RESPONSIVE BUILDINGS ENVELOPE INTEGRATION IN SUSTAINABLE NEW CITIES PLANNING STRATEGIES

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Abstract

"Cities Are Part of the Climate Change Problem, But They Are Also a Key Part of the Solution" (Robert, 2009) Cities nowadays responsible for the larger part of global energy consumption, therefore major contributors of greenhouse gas emissions. Furthermore, cities have key capabilities to act on global climate change through their responsibilities over urban sectors like buildings. With the growing importance of the environment as a global issue, sustainability has been adopted as a common political goal, the United Nations world commission of environment and development defined sustainability as the ability of meeting the present needs without affecting the future generations capabilities to meet their own needs. The Responsive building envelopes are expected to play a significant role in new sustainable cities urban planning principles as a part of problem solving by preventing energy consumption in buildings, thus the urban environment as well, also they're valuable to boost the balance between several energy flows at single- and multi building scale, in addition to optimize user experience and indoor comfort by providing an interactive interface with the outdoors. Using responsive buildings envelopes could be utilized as a mean of decreasing carbon emissions in urban environment and can be integrated into sustainable new cities planning strategies. The aim of this research is investigating the role of responsive building facades in new sustainable urban planning and setting out planning strategies for new cities to design a network of responsive buildings in order to reduce urban energy consumption.

Keywords

Energy Efficiency; Energy planning; Responsive Buildings Envelopes; Sustainable New Cities; Urban Planning

1. Introduction

Cities can be considered as a livable system depending on some inputs like water, materials used and energy that consumed to run the city and transformed into wastes, and some negative outputs like urban energy consumption that can be considered as one of the largest reasons of producing carbon dioxide (CO2) emissions. (World Commission on Environment and Development, 2000)

The City as a System – Rogers Model in light of the international interest in global warming issue, and the constant search for ways, and solutions to prevent the encroachment on the world's energy capabilities, the building envelopes have been used as a solution to reduce building energy consumptions in cities as stated by the Intergovernmental Panel on Climate Change (IPCC) as one of the largest energy consumption sectors Higher than the industrial, and transportation sectors together. (Rogers & Gumuchdjian, 1997)

The building Envelopes role has evolved from protection only to energy storage, and generation according to need through many improvements in terms of materials, system designs, and energy efficiency simulations. (Ellika Taveres-Cachata, 2019)

2. Research significance

Controlling the amount of pollution, hazardous emissions , and reducing energy consumptions is the main purpose of many architects , and engineers whom researched how to protect the built space from pollution, energy waste , and carbon dioxide emissions throughout the past decades but this research is primarily concerned with the role of responsive building envelopes in creating a positive environmental impact in buildings, Thus in urban communities, through refining their effective role within sustainable urban planning principles as a type of research that seeks to develop its role on a larger scale.

3. New cities concept

New Cities Concept is one of the urban patterns appear From the late of 19th century and the beginning of 20th, centuries with the emanation of the urban geography, in which the new cities occurrence has been linked to the British urban experience, it

spread on the global level for a while till Ebenezer Howard came with the garden cities idea in late 19th century, then the new cities booming after World war II that negatively affected most of the British cities , thus a primary goal was introduced by the state of establishing new cities for enhancing the life of London residents after war. (Lee, 2020)

New Cities identity is hard to be determined because it has many objectives differed according to the place, and era but its goals all ranged between reducing population in congested metropolitan centers, creating a successful, and positive environmentally, economically, and socially poles, and degraded areas development in which faces some problems (Table 1) on different sectors can be summarized in points as follows: (Elshafei, 2016)

