**European legislation and incentives programmes for Demand Side Management**

**1. Introduction**

The European Union (EU) building sector consumes significant resources, with the sector estimated to be worth 10% of global Gross Domestic Product (GDP) and employing 111 million people (UNEP, 2016). Throughout their life cycle, from the extraction of materials, the manufacturing of construction products through construction, use and maintenance, buildings in the EU account for approximately one half of all extracted materials and energy use, in addition to one-third of water consumption and generated waste (EU, 2016). In addition, the building sector also has a significant societal and economic impact (Castro *et al*., 2017).

In the Roadmap to a Resource Efficient Europe, buildings are highlighted as one of three key sectors to be addressed. Better construction and use of buildings could deliver significant resource savings: 42% of final energy use; about 35% of total Green House Gas (GHG) emissions; 50% of the extracted materials; and up to 30% of the water in some regions (Herczeg *et al*., 2014).

Moreover, the buildings sector has significant environmental, social and economic relevance. Energy policies can be honed through evidence-based methods and appropriate and relevant research contributions. The industry’s focus on ecology can make meaningful contributions to the flow of materials and energy, through, for example, the development of closed cycle approaches. This results in reductions in the environmental impact of construction activities (Mont and Heiskanen, 2015).

Non-Governmental Organizations and Not-for-Profit Organizations have been instrumental in educating consumers. This has improved informed decision-making, highlighted the supply chains’ responsibility, and promoted responsible reuse and ultimately introduced key disruptive innovations and driven industrial improvements (Lazarevic & Valve, 2017). Such initiatives can be instrumental in highlighting the need for initiatives such as the complete lifecycle approach which recognises and supports the balance between social performance and the built and natural environments. To continue to make a contribution, these initiatives must ultimately be sustained by informed methods and appropriate legislation (Lazarevic *et al*., 2012).

In tandem with the above approaches, a significant contribution is required in the fields of education and sociology in order to promote the required increase in responsible demand and reduction in resource and energy use which are necessary to reduce avoidable environmental impacts. This has been proven to be key to providing a comfortable and healthy environment for society as a whole. Past failures such as “Sick Building Syndromes” (SBS), highlight the interdependence of the various actors in the construction process and users which is required to avoid such non-optimised interior environments (Amin *et al*., 2015).

In short, sustainability in the built environment will be arequired reality for future generations.

* 1. **Aims and Objectives**

The aim of this article is to provide an analyse of the state of the art regarding the concept of Demand Side Management (DSM) and current legislation and policies. Based on this, the main forms of intervention and the possibilities for improvement are presented along with a discussion on how these could be applied.

So, the main objectives of this article are:

* Present a summary of the state of the art at the European level regarding the concept of Demand Side Management;
* Discuss the main initiatives and incentives;
* Highlight the main directives and concepts proposed;
* Discuss the best methods for a more holistic approach;
* Highlight a new approach for buildings’ sustainable design.

**2. How is the building industry dealing with the concept of Demand Side Management?**

Within the EU, buildings are responsible for 40% of final energy use and 36% of CO2 emissions as recognised by the Energy Performance of Buildings Directive (EPBD) - Directive 2010/31/EU of the European Parliament and of the Council.

Therefore, the EU is developing policies and directives to ensure the growth of sustainable construction and improve the environmental performance of buildings throughout their whole lifecycle. This includes promoting Eco-Design, including the “Passivhaus” concept, encouraging the use of local resources, proper orientation, natural lighting, smart materials, insulation, double skin facades, energy efficient windows, and modular and prefabricated methods of construction which can be totally recycled, considering the whole building´s lifecycle (Kylili and Fokaides, 2017).

Design calculations need to begin early, when design options can be explored and where the main carbon savings can be updated to decrease the environmental impacts, during the construction lifecycle. This promotes sustainability (Attia *et al*., 2012). There are, therefore, many Building Sustainability Assessment (BSA) methods to help all the stakeholders of the construction´s lifecycle to quantify inputs and outputs. Unfortunately, the context of the companies involved in construction often impedes the establishment of the required concepts. It is inherently difficult for them to maximise their own progress e.g. with the use of models of linear economy and achieve the required economic benefits. This often results in a no-win scenario for the built environment (Din and Brotas, 2016).

The circular concept offers a potential win-win scenario which preserves the environment and stimulates the economy. The main goal of the circular economy is to try and achieve a step change in the way people think not only in the near future, but also for future generations. Education has been identified as a key enabler (Lazarevic and Valve, 2017). Hence, all the stakeholders of the building´s lifecycle should be educated on the key metrics and approaches to mitigate climate change and provide a healthier environment. This involves promoting the circularity in closed cycles, showing the benefits and features in a way that can achieve the environmental goals of assuring the health of future generations (Kylili and Fokaides, 2017).

