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Smart cooling systems for the urban environment. Using renewable technologies to face the urban climate change

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ABSTRACT

Urban heat island and global warming increase the urban ambient temperature. Increased temperatures have a tremendous effect on the energy demand for cooling, with a great impact on peak and total electricity demand.

Renewable technologies in the urban environment have been widely regarded as an increasingly important solution to deal with the climate change challenges and energy security. Significant effort is performed in the integration of photovoltaic panels (PV) and micro turbines in the urban context showing a substantial reduction in CO_2 emissions. At the same time attention is drawn to an often-overlooked aspect regarding renewable energy technologies, in that despite having low operating costs their overall benefits are often not well understood and consequently are often evaluated as being less profitable than fossil fuel alternatives, even though they are future proof about energy cost.

The aim of the present paper is to describe the role of renewable energy technologies and zero carbon technologies in covering the future increased energy demand for cooling.

The integration of photovoltaics in the urban environment through PV facades, pavements, and shading devices are discussed.

The role of Information and Computer Technology and smart grids in the efficient management of renewables in urban scale is discussed. The role of smart metering, users 'integration and demand response capabilities for future zero energy urban neighborhoods is revealed.

1. Introduction

The request for energy and energy-related services, to meet social and economic development and improve human wellbeing and health, is constantly increasing. It is well recognized that societies require energy facilities to meet human needs such as space comfort, lighting, cooking, mobility, and communication as well as to serve the various productive processes (Edenhofer et al., 2012). Moreover the significant changes in climate variables that are anticipated and already experienced in the 21st century, as well as the observed ongoing extreme weather and climate events, signifies that adaptation and mitigation to climate change will be a key issue for the urban areas in the near future ("ADAPTATION ACTION PLAN (AAP) the Executive Summary University of Catania," 2011, Müller et al., 2014; Prutsch et al., 2010).

The extent of future climate change depends on some variables including the pace of greenhouse gas emissions, temperature increase rates, and the response of ecosystems to the changing climate. In this framework, all cities face economic, social, energy & environmental challenges each one of them being interrelated with the definite increase in urban temperatures which leads to a significant increase in the cooling demand.

On the other hand, the world's population is growing at unprecedented rates, impacting significantly on the nature of our urban and natural environments. By 2050 we will be nine billion people on the planet, of which 70% will be living in urban areas. That is the reason why Peirce et al. (2008) have rightly called the twenty-first century, the 'Century of the City.'

Nevertheless, the technologies that can make the difference in the urban thermal environment are well documented (Akbari et al., 1997; Akbari and Touchaei, 2013; Santamouris, 2014). The use of cool materials for the urban environment, able to amortize, dissipate and reflect heat and solar radiation, are already in the market and continuously evolving. The existence of the European Cool Roofs Council, the Cool Roofs Rating Council as well as the announcement of the foundation of the Asian Cool Roofs Council proves that there is a high and global market interest. Green infrastructure, green roofs, and green facades is another growing market with a significant potential in contributing to the urban cool island effect (Oliveira et al., 2011; Skoulika et al., 2014).

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Various pilot case studies have shown that urban heat deterioration can be mitigated using the climate change mitigation techniques:

- Ng et al. (2012) studied the thermal effects of greening in improving the urban microclimate in the city of Hong Kong. As a rule of thumb, a reduction of outdoor temperature equal to 1 K is possible when tree coverage is larger than 1/3 of the total land area for areas where the building coverage ratio is almost to 44%, which is the average value in Hong Kong.
- The improvement of microclimatic conditions in Athens Greece was studied by Gaitani et al. (2011). Through a series of interventions such as increased greenery, installation of cool materials, increase shading and use of earth to air heat exchangers, the area's comfort conditions were significantly improved.
- Almost 4500 m^2 of cool pavements were used to rehabilitate a major urban park in the greater Athens area. It was found that the extensive application of reflective pavements, under the particular climatic conditions, may reduce the peak daily ambient temperature during a typical summer day up to 1.9 K while surface temperatures were reduced up to 12 °C (Santamouris et al., 2012)

But are these technologies sufficient? Can urban climate changes be adequately mitigated and simultaneously reduce the constantly increasing cooling demand? Or should we also focus on increasing the renewable energy production in the urban environment? How can we increase the potential to introduce low or zero carbon micro-renewable energy technologies in cities?

Recent studies show that future energy demands for cooling will be dramatically increased (IPCC, 2014; Santamouris, 2016, 2014) the upcoming decades. As Santamouris noted in Santamouris (2016) the growing use of air conditioning to satisfy the indoor thermal comfort will increase the cooling demand depending on the increase of the ambient temperature. At a global level, it is estimated, that a possible increase of the average ambient temperature by 1 K, may result in an energy consumption for cooling worth of 75.1 billion dollars. This trend is depicted in Fig. 1 (Petri and Caldeira, 2015) showing a significant increase of Cooling Degree Days and a considerable decrease of Heating Degree Days.

Based on the above, the integration of renewables in cities to cover future increased cooling demands should be a top priority.

Existing literature in renewable energy shows that renewable energy technologies continue to grow as improved performance, efficiency, and reliability, at lower costs, is pursued by researchers ("Cities, Towns & Renewable Energy Yes In My Front Yard," 2009). The potential offered by distributed energy systems, which usually involve a significant share of renewables, is becoming apparent as smart meters and intelligent grids (Tsoukalas and Gao, 2008) are deployed.