PROBLEMS	EXPLANATION AND CLARIFICATION
URBAN	Some of these new cities suffers from lack of population attraction due to some reasons like difficulty in establishing efficient commercial and public services, lack of suitable job opportunities for all residents, causing daily movement to and from the city and creating severe congestion and burden on traffic and consequently increasing rates of energy consumption which turns it into an Urban encumbrance instead of being a solution. (Elshafei M. M., 2017)
ECONOMIC	Lack of New investments encouragement resulting in Failure to achieve the required economic development in terms of economic resources and capabilities, thus failure in creating an economic balance at the Local and national border framework level. (ali, 2004)
SOCIAL	Absence of various social services that can meet all the social segment's needs, Lack of diverse housing opportunities meeting the needs of different population in terms of the sizes of families and cultures. These new urban patterns (New Cities) severely affected by the unemployed problem as it is difficult to find a suitable job opportunity in the new cities characterized by economic and social insurance elements. (Elshafei M. M., 2017)
ENVIRONMENTAL	1. ▪Poor Compatibility with the environment, which must be obvious within the environmental limits and natural resource protection, and responsible consumption of resources, recycling and use. (al, 2005) 2. ▪Do not Use the renewable energy which could be a source of dramatic increase in energy efficiency. ▪Shortage in the Recycling and reuse of materials. 3. ▪About 3% of the earth's surface is occupied by cities, but it has a tremendous density of population, manufacturing, and energy use, so it's considered as a successful image of the urbanization with many social and economic advantages but also has several environmental problems, this will lead to extensive local emissions and destruction of the environment. Environmental effects of cities often reach further than their metropolitan borders; cities have a significant impact on the surrounding urban, regional and worldwide ecosystems. (Poredoš, 2011) ▪Urban environmental problems above all involve, insufficient water resources, sanitation, solid waste, electricity supply, lack of green and natural areas, urban growth, soil and air pollution, traffic, noise, etc. (UNEP, 2012)

4.Sustainable new city planning

To create a sustainable urban environment, it is essential to measure and analyze policies, infrastructural facilities, socio-economic aspects, resource use, emission levels, as well as other processes related to, and take advantage of, the metabolism, prosperity, and quality of life of the city. (European Commission, 2015)

Strategic Urban sustainability planning takes on an all-encompassing vision of the city and the metropolitan dynamics. Its general objective includes identifying the desired city model and working towards the collective vision of the future thru the collaboration of public and private efforts, the involvement of citizens and investors, energy changeling, adapted to the new context, and improvement of the living conditions of affected inhabitant. In addition, strategic planning offers a methodology that assist cities in order to find out their strengths and weaknesses, develop appropriate local development strategies, and prioritize the efficient allocation of resources. (European Commission, 2015)

The primary additional benefit about strategic planning is how it improve the interaction among the main actors and enhances dedication of the involved communities. Usually, a City Development Strategy is the identifiable end result of strategy planning, which develops all aspects of the city, integrating in the same territory technical, environmental, political, social and economic interests. (European Commission, 2015)

5.Integration between sustainable new city planning, and energy planning

By changing the way energy is consumed, cities can play a significant role in the transformation of the energy sector around the world. They are responsible for about three quarters of all energy use, directly or indirectly, and greenhouse gas emissions, so that cities play avital role in helping us to achieve the EU's decarburization targets for 2030 and 2050. Their impact goes further than their consumption and emissions of energy. The commitment of cities and their inhabitants is also to tackling the socio-economic and environmental issues facing the world today. (European Union, 2017)

6.Implementation of energy strategies

Although there is still a significant barrier between urban planning objectives and the energy sector, for several years now, the relationship between urban form, energy consumption, and climate change has been recognized. There should be a natural

connection between urban development and energy development. Separateness between urban, and energy development has created the world energy challenges that demand a new improved set of planning strategies. (Quitzau, et al., 2018)

According to Energy Efficient Communities (IEA-EBC Annex 51) It is only possible to achieve efficient urban energy planning, by the integration of energy planning in the whole process of urban planning. However, there is a lack of consideration of energy concerns in urban planning processes in many countries, which is of great concern, as, with the increasing impact of climate change, municipalities and energy providers are responsible for creating policies that adjust to current conditions and mitigating future impacts. Both parties, governments, and energy providers, should collaborate their actions, and both need a comprehensive set of tools, and strategies for managing their resources as well to reduce the emission of greenhouse gases. (Jan Schiefelbeina, 2017)

7.Three scales of implementation

Implementation is processing through different urban development scales (Table 2), It could address the master planning of a new district, the renovation of an existing building, or the development of a strategic plan for the city, depending on how the development is scoped and framed. However, this research will focus on city-scale strategies. (Quitzau, et al., 2018)

scale	Planning developer	Professional community	Local community	
City scale	Strategic plans. Formal hearings or voluntary cooperation.	Planners. Policy makers. The participation of professionals and legislators.	Constantly involved NGOs and stakeholders. Government residents thru means of hearings and organized gatherings.	
District scale	Master's planning. Detailed proposals, Competition. Formal authorization, Unofficial collaboration	Planners, architects, developers and consultants. Direct cooperation on plans.	Local representatives and interested stakeholders through meetings and hearings. Local citizens and industries/ businesses.	
Buildings scale	Plans and blueprints for construction. Official validation, Informal collaboration	Planners, developer, architect and consultant. Direct and close dialogue.	Neighbourhood discussion and engagement. Active conversation with end-users or indirect representation of local needs.	

