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RES Implementation in Urban Areas: An Updated Overview

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Abstract: In the past, national energy planning guided the development of a central program for infrastructure investment over a defined time period. However, in the current geopolitical context, environmental damage, fossil fuel depletion, and territorial imbalance caused by the centralised energy model are all factors that require a change of energy structure, establishing actions to invest in energy diversification, and solid commitment to local renewable energies. This also implies an enhancement of the role played by local bodies, and particularly by municipalities, in achieving the targets of the Kyoto Protocol and now of the Paris Agreement, because renewable sources need to be studied, applied, and exploited at the local scale. Within this framework, this paper is organized as an overview on the promotion and implementation of the major RES technologies in the deployment of the new energy paradigm at the urban scale, taking into account multiple targets. A survey of existing literature underlines how the RES topic is mostly approached as a problem of energy supply and implementation of technology, but actual sustainability in terms of a social development process and improvement of quality of life by residents is often neglected. Then, this overview stimulated the authors to highlight three main critical issues and gaps and support the need of an all-encompassing approach as a final recommendation for a general RES urban planning advancement.

Keywords: renewable energy sources technologies; urban areas; sustainable energy planning

1. Introduction

Nowadays, several methodologies and strategies have been developed to define energy systems that are more sustainable and mainly based on local resources [1]. This is because decentralised energy generation offers several advantages in comparison with traditional systems, in terms of environmental impact, service reliability, and even economical costs [2]. Therefore, the philosophy of the European Commission has been, since 1997, to shift electricity generation towards a more balanced configuration based on the exploitation of renewable energy sources (RES) at the local level [3]. More recent studies confirm that the compatibility of socioeconomic development with a sustainable energy model, respect for the environment, and local wealth, is more and more a perceived issue [4,5].

On the other hand, generic declarations of intent are evidently not sufficient to produce an effective advance towards a more sustainable energy management [6]. As Jaccard wrote [7], environmental policy to reduce CO_2 emissions needs to fit the actual situation and be customised to the specific territorial conditions, and urban energy systems are a key tool in assessing better designs, new policies, and related technologies. The supply-oriented framework within which energy planning has traditionally been conducted may be useful for siting large refineries, power plants, and transmission corridors, but it is not helpful for mitigating conflicts at the site level, encouraging the adoption of new technologies, managing the demand for energy or, especially, coordinating the diverse users of smaller local energy facilities [8]. This has been clearly demonstrated by the limited effects of the governance actions implemented during the first years of the last decade, and, above all, in the case of RES, where targets of efficiency in supply have to be considered in parallel with those of social development of territorial communities. RES implementation, in fact, promotes a local exploitation of differentiated potentials in order to contribute to an actual emancipation of actors, according to the physical features of their territories. This change of perspective, strongly affirmed in legislative actions, is quite neglected as a criterion in the scientific literature for evaluating the success of initiatives concerning renewables: technological issues and efficiency matters (that are clearly important) are mostly the only criteria investigated [9,10].

In the past, national energy planning guided the development of a central program for infrastructure investment over a defined time period. However, in the current geopolitical context, environmental damage, fossil fuel depletion, and territorial imbalance caused by the centralised energy model are all factors that require change of energy structure [11], establishing actions to invest in energy diversification [12], and solid commitment to local renewable energies [13]. This also implies an enhancement of the role played by local bodies, and particularly by municipalities [14], in achieving the targets of the Kyoto Protocol and now of the Paris Agreement, because renewable sources need to be studied, applied, and exploited at the local scale [15]. The decisive role of municipalities in the mitigation of the main causes (and consequential effects) of climate change must be acknowledged, especially considering that 80% of the energy consumption and CO_2 emission is associated with urban activities.

It is well known that more than 50% of the world’s population currently lives in urban areas. This figure is expected to rise to 70% by 2050 [16]. At first, cities were located strategically close to essential resources [17] and the society was fuelled by renewable energy such as wind, water, or biomass [18,19]. The industrial revolution, with the exploitation of fossil fuels, fostered the current type of development [20] in which cities import most of their raw materials, food, and energy, and use them in an inefficient manner that results in waste outflows of materials or emissions, resembling a linear metabolism resource-to-waste pattern [21]. Centralised approaches to energy conversion, delivery, and consumption constituted the original framework for provision of modern energy services. However, nowadays the growth of decentralised energy systems indicates a new frontier in urban energy planning and design, presenting a series of experiences for renewable energy development in concerned regions as a fundamental step of the shift to the decentralised energy paradigm [22]. At the same time, as Giurco et al. [23] underlined, it is crucial to study local characteristics to define obstacles and potential strategies for sustainable resources. As investigated in the paper, existing literature showed the taking into account of the local differentiated situations (in terms of territorial features and people conditions) as a lacking point [24,25].

