

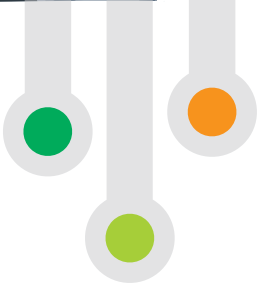


ePANACEA

Smart European Energy Performance Assessment & Certification



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Report on the selection of the open-source simulation tool and its compliance with ISO 52000 series

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OVERVIEW OF THE ePANACEA PROJECT

After 10 years of track record, the current EPC schemes across the EU face several challenges which have led to a not full accomplishment of 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 Europe, 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 of ePANACEA is to become 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: a feedback loop with policy makers, carried out through the so-called Regional Exploitation Boards (REBs) covering EU-27+UK+Norway on the one hand, and dialogue with end-users, established by means of specific thematic workshops, on the other.

Thanks to these participatory actions, the acceptance of the ePANACEA approach will be tested and validated in order to become aligned with and meet the needs of national public bodies, end-users and other stakeholders.

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

EXECUTIVE SUMMARY

This report is focused on the selection of the most suitable tool for being used in the context of ePANACEA energy assessment Method 3, based on advanced dynamic simulation. The development of Method 3 of the ePANACEA methodology requires a simulation tool with a number of specific capabilities such as: (1) Open source, (2) free of charge, (3) HVAC system modelling and sizing, (4) Load Calculation, (5) lighting system modelling, (6) Air flow simulations and (7) Modularity.

The aim of this report is to conclude the tool that best suits these needs. For this purpose, a research on the different BEM tools available in the current market has been carried out, analysing how well each of them meets all features required.

With the findings obtained, a decision matrix has been elaborated. In this matrix, each capability is weighted according to its repercussion on the development of Method 3. Not all the evaluated capabilities have the same influence on the development of the project; for example, the use of an open source tool is more important than the fact that its development is modular.

The results of the matrix show that the most suitable tool for the development of Method 3 is **EnergyPlus**. EnergyPlus is an internationally recognised calculation engine used by many other simulation tools. This tool meets all the requirements indicated above for the tool that will be the basis for the development of Method 3 within ePANACEA energy assessment methodology.

EnergyPlus in combination with OpenStudio (also an open source and free of charge tool) allow meeting other relevant requirements for the development of the ePANACEA project such as: the ease of modelling complex geometries, the ability to perform a high-level supervisory control for building systems, the ease of programming energy measures, the availability of a Building Component Library (BCL) or the ability to perform parametric analysis.

While the calculation tool is important, it is also important that it complies with the requirements set out in the current EPBD. Based on what the EPBD dictates, EnergyPlus shall comply with ISO 52000-1, ISO 52003-1, ISO 52010-1, ISO 52016-1 and ISO 52018-1 of the ISO 52xxx series. Of these standards, only ISO 52016 relates to the energy assessment of buildings and its calculations, and compliance with all other standards is limited to the completion of Annex 1 of each standard with the specifications selected for the EPC.

The EN ISO 52016-1 is based on the reference procedure of 52017-1 using some simplifications. The EN ISO 52017-1 standard describes a general method for physics modelling (i.e. energy balances). It is intended to be used by specialists to develop hourly or sub-hourly calculation methods for indoor temperatures and/or heating, cooling and/or humidification loads of a thermal zone in a building.

The BESTEST (Building Energy Simulation Test) procedure was developed for systematically testing whole building energy simulation programs and diagnosing sources of predictive disagreement. The BESTEST reference is mentioned in the Quality Control section of EN ISO 52017-1 standard. The EnergyPlus building energy simulation software has been tested with several test suites among them ANSI/ASHRAE Standard 140-2011 (BESTEST).



GLOSSARY

BCL: Building Component Library

BEM : Building Energy Modelling.

BEPS: Building Energy Performance Simulation

BES: building Energy Simulation

BESTEST: Building Energy Simulation Test.

BIM : Building Information Modelling

SEPAP: Smart Energy Performance Assessment Platform

EEM: Energy Efficiency Measure

EMS: Energy Management System

EPC: Energy Performance Certification

IBPSA: International Building Performance Simulation Association

Method 1: energy assessment for buildings developed under ePANACEA project (performance data-driven)

Method 2: energy assessment for buildings developed under ePANACEA project (simplified method based on monthly calculation interval)

Method 3: energy assessment for buildings developed under ePANACEA project (detailed method based on dynamic simulation and calibration)

SaaS: Software as a Service



1. INTRODUCTION

Whole building energy simulation (BES) models play a significant role in the design and optimization of buildings. Simulation models may be used to compare the cost-effectiveness of energy efficiency measures (EEMs) in the design stage as well as during the operational stage, including tailored recommendations on energy efficiency for deep and/or stage deep renovations, as well as EEMs based on user behaviour or control strategies for energy conservation.

However, due to the complexity of the build environment and inherent uncertainty of input parameters, it is difficult to achieve an accurate representation of actual building operation. Therefore, using measured data for calibration allows achieving more accurate and reliable results. Recent research is focused on automatically producing building energy models using measured data (i.e. automated calibration) which reduces the complexity and improves the efficiency of the whole process.

With this purpose, ePANACEA concept implies the development and optimization of the procedure for using dynamic simulation techniques for building performance energy assessment and certification. Advanced dynamic simulation techniques allow a high level of accuracy as well as quality outputs, including; (1) prediction of building energy performance (e.g. corrected by climate), (2) disaggregation of consumption per energy service and/or type of fuel, (3) identification of energy efficiency measures and (4) estimation of potential energy savings and economic viability calculation.

Despite of the multiple benefits of using dynamic and calibrated simulation modelling for energy assessment, traditional calibration procedures are time intensive and require specially trained personnel with expert knowledge. To reduce the computational effort of these methods, Method 3 of ePANACEA concept will include an auto-calibrating procedure that will allow developing the model faster than traditional approaches.

The assessment Method 3 within ePANACEA project (i.e. advanced & automated simulation modelling based on dynamic simulation for EPCs), mainly focused on auto-calibration of BEPS, requires a dynamic and customizable simulation tool with high calculation potential, prioritizing the availability of modelling the whole building physics.

This report focuses on the selection of the most appropriate simulation tool and its compliance with ISO 52000 series (i.e. Directive (EU) 2018/844 requirements) for being used under the development of the energy assessment “Method 3” within ePANACEA methodology.



2. EVALUATION OF SOFTWARE TOOLS FOR BEMS

Since the ePANACEA project is focused on Energy Performance of Buildings assessment, the first filter in the search for an energy simulation tool, on which to implement new functions, will be the capability offered by the tools for of whole building energy simulation in both commercial and residential buildings, the latter being either single-family or multi-family.

The requirements of a dynamic simulation tool can be divided into two types: functional and non-functional. Functional requirements refer to the tool's simulation capabilities of the different parameters of the building, among them: the tool's capacity to model different HVAC systems and sizing them, modelling of lighting systems, calculation of heating and cooling loads of the building, etc. Non-functional requirements are other tool's features that are not directly related to the building performance, for instance flexibility, safety, cost, etc. Based on the needs detected for the development of Method 3, the following capabilities have been evaluated for the selection of the simulation tool: (1) Open source software: computer program that allow access to their programming code, (2) Free of charge: available at no cost, (3) HVAC system modelling and sizing: accessibility of the tool to the definition of different HVAC systems definition and auto-sizing capabilities, (4) Load Calculation: assessing the amount of thermal energy that would need to be added or removed to a space to maintain the temperature in a range , (5) Lighting system modelling: defining lighting systems and lighting control strategies, (6) Air flow simulations: ability to perform air flow analysis for building and (7) Modularity: separating the contents of a tool into independent and interchangeable modules, each containing everything needed to be solved independently. These seven capacities will be further elaborated in the following chapters.