Table2: characteristics of energy planning implementations scales (DTU & AAU, 2017

8.Impact of building envelopes in cities energy consumption

The construction industry sector playing a vital role for cities' climate and energy action plans, as a producer of nearly 40% of the world's direct and indirect greenhouse gas (GHG) emissions, and more than 38% of world energy consumption more than in industry or transport. In the meantime, recent studies show that 20 to 60% of all energy used in buildings is affected by the design, and construction of buildings envelopes due to their function as an environmental filter.

Architects, planners thus face the challenge of optimizing buildings envelope design in order to decarbonize this sector. Policy frameworks as well as the participation of professionals in the field both are essential tools to promote innovative solutions designed to meet the needs, opportunities, and climatic changes of individual cities. Innovations in the efficiency of building envelopes, properly implemented, offer significant economic efficiency, better residents well-being in addition to assist reducing the rise in global temperatures, and increase urban resilience. (WWF - World Wide Fund For Nature, 2018)

9.From static to responsive buildings envelope to improve buildings energy efficiency

Through the last decade designing Energy efficiency buildings turned around two main strategies to enhance buildings energy performance; First installation of highly efficient energy recovery systems, second use of passive design solutions to improve the efficiency of building envelopes by optimizing buildings shape, improving insulation materials for envelopes and windows, however, this static design concept cannot be sufficient to achieve environmental sustainability targets. (Paola Galloa, 2017)

This is based on the fact that the limitation of Static envelops to how much energy savings can be achieved as they are incapable of interact with the outdoor conditions which would benefit the indoor environment consistently, as well as give buildings users the ability to modify the envelope to meet their needs. With seasonal variability, and changing of weather patterns, static envelopes cannot provide consistent climate control. (Paola Galloa, 2017)

"Responsive building envelopes" could solve problems faced by static envelopes by supplying the ability to play more than one role at a time according to outdoor climate conditions, for example, allowing solar heat during certain times but restricting it at other times, shifting between functions in adaptation to different conditions allows envelopes to decrease energy consumption and improve the efficiency of building energy. (Ellika Taveres-Cachata, 2019)

10.Classification of responsive Building envelope systems

Responsive systems are primary classified into three different categories shown in (Figure 2) according to responsivity type.

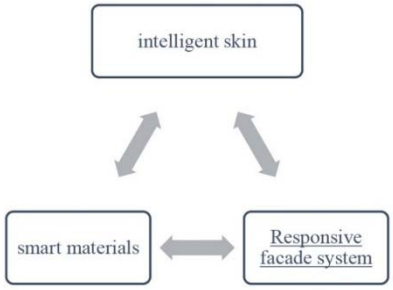


Figure2: classifications of responsive system (Hadeer Samir, 2019)

10.1 smart material

"Smart materials" are described by Addington and Schodek as systems with "embedded technical functions" which provides specialized environmental responses, operating either through internal change in physical possessions or through external exchange of energy." Due to their integral features, smart materials can play an important role in responsive envelopes, as shown in (Figure 3). One of the most crucial features of smart materials is that they are capable of transforming their Materialistic Features, and/or shape or exchanging energy without the need for an outward power source. (MARKOPOULOU, 2018)

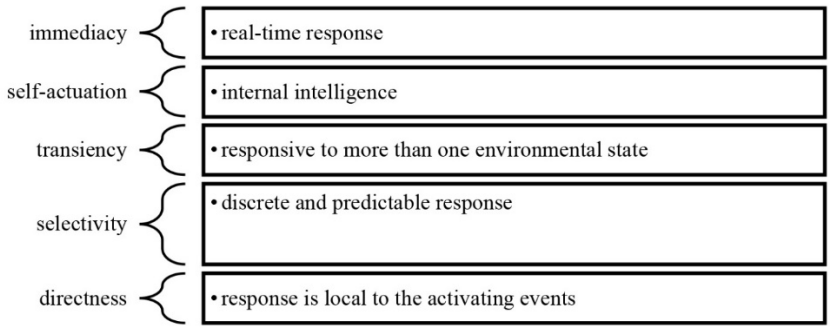
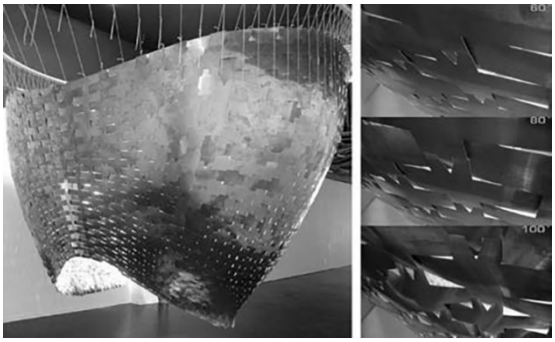