The European Union (EU) adopted this approach as a baseline for its energy policy [26,27]. As a consequence, European cities and regions have undertaken local actions to increase energy efficiency and the use of renewable energy sources [28] to mitigate climate change and promote transition to a low-carbon society [29,30]. In 2008, as a consequence of the adoption of the Renewable Energy and Climate Change Package [31], the European Commission launched, at a local level, the initiative of the Covenant of Mayors (CoM) and the related SEAP (Sustainable Energy Action Plan) at the municipal scale [32]. From then on, the entire EU strategy for energy sustainability was focused on the involvement of local administrations and organisations, and increasing attention was paid to the territorial dimension in the exploitation of renewable energy sources [33].

Within this framework, this paper proposes an overview on the actual application of renewable sources within the city context and their contribution to the deployment of the new energy paradigm at the urban scale. In particular, RES technologies applied in urban areas are thoroughly analysed in Section 2, while resultant criticalities and recommendations are drawn up in Sections 3 and 4.

2. Overview on RES Existing Literature

In the shift towards low-carbon scenarios in the urban context, already in the late 2000s Omer [34] highlighted how the promotion and the use of energy source alternatives to fossil fuels are essential options. Nowadays, an increasing number of cities are supplying urban energy demand with RES: in 2013, almost 20% of all transport and building energy use in cities was supplied by renewable energy [35]. At a global urban level, wind and solar photovoltaic power plants presented in the last years a strong growth, while in the heating, cooling, and transport sectors this trend has been slightly slower [36], with warm water and heating supplied in most buildings by natural gas boilers.

It is well known that the choice and implementation of the most suitable RES technologies strongly depend on the city characteristics, namely geographical location, climate, morphology, and surrounding landscape; they also depend on city dimension, development, population density, and energy demand (Figure 1). The following sections address the state of the art regarding these arguments, specifically focused not simply on RES development, but on their implementation in urban areas.