For each of the tools, the capabilities with which it complies will be assessed. It may be the case that no single tool meets all the requirements. To solve such a scenario, a decision matrix will be elaborated in which each of the tool's capabilities will be evaluated. The evaluation of each capability will be proportional to its importance for the project. The result of the matrix will be the most suitable tool for the development of the assessment method 3 of the ePANACEA methodology.

2.1. Inventory of BEMs software tools

In order to decide which of the existing tools is the most suitable to be used as a basis for the development of the Method 3 of the ePANACEA methodology, an intensive search for tools that allow the energy simulation of commercial and residential buildings has been carried out. After the pre-evaluation of around 50 energy assessment tools for BEMs, the prioritization of the key requirements allowed the short list shown below:

Table 1: Available Building Energy Software Tools

Tool	Tool Description
1	<p>DesignBuilder</p> <p>OpenGL solid modeler, allows building models to be assembled simply by positioning, stretching and cutting 'blocks' in 3-D space.</p> <p>Design Builder is software specialised in the environmental and energy simulation of buildings. Its advanced features make it possible to evaluate aspects such as comfort levels, energy consumption and carbon emissions.</p> <p>DesignBuilder's integrated approach enables to develop one core model and use it to run a variety of analysis types using different engines (EnergyPlus, Radiance, or CFD). DesignBuilder is used to quantify the impact of the design strategies on building environmental performance, or simply to demonstrate compliance with</p>





		building regulatory codes and certification schemes such as LEED, Energy Star and BREEAM
2	IES Virtual Environment	<p>IES allows the design and operation of comfortable buildings (visual and thermal comfort) that consume significantly less energy. It has an easy-to-use GUI and graphic as well as numerical reporting features to easily share data across a team at stages of design, construction and operation.</p> <p>IES can be used to test different options, identify best passive solutions, compare low-carbon technologies, and draw conclusions on energy use, CO2 emissions, occupant comfort, light levels, airflow and much more, to inform design, ensure compliance with building regulations or with rating systems such as LEED, BREEAM, GreenStar, Green Mark and more.</p>
3	Modelica Buildings library	Modelica Buildings library is a free open-source library with dynamic simulation models for building energy and control systems. Principal strengths of Modelica Buildings library are: its virtual rapid prototyping, including model use during operation; its multi-physics, combining buildings, HVAC, pollutant transport, electrical systems and supervisory and local loop controls; and that is capable to model supervisory and local loop control sequences.
4	Simergy	Simergy is a building modelling platform used to create models and then predict their performance using several simulation engines. Current simulation engines include EnergyPlus, Radiance, and the CBECC building code compliance engine.
5	EnergyPlus	EnergyPlus is DOE's whole-building energy simulation engine. EnergyPlus includes advanced simulation features including sub-hourly time steps, simultaneous solution of zone conditions and HVAC system actions, a modular HVAC structure that accommodates a wide range of system configurations, and a runtime scripting language for user-defined control strategies.
6	Autodesk Insight	<p>Autodesk® Insight is a powerful guide to Better Building Energy and Environmental Performance. It is a fast, intuitive outcome driven guide to better building energy & environmental performance throughout the building lifecycle. It let visualize and interact with key performance indicators, benchmarks, factors, ranges and specifications with real time. Modelling with FormIt Pro and Revit to generate insights using analytical model creation and visualization of performance information directly in the modelling environment.</p> <p>It uses industry simulation engines (for example EnergyPlus) for whole building energy, heating, cooling, daylighting, and solar simulations with parallel cloud computing techniques to represents millions of potential outcomes simultaneously.</p>
7	HVACSIM+	Simulation model of a building HVAC (heating, ventilation, and air-conditioning) mechanical system plus HVAC controls, the building shell, the heating/cooling plant, and energy management and control system (EMCS) algorithms. The main program of HVACSIM+ (HVAC SIMulation PLUS other systems) employs a hierarchical, modular approach and advanced equation solving techniques to





		perform dynamic simulations of building/HVAC/control systems. The modular approach is based upon the methodology used in the TRNSYS program.
8	Honeybee	Honeybee tool connects the visual programming environment of Grasshopper to four validated simulation engines - specifically, EnergyPlus, Radiance, Daysim and OpenStudio - which evaluate building energy consumption, comfort, and daylighting. These plugins enable a dynamic coupling between the flexible, component-based, visual programming interface of Grasshopper and validated environmental data sets and simulation engines.
9	EcoDesigner Star - ArchiCAD – Graphisoft	EcoDesigner STAR tool offers standard-compliant energy analyses on the BEM and produces a detailed building performance report, all within the familiar ArchiCAD design environment. . Essentially technicians can use their ArchiCAD BIM as a BEM. EcoDesigner supports authoring tools in ArchiCAD by fully integrating energy evaluation and reporting, according to international energy standards into the BIM.
10	EFEN	EFEN is a next generation energy analysis tool using EnergyPlus simulation engine and intelligent building generator. It is packaged in a suitable program for quick analysis in early stages of design, comparative energy analysis of different fenestration options and prediction of the whole building energy use, and prediction of the size of HVAC equipment.
11	ESBO	<p>ESBO (Early Stage Building Optimization) is a simulation tool for building design optimization based on EQUA's building performance software IDA Indoor Climate and Energy (IDA ICE).</p> <p>ESBO allows to experiment with different building designs and equipment in order to predict the consequences on energy use and comfort. Room-level and central HVAC systems may be evaluated, as well as glazing, shading and construction materials - all without the need of creating a complete geometric model of the building. Three types of studies are possible with ESBO: 1/ Whole year energy use. 2/ Cooling design (or summer overheating) according to the ASHRAE heat balance method and 3/ Heating design (winter heat load) according to the ASHRAE heat balance method.</p>
12	IDA Indoor Climate and Energy	IDA Indoor Climate and Energy (IDA ICE) is a whole year detailed and dynamic multi-zone simulation application for the study of indoor climate as well as energy. The physical models of IDA ICE reflect the latest research and best models available, and results compare well with measured data. While serving a global market, IDA ICE is adapted to local languages and requirements (climate data, standards, special systems, special reports, and product and material data).
13	TRNSYS	TRNSYS (TRaNsient SYstem Simulation Program) is an open source, energy simulation program. TRNSYS includes a graphical interface, a simulation engine, and a library of components that range from various building models to standard HVAC equipment to renewable energy and emerging technologies. TRNSYS also





		<p>includes a method for creating new components that do not exist in the standard package.</p> <p>This simulation package has been used for HVAC analysis and sizing, multizone airflow analyses, electric power simulation, solar design, building thermal performance, analysis of control schemes, etc. TRNSYS also interfaces with various other simulation packages such as COMIS, CONTAM, EES, Excel, FLUENT, GenOpt and MATLAB.</p>
14	Sefaira Systems	Built on EnergyPlus, Sefaira Systems enables users to carry out analysis of HVAC options and deliver insight quickly and cost-effectively. It can be used to: justify high-performance designs, define space requirements early and explore multiple systems to optimise performance.
15	Sefaira Architecture	Sefaira offers both SketchUp and Revit realtime plugins that provide constant feedback on both energy & daylighting metrics, as well as web apps for deeper comparative and parametric analysis. Sefaira's Web App for architecture is built for comparative and parametric analysis. Cloud computing enables multiple parallel runs with no reduction in speed
16	FineGREEN	FineGREEN is a BIM simulation environment that combines the Building Information Modeling power and user friendliness of the 3D Building interface, with the reliability and accuracy of the EnergyPlus® calculation engine.
17	ENERWIN Pro - Annual energy simulation for new or existing code-compliant buildings.	ENERWIN PRO© is a Windows-based hourly energy simulation model for evaluating whole-building energy performance and peak loads. The program features an interactive graphical interface for input and output and a built-in weather database for 4777 cities.
18	Smart-Energy	Smart Energy is a state-of-the-art web based energy analysis and thermal load simulation tool that uses the EnergyPlus engine.
19	COMFIE	Performs hourly simulations of buildings, in order to provide with accurate estimates of a building's energy needs and temperature profiles. The output comprises the yearly and hourly heating loads, hourly and mean temperatures in the thermal zones. COMFIE building model is also coupled to additional modules (PV generation, earth tube). Graphs and histograms may be obtained from PLEAIDES, the user-friendly interface of COMFIE.
20	CYPETHERM Suite	Group of CYPE programs for thermal and energy analysis of buildings according to the Radiant Time Series Method (RTSM), proposed by ASHRAE. The applications that work with the 3D model of the building are integrated in the OPEN BIM workflow via the IFC4 standard.
21	BSIMAC	BSIMAC's three main functions are: (a) calculation of the cooling/heating loads and the required capacities of HVAC equipment, (b) annual energy simulation of the building and HVAC equipment, and (c) calculation of the expected room (space)



