Development of renewable energy strategies for small urban areas

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Abstract

The role of municipalities to foster renewable energy generation has been recently recognized and pointed out. First, their involvement comes from the fact that strategic planning at a local level is necessary due to the site-specific nature of renewable sources. Second, in the last years, the role of citizens has turned out to be a critical issue as demonstrated, for instance, by the NIMBY syndrome, suggesting local governments' participation in the process, since they can benefit by a closer connection to inhabitants. Third, the point of view of local governments, who are the institutional actors more directly involved, can help to better estimate both technical and non-technical barriers for the growth of renewable energy.

Starting from the analysis of a small urban area, Corinaldo, located in Central Italy, whose electricity production from renewable sources is able to cover about 70% of the entire municipal electricity use, the present paper aims at identifying renewable energy strategies for small urban areas that can be suitable for big cities and metropolitan regions as well. First, the main energy strategies carried out by the municipality under study have been identified; second, the main barriers and measures to a much higher renewable energy penetration have been discussed. This analysis has been conducted with the aid of a specific tool, EnergyPlan, developed by the Aalborg University to evaluate energy alternatives based on renewable energy systems. Finally, general findings suitable for fostering renewable energy penetration have been pointed out. In particular, results show that the higher percentage of renewable energy on the total energy demand, which generally characterizes small urban areas, mainly derives – other than from the obvious reason related to the area dimension – from the closer

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connection between the local governance and citizens, able to improve communication and succeed in delivering important messages.
Keywords: renewable energy systems, local energy planning, municipality.

1 Introduction

Despite the uncertainties of world economy, energy consumption is increasing and in 2010 CO_2 emission concentration has reached a new peak.

According to the World Energy Outlook 2011 [1], even if all the energy policy measures currently under discussion are undertaken, the average long-term ambient temperature may rise over 2° above pre-industrial level, causing potentially catastrophic consequences (such as increase of sea level, catastrophic weather events, glacier retreat, species extinctions) meaning that new energy policy measures need to be studied and implemented.

Scientists agree (with a probability of accuracy higher than 90% [2]) that these phenomena come from greenhouse gas emissions (GHG) arising from anthropogenic activities, mainly caused by fossil fuel energy production.

Renewable Energy Systems (RES), other than energy efficiency and savings measures, have been identified as a key strategy for future energy production by all national and international programs [3].

Differently from fossil fuels, renewable energy sources 'are naturally replenished within a time span of a few years' [4], cause low pollution and near-zero carbon dioxide emissions, and – if properly planned – they can: i) improve both the social and economic development, ii) provide a secure energy supply and iii) increase the energy access in remote areas.

RESs comprise several technologies, which can be applied for electric or thermal energy production, as well as for renewable fuel production. Some of these technologies are mature and already economically competitive, but most of them need: i) policy measures for their deployment, ii) an important effort in R&D, iii) economies of scale and iv) a more competitive market of renewable energy suppliers to reduce cost of technology investment.

Furthermore, in order to increase the share of renewable energy into the existing supply system, a strong effort should aim at increasing the flexibility of the distribution network and developing energy storage technologies.

Recently, the role of municipalities to foster renewable energy generation has been recognized and pointed out: in 2010 local authorities received official recognition in international climate negotiations, where they were designated as "governmental stakeholders".

The involvement of municipalities, first, comes from the fact that strategic planning at local level is necessary due to the site specific nature of renewable sources.

Second, in the last years the role of citizens has turned out to be a critical issue, as demonstrated, for instance, by the NIMBY syndrome, suggesting the need to involve local governments, which can benefit from a nearer connection with inhabitants.

Moreover, the point of view of local governments, who are the first institutional actors involved, can help to better estimate both technical and non-technical barriers to RES implementation.

Although it is widely recognized that the major contribution to CO_2 emissions derives from big cities and metropolitan regions [5], the present work focuses on renewable energy strategies for small urban areas.

As a matter of fact, according to a recent study about renewable energy supply in Italian municipalities, which classifies Italian urban areas on the basis of both the total installed power generation from renewable and its ability to cover the energy demand of the household sector the 67% of municipalities belonging to the highest-ranking position are characterized by less than 5’000 inhabitants. Starting from the analysis of a small urban area, Corinaldo, whose electricity production from renewable covers about 70% of the total electricity use, the work aims at identifying teachings from renewable energy strategies developed by small urban areas, which could be adapted to big cities and metropolitan regions.