The starting point of the present work is the fact that urban overheating is here and that adaptation to climate change in cities is an absolute necessity. Therefore, the aim of the present paper is to analyze the role and potential of renewable energy integration in the urban environment. Advanced and cutting edge renewable energy technologies are presented in Section 2 showing the research potential of renewables 'integration in cities.

Section 3 is devoted to the role of Information and Computer Technology in efficiently deploy renewables to cover urban cooling demand in local urban scale. Finally, conclusions and prospects are included in Section 4.

2. Advanced renewable technologies in urban environment

The integration of renewables in the urban environment represents a significant challenge for the research community. Some cities have already shown a substantial interest in integrating renewable energy.

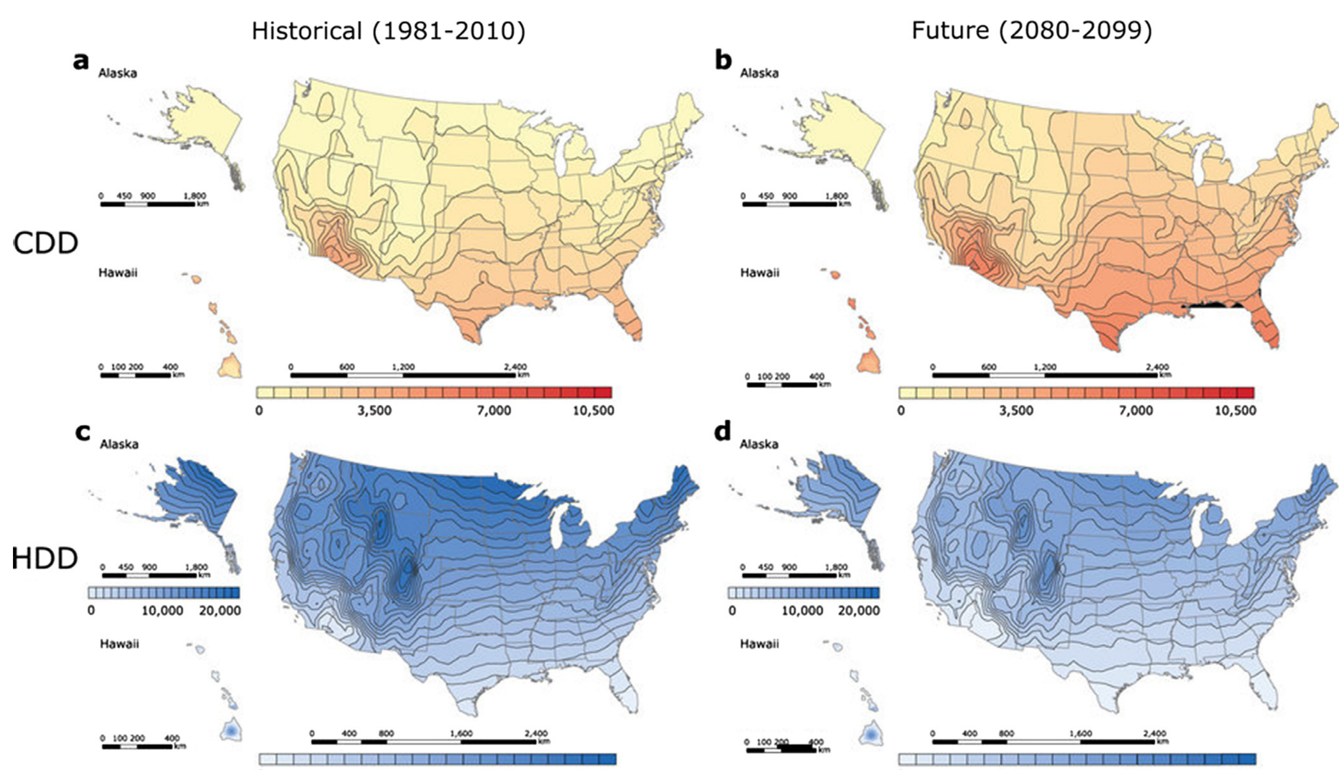

Fig. 1. The evolution of cooling and heating degree days in the USA (Petri and Caldeira, 2015).

For example, Rotterdam has adopted an Energy Approach Planning called REAP (Lenhart et al., 2015). According to theCity's Development Department representative, REAP's greatest strength is bringing energy technologies planning terminology to urban planning and vice versa, by working across organizational lines with different departments and actors. Renewable energy is a key technology to this process. The City of Copenhagen has already set a goal of achieving 100% renewable energy to become the first carbon neutral capital by 2025 (Mathiesen et al., 2015). Offshore wind already supplies enough power to cover most of the city's electricity needs. This power is fed into the national grid where it provides 10% of the nation's electricity requirement.

In the USA, the Solutions Project (http://thesolutionsproject.org/) supports the transition to a 100% renewable energy for various cities. A 100% campaign is established both in US and International level.

Renewables' installation is performed in different scales as depicted in Fig. 2.

Although central renewables installation and community scale renewables have been considered for rural or peri-urban locations, with numerous installations that provide significant insights into the technologies (i.e. wind parks, photovoltaic installations, (Koutroulis et al., 2009; Michalena and Angeon, 2009; Wu et al., 2016), the integration of renewables into the urban environment is still a major challenge.

To overcome the challenges related to the urban integration of renewables, one could suggest maximizing the installation of renewables in the urban periphery. A major argument in this approach arises from the fact that installing more and more renewables at the urban periphery creates significant pressure due to the continuous expanding of resource needs for land. Land in the urban periphery is required for agriculture, forestry, energy, transport and industrial applications. Therefore, although renewables can be much easily installed in the urban periphery, this may not always be feasible.

