**Hybrid heat pump**	**H/M/M/H**	**0,74**	**0,63**	1	0,5	0	1	**0,75**	1	0,5	**0,94**
5	RE	**BIPV**	**H/L/M/H**	**0,71**	**0,38**	0,5	0	0	1	**1,00**	1	1	**0,78**
6	RE	**Hybrid solar panels**	**H/M/M/M**	**0,68**	**0,25**	0	0,5	0	0,5	**1,00**	1	1	**0,89**
7	RE	**Booster heat pump**	**H/M/M/M**	**0,64**	**0,50**	0	0,5	0,5	1	**0,75**	1	0,5	**0,72**
7	EES	**Neighbourhood battery**	**M/M/L/L**	**0,64**	**0,50**	1	0,5	0	0,5	**0,75**	0,5	1	**0,72**
7	RE	**Cooperant at an energy community**		**0,64**	**0,63**	0	0,5	1	1	**0,50**	1	0	**0,94**

Table 4: Twelve technologies with seven highest scores. The five selected technologies are highlighted in red (EV battery & EV charging infrastructure are combined).

5. CONCLUSIONS AND NEXT STEPS

From the twelve technologies that reached the seven highest scores (0,63 to 0,82), **five technologies were selected**. **The selected technologies are:**

Collective self-consumption

- It was clarified that this technology focuses on multi-family buildings, rather than on multiple single-family buildings.

Centralised heat-pump

- One particular aspects that could be investigated is the use of a single centralised ground-coupled heat pump versus a single centralised heat source (for example a bore field), used by multiple individual heat pumps.

Electric vehicle battery & EV charging infrastructure

- It was decided to combine these two technologies.
- It is recognised that electric vehicles are not includes in the EBPD. However, given the high importance of this technology in the near future, it might be relevant to develop a methodology for it.
- This technology also includes vehicle-to-grid energy flow.

BACS – Building Automation and Control System

- Although BACS are already (partly) included in existing building energy performance assessments, they are highly relevant to further improve the energy efficiency of buildings.

Cooperant at an energy community

- It is recognised that is will be a challenge to assess the system impact on individual building level.

These selected technologies will be presented at the 1st Regional Exploitation Board Meetings and received feedback used for further work in task 4.2 on a methodology to assess the impact on the building energy performance (or the wider energy system) to be incorporated in simplified energy balance calculations of existing energy performance certification schemes.