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Vol.15 n.3 December 2022

print ISSN 1970-9889 e-ISSN 1970-9870
University of Naples Federico II

TeMA

Journal of
Land Use, Mobility and Environment

THE CITY CHALLENGES AND EXTERNAL AGENTS. METHODS, TOOLS AND BEST PRACTICES

3 (2022)

Published by
Laboratory of Land Use Mobility and Environment
DICEA - Department of Civil, Architectural and Environmental Engineering
University of Naples "Federico II"

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Editor-in-chief: Rocco Papa
print ISSN 1970-9889 | on line ISSN 1970-9870
Licence: Cancelleria del Tribunale di Napoli, n° 6 of 29/01/2008

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The cover image shows the Irpinia hills at sunset, highlighting the enhancement of two renewable energy sources: sun and wind.
The photo was taken by Giuseppe Mazzeo in August 2022, in S. Andrea di Conza, Avellino, Italy.

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TeMA

Journal of
Land Use, Mobility and Environment

TeMA 3 (2022) 517-531
print ISSN 1970-9889, e-ISSN 1970-9870
DOI: 10.6092/1970-9870/9549
Received 3rd December 2022, Accepted 16th December 2022, Available online 30th December 2022

Energy saving and efficiency in urban environments: integration strategies and best practices

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Abstract

As engines of growth and socio-economic development, cities are responsible for 66% of global energy consumption and 70% of emissions. The current energy crisis makes it more imperative than ever to integrate energy saving and energy efficiency into the governance of urban and territorial transformations, from strategies to tools, at all scales of the city: from the building to the neighbourhood, from large urban areas to the territory as a whole. With a bottom-up approach, this contribution identifies, starting from a review of best practices, strategies and solutions for energy saving and efficiency for the different urban fabrics, as an integral part of the tools for the governance of urban and territorial transformations. The contribution concludes with an analysis of the energy consumption of a case study and the identification of possible interventions. The application highlights the strong interactions of the city's energy performance containment with other urban dynamics, including vulnerability to natural phenomena.

The article is the first step of a wider research aimed at developing an expert system to support decision-making by identifying energy-consuming areas and proposing potential transformation scenarios due to urban characteristics.

Keywords

Energy consumption; Energy crisis; Urban environments.

How to cite item in APA format

Guida, C. (2022). Energy saving and efficiency in urban environments: integration strategies and best practices. *Tema. Journal of Land Use, Mobility and Environment*, *15* (3), 517-531. http://dx.doi.org/10.6092/1970-9870/9549

1. Introduction

In recent years, the reduction of energy consumption and the improvement of its efficiency have assumed a more strategic role than ever before. On the one hand, the impacts of climate change-related phenomena on cities and communities around the world urgently call for the implementation of concrete, scalable and workable solutions (approaches, methods, procedures and policies) to mitigate and adapt urban environments to extreme events (Fasolino et al., 2020). On the other, the current energy crisis is delivering a shock of unprecedented breadth and complexity to the industrialised West, making the energy issue more urgent than ever, as a consequence (Chu, 2022).

Regardless of the source, energy is a major factor in urban development. Hence, urban areas substantially influence global energy demand and energy-related emissions. Cities consume about 75% of global primary energy and emit between 50% and 60% of total greenhouse gases (UN-Habitat, 2022). This trend peaks at approximately 80% when the indirect emissions generated by urban inhabitants are included (Su et al., 2022). As far as the European scenario, cities take up only 4% of the EU land area yet are home to 75% of citizens, and this number is expected to rise to approximately 83.7% by 2050 (Steurer & Bayr, 2020). The energy footprint of cities is due to many sectors. Buildings, for instance, consume vast amounts of energy at all stages of their existence (Gargiulo & Russo, 2017): energy is needed for the raw materials, construction process, maintenance, and daily operational needs such as lighting, air conditioning, and cleaning (Xie et al., 2018; Sharma et al., 2022). In addition, urban sprawl, increasing distances between destinations, and inefficient public transport systems prompt overall reliance on private motorised transport, such as cars, which have a high energy consumption, mostly of petroleum products (Gargiulo et al., 2012; François et al., 2021).

The IPCC's Sixth Assessment Report (2022) highlights the close linkage between the energy performance of urban environments and their resilience when climatic events (floods, water bombs, heat waves and droughts) occur. The report also shows that the risk people and assets face from climate change hazards has increased significantly. Hence, investments to accelerate the transition to renewable resources and withdrawal from fossil fuels are needed to mitigate GHG emissions but may also increase the overall resilience of the energy system. Due to climatic or meteorological events, power or fuel supply disruption impacts all other infrastructure sectors and affects businesses, industry, healthcare and other critical services (Groundstroem & Juhola, 2019). The economic impacts of climate change risks are significant. For example, in the EU, the expected annual damages to energy infrastructure, currently €0.5 billion per year, are projected to increase by 1,612% by the 2080s (Forzieri et al., 2018). In China, 33.9% of the population is vulnerable to electricity supply disruptions from a flood or drought (Hu et al., 2016), whilst in the USA, higher temperatures are projected to increase power system costs by about USD 50 billion by the year 2050 (Jaglom et al., 2014). Recent studies from Stockholm, Sweden, show that future heating demand will decrease while cooling demand will increase (Nik & Sasic Kalagasidis, 2013). A study from the USA showed that climate change would impact buildings by affecting peak and annual building energy consumption (Fri and Savitz, 2014). Finally, climate change can, for example, influence energy consumption patterns by changing how household and industrial consumers respond to short-term weather shocks and how they adapt to long-term changes (Auffhammer and Mansur, 2014).