There are a lot of current technologies which can be applied in buildings to improve energy efficiency by energy harvesting, energy storage, and the incorporation of renewable sources - the sun, wind and geothermal energy (on-site, off-site and nearby in combination with load management) (Karunanithi *et al*., 2017). There can be enabling interconnections between all the elements. For example, with a correctly dimensioned grid, efforts to reduce the demand in the peak periods and conserve energy during the least demanding period, it will be possible to use or sell energy back during the peak hours ensuring a good pathway to demand response (Strbac, 2008).

Combined and dynamic tariffs, designed to provide a win-win scenario, can be applied by the energy service companies, which can be monitored and measured to achieve an improved paradigm in the way that companies manage their systems and resources. Therefore, it will be easier to supply the demand with the existing infrastructure and implement simple incentives for users.

The circular economy offers a paradigm shift - an industrial system that is restorative and regenerative which considers different building lifecycle phases, the required low carbon economy and a sustainable growth which ultimately facilitates the maximisation of benefits and the reduction of costs. In addition, it also delivers dynamic and interactive services and enables expert assistance, learning, and peer-to-peer sharing experiences to reduce human error (Bergaentzlé *et al*., 2014).

The concept of Internet of Things (IoT) promotes the connection of billions of devices and sensors enabling decision making among the stakeholders from manufacturers to governments and research labs, providing real-time tracking and monitoring. It offers the potential to improve efficiency with artificial intelligence with an automated demand, and connecting person to person, person to machine, machine to person and machine to machine (Vermesan and Friess, 2013).

In this way, IoT can for example improve the 3D printed constructions. The process of construction can almost be done on-site reducing the necessity for the transportation of materials and manufacturing to the construction site. It will lead to reductions in resources and waste. Most of the resources needed can be reutilised in closed cycles, thereby increasing energy efficiency, reducing the potential environmental impacts and improving social performance. If this is properly done, it can provide considerable benefits in the drive for sustainability and short Return on Investment with consequential longer-term paybacks both for the environment and stakeholders (Duballet *et al*., 2017).

Warren (2015) argues that there are distinct variations in the definition of the concept of DSM, which must be considered in addition to the varying approaches in order to come to a correct, holistic DSM definition. The author reinforces a new holistic definition of DSM, claiming that this one refers to technologies, practices and monitoring processes to energy demand with the purpose of managing the decrease of energy utilization to attain fewer costs for the whole energy system.

Finally, it takes more than money to produce effective disruptive pathways to achieve environmental, social and economic rewards. All the necessary ingredients such as unlocking habits and promoting innovation and healthier education, should be well-articulated to push forward efficiency to achieve a zero-carbon economy. This will be necessary to achieve the EU’s goals over the coming decades (Bragança *et al*., 2014).

**2.1 International policies, initiatives and perspectives**

A focus on buildings is one of the most significant ways in which to achieve an improvement in energy efficiency. In the EU, just under 2% of the buildings are well designed to meet the demand response of all the stakeholders during their lifecycle according to the Energy Efficiency Directive (EED) with almost 60% of space heaters being inefficient and almost 40% of the windows being single glazed. This needs to be improved not only in new build but also in the rehabilitation of buildings already constructed.

Hence, smart materials like phase change materials and thermally active mortars should be included in the construction solutions in the envelope. Double skin facades, operable windows, natural lighting (to reduce unnecessary electrical usage) can, therefore, provide a healthier air quality inside and outside of the buildings (Rahimpour *et al*., 2017).

Demand response is crucial for meeting future energy needs with lower supply and transmission capacity, given that the eco-design work plan can be accompanied by storage technology and services. Thermal energy storage systems will increase grid flexibility (Smale *et al*., 2017). Electrical energy cannot currently be stored in an effective way, so it needs to be distributed and used in the most sustainable way, minimising waste. So, the paradigm of DSM is fundamental (Dabur *et al*., 2012). Thus, the consumers need to be engaged and understand the value and conditions of the programmes and a cost-benefit analysis should be well understood through appropriate benchmarking (Smale *et al*., 2017).

Therefore, in line with the evolutionary and ever increasing pace of technology development, construction should be sufficiently modular to enable effective re-adaptation during its lifecycle through to a sustainable demolition process at end-of-life (Lehmann, 2013). In the earlier design stages, eco-designers should provide a preliminary risk assessment which should be explicit and specify an initial and operational cost analysis. During the implementation stage, this should be adapted based on circumstances and unfolding requirements. Continuous monitoring will be the key to sustainable management throughout the building lifecycle as, with an automated prediction, the grid provides a signal to the building and the building will respond. This will be an approach to make the system restorative and regenerative, rethinking the pathways to sustainability (Bragança *et al*., 2014).

