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# Executive Summary

This report is Deliverable 2.4 of E-DYCE project, which utilizes the outputs of WP1 to consolidate the E-DYCE DEPC process into a protocol. In Chapter 1, the framework for the development of the protocol is split into four steps:

1. Specification of E-DYCE DEPC scope, where the performance gap (PG) detection and reduction is seen as an ultimate outcome of the E-DYCE certification.
2. Detailing of E-DYCE DEPC methodology to carry out the certification.
3. Development of the protocols for E-DYCE DEPC, including the relevance and adoption of specific CEN/ISO standards.
4. Structuring identified KPIs to offer to the end-users the best possible service by addressing their needs.

In this regard, Section 2 details the scope of E-DYCE DEPC, stating that the E-DYCE DEPC approach is dedicated to accurate energy performance evaluation, where the primary purpose of comfort considerations is then to detect causes of the performance gap and to support potential improvement for PG elimination and the energy need reduction.

The E-DYCE DEPC methodology is detailed in Section 2, defining the assessment schemas for the E-DYCE certification according to EN ISO 52000-1. Following assessment schemas are selected for application within E-DYCE:

- [EPC], where building energy performance is estimated according to the current steady-state approach (EPBD 2018 Directive).
- [DEPC – AS], where building energy performance is estimated for standard weather conditions and standard loads.
- [DEPC – AA], where building energy performance is estimated for actual climatic conditions and loads, which are modified from standard, to approach real conditions, so-called "Adapted conditions", which are defined in section 2.2.2.
- [DEPC-O], where building performance is estimated under the actual climatic conditions and actual building use and operation data, so-called monitored performance.

Finally, in section 3, the key performance indicators for E-DYCE DEPC are summarized and grouped into the following main families. These families are:

- ***Energy operation KPIs*** -more specifically the energy needs in the building, to support identification of the performance gap.
- ***The energy signature KPIs*** -to ease the evaluation of the performance gap of a building/zone due to the operational thermal conditions.
- ***Comfort/quality KPIs*** – to support detection of causes for the performance gap.
- ***Free-running operation*** **KPIs** – to address issues in certification of low-tech buildings, but also to support passive strategies application in buildings.

# 1 Introduction to E-DYCE DEPC Protocol

E-DYCE (Energy flexible Dynamic building Certification) is the Energy Performance Certification which offers near real-time optimization of building performance and comfort, by capturing the building's dynamic behavior and at the same time providing transparent feedback, through an intuitive protocol interface. This includes a potential forecast of performance, related to climate change, change of user behavior, and the assessment of renovation roadmaps.

Among other things, the E-DYCE objective is to support communication between labeling professionals, building owners, and energy service companies to cultivate benefits in both indoor climate and energy savings, including the free-running potential and smartness in buildings.

The shortcomings of current steady-state labeling approaches (EPBD 2018 Directive) are identified as the main open issues in E-DYCE deliverable 1.2 to be treated within the E-DYCE project. These are listed below.

- Free-running and passive technologies
- The smart readiness vision
- Energy metering and district network communication
- Dynamic hourly models and performance gap
- Renovation and operation roadmap

For each initially identified issue, a list of relevant Key Performance Indicators is established in deliverable 1.2, where KPIs are grouped according to the following main families:

1. Energy and energy efficiency (including a reduction in energy needs)
2. Free running operation and potential exploitation (including temperature performances)
3. Comfort/quality (including thermal comfort improvement, indoor air quality)
4. Smartness readiness
5. Correlated indicators (including Energy demand forecast; Economic indices; and Climate change impact indices)

It is relevant to mention that this report (deliverable 2.4) addresses only the KPI within the first three groups (1-3), as these are directly integrated into E-DYCE protocol, which consolidates the E-DYCE DEPC process. Furthermore, family 1, dealing with the energy and energy efficiency in this report is split into the energy operation and the energy signature, as it is elaborated in section 0. Meanwhile, the other families of KPIs (4-5) have a different nature, and they do not take an active part in the E-DYCE certification process but can function as a supplement to it. The correlated indicator in the family 5, such as the energy demand forecast is addressed in task 3.4 of the project, and it is aimed at informing users and thereby at influencing their behavior positively. The economic indices in the family 5 are addressed in the project via the renovation roadmaps using the least coast approach for weighting the energy savings against the cost of intervention. Finally, it has to be mentioned that the climatic change impact indices are not addressed in E-DYCE.

E-DYCE platform includes Python Real-time Energy dynamics and Climate Evaluation module (PREDYCE), which can offer parametric simulation, simulation under real weather data conditions, comparison between calculated and measured performance, performance evaluation with changed conditions of use, etc. These capabilities within the dynamic building simulation address the above-stated issues while resulting in a massive amount of output being produced. Thus, in the E-DYCE the advantage of vast capabilities to produce results can become a challenge to identify, calculate, and isolate relevant results.

This challenge is addressed in this report by the consolidation of the E-DYCE DEPC process by:

1. Specification of E-DYCE DEPC scope, where the performance gap reduction is seen as the ultimate outcome of the E-DYCE certification.
2. Detailing of E-DYCE DEPC methodology to carry out the certification.
3. Development of the protocols for E-DYCE DEPC, including the relevance and adoption of specific CEN/ISO standards.
4. Structuring identified KPIs to offer to the end-users the best possible service by addressing their potential demands.

# 2 E-DYCE DEPC approach

This section addresses the scope of E-DYCE DEPC and details the methodology for the E-DYCE DEPC certification in relation to the well-known static EPC approach (EN ISO 52000-1) and discusses the potential E-DYCE process in relation to the DEPC stages described in the Grant Agreement.

## *2.1 The scope of E-DYCE DEPC*

The inability of current steady-state energy labeling approaches to accurately reflect dynamic conditions within and outside the building is argued to be the main reason for the presence of the performance gap, resulting in limited exploration and incitement for the potential improvements.