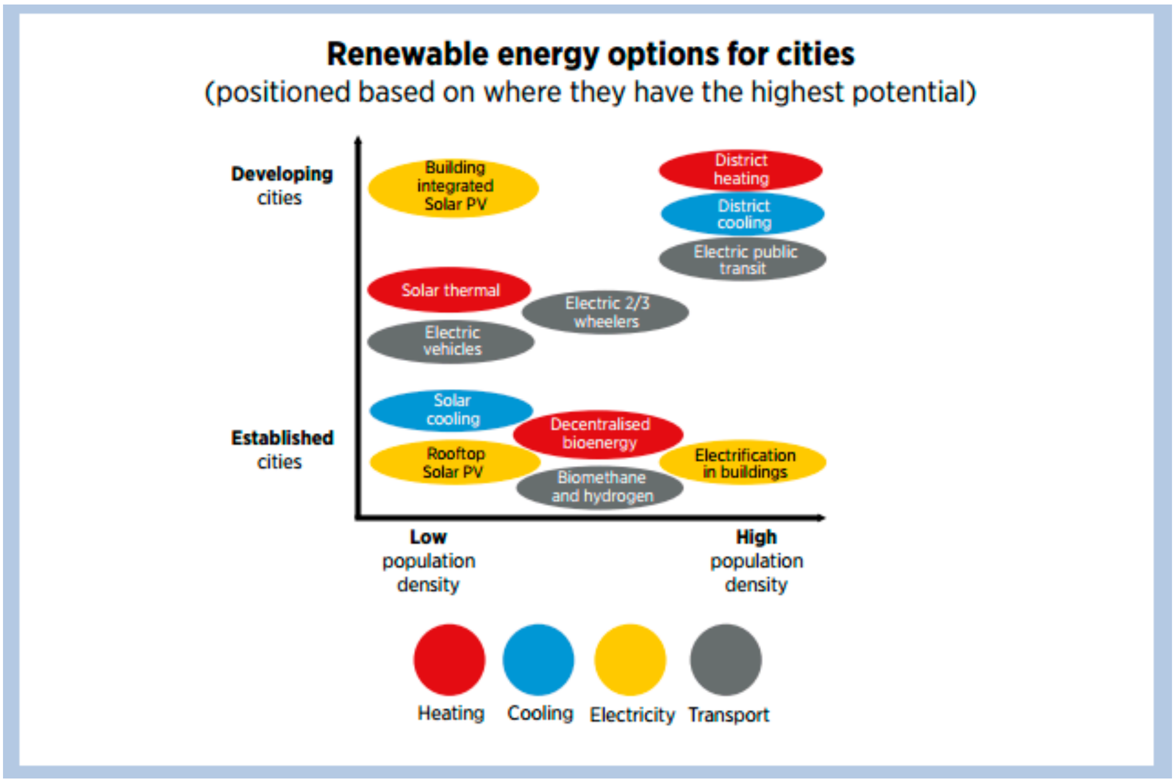

Figure 1. Renewable energy options for transport and buildings in different city types [35]. Note: renewable energy is assumed to be used for the electrification and district energy options. Renewable energy options are positioned based on where they have the highest potential.

The use of RES at the urban level not only has recognised advantages in terms of natural and long-lasting replenishment and zero or almost-zero CO_2 emissions, but they are also a sustainable alternative to fossil fuel dependence. Renewables offer further benefits including the creation of new economic opportunities and consequently increased employment levels, a contribution to local energy supply problem during peak demand, and help in fulfilling the goals of global agreements on environmental protection. On the other hand, renewable energy development inside cities is not obvious. Both Panwar and Kaushik [37] and Baños et al. [38] evidenced that the complexity of urban contexts, the intermittence of the sources, the dependence on the climate in some cases (solar or wind for example), and the rather high maintenance costs are to be considered in planning RES implementation on a city scale. In the following, the urban exploitation of main RES technologies is analysed, with highlights on particular benefits and constraints.

2.1. Hydropower

Nowadays, hydroelectric power produces 71% of all renewable electricity. In 2016 it generated 16.4% of the world's electricity from all sources, reaching an installed capacity of 1064 GW [39]. On a small scale, it is considered the most cost-effective energy technology for future renewable energy developments in Europe, whereas by now further large-scale installations are considered environmentally unacceptable [40]. Present-day smaller-scale generation, in fact, is challenging the traditional centralised large-scale plant dominance and is enhancing at a local level the trend towards small hydropower (SHP) and mini/micro hydropower (MHP). SHP and MHP are reliable, well-advanced technologies ensuring the highest efficiency (>90%); these plants are often built by refurbishing and retrofitting existing dam sites and irrigation canals [41] or by exploiting the connection with the urban water supply systems [42], with a much lower environmental impact than large hydropower. Regarding the economic aspect, Sachdev et al. [43] and Fujii et al. [44] agreed that initial investments can be relatively high, but those are balanced with low operating and maintenance costs and long-lasting plant life (more than 50 years), especially when compared with large-scale generating infrastructures.

2.2. Solar Power

Considered the most unlimited of all RES options, solar energy was noted by Marszal [45] to be increasingly exploited; recent cost reductions and technical advances in the implementation have made solar technologies increasingly attractive at city scale, allowing buildings to become more and more independent energy-wise. Solar power urban installations can be efficiently placed on building roofs, where plants produce less visual impact and obstruction and where the greatest amount of resource is available [46].

Mohajeri et al. [47] underlined that urban settings are not always appropriate for solar energy applications and that preliminary checks are necessary to ensure that panels are not installed in the shade of surrounding structures. In past years, several methods to estimate available roof area and solar potential at the urban level for solar energy generation have been established [48,49], thereby ensuring an actual return on the investment.

The real potential of solar energy is in the many applications it offers at city scale, because it can be used for the production of both electricity and heat in public and residential buildings and facilities, as well as in urban transport. Furthermore, as highlighted by Adam et al. [50], solar panels are generally characterised by low maintenance, quick installation and dismantling, and no moving parts. As an RES technology a solar panel is easy to set up and also safe in city areas.