Consideration needs to be given to the buildings energy need throughout it’s lifecycle, encompassing the perspectives of embodied energy, operational energy (heating, ventilation and air conditioning (HVAC) appliances, lighting & auxiliary systems), manufacture, maintenance and finally demolition. If done correctly, this could promote the astute use of renewable energy sources which can either be on-site, nearby the building or off-site, providing a real commercial and technological alternative to fossil fuels (Muñoz *et al*., 2017).

Supplying innovation in terms of how buildings (and all the stakeholders) operate and interact during the full life, places users centre stage, and support the competitiveness of European industry. So, technologies and services promote smart solutions to energy users that give control to stakeholders to optimise their energy use, developing new materials and new technologies for building energy efficiency solutions. Furthermore, optimised construction processes offer a win-win scenario for a sustainable development, modelling and prediction (Ford *et al*., 2017).

Applying efficient solutions such as building and subsystems control in combination with efficient lighting, promotes solutions which make use of artificial intelligence with smart meters and monitoring facilitated by automated technologies. Hence the grid, the building, and its occupants make use of data analysis, sharing the necessary information, helping real-time coordination and promoting balance between construction, people and nature (Georgievski *et al*., 2017).

**2.1.1 DSM policies**

DSM policies can be implemented through individual initiatives or in a package of policies. Currently, the most successful DSM policies have been found to be Utility Obligations, Performance Standards, and Utility Business Models, while DSM policies which have enjoyed lesser success include Labelling, Information Campaigns, and Loans and Subsidies (Warren, 2015).

Warren (2015), argues that the policy package “Utility Business Models/Market Transformations” includes the most innovative long-term DSM strategies. These aim to change the actual business models with resultant benefits to energy supply and demand, whilst simultaneously taking into account the market transformations towards energy efficiency. However, it is a significant challenge to implement them in a sustainable way, considering the existing decentralised and liberal energy efficiency market. Nevertheless, a disruptive approach is necessary in order to face one of the main limitations of Smart Grids. These systems which mainly focuses on electricity, require approaches which do not reimagine the existing energy systems through all stages of the lifecycle. Rather, approaches which address the current address market needs in an environmentally friendly manner are needed, whilst also recognising that existing systems have essentially been designed to increase profits rather than encourage users to reduce their energy demand.

In DSM policies related to Market Transformations, the adequate incentives with long-term support have been identified as a key success factor. On the other hand, the main failure factors are technical problems, monitoring deficit, and legislative certainty. So, the evaluation of DSM policies is ex-ante or ex-post, or a combination of both approaches (Warren, 2015).

The ex-ante approach considers the legislation effects (expected an estimate) and requires relatively little resources for analysis. On the other and, the ex-post approach requires measurement and monitoring the legislation impacts. This increases the credibility of the ex-ante approach, albeit at the expense of more resources and time as it is based on empirical results.

The combination of both approaches will make them cyclically more efficient and sustainable (Fischer, 1995; Mundaca and Neij, 2010).

**2.1.2 Directives and perspectives of approaches**

There are many stakeholders appealing to governments to adopt innovative and proactive ways to enable disruptive approaches to shift the paradigm of social and environmental performance (Fine and O´Neill, 2010).

Legislative flexibility should be provided to promote a holistic approach to the social and environmental challenges given the constant innovation, research, and technological development which is increasingly present in society. All stakeholders need to be integrated into all the process steps, to understand the values and conditions in order to apply the correct measures and incentive and financial programs. This increases the frequency of data and information sharing (which should take place, if possible, in real-time) (Smale *et al*., 2017). Consequently, a combined theoretical and conceptual approach will be necessary, enabling innovative approaches to interpret and reinterpret public which promote a critical constructivism. The overlap of policies and lack of clarity and transparency have been identified as the main causes of failure for DSM policies globally.

Given the significance of life-cycle consideration in buildings in the many Directives, it is important to know if a common Directive related to all the factors of buildings and construction, could be helpful. This could provide an overarching perspective for DSM policies encompassing all the energy system in construction and buildings. It would go beyond a singular focus on (for example) electricity from the project initialisation phase, rethinking all the methodologies and processes in a holistic fashion and making them available to all the stakeholders, thereby symbiotically improving the Directives and BSA methods. Addendum, combining ex-ante and ex-post approaches that include more factors is crucial to the exponential success of DSM policies but also all the construction policies (Warren, 2015).

**2.1.3. Energy Performance of Buildings Directives**

The differences between the criteria of the different assessment tools make the definition of “Sustainable Construction” subjective and make it difficult to compare the results obtained from each of the methods (Castro *et al.*, 2017). In this context, the International Organization for Standardization (ISO) and the European Committee for Standardization (CEN) have been active in producing standards (eight and eleven respectively) for the environmental and sustainability assessments of buildings.

