

ENERGY SAVING IN TALL BUILDINGS: FROM URBAN PLANNING REGULATION TO SMART GRID BUILDING SOLUTIONS

V. Antonucci, C. D'Alpaos and G. Marella
Department of Civil, Architectural and Environmental Engineering
School of Engineering
University of Padova, Padova
Italy

ABSTRACT

In Italian urban planning, the economic issues addressed in new high-rise settlements are mostly approached in the developer's perspective. In private-public partnerships, investments sustainability is usually valued by public authorities in terms of construction costs, market prices and public works and infrastructures built by the private developers. In case of high-rise projects, the main aim of the public authority is to guarantee that the project be accepted by as many local residents as possible before the project even starts. In recent years, there has been an ever-growing focus on energy saving and sustainability for buildings. Italian regulation has generally approached these issues as far as building structures and materials are concerned, and in the most advanced regional urban legislation, it also focuses on the construction site. There does not, however, appear to be any attention paid to the sustainability of new developments as a whole. Italian zoning does not deal with the energy issues related to investment projects and their externalities, neither in urban development nor economic perspectives. The English Leed protocol, which focuses on urban sustainability evaluation, is barely used, and when it is, it is because the private developers has chosen to do so, not because it has been required by law. Not one public administration in Italy has yet to implement it. This paper investigates the economic issues related to energy consumption in new metropolitan areas, with specific reference to tall buildings and high density developments. Due to the specific construction typology, dimension and complexity, tall buildings might be considered as urban developments in their own right. More specifically, the paper discusses how the energy demand and consumption of a single building can affect the energy trade-off of entire cities.

Key words: building height, skyscrapers, smart city, smart grid, urban planning, sustainability

Introduction

Italian urban planning does not take into account the energy costs of new developments or the negative externalities related to different building typologies. Reducing energy consumption is only dealt with in terms of air pollution and natural environmental protection. National and local urban planning legislation only focuses on energy saving for new buildings and retrofitting and there is no national or local legislation that indicate energy consumption requirements for new developments.

Energy consumption and energy saving are critical aspects of EU policy and research, especially with regards to EU Smart Cities funding to European States within 2020. One of the most innovative areas of research is the Smart Grid system which exploit alternative energy sources, promote a more efficient use of existing power grids and reduce the environmental damage caused by traditional power plants. These objectives are important not only in a generic sustainability perspective, but are related to the scarcity of natural and economic resources, which makes it necessary to re-think current practices of production and usage of electric energy.

In recent years, each EU state member has improved and upgraded its national, regional and town legislation regarding energy savings and has promoted academic studies and pilot projects. In national and regional legislation, Italy has introduced energy parameters for energy reduction in new building developments. However, these norms focus solely on individual buildings rather than larger urban developments and do not consider the interaction between buildings and new developments as a whole in terms of energy consumption.

The aim of this paper is to discuss the way urban planning legislation in Italy might benefit from taking innovative distributed generation systems and new devices for saving electric energy consumption into account. The following section focuses on current town planning acts in Italy with respect to the economic feasibility of real estate investments and energy saving regulations. This is followed by a discussion of high-rise development properties in terms of energy usage and consumption in other contexts. Section 4 presents the smart grid system and the way it has been used in other contexts in the case of tall buildings. The paper concludes with a discussion of the ways in which local urban planning legislation could potentially promote the development of groups of tall buildings that could reduce energy consumption.

Energy and Town Planning Acts

In Italy the economics that determine how new settlements will be developed are based on norms and laws that mostly consider the developer's vision, especially in highly-populated urban areas. When considering the economic sustainability of large urban areas, the public sector only considers the economic gain for the developer who is required to demonstrate the economic feasibility of a given project and what their business model is. Even when considering what benefits a new development might bring to a city or town, be it greenfield or brownfield, the local government only checks the presence of the needed standards regarding public services such as parks, schools, community services, and how the development will meet the basic needs to be an integral part of the city. When these requirements are not met, the public authority requests that the private developer pay to local administration the amount equal to the public works construction.

