SMART CITIES USING SMART CHOICES FOR ENERGY: INTEGRATING MODERN BIOENERGY IN CONSUMPTION

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Abstract
The paper brings into the spotlight the concept of smart city, emerging from major economic, social and environmental considerations and developed to provide new possibilities for the inhabitants, but also to limit the impact of human activities on the environment. Thus, the authors initiate a presentation of attempts to define the smart city, highlighting the six dimensions on its development in a sustainable context. Moreover, as one of the greatest challenges of mankind today is to ensure the increasing demand for energy by maintaining the balance with the environment, the paper highlights aspects regarding the use of a form of renewable energy, known as bioenergy. This is one of the key factors for ensuring the sustainable development of smart cities and beyond. Taking into account that smart cities have a smart energy approach, in the last part of the paper the authors present ways to integrate bioenergy into the functioning of such urban areas in Europe and build a map of smart European cities which make use of bioenergy in the benefit of population's consumption.
Keywords: biofuels, bioenergy, bioenergy entrepreneurship, smart city, sustainability.

1. INTRODUCTION

In the last century mankind has developed in an extraordinary way, carrying out the activities first with the help of the power of steam, and then with the help of various fuels. Although the growth was rapid, the negative effects did not cease to appear, the new methods used to facilitate activities leading to the release of significant quantities of gas into the atmosphere, which affected the global climate, almost exhausted the natural resources generating pollution. However, in recent decades, humanity has become increasingly aware of the seriousness of the facts and has been trying to find ways to reduce

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the impact that human activities have on the planet as a whole. An important way to reduce pollution and bring people closer to nature is to transform urban agglomerations into the so-called smart cities.

Smart cities are those developed settlements that incorporate at least one of the following dimensions (Oberg et al., 2015): smart economy (innovation, productivity, private initiative), smart mobility (accessibility, sustainable transport system), smart environment, smart people (skill level, creativity, flexibility), smart living (quality of life), intelligent governance (public and social services, institutional transparency). Nowadays, more and more cities, located in different parts of the world, are taking the necessary measures for the transition to the concept of a smart city, offering new possibilities to the residents and limiting the impact on the environment. A handy way to reduce pollution resulting from activities undertaken in cities around the world is to use bioenergy. Currently, the bioenergy sector has acquired a special dynamic in the world energy economy, due primarily to the fact that it is considered a clean and renewable energy source that can bring considerable improvements to the environment (Marinescu & Cicea, 2018; Marinescu, Cicea & Colesca, 2019; Popescu & Luca, 2017) and which, as a form of renewable energy, can contribute to economic growth, as has been shown in various researches (Pirlogea & Cicea, 2011). In this way, the smart cities sought to make the transition from the traditional energy system to the use of bioenergy, respecting the sustainability criterion specific to the concept of "smart city", which led to the reduction of fossil fuel consumption, the revitalization of the socio-economic conditions of the residents and to creating new jobs.

2. THE SMART CITY

Cities can be considered bodies dominated by human activities that undergo dramatic changes due to all these manifestations. According to Yigitcanlar et al. (2019) human activities have several negative effects consisting in: braking natural habitats, simplifying species composition, braking hydrological systems and changing energy flow and nutrient cycle. In this respect, sustainable urban settlements are sensitive to adequately addressing these issues. For this reason, the concept of a smart city has emerged.

The notion of smart city differs from the urban settlements that we know by a series of elements influencing all activities of the inhabitants from the respective area; these activities are interconnected by the use of information technologies (new technologies have the capacity to transform the business environment, the environment and the future of humanity (Morărescu, Ștefan, Popa & Albu, 2018)).