Considering funding programs, it is possible to highlight Horizon 2020, which is the biggest EU Research and Innovation program ever, over seven years (2014 to 2020). The EU established demanding targets to be achieved by 2020, 2030 and 2050: reduction of GHG emissions; the share of renewable energy consumption; energy saving compared with the business-as-usual scenario; and the share of renewable energy in the transport sector.

Regarding legislation, there are published directives and standards about building materials (ISO/EN 15804), construction and demolition waste (Directive 2008/98/EC) and indoor environment quality (EN 15251). Although, in relation to sustainable buildings, the legislation is mainly focused on energy through the Energy Performance of Buildings Directive and Energy Efficiency Directive.

Directive 2002/91/EC, approved in December of 2002, aimed to promote the improvement of the energy performance of buildings in the EU by means of economic feasibility, considering the climate and the local conditions of each Member State (MS). The purpose was to increase the energy efficiency of the building and thereby improve their quality (new buildings or renovated), reduce the external energy dependency, decrease the emission of GHG and increase citizens awareness and information. The Energy Performance of Buildings Directive (EPBD) imposed the energy certification system to demonstrate their performance level, through an integrated calculation method. This method accounts for the thermal characteristics of the building, heating and cooling systems, domestic hot water (DHW) preparation, ventilation, lighting and passive solar systems, among others. The EPBD also imposed minimum requirements for the energy performance of new buildings and major renovation works, and the need to regularly inspect boilers and air-conditioning systems and the heating system (EU, 2002).

This directive implementation had some obstacles such as the MS diversity of the built environment and the low ambitions exhibited by some MS. The low renovation rate was also responsible for reducing compliance with the objectives, in addition to the lack of credibility of some energy certificates and the obligation to report the national implementation results.

In 2010, the EPBD was reformulated by the Directive 2010/31/EU (EPBD-recast). This new directive intended to: (i) reduce the CO2 emissions to mitigate climate change and, (ii) promote the development of sustainable and energy efficient solutions. Therefore, the following goals were established until 2020: (i) 20% reduction in energy, (ii) 20% reduction in CO2 emissions and, (iii) 20% increase in the use of renewable energy.

Recently, Directive 2018/844/EU of 30 May 2018 was published amending Directive 2010/31/EU on the energy performance of buildings and Directive 2012/27/EU on energy efficiency. The main goal of this new Directive is to increase the average renovation rate in a cost-effective manner: (i) introduce building automation and control as an alternative to physical inspections; (ii) encourage the implementation of efficient mobility infrastructures and, (iii) and introduce a smart readiness indicator to measure the technologic capacity of buildings. Thus, the following amendments can be highlighted (EU, 2018):

* Insertion of new definition for “building automation and control system”;
* Implementation, until 2050, of a long-term renovation strategy to support the renovation of the building stock, into a highly energy efficient and decarbonised one;
* Commit the Commission to the implementation of an optional Common Union scheme for rating the smart readiness of buildings;
* Establishment of regular inspections of heating systems or of systems for combined space heating and ventilation, with an effective rated output of over 70 kW;
* Determination of the primary energy use in kWh/(m2·year) as a numeric indicator to express the energy performance of a building for the purpose of both energy performance certification and compliance with minimum energy performance requirements.

The MS should establish proper sustainable ways to promote the gradual ongoing adaptation of existing buildings to nearly Zero Energy Buildings (nZEB). On the other hand, the long-term strategy should consider the rehabilitation and new buildings in a distinct and reciprocal way, considering the different climatic conditions and buildings specifications, and taking into consideration the stage by stage process in individual projects (including the building passports). A digitised approach to the construction which is made available to all the stakeholders in all the building stages will be crucial to carrying out a completely sustainable method of achieving the EU goals to energy efficiency (EU, 2018).

**2.1.4. nZEB – nearly Zero Energy Building**

The Energy Performance of Buildings Directive (EPBD, 2010/31/EC) introduced the definition of nZEB as a building with very high energy performance where the nearly zero or very low amount of energy needed should be extensively covered by renewable sources produced on-site or nearby. It requires that nZEB are built in member states from 2018 (in the case of public buildings) and 2020 (in the case of all buildings). Each member state must define the energy use required to achieve nZEB (Figure 1).

Figure 1 - Key years for nearly Zero-Energy Buildings (BPIE, 2014)

The EPBD also establishes a benchmarking system (the principle of “cost-optimality”) to guide the MS in setting energy performance requirements contained in national or regional building codes and keeping them under regular review. Under the EPBD, cost-optimality sets the minimum level of ambition for both building renovation and new buildings. National minimum energy performance requirements are to be reviewed every five years and strengthened if they are significantly less ambitious than the national cost-optimal levels.