		temperatures with no cooling or heating on summer and winter design days.
22	Simulation X Green Building	<p>Simulation X Green Building is a flexible simulation environment for modelling, calculation and analysis of building and district energy systems. Power, heat and in particular coupled networks: fit generation capacity, transmission paths and storage accurately to various usage scenarios</p> <p>Regarding e-mobility, SimulationX can modeled, simulated and analyzed charging stations with their own energy supply, examining the influence of recuperation in your power grid and using electric vehicle fleets as mobile energy storage.</p>
23	eQUEST	<p>eQUEST is a whole building energy performance design tool. Its wizards, dynamic defaults, interactive graphics, parametric analysis, and execution make eQUEST able to conduct whole-building performance simulation analysis throughout the entire design process, from the earliest conceptual stages to the final stages of design</p> <p>eQUEST's simulation engine is DOE 2.2</p> <p>Its inputs can be provided at three levels: schematic design wizard, design development wizard, and detailed (DOE-2) interface.</p>
24	OpenStudio	<p>OpenStudio is an open-source SDK (software development kit) for building energy simulation. OpenStudio provides a large library of common helper functions for creating, querying, and transforming energy models, running simulations, and working with results.</p> <p>A significant feature of OpenStudio is that its API (application programming interface) is accessible via a variety of scripting languages. The scripting facility allows OpenStudio to be customized and extended in a flexible way. Among its most common utilities is the automation of energy conservation measures that can be applied to existing models, hence the scripts are often referred to as "measures".</p>
25	Tas Engineering	<p>Tas is a building modelling and simulation tool, capable of performing dynamic thermal simulation for large and complex buildings, and allows designers to accurately simulate daylighting and predict energy consumption, CO2 emissions, operating costs and occupant comfort</p>
26	Ecotect	<p>ECOTECH is a conceptual design analysis tool that features overshadowing, shading design, lighting, acoustic and wind analysis functions as well as thermal. It uses the CIBSE Admittance Method to calculate heating and cooling loads for any number of zones within a model. These loads factor in direct and indirect solar gains (with the option of calculating full overshadowing percentages for each hour of the day throughout the year), internal gains, inter-zonal heat flow and pull-down loads due to intermittent usage. It can display hourly internal temperatures and load breakdowns as well as annual temperature distributions and the effects of thermal mass.</p>



These tools (table 1), available in the market today, that allow the whole building modelling and dynamic simulation present different characteristics. For instance: open source tools, closed source, free, under paid, free under special conditions such as for academic use, tools for being used on Windows, Linux, Mac OS or Web/SaaS platforms.

2.2. Criteria set for evaluation

The selection of the most suitable tool will be made on the basis of the criteria set listed below: one that meets the highest number of indispensable or recommendable requirements for the development of the ePANACEA methodology of the project. The requirements to value are:

1. Open source tool
2. Free of charge
3. HVAC system modelling and sizing
4. Load Calculation
5. Lighting system modelling
6. Air flow simulations
7. Modularity

As the tool will be used in different countries, it is not required to check regulatory compliance at the moment. On the other hand, the plugin to check compliance can be developed by each country later. Similarly, given that one of the main objectives of the project is the harmonisation of the EPCs across the EU-27+Norway+UK, it is not necessary that the tool includes any previous rating capabilities.

2.2.1. Open Source Building Energy Software Tools

Open source software is code that is designed to be accessible to the public: code can be used and modified to create new extensions, patches or solutions. Open source is exactly what allows any developer to create compatible applications which can solve almost any computational need.

Open source software is developed in a decentralised and collaborative way. It is often cheaper, more flexible and more durable than proprietary alternatives, because it is developed by communities rather than by a single author or company.

Starting from an open source software for the development of the method 3 of ePANACEA methodology allows to adopt current capabilities of the software as a base, concentrating the ePANACEA project's effort, not on the creation of building energy simulation tools and/or their "replication" from scratch, but on the most innovative functions of the project such as: the implementation of smart and novel technologies, sensitivity analysis, calibrated simulation, automated calibration techniques and innovative indicators and outcomes that allow the improvement of current EPC schemes in terms of accuracy, convergence of quality, reliability, market trust and user friendliness.

2.2.2. Free of charge

Free software does not depend on decisions of large software manufacturers and is not subjected to impose requirements. The neutrality of this type of software allows the user to decide whether to migrate or update the system. In addition, it avoids intellectual property damage to the software. The management of copyright with the free software philosophy shows that it is possible to legitimately defend these rights without falling into the harmful system of patents, which favours the oligopolies of the sector.

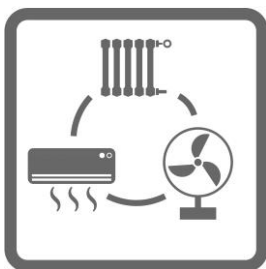
2.2.3. Load Calculation

Load calculation is the method used to determine heating and cooling loads of a building or thermal zone. The amount of heat that needs to be added to a building to bring its users to a comfortable temperature is called the heating load and the amount that needs to be removed, for the same purpose, is called the cooling load.

The hourly load calculation in a building is essential to be able to perform a calibrated energy model. Using a tool that already has this capability eliminates the need to develop it within the Method 3, allowing focusing efforts on the innovative features of the ePANACEA project such as inverse modelling, building model calibration.

2.2.4. HVAC system selection and sizing

Besides the introduction of thermal characteristics of the building envelop and load calculation, the thermal energy performance of a building is intrinsically related to the definition of its HVAC systems, including generation and distribution systems for heating, cooling and ventilation services. In this sense, it is necessary that the simulation tool include the possibility of HVAC definition through a wide range of possibilities for generation (e.g. boilers, heat pumps, chillers, etc.), emission systems (e.g. baseboards, low temperature radian floor, fan coils, air handling units, etc.) and distribution systems (e.g. fans, pumps, pipes, etc.).



On the other hand, building energy modeling tools often include auto-sizing capabilities. This is particularly relevant when it is desired to model complete and complex HVAC systems, since the number of input parameters required can increase drastically (i.e. thermal power, air flow rates, water flow rates, heat exchangers and coil thermal characteristics, etc.)

This capability is specially desired for the tool used in Method 3, since it aims to develop accurate models in a cost-efficient way, which means that modeling HVAC systems as a whole is needed but optimizing the effort on introducing input parameters.

2.2.5. Lighting system modelling

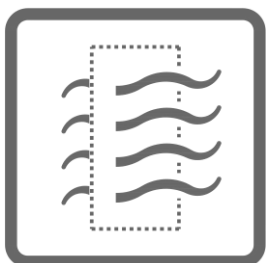
Lighting is one of the most relevant services in commercial buildings and has a significant influence on their energy consumption and therefore on their global energy assessment.

Then, Method 3 requires a tool able to model lighting systems as a whole, for instance power density, level of illuminance provided and lighting schedules, including smart control strategies that allow energy savings such as lighting control according to natural light availability.

