

Asset

on the virtual, semi-physical, and physical development of assets, including stored information such as requirements, BIM model, sensors, BMS, and other related data and documentation.

While the storage and collection representation, the optimizing energy efficiency-related actions throughout all asset life cycle stages. The

for the energy efficiency analysis required for asset design. It can also be employed during construction and maintenance phases to achieve the best possible energy efficiency decision considering physical and operational data.

The bottom layer represents the main constituents of the BIM model according to the group of information management standards [17]. The first part is for defining concepts and principles, while the second is focused on the information delivery phase of the asset. Part 3 is based on information management during the operational phase. It is stated in the standards that a project information model (PIM) is an information model relating to the delivery phase of an asset, and an asset information model (AIM) is an information model relating to the operation of an asset. It is evident that BIM and DT overlap in the construction phase since BIM can deliver object-based data utilized for the DT.

4.3 Introduction of GIS in EPC

In the D²EPC project and GIS context buildings are described and considered in the concept of BuildingsExtended3D, i. e. with correct geometric dimensions, proportions, scale, but not considering geolocation of a particular building. These 3D designs depict the correct building proportions and scale, but the correct geolocation is yet to be defined. To this end, several methods of geolocation can be applied, depending on the existence and availability of data: If the building under study is already correctly geo-referenced (projection information can be obtained from cadastral information and/or other spatial databases), a simple projection procedure should be applied.

In the case of not geo-referenced EPCs for buildings or lack of information, two data acquisition methods can be applied. The first is geolocating the building/parcel using a GPS/GNSS procedure to provide the best and most reliable accuracy results. The other approach is addressing geocoding method used to collect appropriate geolocation data.

In parallel with the geo-referencing procedure, it is also essential to determine the unique geographical location of each building. By adopting a common reference coordinate system for all the under-study regions/cases, a unique code can be created in many

possible ways, using the coordinates of each plot of land. A simplified way to create a unique geocode for the case studies is to convert a polygon shape feature into a centroid point and extract 2D coordinates from this centroid point.

The definition of the Z - height value of a unit (building, apartment, etc.) - is as important an EPC element as the aforementioned geolocation features. Same as for geolocation, the different data acquisition scenarios may be applied: a) Floor/height information is available in official registries, spatial governmental agencies. b) If there is no known recorded and registered data, there are few options for data acquisition. The first is to use GPS/GNSS measurements taken on-site, which will give an accurate altitude. Another approach is the application of a widely agreed assumption that the height of one floor equals 3 meters; in this scenario, it is possible to identify the floor number in each building (floor = building

The use of geospatial technologies and accurate data location could improve the processes related to the data needed to assess the energy performance and needs of buildings and urban areas. In addition, the use of geolocation practices can increase decision-making effectiveness by different stakeholders (policymakers, technicians, citizens). Online and web-based tools that can provide near real-time data on the actual energy performance of buildings at the building or regional level could provide public authorities, governments and energy service companies with crucial regional insights. A unified scheme for monitoring and evaluating energy efficiency policies and practices, using a standard set of spatial data (dwellings, buildings, neighborhoods), could improve the synergies between existing energy initiatives and the adoption of new initiatives.

4.4 Introduction of financial schemes

Introducing financial schemes in EPC is suggested in this study. Based on the well-established principle of lifecycle costing, a set of financial indicators could be developed to allow the individual elements of

standardized numerical values. The delivery of such indicators could allow the use of EPCs for the financial evaluation of energy upgrading measures for buildings. For example, financial awards (e.g. tax reliefs) should be included if the building owner exceeds new EPC requirements and class. In the opposite case penalties should imposed based on

5. D²EPC System Architecture

A novel methodology for dynamic EPC is being developed within the H2020 D²EPC project, which introduces the aspects of SRI, occupant comfort, LCA, integration with DT, and GIS systems. Key functionalities of D²EPC architecture are presented in Fig. 2.