In other words, economic feasibility valuation is well-known and is determined by verifying that the revenues from the sales of a development that has transformed the local environment are significant enough to pay for the cost of production, the industrial and market risks, the financial costs and the profit of the developer during the timespan of the development. Furthermore, when there are significantly large new settlements, the local administration has an interest in sharing the project with the developer in order to manage the social conflict that often comes from local stakeholders who are aware of the consequences that major developments can lead to in terms of greenfield consumption and of changing land use from the existing one to a new one. In Italy, this approach and debate is widely shared across disciplinary literature from urban policy, to urban economics and more in general to the social sciences [1] [2].

However, there appear to be several weak points in the legislation of public administrations if we consider the useful life of new developments that have been promoted as part of urban development projects especially if we consider the social costs, both public and private, of urban development in terms of energy consumption. Furthermore, the urban planning and building norms have no specific rules related to the energetic sustainability of large developments but rather focus solely on the energetic sustainability of individual buildings in terms of a reduction in energy consumption. Indeed, these norms do not take into consideration the diverse types of buildings and how developments will influence the overall urban area.

To date, Italian norms on an urban planning level, both normative and based on incentives, have only dealt with containing energy consumption and working to reduce environmental pollution.

The first class of norms basically promotes two objectives: containing land use and protecting environmental resources (e.g. rivers, forests, etc). The former is usually

dealt with by establishing a maximum amount of agricultural land that can become land used for building purposes. The latter poses two issues: on the one hand there are limitations regarding how areas that are environmentally important can be developed and on the other how to mitigate the construction of facilities or buildings that will conserve the environment and landscape.

On both a national and local (regional and township)¹, Italian legislation offers incentives for retrofitting buildings by allowing increases in the volume of a building and by reducing the administrative costs to develop a new building. The local authority does not analyse the effects of these choices on market demand: the local authority does not verify if incentives are proportional to the number of on-going energy retrofitting or to the cost that such changes had in terms of increased development in an urban area. Moreover, it is worth questioning whether public incentives to reduce the costs for the developers are really proportional to the collective benefits in terms of reduced energy consumption. The choice to use incentives has never been and still is not accompanied by a business model that makes it possible to analyze the effects such incentives might have on the real estate market.

The relevance of this legislation becomes even more significant if we consider new high-density developments. If urban sprawl leads to an increase in atmospheric pollution caused by congestion and the increased use of private means of transportation as well as increased land consumption, then tall buildings and skyscrapers are by their very nature extremely complex entities that entail increased energy consumption just to manage the buildings (water, waste management, and electricity).

Current Italian building and urban legislation does not take these issues into account, but on the contrary it appears to have decided to support containing building consumption in a one-off perspective and solely in the short term. To date all legislation supports investments in helping existing buildings reduce their energy consumption rather than promoting norms that support technologies that will help reduce costs via alternative management and a more thoughtful approach to consumption that could lead to a significant reduction in both individual and collective costs, especially for tall buildings.

¹ See the main references on Italian national laws, which regional laws are based on, building saving energy systems. L. 10/91 - *Norme per l'attuazione del Piano Energetico Nazionale in materia di uso razionale dell'energia, di risparmio energetico e di sviluppo delle fonti rinnovabili dell'energia*; D.Lgs. n. 192 del 19.08.2005 *Norme per l'attuazione del Piano Energetico Nazionale in materia di uso razionale dell'energia, di risparmio energetico e di sviluppo delle fonti rinnovabili dell'energia*; D.M. 26.06.2009 *Linee Guida Nazionali per la certificazione energetica degli edifici*.

Energy and Tall Buildings

Tall buildings are extremely costly in terms of both development and management. The economic sustainability of constructing tall buildings is analyzed by considering the cost of construction [3] [4] [5] in both technological terms as well as economical-financial ones, but the issue of energy management and cost control is dealt with solely from an technological perspective and not a financial one. Progress in terms of technical solutions for construction and energy saving do not appear in the current scientific literature to be accompanied by an economic evaluation of building management costs.

At the same time, interventions carried out to contain and/or reduce consumption are more and more common for both new and restructuring projects [6]. Deep retrofit is not only considered necessary for existing buildings that have to meet new energy standards but is also considered a significant investment for the improvement of property portfolio performances due to increased costs of regular maintenance of the building, widely affecting both rents and market values [7]. This becomes that much more relevant in fragile markets such as those in southern Europe where developers need to maintain profitable investments in a marketplace where there is a consistent decrease in profits and the value of real estate from 2008 to date and in markets that are extremely volatile such as those in the anglo-saxon countries and the far east. In the former case, the significant decrease in demand leads to a shift in investments towards more sustainable buildings, i.e. those that have lower management costs, while in the latter, the competition for innovation in real estate market is limited by the efficiency of investments that requires a significant capital expenditure. Consequently, energy requalification and keeping costs down in tall buildings become one of the ways to guarantee both investments and an increase in a building's efficiency.

