Smart Buildings

An IEEE European Public Policy Committee Position Statement

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The IEEE European Public Policy Committee (EPPC), representing a large community of European engineering professionals, calls on European Union (EU) policy makers to take immediate action to strengthen the development of smart buildings in Europe with a view to consolidating the European leadership in this field, reducing the environmental impact of human activities on the climate, and creating new jobs.

Recommendations for legislative work on smart buildings

Energy efficiency and smart management in buildings:

- **Energy optimized buildings:** New and existing buildings should be optimized to reasonably minimize energy demand. This must include the full building lifecycle, regarding building design, useful and final energy consumption with respect to local opportunities, challenges, and self-produced energy. A holistic approach covering both passive and active components should always be used when planning for energy optimization.

- **Smart management:** The Energy Performance of Buildings Directive (EPBD) should require buildings to be equipped with continuous monitoring and effective supervisory control functionalities. The EPBD should clarify in detail what these functionalities should entail. In addition, monitoring, analysing and benchmarking of the energy performance are necessary in order to provide the building owner or manager with advice on how to improve the energy efficiency of the building. Buildings should be incentivised to be equipped with demand-response functionality for electricity and for other forms of energy.

- **Exploit synergies of scale:** Smart buildings should be designed and optimized not only on an individual basis (as stand-alone systems) but as Systems-of-Systems (considering particularly structural evolvability as well as functional emerge functionalities and behaviours). Communities should be formed by including neighbouring buildings with the aim of creating synergies where possible (e.g., shared community storage), as well as avoiding adverse effects that may arise from operating stand-alone (e.g., undersized local renewable sources not meeting the demand of the building). Depending on the population and energy use density, centralized vs. decentralized energy system architectures are both vital options that require cost-benefit analysis on a case-by-case basis. In order to boost resilience, the connection of the buildings to the district energy grid should consider the transfer between different energy carriers (e.g., thermal, electrical) in line with the European Framework for Power-to-X. Therefore, national and local planning should provide for optimization at the system level including setting the requirements to the building stock.

- **Retrofit:** Incentives for reducing and optimizing the energy demand (useful and final energy) in existing buildings should be provided. The current renovation rate is very low and retrofit has the highest overall reduction potential when compared to the costs. Incentives should target energy efficient solutions/technologies (e.g., LED lighting, insulation, HVAC, energy efficient pumps, windows, digitalized and networked building management and supervisory control, etc.) that reduce energy consumption while not compromising consumer comfort, and incremental retrofits should be avoided given the long lifetime/investment cycles. Retrofitting of energy efficient solutions/technologies must also consider the impact of climate change on consumer behaviour which, for example, might result in a shift from heating to cooling demand. With respect to the lifetime of building and building technology (e.g., HVAC, lighting), there might be changes in purpose and demand.

Local energy generation, storage and sector integration:

- **Local energy production:** Buildings should integrate renewable energy production (REP) to balance consumption (Net-Zero Energy Buildings) or even provide net energy to the grid (energy-plus buildings) with flexible use-demand price models enabling optimization at a system level. The dependence on the energy imports can be reduced while improving the resilience of the energy system. All of this should create a positive impact on the grid and the curtailment of renewable energy production avoided.

- **Local Energy storage:** Support the installation of energy storage in buildings where/when cost-efficient (i.e., behind-the-meter storage solutions) to allow time shift of energy consumption, facilitate the system integration of intermittent renewable energy sources, and allow tapping local heating and cooling potential through thermal storage. The potential for demand side management is greatly enlarged by sectoral coupling through storage technologies that convert electricity to heating, cooling and mobility (e.g., electric vehicle charging). Local storage can be leveraged by the utility when these are integrated in a community/district network, giving rise to community microgrids where buildings can exchange energy.

Stakeholder-specific incentives: investors, occupants, facility managers:

- **Minimum standards:** Ambitious minimum energy performance standards should be set for new and existing buildings, including implementing retrofit requirements for the installation of smart building automation and supervisory control systems supported by digitalization and networking technologies.

- **Investors:** Create a framework to significantly increase the global renovation rate from the current rate of less than 1% of existing buildings per year up to 3%. This should be based on legislative as well as voluntary measures and include a focus on better access to funding for such projects.

- **Occupants:** If occupants are neither building owners nor bear the costs or benefits of the buildings' energy system, they have little intrinsic incentive to make buildings smart. Here is the biggest opportunity for digitalization and smart management of building technology. For the opposite situation, when occupants bear the costs, it still matters whether they have an influence on investments and return.

- **Facility management:** The comparability of individual buildings or households' energy performance can be provided to facility managers (anonymized) from smart buildings. The use of Smart Readiness

Indicators can be a tool for this. The Smart Readiness Indicators can highlight inefficiencies or unlock potentials. The assessment of the energy performance of the building and its technical systems should include part load situations and be documented and passed on to the building owner. A high degree of understanding in building technology, engineering and ICT is a premise here, and the effort needs to find a return.

- **Government:** Set ambitious minimum energy performance standards for new and existing buildings. Address financing, a key stumbling block, e.g., by supporting the development of financing models for retrofit where business innovation is required – this could be in the form of ESCO models. Stimulate innovation market uptake of new technologies by removing barriers for pilot projects and test beds.