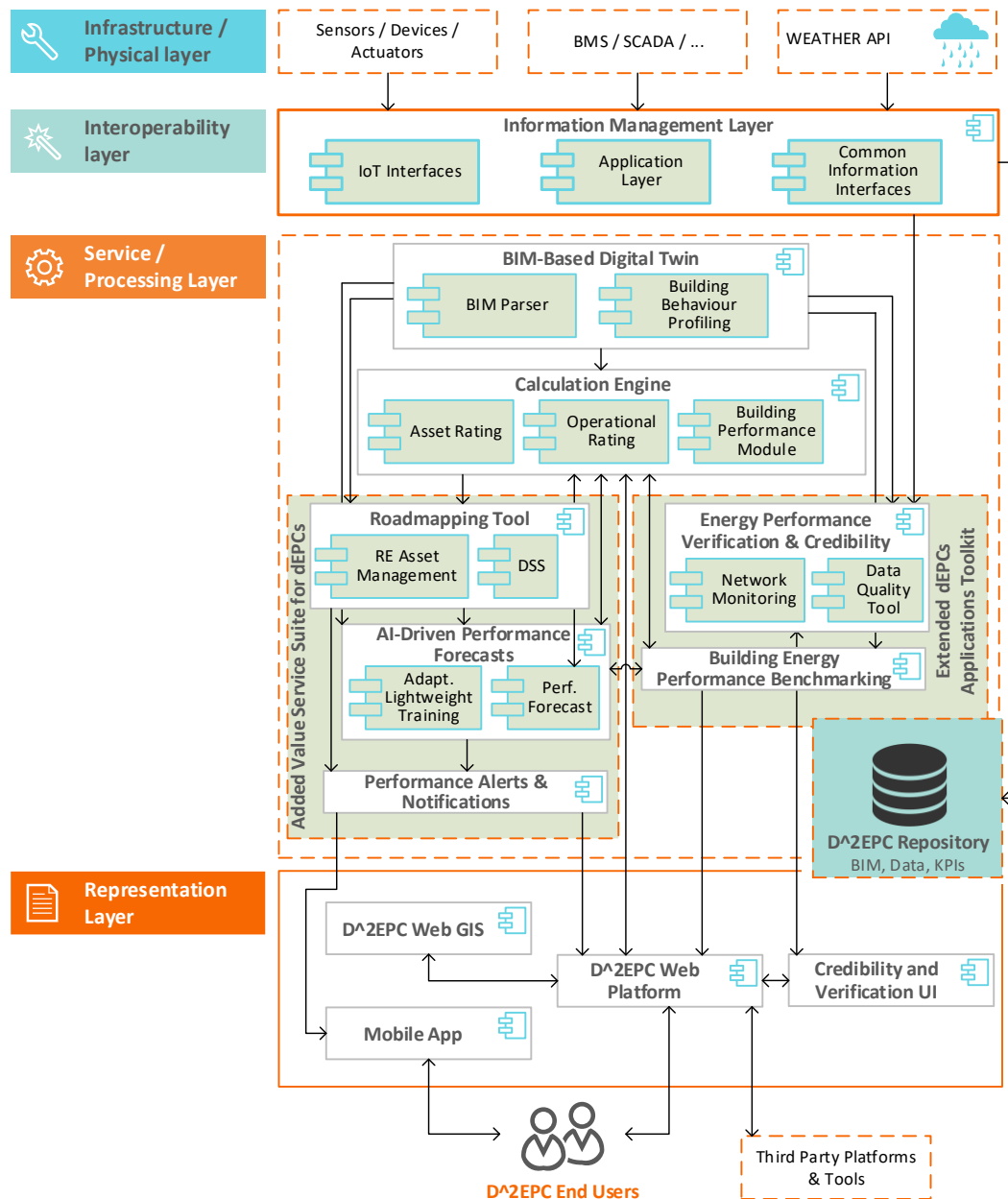


Fig. 2. D^2EPC System Architecture [18]

D^2EPC framework consists of four layers:

- Infrastructure/Physical Layer,
- Interoperability Layer,
- Service/Processing Layer, and
- Representation Layer [18].

Infrastructure/Physical Layer. All devices, sensors, actuators, and systems are included in this layer, including BMS (Building Management Systems) and SCADA (Supervisory Control and Data Acquisition), enabling dynamic EPCs. Weather data can be fed on-site or through external weather APIs from the weather stations.