2.3. Solar Photovoltaics

Several studies estimated the photovoltaic (PV) potential of cities, highlighting the capability to satisfy a high percentage of the electricity demand depending on the latitude and the technological evolution of the installed panels, especially in solar-powered urban microgrids [51,52]. Gasparatos et al. [53] noted that solar PV panels may be distributed and mounted on any sun-exposed area, even offshore [54], making this technology suitable for integration into the urban environment; at the urban scale they can also be arranged in building-integrated grid-connected photovoltaic systems to supply the energy demand of large urban areas.

On the other hand, PV technology is not as simple as that of solar thermal due to the need to convert from direct to alternating current, making photovoltaic panels more complex and expensive to install. Moreover, component materials in most PV modules are potentially harmful; mounting and disassembly must be carefully managed to prevent environmental damage in city centres.

2.4. Solar Thermal

In their paper on solar water heating, Wang et al. [55] showed how solar thermal panels represent a very interesting solution for the high energy demand in buildings; with efficiencies up to 80%, this simple and low-cost technology can be widely used in urban contexts, especially for space and domestic water heating. Del Amo et al. [56] observed recently that nowadays solar thermal technology is installed mainly in residential buildings, where only installations with small dimensions are possible due to the limited roof space. This causes longer payback periods with respect to larger solar areas, due to high indirect costs (such as for pumps or storage tanks).

2.5. Concentrated Solar Power

Usually employed in intense solar fields, concentrated solar power is infrequently applied in urban contexts, although some studies show how stand-alone installations can be implemented in the building sector as water domestic heaters [57] or cooling systems [58], or can be integrated with other RES for electrical and thermal energy [59]. Furthermore, the analysis by Pihl et al. [60] based on Life Cycle Assessments (LCA) confirmed that concentrated solar plants have low environmental impact and high lifetime energy return, making this technology suitable for application at the local urban level.

2.6. Wind Power

Kumar et al. [61] observed that, although the use of wind energy has been increasingly growing in recent years, to date this renewable resource has not been harnessed at the city level despite the great potential in such an environment and the best operation of wind energy systems at small and medium scales [62].

This big opportunity deserves to be exploited with appropriate technology. Toja-Silva et al. [63] demonstrated that, in urban contexts with tall buildings, the wind speed can increase locally near buildings, requiring special attention to turbulence and wind speed variability that could stress turbines. Nowadays, in urban areas wind energy generators are deeply integrated in the architecture and turbines are installed in buildings; this poses several challenges such as visual impact, noise emissions (both audible and infrasound), and low-frequency vibrations transmitted to the building structure [64]. As pinpointed by Devlin et al. [65], wind power benefits from integration with gas generation. In this way, diffusion of wind power technology inside the urban areas can be facilitated and unknowns to the power system from stochastic energy sources can be mitigated. Renewable (wind) and traditional (gas) power generation can be integrated, thereby enabling reduction in power system emissions and greater security of energy supply.

The economical point of view was analysed in Cooney et al. [66]. Small wind turbines installed on building roofs appear to be a suitable choice due to the proximity to the energy demand area, in contrast with distant traditional wind parks with their high costs caused by capital investments and power network integration (accounting for approximately 80% of the total project lifetime cost).

2.7. Biogas

Due to population growth and city expansion in the urban environment, waste disposal represents a significant problem. A large amount of municipal solid waste is dumped in increasingly saturated landfills, generating further environmental and management issues and expenses [67]. At the same time, as discussed in Silva dos Santos et al. [68], a high amount of domestic sewage generated within cities needs to be correctly treated to avoid pollution damages both in groundwater and in sea or river waters.

Organic urban waste, as well as sewage water, can be transformed instead into an energy source through their treatment in biogas production plants. However, such potential has not yet been fully exploited, mainly because of a certain social opposition to biogas use in cities. The experience reported by Cavicchi [69] is somehow representative of a diffused opposition to this technology.

Recent studies from Hagos et al. [70] and Zhang et al. [71] testified to the ongoing progress in this sector. Through suitable and efficient processes of anaerobic digestion, biodegradable waste is decomposed to biogas, a combination of methane and carbon dioxide, whose combustion can generate cost-effective energy (both thermal and electrical) that contributes to solving at the same time urban waste and energy demand issues at the city level.