TABLE 1 - SELECTED DEFINITIONS FOR THE CONCEPT OF SMART CITY

No.	Reference	Definition	Fields
1	(Yigitcanlar, Buys, & Kamruzzaman, 2018)	An ideal model for the construction of 21st century cities, which involves a systemic approach and a sustainable and balanced development in the economic, social, environmental and institutional field.	Community, technology, innovation, sustainability, planning.
2	(ITU, 2014)	„A smart sustainable city is an innovative city that uses information and communication technologies (ICTs) and other means to improve quality of life, efficiency of urban operation and services, and competitiveness, while ensuring that it meets the needs of present and future generations with respect to economic, social and environmental aspects"	Technology, productivity, innovation, community, prosperity, sustainability.
3	(Alkandari, Alnasheet, & Alshaikhli, 2012)	„A smart city is one that uses a smart system characterized by the interaction between infrastructure, capital, behaviors and cultures, achieved through their integration."	Technology, productivity, community, governance.
4	(Lazaroiu & Roscia, 2012)	An ecological environment and an efficient urban center of the future endowed with advanced infrastructure such as sensors, electronic devices and networks that stimulate sustainable economic growth and a high quality of life	Technology, productivity, sustainability, prosperity.
5	(Caragliu, Del Bo, & Nijkamp, 2011)	The smart characteristic apperas as a result of investments in human and social capital, as well as through traditional transport infrastructure and modern IT technologies that fuel sustainable economic growth and high standards of quality of life.	Community, technology, governance, sustainability, accessibility.

Source: authors after mentioned sources

The above table presents a series of definitions of smart cities, sorted according to the year of their appearance, derived from the researchers' work, Yigitcanlar, Buys & Kamruzzaman (2018).

The smart city is a recent phenomenon that has spread globally at a very fast pace. Nowadays smart cities met on all continents, are mainly characterized by smarter urban spaces, as well as the use of technologies to manage traffic, pollution and poverty issues. Dameri (2013) presents the following details about smart cities: first, the concept of smart city is used to identify a wide range of heterogeneous solutions and urban programs, involving different types of technologies and aiming to reach a set of different objectives and at the same time not very well defined. Second, similar concepts are used to define the same types of projects and solutions, even if each of them can be attributed to the idea of a smart city: „digital city", „intelligent city", „cognitive city".

According to Mutule et al. (2018), a smart city is an urban development that meets the needs of citizens in a sustainable and safe way taking into account six vectors: smart economy, smart mobility, smart environment, smart governance, smart living, smart people. All these variables need energy in different forms and modes, and despite the fact that the notion of energy is missing from the six concepts

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mentioned above, energy is considered to be the key to sustainable development of smart cities, influencing these dimensions directly, as shown in Figure 1. The concept of smart city is closely linked to the concept of smart energy city, which involves more professional approaches, focused on selecting or adopting those solutions (necessary for the development of the city) based on an integrated approach to energy issues, aspects that have a crucial role in the sustainable development of smart cities. The role of public authorities in the development of such cities is essential, because of their actions, decisions and understanding of their responsibility, depending on the support and integration of energy projects at urban level (Zamfir, 2013). At the same time, they also depend on the so-called "smart" policies whose purpose is to integrate green energy into consumption (Zamfir, 2013).

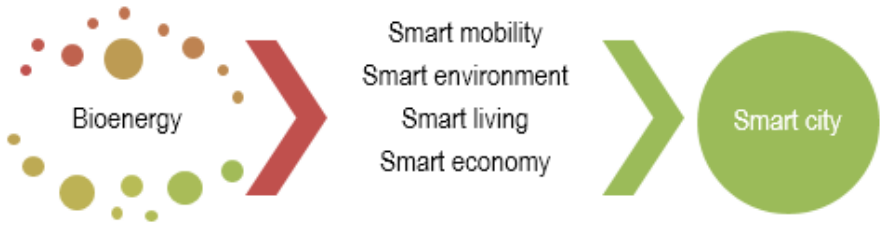

Figure 1 - The influence of bioenergy on the dimensions of the smart city
Source: authors

3. THREE GENERATIONS OF BIOFUELS FOR SMART CITIES - ENTAILING ENTREPRENEURIAL OPPORTUNITIES

At present, one of the greatest challenges of humanity is to ensure the increasing demand for energy by maintaining the balance with the environment (Pirlogea, 2012). The annual growth of the world`s population has led to an increase in global energy demand. As a result, using fossil fuels is no longer an alternative neither in terms of environmental protection nor in the construction of smart cities, so a handy solution to meet the energy demand is to use biofuels. As a general principle, bioenergy is produced from the use of biomass. When biomass is in the process of development, it absorbs carbon dioxide from the air. Subsequently carbon dioxide is released into the atmosphere when the biomass is subjected to the combustion process. The process of absorption and release of carbon dioxide from and into the atmosphere is thus uninterrupted within the framework of the generation of bioenergy, which leads to maintaining the same level of carbon in the environment (Mahalingam, 2015). Biofuels have evolved from one period to another, and at present they are considered to be the largest renewable fuels in the world in terms of consumption and production, due to the increased demand to replace fossil fuels, reducing greenhouse gas emissions into the atmosphere and preventing global warming (Bindra et al., 2017). In other words, the use of biofuels in smart cities provides the sustainability that