Method 3 shall include a detailed definition of the lighting system and be able to calculate the lighting demand and energy consumption associated with the lighting installation in buildings.



2.2.6. Air Flow simulations



Knowledge of airflow in and around buildings is necessary for heat and mass transfer analysis such as load energy calculations, for thermal comfort assessment, for indoor air quality studies, for system control analysis, for contaminant dispersal prediction, etc. (Hensen, J.L.M. 2004).

The definition of outdoor air flow rates for each air handling system will be required within Method 3, as well as their hourly variation profile, if any.

One of the main reasons why the control of air flow rates is important for building energy performance is energy savings, i.e. air leaking out of a building must be replaced with outdoor air which requires energy to condition it. Approximately 30% to 50% of space conditioning energy consumption in many well-insulated buildings is due to air leakage through the building envelope. Convective circulation and wind washing both reduce the effectiveness of thermal insulation and thus increase energy transfer across the envelope.

In addition to influencing energy efficiency, air flows influence humidity control within the building, as well as human comfort and health. The envisioned next generation of energy performance certificates aims to include among its results those that building users consider relevant.

On the basis of the user workshops carried out in the ePANACEA project, one of the aspects that users have shown interest in is in regards to comfort and Indoor Air Quality indicators. Therefore, the ability to perform air flow analysis for building simulation is positively evaluated.

2.2.7. Modularity

Modular programming is based on the top-down design technique, which consists of dividing the original problem into several subproblems that can be solved separately, and then recomposing the results to obtain the solution to the problem. A subproblem is called a module and is a part of the problem that can be solved independently. The fact that a module is independent allows, on the one hand, concentrating on solving it, forgetting the rest of the problem, and on the other hand, it allows reusing the solution obtained for another part of the program or another different program.

Modularity in calculation programs allows researchers to develop modules simultaneously without interfering with other modules under development and with limited knowledge of the entire program structure. This feature is essential to promote both the widespread use and the broad development of software models. The success of programmes is greatest if the pool of potential model developers is significantly increased, so that interest and economics drive which models are added to the programme rather than their extensions being limited by a lack of intellectual resources.

The use of a modular programme will facilitate the development of Method 3 by being able to generate, into the ePANACEA project, modules of each new capability and so allow their independent implementation depending on the necessities.

2.3. Decision matrix and tool selection

For the selection of the dynamic simulation tool that will be finally used to develop the energy assessment Method 3, a decision matrix has been developed according to the criteria set. Then, the features described in the previous sections have been evaluated through this decision matrix and their weighting factors.

As mention before, some of these capabilities referred to non-functional requirements while others are referred to functional requirements. Non-functional capabilities have been considered most important features for the methodology development; therefore, a higher score has been allocated to these. The scores given are as follows:

Non-functional capabilities

- Open source: 3 points. The benefits of using open source software are innumerable, including the possibility of developing in a decentralised and collaborative way.
- Free of charge: 2 points. The availability of free simulation tools on the market is a great advantage. The use of free software for the development of method 3 within the context of ePANACEA project makes the project independent of the proprietary business decisions.

Functional capabilities

- HVAC System Selection and Sizing: 1 point
- Load calculation: 1 point
- Lighting simulation: 1 point
- Air Flow Simulation: 1 point
- Modular Approach: 1 point



The content of these functional capabilities in the tools is not as essential as the previous characteristics, since the use of an open source and free of charge tool would allow the implementation of these needs from the development of the ePANACEA project itself, if necessary. However, the greater number of functional capabilities contained in the base tool will allow the optimisation of ePANACEA project resources in the development and implementation of the most innovative and relevant aspects for the project in the selected software. For all these reasons, each capability of the software is evaluated with 1 point.

The resulting matrix is shown below.





Table 2: Decision matrix for the selection of the base software for the development of method 3 of the SEPAP methodology

Tool*	Open Source Free of charges		Load Calculations	HVAC System Selection and Sizing	Lighting Simulation	Air Flow Simulation	Modular Approach	Calculation Engine/ Collaboration with program	Normalized Global Rating (0-1)
	Points assigned	3	2	1	1	1	1		
1 Design Builder			x			x		EnergyPlus	0,2
2 IES Virtual Environment			x	x	x			IESVE	0,3
3 Modelica Buildings library	x	x				x	x	Modelica	0,7
4 Simergy		x		x				EnergyPlus	0,3
5 EnergyPlus	x	x	x	x	x	x	x	EnergyPlus	1
6 Autodesk Insight					x			EnergyPlus	0,1
7 HVACSIM+		x	x	x			x	HVACSIM+	0,5
8 Honeybee	x	x			x			EnergyPlus	0,6
9 EcoDesigner Star - ArchiCAD - Graphisoft	x			x				StruSoft's VIPcore	0,4
10 EFEN				x				EnergyPlus	0,1
11 ESBO		x	x					IDA ICE	0,3
12 IDA ICE				x				IDA ICE	0,1
13 TRNSYS	x						x	TRNSYS	0,4
14 Sefaira Systems			x	x				EnergyPlus	0,2
15 Sefaira Architecture					x			EnergyPlus	0,1
16 FineGREEN			x	x				EnergyPlus	0,2
17 ENERWIN Pro - Annual energy simulation for new or existing code-compliant buildings.			x					ENERWIN	0,1
18 Smart-Energy			x					EnergyPlus	0,1
19 COMFIE			x					COMFIE	0,1
20 CYPETHERM Suite		x	x					EnergyPlus	0,3
21 BSIMAC			x	x				BSIMAC	0,2
22 SimulationX Green Building				x				Modelica	0,1
23 eQUEST			x			x		DOE 2.2	0,2
24 OpenStudio	x	x			x			EnergyPlus	0,6
25 Tas Engineering			x	x			x	Tas Engineering	0,3
26 Ecotect			x		x			CIBSE	0,2

The matrix has been completed on the basis of information obtained from the "Building Energy Software Tools" website (<https://www.buildingenergysoftwaretools.com/>) as well as from official websites. The overall rating in



Table 2 has been normalised to lie between the values 0 and 1.

According to the result of the matrix, the most suitable tool for Method 3 development is **EnergyPlus**.

EnergyPlus is a simulation tool designed to model buildings with their heating, cooling, ventilation, lighting, DHW,... systems. This calculation engine was designed to be an element within a system of programs that would include a graphical interface for the building to be described by the user, such as OpenStudio. Although EnergyPlus can be used independently without such an interface, OpenStudio greatly facilitates the input of complex geometries and building systems.



As can be seen in the matrix (

Table 2), OpenStudio, like EnergyPlus, is also an open-source and free program, which makes it suitable to be used in combination with EnergyPlus for the Method 3 development, thus adding the benefits of both programs.

It is important to highlight the fact that, while some building energy performance simulation (BEPS) tools are in themselves their own calculation engine, many others act just as a graphical interface for introduction of input parameters into the models and use other programs as their calculation engine. For example; DesignBuilder uses EnergyPlus as calculation engine and eQUEST uses DOE 2.2.

The previous matrix includes a section identifying the calculation engine of each of the assessed tools. As can be seen, a large percentage of the most recognised BEPS tools use EnergyPlus as their calculation engine or are complementary tools to it (46%). This is indicative of the high reliability of the EnergyPlus software on the current market.

2.4. Key aspects of the tool selected

In addition to all the aspects assessed in the decision matrix, it is worth noting that EnergyPlus and OpenStudio have a number of other capabilities that are beneficial for the development of the ePANACEA project.

Below is a brief summary of some of the key aspects of the selected tools:

2.4.1. Ease of modelling complex geometries

SketchUp was born as a 3D modelling software that has always aimed to be simple, yet powerful and capable of delivering exceptional results. This tool also has two versions, one of which is a paid version (SketchUp Pro) and a second free version (SketchUp Make). This simplicity in its 3D modelling, the possibility of making it available free and the fact that it is an open source tool have made it a 3D modelling computer program for a wide range of applications in drawing, architecture, interior design, mechanics, etc. There are more than 100 alternatives to SketchUp for various platforms.