Another significant aspect argued to cause the performance gap is related to the building use and the operational conditions. The first one is normally expressed by the occupancy and the internal loads in the building and the latter one addresses the use/abuse of the systems in the building. Building operational conditions are typically expressed through preferences to the set-points, habits for natural ventilation, use of shading, but also can relate to the ways occupants resolve comfort issues, if there are any. In this perspective, the deviation between the expected and realized comfort conditions within a building can be seen as a way to identify and (if relevant) quantify the increase of the energy demand caused by this deviation.

In this regard, not only the buildings with mechanical systems can be characterized in terms of the performance gap, but also the low-tech buildings with absent mechanical systems or the hybrid ones, i.e. heating system present/no cooling system or cooling system present/no heating. In mechanically operated buildings, the performance gap will then be evaluated via traditional performance indexes, for example, heating/cooling needs, which are sensitive to the operational conditions and building use. For the low-tech buildings, fully or partly functioning in the free-running mode, defined in Deliverable 1.2, the fictitious energy needs can be representative of the performance gap.

With the scope of performance gap (PG) detection and its' further reduction, the E-DYCE DEPC approach is dedicated to accurate energy performance evaluation, where the primary purpose of comfort considerations is then to detect causes of the performance gap and to support potential improvement for PG elimination and the energy need reduction.

A clear definition of the E-DYCE scope is of key importance for detailing the E-DYCE methodology and for the development of the E-DYCE protocol and selection of the right KPIs.

## *2.2 E-DYCE DEPC methodology*

The logic behind E-DYCE DEPC approach is described in the grant agreement and is further detailed in D1.2, where the functionality and the links between E-DYCE modules are elaborated. Though, the certification procedure and the information necessary to certify a building according to the E-DYCE approach have not yet been defined.

Deliverable 1.2 describes three main stages of the E-DYCE process, these are:

- Stage 1: Inputs and data collection;
- Stage 2: Monitoring and implementation of dynamic certification methodology; and
- Stage 3: User feedback and actuation.

For the certification procedure, Stage 1 is responsible for the definition of the baseline model of the building or building space unit. Stage 2, is dedicated to the development of the models that can address the shortcomings of the present steady-state EPC, by incorporating capabilities of E-DYCE modules, such as free-running operation, sensor inputs, model calibration, operational rating, weather forecast, etc. Stage 3 corresponds to the communication of outputs from Stage 1 and Stage 2 to the user.

The principal development of building models for Stages 1 and 2 of the E-DYCE process is addressed in WP2 and WP3. Also, the definition of a baseline model and the models in Stage 2 must be made already in this protocol, as it is critical for the E-DYCE certification process. Moreover, it requires a decision about zoning and system-related assumptions in the models. The zoning assumptions, in this case, are related to the geometry of the model and rely on a common methodology to be developed within E-DYCE for the definition of thermal zones within the model. The system-related assumptions, on the other hand, are related to the definition of systems within a model, where the same system can be modeled in several ways including loads, schedules, and set-points in multiple ways. With regards to geometry and systems in the models, EDYCE approach seek for simplicity in model development while ensuring good credibility of results. This activity is reflected in Task 2.3 and 3.5.

For the time being, the E-DYCE protocol is developed without final decision about zoning or systems. That means that a refinement of the protocol may take place in the future.

Looking at, the scope of the E-DYCE project about the performance gap detection and its reduction, it can be argued that the models in Stage 2, ideally, must approach the actual building performance, if all issues of the current EPC have been addressed. In practice, though, it will not be possible, due to many reasons, such as: compulsory model simplification, absent data about user behavior and building operation, assumed envelope properties, etc. Therefore, building models in Stage 2 can only to some degree contribute to the elimination of the performance gap, when compare between models in Stage 1 and Stage 2.

The performance gap is closely related to the assessment schema used for the certification. In E-DYCE deliverable 1.2 it is stated that the procedure for the rating of buildings in E-DYCE will be based on EPC assessment types according to EN ISO 52000-1, (Table 1). In addition, it is concluded that the static EPC asset rating should be included along with dynamic operational and asset rating, to function as a reference when moving from EPC to DEPC.

**Table 1. Assessment types for EPC according to (EN ISO 52000-1)**

| Type of EPC | Sub-type | Building | Climate | Loads |
|---|---|---|---|---|
| Asset rating | Design | Design | Standard | Standard |
| | As-built | Actual | Standard | Standard |
| | Actual | Actual | Actual | Actual |
| | Tailored | Purpose-based | | |
| Operational | Actual | Actual | Actual | Actual |
| | Climate-corrected | Actual | Corrected to standard | Actual |
| | Use-corrected | Actual | Actual | Corrected to standard |
| | Standard | Actual | Corrected to standard | Corrected to standard |

Schemas relevant for the E-DYCE certification procedure are summarized in Table 2. Here, only one type of dynamic operational rating is included, namely Operational – Actual [DEPC-O]. Among other things, it functions as a reference for PG estimation when moving between different schemas of asset rating. DEPC-O always refers to operational building certification under the actual climatic conditions and actual building use and operation, based on measured properties when no corrections have been applied.

Contrary to the operational rating, the asset rating in E-DYCE DEPC process is introduced at several levels and represents calculated values of building performance:

- [EPC] – building performance estimated according to current steady-state approach (EPBD 2018 Directive).
- [DEPC – AS] – building performance estimated in Stage 1 of E-DYCE DEPC process, for standard weather conditions and standard loads. For this model, a definition of standard conditions has been made and it is elaborated on in section 2.2.1. These conditions to a higher degree correspond to EPC calculation conditions. Thus, by moving from EPC to DEPC-AS model, only some of the dynamic aspects of building performance are being addressed, for example, 24-hour load profiles, climatic conditions, and the possibility for detailed inclusion of thermal mass of the building.
- [DEPC – AA] – building performance estimated in Stage 2 of E-DYCE DEPC process, performed for actual climatic conditions and loads which are modified from standard, to approach real conditions. In Table 2 these conditions are named “Adapted”, meanwhile the definition of these conditions is found in section 2.2.2. Accordingly, the models in Stage 2 of the E-DYCE DEPC process are the closest approximation to an actual building operation. These models include all aspects of dynamic building performance that are possible to address in the models under standardized procedures.