characterizes these types of urban settlements, all based on the innovation and technologies created precisely in support of environmental protection and sustainable development. Depending on the origin and the production technology involved, biofuels are divided into three distinct generations (Bindra et al., 2017).

The first generation of biofuels is also called the generation of conventional biofuels and derives from various plant cultures that have energy-containing molecules such as sugars, starch, vegetable oils and cellulose. As these biofuels are produced largely from food raw materials, they have a negative impact on food security and offer limited amounts of biofuel. The most common conventional biofuels are bioethanol, biodiesel, biogas and solid biofuels such as wood, sawdust, wood briquettes. The first generation of biofuels represents a big step towards energy independence, reducing the consumption of fossil fuels to ensure the energy needs. In smart cities, biodiesel can be a good choice for car owners, given that they are now major contributors to global pollution and global warming. Biodiesel is non-toxic, renewable, biodegradable and environmentally friendly, available in a very short time. Also, biogas can be used for cooking activities or to replace gas for those vehicles equipped with this power generation system.

The second generation of biofuels is known as advanced biofuels and is produced from biomass including lignocellulose, non-feed materials such as straw and forest waste. The first generation of biofuels is synthesized from sugars and vegetable oils that are found in crops and that can be easily extracted using conventional technologies. In contrast, the second generation of biofuels derives from biomass of forestry and agricultural residues, which makes it difficult to extract the required product and implies a series of physical and chemical treatments to convert biomass into fuel.

The third generation of biofuels is based on the production of biomass from algae. Algae can be transformed into various types of renewable biofuels including bioethanol, biodiesel, biogas, biohydrogen, etc. Biofuel production involves the transformation of biomass from algae into energy sources, and the transformation process can be divided into three categories: biochemical, chemical, thermochemical. Microalgae contain more lipids than other plants used as biomass in the production of biofuels, and the higher productivity of oil from biomass from microalgae compared to oilseed crops makes them a more economical alternative for biodiesel production. Furthermore, it is proven that Monoruphidium minutum algae can use CO2 from the smoke emitted by various pollutants (Bindra et al., 2017).

All in all, the bioenergy industry, as shown above, with its three generations of biofuels is full of entrepreneurial opportunities, even if they refer to direct participation of investors or to the support

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industries and economic activities (Hay, 2014). The concept of bioenergy entrepreneurship arised and is considered a tool for rural and urban development. Along with green energy entrepreneurship, these two concepts bring into the light two other types of entrepreneurs: bioenergy entrepreneurs (Hay, 2014) and green or renewable energy entrepreneurs, both concerned on the advancement of business services in the energy field and acting as a catalysts for impoving the uptake of green energy technologies (Gabriel, 2016).

4. WAYS OF INTEGRATING BIOENERGY WITHIN SMART CITIES

Pollution and covering the electricity needs for all inhabitants are among the main problems of cities in view of the transition to the concept of smart cities. Moreover, depending on the geographical region in which the cities are located, these two problems differ in intensity and size. For example, energy consumption differs from city to city, and within a city we can say that there are variations from one area of the city to another. While cities in developed and developing countries use energy sources to provide transportation and buildings, in cities in underdeveloped countries, energy consumption is largely influenced by the industrial sector (as in some areas of Asia and South America) (GlobalData, 2017). There are differences between the levels of pollution in the cities from underdeveloped countries, which are noticeable through complex industrial activities (with a strong impact on the environment) and the cities from developing and developed countries that implement innovations and find means to limit the impact that some economic activities have on the environment. In other words, the smart cities have found ways to integrate renewable resources into daily activities, so that the impact on the environment is less, with beneficial effects on all phenomena closely related to pollution. Among the cities that have found ways to integrate bioenergy in order to carry out the activity of the population one can mention: (GlobalData, 2017):