A complementary aim in national nZEB implementation is the integration of renewable energy sources. Directive 2009/28/EC of the European Parliament and of the Council (the “RES Directive”) requires the MS to introduce in their building regulations and codes appropriate measures in order to increase the share of all kinds of energy from renewable sources in the building sector. The provisions of the EPBD drive the use of on-site renewable energy sources, as the local energy produced reduces the primary energy associated with the delivered energy. In this way, on-site renewables are part of the calculation of the energy performance of the building.

**2.2. European initiatives, legislation and incentive programmes**

The EU’s Horizon 2020 Research and Innovation programme focuses on the main areas of the users, buildings, public authorities, industry and heating and cooling, and innovative financing. In energy efficiency, it follows a pathway which aims to improve market uptake, and the removal of barriers between users, the market and the government through the use of sustainable policies. Hence, it supports the transition to a secure, clean and efficient energy system for the EU, enabling a clean and efficient supply to a competitive low carbon economy, improving the environment and the efficient use of resources. Therefore, it envisages a climate change resilient economy and society, sustainable management of natural resources and ecosystems, and a sustainable supply to meet the needs of a growing global population within the sustainable limits of the planet´s natural resources and ecosystems, generating and sharing economic and environmental benefits (Polzin *et al*., 2017).

Adequate financial incentives must be created and adapted to enable the digitalisation of the construction sector, enabling connection to all stakeholders during each and every stage of the buildings’ lifecycle. Thus, an integrated approach during the implementation of projects will contribute to achieving real-time monitoring and feedback, including objective and subjective parameters (Figure 2).

Figure 2 – Circular project design and engineering workflows

In this way it could be possible to achieve the long-term strategy for the development of a database of the current stock of buildings. This could enable the optimisation and the rehabilitation of the building stock in a sustainable manner, encouraging social inclusion and building a “cloud” of the same type of buildings and construction projects that are accessible to all stakeholders. Thus, the MS could opt for the optional introduction of building renovation passports to facilitate step-by-step renovation.

**2.2.1. Implementation of the nZEB requirement using the Passive House standard**

In meeting the requirements of the EPBD, each MS can decide how best to do this. Several administrations have decided to implement nZEB through the well-established Passive House (PH) standard, as outlined in the PassREg report (EU, 2015). For example, Luxembourg specified the Passive House Standard in its National Energy Efficiency Action Plan. In the Brussels Capital Region, nZEB requirements were officially defined in 2011 and enforced from 2015 according to the principles of the PH standard. The building sector has gradually adapted to the PH method and today PH based nZEB requirements are mandatory for all new buildings (Figure 3).

Figure 3 - Proportion of nZEB dwellings relative to total new build dwellings in Brussels (BPIE, 2014)

A case study comparing the PH standard and the nZEB standard carried out in the Republic of Ireland found that a dwelling constructed to comply with the PH standard and the pre-nZEB national building regulations was nZEB compliant when assessed using the national Building Energy Ratings (BER) method (Colclough *et al*, 2017a).

A key finding of the study was that care must be taken when comparing specific primary energy consumption figures. The nZEB standard in Ireland (to be finalised in 2019) requires that on average, dwellings should use less than 45 kWh/m2/a for regulated loads. To comply with the PH standard, dwellings must consume less than 120 kWh/m2/a of primary energy, as determined by the Passive House Planning Package (PHPP), with respect to total energy use (PHI, 2016). It, therefore, appeared that the nZEB standard is more stringent than the PH standard. However, this is not a like-for-like comparison, as the nZEB standard only considers regulated loads (lighting, ventilation and domestic hot water and space heating) and the PH considers all loads. When assessed using the same national assessment method, the regulated load energy use was determined to be 24.37 kWh/m2/a, significantly below the nZEB requirements.

Further, another study found that three quarters of the Passive Houses built to the minimum building regulations in Northern Ireland, were nZEB compliant with respect to primary energy consumption, without having been designed to achieve the nZEB target (Colclough *et al*, 2017b).

However, when implementing low-energy buildings (passive house or nZEB), avoidance of overheating must be considered through appropriate strategies for shading and ventilation, especially where there is a lack of regulatory requirements to avoid overheating. In the urban context, natural ventilation through openable windows needs special consideration given the context of external air quality and security - which can in certain circumstances rule out purge ventilation (Mlakar and Strancar, 2011; McLeod et al., 2013; Lomas and Porrit, 2017).

Further work needs to be done through Post Occupancy Evaluation and behavioural sceince in order to optimise an adaptive approach for the key design variables. This will facilitate whole life cycle optimisation (Mlakar and Strancar, 2011; McLeod et al., 2013; Lomas and Porrit, 2017).