**Table 2. Assessment types for EPC according to (EN ISO 52000-1)**

| Type of assessment | EPC/DEPC | Short name | Sub-type | Building | Climate | Loads | Comment |
|---|---|---|---|---|---|---|---|
| **Asset** | EPC | EPC | Design | Design | Standard | Standard | EPC-label |
| | DEPC | DEPC – AS | As-built | Actual | Standard | Standard | Asset rating Standard |
| | DEPC | DEPC – AA | As-built | Actual | Actual | Adapted | Asset rating Actual |
| **Operational** | DEPC | DEPC – O | Actual | Actual | Actual | Actual | Reference for PG evaluation |

In this way, the suggested E-DYCE DEPC procedure relies on already existing standardized procedures, provides a reference to well-known static EPC schema, and at the same time meets the goal of E-DYCE project for performance gap detection and elimination, while being transparent and applicable for any building type and independent of the technologies present within the building.

Here, it is important to highlight that in E-DYCE DEPC total demands are seen of less importance, as the certification is performed for the distributed demands, such as energy demand for heating, cooling, domestic hot water, artificial lighting, etc. This also means that some of these demands can be absent, but the certification can still be carried out. This also explains why E-DYCE certification will not generate a new type of label, but instead uses already existing labeling schema for PG detection and reduction.

### 2.2.1 Definition of standard conditions in DEPC –AS

Standard conditions in DEPC-AS are representative of standard conditions in EPC calculation procedures. In this way, it is possible to ensure that the dynamically calculated energy demands in DEPC-AS models are directly comparable to the EPC results if distributed to corresponding demands. For example, standard conditions in DEPC-AS will be identical to the conditions used in the hourly method to calculate the energy loads and needs for heating in ISO 52016-1. Thus, the heating demand calculated according to EPC schema and according to DEPC-AS are comparable.

Accordingly, the identification of standard conditions is not a part of E-DYCE project, as the framework for their definition and identification is already described in EN ISO 52000-1 and other relevant standards.

### 2.2.2 Definition of adapted conditions in DEPC –AA

The adapted conditions are defined as conditions that approach actual building use and operation. These conditions include such aspects as loads, set points, and schedules, which typically relate to users and systems in buildings. These aspects will be explained in section 2.2.3.

Knowledge of these conditions can be limited even after completing an inspection. Therefore, several levels of these adapted conditions can be identified, where the user can select among pre-defined conditions, alter pre-defined conditions, and/or generate their adapted conditions, if feasible.

The adapted conditions must be able to address:

- National or local operational tradition, which is identified using national standards or guidelines
- Dynamic capability of the systems in the building. More specifically, the dynamic control of the system in the model shall take place only if the stated system control can actually be performed

in the building to ensure that the actual system capabilities are aligned with the way they are being modeled.

- Actual building use, by allowing the user to refine the adapted conditions according to the inspection results.

It is essential to mention, that not all of the above points can be realized to the same extend within the E-DYCE project, but these are named, to illustrate the potential upgrade of the E-DYCE DEPC approach if commercialized.

### 2.2.3 Identification of adapted conditions

The adapted conditions can be established at three different levels:

- Based on *national/local* guidelines or requirements
- Based on the *inspection plan*, which does not include building monitoring, but still addresses specific dynamic properties of the building and its systems and can include short-term measurement as a part of the inspection, i.e. blower-door test for building tightness, thermographic test for identification of the cold bridges, questionnaire with tenants, etc.
- Based on information from the long-term *monitoring* of the building, which allows modifying system definitions and schedules in the model

These adapted conditions include specification of loads, schedules, and set points within the building for:

- Internal loads (occupancy and appliances)
- Cooling and heating systems
- Ventilation system, including natural ventilation and infiltration
- Shading system

In table 4, standard conditions, identified according to EN 16798-1 are presented against Danish rules and guidelines. The example does not include any inspection- or monitoring and therefore these conditions are only marked as potentially available (✓).

It is important to mention, that besides the set-points and loads, the adapted conditions can include schedules, which are defined for weekdays and weekends. An example of a schedule for the internal loads from occupants is given in Figure 1. Although the schedule for building use can be altered, it is assumed that the overall building use and the operation time remain the same as in the standard conditions.

The adapted conditions are only defined as representative of the demo cases in E-DYCE.

**Table 3. Parameters in the definition of building operation time acc. to EN 16798-1.**

| | |
|---|---|
| **operation time** | Hour at day, START |
| | Hour at day, END |
| | Breaks, inside range |
| | days/week |
| | hours/day |
| | hours/year |

