1) Recommendations on energy assessment methodology and tools for EPCs from a technical perspective

The suggested methodology from ePANACEA project aims to overcome current EPC challenges:

- Challenge 1: gap between standard outcomes of EPC schemes and real consumption patterns
- Challenge 2: lack of accuracy of the building's energy assessment results
- Challenge 3: poor user awareness related to energy efficiency
- Challenge 4: lack of convergence across the European Union
- Challenge 5: inclusion of smart and novel technologies
- Challenge 6: lack of trust in the market

To overcome the above challenges, the next generation of EPCs needs to include:

A next generation of features related to input data, covering for instance:

- Improved consideration of user behaviour and occupant patterns.
- Inclusion of smart and novel technologies, such as on-site production of renewable energy and advanced energy management systems.
- Use of building monitoring data to increase accuracy

A next generation of outcomes that include among others:

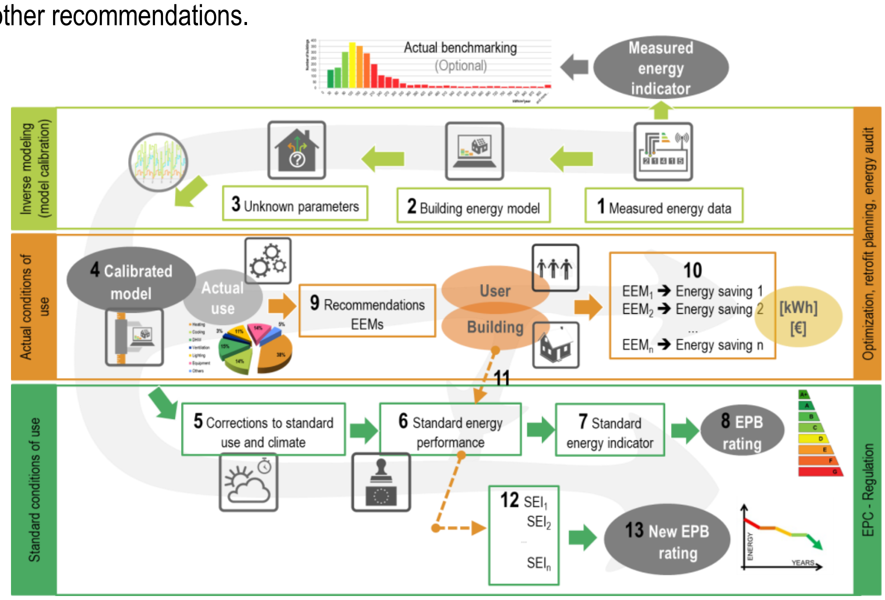
- New global and partial indicators better understandable by end users based on actual energy use
- Recommendations related to user behaviour.
- Tailored recommendations based on cost-optimal solution for deep renovation of buildings.
- Double oriented information included in the EPC; on one side focused on Administration needs based on standardized operational conditions and on the other side focused on building users' needs based on actual use.

A next generation of tools:

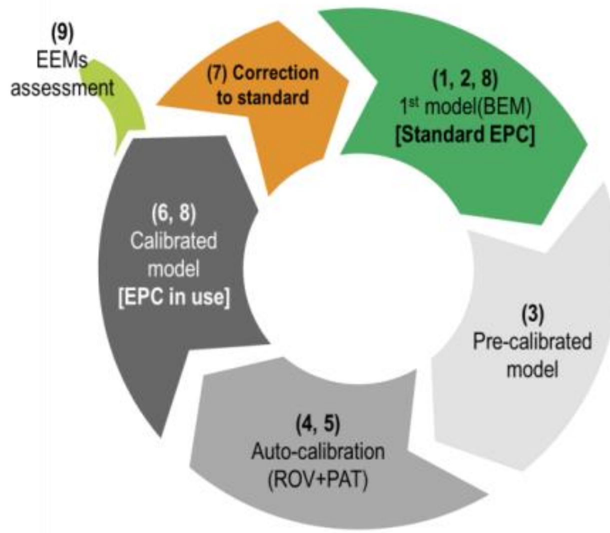
Next generation of EPCs needs a next generation of web based tools and their innovative capabilities, taking advantage of power computing on cloud.

ePANACEA suggestion integrates inverse modelling and automated calibration procedures for dynamic Building Energy Simulation (BES), obtaining very accurate models but reducing at the same time the computational cost and improving the cost-effectiveness of the whole process.

The suggested approach to cover the double perspective (Administration and user needs) is summarized in the figure below, also included in the report [Report on the use of innovative certification schemes and its implementation | Zenodo] among other recommendations.



Specifically this approach, which is based on the use of auto-calibration of white-box building energy models to improve accuracy and provide results based on both, standardized and actual operational conditions, is explained in this video tutorial about ePANACEA method 3 of energy assessment: ePANACEA Method 3 of Assessment - Tutorial - YouTube. The global concept of the suggested methodology for EPCs is most summarized in the figure bellow, the so-called "**EPC cycle**". This approach implements a sequential structure that enables obtaining a calibrated model based on actual consumption patterns (i.e. EPC in use) at the same time that will provide a more accurate standard EPC after correction by climate and use. This approach covers two different perspectives for the EPC; on one side improving the information provided to end-users based on their actual consumption patents through the "EPC in use" and on the other hand, the "Standard EPC" will keep the Administration requirements for the objective comparison of the buildings stock.



