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Efficiency Based Model for Solar Urban Planning

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Abstract**—**Today is widely understood that global energy consumption patterns are directly related to the urban expansion and development process. This expansion is based on the natural growth of human activities and has left most urban areas totally dependent on fossil fuel derived external energy inputs. This status-quo of production, transportation, storage and consumption of energy has become inefficient and is set to become even more so when the continuous increases in energy demand are factored in. The territorial management of land use and related activities is a central component in the search for more efficient models of energy use, models that can meet current and future regional, national and European goals.

In this paper a methodology is developed and discussed with the aim of improving energy efficiency at the municipal level. The development of this methodology is based on the monitoring of energy consumption and its use patterns resulting from the natural dynamism of human activities in the territory and can be utilized to assess sustainability at the local scale. A set of parameters and indicators are defined with the objective of constructing a systemic model based on the optimization, adaptation and innovation of the current energy framework and the associated energy consumption patterns. The use of the model will enable local governments to strike the necessary balance between human activities and economic development and the local and global environment while safeguarding fairness in the energy sector.

Keywords**—**Solar urban planning, solar smart city, urban development, energy efficiency.

I. INTRODUCTION

TODAY it has become clear that the natural process of urban development is directly related to the increase in energy consumption which in turn is a factor of human activities. This development does not occur in an optimized and efficient manner but rather is dependent on external energy sources for its need. Most if not all of this energy comes from non-renewable sources which indicates that this context cannot continue if the global energy price increase is taken into account.

In the context of articulation between the occupation of the territory and the existent territorial dynamic the definition of an energy efficient urban model that can integrate human activities at a municipal level is seen as a fundamental to integrate European, regional and local planning policy.

Several national, regional and even local factors such as economic competitiveness, social cohesion, environmental sustainability, cultural development and quality of life are dependent on the ways in which cities function and their ability to insert themselves into networks of innovation and development. This integration, associated with the development of the society will induce an increase of energy consumption that does not always occur in a sustainable fashion. If we utilize resources responsibly and manage them efficiently it is possible to achieve a greater diversity of services and comfort without increasing energy consumption [1].

The panorama of urban development and the contribution that the built environment represents at the level of energy consumption and particularly that which derives from non-renewable sources demands those new actions are devised to effectively reduce consumption. This reduction is dependent on the reconfiguration of the traditional energy grid into a smart grid that will optimize available resources and will contribute to the achievement of the European Union 202020 goals, [1], [2].

In the past couple of decades entire cities have directed their efforts towards achieving competiveness in areas like science, innovation and technology mainly through the creation of industrial an technological parks. These spaces were created with two main objectives: first to indicate knowledge and guarantee a transfer between universities and industries and second to promote economic growth and revitalizing urban areas.

Urban societies have become interlinked with instantaneous communication systems that offer global connectivity in real-time. These systems that have enabled tools like the internet to flourish now demand that cities be transformed from their industrial past into cities of information and knowledge [3], [4].

In this context the challenge of combining both competitiveness and sustainability is today one of the foremost challenges faced by cities, [5].

New ways of thinking and organizing cities are bringing technological innovations and new planning methods related to current territorial dynamics and concepts like sustainable cities, future cities, smart cities and digital cities.

The concept of smart city appeared in the late 90's to designate the commitment of cities to, when realizing the scarcity of resources, develop a process of resource optimization and management. More recently, due to the urgency of climate change and population growth, and the consequent resource depletion [6], smart cities have stood out as large scale project that can mitigate these problems.

It has become common to use "smart city" to describe a city that integrates in its territory some kind of "intelligent" industry. Yet the concept of smart city is wider it concerns other factors that contribute to the development and

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sustainability of a city. It is a concept that is integrated with sustainability by controlling resource consumption, particularly energy resources. On the other hand the concept is related with the behavior of city dwellers which can vary according to social and cultural differences, education, etc. The term smart city also refers to the relationship that must occur between citizens and local administration. A type of local governance that offers proximity with residents and non-residents can be achieved through new technologies such as communications platforms that offer e-government. Smart city can also be used to refer to the use of modern technology in daily urban life based on:

1. Use of Information Technologies, saving time, effort and cost (shopping, museum access, libraries, etc.);
2. Use of modern transport systems (smart transport systems), optimizing routes and traffic to increase urban mobility;
3. Use of modern technologies that contribute to the security, efficiency and resource consumption among others, [7].

In the final report “Smart Cities – Ranking of European medium-sized cities” [10], essential factors that make smart cities are organized in classes that range from economy, population, mobility and governance.