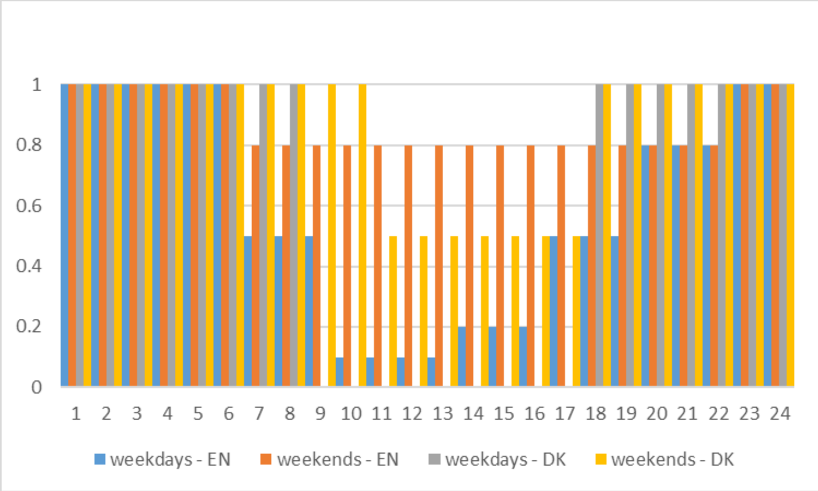


**Figure 1. Schedule of occupancy according to EN 16798-1 and according to guideline in Denmark.**

**Table 4. An example of standard and adapted conditions for a dwelling in DK.**

| Residential, apartment. DENMARK | Standard | Standard- Modified | | |
|---|---|---|---|---|
| | | National/Local | Inspection-based | Monitoring |
| Occupancy: | | | | |
| Occupants (dry) W/m2 | 2.8 | 1.5 | ✓ | ✓ |
| Appliances: | | | | |
| Appliances, W/m2 | 3 | 3.5 | ✓ | ✓ |
| Lighting, W/m2 | 0 | 0 | ✓ | ✓ |
| Shading: | | | | |
| Max irradiance for activation | 300 W/m2 | - | ✓ | ✓ |
| Min irradiance for deactivation (shading up) | 200 W/m2 | - | ✓ | ✓ |
| Heating: | | | | |
| Start of the heating season, date | Defined according to demand | Defined according to demand | Suggested methodology | ✓ |
| End of the heating seaoson, date | | | | |
| Heating set point, deg C | 20 | 20 (dwellings), 22 (other) | ✓ | ✓ |
| Cooling: | | | | |
| Start of the heating season, date | - | - | ✓ | ✓ |
| End of the heating seaoson, date | | | | |
| Cooling set point, deg C | 26 | 26/27 | ✓ | ✓ |
| Ventilation: | | | | |
| Start of ventilation, date | 01-Jan | 01-Jan | ✓ | ✓ |
| End of ventilation, date | 31-Dec | 31-Dec | ✓ | ✓ |
| Mechanical airflow rate(min), l/s per m2 | 0.5 | 0.35 | ✓ | ✓ |
| Natural ventilation rate (min), l/s per m2 | 0 | 0 | ✓ | ✓ |
| Infiltration rate, l/s per m2 | 0 | 0.13 | ✓ | ✓ |
| Humidity min, % | 25 | none | ✓ | ✓ |
| Humidity max, % | 60 | none | ✓ | ✓ |
| Hot water | | | | |
| Domestic hot water use, l/m2 per year | 100 | 250 (dwellings) 100 (other) | ✓ | ✓ |

*✓ – means that this information can potentially be available as a result of inspection or monitoring*

## *2.3 E-DYCE DEPC process*

Deliverable 1.2 – "Definition of dynamic and operational EPC specifications" introduces main E-DYCE modules, all of which are necessary to perform DEPC. In full, the role of each E-DYCE module for the DEPC process will be specified by the end of the project. This section describes superficially the actions, related to some of the modules only to support the understanding of the E-DYCE certification process.

Stage 1 includes the building inspection, DEPC-AS model development, and its first run followed by the preparation of the monitoring plan. These actions provide a jumpstart for obtaining actual climatic conditions, definition of adapted conditions, operational data, etc., which are the key for E-DYCE DEPC.

In Stage 2, the implementation of the inspection plan, in terms of DEPC-AA models generation as well as the alignment of the monitored data (DEPC-O) with the results of simulation in Stage 1 and 2 are carried out. These actions represent the first and the main step necessary for E-DYCE certification. Integration of the prediction and retrofitting modules do not influence the certification process, but function rather as a supplementary service for the end-users towards building energy improvement.

Similarly, the user feedback in terms of certification, in Stage 3 will only include the information about building performance within selected in Table 2 certification schemas. Furthermore, the information produced in Stage 3 of E-DYCE DEPC is highly correlated with the extent of initial information gathered in Stage 1 and generated in Stage 2. The initial content of the E-DYCE DEPC procedure is proposed in this report, but the validation and optimization of it will be carried out throughout the lifetime of the project. First, when the protocol is applied and tested within the pilot buildings, the final conclusions can be drawn and can be found in the outcome of WP7.

## *2.4 End users' identification*

The E-DYCE DEPC methodology can offer multiple services to different end-user profiles, as described in the E-DYCE deliverable D1.2, including the service of data analysis and the graphical output. The resourceful communication between the E-DYCE platform and the end-user can only be achieved if the information that the user requires is accessible and concise.

As it is explained in the deliverable D1.2, E-DYCE will focus on its related logic and data analysis according to specific user profiles, to ensure efficient communication with the end-user. In the deliverable, two main categories of users are identified as follows. Please note that the name of the group 'a' has been modified from D1.2 to better reflect the user groups within E-DYCE DEPC procedure.

a. *Building energy professionals*, which include: (1) the energy certification party– who materially performs energy certification analyses. This category varies across the Member States and needs to be adapted following local processes. Usually, certifiers are private companies and use certified and approved tools. The E-DYCE framework will augment certifier capabilities to perform dynamic analyses on the energy behavior of buildings. (2) the professional building owners, and (3) the professional building administrators/operators, who hold the same or nearly the same competencies as the energy certification party. This type of user is characteristic of large housing associations, where the tasks energy analyses and optimization of the building operation are performed in-house rather than outsourced.

b. *Tenants/users, operators, or owners of small buildings*. These end-user profiles will use the E-DYCE framework for informative and operative purposes to monitor the building and receive push notifications on real-time operational suggestions and/or recommendations about planning and renovations according to specific profiles.

Deliverable D1.2 has already identified the overall needs of the two user categories. In this report, the needs are elaborated to establish the Key Performance Indicators and to suggest their potential graphical presentation that would, in a concise and understandable format, respond to the users' demands and the scope of E-DYCE DEPC.

# 3 E-DYCE DEPC certification

E- DYCE DEPC concept aims at extending the building energy professionals' capabilities towards their customers and offering useful information to the tenants, which can potentially include push notifications on real-time operational suggestions and/or recommendations about planning and renovations according to specific profiles.