Therefore, cities should shift from the current unsustainable fossil fuel energy dependency towards using renewable energy sources, not only because of the dynamics of the energy crisis, but also curb negative externalities such as pollution, greenhouse gas emissions and potential damages due to climate change-related events.

In addition to the scramble to comply with the Paris Agreement (United Nations, 2015) and limit the global temperature increase to 1.5°C by 2050, the ongoing energy crisis is a further impetus for change. Even if it shares some parallels with the oil shocks of the 1970s, there are important differences (Sturm, 2022). Today's crisis involves all fossil fuels, while the 1970s price shocks were largely limited to oil at a time when the global economy was much more dependent on such energy resource. Moreover, the entire word economy is much more interlinked than it was 50 years ago, magnifying the impact. That is why it can be claimed as the first global energy crisis (Zakeri, 2022), mainly caused by the increase in energy prices since 2021 because of the rapid economic recovery, maintenance work that the pandemic and adverse weather conditions had delayed, and earlier decisions by oil and gas companies and exporting countries to reduce investments. All that led to already tight supplies, exacerbated by Russia's attack on Ukraine. Another significant difference to the gas crisis of 1970 is that, nowadays, urban areas account for the greatest shares of both the global population and world economic activity, two key drivers of energy use (Fig.1).

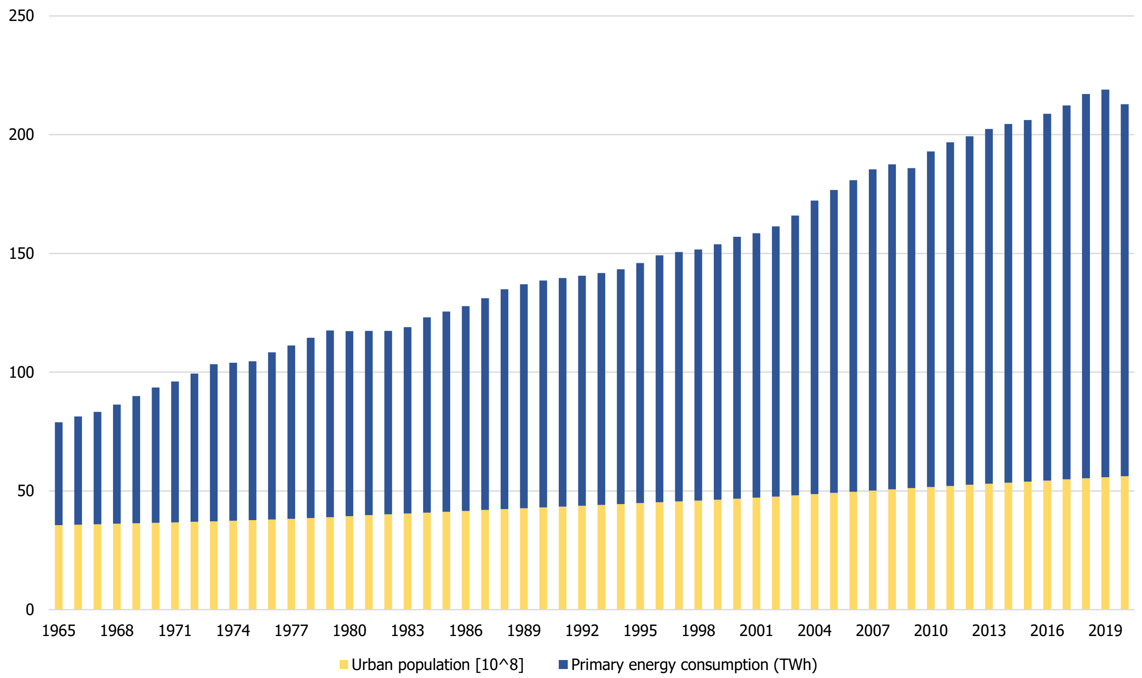

Fig.1 Urban population and energy consumption trend, 1965-2020 (OurWorldinData)

The overview, albeit brief and certainly not exhaustive, of the challenges that cities face and will face during the 21st century, described in this paragraph, gives a glimpse of the extent to which energy saving and efficiency in cities may influence urban resilience to climate change impacts and fossil fuel dependency. In order to effectively face (the combination of) these challenges, urban planning, building regulations, and other plans and policies should be integrated to enable deep and cost-effective decarbonisation of each urban activity.