**3. Holistic approach to the concept of Demand Side Management**

The concept of DSM emerged in the 1970’s, after the first worldwide energy crisis, and seeks to decrease both the peak demand and overall energy use. In keeping with this, both societal and technological development requires the astute introduction of automation and monitoring, information flows, communication and automation systems which not only promote reliability but also optimisation of the overall building lifecycle.

Driven by this, a growing number of countries have started to consider DSM in a more holistic fashion. For this reason, the BSA methods started to have an increasing presence in the market since 1990. According to these methods, a building is a sustainable building when it is built in an ecologically oriented manner that reduces its impact on the environment (Berardi, 2013). So, most of them are based on a holistic sustainability approach, and focus only on the key sustainability indicators - given that the assessment of all links between the natural and artificial environments would lead to an extremely time consuming and impractical process (Conte & Monno, 2012).

The most common methods are based on the three main pillars of the concept of Sustainable Development (Environment, Economy and Society). Within these categories, these methods usually present a list of criteria which are used to evaluate the building's performance. As part the assessment process, each method has a different weighting for each criteria, with energy typically being the most significant category, representing between 20% and 30% of the final marks.

**3.1. Building Sustainability Assessment methods**

The major reason, which promoted the development of systems to support environmental performance assessment of buildings, was that the countries were unable to say how sustainable a building was. This is also true for the countries and design teams, which believed that they were experts in this field (Castro, *et al*., 2015).

Therefore, several countries have developed their own systems for sustainability assessment, adapted to their local situation and presenting them as capable of guiding the overall performance of this sector. Most of these systems are based on local rules and legislation, in locally conventional construction technologies, with the default weight of each indicator set according to the actual local socio-cultural, economic and environmental contexts (Crawley & Aho, 1999).

Among the systems and assessment tools currently available on the market the following are acknowledged for their accuracy and increased market penetration: BREEAM (Building Research Establishment Environmental Assessment Method); CASBEE (Comprehensive Assessment System for Building Environmental Efficiency); DGNB (Deutsche Gesellschaft für Nachhaltiges Bauen); Green Star; HQE (Association pour la Haute Qualité Environmentale); LEED (Leadership in Energy & Environmental Design); NABERS (National Environmental Australian Building Rating System); and SBTool (Sustainable Building Tool).

**3.2. Implementation of the BREEAM in The Edge Office Building**

The Edge Office Building in Amsterdam (Figure 4) is considered by BREEAM to be one of the smartest buildings in the world, with its high BREAAM score (98.36%), highlighting the possibilities for new building’s construction. It is a high-profile green building with a pro-active approach to building management: constantly measuring, monitoring and analysing energy use patterns and data, enabling periodic adjustments to maintain a balanced energy usage and a comfortable building environment (BREEAM, 2017).

Figure 4 - Edge Office Building (Tilleman, 2014)

The building´s orientation is based on the path of the sun. It creates adaptable and intelligent workspaces (Figure 5) by integrating many smart technologies like connected lights which can measure occupancy movement with sensors and Ethernet powered lighting system.

Figure 5 - Form Evolution vs. Daylight Analysis (PLP/ARCHITECTURE, 2014)

This building can achieve the highest levels of sustainability with a collaborative working environment (Figure 6). The main advantages are improving public health, increased energy security and reduced environmental pollution, and at the same time, it has economic benefits, using renewable energy sources provided by wind, rain, tides, sunlight, solar heat, geothermal, hydroelectricity in combination with biofuels. It uses concepts like DSM, Energy Storage and Supply Side Management, demonstrating the concept of sustainable Smart Grids.

Figure 6 - Inside the Edge Office Building (Tilleman, 2014)

The aquifer Thermal Energy Storage (TES) is central to meeting the energy needed for heating and cooling. Rainwater is collected to flush toilets and irrigate terraces and gardens. The parking lot has dozens of charging stations for electric vehicles and large spaces to store bicycles. The building can enable its users (via a smartphone application) to find a parking space, find a free workstation, and customise temperature and lighting in their workspace. The Edge is a fully realised vision of the IoT, but it requires an enhanced approach to property management facilitated by data analysis and information obtained via data mining.

It also applies the concept of Demand Management Education (DME). Waste generated by each user is tracked and charged by weight, encouraging conservation, reuse and recycling in closed cycles. This building is constantly trying to find opportunities to reduce its carbon footprint and has become a new global benchmark for work environments, which will be enhanced and lead EU towards a smart and decarbonised building stock by 2050 using systems such as dynamic and self-learning control systems.