One the other hand, there are pilot projects in community scale showing that the zero energy goal can be achieved by the successful integration of renewables, while simultaneously the energy demand with energy supply is balanced using advanced energy management technologies and exploiting microgrid and smart grid capabilities. Some examples are the Leaf Microgrid in Italy (Comodi et al., 2014; Provata et al., 2015) where using optimization techniques the energy cost is reduced. Load matching through demand-side management (DSM) approaches are also proposed (Lopes et al., 2016) as well as the role of appliances in the generation and consumption matching is discussed by Darghouth et al. (2011).

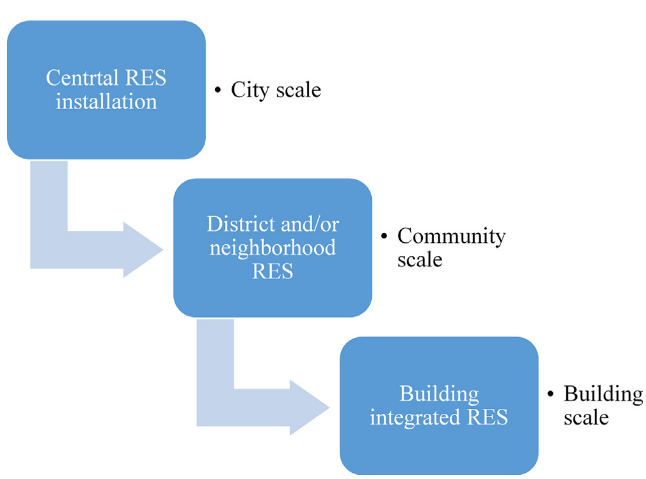

Fig. 2. The scales of renewables integration in the urban environment.

In the next paragraphs, the integration of renewables in the district and neighborhood scale as well as the building integrated renewables are analyzed. Various case studies are analyzed and discussed to reveal the applicability of renewables in city scale.

2.1. Cutting edge technologies for the integration of renewables in district and neighborhood scale

Starting from the district and neighborhood scale, the generation of power from renewables in this scale is of primary importance as it supports the reduction of the energy generation load and transmission infrastructure (Ishugah et al., 2014).

Wind and solar energy cutting edge technologies have been developed ready to be integrated into the urban environment.

Different types of wind turbines are encountered that try to minimize the affection of turbines' performance by the turbulent wind flow in the urban environment (Karthikeya et al., 2016). The horizontal type wind turbines need to be carefully installed to avoid problems with aesthetics, maintenance issues as well as birds' trapping (Ishugah et al., 2014). Some examples of horizontal wind turbines 'integration is depicted in Fig. 3. The particular wind turbines generate about 100,000–2,000,000 kW h depending on the size and application in the urban scale.

Moreover, different designs have been introduced for the vertical axis wind turbines in the urban environment. The main advantages of the vertical configuration are:

- The vertical wind turbines should not be oriented towards a particular wind direction (Ledo et al., 2011; Peacock et al., 2008)
- The generator and gearbox can be installed in the lower part of the turbine or even in the ground, thus facilitating the maintenance works.
- The vertical wind turbines can handle higher levels of turbulent flow.
- They can be integrated into various configurations minimizing aesthetic problems. A tree design is proposed in Fig. 4.
- The production cost is reduced due to modular formations that can be developed.

Moving to the solar energy applications for the urban environment we can find installations of different systems and technologies.

An impressive technology is the photovoltaic pavements and floors that can be included in the urban texture (see Figs. 5 and 6). Solaroad project (http://en.solaroad.nl/) in the Netherlands and Solar Roadways in US are incorporating photovoltaic panels in the road and exploit large surfaces within cities to generate electricity that can be used by local users. Prefabricated slabs made by concrete modules of 2.5 m × 3.5 m with a translucent layer of tempered glass, which is about 1 cm thick are used. Underneath the glass are the crystalline silicon solar cells. The top layer shows an important difference from the traditional road surface, and it has to be translucent for sunlight and repel dirt as much as possible.

Moreover, as studied by Efthymiou et al. (2016), the use of photovoltaic pavement can reduce the surface temperature of the paving structure by 5 K contributing to a reduction of the urban thermal deterioration.

Also, small Combined Heat and Power (CHP) plants in neighborhood scale will change the way people perceive heating, ventilation and air conditioning (HVAC) systems in residential level (Ondeck et al., 2015) and may provide the necessary technological instruments to fight urban energy and fuel poverty. While small scale CHP is not widely deployed, there are some very interesting case studies especially in Denmark where 52% of the electricity demand is met by CHP connected to district heating and cooling systems (Fig. 7) (Andrews et al., 2012).