The current energy crisis may represent a historical turning point for urban planners, stakeholders and citizens to integrate the energy issue into urban and town planning tools. Under the impetus of recovery plans developed in response to the economic crisis resulting from the Covid-19 pandemic, both the aims and contents of urban planning tools are increasingly characterised by a marked orientation towards finding answers for the new and urgent demands of environmental sustainability and energy saving.

With regard to the Italian context, the government has allocated substantial funds to incentivise energy efficiency and the improvement of building quality (Ecobonus). This practice has been widely used but does not reward community-based activities aimed at improving the quality of larger urban areas. Given the close linkage of the energy challenge to climate resilience, an urban approach would be preferable.

Hence, the innovative feature of this research would be the extension of investigation scale from building to urban environment. However, it is still unclear how to proceed with more appropriate planning forms in this sense, integrating energy models and scenarios into the procedures and methodologies of urban and territorial transformation governance.

This contribution is the first step of wider research which tries to answer this question by developing an expert system to support decision-making in identifying energy-consuming areas and proposing potential transformation scenarios according to existing urban characteristics. To this end, the paper analyses best practices, strategies and solutions for energy saving and efficiency for the different urban fabrics, which have been integrated into tools for the governance of urban and territorial transformations. Following this introduction, the reduction of energy consumption will be delved into to highlight its connection to urban and territorial planning governance. The third paragraph will summarise the review-based evidence from best practices, analysing possible solutions for different urban textures. The fourth section is dedicated to the lessons learned by the best practices, highlighting the most common sectors of interventions and their eventual integration into urban planning tools. Before the conclusion, a case study is analysed: energy consumption of a small residential area has been related to other urban features, and a set of possible solutions have been identified.

2. The reduction of energy consumption and new possibilities/opportunities for the governance of urban transformation

Although in the last few decades, many efforts have focused on defining measures to reduce consumption at the building scale, there has been increased awareness of the need to undertake measures at the urban scale (Papa et al., 2016; Bellezoni, 2021). Thus successful, isolated episodes of energy savings in buildings have proved insufficient to respond concretely to the problem. In fact, cities are naturally positioned to undertake energy-saving and efficiency processes: the density of human, economic and intellectual capital in cities can be a driving force for the acceleration of clean energy development and deployment and, more effectively, promoting and developing energy-saving strategies and interventions (Butters et al., 2020; Fasolino et al., 2020; Thellufsen et al., 2020; Nastjuk et al., 2022). As more and more cities take the opportunity to act as innovation hubs and test beds for sustainable urban energy technology, the closer the whole world will be to providing secure, sustainable and affordable energy for all (Sancino et al., 2022). Hence, a growing *momentum* is being recorded behind the city's role in taking action on energy saving and efficiency (Breetz et al., 2022; Fraser et al., 2022). The focus on cities and their role in the ecological transition are certainly due to large urban areas being complex organisms with a high degree of entropy (Gargiulo & Papa, 2021) and, therefore, among the largest contributors to energy demand and climate-changing gas emissions (Qian et al., 2022).

This scenario calls for a more conscious approach to urban and territorial governance issues (Oktay, 2022). It implies a multidisciplinary working method, with particular attention to the achievement of energy efficiency at all levels: from the building to the neighbourhood, from urban areas to the territory, from citizens' behaviour to the good practices of the public administration, introducing a monitoring routine practice of the implementation phase and the activity when fully operational, also with feedback value concerning plans and programmes (Papa et al., 2016).

The current energy crisis and the need to keep financial and security threats at bay may lead the way for urban planners to integrate territorial planning instruments with energy contents, typically dealt with by specialist tools. It is no coincidence that a transition state characterises the current phase of spatial governance and urban planning, accelerated and prioritised by fiscal *stimuli* such as Green Deal, Next Generation EU, and RePower EU, to boost and recover the European economy (Lambert et al., 2022; Sgambati, 2022). In fact, from the point of view of purpose and content, the evolution of urban planning instruments is increasingly characterised by a marked orientation towards finding answers to the new and urgent questions of sustainability and energy saving. However, it still does not appear clear how to proceed with more appropriate planning forms in this sense, if not by integrating traditional urban planning tools with the more recently established sector ones, such as energy performance forecasting models. The development of legislation and sector regulations gives an account of the need to remedy the shortcomings of traditional planning techniques and how this need stems from a new sensitivity and awareness of the limits of natural energy resources and the problems associated with the energy and climate crises. In recent years, the introduction into territorial governance procedures of technical tools designed for this purpose has, in its way, provided the revision and updating of urban planning instrumentation from an environmental perspective. It is not, therefore, the result of an organic reform of the instruments for governing urban and territorial transformations but rather the attempt, at least on the part of the legislator, to progressively bring closer together and make an effort to integrate two spheres of undoubted influence, the urbanised territory and energy consumption, which are as distinct as they are complementary. In particular, the energy-saving issue is the foundation of the social and economic model of transformation for the near future and the turning point for sustainable, smart and energy-resilient urbanisation (Papa et al., 2015). Thus, good practices capable of a new and decisive integration between the two fields of influence are not always traceable in practice. More often, the outcome of planning strategies and interventions and programming activities is the juxtaposition of technical documents conceived as products of specialised and non-converging sectors without necessarily precluding the possibility of finding a synthesis between the two fields of influence.