- Aberdeen, Scotland – within the limits of the Scottish city, it was allowed to install in different buildings individual plants that operate on a biomass basis. These buildings include the City Hall, a hospital and even a general school;
- Monterrey, Mexic – the city uses a biogas-fired power station that generates waste and supplies the subway;
- Ruhr region, Germany – the interconnection between two trans-regional networks allows industrial waste to be transformed into heat, thus ensuring centralized heat for approximately 500000 homes;

- New York – within the city a program that started in 2013 is running, aiming to produce methane from food waste;

Belo Horizonte, Brazil – a large biogas-fired power plant became operational in 2010, producing 28000 MWh per year, which represents the energy consumed by approximately 30000 consumers.

5. SMART EUROPEAN CITIES THAT INTEGRATE BIOENERGY IN CONSUMPTION

Stockholm, the capital of Sweden, is one of Europe's smart cities, considering how it has managed to integrate bioenergy into both the specific activities that generate heat and electricity, as well as in transport. For this city, centralized heating, from heat and electricity cogeneration, is the dominant system, and less than 20% of the energy comes from the use of fossil fuels. As for the rest of the energy, it comes from biomass, waste and heat pumps. In addition to heat generation, the system also generates 20 TWh of electricity. The heat pumps also provide centralized cooling of the different areas of the city (World Bioenergy Association, 2016). The most important plant that generates heat and energy using bioenergy is in the Vartan area, near Stockholm. Stockholm is a pioneering city in the use of renewable energy in transport. Buses that provide public transport through the city operate on biogas, biodiesel and bioethanol. Also, most vehicles use biofuels and currently about 20% of the total amount of fuels used is renewable. Hydrogenated vegetable oil dominates the market, replacing diesel fuel, which combustion has proven to be harmful to people and the environment. Biogas is produced using wet organic waste, but also organic waste from households. The ethanol used is produced from cereals or is imported from abroad, and biodiesel is made mainly from rapeseed oil and other vegetable oils (World Bioenergy Association, 2016).

Tallinn, the capital of Estonia is known for the fact that in recent years it has become a smart city especially through the excellent digital services made available to the citizens who are prepared and willing to use them, this city influencing the whole country (Plantera, 2018). In fact, Tallinn's path for becoming a smart city was based on three keywords: accessibility, interoperability and ease of use, the last of which translates into minimizing bureaucracy and time-consuming procedures, not producing direct value. In addition to digitization, Tallinn is known as a smart city also through the systems of electricity and thermal power generation that protect the environment. One of these is the biomass-based power station with a capacity of 67 MW thermal energy and 21.4 MW electricity inaugurated in 2017 (Bioenergy International, 2018).

Copenhagen is the capital of Denmark and has over 1.3 million inhabitants, also called the best city in the world where one can live in, based on an analysis of EasyPark that took into account the smart city

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index (Copenhagen Convention Bureau, 2017). More than 98% of households in the city are connected to the centralized system of heat generation. The most eloquent example for integrating bioenergy is the Avedore power station, which uses biomass instead of coal, generating heat with little impact on the environment (Forsberg, 2017). The city also produces electricity by using biomass in the power plants that combine heat and electricity. In addition, electricity supply system also counts on wind turbines located on land or in the sea.

In fact, smart cities in Europe have found various ways of integrating bioenergy into their own activities, as can be seen in table 2. This includes examples that have subsequently served to map smart cities, which use bioenergy for their own energy consumption.