In such a case, E-DYCE DEPC must be able to provide necessary information to the end-users, to emplace the above-mentioned capabilities. Concerning the energy certification stand-alone, it is a matter of identifying and providing the user with the Key Performance Indicators of the building. Next, these must be organized in such a way that they appear sufficient and can, in full, respond to the users' needs. They must be able to express building performance, independently of the level of detail in the model (i.e. mono-zone or multizone model), and it should be possible to aggregate those indicators at annual, monthly, weekly, daily, or hourly resolution, depending on the user need and monitoring data availability.

If possible, the KPIs must be calculated every time for all asset and operational certification schemas used in E-DYCE DEPC (Table 2). Though, it can be unclear which KPIs are necessary for the certification, how the certification will be carried out using selected KPIs, and what KPIs have the informative character, to support the user in optimization of building performance. On that matter it has to be mentioned that the E-DYCE energy certification aim is not about generating a new label for the building, but rather about detection of causes for PG presence and actions to its' subsequent reduction, while the E-DYCE DEPC methodology is strongly anchored in the current EPC rating, where the EPC is used as a benchmark for E-DYCE DEPC. Therefore, the KPIs selected for E-DYCE DEPC process are primarily related to energy needs in the building.

### 3.1.1 KPIs in the E-DYCE DEPC

It is now identified that the sufficient for E-DYCE DEPC KPIs have to represent the following categories:

- *Energy operation KPIs*, more specifically the energy needs in the building, to support identification of the performance gap. These must be available in a distributed format, to identify which type of energy needs causes the performance gap. Given the nature of the simulation tools and modules used in E-DYCE, only the energy demand for heating/cooling and the electricity demand for lighting and for running (some) technical systems in the building can be calculated. Calculation of the energy demand for Domestic Hot Water (DHW) is not possible in Energy Plus models nor in majority of other similar tool. However, the operational energy DHW for dwellings can be estimated using the methodology developed in task 2.3. In this method, the monitoring data from the smart heat meters are separated into two shares: energy demand for heating and the energy demand for domestic hot water.
- *The energy signature of a building* (or building zone), in contrast to D 1.2 is now seen as a separate category, not to replace, but to ease the evaluation of the performance gap due to operational thermal conditions in the building.
- *Comfort/quality KPIs* have a primary function – to support detection of causes for the performance gap. Optimally, the performance gap caused by operational thermal conditions is evaluated using the energy signature. On the other hand, the presence of over-or

underventilation is undesirable in buildings and eventually will require optimization to maintain satisfactory comfort conditions or to reduce the performance gap. Thus, the air quality related KPIs can support the identification of these issues within the building.
- *Free-running operation* KPIs can address issues in certification of low-tech buildings, but also can be used to support passive strategies application in all types of buildings (also mechanically driven buildings)

Looking upon the KPI categories mentioned above, one can argue that number of KPIs considered for DEPC is rather limited compared to the capabilities of the E-DYCE simulation platform. However, there is a fine line of balance between over information and the lack of it. In the following sections of this protocol, it will be shown that the selected KPIs are adequate for the scope of E-DYCE. In the future, when the E-DYCE DEPC procedure has been tested, additional KPIs can be rolled out, if needed.

To make the final selection of KPIs for E-DYCE DEPC, the user needs must be evaluated along with the format for concise account and presentation of this data to the user. The information packages, in E-DYCE DEPC, are the result of such evaluation (section 3.1.2, 3.1.3). Another aspect considered in the information packages is the character of user needs, by distinguishing between:

- A need for obtaining E-DYCE DEPC certificate, which consists of a single document, describing overall building performance.
- A need for fast screening, to obtain a complete and simple overview of the building performance in all domains of E-DYCE certification, including asset and/or operational rating. The information required by the user, in such a case, will solely depend on a user group.
- A need for inspection and optimization of building performance shall ensure all necessary data to detect faults and identify causes for performance gaps. This need is characteristic for the building energy professionals and therefore it will not be addressed for the tenant-user group. For the building energy professionals, it must include the information that allows them to take action to eliminate the gaps, optimize building performance, suggest adjustments to the user behavior, and/or initiate an exploration of the renovation roadmaps.

A summary table of all KPIs in E-DYCE DEPC is available in sections 3.1.2 and 3.1.3 together with the reference to their calculation methodology and a suggestion for their presentation to the user.
KPI-tables must be seen as a comprehensive list, meanwhile for each building the level of detail in monitoring and modeling will define the net list. In addition, the tables provide an overview for which assessment schema the KPI that should be calculated if possible (✓) and those that cannot be calculated (✕) due to the following reasons:

- Limitation in the calculation of global energy performance index in E+ (or similar calculation tool) due to not present calculation models for, for example: energy demand for DHW and distribution loss on installations.
- Absence of operational data or limitations in the monitoring plan
- Incomplete building inspection

That is also why the information packages must be seen as an extensive list of parameters that we shall strive to obtain in the long term but might need to accept their absence in the early stage of the E-DYCE DEPC lifetime.

Next, the minimum preferable time-resolution (evaluation period) for calculation of KPIs and the corresponding maximum period for its aggregation is defined in the tables. It must be mentioned that the empty cells in the tables signify that this data is irrelevant for the E-DYCE DEPC process.

Finally, the tables inform about the zoning approach in the monitoring and simulation which allows performing calculation of each specific KPI (✓). The zoning in the tables relates to asset zoning and operational zoning. The asset zoning refers to the simulation models used for the asset rating, but more specifically to the definition of the thermal zones in these models. In such a case, a mono-zone model consists of only one thermal zone and a multi-zone model will consist of several thermal zones in the model. Operational zoning reflects the approach for monitoring KPIs for operational rating, where a KPI can be measured as one value for the whole building (mono-zone) or as several values, measured in specific rooms or sections of a building (multi-zone). In the future, the information packages can be expanded with the assessment boundaries for specific KPIs.