OpenStudio is one of these programs. When installed, it introduces an additional toolbar in the SketchUp interface that allows users to quickly create geometry needed for EnergyPlus as well as other parameters of the building such as type of construction, thermal zones, windows and boundary conditions among others.

2.4.2. EMS Control

Among all simulation capabilities contained in EnergyPlus is the ability to provide a way to develop custom modelling and control routines for its models. The Energy Management System (EMS) is one of the high-level control methods available in EnergyPlus. An EMS is able to access a wide variety of “sensor” data and use this data to direct various types of control actions. The concept is to emulate, inside EnergyPlus, the types of controls possible with the digital energy management systems used in real buildings.

In the hierarchy of EnergyPlus controls, the EMS module is a high-level, generalized, supervisory control for building systems. The EMS replicates the functionality of many of the existing high-level control objects in EnergyPlus, can turn on and off pumps and fans, can turn on and off lights and electric equipment, change the set points on zone thermostats, and dispatch on-site generation, can change the set points on system nodes, can turn on and off supply-side heating, cooling, and heat rejection equipment (i.e., boilers, chillers, cooling towers, etc.) and can turn on and off on-site generation equipment.

The EMS allows writing its own custom computer programs having a thorough understanding of how someone wants its models to behave. The EMS uses the EnergyPlus Runtime Language (Erl) for custom programming of control routines.

2.4.3. Ease of programming energy measures

In OpenStudio it is possible to program measures in a simple way. A “Measure” is a program (or 'script', or 'macro') that can access and leverage to a building energy model and create changes, defined by an OpenStudio model (.osm).

Typically, a "measure" modifies an existing .osm to implement a particular energy conservation measure (ECM). For example, a measure may vary the thickness of the thermal insulation of the building envelope, modify the characteristics of the windows, or change the hours of operation or occupancy.

OpenStudio also has so-called "reporting" measures that can generate reports on the input and/or output data of a given energy model.

The easy generation of energy conservation measures as well as reporting increases the benefits of using such a tool for the next generation of energy performance certification of buildings.

2.4.4. Building Component Library (BCL)

In addition to the useful OpenStudio capabilities, OpenStudio offers the Building Component Library (BCL) (<https://bcl.nrel.gov/>) where users can browse through a large number of already developed measures for OpenStudio. The Building Component Library (BCL) is a comprehensive online library from the US Department of Energy. Users can use the freely available, uniquely identified components to create energy models.

The BCL contains components that are the building blocks of an energy model. They can represent physical characteristics of the building, such as roofs, walls and windows, or they can refer to related operational information, such as occupancy and equipment schedules and weather information. Each component is identified by a set of attributes specific to its type, as well as other metadata such as provenance information and associated files.

The BCL also contains energy conservation measures (ECM), referred to as measures, which describe a change to a building and its associated model. For the BCL, this description attempts to define a measure for reproducible application, either to compare it to a baseline model, to estimate potential energy savings, or to examine the effects of a particular implementation.

Measures can be downloaded directly from BCL via the OpenStudio application and the ParametricAnalysisTool.

2.4.5. Parametric Analysis Tool

OpenStudio has the OpenStudio Parametric Analysis Tool (PAT) that allows the programme to perform parametric analysis using the tool. This tool allows quickly trying out and comparing manually specified combinations of measures, optimizing designs, calibrating models, performing parametric sensitivity analysis, etc. Manually specified combinations of measures may be run locally on your computer. Algorithmic analyses (e.g. optimization, etc) can be run on the cloud.

3. ePANACEA CONCEPT

The ePANACEA concept redefines the EPC (Energy Performance Certification) for buildings beyond the current concept. ePANACEA aims to develop an energy assessment and certification methodology valid at different levels, from EPC assessor to end users and policy makers, and from a basic assessment to a complete energy audit. The ePANACEA methodology is the result of this holistic, accurate, flexible and modular approach for EPCs, which will be integrated on a web platform so-called the SEPAP (Smart Energy Performance Assessment Platform).

Next generation of EPCs needs a next generation of Web based tools and their innovative capabilities. In this case, the whole ePANACEA methodology, based on three different energy assessment methods and its decision matrix for the selection of the most suitable one for each assessment object, will be integrated on the SEPAP.

The SEPAP will integrate inverse modelling and automated calibration procedures for dynamic Building Energy Simulations, obtaining very accurate models but reducing at the same time the computational cost and improving the cost-effectiveness of the whole process.

The decision matrix provides guidance on the most suitable method to use with a reasonable accuracy and uncertainty level according to the building type and other characteristics of the assessment object (for instance: availability of data, building use, building size, complexity of HVAC systems, presence of BACS and/or RES technologies, etc.).

1. Assessment method 1: Smart & performance data-driven energy performance assessment (IEA EBC Annex 71).
2. Assessment method 2: Simplified method based on monthly calculation (ISO 52016) interval and its calibration.
3. Assessment method 3: Advanced & automated simulation modelling based on hourly calculation (ISO 52017) and its calibration.

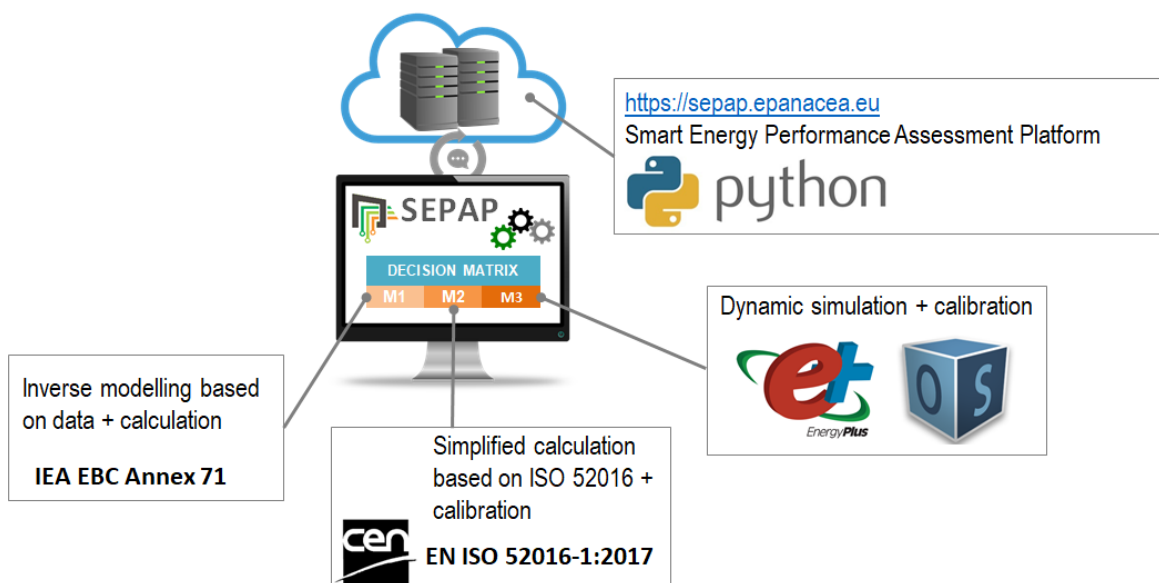


Figure 1: ePANACEA approach for the methodology development

Due to Method 3 is envisioned as the most complete of the three assessment methods, covering a higher number of features and capabilities, aiming to meet the highest level of accuracy of the outcomes, for instance the disaggregation of energy use per each service or energy saving quantification derived from EEM – Energy Efficiency Measure - implementation, it will require



a combined approach based on a local tool, that means locally installed in the user PC, besides the SEPAP (web platform). This approach is schematically represented in the figure below.