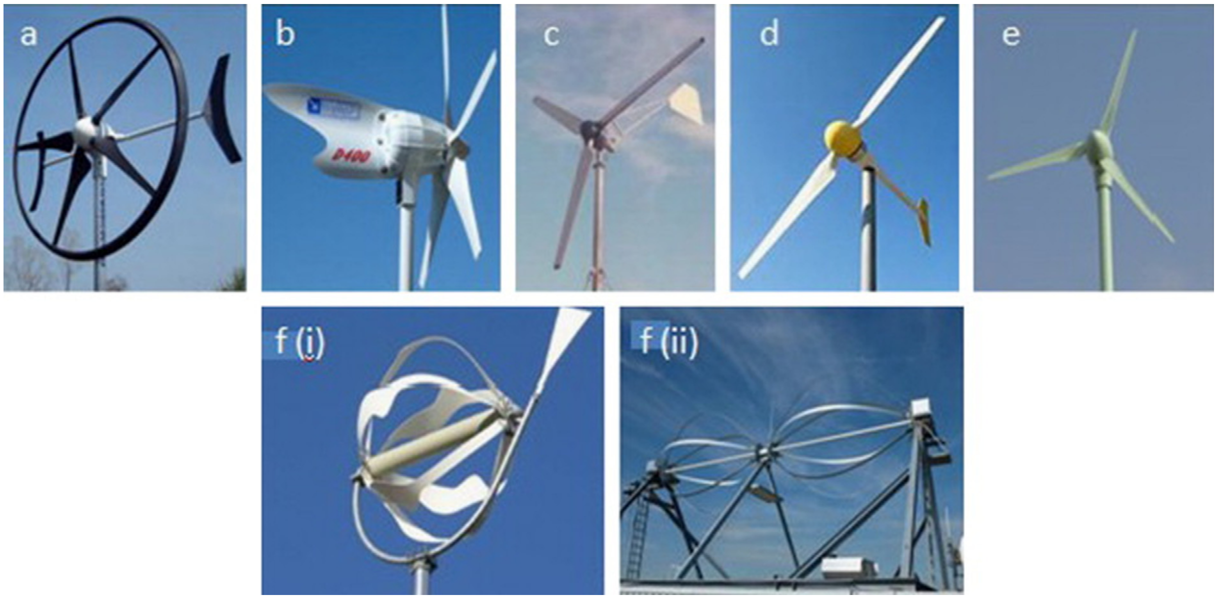

Fig. 3. (a) Swift wind turbine, (b) Eclectic wind turbines, (c) Fortis Montana wind turbine, (d) Scirocco wind turbines, (e) Tulipo wind turbine, and (f) the Savonius type, (i) Energy Ball and (ii) WindWall (Ishugah et al., 2014).

Fig. 4. Vertical wind turbines in the urban environment forming a tree developed by Newwind Srl (Courtesy Newwind Srl).

CHPs can also be combined with different renewable cutting edge technologies. An example of such technologies is the high concentration photovoltaics (HCPV) (Bonsignore et al., 2016) which due to the exploitation of sun radiation a reduction of components such as cells, optics, heat exchangers can be achieved. CHPs combined with concentrated solar power can be a very promising solution since they produce, apart from the output of the multi-junction cells with efficiency larger than 40%, the thermal energy in the form of a hot fluid (Paredes et al., 2015). This potentiality stimulates the effort to develop PV/T hybrid technology for district level combining high performance and reliability technologies. An example of such technology is the HCPV formulated in the framework of the FAE ''Fotovoltaico ad Alta Efficienza'' (''High Efficiency Photovoltaic'') Research Project funded by the Sicilian Region (http://www.ideasrl.it/?portfolio=solare-a-concentrazione) (Bonsignore et al., 2016).

2.2. Integration of renewables in urban buildings

Building surfaces can be ideal for the integration of renewables but high costs, technical and aesthetic considerations have kept

Fig. 5. Photovoltaic pavements (Efthymiou et al., 2016).

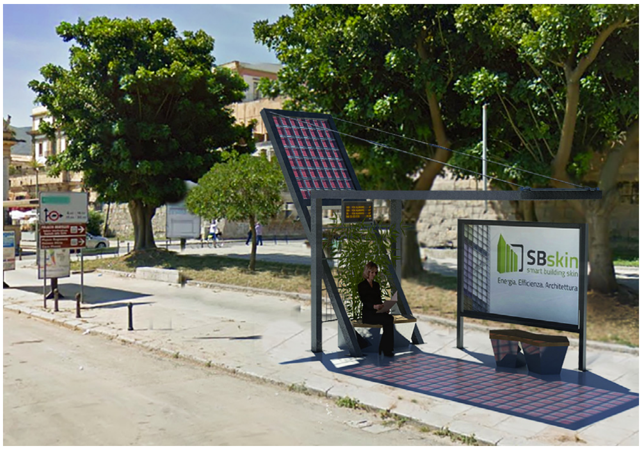

Fig. 6. Integration of photovoltaics in district level (Corrao et al., 2015).

building owners from using this potential. The aim of the present section is to pinpoint cutting edge technologies for the installation and integration of renewables in the building fabric.

One of the energy technologies that are considered in an urban environment is the use of micro-wind turbines designed to be mounted on various buildings. The overall performance of the wind turbine varies depending on the turbine's positioning, the roughness of the surrounding area, the size and height of the neighboring building, etc. An example of wind turbines 'installation on a rooftop is the Boston Logan airport building ("Boston Logan airport building wind turbine," 2008) as shown in Fig. 8. The 20 turbines installed generate about 100,000 kW h annually, which is equivalent to 3% of the buildings energy needs.

Wind turbines are also integrated into the design of the high-rise buildings. The heights of the skyscrapers or other high-rise buildings can extend to the upper levels of the atmospheric boundary layer, where wind velocities are both increased and less turbulent compared to the ground. An example of such integration is the Pearl River Tower where four wind turbines are installed in two different levels of the building (positions T1–T4, Fig. 9). The estimated energy produced by the T1 and T2 wind turbines are quite lower (487 kW h approximately) than those installed in T3 and T4 which is calculated equal to of 3613 kW h 3118.59 kW h respectively.