TABLE 2 - SMART CITIES FROM EUROPE WHICH INTEGRATED BIOENERGY IN CONSUMPTION

No crt.	Smart city / Country	Type of bioenergy	Purpose	Observations	Source
1	Stockholm / Sweden	Solid biomass, biodiesel, biogas, ethanol.	For heat generation, Transportation	Approximately 190000 households are served by a cogeneration plant for electric and thermal energy. The capacity of the plant is 130MW electricity and 280 MW heat. The public transportation operates on a basis of biogas, biodiesel, ethanol.	GlobalData Event Analysis (2017) World Bioenergy Association (2016)
2	Helsinki / Finland	Solid biomass (pellets)	For heat generation	It is intended to replace coal-fired plants by 2024.	Bioenergy International (2018)
3	Tallinn / Estonia	Biomass (forestry waste)	For heat and electricity generation	A cogeneration plant with a thermal power of 67 MW and an electric capacity of 21.4 MW, which will provide 20% of the city's thermal needs.	Bioenergy International (2017)
4	Riga / Latvia	Biodiesel from rapeseed oil	Transportation	Biodiesel obtained from rapeseed processed in plants such as SIA Bio-Venta which can produce up to 100000 tonnes per year.	BioVenta (2013)
5	Kaunas / Lithuania	Biomass (wood chips, sawdust, forestry waste)	For heat generation	The Kaunas urban heating system provides heat for 118000 people, using three boilers using biomass with a total capacity of 70 MW.	Bioenergy Europe (2019)
6	Vilnius / Lithuania	Biomass (forestry waste)	For heat generation	40% of the city's heating needs are covered by the use of bioenergy.	Danpower Baltic (2015)
7	Plovdiv / Bulgaria	Biodiesel	Transportation	"Gamakol" EOOD is one of the most well-known biodiesel producers from Plovdiv.	Biodiesel chains (2007)
8	Poznan / Poland	Biomass	For heat and electricity generation	Power plants consume around 210000 tonnes per year, helping to avoid a similar amount of CO_2 emissions.	Veolia Environment SA (2016)
9	Lodz / Poland	Biomass	For heat and electricity generation	The electricity and heat supply network in Lodz serves 60% of the city's population.	Veolia Environment SA (2016)

No crt.	Smart city / Country	Type of bioenergy	Purpose	Observations	Source
10	Antwerp / Germany	Biomass Biodiesel	For heat generation, Transportation	The city of Antwerp is located at the intersection of numerous commercial chains, in the heart of the Western European pipeline network, which provides an extensive and secure supply chain and serves various centers and cities worldwide..	Port of Antwerp (2016)
11	Gothenburg/ Sweden	Solid biomass, incinerated waste, Biogas	For heat generation Transportation	The city of Gothenburg is home to few oil refineries, being the second largest city in Sweden with over 900000 inhabitants. Over 80% of households are connected to the centralized system for generating heat.	World Bioenergy Association (2016)
12	Copenhagen/ Denmark	Solid biomass	For heat and electricity generation Transportation	98% of the inhabitants are connected to the centralized system for generating heat, resulting from the use of wood pellets, chips, sawdust or waste.	World Bioenergy Association (2016)
13	Lisbon/ Portugal	Biomass	Electricity	Portugal has nine plants that use biomass, producing electricity of 309 MW. Also, 65% of the total waste is stored and incinerated.	Esteves et al. (2011)
14	Malaga/ Spain	Biogas	Steam generation in the feed manufacturing process	Through the use of biogas in various anthropic activities, a CO_2 emission reduction of 13274 tonnes was obtained.	Ecoterrae (2017)
15	Todoella/ Valencia/ Spain	Biomass	For heat generation and hot water	The heating system increases the value of the properties	Fedarene (n/a)
16	Bordeaux/ France	Biomass	For heat generation	The use of biomass leads to the reduction of 3500 tons of CO_2 emissions, as compared to the use of fossil fuels.	Bouygues Immobilie Corporate (2012)
		Biogas (Biomethan)	Replacing fossil fuels	This type of bioenergy reduces fine particles emissions by 85%, CO_2 emissions by 90% and noise pollution by up to 50%. Its production capacity is 60 MW, which reaches 500 GWh for a full year of production.	Air Liquide Creative Oxygen (2018)
17	Rennes/ France	Biomass	Heat generation	The plant supplies heat to 21000 households. It contributes to the reduction of over 37000 tonnes CO_2 emissions per year.	European Energy Efficiency Fund (2013)
18	Vienna / Austria	Biomass	Heat generation	The main energy source of the city is represented by waste incinerators, which ensure the centralized heating of over 270000 people.	Global Data (2017)
19	Amsterdam/ Netherlands	Incinerated waste	Electricity and heat generation	The plant in the port area of Amsterdam is owned by the public administration and can consume up to 530000 tonnes of household waste to serve over 1.4 million inhabitants.	Energy from Waste – Amsterdam (2013)