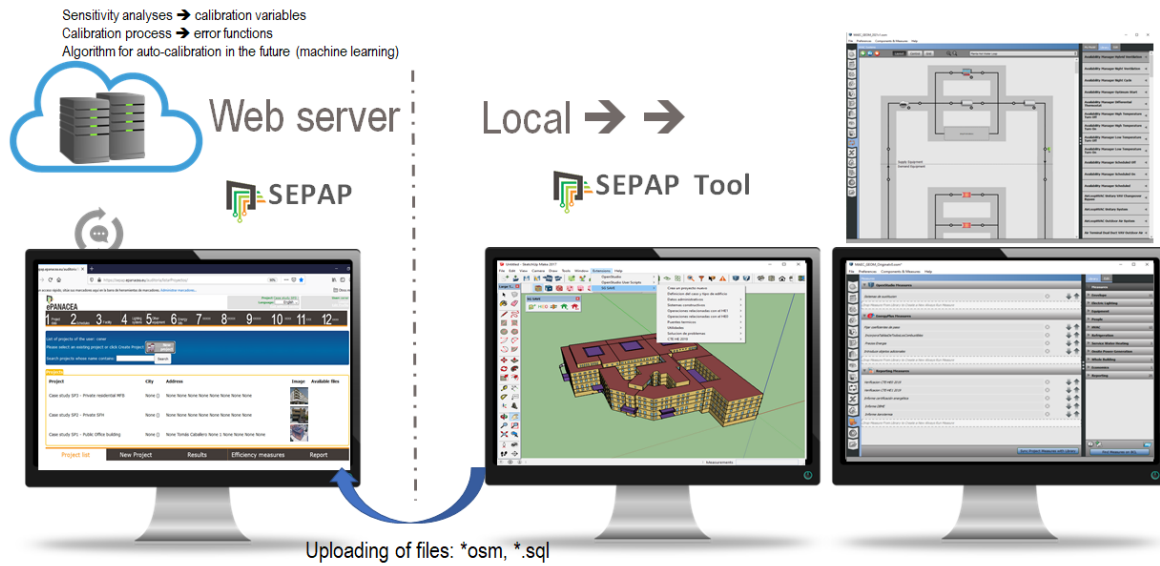


Figure 2: Tools supporting the development and implementation of Method 3 within ePANACEA concept

The local tool, so-called the SEPAP tool will allow the modelling through Open Studio in an easier manner, including specific measures for some modelling aspects such as introduction of some typical combinations of HVAC systems as well as control strategies (BACS). Then the model can be run locally and the files exported from the SEPAP tool (i.e. formats *.osm and *.sql) will be uploaded to the SEPAP (web platform) in order to take advantages of their capabilities to applied automated calibration techniques.

Finally, all information regarding the building model, input parameters (e.g. building information such as measured data) and results from the energy performance assessment conducted will be stored on the SEPAP to be consulted by technicians and consumers.



4. ISO 52000 SERIES COMPLIANCE OF METHOD 3

The ISO 52000 is part of a series (52xxx series) aimed at the international harmonization of the methodology for assessing the energy performance of buildings. This series is referred to as a "set of EPB standards". All EPB standards follow specific rules to ensure overall consistency, unambiguity and transparency, providing certain flexibility with regard to the method.

Directive 2010/31/EU in its ANNEX I: Common general framework for the calculation of the energy performance of buildings already mentioned that the methodology for the calculation of the energy performance of buildings in Member States "...shall take into account European standards and shall be consistent with relevant Union legislation...".

Annex I of Directive (EU) 2018/844 includes among its requirements that: *"Member States shall describe their national calculation methodology following the national annexes of the overarching standards, namely ISO 52000-1, 52003-1, 52010-1, 52016-1 and 52018-1, developed under mandate M/480 given to the European Committee for Standardisation (CEN). This provision shall not constitute a legal codification of those standards."* The annexes to the standards with which the Member States must comply are listed below:

<p>ISO 52000-1:2017: Energy performance of buildings - Overarching EPB assessment. Part 1: General framework and procedures.</p> <p>Annex A (normative). Input and method selection data sheet – Template (default choices are provided in Annex B)</p>
<p>ISO 52003-1:2017: Energy performance of buildings – Indicators, requirements, rating and certificates. Part 1: general aspects and application to the overall energy performance.</p> <p>Annex A (normative). Input and method selection data sheet – Template (default choices are provided in Annex B)</p>
<p>ISO 52010-1:2017: Energy performance of buildings – External climatic conditions. Part 1: conversion of climatic data for energy calculations.</p> <p>Annex A (normative). Input and method selection data sheet – Template (default choices are provided in Annex B)</p>
<p>ISO 52016-1:2017: Energy performance of buildings – Energy needs for heating and cooling, internal temperatures and sensible and latent heat loads. Part 1: Calculation procedures.</p> <p>Annex A (normative). Input and method selection data sheet – Template (default choices are provided in Annex B)</p>
<p>ISO 52018-1:2017: Energy performance of buildings – Indicators for partial EPB requirements related to thermal energy balance and fabric features. Part 1: Overview of options.</p> <p>Annex A (normative). Input and method selection data sheet – Template (default choices are provided in Annex B)</p>

Of the standards listed in the table above and based on the relative position of all these documents within the set of EPB standards in the context of the modular structure as set out in EN ISO 52000-1, shown in Table 3, only standards 52016-1, 52017-1 and 52018-1 refer to the description of the building (as such). Of these three standards the relative position of 52018-1 would be module M2-4 referring to "Ways of expressing energy performance". The compliance with this module M2-4 will be done by the energy certification report issued by the SEPAP development within the ePANACEA project.

The other standards (52000-1, 52003-1 and 52010-1) are standards referring only to general descriptions of the EPB itself.



Table 3: EPB standards in the EPB modular structure EN ISO 52000-1. (Font: “EPBD: the “software proof” check of the CEN / ISO standards– from the methodology to practical tools” REHVA Journal – October 2016)