The integration of photovoltaics in building elements has attracted a lot of research efforts the last decades (Petter Jelle et al., 2012). Some examples include:

- The development of Dye-sensitized Solar Cells (DSCs) that can be integrated into the glazing façades (Shukla et al., 2016). An example of such technology is the SBSkin described in Corrao et al. (2015). With an installation of to 185 kW_P almost 112,000 kW h electricity is produced on an annual basis. The installation of the specific PV DSC module contributes to a decrease of 14% of the cooling loads due to the reduction of extra heat gains apart from the electricity produced.
- The installation of photovoltaics at the rooftop of Fraunhofer Institute for Solar Energy Systems ISE (Sprenger et al., 2016) where the various parts generate different amount of DC and AC power depending on the shading (Fig. 10).
- Photovoltaic (PV) double-skin façades comprising PV cells incorporated into a double-skin with a thick air gap where the gap acts as a solar chimney and the air flow is driven partially or wholly by buoyancy (stack effect). As a result, during hot periods the air gap can cool PV components while acting as a thermal barrier for the building (Saadon et al., 2016) (Fig. 11).

Another interesting application is the integration of Fresnel collectors installed on the rooftop of a school which covers the energy demand for cooling for various buildings in the area of Nicosia, Cyprus (Kampelis et al., 2016). A view of the collector is depicted in Fig. 12. This collector has been specially designed by Idea Srl to assure the independent rotation of each collecting element of the primary optics. This allows the complete rotation of the supports that can host a PV panel on the back to provide electrical energy in the absence of a suitable direct radiation for thermal energy exploitation.

The technical specifications and main features of the Linear Fresnel collector are:

Mirrors: 288 mirrors (2000 mm × 32 mm dimension per unit) and 144 collecting units distributed into18 rows × 8 modules
Heat transfer fluid: White oil (Duratherm 450)
Maximum thermal power: 70 kW, 170 °C outlet nominal temperature

In the roadmap of innovative technologies, hybrid renewable technologies can play a significant role. One indicative example

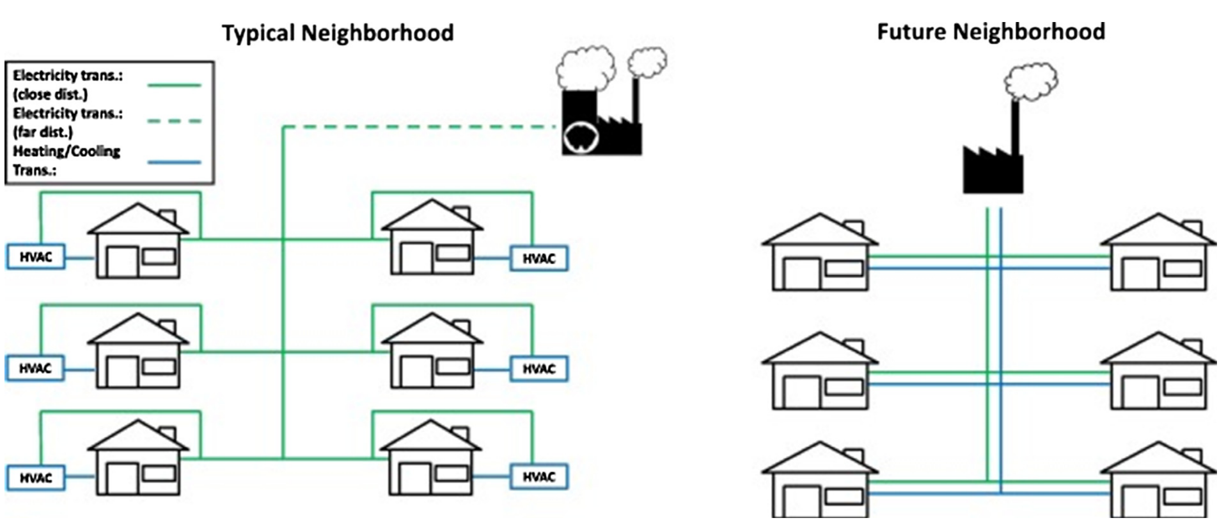

Fig. 7. The typical and future neighborhood for HVAC installations in district level (Ondeck et al., 2015).

Fig. 8. Integration of horizontal type wind turbines in the urban environment (Ishugah et al., 2014).

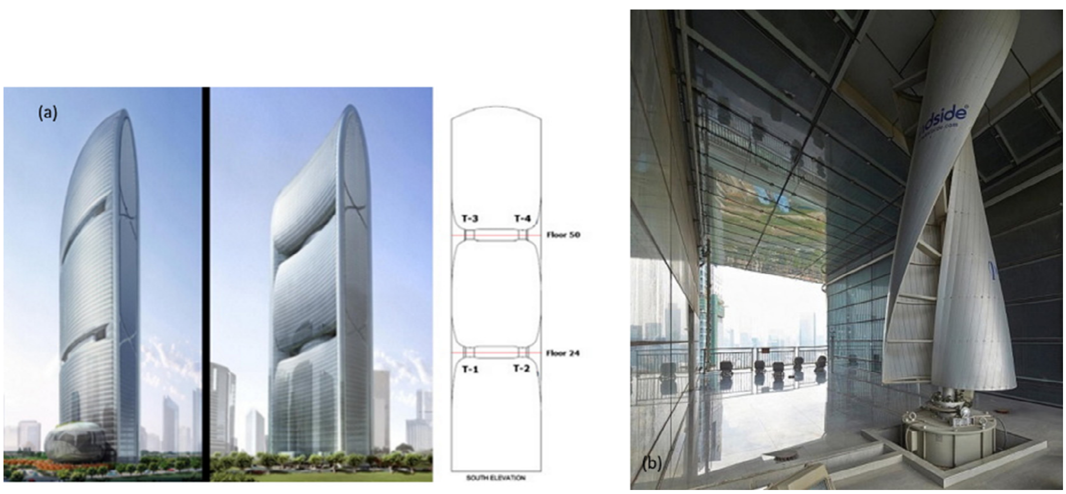

Fig. 9. Wind turbines in high rise buildings: (a) Position of wind turbines and (b) the vertical wind turbine installed in the building (Li et al., 2016).