In a smart economy a spirit of open competition reflects positively on innovation and entrepreneurship as well as reinforces the productive capacity and ability to compete in the international market.

A Smart population is multicultural, constituted by the various social ladders, flexible and creative with a level of knowledge and qualification that propagates a will to know more thought life and participate in the public decision making processes.

Smart governance, incentivizes participation on various level, including decision making, public services, social services and in the definition of strategies and perspectives towards transparent governance.

Smart mobility demands easy accessibility on all scales, local, national and international. Furthermore credible alternatives are also important as well as the providing of transport infrastructure and its continuous development and investment.

A Smart environment is attractive from the natural standpoint from a pollution standpoint because different policies are incentivized to control pollution levels and adequately manage the environment as a resource that provides services.

Smart life spans the development of activities of support and leisure with the existence of cultural, educational, tourist, health and safety conditions that enhance the quality of life and social cohesion.

According to the concept of smart city the smart grid proposes the creation of a network that has the ability to adapt in real time to the reality of user demand. The smart grid is touted as being safer in dealing with natural disasters than the traditional grid. It is more advantageous on the economic point of view because of the ability to optimize supply and demand. The smart grid can gather and articulate information on the consumption to enhance quality of life.

The research methodology is structured in phases composed by steps that in joint articulation can harness the complex information system that supports the development of the investigation. To develop a model for solar urban planning a set of analytical studies of the territory was required after careful state-of-the-art review and integration of the energy dimension. To achieve this in a depth analysis of the territory was carried out taking into account several factors such as: morphology, dynamic, functioning as well as matters regarding human activities and development. In a second step studies on infrastructures, accessibility, mobility, environment, built environment, population, consumptions and energy flows were carried out. These elements support the analysis on the solar potential of the urban territory and allow for a categorization of different types of urban fabric. This extensive analysis brought great knowledge of the territory and allowed the optimization and production of energy to be distributed efficiently throughout the grid so that cities can benefit in the energy dimension.

II. A Model for Solar Urban Planning

It is essential to seek out new energy solutions for the urban territory that allow the diminishing of energy dependence of cities while at the same time reduce the environmental impact that results from the resource consumption of human activities, [9]. With the process of demand of energy from a given territory the need to characterize that unit becomes a necessity if an energy grid that can be modeled to achieve energy efficiency between different units is to be created.

When mentioning energy it is necessary to understand that it is present in all living organism and can be generated by objects and that any energy use generates heat. In this context we can think of the territory as a living organism that consumes energy and that that consumption can be broken up into smaller pieces. Those smaller pieces are not equal among themselves and therefore their consumption varies from positive to negative.

The atom is a relatively stable element, it is constituted by a nucleus that in its turn is made out of protons and neutrons and encircled by a cloud of electrons and so for an element that is made out of different pieces to become stable it is necessary that those pieces are in balance. Transposing this analogy to the territorial context we can view the territory as made out of different pieces of positive and negative consumption that can be balanced through changes in energy.

The delimitation of positive, negative and neutral areas must be done with regards to the needs of energy consumption versus the potential for energy production. In this way the energy balance can be achieved and systematically transposed to adjacent territories, like a molecule then a system of molecules (Fig. 1).

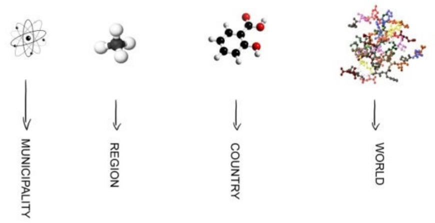

Fig. 1 Model Evolution [12]

Once the concept that frames solar urban planning is understood it is necessary to reflect on what is the best way to apply it to reality, knowing in advance that it will be a significant change on current organizations.

This model is a process that to be applied at the macro scale would require great efficiency at all levels which in turn requires a very specific implementation process for each case. That would render the process unattractive from both an economic and political standpoint as it would mean that wholesale reconstruction of vast urban areas that are deemed to be unsustainable in energy terms. On the other hand at the micro scale this can be an efficient process with great public acceptance. These stakeholders would benefit from the model and therefore promote and bottom-up approach rather than a top-down on (Fig. 2).