Interoperability Layer. This layer is responsible

both for the management of the received information from the Infrastructure/Physical Layer and the interoperability of the various interconnected devices. It retrieves the necessary information and streams it into the D^2EPC repository in the proper data format. As current IoT solutions, either available on-site or installed, are quite diverse in terms of communication protocols, data acquisition, etc., interoperability is considered one of the most cumbersome challenges when deploying and integrating a digital solution for dynamic EPCs [18]. D^2EPC will employ IFC4 standard to ensure data interoperability”.

Service/Processing Layer. Processing and decision-making functionalities are included in this layer of D^2EPC architecture. State-of-the-art methodologies allow the evaluation of incoming data's quality and credibility, the mapping of static and dynamic

building (near) real-time information, as well as the calculation of a wide variety of metrics and indicators. Furthermore, recommendations for cost-effective building upgrades and benchmarking are also introduced here. This layer employs the BIM-based Digital Twin concept, which means operational data are collected, represented, and used for analytics, and in turn, the assessment process is automatic.

One of the main components of the D²EPC architecture is the Calculation Engine. It consists of three modules which deal with the Asset and Operational Rating schemes, while the third sub-module is related with the calculation of certain KPIs related to the overall performance of a building. A variety of indicators are calculated relevant smart readiness, comfort and wellbeing, financial and life cycle assessment aspects, to enrich the EPC procedure.

The Roadmapping Tool for performance upgrade will enable novel decision support algorithms for strategic scenarios generation, enabling user-centered suggestions on building performance and upgrades.

The module AI Driven Performance Forecasts utilizes artificial intelligence algorithms to train dedicated models. These models will be used for forecasting the future energy performance of the building taking into account the both the data streams as received from the building, as well as outside parameters that affect the building's energy performance. A lightweight approach will be employed to reduce the need for the processing power and the actual forecasting should only be used when needed.

The actual performance of the building is monitored through the Performance Alerts & Notifications component, which will also enable the occupants to personalize their indoor environment settings.

An automatic and continuous verification process will be enabled with the Energy Performance and Credibility component, which analyses the IoT data streams and performs a constant check on sensor's health and data quality.

The classification and comparison of the particular building data with reference to certain metrics will be carried out through the Building Energy Performance Benchmarking component, which is linked to the Roadmapping tool for increasing the building performance.

Representation Layer. The representation layer enables the D²EPC platform interaction with the end-users and third-party platforms. The Web Platform will enable the representation of different KPIs and provide dashboards and analytics results, while the Web-GIS module will provide geospatial information using maps and 3D models.

6. Conclusions

The following new indicators are suggested to be included in the dynamic EPC: SRI, human comfort-related indicators, LCA, and financial schemes.

By integrating BIM into the EPC scheme, it is possible to obtain object-based information related to a particular asset (e. g. class, related properties and processes, aggregation, etc.). A semantically rich BIM model can be considered the basis for a digital twin, which can be used for energy performance modelling from the design to the maintenance phases of the asset. Complemented by sensors/BMS/IoT and other data, the DT can visualize and inform the users about the impact of their behavior on EPC. As DT can take management action to eliminate user culpability, it can be used to achieve the highest possible energy performance class for a building. In addition, the sensing and monitoring functions of DT can be used to prevent inefficient energy impacts of the appliance through smart assets or the IoT.

Correctly locating the geographic location of the dynamic EPC will provide a better understanding of the energy performance status of each dwelling/building over a given monitoring period. In addition, the EPC can be tailored to spatially and visually relate the exact location of the building to other relevant climatic factors (climate change indicators, the greenness of the neighborhood, incoming sunlight, etc.). At the same time, it will help to explore innovative geolocation practices to overcome the lack of existing cadastral data.

New technologies that didn't existed at the time when the current EPCs schemes were developed, enable new approaches towards building energy certification. D²EPC platform aims to integrate IoT, AI, and other novel technologies to enhance end-user awareness and facilitate a more sustainable life cycle of buildings. Nevertheless, integrating these technologies into a coherent unified tool is still a challenging task. D²EPC aims to provide a demonstrator platform that will help increase the understanding of European building stock's EPCs.

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Data Statement

Data sharing not applicable to this article as no datasets were generated or analysed during the current study.