Digitalization and buildings[1]**:**

- **Smart management of HVAC and lighting:** Boost smart management of HVAC and lighting based on actual and predicted demand and occupation. Use the opportunity of demand side management (DSM). Enforce and standardize building information models (BIMs).

- **Waste management:** ICT infrastructure for waste management should be part of the overall smart building ecosystem - from both the perspective of waste reduction and efficient recycling under the umbrella of a circular economy approach, as well as in terms of improving overall hygiene conditions for the community.

- **Improved data communications:** Smart buildings are sharing consumption data and DSM (and other services) to enable higher overall system efficiency, while respecting data privacy and maintaining cyber security through adequate service-legal-agreements. This calls for standards and regulations.

- **Reliability and obsolescence:** The downside of modern technology is the short life span, weak reliability and quick obsolescence due to technological progress. Devices and standards need to become future-ready, and durable and updateable. The systems and architecture need to be modular, which enables some modules to be replaced or upgraded based on technology advancement and standards without the need to replace the entire system. Likewise, scalability of smart building architecture is an important element when considering digitalization – independent of the size of the building, number of occupants, the position of the building as a system within a system-of-buildings and within the (smart)-city and/or -grid, etc.

Contribution of Smart Buildings to the European Green Deal

For the European Union, 40% of the final energy consumption and 36% of the energy-related greenhouse gas emissions take place in buildings[2]. A massive reduction of buildings' energy demand and of their carbon footprint

[1] Supportive documents:
IEEE 1888-2014 - IEEE Standard for Ubiquitous Green Community Control Network Protocol.
IEEE 1901-2020 - IEEE Standard for Broadband over Power Line Networks: Medium Access Control and Physical Layer Specifications.
IEEE 1905.1-2013 - IEEE Standard for a Convergent Digital Home Network for Heterogeneous Technologies.

[2] Inception note for the revision of the Energy Performance of Buildings Directive: Energy efficiency – Revision of the Energy Performance of Buildings Directive (europa.eu)

would thus significantly contribute to the commitment by the EU to reduce greenhouse gas emissions to 80-95% below 1990 levels by 2050. Buildings need to become more efficient as well as better connected to the energy system in order to fulfil new functions that support the transition from fossil fuel dependency to renewable and sustainable generation. Promoting smart buildings[3] is an obvious and constructive way to realize the objectives set out in the European Green Deal[4] and to fulfil the EU Digital Agenda[5], if the proper regulatory framework is created. Positive spillover effects in the economic, environmental, societal, and political impacts can then also be expected.

Smart technologies are seen as key enablers to make buildings play a more active role in the energy system, without there being a universal concept of what "smart building" exactly constitutes. A range of smart functionalities and components are summarised under "Building Automation and Control Systems" (BACS[6]), defined by industry in the European standard EN 15232. Attempts to define smart solutions and functionalities in a coherent and structured way have been made with the Smart Readiness Indicator (SRI) for buildings and in Eco-design Lot 38 on BACS.

A smart building:

- Uses smart technology to achieve higher **energy efficiency**, e.g., through self-learning control systems.
- Plays an active role in decarbonizing the wider energy system and integrating fluctuating renewables by interacting with the grid and providing **demand-side flexibility** through precise control of energy flows, demand response and storage.
- **Empowers residents/owners** to take control of their energy consumption/flows in the building by providing them insights on energy flows and enabling them to control them from within and outside the building.
- Supports **optimal operation** of the building, thereby providing comfort and a healthy indoor environment to users as well as lower cost-of-ownership.

Over a buildings' lifespan there are different phases, which all will have an impact on a cost-benefit analysis. The phases - from cradle to grave - include planning, construction, use, renovation, reuse, and finally, demolition and recycling. Smart buildings must be smart in all those phases, following a holistic thinking and the concept of sustainability within a circular economy approach. The calculation of costs must include materials for construction as well as consumables for operation and maintenance, and materials for the end-of-life-phases, while considering smart devices and adequate use of data and digitalized information. Smart devices, such as meters and sensors, among others, offer unforeseeable potential to elevate the quality of buildings and living therein. The benefits are usability, comfort, opportunities for energy savings and, from the energy systems' perspective, sector integration and support of renewable energy sources. Life cycle assessments will help to identify how policies for smart buildings should be designed. Building information models (BIM)[7] provide the digital standard to manage

[3] https://ec.europa.eu/energy/en/topics/energy-efficiency/energy-performance-of-buildings/energy-performance-buildings-directive
[4] https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en
[5] https://ec.europa.eu/digital-single-market/en
[6] Definition of BACS in the 2018 EPBD: "building automation and control system" means a system comprising all products, software and engineering services that can support energy efficient, economical and safe operation of technical building systems through automatic controls and by facilitating the manual management of those technical buildings systems.
[7] https://ec.europa.eu/jrc/en/publication/building-information-modelling-bim-standardization

buildings over the lifespan, whereas purpose-driven indicators like the Smart Readiness Indicator for Buildings (SRI)[7] shall help evaluate their overall performance.