In an interpretation that hopefully is not juxtaposed but rather complementary to urban planning, the sphere of planning for energy consumption and transition to renewable resources can provide an innovative contribution to the vision of urban and territorial governance and integration, in the sign of environmental sustainability and urban planning technique, by making the issue of energy requirements part of an urban accounting work to be contextualised in the broader municipal budget. It is a matter of establishing a close dialogue between often inhomogeneous territorial government tools, conceived with different purposes in different historical moments, which, however, has the possibility of finding in the good practices of policy-makers that unity is given by the uniqueness of the territory and the limits of its development.

Many experiences from real-world practice revealed that energy efficiency and saving simulation models focus on individual buildings rather than whole urban areas (Papa et al., 2014). The lack of a holistic approach makes it difficult for urban planners to consider energy efficiency and supplies when designing and planning refurbishment actions or new city developments. Moreover, the lack of quantitative information to seriously evaluate energy savings, or the cost and impact of retrofitting, renewable energy options, cogeneration or district heating extensions, is the gap that this research, starting from analysing some interesting best practices, aims at filling.

3. Lessons from some best practices

In order to define suitable strategies and interventions to reduce energy consumption in urban areas, different real-world planning practices have been analysed. The case studies were selected to collect as large a sample as possible, not only in terms of the proposed interventions but also concerning the characteristics of the urban areas in which they were implemented. Furthermore, the selection of best practices was carried out according to two eligibility criteria. The first concerns the scale of the intervention, so those limited to the building scale were excluded; the latter relates to the integration of transformation choices in the tools of urban and territorial governance, so only those for which an update/revision or the drafting of an *ad hoc* urban plan were selected as best practices. Even if not exhaustively, the sample collects the following best practices:

- Solar-City Linz-Pichling (Austria), 1996;
- Beddington Zero Energy Development, London (United Kingdom), 2000-2002;
- Ecociudad Valdespartera, Zaragoza (Spain), 2001;
- Urbes Project Barcelona (Spain), 2018;
- Izmir (Turkey) Sustainable Energy Climate Action Plan and the Façade Rehabilitation Project of its historical centre, 2020;
- UrbanGaia project in Coimbra (Portugal), 2020;

- North Walsham (United Kingdom) Heritage Action Zone Projects, 2021;
- Nordhavn, Copenhagen (Denmark), ongoig;
- Social Housing programme for Torri Madonna Bianca, Trento (Italy), ongoing.

The sample of best planning practices was selected by consulting several international databases (weADAPT, C40, ESMPA) and scientific papers (Zanon & Verones, 2013; Amado & Poggi, 2016; Cajot et al., 2017; Scorza & Santopietro, 2021; Stober et al., 2021; Ruggiero et al., 2021). What emerges is a very mixed picture of cities: from those in northern Europe, whose interest in environmental, climate and energy issues has its roots in the 1970s and led the research and development of alternative energy sources to fossil fuels, to cities where only more recently have these issues found a place in the governance of urban and territorial transformations. The choice of case studies to be analysed also took into account the type of urban fabric to which the energy efficiency and saving measures were implemented. The following table summarises interesting features of the selected planning practices (Tab.1).

Case study	Country	N. citizens	Area extension [ha]	Actors involved
Solar City, Linz-Pichling	Austria	4,000	60	Municipal administration
Beddington, London	United Kingdom	21,044	161	Borough Council, private companies
Valdespartera, Zaragoza	Spain	20,000	600	Ministry of Defence, Municipal administration, University, private companies, banks
Barcelona	Spain	1,620,343	1,014,000	Metropolitan administration, University, private companies
Izmir	Turkey	2,965,900	9,190,000	Municipal administration, citizens associations, private companies
Coimbra	Portugal	134,463	3,190,000	Municipal administration, citizens associations
North Walsham	United Kingdom	11,998	172,700	Municipal administration, private companies, citizens associations
Nordhavn, Copenhagen	Denmark	2,144	20,000	Municipal administratio, private companies, research institutes, University
Torri Madonna Bianca, Trento	Italy	1,400	40	Municipal administration, private companies, citizens associations

Tab.1 Overview of selected best planning practices

Some of the best practices gather experiences of urban transformation governance in newly built contexts. That is the case of the Solar City in Linz (Austria), where a radio-centric urban layout has been implemented, symmetrical to two main axes, which corresponds to a model of ideal sustainability and energy efficiency, surrounded by a green belt. In this case, the energy saving and efficiency of the district are due to the orientation of the buildings and their building quality, which compensates for the not-always-optimal location, and to the high concentration of open spaces: private gardens, semi-public green areas owned by companies but in public use, pedestrian paths and parks. In addition, the city of Linz relies on its energy park, which can meet the average energy demand of approximately 21-28 kWh/sqm per year per building, contained through active and passive energy-saving technologies. Similar examples can be observed in the Valdespartera district in Zaragoza (Spain) and Beddington in London (UK). The Spanish district is a recently built urban neighbourhood where the governance of urban transformations played a key role in building an energy-efficient urban environment and responding to social and economic issues. In an area of former military assets, the Ecociudad de Valdespartera converted an area of approximately 240 hectares into 9,500 social residences. Several features were considered to have the lowest footprint possible: the strategic placement of trees for cooling, the orientation of buildings to maximise shaded areas, and the use of solar heating and natural ventilation.