Source: the authors based on the mentioned sources

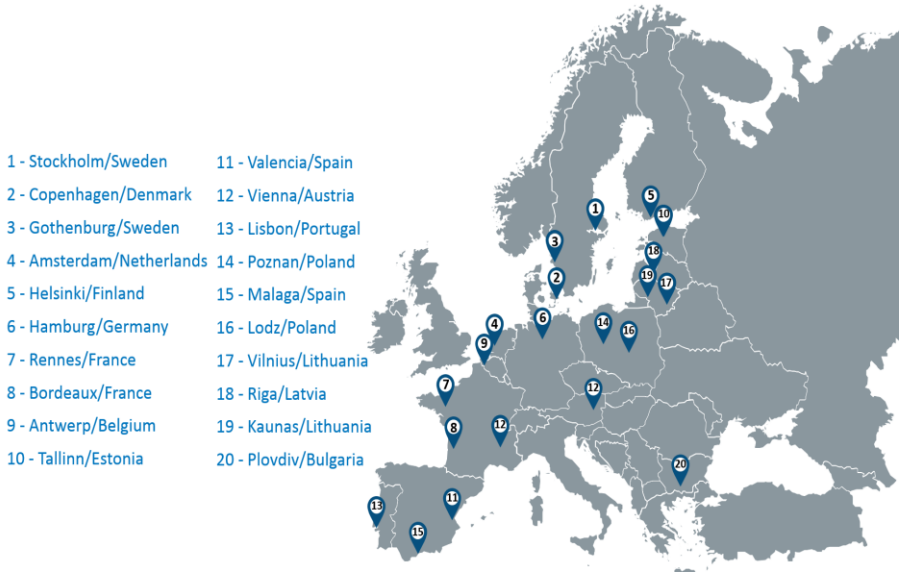

FIGURE 2 - THE MAP OF SMART EUROPEAN CITIES WHICH INTEGRATE BIOENERGY IN CONSUMPTION
Source: the authors

The map represents an element of novelty brought by this paper. The numbering of cities on the map is not accidental, it takes into account the average value of the smart city index (Vienna University of Technology, 2015). It represents a first trial of gathering smart cities that started using bioenergy. We are convinced that there are other big smart cities that could have been included on the map and that, unwillingly, we didn't pay attention to. The map may be enriched with other examples of cities as they direct their consumption to this type of energy.

However, by studying the map, one can observe the fact that smart cities from the Northern and Western Europe place themselves first on the map, according to the value of the smart city index and the use of bioenergy. The Eastern part of the Europe is less covered within the map and in terms of bioenergy integration in consumption.

6. CONCLUSIONS

In order to become truly intelligent, it is imperative for urban settlements in Europe to become sustainable. Reaching this threshold can be achieved in various forms and with varying costs, but a handy solution is the use of bioenergy in all its forms in the current activities. Smart cities in Europe have largely succeeded in shifting from using fossil fuels for public transport or electricity or heat geenration to using alternative fuels based on biomass. This contributes, on the one hand, to the compliance with European Union legislation on renewable energy use targets, and on the other hand, to providing services for population that affect less the environment as compared to the usual services. This also impacts the development of the so-called bioenergy entrepreneurship, which, in our opinion

gathers all bioenergy actors (entrepreneurs, investors, hobbyists, different types of enterprises and organizations), business models and innovative and cost effective alternatives for replacing old traditional fuels.

The development of technologies integrating the three generations of biofuels in the anthropic activities is an objective pursued by all administrations of the smart European cities. Ensuring the profitability of the economic component and ensuring the sustainability for the protection of inhabitants and environment are part of each urban settlement's strategy. The examples of good practices mentioned in the paper can be followed by other administrations in the cities of Europe that consider converting the classic cities, with an industrial profile, into the modern smart cities. Here, smart governance is capable of directing funds in the best ways to respond to the specific components of a smart city, which first of all generates a less polluted environment in which the activities are carried out with greater harmony.

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