2.8. Biomass

Biomass represents the most traditional source of energy used by humans, and even nowadays organic matter is an alternative to fossil fuels in domestic heating and cooking. Usually exploited in rural areas, in recent years biomass has been used also in urban areas, taking advantage of food waste and the trimming of vegetation and wood. According to Titos et al. [72], even if biomass and biofuel are renewable energy sources, differently from other RES and particularly in cooler climates during winter, their combustion is not completely carbon-neutral but produces atmospheric particles (black carbon) that impact on the urban air quality and consequently affect human health.

In two different papers [73,74], Madlener examined biomass exploitation beyond domestic use in large urban co-generation plants. The studies revealed the efficacy of this technology thanks to a good economic return of investment linked to the cost-effectiveness of forest maintenance [73]. Moreover, the convenience is enhanced by proximity, which minimises transportation charges and environmental impact [74].

As in the case of waste, biomass not only supplies both electrical and thermal clean energy but also has a significant role in managing woody residues otherwise dumped in landfill.

2.9. Geothermal Power

The urban subsoil is acknowledged to have a high potential in energy resources that is now possible to evaluate and exploit [75]. In particular, Rivera et al. [76] evidenced that geothermal potential at city scale represents an opportunity, particularly if integrated within urban smart electricity and thermal grids, because this reliable technology can provide heating, cooling, and electricity. Furthermore, nowadays the thermal capacity of low-enthalpy geothermal installations shows a global growth of approximately 7% per year, but is possible to exploit also high-enthalpy installations for electricity and a renewable energy mix [77].

Ground source heat pump technology, transferring heat stored from the ground to heating/cooling systems in buildings, can meet the requirements of low-temperature heating, which constitutes the largest share of heat demand in cities [78]. Moret et al. [79] studied the dependence of geothermal potential on local geology and groundwater depth, with a positive assessment of integration of geothermal energy in urban systems. Nevertheless, as discussed in Bauer et al. [80], geothermal sources have some constraints, in particular in highly populated urban areas where competition for land is strong. In such cases, in fact, specific subsurface planning is greatly needed for optimal use of georeservoirs together with suitable subsurface locations.

2.10. Integrated Microgrids

The crucial role played by smart integrated microgrids in exploiting RES at the urban level is highlighted in several papers mentioned previously, as well as in many other publications reviewing this key issue. Considering solar [51], wind [59], biomass [74], and geothermal [78], all renewables benefit enormously from technology enabling their mutual integration [80,81]. It can be said, together with Niemi et al. [82], that the development of RES in urban areas corresponds to the development of local smart energy grids. Bracco et al. [83] reported an interesting example of a smart polygeneration microgrid completely supplying an educational district, operating in parallel or separately with the conventional grid, and recovering waste heat from the sources. Another example of application on a large scale was presented in Lu et al. [84], demonstrating the flexibility and wide operational range of integrated grids for renewables exploitation. Besides, in a recent paper, McPherson et al. [85]

considered the integration requirements of RES over different time horizons, including hourly, weekly, seasonal, and multiannual regimes. The impact of integrating variable renewables regimes on the electricity system design and operation was quantified, and the key role of grid flexibility in an effective integration strategy was evaluated. In conclusion, if technologies are certainly mature for a wide exploitation of RES in urban areas, the availability of networks able to connect and integrate them is a crucial factor in capitalising on their huge potential.

3. Discussion

As previously observed, although the potential of renewable energies in urban areas is very strong and RES use inside cities is a key point in the strategy for environmental sustainability, actual exploitation of RES is a complex issue [86].

In the past, a spontaneous and uncoordinated approach has often prevailed, that favoured, in the absence of a comprehensive strategy, local and contingent aspects [87]. Indeed, without an integrated approach and, consequently, a coordinated governance [51,88,89], including preliminary assessment of pros and cons and identification of funding sources, action plans for the development of RES risk becoming 'wish lists' [14].