(a) (b) (c)

Fig.2 View from (a) Solar City in Linz, (b) Ecociudad of Valdespartena in Zaragoza and (c) Beddington

The small London borough has instead invested in functional *mixité*, and in offering sustainable mobility services to limit the use of private cars and encourage walking or public transport (Guida et al., 2022). A similar approach was also chosen for the social housing complex in Torri Madonna Bianca, Trento (Italy). It is an ongoing process of constructing a new residential area through implementing retrofitting techniques and energy-efficient systems that heavily rely on ICT. Moreover, new renewable energy resources and novel combined heating, and cooling systems will be installed in selected sites to boost the efficiency of the city's district heating network. The Municipality also wants to push for their Urban Mobility plan, which aims to promote car-sharing of electric vehicles and limit the usage of fuel-based cars. Also in this plan are a set of ICT tools, which will be implemented to optimise the transport system within the city. Implementing new technology products to limit energy consumption in urban areas is one of the key elements for the Danish district.

Nordhavn is being converted from an industrial harbour area into an energy-efficient and high-architectural-quality neighbourhood. As a full-scale smart city energy lab, the district demonstrates how electricity and heating, energy-efficient buildings and electric transport can be integrated into an intelligent, flexible and optimised energy system.

The energy retrofit projects for the former Ottoman town of Izmir (Turkey) and North Walsham (UK) are different. For these territorial contexts, the dynamics related to energy saving and energy efficiency are strongly linked to other challenges: for instance, the protection of resources of historical, artistic and architectural value against extreme climatic and meteorological phenomena, the competitiveness and tourist attractiveness of places. For these places, the range of compatible transformations narrows considerably. Given the overall artistic value, it is not always possible to work on more energy-efficient building materials or a different orientation of existing buildings concerning the heliothermic axis. The focus of the interventions foreseen for the historical centres of Izmir and North Walsham concerns the improvement of open and public spaces to enhance active sustainable mobility.

(a) (b) (c)

Fig.3 View from (a) Torri Madonna Bianca in Trento, (b) Nordhavn in Copenhagen and (c) Izmir

The best planning practices from Barcelona (Spain) and Coimbra (Portugal) differ for the area extension and nature of interventions. They promote nature-based solutions in city-belt areas to limit energy consumption

within the city boundary and damage due to climate-change-related phenomena, particularly sea-level rise and storm surges.
This comparative review has made it possible to highlight not only the range of potential interventions on an urban scale, respecting the starting urban conditions, but also the combination of challenges that different portions of the same cities are facing and that the government of urban transformations oriented towards the reduction of energy consumption can potentially control, from increasing the response of cities to climate change to limiting urban sprawl, from providing green infrastructure to ensuring the provision of essential In the next section, a comparative reading of the case studies is proposed with respect to the fabric in which they were implemented.


(a)


(b)


(c)

Fig.4 View from (a) North Walsham, (b) nature-based solutions in Barcelona and (c) Coimbra

4. Possible solutions for different urban fabrics

4.1 The historical city

The built historic environment has a vital role in the journey towards a more efficient energy-saving future. For historical centres, at least for those urban areas of which Master Plans provide for their protection and preservation, the relationship with the tools of energy planning may concern the possibility of modifications for increasing the energy efficiency of buildings. Such possibility may also be extended to the real estate unit coinciding with the single apartment, the entire building or an aggregate of several buildings. The possibility of interventions in the historic centre, even if diffuse or dimensionally limited, could, in any case, give rise to forms of energy micro-efficiency of the whole historic building fabric, with experimentation of techniques and materials for thermal insulation in buildings with stone or brick bearing structure. In such cases, intervention in historical centres may be called energy retrofit of existing buildings, examples of which are not lacking, especially in Europe, of which the Izmir and North Walsham planning cases are examples, too. This choice is far from trivial since the materials and technologies available are mainly directed at new buildings with reinforced concrete structures.
Urban planning tools, in this regard, should contain a performance specification to achieve efficiency standards for the containment of consumption, with particular reference to residential and historic buildings compatible with architectural and building characteristics. Municipal building regulations are a key lever for promoting and implementing innovative environmental and energy policies. According to a survey carried out by Cresme and Legambiente (2014) on a sample of Italian 1,000 municipalities, 188 building regulations, through obligation (104) or only incentives (85), promote a different way of building that looks towards energy independence. The main guideline that emerges from the analysis of the 188 building regulations is the obligation to design and install thermal energy production systems in order to cover with renewable sources at least 50% of the annual energy requirements for the production of hot water, and to provide for the installation of photovoltaic panels for the production of electricity not less than quantities defined with different values per housing unit by the various regulations.
Other energy efficiency and saving option may imply a changing scale, from the building unit to territorial areas whose forecasts are pursued through urban implementation planning. These actions aim at achieving