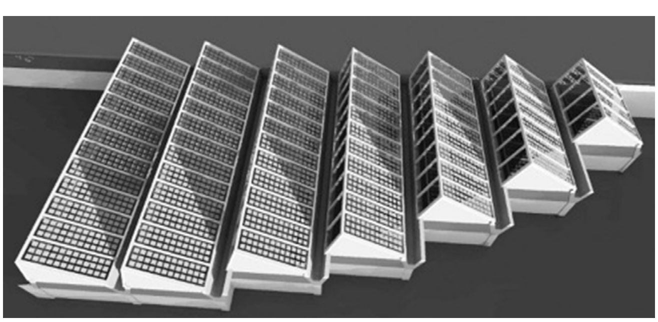

Fig. 10. The PV installation on the rooftop of Fraunhofer Institute for Solar Energy Systems ISE (Sprenger et al., 2016).

is Windrail which can be installed in the side or corner of building's rooftop and produces electricity from both wind and solar energy.

The pressure difference between the façade and the flow surface and the rooftop out of flow area is used in the WindRail channel to over speed the wind velocity and has, therefore, a higher energy density as shown in Fig. 13. Typical over speed factors are between 20 and 70% depending on the individual situation. Smooth surfaces and a low stagnation point, as well as the volume the air flow has to go around, are important factors for high over speed factors. The nominal power of the combined wind and solar installation ranges between 2400 and 2700 W depending on the installation and can be used to cover partially or fully the cooling demands in urban residential and office buildings.

Other ways of integrating renewables into the building fabric are proposed by Tripanagnostopoulos (2014). Static solar concentrator collectors' configurations are proposed building integration, as they can be of a considerable size with greater structural strength and thus minimized stability problems.

Therefore, the roadmap towards the integration of renewables for covering the increased future cooling demand is already open and feasible through the recent technological developments.

3. Information and Computer Technology and smart grids for RES in the urban environment

Based on the aforementioned technologies, the integration of renewables to cover the potential increases of cooling demand in the urban environment seems to be achievable. If this is the case, why there is no significant boost towards that direction? What are the main burdens in the successful deployment of renewables in urban environment and how these can be overcome?

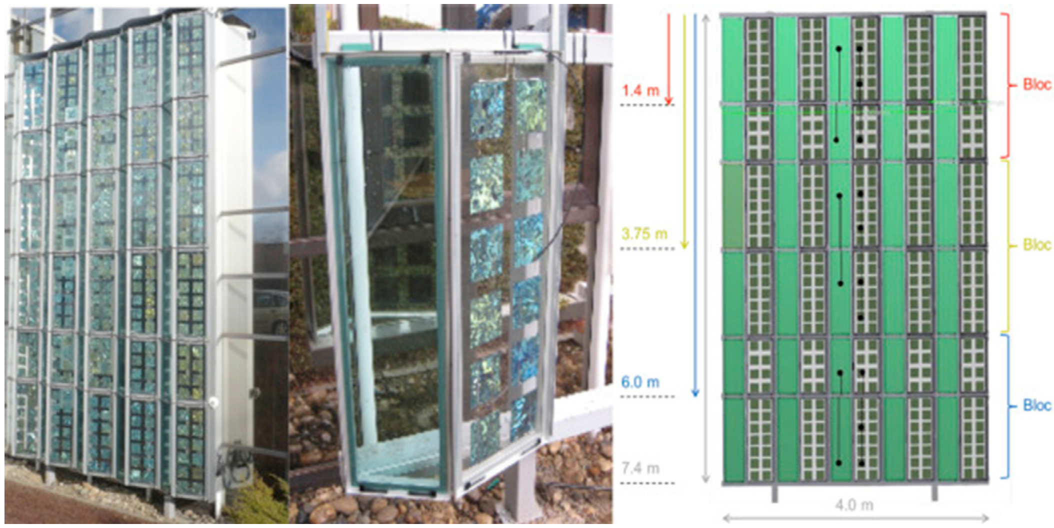

Fig. 11. PV integrated into double skin façade (Saadon et al., 2016).

Fig. 12. The Linear Fresnel system installed on the roof of adjacent school.