Overarching		Building (as such)			Technical Building Systems																					
sub1	IM1	Standards	Descriptions	IM2	Standards	sub1	Descriptions	IM3	Heating	IM4	Cooling	IM5	Ventilation	IM6	Humidification	IM7	Dehumidification	IM8	Domestic hot water	IM9	Lighting	IM10	Building automation & control	IM11	Electricity production	
1	General	EN ISO 52000-1 CEN ISO/TR 52000-2	General	1	General	1	General	EN 15316-1	EN 15316-1	EN 15316-1	EN 15316-1	EN 15316-1	EN 15316-1	EN 15316-1	EN 15316-1	EN 15316-1	EN 15316-1	EN 15316-1	EN 15316-1	EN 15189-1	EN 15232 CEN/TR 15232	EN 15232 CEN/TR 15232	EN 15232 CEN/TR 15232	EN 15232 CEN/TR 15232		
2	Common terms and definitions, units and subscripts	EN ISO 52000-1 CEN ISO/TR 52000-2	Building Energy Needs	2	EN ISO 52016-1 EN ISO 52017-1 CEN ISO/TR 52016-2	Needs	Needs																			
3	Applications	EN ISO 52000-1 CEN ISO/TR 52000-2	(Free) Indoor Conditions without Systems	3	EN ISO 52016-1 EN ISO 52017-1 CEN ISO/TR 52016-2	Maximum Load and Power	Maximum Load and Power	EN 12831-1	EN 12831-1	EN 12831-1	EN 12831-1	EN 12831-1	EN 12831-1	EN 12831-1	EN 12831-1	EN 12831-1	EN 12831-1	EN 12831-1	EN 12831-1	EN 12831-1	EN 12831-1	EN 12831-1	EN 12831-1	EN 12831-1		
4	Ways to Express Energy Performance	EN ISO 52000-1 EN ISO 52003-2	Ways to Express Energy Performance	4	EN ISO 52016-1 EN ISO 52017-1 CEN ISO/TR 52016-2	Ways to Express Energy Performance	Ways to Express Energy Performance	EN 15316-1	EN 15316-1	EN 15316-1	EN 15316-1	EN 15316-1	EN 15316-1	EN 15316-1	EN 15316-1	EN 15316-1	EN 15316-1	EN 15316-1	EN 15316-1	EN 15316-1	EN 15316-1	EN 15316-1	EN 15316-1	EN 15316-1		
5	Building Functions and Building Boundaries	EN ISO 52000-1 CEN ISO/TR 52000-2	Heat Transfer by Transmission	5	EN ISO 13789 EN ISO 13790 EN ISO 14883 CEN ISO/TR 52019-2 EN ISO 10077-1 EN ISO 10077-2 EN ISO 12831	Emission & control	Emission & control	EN 12098-1 EN 12098-2 EN 12098-3 EN 12098-5	EN 12098-1 EN 12098-2 EN 12098-3 EN 12098-5	EN 12098-1 EN 12098-2 EN 12098-3 EN 12098-5	EN 12098-1 EN 12098-2 EN 12098-3 EN 12098-5	EN 12098-1 EN 12098-2 EN 12098-3 EN 12098-5	EN 12098-1 EN 12098-2 EN 12098-3 EN 12098-5	EN 12098-1 EN 12098-2 EN 12098-3 EN 12098-5	EN 12098-1 EN 12098-2 EN 12098-3 EN 12098-5	EN 12098-1 EN 12098-2 EN 12098-3 EN 12098-5	EN 12098-1 EN 12098-2 EN 12098-3 EN 12098-5	EN 12098-1 EN 12098-2 EN 12098-3 EN 12098-5	EN 12098-1 EN 12098-2 EN 12098-3 EN 12098-5	EN 12098-1 EN 12098-2 EN 12098-3 EN 12098-5	EN 12098-1 EN 12098-2 EN 12098-3 EN 12098-5	EN 12098-1 EN 12098-2 EN 12098-3 EN 12098-5	EN 12098-1 EN 12098-2 EN 12098-3 EN 12098-5	EN 12098-1 EN 12098-2 EN 12098-3 EN 12098-5	EN 12098-1 EN 12098-2 EN 12098-3 EN 12098-5	
6	Building Occupancy and Operating Conditions	EN 15798-1 CEN/TR 16798-2 (ISO 17771-1, ISO/TR 17771-2)	Heat Transfer by Infiltration and Ventilation	6	EN ISO 13789 EN ISO 13790 EN ISO 14883 CEN ISO/TR 52019-2 EN ISO 10077-1 EN ISO 10077-2 EN ISO 12831	Distribution & control	Distribution & control	EN 12098-1 EN 12098-2 EN 12098-3 EN 12098-5	EN 12098-1 EN 12098-2 EN 12098-3 EN 12098-5	EN 12098-1 EN 12098-2 EN 12098-3 EN 12098-5	EN 12098-1 EN 12098-2 EN 12098-3 EN 12098-5	EN 12098-1 EN 12098-2 EN 12098-3 EN 12098-5	EN 12098-1 EN 12098-2 EN 12098-3 EN 12098-5	EN 12098-1 EN 12098-2 EN 12098-3 EN 12098-5	EN 12098-1 EN 12098-2 EN 12098-3 EN 12098-5	EN 12098-1 EN 12098-2 EN 12098-3 EN 12098-5	EN 12098-1 EN 12098-2 EN 12098-3 EN 12098-5	EN 12098-1 EN 12098-2 EN 12098-3 EN 12098-5	EN 12098-1 EN 12098-2 EN 12098-3 EN 12098-5	EN 12098-1 EN 12098-2 EN 12098-3 EN 12098-5	EN 12098-1 EN 12098-2 EN 12098-3 EN 12098-5	EN 12098-1 EN 12098-2 EN 12098-3 EN 12098-5	EN 12098-1 EN 12098-2 EN 12098-3 EN 12098-5	EN 12098-1 EN 12098-2 EN 12098-3 EN 12098-5	EN 12098-1 EN 12098-2 EN 12098-3 EN 12098-5	
7	Aggregation of Energy Services and Energy Carriers	EN ISO 52000-1 CEN ISO/TR 52000-2	Internal Heat Gains	7	See M1-6	Storage & control	Storage & control	EN 15316-15 EN 15316-16	EN 15316-15 EN 15316-16	EN 15316-15 EN 15316-16	EN 15316-15 EN 15316-16	EN 15316-15 EN 15316-16	EN 15316-15 EN 15316-16	EN 15316-15 EN 15316-16	EN 15316-15 EN 15316-16	EN 15316-15 EN 15316-16	EN 15316-15 EN 15316-16	EN 15316-15 EN 15316-16	EN 15316-15 EN 15316-16	EN 15316-15 EN 15316-16	EN 15316-15 EN 15316-16	EN 15316-15 EN 15316-16	EN 15316-15 EN 15316-16	EN 15316-15 EN 15316-16	EN 15316-15 EN 15316-16	
8	Building Zoning	EN ISO 52000-1 CEN ISO/TR 52000-2	Solar Heat Gains	8	EN ISO 52022-3 EN ISO 52022-4 CEN ISO/TR 52022-2	Generation & control	Generation & control	EN 12098-1 EN 12098-2 EN 12098-3 EN 12098-5	EN 12098-1 EN 12098-2 EN 12098-3 EN 12098-5	EN 12098-1 EN 12098-2 EN 12098-3 EN 12098-5	EN 12098-1 EN 12098-2 EN 12098-3 EN 12098-5	EN 12098-1 EN 12098-2 EN 12098-3 EN 12098-5	EN 12098-1 EN 12098-2 EN 12098-3 EN 12098-5	EN 12098-1 EN 12098-2 EN 12098-3 EN 12098-5	EN 12098-1 EN 12098-2 EN 12098-3 EN 12098-5	EN 12098-1 EN 12098-2 EN 12098-3 EN 12098-5	EN 12098-1 EN 12098-2 EN 12098-3 EN 12098-5	EN 12098-1 EN 12098-2 EN 12098-3 EN 12098-5	EN 12098-1 EN 12098-2 EN 12098-3 EN 12098-5	EN 12098-1 EN 12098-2 EN 12098-3 EN 12098-5	EN 12098-1 EN 12098-2 EN 12098-3 EN 12098-5	EN 12098-1 EN 12098-2 EN 12098-3 EN 12098-5	EN 12098-1 EN 12098-2 EN 12098-3 EN 12098-5	EN 12098-1 EN 12098-2 EN 12098-3 EN 12098-5	EN 12098-1 EN 12098-2 EN 12098-3 EN 12098-5	
9	Calculated Energy Performance	EN ISO 52000-1 CEN ISO/TR 52000-2	Building Dynamics (thermal mass)	9	EN ISO 13786	Load dispatching and operating conditions	Load dispatching and operating conditions	EN 15316-3	EN 15316-3	EN 15316-3	EN 15316-3	EN 15316-3	EN 15316-3	EN 15316-3	EN 15316-3	EN 15316-3	EN 15316-3	EN 15316-3	EN 15316-3	EN 15316-3	EN 15316-3	EN 15316-3	EN 15316-3	EN 15316-3	EN 15316-3	
10	Measured Energy Performance	EN ISO 52000-1 CEN ISO/TR 52000-2	Measured Energy Performance	10	...	Measured Energy Performance	Measured Energy Performance	EN 15316-3	EN 15316-3	EN 15316-3	EN 15316-3	EN 15316-3	EN 15316-3	EN 15316-3	EN 15316-3	EN 15316-3	EN 15316-3	EN 15316-3	EN 15316-3	EN 15316-3	EN 15316-3	EN 15316-3	EN 15316-3	EN 15316-3	EN 15316-3	
11	Inspection	...	Inspection	11	(existing standards on IR inspection, airtightness,...)	Inspection	Inspection	EN 15316-1	EN 15316-1	EN 15316-1	EN 15316-1	EN 15316-1	EN 15316-1	EN 15316-1	EN 15316-1	EN 15316-1	EN 15316-1	EN 15316-1	EN 15316-1	EN 15316-1	EN 15316-1	EN 15316-1	EN 15316-1	EN 15316-1	EN 15316-1	
12	Ways to Express Indoor Comfort	EN 15798-1 CEN/TR 16798-2 (ISO 17771-1, ISO/TR 17771-2)	Indoor Comfort	12	...	BMS	BMS	EN 15316-1	EN 15316-1	EN 15316-1	EN 15316-1	EN 15316-1	EN 15316-1	EN 15316-1	EN 15316-1	EN 15316-1	EN 15316-1	EN 15316-1	EN 15316-1	EN 15316-1	EN 15316-1	EN 15316-1	EN 15316-1	EN 15316-1	EN 15316-1	
13	External Environment Conditions	EN ISO 52010-1 CEN ISO/TR 52010-2	External Environment Conditions																							
14	Economic Calculation	EN 15459-1	Economic Calculation																							