The limits of such a modus operandi have become more and more evident, and foster an ever wider use of energy planning tools. An interesting review of methods and tools was reported by Mirakyan and De Guio [90], who divided planning procedures into different phases and steps and established connections among them. Several software resources and methods were analysed and compared. The complexity of integrated energy planning revealed that not a single method or tool could address all the planning problems and aspects. The combined use of methods and tools was outlined as more effective, also when applied to the renewables sector. Methodologies combining the multi-criteria decision analysis (MCDA) method (also in Mardani, 2015 [91]), the 'Delphi' method, the SWOT analysis, geographical information system (GIS), fuzzy logic, and the problem structuring method were identified for the different planning phases and in particular for the 'prioritisation and decision' phase. Multi-energy system (MES) planning was also the goal of Van Beuzekon et al. [92], who analysed 13 optimisation tools applicable to a city scale. The study confirmed the necessity to combine different tools to overcome all challenges coming from the integration of RES in a 'smart city' context. In particular, an irreducible gap seems to exist between the time steps used for long-term energy planning tools and for short-term analysis of renewable resources. This subject deserves further study, as well as the evaluation of the accuracy of predictive methods. Uncertainties in integrated energy planning were thoroughly reviewed by Mirakyan and De Guio [93]. They pointed out different sources and dimensions of uncertainty in integrated energy planning in a city or territory, even involving renewables, and proposed a conceptual basis of uncertainty involving different types of uncertainty formalised in a coherent and holistic way. At the same time, Niet et al. [94] warned against the risk of exceeding estimates of emissions savings in the case of uncertain technologies and indicated the need to incorporate risks in optimal models. Life cycle assessment (LCA) was also demonstrated to be helpful in evaluating the true environmental suitability of energy policies at the local level [66], because LCA considers secondary effects that alter the expected results and that of hidden long-term implications.

The set of results previously reported confirms the difficulty of an effective renewables policy in cities and, by extension, the inadequacy of planning tools for the urban development of RES that are focused solely on each single form of energy. Those kinds of tools, as discussed in Oludunsin et al. [95] for biomass, in La Gennusa et al. [96] for solar energy, in Ishugah et al. [97] for wind energy, in Tkáč and Vranayová [98] for small-scale water energy systems, or for other RES technologies, are considered meaningful for assessing the potential of a specific renewable source, but their territorial outcomes are not consciously understood. In fact, urban energy planning requires integrated scenarios quite difficult to foresee: according to literature, this category of tools can be helpful but needs to be integrated in an all-encompassing way, through the combined use of planning methods and a higher-level governance system. Many authors recognized the importance of an integrated approach and the need of a social involvement by communities; but, at the same time, these issues are only deepened in sector literature (about participation, stakeholders' engagement and so on) as "collateral", and "put aside" with respect to other energy elements (exploitation, performance, . . .), not contributing to enhance the wider conception of the term "sustainability".

Some present features of integrated urban energy planning have been recently highlighted by Karunathilake et al. [99]. The study proposed a systematic approach to renewable energy integration in community development. Diverse scenarios were assessed based on the life cycle cost (LCC) and greenhouse gas (GHG) emission reduction, comparing them on the basis of costs and benefits to key stakeholders. The study found that the benefits that can be achieved by including RES into the local energy mix can vary depending on deployed energy sources. Hence, the local power grid mix influences the feasibility and acceptability of renewables integration for a certain location, with public administrations playing a relevant role in fostering renewables through incentives such as tax credits or grants [100].

The current trend is towards a wider and more integrated use of planning tools for RES management in urban areas. Limited success or frustration in the urban use of RES result from a lack of integration derived from a poor planning methodology. As outlined well by Adil and Ko [22], integration with urban planning and existing infrastructures, with the social dynamics of local communities, with community to national policies for climate change adaptation, and with new technologies and associated social responses, are many key issues for the long-term development of renewable energy technologies in cities and urban regions, strongly connected to the "core" of urban sustainability and quality of life [101–103]. In their recent paper, Adil and Ko also evidenced the limitations of an exclusively technical approach. Political and social issues, as well as psychological and behavioural aspects, are relevant parts of the RES planning process. This concept is not a total novelty, because already in the past decade Terrados et al., in two papers [1,104] noted that even the combined use of planning tools for renewable energy planning is not sufficient if community participation and local expert involvement are not properly activated. In this sense, in existing literature we observed a sort of dichotomy that shows us how social perspectives in local contexts are distant from exploitation of RES hypothesis and vice versa. In fact, even if the methods mentioned previously do not apply only to RES, they evidently have an impact on the exploitation of different renewables in urban areas, defining a proper strategy for their use and also their role on the "vision" of the city. Resource availability and its usability, targets definition and weighting, quantification of the expected results, criteria for prioritisation and decision, and action monitoring are many elements that models address regarding RES [105]. Moreover, land use deserves to be quantitatively modelled and properly planned, because when RES share increases, urban density is affected and residential use is limited. Hsieh et al. [106] demonstrated how through a predictive method, an ideal mix of land uses can be determined and the consumption of local renewable energy can be increased. Interactions among technical, political, environmental, economic and social issues are multiple.