Figure 3: characteristics of smart materials (Dewidar, 2013) edited by (author)

Examples for smart materials used in responsive building facades include: aerogel – the artificial low-density translucent material used in openings glazing, thermochromic (Figure 4), and phase changing materials like micro-Coated wax, salt hydrates and ETFE (Figure 5). (G. Thun, 2013)



(Figure4) Smart Thermometer Self- Ventilating Skin: installation of prototype and details of skin performance under different temperatures, 2010 (G. Thun, 2013)

(Figure5) Smart envelope comprised of

ETFE encased solar-activated lamella shades developed for the Media-TIC building in Barcelona, Cloud 9 Architects, (Hadeer Samir, 2019)

10.2 Intelligent Skin

The aim of an intelligent building skin is to improve the buildings system according to the outdoor climate conditions, energy consumption, and users' comfort. Using building automation, and physically responsive features (figure 6) such as louvers, sunshades, operable windows or smart material assemblies.

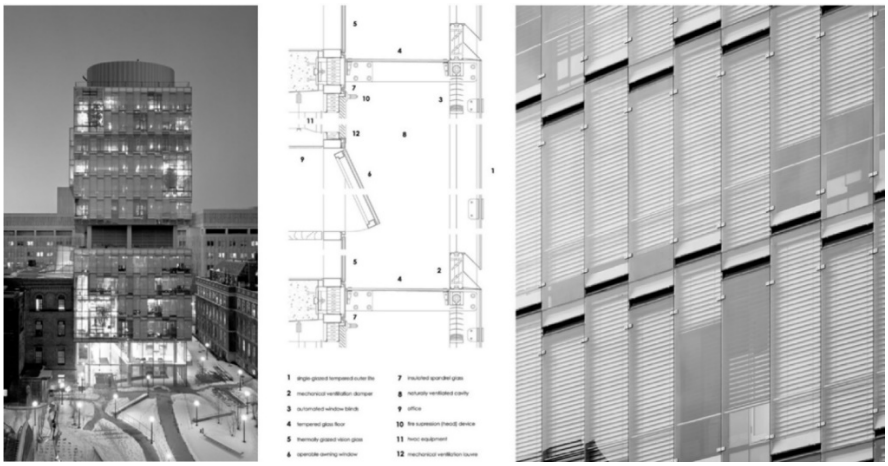


Figure 6: Intelligent double-skin façade system for the Terrence Donnelley Centre for Cellular and Bimolecular Science at the University of Toronto with integral automatic shading (G. Thun, 2013)

10.3 Responsive facades system

The term ''responsive" in building envelopes describe "the interact, and response between natural, and artificial system using computational algorithms to ensure the building system's ability to self-adapt and learn over time.

As a result, responsive building skins, not only assimilate mechanisms for users sensing, and feedback, but is also committed to instruct the building, and its residents. Data is

presented to the building's users so that they can gain awareness by time, and regulate their actions according to climate, and energy load. Finally, both the building and the residents are in an ongoing, evolving conversation. (G. Thun, 2013)

11.From building scales to city scale

Responsive envelopes on a single building scale can maximize energy efficiency by minimizing total energy consumption and harvesting renewable energy by converting it to electricity or preserving it as thermal energy in the building mass. The use of glazed materials with controllable optical and physical properties in responsive building envelopes, for example, shows obvious reductions in energy demand compared to conventional facades. When linking these envelopes together, the same results can be predicted on a district or city scale. (Ellika Taveres-Cachata, 2019)

Planning new sustainable communities to be able to support a grid of responsive and smart buildings involves looking at various scales of action and recognizing how smaller groups of buildings will act on their own and how they operate together when they link with each other in neighborhoods, districts and cities.