### 3.1.2 Information packages for tenants

Tenants/users, operators, or owners of the building is the group of E-DYCE DEPC end-users, that will benefit from building monitoring and push notifications on real-time operational suggestions and/or recommendations about planning and renovations according to specific profiles. At the same time, this group of users may have different technical backgrounds and insights in building performance. Therefore, the “information package” for this group of users shall ensure that all users in this group can understand the information provided.

This user group is normally interested in the performance of their own space. At the same time, it is too ambitious to expect that the E-DYCE simulation and monitoring program can provide all members of this group with personalized information. However, it is an ambition in E-DYCE to allow users, when possible, to know about the performance of their own space compared to average performance in the building. Such information can be provided to the user after the GDPR considerations have been made.
In the following table can be found KPIs selected within each category to be provided to the user:
It is necessary to explain that the final energy need is selected as a relevant KPI for the tenants, to avoid any confusion that can take place when the user compares the data from E-DYCE DEPC with the energy bill. Also, the information about the energy need or comfort conditions in the EPC label, as well as the DEPC-AS schema are irrelevant for the tenant and therefore omitted.

**Table 5. KPIs for tenants.**

| KPI | Symbol | Assessment schema | | | | Evaluation period | | Asset zoning | | Operational zonning | | Ref. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | EPC | DEPC-AS | DEPC-AA | DEPC-O | Min | Max | Mono | Multi | Mono | Multi | |
| Global energy performance index | Q_gl | | | ✗ | ✗ | month | year | ✓ | ✗ | | | ISO 52000-1:2017 |
| Final energy need for heating | f_Q_h | | | ✓ | ✓ | week | year | ✓ | ✓ | ✓ | ✓ | For EPC: ISO 52000-1:2017 and for DEPC: EN |
| Final energy need for cooling | f_Q_c | | | ✓ | ✓ | week | year | ✓ | ✓ | ✓ | ✓ | ISO 52016-1:2017 and ISO 52017-1:2019 |
| Final energy need for DHW | f_Q_dh | | | ✗ | ✓ | week | year | ✓ | ✓ | ✓ | ✓ | |
| | | | | | | | | | | | | |
| Final energy need for heating for an average space in the building | f_Q_h_av | | | ✓ | ✓ | week | year | ✗ | ✓ | ✗ | ✓ | For EPC: ISO 52000-1:2017 and for DEPC: EN |
| Final energy need for cooling for an average space in the building | f_Q_c_av | | | ✓ | ✓ | week | year | ✗ | ✓ | ✗ | ✓ | ISO 52016-1:2017 and ISO 52017-1:2020 |
| | | | | | | | | | | | | |
| Operative temperature | t_op_i | | | ✓ | ✓ | week | | | ✓ | | ✓ | |
| $CO_2$ concentration | CO2 | | | ✓ | ✓ | week | | | ✓ | | ✓ | |

*✓ – the KPI can potentially be calculated/measured*

*✗ – the KPI cannot potentially be calculated /measured*

### 3.1.3 Information packages for the building energy professionals

The building energy professionals, such as the energy certification party, who materially performs energy certification analyses, the professional building owners, or administrators, as a user-group are characterized by high technical insight, where the E-DYCE project aims at expanding their capabilities to perform dynamic analyses on the energy behavior of buildings. That also means that this type of users has versatile needs ranging among the need for certification alone, the need for screening, and/or the need for inspection and optimization and planning renovation (energy renovation). The need for certification, as a stand-alone action, will be addressed in the section about the E-DYCE DEPC certificate, meanwhile, the other two groups of needs are addressed below.

Considering a need for fast screening, this type of user must have access to concise information about building energy performance, according to EPC label and other assessment schemas in E-DYCE. Furthermore, if possible, they must have a possibility of detecting any significant outliers among the zones within the building, for the reason of fault detection or out of control operation. Ideally, the user must be able to screen if the building performance has changed significantly over the recent years, it is, therefore, relevant to consider if relevant KPIs for the previous year must be included.

The inspection and performance optimization of the building, in E-DYCE, targets the reduction of PG, therefore the inspection shall support the user to detect causes of the performance gap with the aim of their elimination. KPIs that allow doing that are also included. Potentially, a guide to the use of KPIs for inspection can be prepared upon the availability of the data from the demo sites.