To sum up, there is currently in urban energy planning a weak ability to link the use of RES to the characteristics of the territory and of the specific urban area. In other words, generally speaking, until now the use of different renewables and the role attributed to each RES type in a specific context do not follow from an analysis of generation potentials and exploitation previsions aimed at fostering social development conditions [107]. Many improvements in multidisciplinary studies and tools are auspicated. In that case, urban energy planning started from an adequate and thorough analysis of the features of each city in terms of potential for the different types of renewables.

4. Conclusions: Better Studies and Tools for Renewable Energy Planning in Cities

In urban energy planning, renewables are usually considered to play an important role in terms of reducing CO_2 emissions and increasing energy efficiency. In particular, in the SEAPs the generation of RES electricity is regarded as a key element in achieving the 20% emission reduction target by 2020, in line with the strategy adopted by the European Union. However, that role appears to be less effective when one examines the presence (and related request) of the adequate tools. The transition towards a local-designed energy supply is an actual challenge for those communities which were traditionally oriented to site large refineries, power plants, and transmission corridors. In fact, in the past, national energy planning guided a centralized development of infrastructure investment that is nowadays requiring a structural change of energy structure, whose commitment in RES is a substantial part.

The overview operated in the paper allows authors to pinpoint three main recommendations, useful for further research, in a period of transition in energy deployment, but also of fertile investigation in the field of relations between territorial development and social conditions. The scientific community has a strong role in promoting accurate and adequate approaches to the problem, considering multiple factors and underlining lacking points.

- As a first point, the "urban question" is often cited in literature but not consistently considered. There is a lasting dichotomy between the image of urban areas as targets of investments and in need of energy supply, and another representation of them as communities (formed by residents, politicians entrepreneurs, etc.) with their own vision of collective development. Several times, these two sides are investigated but in a separate way and, so, we can affirm that the "city question" connected to RES (city as "polis", with an all-encompassing meaning) has not been really taken into account in its complexity.
- The improvements in RES exploitation were investigated in terms of massive investments and implementation of supported policies (see CoM). But, as far as situ-specified and self-determined visions by communities, existing literature has neglected this point. Problems in RES are deepened in terms of technical or modelling solutions, but not of better conditions experienced by residents as a concrete effect of their introduction. According to initial intentions, the implementation of these kinds of technologies is directly connected to social development of the local conditions of territories and the awareness about them by residents; if this point is not respected, the implementation of RES is clearly not successful. Surprisingly, this consideration is mostly absent in existing literature and in general in scientific research. In other words, this is not considered as a criterion of investigation to really check the soundness of investments and advancements.
- Concluding with a disciplinary remark, the advancement in RES studies is crucial for scoring the targets of an integrated introduction of renewables in cities. Especially, the role of urban energy planning, together with a coordinated governance, is essential to guarantee a citizen-oriented approach, able to put technologies at the service of people.

The critical points in implementation were underlined by authors in order to emphasize the need of specifically designed methods and tools (with a scientific base), comprehended in an all-encompassing way to treat this complex issue in the literature production; they can, at that point, really contribute to the shift towards a decentralized energy paradigm and the achievement of ambitious goals in sustainability policies related to decarbonization and climate change.

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Abbreviations

EU	European Union
GHG	greenhouse gas
GIS	geographical information system
IRENA	International Renewable Energy Agency
LCA	life cycle assessment
LCC	life cycle cost
MCDA	multi-criteria decision analysis
MES	multi energy systems
MHP	mini/micro hydropower
PV	photovoltaic
RES	renewable energy sources
SHP	small hydropower
SWOT	strengths weaknesses obstacles and threads

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