The workflow's steps included within the "EPC cycle" are explained as follows:

1. Data gathering; building documentation, utility bills, monitoring data from BMS, spot measurements, actual weather data…
2. Development of a first version for the BEM with dedicated tools
3. Definition and adjustment to actual peak loads and operational schedules
4. Classification of data sources to define calibration variables and their ROV (range of variation-%)
5. Auto-calibration: use of parametric assessments and optimization algorithms.
6. Selection of the final calibrated model (i.e. values for calibration variables).
7. Correction to standard; weather data, operational schedules, peak loads…
8. Results: overall performance indicators, partial indicators, monthly disaggregation per fuel and service.
9. EEMs based on actual use (i.e. calibrated BEM)

Some conclusions regarding the suggestion/recommendation to increase quality of energy assessments:

- The development of accurate models that reduce the current performance gap between theoretical and real consumption is possible with cost-effective procedures (e.g. 2-3 work days for complex buildings).
- With the appropriate tools, it is possible and viable to extrapolate the methodology based on auto-calibrated white-box models, from the scientific to commercial environments.
- The multiobjective optimization based on genetic algorithms plus parametric analysis, enables the reduction of computational cost of the calibration process.
- The automatization of the workflow based on available computational tools will reduce professional training requirements in terms of cost and time.

- If the suggestion of energy efficiency measures is not based on actual energy use of the building (i.e. calibrated model), we cannot ensure an accurate forecast of energy saving derived from their implementation.

- The use of calibrated models within EPC schemes would reduce the uncertainty of some parameters, also used for the "EPC standard", such as envelope thermal transmittance or air changes per hour.

- End-users show a higher level of engagement on energy efficiency when the EPC information is based on their occupant behaviour patterns (i.e. real energy use) and they perceive this information as helpful for decision making regarding investments on energy refurbishments.

2) Main policy recommendations from D.3.2[1] *Insights on user perceptions and needs regarding the Energy Performance Certificate (EPC)*

Recommendations for the implementation of EPC as a policy tool

- Registration of EPCs should be mandatory and there should be central institutions where the EPCs are registered.
- Site visits should be mandatory when issuing an EPC.
- Energy auditors should be certified in order to improve the quality of the EPC.
- Requirements to issue an EPC should become more precise and demanding so that less experts are allowed to issue an EPC. EPC certifiers should receive regular training
- In addition to improving the enforcement and quality monitoring of EPC, also the *communication* about the EPC to end-users should be improved by intermediaries (certifiers, assessors, building companies, selling agencies and town councils).

Recommendations for the generation of the EPC

- Include electricity demand in the EPC since in the long term the use of electricity in households will increase (e.g. looking at Electric vehicles, PV-systems and heat pumps).
- Include information about solar gains of the building.
- Normalize energy demand for local weather.
- Use a comprehensive database for calculating and storing data. Database should provide updated information about e.g. measures, investment costs, energy costs, conversion factors.

Recommendations for the content and visualization of information in the EPC

- If a common EPC template is chosen for EU member states in order to harmonize the EPCs there should be space for additional national indicators and it should be possible that countries apply their own rating scheme (e.g. double glazing might be good in Spain but not in Finland, nuclear energy is considered as sustainable in France but not in Austria etc.)

[1] Insights on user perceptions and needs regarding the Energy Performance Certificate (EPC) | Zenodo

- Split the EPC into pages oriented towards a) experts & administration and b) end-users due to their different understanding and interests.
- Pursue the idea to make the EPC digital. This would have the advantage that additional information could easily be accessed by interested end-users and that the information could be updated ("dynamic EPC).
- Provide partial indicators e.g. for walls, floor, roof, doors and windows to make it comprehensible where the weak points of the building are.
- Include additional indicators: indoor air quality, thermal comfort, smart readiness of the building, the fraction of RES production for statistical purpose and national energy policy.
- Use benchmarking for final energy use and CO_2 emissions (importance of the reference).
- General concern: be clear about the purpose of an improved EPC. A high quality EPC will cost more. Can a mandatory document become much more expensive?

Recommendations for the EPC oriented towards experts and administration

- An annex with e.g. information about the data used for calculation of the EPC should be included (expert, Germany)

Recommendations for the EPC oriented towards end-users

- Streamline the content of the EPC for end users: do not make the EPC more complex, reduce the content for end users, additional information should be covered in an additional document/tool. The EPC for end users could be simplified by graphic representations, clear and short messages. E.g., indicators such as the total energy efficiency factor fGEE (included in the Austrian EPC) and primary energy use, are often not understood by end users could be left out.

- Show the end-user dimension in the EPC because this would show how behavior patterns affect the energy use inside the building. E.g. consider a customizable EPC/ the use of user profiles. Experts suggested using an additional tool to "interpret" the numbers in the EPC according to one's consumption behavior and household composition to set the values provided in the EPC into context and to make them more tangible to the end user.
- Include cost indications in the EPC.
- Provide more detailed and individual recommendations for renovations
    - Information on what measure (and how much it would cost) to upgrade the energy efficiency class for example from G to F, or to E (road map)
    - Provide information about realistic investment costs, annual energy savings.

In order to directly refer to draft revision of the EPBD, comments below in red font:

Annex V- proposal for recast EPBD 2021 recommendations.
" On its front page, the energy performance certificate shall display at least the following elements:

(a) the energy performance class; ☑

(b) the calculated annual primary energy use in kWh/(m^2 year); ☑

(c) the calculated annual primary energy consumption in kWh or MWh;

During the last user workshop we received the feedback that it is sufficient to provide information in kWh/m2year. By knowing the area of the building, information in kWh or MWh can easily be calculated.

(d) the calculated annual final energy use in kWh/(m2 year); ☑

(e) the calculated annual final energy consumption in kWh or MWh;

Same comment as above.

(f) renewable energy production in kWh or MWh; ☑

(g) renewable energy in % of energy use; ☑

(h) operational greenhouse gas emissions (kg CO2/(m^2 year)); ☑

(i) the greenhouse gas emission class (if applicable)."