**Table 6. KPIs for certification party.**

| KPI | Symbol | Assessment schema | | | | Evaluation period | | Asset zoning | | Operational zonning | | Ref. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | EPC | DEPC-AS | DEPC-AA | DEPC-O | Min | Max | Mono | Multi | Mono | Multi | |
| Global energy performance index | Q_gl | ✓ | ✗ | ✗ | ✗ | month | year | ✓ | ✗ | | | For EPC: ISO 52000-1:2017 and for DEPC: EN ISO 52016-1:2017 and ISO 52017-1:2019 |
| Primary energy need for heating | Q_h | ✓ | ✓ | ✓ | ✓ | week/month | year | ✓ | ✓ | ✓ | ✓ | |
| Primary energy need for cooling | Q_c | ✓ | ✓ | ✓ | ✓ | week/month | year | ✓ | ✓ | ✓ | ✓ | |
| Primary energy need for DHW | Q_dh | ✓ | ✗ | ✗ | ✓ | week/month | year | ✓ | ✓ | ✓ | ✓ | For EPC: ISO 52000-1:2017 and for DEPC-AS+AA: EN ISO 52016- |
| Primary electricity need for running technical installations | Q_tech | ✓ | ✓✗ | ✓✗ | ✗ | week/month | year | ✓ | ✓ | ✓ | ✓ | For EPC: ISO 52000-1:2017 and for DEPC: EN ISO 52016-1:2017 and ISO |
| Primary electricity need for lighting (if relevant) | Q_l | ✓ | ✓ | ✓ | ✗ | week/month | year | ✗ | ✓ | ✓ | ✓ | |
| | | | | | | | | | | | | |
| Primary energy need for heating for an average space in the building | Q_h_av | ✗ | ✓ | ✓ | ✓ | week/month | year | ✗ | ✓ | ✗ | ✓ | For EPC: ISO 52000-1:2017 and for DEPC: EN ISO 52016-1:2017 and ISO 52017-1:2019 |
| Primary energy need for cooling for an average space in the building | Q_c_av | ✗ | ✓ | ✓ | ✓ | week/month | year | ✗ | ✓ | ✗ | ✓ | |
| Primary energy need for heating for the critical zone | Q_h_cr | ✗ | ✓ | ✓ | ✓ | week/month | year | ✓✗ | ✓ | ✗ | ✓ | |
| Primary energy need for cooling for the critical zone | Q_c_cr | ✗ | ✓ | ✓ | ✓ | week/month | year | ✓✗ | ✓ | ✗ | ✓ | |
| | | | | | | | | | | | | |
| Energy signature, global solar correlated | EN_SIG_2D | | ✓ | ✓ | ✓ | month | year | ✓ | ✓ | ✓ | ✓ | EN 15603:2008, Acquaviva et al., 2015; Eriksson et al., 2020; Hitchin and Knight,2016 |
| Energy signature, global solar correlated for the critical zone (heating) | EN_SIG_2D_h | | ✓ | ✓ | ✓ | week/month | year | ✓✗ | ✓ | ✗ | ✓ | |
| Energy signature, global solar correlated for the critical zone (cooling) | EN_SIG_2D_c | | ✓ | ✓ | ✓ | week/month | year | ✓✗ | ✓ | ✗ | ✓ | |
| | | | | | | | | | | | | |
| Fictious Energy need for free-running mode (cooling) | FICT_COOL | ✗ | ✓ | ✓ | | week/month | year | ✓ | ✓ | ✓ | ✓ | E-DYCE deliverable 1.2 |
| Fictious Energy need for free-running mode (heating) | FICT_HEAT | ✗ | ✓ | ✓ | | week/month | year | ✓ | ✓ | ✓ | ✓ | E-DYCE deliverable 1.2 |
| | | | | | | | | | | | | |
| Number of free-running hours (cooling season) | n_fr_c | ✗ | ✓ | ✓ | ✓ | week/month | year | ✓ | ✓ | ✓ | ✓ | E-DYCE deliverable 1.2 |
| Number of free-running hours (heating season) | n_fr_h | ✗ | ✓ | ✓ | ✓ | week/month | year | ✓ | ✓ | ✓ | ✓ | |
| Number of free-running hours for critical room (cooling season) | n_fr_cr_c | ✗ | ✓ | ✓ | ✓ | week/month | year | ✓✗ | ✓ | ✓ | ✓ | |
| Number of free-running hours for critical room (heating seson ) | n_fr_cr_h | ✗ | ✓ | ✓ | ✓ | week/month | year | ✓✗ | ✓ | ✓ | ✓ | |
| | | | | | | | | | | | | |
| Number of hours when CO2 level is below category I, for heating season | n_co2_h_bI | ✗ | ✓ | ✓ | ✓ | week/month | year | ✓ | ✓ | ✓ | ✓ | adapted from EN 16798 |
| Number of hours when CO2 level is below category I, for cooling season | n_co2_c_bI | ✗ | ✓ | ✓ | ✓ | week/month | year | ✓ | ✓ | ✓ | ✓ | |
| Number of hours when CO2 level is above category III, for heating season | n_co2_h_aIII | | | | | | | | | | | |
| Number of hours when CO2 level is above category III, for heating season | n_co2_h_aIII | ✗ | ✓ | ✓ | ✓ | week/month | year | ✓ | ✓ | ✓ | ✓ | |
| Number of hours when CO2 level is below category I for the zone with maximum heating/cooling demand | n_co2_cr_bI | ✗ | ✓ | ✓ | ✓ | week/month | year | ✗ | ✓ | ✗ | ✓ | |
| Number of hours when CO2 level is above category III for the zone with minimum heating/cooling demand | n_co2_cr_aIII | ✗ | ✓ | ✓ | ✓ | week/month | year | ✗ | ✓ | ✗ | ✓ | |
| | | | | | | | | | | | | |
| Operative temperature in the critical zone for heating season | T_op_cr_h_i | | ✓ | ✓ | ✓ | week | year | ✓✗ | ✓ | ✗ | ✓ | EN 16798-1 for adaptive comfort; EN ISO 7730 for Fanger model |
| Operative temperature in the critical zone for cooling season | T_op_cr_c_i | | ✓ | ✓ | ✓ | week | year | ✓✗ | ✓ | ✗ | ✓ | |
| Operative temperature in the critical zone in free-running for heating | | | ✓ | ✓ | ✓ | week | year | ✓✗ | ✓ | ✗ | ✓ | |
| Operative temperature in the critical zone in free-running for cooling | | | ✓ | ✓ | ✓ | week | year | ✓✗ | ✓ | ✗ | ✓ | |

*✓ – the KPI can potentially be calculated/measured*

*✗ – the KPI cannot potentially be calculated /measured*

### 3.1.4 E-DYCE DEPC certificate

The format and the content of the E-DYCE certificate must be developed for the concise presentation of the results of E-DYCE DEPC. It shall include the key performance indicators, presenting the overall performance of a building or its domain, including the performance gap evaluation and the key aspects of its indoor environmental quality, the utilization of its free-running potential, etc. The format of such a certificate is therefore sensitive to the outcome of several E-DYCE modules, which are not yet fully established. Therefore, the content of the E-DYCE certificate must be addressed at a later stage in the project, when the missing modules are fully developed and the data from the demo sites are available, then different scenarios for the E-DYCE certificate format can be drafted and evaluated.