The idea is to design a connected node containing a group of buildings that share resources, such as climate data, thermal and electrical energy flow. The nodes are linked to a grid via the major energy control center or part of the Intelligent Operations Center (IOC) to control interactions based on the set target through particular strategies or otherwise "learning responds" (Figure 7). (L. Yang, 2015)

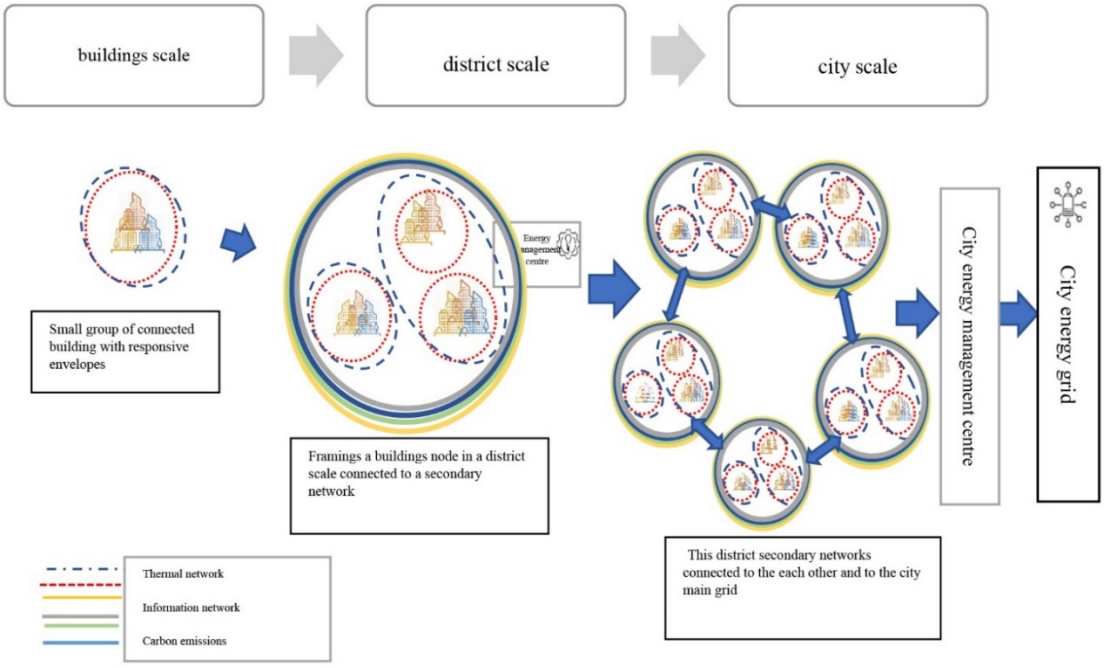


Figure 7 responsive buildings envelope from buildings scale to city scale (author)

A secondary network can be formed by this building nodes, and share resources together in various patterns. For instance, buildings will directly share thermal energy without intermittent storage. This distributed configuration is helpful to develop multiple levels (named secondary management information networks for a district scale. This swapping of resources along with buildings demand an information flow network such as, live schedules, forecasted energy use profiles, energy prices, as well as weather data, Thus, energy consumption can be regulated within real-time conditions. (L. Yang, 2015)

12.Strategies to insure the ability of responsive buildings implementations in new cities

Buildings are an integral, and elementary part of worlds ’s energy system, and will play an important role in the transition to a smart sustainable decarbonized economy - all countries need to major steps in order to effectively facilitate this transformation. Using responsive envelopes buildings will act as highly efficient micro energy hubs which consume, generate, store, and supply energy, ensuring the system efficiency. These could enable them to support the energy system's long-term balance, characterized by a large exchange of energy, by storage and demand responses. So as to realize this, there's a necessity to Increase investments in building renovation. (Frances Bean, 2017)

Smartness strategies to be implemented in the coming years have been proposed by the European Commission to determine the technical readiness of a building to interact with its inhabitants and the energy grid and to handle efficiency effectively. The indicators and strategies should, according to the Commission, cover the following points shown in (Table3).