4.1. Energy assessment

As mentioned in the previous section, only the standards EN ISO 52016-1 and EN ISO 52017-1 are related to the calculation of energy assessment of buildings as such. For this reason, this section focuses on the compliance of these standards by EnergyPlus tool.

The ISO 52016-1 standard specifies the hourly calculation of the energy need for heating and cooling and the internal temperature. The method covers also the hourly calculation of the design load for cooling, heating, humidification and dehumidification for a thermal zone and for a sub system. As with all ISO 52000 series standards, the indicated recommendations (default choices) in it are not mandatory and offer some flexibility, although strict compliance is based on following specific rules to ensure consistency, unambiguity and transparency above all. In this regard, this document indicates that Table C.1 will be used to identify alternative regional references in line with ISO's Global Relevance Policy.



Section 5.2.1 of EN ISO 52016-1 specifies; *"The hourly calculation procedures in this document are derived from the reference calculation procedures as given in ISO 52017-1"* and *"The underlying document is an application of the method provided in ISO 52017-1. In function of the application, specific assumptions, simplifications, solution techniques and input data restrictions are provided in the underlying document"*. The EN ISO 52016-1 is based on the reference procedure of 52017-1 using some simplifications. Looking at the modular structure of the EPB standards (Table 3) and checking it, can be seen that the modules referred to in EN ISO 52017-1 and EN ISO 52016 are the same: M2.2, M2.3, M3.3, M4.3, M6.3 and M7.3.

The EN ISO 52017-1 standard describes a general method for physics modelling (i.e. energy balances). It is intended to be used by specialists to develop hourly or sub-hourly calculation methods for indoor temperatures and/or heating, cooling and/or humidification loads of a thermal zone in a building.

The BESTEST (Building Energy Simulation Test) procedure was developed for systematically testing whole building energy simulation programs and diagnosing sources of predictive disagreement. This way, the appropriateness of a given software package for a given design problem, could quantitatively be judged.

The BESTEST reference is mentioned in the Quality Control section of EN ISO 52017-1 standard where it is stated that: "The "BESTEST" test suite, standardized as ANSI/ASHRAE 140, comprises a number of test cases that are appropriate for validation of the calculation methods described in this document."

This standard also clarifies that EN ISO 52016-1 includes specific procedures based on the generic procedures of this document (EN ISO 52017-1) and uses for validation a subset of the BEST (standardised as ANSI/ASHRAE 140): *"... Instead, the "BESTEST" test suite, standardized as ANSI/ASHRAE 140, comprises a number of test cases that are appropriate for (optional) validation of the calculation methods described in this document. The relevant subset of BESTEST cases is similar to the test cases of ISO 13791. The most relevant BESTEST cases have been adopted in ISO 52016-1 for verification of the specific calculation procedures of that standard."*

Back to EnergyPlus compliance with 52016-1 and 52017-1, what makes a calculation engine as reliable as possible is to make it as bug-free as possible. For that an important ongoing part of EnergyPlus development is testing using industry standard methods as major builds are completed. The EnergyPlus building energy simulation software has been tested with several test suites among them ANSI/ASHRAE Standard 140-2011 (BESTEST). EnergyPlus testing reports are available on its website for many of the BESTEST suites compare the results of multiple simulation programs.

EnergyPlus is more general than EN ISO 52016-1 standard prescribes (e.g. conduction transfer functions, integrated solver instead of energy demand balances first and supply balances later). The International Building Performance Simulation Association (IBPSA) recognized EnergyPlus as a detailed dynamic simulation tool. EnergyPlus results have been validated over

the years in numerous papers. I. Ballarini, A. Constantino, E. Fabrizio and V. Corrado (2019), in "The Dynamic Model of EN ISO 52016-1 for the Energy Assessment of Buildings Compared to Simplified and Detailed Simulation Methods" compared the hourly method for the assessment of the energy needs of buildings for heating and cooling introduced by EN ISO 52016-1 against EnergyPlus. They concluded that the hourly method of EN ISO 52016-1, properly customized as regards input parameters, demonstrated to provide results that are more similar to the ones of a detailed dynamic simulation (EnergyPlus) if compared to the hourly method of EN ISO 13790 that is a simplified method considered reliable for the energy needs assessment of simple case studies.

According with the specifications of the ISO 52017-1 standard; *"The absence of conformance criteria and deviation allowances is a drawback of the ANSI/ASHRAE 140 test suite. At the same time, the available results from renowned software tools are not per se the best results because each of these tools has its specific type of application and scope with specific limitations."* This could be one of the reasons why EnergyPlus, although being a detailed and globally renowned dynamic simulation software tool and having performed comparative testing of the ANSI/ASHRAE 140 Standard does not specify that it complies with EN ISO 52017-1. On the other hand, under the current EPBD framework, EnergyPlus engine is currently recognised by some Member States as a valid tool for building energy performance assessments in the context of EPC schemes and verification of minimum energy performance requirements.

On 8th of May of 2019, the Commission published a document of recommendations on how to implement the EPBD 2018: <https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1557992239852&uri=CELEX:32019H0786>. Point 3.3.1 states:

"In response to the need for greater comparability and transparency, the EPBD requires Member States to describe their national calculation methodology in line with the national annexes to the overarching standards (168) developed by the European Committee for Standardisation (CEN) under mandate M/480.

"While Recital 40 of Directive (EU) 2018/844 recognises that the use of the EPB standards [...] would have a positive impact on the implementation of the EPBD, Annex I to the EPBD makes clear that this is not meant to be a legal codification of those standards or to make them mandatory."

4.2. Certification procedures

As Table 3 shows the standards ISO 52000-1, ISO 52003-1 and ISO 52010-1 are standards referring to General Descriptions of the EPB itself and the ISO 52018-1 relative position, in that figure, is module M2-4 referring to "Ways of expressing energy performance".

As well as in ISO 52016-1 and ISO 52017-1 there is a "Validation" section (where it must be justified that the energy assessment selected meets the standard requirements), the compliance of the ISO 52000-1, ISO 52003-1, ISO 52010-1 and ISO 52018-1 standards is just linked to give the information of the choices made for each of the descriptions, inputs, methods, procedures... by regulators. These choices, that can be informative default choices or choices adapted to national/regional needs, are collected in the Annex A or in case of default choices Annex B.

Therefore, compliance with these ISO 52000 series standards is defined by current regulations and is independent of the calculation tool used for the energy assessment.

However, this calculation tool shall take into account the choices selected in these standards and be able to adapt its outputs to comply with them.

Since both EnergyPlus and OpenStudio are open source tools, compliance with these standards is not a problem and appropriate measures can be programmed for compliance within the ePANACEA project, if necessary.





5. REFERENCES

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