The Empire State Building in New York is a good example: \$90 million were spent [8] on the energy requalification of the building and this led to an annual savings of management costs for both the tenants and the property of \$4.4 million, i.e. 38% of the building's overall consumption. This example is ideal because despite being a trophy building, i.e. a building considered to have secure investments in terms of profitability, it was decided that the costs related to energy consumption need to be reduced even though there was solid profitability with prime tenants. Based on the Life Cycle Cost Analysis (LCCA), the investments aimed to reduce heat loss, improve the efficiency of the air conditioning systems and monitor consumption and heating ventilating and air conditioning (HVAC) functioning in real time. Adopting digital systems for controlling HVAC in real time is one of the basic approaches to innovation in the field of electricity production and consumption according to the so-called Smart Grid. This field of research is less developed despite being one of the greatest potential for its relevance on micro and macro scales, ranging from building projects to urban developments.

Smart Grids and Tall Buildings

There are varying definitions of Smart Grid (SG) but there are several basic aspects that are shared within the scientific community: distributed energy production based on the use of renewable sources on a local level using power stations that are smaller than those traditionally used; a bidirectional flow of energy instead of the traditional unidirectional flow; real-time production in response to energy consumption needs; and a new role for the end-user from consumer to prosumer [9] [10].

A new paradigm for distributed energy production [11] poses new opportunities for both urban areas as well as the buildings they house; this is especially relevant in the case of buildings that are, in terms of numbers of people and size, comparable to neighborhood developments.

The technologies used to develop smart grids are well-known and readily available regarding both production and distribution. However, whereas the technical factors are taken into consideration, what is missing is an economic evaluation, or rather a consolidated business model for diverse investments (e.g. smart grid, micro grid, differences in terms of cost depending on what is needed) and estimates of the break-even point of investments with regards to savings. This depends, on the one hand, on the fact that the approach is still experimental and, therefore, there is a limited number of cases to refer to, and on the other to the significant number of production and consumption variables that depend on the size of the network but, more importantly, the behavior of the prosumers.

The most interesting aspect in terms of innovation is that the more widespread the network of prosumers, the greater its potential to be efficient in terms of energy production and efficient use of resources. Even though there are clearly benefits to individual homeowners developing smart-grid homes, this solution does not fully exploit the full of auto-consumption of the energy produced. However, the network is effective if it connects a large number of users who can coordinate their consumption in relation to their production. From an economic point of view, the efficiency of a smart grid increases with the number of buildings that take part in it. This is why tall buildings that are either residential or not are the best type of building for this type of technological innovation.

First of all, tall buildings and skyscrapers are major consumers of energy and resources. Those who live in these buildings and/or use the spaces represent a significant segment of market demand in quantitative terms. This demand, therefore, is marked out by a significant expenditure² which can justify investments in building innovation. There are two other aspects that are relevant: the first is technical, the

² The literature clarifies that tall buildings and skyscrapers are part of the real estate luxury market [3].

second related to regulations. With regards to the former, there are two points worth making: the first related to energy production, the second to energy consumption. The very nature of tall buildings guarantees that there are extensive vertical surfaces which, if are facing south, can produce energy using photovoltaic panels. This is a well-known technology that has been extensively trialed and used. Furthermore, the vicinity of a large number of consumers located close to a power station makes it possible to limit and contain the costs of energy distribution.

The fact that prosumers are close to a grid is not solely a technical factor, but more importantly it makes it possible to exploit the grid as much as possible with regards to consumption. This aspect is clearly not a technical aspect of the system but it does demonstrate that smart grids can be a potential success factor for the regulation regarding smart grids.

Tall buildings and skyscrapers are regulated by community contracts [12] or homeowner associations [13]: in Anglo Saxon countries, and especially the United States, there are very specific regulations regarding how people are to behave within the building in both private and public areas. These regulations can be put in place by the owner and enforced by the building manager in such a way that tenants have to adhere to a set of rules that are much more specific than those required by local legislation. In a similar fashion, rules can be agreed upon and put into place by the group of private homeowners.