**4. Proposal of a new approach**

Research shows that the most relevant decisions regarding buildings’ performance occur during early design stages (Kohler and Moffatt, 2003, Son and Kim, 2015). These stages are like blank pages where anything can be drawn, enabling an easier implementation of new solutions to improve social and environmental performances, without compromising the costs (Bragança *et al*, 2014). Introducing sustainability concerns, early in the design improves the project resources optimisation and the environmental performance at lower costs, as these tend to increase as the design evolves (ECDG, 1999).

Sustainable design requires an integrated design process (IDP) and a more involved approach rather than a conventional one (Trumpf, 2007). IDP aims to aid design teams avoiding sub-optimal design solutions (Larsson, 2009). In IDP, project goals are set early in the process making it easier and more cost-effective to integrate them into the design. All participants should work together with commitment to accomplishing the established goals, making feedback loops whenever needed.

In this sense, the most important goals should be established at the start of the project, defining targets against which the design alternatives should be compared. This enables the identification of measurable criteria to help designers defining the solutions that would accomplish the project goals, with minimal environmental impacts and costs. When project briefing is poor or incomplete the probability of failing to design sustainable buildings increases (Son and Kim, 2015). Also, if the goals are not easily measurable and understandable, inefficiencies and limitations to their achievement could occur (Deru and Torcellini, 2004). Moreover, existing BSA tools are mainly applicable in latter design stages or after construction because assessment methods require a myriad of detailed data. This highlights the importance of high-quality planning and the need to have a method that enables the design team to confirm the approach early and aid decision making towards carrying out the sustainable target goals.

Taking this into account, a support design method and tool was developed to facilitate designers at early design stage to building more sustainable buildings by alerting them to how sustainability is deeply connected to all design criteria, constraints, and decisions. It allows project teams to compare the sustainable performance of different design solutions and verify which is the most sustainable. This procedure enables both quantification of each alternative’s performance and aids decision-making through comparison of those alternatives’ sustainable behaviour at each indicator level. This method was firstly developed for single family buildings as these represent 75% of the EU building stock (BPIE, 2011).

**4.1. Early Stage Design method to ensure dwellings sustainability**

The approach established has the following premises: (i) be simple and easy to use; (ii) be in line with international standards for sustainable construction; (iii) embrace the three sustainability dimensions; (iv) allow simultaneity of quantitative and qualitative criteria; (v) give required guidance to understand the implications of sustainability in the design; and (iv) enable establishing goals and requirements of the clients while having the capacity to meet this demand and have the building perform as required.

The tool follows a decision-tree structure, with four levels: areas aggregate the main topics; categories establish the general and strategic objectives; indicators represent the main issues addressed; and, whenever needed, sub-indicators address more accurate measures.

Broadly the categories are: (i) Selection of materials – comprising the materials lifecycle environmental impact and the efficient use of resources; (ii) Efficiency – comprising resources efficient use; (iii) Health and comfort – consisting of inhabitants’ health and comfort indicators and in the building’s functionality; (iv) Functionality – accounting for the aspects related to the easiness in using the building and its suitability for its users’ needs; (v) Life Cycle Costing – covering investment, operational and end-of-life costs; (vi) Place – encompassing the site conditions, ecology and social constraints; (vii) Technical and Management – accounting for project quality and management. Each of these categories is further divided into one or two stages. Each stage represents a sustainability indicator to be evaluated. A total of nineteen indicators were distributed to these categories, divided into thirty-five sub-indicators. Designers can select the ones to be evaluated and the order to do so. There is no compulsory sequence nor pre-requisite aspects.

The performance achieved in each indicator is presented through three indicative performance levels which were developed to aid understanding. Level 1 corresponds to the lowest performance and level 3 to the highest. The rationale behind the benchmarks used to define the levels varies according to the indicator’s scope.

The workflow of the tool consists of firstly defining the main objectives and goals for the project, followed by the definition of the indicators to account within each category. After that, a given solution can be evaluated in each indicator and alternatives can be added and compared with the first. Then, the tool provides the performance results and indicates which of the evaluated solutions performs better (Figure 7). Unlike existing BSA tools, this design support method does not weigh or aggregate the performance achieved in each indicator, results are displayed individually, as mid-point indicators.

Figure 7. Early design sustainability support method workflow

Using this method, designers can assess a solution performance considering different sustainability issues and compare it to other solutions. On the other hand, an indicative performance level can be defined for a given indicator, and recommendations on how to achieve such goals are given. In this way, the tool contributes and enables a thoughtful design, instead of prescribing a recipe for success. It informs all the parties about sustainability and aids establishing the sustainability goals to pursue at the very beginning of the project, contributing to a more conscious and informed decision.