substantial protection of the historic centre. They could be included in a strategy whose objective is the recovery or even partial transformation of the historic centre, for example, with targeted replacements aimed at improving urban conditions in some well-identified and motivating situations (collapsed buildings, ruins, buildings to be demolished as they are in poor static condition and of no historical testimonial value), using insertions of new energy-efficient construction.

The presence of any voids within the historic fabric could be taken in a systemic key as a form of soil protection to increase the possibility of air, light and ventilation for the historic fabric and to improve soil permeability with the planting of trees for heat island mitigation.

Urban planning tools may also intervene by focusing on roofing in order to:

- collect and store rainwater for a functional secondary water network for condominium needs (for instance, cleaning and irrigation of green spaces);
- recover terrace and roof surfaces for the installation of photovoltaic panels;
- establish garden roofs to improve the insulation of roof slabs and mitigate the heat island effect;
- create passive solar systems as an accessory residential surface for the sole purpose of energy saving.

In more general terms, redevelopment interventions in the historic centre with recovery plans or even transformation/replacement found in the energy retrofit of the buildings, and more generally of the existing fabric, an adequate response to the new standards for the containment of energy consumption and the improvement of housing quality in areas characterised by a strong building degradation. This is a common case in those cities that have taken advantage of those large urban renewal programs (often, unfortunately, due to sanitary issues) that have especially characterised the urban planning culture between the nineteenth and twentieth centuries. Those transformations usually had complementary effects exacerbating the degradation of the historic centre for the parts that survived the implementation of the new interventions.

In conclusion, as far as the historic city is concerned, the review of best practices revealed that the relationships between urban and energy planning guidelines and tools are mainly found with the following guidelines: improvement of the building envelope and use of renewable energy sources.

4.2 The consolidated city

The consolidated areas within a city include largely urbanised areas, often coinciding with the consolidated suburbs that begin where the historical centre ends. They can be areas of completion and potential transformation or consolidated areas. These areas of the city can be further classified by operating within the more overall category and detailed according to certain criteria, including building quality, with particular reference to energy characteristics; the bioclimatic qualities of the urban layout (e.g. orientation and exposure); the potential of land utilisation for greater densification of the building fabric, including for the realisation of activities supplementary to residence (parking, commerce, public facilities, services); sufficient road access to the area also for public transport; green spaces for the formation of urban environments with microclimate, capable of counteracting the heat island effect; public assets such as public housing districts to be preserved and to undergo a process of energy retrofit.

According to the building stock usually characterising newly developed city areas, energy saving and efficiency interventions may include the adaptation of existing buildings to new energy efficiency standards, with particular reference to the building envelope, the installation of systems for the production of renewable energy, and the use of roofs, including roof gardens.

Moreover, energy plans may encourage transformation or completion interventions with new construction, preferably with high density and high energy efficiency, with particular reference to the bioclimatic quality of the building system.

The possibility of providing for new building interventions in open urban areas in consolidated city could be directed especially to the experimentation of sustainable housing programs such as self-building, co-housing, and social housing, of which there are beginning to be some particularly interesting experiences in Italy as well. These are opportunities put in place to respond to the long-standing housing emergency of those social groups that do not qualify for public housing but are also unable to afford the market prices of housing. Specifically, regarding co-housing, a project usually includes 20 to 40 families living together as a neighbourhood community and managing common spaces collectively with economic, social and environmental benefits. This practice, together with the participatory design approach, promotes energy savings and mitigates the community's environmental impact through actions such as establishing solidarity purchasing groups, car sharing or the location of various shared services.

As highlighted by the case study analysis of Beddington and Trento, the relationships between urban and energy planning tools mainly concern the following domains: soil protection, heat island reduction, bioclimatic quality of urban design, improvement of the building envelope, and use of renewable energy sources.

4.3 The transforming city

The transforming city concerns urban areas destinated for new residential and non-residential developments. It can also be defined as a building expansion zone identifiable as urban suburbs with neighbourhoods characterised by the almost absolute presence of residences, lack of services and facilities, dependence and insufficient connection with the city centre. On the other hand, these urban areas are those where the range of potential urban interventions is wider than elsewhere.

The possibility of further expansion of our cities, to the detriment of the preservation of the still existing soil, should be limited to these areas, upon the demonstration of the need for new residential developments and lack of usable areas for this purpose in much-urbanised areas. In this case, however, the need for new residential developments could not be met without further land consumption. The model of reference should be sought in eco-sustainable neighbourhoods, some important examples of which have been included in the case studies (the Ecociudad of Zaragoza and the Solar City in Linz). The review of some interesting best practices highlights that developing inner cities should consider the following guidelines: soil protection, heat island reduction, bioclimatic quality of urban design, improvement of the building envelope, and use of renewable energy sources.