Role of Smart Buildings in the energy system

With the fast and large uptake of smart meters taking place, buildings are being seen more and more as an opportunity to make substantial changes in the energy system, starting from the fundamental brick where energy services are required. In particular, increasing attention is being paid to smart buildings that, through state-of-the-art building energy management systems, can enable coordination and optimal deployment of building-level low carbon technologies, such as photovoltaics, electric vehicles, heat pumps, and so on. This includes local energy generation from any renewable source and a broad range of energy storage options.

With the introduction of smart technologies, buildings can become active instead of remaining passive, as most of them are today. Passive refers to the understanding that buildings are merely a location of energy end use (or final consumption), carrying a notion of disengagement from the energy usage. Smart buildings will form microgrid clusters that integrate decentralized renewable energy sources with local generation, be capable of producing electricity, storing it, and managing the relation with the power grid, injecting or consuming electricity depending on the needs of local consumers, and optimising the energy bill as well as the related CO_2-emissions. They will allow extensive usages of electricity for electrical vehicles and heat pumps to lower carbon emissions. Both these technologies will affect the electricity consumption pattern in buildings. Decreasing the overall energy demand in buildings, supplying locally produced energy, and decentralising the system will increase resilience in terms of stability and independence.

To fulfil these new tasks, they will achieve a transformation from end-user of electricity to ‘prosumer’ of electricity, being producers and consumers at the same time. Demand side management (DSM), digitalization and networking, smart meters, Internet of Things, blockchain, among other ICT technologies, when adequately used are key success factors for this transformation, provided laws, regulations and policies support this potential.

Several pilot projects of smart buildings and optimization are currently being realised (e.g., NIST’s Virtual Cybernetic Building Testbed or EMPA’s NEST). Smart buildings have been experimenting with many features. Smart buildings with local generation and storage can form a microgrid that is able to disconnect from the grid and run autonomously during a certain period, typically during peak demand. They have the facilities to store renewable energy produced by photovoltaic (or other sources) and to sell (or use) it when it is most economically interesting. Through scaling of renewable energy production and storage, the potential can also be combined between several buildings and shared at district level, forming microgrid clusters that reach a higher synergy.

Thermal storage, district heating, inverter-driven air-conditioning and heat pumps are a few of the promising technologies that can address a buildings’ heating and cooling demand. While the overall energy and fossil fuel needs are reduced, a comparably small increase in electricity demand can be expected as a trade-off when installing a more efficient heating system. Together with advanced thermal insulation of the building envelope (reducing the overall thermal demand), these are the objectives for retrofitting. While reducing the energy demand, no retrofit measures and implementations of new technologies should decrease the standard of living (though actual cost may increase).

Smart buildings can also integrate a management tool (a Building Automation Control System, BACS) to supervise and control lighting, shutters, HVAC, and a dedicated low voltage switchboard for load shedding. They utilize energy measurement to learn about consumption patterns as well as other information like weather forecasts and thereby contribute to demand prediction and control (as part of DSM).

Risks and opportunities of ICT in buildings

Making a building smart requires monitoring, automated features, connectivity, interoperability, and management, altogether possibly in real-time. The initial step of energy management is to have access to the digitized data. For this purpose, measurement and metering equipment for production and demand of electricity and thermal energy has to be installed, the so-called smart meters. Multiplying the points of measurement already provides significant information and data to both energy system operators and energy end users. Energy consumption can now include accurate cost allocation to specific consumers by sub-billing, alarms in case of abnormal consumption, behavioural patterns, energy efficiency, etc. Access to building (and consequently consumer behaviour) data together with remotely controllable smart devices is naturally a security risk, which is common to the more interconnected world. Privacy and cybersecurity must be supported by hardware, software and procedures of data- and service-handling and storage from all parties including service-providers and -consumers, energy suppliers and local community facilities.

In gathering data, it is then possible to analyse the energy usage and to benchmark the building energy performance against similar buildings. Further steps to improve energy efficiency may be achieved by using specific energy management algorithms, based for example on machine learning algorithms and artificial intelligence, embedded in devices and systems or located in a data and information cloud (facilitated by the Internet of Things and Internet of Services). These innovation steps need investments and, if done, they support not only energy efficiency but also help detect and diagnose equipment faults, as well as assess energy comfort and maintenance impact. For example, automatic controls can be set up at the zone or room level, allowing interactions by the occupants, to mutualize control functions for lighting, shutters, HVAC and space management, implemented with a granularity as economically reasonable, so as to deploy scheduling and occupancy strategies. As another example, artificial intelligence can be used to optimize heating based on usage data and weather forecasts. As far as equipment fault diagnosis is concerned, some sensors already intended to collect data regarding energy efficiency analysis, can provide data for diagnostic purposes as well. Optimization leads buildings to be grid-aware, becoming an extension of the smart grid in order to maximise the return on investment (ROI) of asset and future energy efficiency investments. As a result, buildings tend to reduce their consumption, and even to become energy positive. Short term and operational benefits of smart buildings and districts should be evaluated against a life-cycle assessment, as scientific knowledge and experience from application are still limited about the long-term impact of respective policies.

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