Therefore, this tool distinguishes from existing BSA methods as it is applicable at early design, being prepared to deal with fuzzy and scarce date. It does not entail comprehensive calculations, considering only existing data, assumptions and establishing objective to be fulfilled in later stages of the design when data is made available. It aids designers compare alternatives in advance of their implementation, enabling them to evaluate which option to pursue based on the sustainable performance achieved rather than just assessing an established design solution. Additionally, by introducing sustainability concerns early in the building projects, it improves project resources optimisation and the impact of changes in the building design have lower or zero cost. Another advantage of this early design method is that certification is neither compulsory nor required. Its intent is not a label at the end of the construction, but a procedure to ensure sustainability has been accounted for during design. In fact, after designing a building using such a tool, a sustainability certification can be filed in any existing BSA method, without prejudice.

A shortcoming of this tool for the time being, although meant as a positive aspect, is the lack of aggregation. By aggregating the individual performances achieved at each indicator, an indicative overall performance level could be presented to building promoters enabling them to understand how their decisions would contribute to the “real sustainable performance” of their homes or give a comparison to existing BSA certification levels.

**5. Discussion**

The relevance of early design phases in reaching sustainability goals is undeniable. The sooner sustainability aspects are dealt with and considered in the project process the higher the probability of achieving a more sustainable building. Nevertheless, as previously stated there was no tool that could deeply aid designers’ decision processes at early design, when data is scarce. The existing BSA methods account for sustainability when enough data is available for an accurate quantification. Designing a sustainable building is not a simple process. There is none specific recipe for doing so. Thus, the sustainable design requires an iterative approach, which is enabled by the tool presented. This method carries out simple evaluations whilst allowing solutions comparison rather than simply prescribing one. Designers can pre-establish an intended performance level and be guided on how to achieve it or can verify the sustainability of the solutions under study.

Through using this tool, designers become more aware of sustainability concepts and concerns, improving their knowledge and consciousness on such topics. Although the early design support tool is intended to be practical and simple to use, it will promote the improvement of building performance, increasing comfort and wellbeing, while minimising environmental and economic impacts.

The knowledge improvement contributes to improving the debate and research of sustainable construction, thereby increasing the quality of new and refurbished buildings. The effect of the synergies associated with the investigation, innovation, and education will also incorporate the simultaneous evaluation of the financial costs. This will minimise the negative effects of the energy efficiency return measures and might result in positive transformation effects.

Taking into consideration the normative evolution and the paradigm of companies involved in the construction process and the whole real estate park, it is necessary to develop strategies to incorporate several technologies and innovative processes that demonstrate a high level of social and environmental performance and enhance meta-cognitive methods. This will enable the identification of some hidden problems which otherwise are not easily spotted by everyone involved. These have negatively impacted on outcomes in the past as is evidenced by Sick Building Syndrome.

The tool could also enable the implementation of blockchain technologies to develop new energy markets, and development of new investment funds. This is achieved by providing a holistic perspective incorporating BSA methods, legislation, and energy performance certificates simultaneously enabling transparency and enhancing security by providing a single digital platform.

Thus, to develop a holistic approach encompassing all stakeholders in DSM, enabling the optimisation of legislation with "ex-ante" and "ex-post" approaches, it is crucial to adopt real-time monitoring in all the steps of construction, at an individual project level and involving all stakeholders (Warren, 2015). To achieve this, disruptive innovation is necessary including the promotion of decentralised and liberal approaches.

**6. Conclusions**

A resilient environment, society, and economy, with responsible and sustainable demand management, promotes an efficient supply and is more adapted to the constant population increase. This creates healthy ecosystems and ensures the sustainability of planet Earth and its natural resources. Therefore, it is essential to foster research into dynamic and disruptive methods that promote a set of ideas that encourage the promotion of voluntary and sustainable change by all building environment lifecycle stakeholders, thereby promoting use reduction and energy efficiency.

Ensuring producer responsibility, as well as the development of educational information networks and the sharing of experiences among different stakeholders, is the best ways to achieve the sustainability of the built environment. This can be achieved by fostering the circular economy and by making clear links between human rights and duties, especially in the urban environment. In this way, the promotion of responsible demand management, by providing technical and qualified assistance at an individual, commercial and industrial level, is important in addition to the continued development of disruptive approaches towards sustainability.

The passive design of buildings, the creation of flexible, adaptable and intelligent spaces, through the integration of monitoring technologies, are key enablers that will support the revision of the EPBD, to ensure the correct indices are used for new constructions or significant energy refurbishments. In this sense, the Early Stage Design method could promote better sustainable solutions and provide key insights for energy efficiency.

The circularity of all these concepts promotes the sustainability of all energy networks, contributing to the development of buildings with zero emissions and improving the social and environmental behaviour of their stakeholders. Thus, optimal lifecycle cost concepts, coupled with research based on social performance promotes flexibility and temporal management of the legal regime for urban rehabilitation, contributing to urban resilience and the avoidance of climate change.

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**Conflict of Interest**

The authors declare no conflict of interest.

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