4.4 The ecosystem city: natural, seminatural and agricultural environments

The endowment of green areas at the urban and territorial scale implies finding conspicuous areas within the municipal territory to fulfil this standard. In addition to the quantitative aspects of green and blue infrastructures, it is interesting to define its systemic aspects that connote its strategic role in the overall energy saving and efficiency performance, to be understood in this case as extended to the entire city context, in the relationship between urbanised and non-urbanised areas (parks, green belt, countryside). Soil conservation involves the preservation of open and un-urbanised spaces with natural features (scrub or forest), seminatural (countryside still present in the city, new crops for urban gardens and urban farms), abandoned and dispersed fallow to be reconnected, through the creation of ecological corridors, in a system including larger areas (natural or cultivated) as well as smaller ones thus giving substance to the city of ecosystems.

Concerning the city of ecosystems, the relationships between strategies and urban and energy planning tools can be found with the following addresses: soil protection, reduction of urban heat islands, and bioclimatic quality of urban design.

The case studies of Barcelona and Coimbra highlighted the almost exclusive interest of the government of urban and territorial transformations in this aspect. At the same time, other examples, such as the Austrian Solar City, integrated these green solutions outside the urban space in combination with solutions of a different nature.

5. A baseline case study

To support local policy makers' decisions and foster the transition towards a low-carbon future, a growing body of international researchers has been studying the complex and multidimensional relationship between cities and energy consumption. Previous researches were developed following the approaches summarised in this contribution on the relationship between the urban form and energy consumption, between urban form and climate change and, further, on the relationship between city and vulnerability to climatic and natural risks. Some of them proposed intervention classification of urban settlements to reduce energy consumption and climate-change-related risks, which, at the same time, take account of aspects related to the microclimatic welfare of dwellings, urban quality and the creation of economic value of the existing building stock (Gargiulo & Lombardi, 2016; Guida et al., 2022). In particular, a neighbourhood in a densely residential area was studied, with high vulnerability levels in terms of supplies and location. It is a district in the city of Naples, one of the most densely inhabited metropolitan areas in Europe, within which an urban environment with homogeneous constructional, settlement and morphological characteristics was identified, namely Rione Gemito in the Arenella neighbourhood, a complex of 29 buildings, developed between 1946 and 1948, social building, from a project by Marcello Canino and Alfredo Sbriziolo. Conceived to house the homeless from the Second World War, the complex is designed in a cross-shape where the buildings are arranged lengthwise along two rows either side of a broad tree-lined avenue (via Altamura), according to a late 19th-century pattern of an ordered residential neighbourhood (La Gala, 2006).