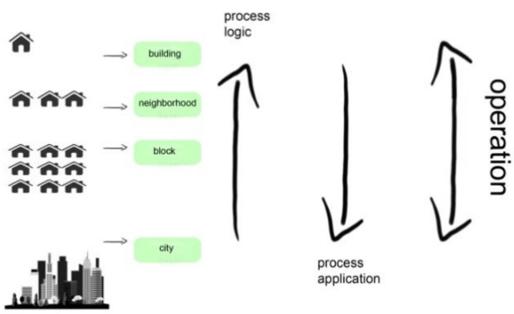

Fig. 2 Implementation scheme, [12]

Energy can be seen as the ability to produce work and that is why the efficiency in the use of energy is direct relationship with the amount of energy introduced to the system. The classification of buildings and zones in the model is associated with factors and parameters that equate the direct relationship described above. The description of the various types of zones and buildings is as follows:

- Positive zones and buildings – units with the ability to produce energy that is superior to their needs;
- Negative zones and buildings – units without the ability to produce energy to satisfy their demands;
- Neutral zones and buildings – units that have a ability to supply energy equal to their demands;

"The consumption of energy in our home depends on various factors such as: geography, construction quality, insolation, equipment type and use" [10].

The model for solar urban planning must have the ability to receive the diversity the territory offers. Because of this diversity in realities the processes of energy classification groups several factors and parameters that are flexible and adjusted to the different typologies that can occur in the built environment. The territory, when constituted by positive, negative and neutral units that already exist requires that the classification system be adjusted to the nature of every unit being assessed so that they can be organized with regards to its energy contribution towards the global energy network. [11]

To verify the required coherence in relationship to the energetic behavior of each element that constitutes the territory the model must be center on the energy element that in its turn is related and interlinked in a balanced manner with all the restraints emanating from the strategic axis and actions defined. The model must then be compatible with both short and long term actions and not derail the global intervention objectives and work as a flexible and diverse system that can adjust to the different realities and even changes in them.

III. A Model for Solar Urban Planning, Implementation

"To describe a smart city and its six characteristics it is necessary to develop a transparent and easy hierarchic structure, where each level is described by the results of the level below." [8]

The implementation of the model must follow a phased procedure, monitored and able to be adapted to the diversity of the territory (Fig. 3).

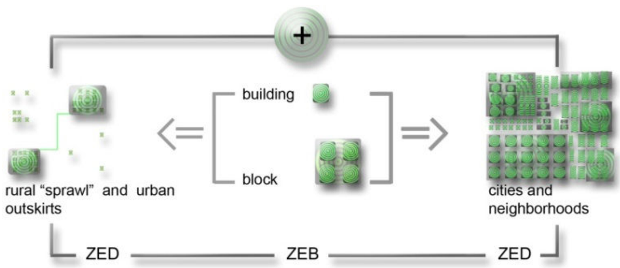

Fig. 3 Realities of implementation [12]

After adapting to the territorial reality it is necessary to analyze energy at a quantitative and qualitative level (consumption patterns, production potential and production and consumption units). Following this initial analyses the initial energy pattern information is crossed with the varied typologies of characterization (environment, infrastructures, mobility, built environment, fluxes and dynamics) delimitating zones that have similar energy features (in terms of consumption and production) and are adapted to the territorial and urban reality. Then the restrictions and constraints in the existing territory must be assesses so that no incompatibilities remain that could create an incoherent territory. The drawing of the energy efficient grid is the final step of this process.

IV. A Model for Solar Urban Planning – Oeiras E-City Case-Study

A. Consumption Patterns (Identification of Zones According to Their Consumption/ Patterns).

Delimitating zones according to their energy consumption pattern using the same temporal framework (Fig. 4):

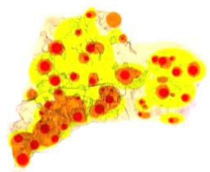

Fig. 4 Energy consumption patterns, [12]

B. Production Patterns (Quantifying Energy Production)

Zone delimitation with high production potential using various parameters (example: rooftop area available for solar panel installation) (Fig. 5).

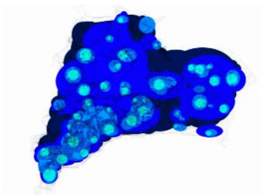

Fig. 5 Production potential [12]

C. Production and Consumption Cores (Territorial Delimitation of both Production and Consumption Cores)

Delimitation of the production and consumption cores in the territory by crossing the two previous analyses (Fig. 6).

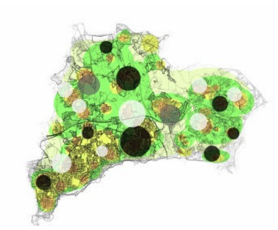

Fig. 6 Core definition [12]

D. Environment and Territory

Adapting existing cores to territory capacities to guarantee a environmental harmony (Fig. 7).

Fig. 7 Natural constraints, [12]

E. Infrastructures and Mobility

Identification of the infrastructure grid will contribute to diminish the need for new elements (such as existing power lines) in the implementation of the new model (Fig. 8).