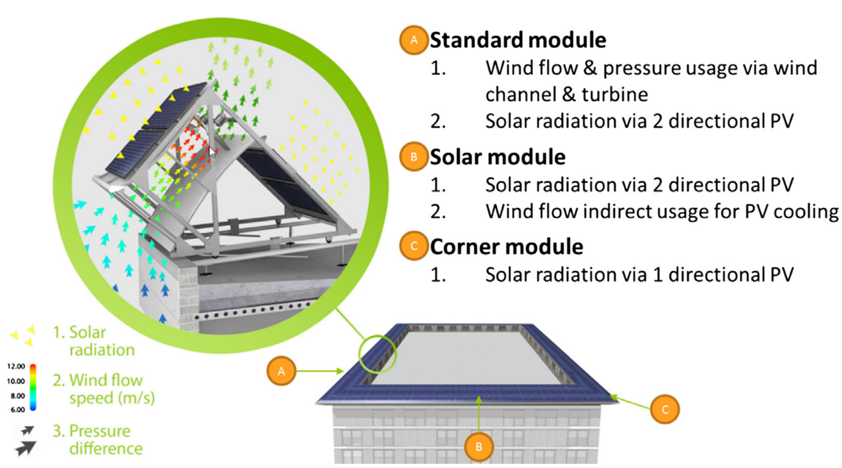

Fig. 13. The Windrail operational characteristics (courtesy Anerdgy SA).

The most critical burdens can be summarized into the following:

- Lack of space is a very critical point for renewables in urban level due to the fact that most renewable investments in the urban environment are guided by incentives on installing renewable energy technologies at the *individual* level (Marques et al., 2010; Zahedi, 2011). So people are trying to cover their own individual energy demand for cooling while limited motivations are provided for community, neighborhood

or district level. The coverage of cooling demand in the urban environment in individual level has limited impact on the zero energy goal. As mentioned by Dóci and Vasileiadou (2015), more motivations are expected for investors to participate in renewable energy communities 'installations related to group projects. This is because joint actions may achieve the common interest, i.e. facing space limitations and subsequently cost limitations more effectively. Gain and normative motivations are the key drivers for joint energy production in urban community level. Consequently, people should clearly understand the benefits from a common renewable energy installation, which are mainly reduction of initial investment cost, reduction of operational energy cost and improvement of indoor environmental quality within the urban thermally deteriorated environment.
- The initial investment cost is another considerable burden. People living in low-income households cannot even consider the possibility of installing extensive renewables. Therefore, energy production and consumption matching are necessary while it should be supported by increased awareness and users' integration via demand response capabilities (Bartusch and Alvehag, 2014).

All the aforementioned burdens can be overcome by the use of Information and Computer Technology (ICT) and the extensive implementation of smart grids and microgrids.

Smart/microgrids can create a revolution in the urban built environment. The accumulated experience of the last decades has shown that the hierarchical, centrally controlled grid of the 20th Century is ill-suited to the needs of the 21st Century. The smart microgrid can be considered as a modern electric power grid infrastructure for enhanced efficiency and reliability, thus ensuring effective optimization of resources, while users, energy technologies, and energy demand can be well integrated and interconnected.

Smart Grids open the door to new applications with far-reaching interdisciplinary impacts: providing the capacity to safely integrate more renewable energy sources (RES), smart buildings and distributed generators into the network; delivering power more efficiently and reliably through demand response, comprehensive control and monitoring capabilities; enabling consumers to have greater control over their electricity consumption and to actively participate in the electricity market, thus managing their resources and minimizing discomfort without putting extra burden on the grid.

Through the smart grids' implementation and the exploitation of ICT the following can be accomplished:

- Effective renewable energy generation and consumption matching through the deployment of smart meters and energy data gathering in district and neighborhood level that will support the coverage of cooling demand.
- Reduction of energy costs through demand response capabilities that support simultaneously users' integration.

All these are discussed in the next sections.

3.1. Smart metering and balancing the energy production with the energy consumption

Smart metering with sensor based approaches is exploited in various applications for large buildings and district scale (Papantoniou et al., 2014a). The energy data collection via smart metering allows the effective understanding of energy demand which can be effectively coupled with energy generation via renewables. Therefore through smart metering, advanced expert systems and control algorithms for cooling load prediction and shaping in small communities can be performed (Kolokotsa et al., 2011; Provata et al., 2015). This may allow a minimization of the renewables installation, thus reducing the overall investment and maintenance costs. Various case studies have shown that smart metering can play an important role in reducing the energy costs. For example, the installation of smart metering and advanced energy management in hospitals showed a reduction of energy costs between 25 and 30% for all pilot hospitals while the initial investment was minimized by the use of existing ICT capabilities and infrastructure for the interconnection of energy systems (Kolokotsa et al., 2012; Papantoniou et al., 2014b). Since 2012, Technical University of Crete has developed a strategy to support its sustainability by investing in energy efficient technologies. In this framework, smart meters were installed at various points of the campus power grid to provide energy consumption breakdown and monitoring. Simultaneously a raising awareness campaign was initiated, and messages are sent to the Campus users to motivate the reduction of the energy waste. Through the energy map of the Campus (http://www.tuc.gr/3879.html), real-time energy data and the information are available online. This strategy led to a reduction of the energy consumption by 17% simply through monitoring and informing the end users. Additionally, in the framework of a research project**,** smart meters, and wireless sensors are installed in two buildings of the Environmental Engineering Department of the Technical University of Crete, formulating the first aggregated BEMS in the Campus (Kolokotsa et al., 2016). Monitoring results indicate a potential reduction of annual energy consumption of approximately 30% due to the reduction of the energy waste in both buildings and outdoor spaces (outdoor lighting, etc.). This infrastructure will be supported by the installation of 500 kW photovoltaics installation in the parking lots, buildings, etc.

Moreover, smart metering supported by data aggregation algorithms may provide useful insights on how energy is consumed in district/neighborhood scale and perform the necessary actions to optimize the renewables operation. Distributed Data Aggregation Algorithms are algorithms used to compute an aggregation function in a decentralized way and has the computing capacity to process large amounts of data.