Smart energy grids	4. Networks for distribution and delivery should develop towards what we term smart grids. This new generation power infrastructure is built to be bi-directional; energy can be produced and consumed by nodes. In addition, not only power, but also information that helps end-user energy control are transported by smart grids. (Frances Bean, 2017)
Micro grids	5. A micro grid is a local grid which can act as a section of the national grid furthermore on a separate basis, isolated from the national grid, with local sources of electricity and local loads. Microgrids are contributing to resilient new cities and are helping to reduce Losses of energy in transmission and delivery while maximizing energy efficiency. (Deloitte , 2015)
HEAT PUMPS	Through using power and thermal energy via renewable sources, heat pump systems provide a 100 % sustainable approach for building heating and cooling. Also, it is possible to coordinate the use of heat pumps according to grid specifications towards flexible use and demand response. (Frances Bean, 2017)
DISTRICT ENERGY & Heating	• Preparing for District Energy. Verify that facilities are designed to connect to a district energy grid where one operates or is planned for growth. • District heating-linked end-users may also selling their surplus energy in a dynamic energy market, cutting the heat-load peak, and allow the district heating provider to close down peak-load boilers. Excess heat (e.g., heat recovery from cooling systems or data centers), heat pumps powered by photovoltaic solar panels, along with geothermal and solar thermal energy may be used in district heating. (Lisa King, 2017)
SMART METER DEPLOYMENT	• Smart meters can motivate end-users by encouraging them to have more knowledge and control of their energy system. Accurate measurement of energy consumption is a requirement for the valorization of demand response facilities in order to provide real-time statistics on the energy consumed. • • All thermal energy meters should be "actual" energy meters able of calculating flow rates along with temperatures of supply and return and energy usage computing. Meters shall conform to CEN (European Committee for Standardization) Standard EN 1434. (Lisa King, 2017)
Cooperation in energy markets	• In order to maximize the advantages of integrating technological advances, firms and policymakers need to work together as efficiently as possible. In order to establish regulations that support the transformation that the energy market is going through, collaboration between companies and governments is needed. • In order to coordinate technological advances, cooperation between companies is required. By connecting companies, standardization helps tremendously in this context. (e.g., when attaching a smart meter to residential responsive devices). (European Union, 2017)
Data & technologies	• The process of extracting data from a wide range of sensors in public spaces, transit networks, power grids and other types of user equipment provides real-time insight into transport patterns, energy flows, pollution and human behavior. It is not sufficient to use these data sources in isolation from each other to build smart islands. • However, sensors alone are not sufficient, a city requires a mature IoT (internet of things) software framework to handle the sensors, obtain and process data and make this information accessible via application program interfaces for smart solutions. (Deloitte , 2015) • City-wide use of advanced analytics of mature data (real-time, big data, predictive
Seasonal Thermal Energy Storage (STES)	• Technology that can easily adjust to operational loads, consume or release energy as needed, or turn a specific final energy into another type of energy, will be

	valued highly in an increasingly complex energy environment. Battery-based systems are potentially an important part of potential construction-related storage, but other technology alternatives, such as thermal and hydrogen storage, must also be considered. (European Commission, 2015) • During the summer season, most office buildings in cities generate excess heat. In the summer season, this heat may be stored underground and pumped back up throughout the winter season. By recycling heat generated in the past, energy consumption can be reduced in this way. (Frances Bean, 2017)

Table 3 strategies to ensure the implementations of responsive buildings envelops and smart buildings in new cities

13.Conclusion

So, as a conclusion there is a direct relationship between the urban planning principles and the energy consumptions prevention strategies, appears obviously in the fact that the sustainable urban planning is about meeting the residents needs without any future negatives or energy decline.

Using the responsive envelopes for ensuring an energy Saving role is an important approach for sustainable urban planning development towards a successful urban environment by embedding strategies that can help in connecting the buildings to form a wider concept for energy controlling, and ability development.

Responsive building envelopes will play a crucial role in converting the world's energy usage into a more decentralized, sustainable, integrated and flexible system that guarantees sustainability and allows optimum use of all resources while at the same time enabling a healthy living and working atmosphere for inhabitants.

Planning new cities process should put in to consideration the required infrastructure for the implementations of responsive buildings from the district scale into the city scale.

In order to provide optimal solutions, areas such as artificial intelligence, big data, and the internet of things are crucial to be integrated into responsive buildings envelops for the optimization of those materials, and systems within the cities.

References

al, G. B. (2005). Back to the city: A route to urban sustainability: future forms and design sustainable cities. Oxford: Architectural Press.

Ali, m. a. (2004). the mechanism of urban growth in the new communities.