Fig. 8 Infrastructure grid, [12]

F. Built Environment

Zone delimitation that due to their characteristics can be aggregated in regards to future implementation of the solar urban model (Fig. 9).

Fig. 9 Built environment, [12]

G. Territorial Dynamics

Accommodation of territorial dynamics is a result of human activities (Fig. 10).

Fig. 10 Territorial dynamics, [12]

H. Restrictions and Constraints

Articulate the implementation of new urban areas with instruments excluding incompatibilities and other incoherence's at the urban and legal context (Fig. 11).

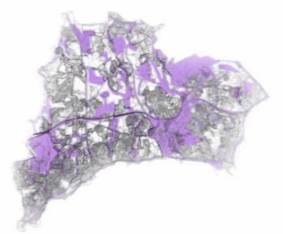

Fig. 11 Restrictions and Constraints, [12]

I. Creation of the Energy Grid

Elaboration of the energy grid in a balanced state, through energy swaps in a global context (Fig. 12).

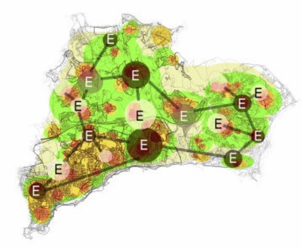

Fig. 12 Energy Grid [12]

J. Development of the Energy Grid

Development of the energy grid in a balanced state, through energy consumption patterns adaptation.

VII. CONCLUSIONS

Solar urban planning has been developed as a new concept which is intrinsically linked to the development of Smart Cities. This concept is based on the structure of an atom: the neighborhoods behave as the atomic constituents having positive, negative and neutral energetic "charge", this differential is managed by a smart grid that distributes energy to whole city or area responding to its energy needs and maintaining a stable balance.

The methodology presented is based on this context and demonstrates that it is possible to develop urban models that provide conditions for solar energy production in building rooftops to create a solar energy supply that can offset urban areas that cannot balance their energy needs. The project has, in its current stage, identified a group of key parameters that should be applied to future urban planning in order to develop energy balanced cities.

On the other hand the determination of future land and building use should provide the necessary information to predict the both its energy demands and the adjustments required to reduce them towards energy efficient cities.

The development of a GIS platform supported on the proposed urban parametric elements will allow a real-time and in depth analysis of both the geometric and spatial characteristics of open spaces, buildings and their energetic performances. This will allow the development of a correctly dimensioned smart grid network that integrates all sub-spatial units.

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REFERENCES

[1] Adene. (2011). Energia, Guia da eficiência energética. Lisboa: Adene - Agência Para a Energia, (in portuguese).
[2] ESMI (Dr. Howard Porter; Klaus-Dieter Axt). (2009). We Make Metering Smart. Belgium: European Smart Metering Industry Group.
[3] Martins, N., Figueiredo, C., Azevedo, F., Ribeiro, F., Proença, M., & Abreu, M. J. (2007). Cidades Inovadoras e Competitivas para o Desenvolvimento Sustentável. Lisboa: Departamento de Prospectiva e Planeamento e Relações Internacionais (in portuguese).
[4] Fusero, P. (2008). E-City Digital networks and cities of the future. Barcelona: LISt Lab.
[5] (Centre of Regional Science, Vienna UT, October 2007.European Smart Cities.)
[6] Amado, M. P. (2005), Planeamento Urbano Sustentável. Caleidoscópio _ Edição e Artes Gráficas, Casal de Cambra (in portuguese).
[7] Mahizhnan, A. (1999). Smart cities -The Singapore case. Cities, Vol. 16, No. 1 . Cities (pp. 13-18). Elsevier Science Ltd.
[8] Giffinger, R., & et al. (2007). Smart cities: Ranking of European medium-sized cities. Vienna: Centre of Regional Science, Vienna University of Technology.
[9] Amado, M. P., and F. Poggi. "Towards Solar Urban Planning: a new step for better energy performance." Energy Procedia .30 (2012): 1261-1273.
[10] ADENE. (2010). Guia Da Eficiência Energética. Lisboa: ADENE-Agência Para a Energia.
[11] Amado, M. P., and F. Poggi. "Planning for Solar Smart Cities" CISBAT 2013. Lausanne, Switzerland: EPFL, Lausanne, Switzerland, 2013.
[12] Oeiras, C. M., andGEOTPU – Grupo de Estudos do Ordenamento do Território e Planeamento Urbano. (2012). Projecto de I&D do Programa Promoção e Capitação Institucional - OEIRAS E-CITY (PCI03 - 267 - 9002) _ RELATÓRIO I, Oeiras (in portuguese).

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