In such a system, the use of private spaces is regulated in agreement with the owners of neighboring buildings making this an optimal opportunity for extending norms for the use and consumption of energy to experimenting with smart grid approaches. Indeed, adopting a shared and distributed technology for the production and consumption of energy can become part of existing regulations in a much easier and effective way than in places where consortia must be created to bring together buildings that are physically distant from one another, such as is the case in urban sprawl, and where setting up energy production plants could be more expensive [14].

It is also worth noting that introducing specific regulations regarding electricity can be facilitated when there is a limited number of property owners: indeed in Anglo Saxon countries many residential buildings have a sole owner such as company buildings in South - Europe.

The Influence of Norms on the Spread of Smart Grids

How can norms and regulations support the technological innovation of smart grids? In the field of smart grid research in the EU, two of the main goals to be reached by 2035 are a functioning energy market based on distributed energy production and regulatory innovations that can support this goal [15].

With specific reference to the Italian market, can a norm support the implementation of distributed energy production? It is beyond the scope of this paper to discuss the role national legislation might play in adapting existing high voltage power plants. Indeed the aim is to reflect on the implications of updating local urban planning and building norms, after having highlighted energy issues related to different classes of population density and differing needs and potential benefits of specific types of construction.

The greatest opportunities currently available in the Italian real estate market in terms of investments are in the revitalization and redevelopment of brownfields. Such sites have a greater concentration in large urban areas. This type of restoration can also take place by increasing buildings volume which requires, beyond certain thresholds, the use of particular typologies such as tall buildings and skyscrapers, which have different costs than low-density buildings.

From an economic point of view, the incentives available for the energy redevelopment of buildings or the construction of new low-consumption buildings only provide for initial investments whereas smart grids require a vision that includes the day-to-day costs of the building which are the only way to demonstrate the actual economic benefits of adopting smart grids. Current urban planning laws do not deal with energy issues on an urban scale, such as shared energy management in neighborhoods or tall buildings. There are examples of more advanced urban energy efficiency legislation such as the English Leed protocol which nonetheless does not focus specifically on electricity production.

In any case, in order to exploit existing legislation, local governments would have to allow owners greater power to manage shared facilities and resources in order to develop a network and possibly a consortia of owners both in the case of building new power station as well as in the case of the energy redevelopment of a group of existing buildings. Currently, Italian legislation regarding the management of residential buildings does not allow for private or local regulation whereas the relationships between the owners of the units are regulated by a national norm.

Furthermore, regarding to current incentives, local governments could offer energy providers subsidies that are currently only regulated on a national level. Clearly in order to be efficient, a local system of electric energy production would have to be regulated by local norms and regulations.

Finally, it would benefit all players if local authorities developed an evaluation system of buildings that have already received economic incentives in order to assess whether there have actually been savings in terms of consumption. Such a system should determine the relationship between the cost of the public investment to promote energy consumption reduction with the actual energy consumption.

Conclusions

Energy consumption reduction is one of the main topics being discussed in the development of the European Urban Agenda [16] and innovation in the field of energy is one of the main areas to receive funding from the European Union up to 2020. There are many ways these issues can be dealt with on an urban level and one of the most significant ones for both urban areas and individual buildings is using smart grids to produce shared energy and manage production and consumption in real time.

In densely populated areas, especially where there are tall buildings and skyscrapers, the potential of smart grids to make a difference is greater because of the high costs of energy management and the proximity of a large number of consumers. These types of buildings also have norms and regulations regarding the use of shared and private spaces that could serve as a basis for developing shared energy consumption. However, in Italy, local urban planning legislation is not currently prepared to promote this kind of innovation. The only incentives currently available are to invest in the energy requalification of existing buildings and there is no evaluation process to assess whether or not such interventions actually lead to a reduction in consumption and reduced costs. Consequently, there are numerous opportunities for research into how to improve this situation. Currently there are no case studies of a cost analysis regarding the potential benefits of smart grids on different scales just as there are no business models.

An economic analysis of the effectiveness of distributed production systems could help inform the choices local legislators make regarding urban planning. Legislation regulating urban planning and building management need to support not only technological innovation, but more importantly the behavior of local inhabitants who currently do not benefit from any norms or regulations that could promote a radical change in consumption habits by using a smart grid.

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