Various aggregator algorithms with real-time energy management systems have been defined and tested supporting the grouping of neighborhood buildings (Igualada et al., 2014; Kotsis et al., 2015).

Therefore, smart meters and intelligent sensors provide the basis for the information exchange among the technologies and the users. This is a key enabler for understanding the anticipated increased cooling demands of the future was well as for managing effectively the energy production by small renewables.

3.2. Demand response and users' engagement

Smart grids entail a more pervasive technology that influences the daily life of users. Although users have not been actively involved in previous grid innovations, the role of users in the future energy system is critical (Verbong et al., 2013). As mentioned in the previous paragraph, smart meters coupled with intelligent platforms and software apps via internet and smartphones provide the basis for the information exchange. This will enable small size electricity consumers to become also producers, so-called prosumers, effectively managing their own energy production and consumption. Therefore, the smartness of "smart grids" depends upon the end users' behavior, awareness, and engagement. The smartness is focused not only on elimination of black-outs, but also on making the grid greener, more efficient, adaptable to customers' needs, and therefore less costly (Covrig and Mengolini, 2013; El-hawary, 2014).

To this end, Demand Response plays a critical role. Demand Response allows energy consumers and prosumers to interact with the power grid in real time. Some of the most significant potential benefits of Demand Response are associated with the increased stability of the power network, efficiency of operations, RES penetration, environmental performance as well as minimization of energy and investment costs (Bartusch and Alvehag, 2014; Bradley et al., 2013). Demand Response is a crucial aspect of energy management given that: (i) electricity supply must always equal demand to maintain frequency balance and (ii) generation costs vary remarkably with peaks in power demand. As a result, consumers are exposed to significant price fluctuations over time, system instability, power losses, etc.

Residential users nowadays (Dupont et al., 2014) are subject to flat or day–night electricity tariffs. In order to apprehend the operational and economic challenges of a large-scale integration of RES, different types of tariffs, supported by Demand Response are an absolute necessity.

As an example, Bartusch and Alvehag (2014) investigated the potential of residential demand response programs in Swedish family homes based on a time-of-use electricity distribution tariff. The implemented approach involved a model of the absolute and relative change in electricity consumption, shift in adjusted electricity consumption and maximum demand between peak and off-peak hours, relative change in the shape of demand curves representing weekdays and weekends and diversified demand. The results indicated significant reductions in demand at times of stress for the local power grid and variations between the home categories assessed related to uneven communication efforts engaging residents in demand response.

DR programs along with intelligent and automated systems and storage in a microgrid scale are considered of vital importance in overcoming the intermittency of Renewable Energy Sources (RES) power generation as well as for providing operational and capacity reserve. Renewable energy sources are a prerequisite for demand responsive blocks of buildings. Either the renewable energy supply can be integrated into the building or it can be provided to the settlements as part of a community renewable-energy supply system based on the topics discussed in Section 2. The grid is used to supply electrical power when there is no renewable power available, and the buildings of a district will export power back to the grid at times of excess power generation. This 'two-way' flow should result in a net-positive export of power from the building to the grid. Short term renewable (wind and solar) power forecasting has been implemented in several energy management applications taking into account electricity tariff information, storage systems and load control for defining optimal operation strategies (Gobakis et al., 2011; Kalaitzakis et al., n.d.; Papantoniou and Kolokotsa, 2014).

Data mining based approaches for predicting next-day energy consumption and peak power demand, with the aim of improving the prediction accuracy are valuable tools for developing strategies of operation, optimization and interactions between blocks of buildings and the smart grid. For example genetic algorithms optimization techniques have been applied to the Smart Leaf Community Microgrid (Provata et al., 2015) in order to reduce energy costs, optimize revenues, achieve near zero net energy, minimize emissions and maintain occupant satisfaction and comfort (Comodi et al., 2014; Provata et al., 2015). In this context, predictive techniques for renewable energy production and energy demand forecasting are combined with the existing pricing policies applied by the local electricity company. The microgrid adjusts the energy stored in the batteries in each hour according to the energy consumption-production matching in order to reduce the energy costs.

Concerning end users, smart grids can play a significant role in the urban environment and climate change due to the physical proximity between consumers, energy production, and energy resources management that helps to increase end users' awareness and engagement. Therefore, engaging with consumers and prosumers when considering renewable technologies in the urban environment is necessary. Prosumers will be willing to change their behavior driven by various reasons, such as environmental awareness or responding to specific price incentives. This should be exploited to cover the increased cooling demand in an effective way by successfully informing end users for the choices they have through smart grids.

4. Conclusions and prospects

The requirements for moving to zero energy communities while climate change is putting pressure in the urban thermal environment are very demanding. Future urban neighborhoods and districts should be places of excellent social progress and environmental regeneration, as well as places of attraction and engines of economic growth based on a holistic, integrated approach in which all aspects of sustainability are taken into account (Charter et al., 2007). They should also support the efficient use of natural resources, economic efficiency, and energy efficiency.

This requires maximized exploitation of cutting edge renewable technologies planned and installed in an efficient manner in both building and district level.

Moreover, smart grids that allow interconnection of users with energy technologies will provide the platform for successful implementation and management of renewable energy generation.

To support the deployment of renewables in urban scale, incentives for community or district scale projects should also be provided. The incentives' mechanism should support joint private or public renewable installation projects where the electricity production will be used to cover a neighborhood's requirements.

Finally, smart grids will provide great information through the deployment of Internet of Things (IoT). IoT will uncover valuable insights into the health and performance of renewable energy infrastructure and the way people are interacting with them.

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