An example of the initial format for the certificate can be seen below:

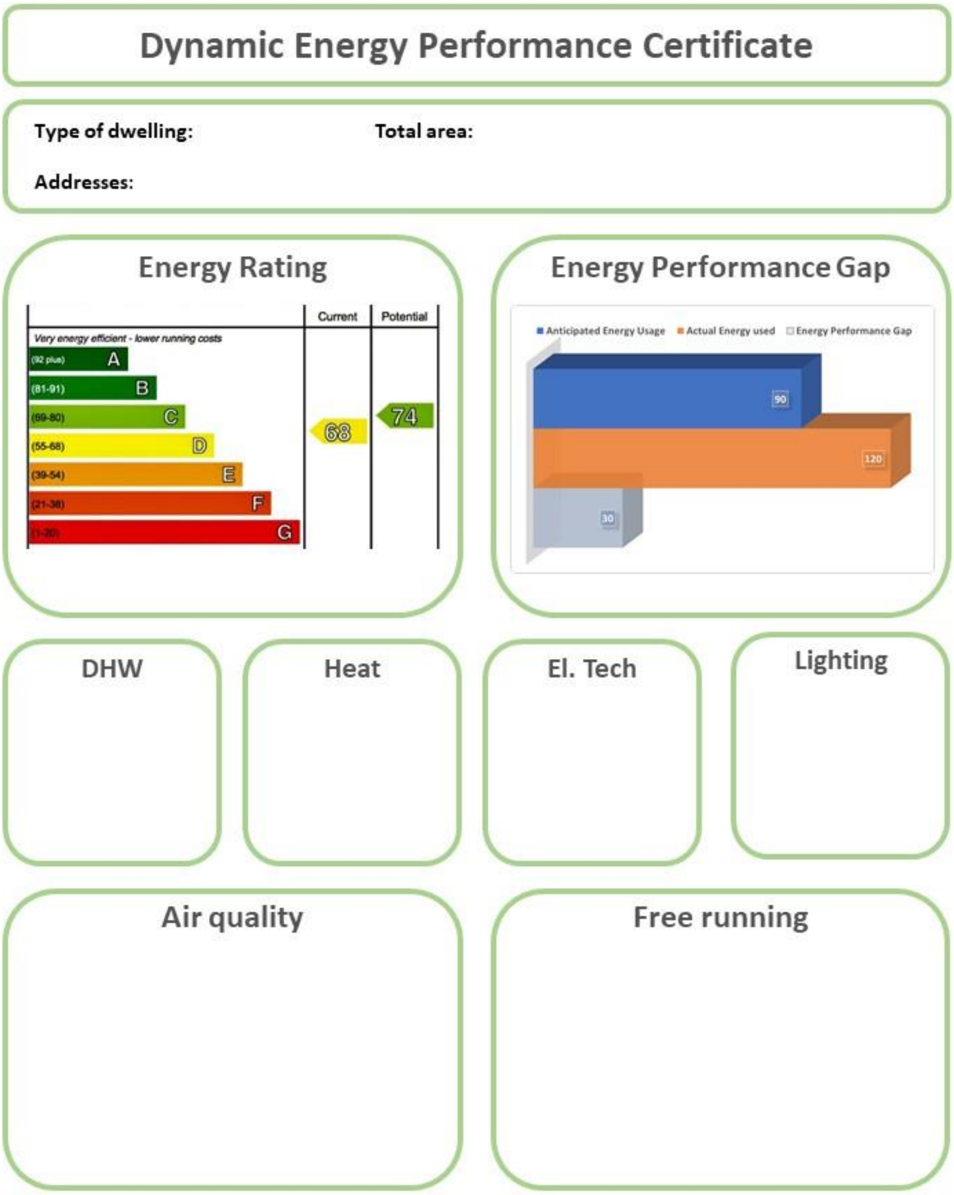


Figure 2. A draft for E-DYCE certificate structure.

# 4 Conclusions for protocol application within E-DYCE

This report is Deliverable 2.4 of E-DYCE project, which utilizes the outputs of WP1 to consolidate the E-DYCE DEPC process into a protocol.

The protocol is developed using the existing assessment schemas (EN ISO 52000-1), employing the static EPC as a benchmark for E-DYCE DEPC and thereby anchoring the E-DYCE DEPC methodology in the current EPC rating. In this way, the E-DYCE methodology can be seen as a strong supplement to the existing certification schema rather than its competitor. Accordingly, the E-DYCE certification will not generate a new type of label, but instead will be dedicated to detecting causes of the performance gap and to support potential improvement for PG elimination and the energy need reduction.

Correspondingly, the total energy demand in E-DYCE DEPC approach becomes less important, as the focus in E-DYCE DEPC methodology is shifted towards the distributed demands, such as energy demand for heating, cooling, domestic hot water, artificial lighting, etc., which can be evaluated with the different degree of detail or can even be left out, if the data necessary for their evaluation is absent. This decision ensures high flexibility of the methodology, as the E-DYCE certification can be carried out practically for any building.

E-DYCE DEPC process will generate information to augment certifier capabilities to perform dynamic analyses on the energy behavior of buildings, to provide an incitement for the potential improvements of the building, to recommend renovations, or to suggest other behaviour. The information generated through E-DYCE DEPC process will vary depending on the information that is fed in, but also depending on what information is actually valuable for the end-user. This report organizes the relevant Key Performance Indicators according to the identified user groups:

a. *Tenants/users, operators, or owners of small buildings*
b. *Building energy professionals*

In this regard, it must be mentioned that the developed protocol will be validated when applied in the pilot buildings, whereby the information fed in and generated upon application of E-DYCE DEPC procedure can be post-evaluated. Thus, the protocol proposed in this report is final, but its application in the pilots may result in an adjustment or its' further specification by the end of the project.

Lastly, this protocol has been developed without a final decision towards geometry-definition (zoning and systems) within the models in E-DYCE. Therefore, both options of the multi- and mono-zone models have been considered in this report. While the mono-zone solution is rather obvious and easy to address, by considering the whole simulation domain as one zone, the multi-zone approach can result in multiple geometrical solutions. The decision of zoning can also depend on the building typology or climate the building is located in, and it is crucial for the E-DYCE DEPC procedure. Actions dedicated to answering this question are being carried out in task 2.3 and task 3.5 of E-DYCE. The findings from these tasks will be integrated into the protocol and tested for the pilot buildings.

# 5 Bibliography

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