Antonio Garrido, Y. P. (2017). The making of a smart city: best practices across Europe. Belgium: European Union press.

Deloitte. (2015). Smart Cities: How rapid advances in technology are reshaping our economy and society. : Deloitte.

Dewidar, K. (2013). Living Skins: A New Concept of Self Active Building Envelope Regulating Systems. Conference: SB 13 Dubahi. Dubahi.

Ellika Taveres-Cachata, b. S. (2019). Responsive building envelope concepts in zero emission neighborhoods and smart cities - A roadmap to implementation. Building and Environment, 446-457.

Ellika Taveres-Cachata, b, Steinar Grynninga, ∗, Judith Thomsena, Stephen Selkowitzc. (2019). Responsive building envelope concepts in zero emission neighborhoods and. Building and Environment, 446–457.

Elshafei, M. &. (2016). Architect's Role In Enhancing Socially Sustainable Communities And Its Reflection On Architectural Education. research gate.

Elshafei, M. M. (2017). Sustainable Social Planning Methodology in new cities. Alexandria: Alexandria University.

European Commission. (2015). Science for Environment Policy Indicators for sustainable cities. In-depth. Bristo.

European Union. (2017). in smart integrative smart city planning.: European Commission press.

Frances Bean, M. D. (2017). Is Europe ready for the smart buildings REVOLUTION.: Performance Institute Europe (BPIE).

G. Thun, K. V. (2013). Responsive Building Envelopes: Characteristics and Evolving Paradigms.

Garrido-Marijuan, A. (2017). The making of a smart city: best practices across Europe. Belgium: EU Smart Cities Information System.

Hadeer Samir, M. S. (2019). Adaptive building envelopes of multistory buildings as an example of high-performance building skins. Classification of Adaptive Building Envelope systems., 345–352.

Jan Schiefelbeina, C. S.-P. (2017). IMPLEMENTATION OF ENERGY STRATEGIES IN COMMUNITIES – RESULTS WITHIN THE CONTEXT OF IEA ANNEX 63. 30th International Conference on Efficiency, Cost, Optimization, Simulation and environmental Impact of Energy Systems. San Diego: research gate.

WWF - World Wide Fund for Nature. (2018, 1 20). EFFICIENT BUILDING ENVELOPES TO REDUCE EMISSIONS. Retrieved from https://explore.panda.org/climate: https://wwfint.awsassets.panda.org/downloads/wwf_opcc_energy_efficiency_series_efficient_building_envelopes_to_reduce_emissions.pdf

L. Yang, Z. N. (2015). Reinforcement learning for optimal control of low exergy buildings. Applied Energy, 577-586.

Lee, D. H. (2020, July 31). Energy is at the heart of the solution to the climate challenge. Retrieved from IPCC (The Intergovernmental Panel on Climate Change): https://www.ipcc.ch/2020/07/31/energy-climatechallenge/

Lisa King, B. P. (2017). The City of Toronto ZERO EMISSIONS BUILDINGS FRAMEWORK. TORONTO: City Planning Division, City of Toronto.

MARKOPOULOU, A. (2018). design behavior Programming the material world for Responsive Architecture. Barcelona: Universidad Politécnica de Catalunya (UPC.

Paola Galloa, R. R. (2017). Adaptive facades, developed with innovative nanomaterials, for a sustainable architecture in the Mediterranean area. Procedia Engineering 180 (pp. 1274 – 1283). Italy: by Elsevier.

Poredoš, K. (2011). SUSTAINABLE CITIES – RESPONSE TO URBAN ENVIRONMENTAL PROBLEMS. Dela 36, 25-40.

Quitzau, M.-B., Hoffmann, B., Petersen, J.-P., Heller, A., Olesen, B. W., & Rode. (2018). Implementation of Energy Strategies in Communities (Annex 63). International Energy Agency.

Robert, K.-C. a. (2009). Competitive Cities and Climate Change. research gate, 3.

Rogers, R., & Gumuchdjian, P. (1997). Cities for a small planet. Boulder (Colo.): Westview Press,

UNEP. (2012). Towards a Green Economy: Pathways to Sustainable Development and A Synthesis for Policy Makers, www.unep.org/greeneconomy. Bellevue, France: 100 Watt, St-Martin-B.

World Commission on Environment and Development. (2000). Report of the World Commission on Environment and Development: Our Common Future. Oxford University Press.