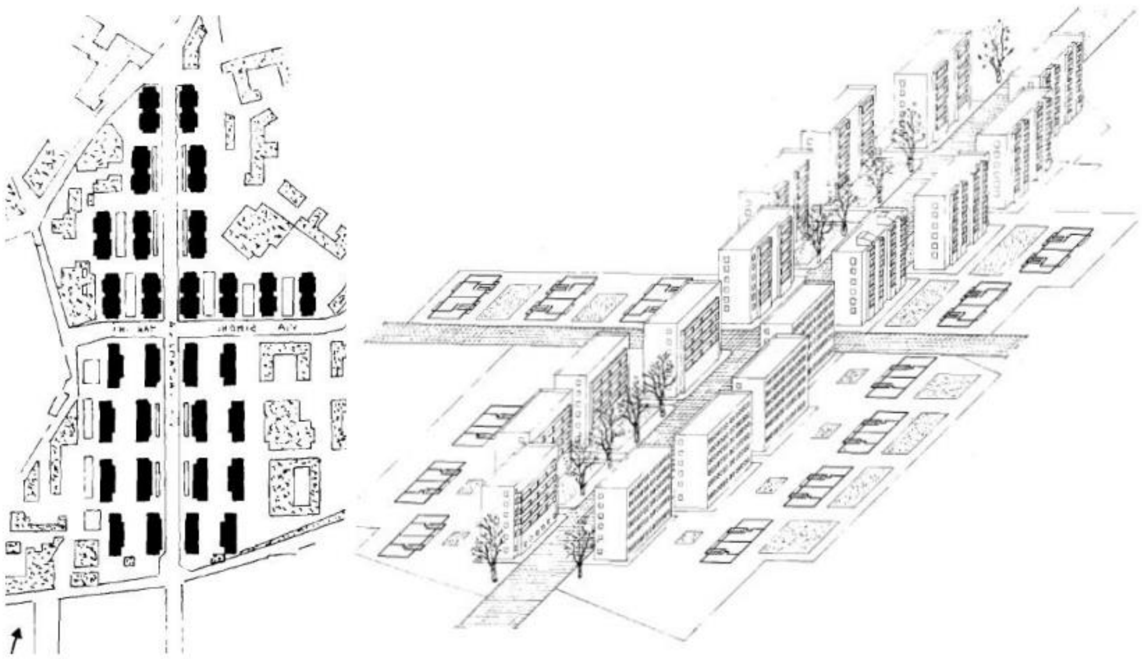

Fig.5 Rione Gemito plan and prospect

The research of Gemito sought to highlight the possibility of identifying integrated strategies to optimize the ever- diminishing supply of resources at the disposal of municipal authorities in order to maximize benefits in terms of reducing energy consumption, reducing urban vulnerability, and improving the quality of the building stock whilst enhancing its value. The intervention proposals were formulated to be grafted onto a theoretical context consisting of the set of recent scientific research developments in very disparate disciplines. The outcomes of the research may support the set up a masterplan of concrete interventions, within which the times, costs and suitable technologies are established.

The attention paid in the research to the importance of tackling the complexity of the issues within a holistic framework represents a significative starting point for the current research. In this sense, although the calculations yielded some significant results, a more rigorous methodology would be designed. Indeed, the research procedure was carried out through two kinds of analysis: the ACP and Clustering, which provide such valid results in terms of correlations between physical parameters and energy consumption. The interesting datum emerging from the comparison of the two elaborations is that the homogeneity of constructive characteristics of buildings plays a determinant role in the correlations of variables and consumptions: actually, it emerged that the more the buildings are similar in terms of physical parameters, the more the correlations are evident.

In this context, it would be worth applying an improved analytical procedure to a less homogeneous area in terms of construction, settlement type and land area than the neighbourhood in question. Such an extension would help enhance the proposed methodology. In this context, selecting a sampling area characterized by dishomogeneous buildings, preferably threatened by different risks or of different intensity than those identified in Rione Gemito, may provide interesting insights for a different selection of measures to combine each other.

6. Conclusions

Given the relevance of energy saving and efficiency in facing the current urban challenges, this contribution is a first step of wider research aimed at developing an expert system to support decision-making in identifying energy-consuming areas and proposing potential transformation scenarios according to existing urban characteristics. In particular, the paper analyses best planning practices, strategies and solutions for energy saving and efficiency for the different urban fabrics, which have been integrated into tools for the governance of urban and territorial transformations. The bottom-up review of interesting case studies revealed that interventions' effectiveness in reducing energy consumption depends on their adaptation and suitability to compatible physical and functional transformations given by state-of-art conditions. One of the more significant findings to emerge from this study is that the energy issue is intrinsically linked to the challenges facing the city in the 21st century. The transition to the use of renewable and more sustainable energy resources and city models with a reduced carbon footprint, made more urgent by the current crisis, is urgently needed to mitigate global warming and adapt cities to the impacts of natural phenomena, including those triggered by rising temperatures. Another aspect highlighted by the review concerns the necessary integration in urban and spatial planning tools of the knowledge, methods and models proper to the energy performance of the components of the urban environment.

Although the study has successfully demonstrated the linkage between energy consumption and urban planning practices, it has certain limitations in terms of in terms of sample size of case studies. Moreover, the bottom-up review lacks quantitative analyses that would be useful to compare before-and-after scenarios. The collection of energy consumption data would be helpful to establish a greater degree of accuracy on this matter. Furthermore, with a small sample size, caution must be applied, as the findings might not be transferable to other territorial contexts. While choosing the case studies this aspect has been taken into account.

The picture defined in this contribution, thus inexhaustive in terms of quantitative assessments, represents the starting point of a wider research, whose aim is to evaluate the extent to which urban characteristics influence energy consumption on a city scale. Based on this framework, the next steps will delve into the developing of a methodology for identifying energy-consuming urban areas and given their inner features, intervention scenarios in order to enable urban planning policies to effectively improve energy saving in cities and reduce urban emissions.

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Image Sources

Fig.1: Author's elaboration from https://ourworldindata.org/;

Fig.2: (a) https://www.urbangreenbluegrids.com/projects/solar-city-linz-austria/; (b) https://arainfo.org/113532-2/; (c) https://www.rinnovabili.it/bozze/bedzed-complesso-eco-compatibile-877/;

Fig.3: (a) https://www.rainews.it/tgr/trento/video/2018/08/tnt-Trento-Edifici-Torri-Economia-Lavoro-Edilizia-Look-Ambiente-59a7f0b6-4c25-41c1-ace6-871c6a90f251.html; (b) https://www.ilsole24ore.com/art/nordhavn-citta-ideale-danese-sull-acqua-sostenibilita-e-suite-luxury-sospese-porto-ADWvKQg; (c) https://www.novo-monde.com/en/things-to-do-izmir-turkey/;

Fig.4: (a) https://www.northwalshamguide.co.uk/north-walsham-directory; (b) https://nrcsolutions.org/beaches-and-dunes/; (c) https://networknature.eu/casestudy/18418;

Fig.5: Sergio Stenti, Napoli moderna, città e case popolari 1868-1980, CLEAN edizioni, 1993.

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