The present work is mainly organized in two sections: i) the first one analyzes the main energy strategies carried out and planned by the municipality under study in order to understand the reasons of a so high incidence of power generation from renewable with respect to surrounding areas − in a range of 5−25% [6] − and ii) the second one, aims at assessing the main barriers and strategies for a growth in renewable generation, with the aid of a code developed by the Aalborg University for designing concrete technical alternatives to fossil fuel energy systems.

2 Corinaldo: a virtuous small urban area in the development of renewable energy strategies

2.1 Population, geography and local energy system

Corinaldo is a beautiful and preserved medieval town in the Central Italy belonging to Marche Region, with a population of 5’152 inhabitants that covers a surface of 42 km^2 (thus its population density is of 106 inhabitants per km^2).

The territory of the municipality lies between 50 and 271 metres above the sea level and 50 kilometres from the seaside.

The area is characterized by a high dispersion of dwellings, from which derives that 30% of them are not connected to the natural gas grid, making necessary the use of both LPG and oil gas for the satisfaction of their heating needs.

The consumption of energy commodities is shown in Table 1: line 4 refers to the consumption of LPG and oil gas for purposes different from vehicle fuelling (*i.e.* heating or agriculture).

Table 2 reports the consumption of electricity and natural gas shared by sector.

Table 1: Consumption of energy commodities in 2008 [7].

Commodity	Value [GWh]	Percentage [%]
Electricity	26.84	30.6%
Natural gas	21.75	24.8%
LPG, oil gas	7.37	8.4%
Vehicle fuels	31.69	36.2%
Total	87.65	100.0%

Table 2: Consumption of electricity and natural gas by sector [7].

Sectors	Electricity [GWh/year]	Natural gas [GWh/year]	Total [GWh/year]
Agriculture	0.18		0.18
Households	5.43	14.4	19.75
Industry	16.9	3.26	20.16
Services	4.43	4.35	8.78
Total	26.94	21.75	48.69

The local industry is the main responsible of electricity consumption with an incidence of 61% on the total, while the household sector mainly affects the natural gas consumption (65% of the total).

Considering the total energy consumption, the most energy-demanding sector is transport sector followed by industry, household and service sector.

As regard electric energy production the only contribution comes from renewable power generation, in details a cumulative PV power plant installed of 8’300 kWe and a cogeneration facility fuelled by landfill gas of 1’600 kWe. The thermal demand is mainly satisfied by boilers that are fuelled by fossil fuels (oil derivates and natural gas as shown in table 1) and a very small percentage by solar collectors, which produce about 0.06 GWh/year.

Data reported in table 3 show the main characteristics of renewable power generation installed and its percentage on total electricity energy demand.

Table 3: Characteristic of renewable power plant installed.

PV power production			
	Power installed [kWe]	Electric energy produced [GWh/year]	Percentage on total energy demand
	8’300	10.32	38.5%
Cogeneration facility fuelled by landfill gas			
	1’600	8.38*	31.1%

*Value registered in 2009 [7].

2.2 Main factors affecting the high incidence of electricity generation from renewable

The present analysis has been based on data collected during the development of the Energy Master Plan that the authors carried out in collaboration with Corinaldo municipality.

As previously introduced the percentage of electricity generation from renewable on total electrical demand is of about 70%, which have to be compared with values of 5%-20% characterizing other areas in Marche Region [6, 8].

Apart from the size of the area, which obviously favours the coverage of a higher percentage on total energy demand, the main reason of this difference comes from the renewable energy strategies developed by the Public Administration (PA), which is highly sensitive to environmental protection and sustainable development issues.

In 2008 the local government developed specific guidelines even before the definition of regional and national recommendations, in order to identify areas suitable for the implementation of PV power plants, with the aim of both preserving the typical municipal landscape and simplifying the implementation of PV power plants.

Light grey areas in figure 1, for instance, shows areas suitable for installing ground mounted PV plants with peak power higher than 200 kWe.

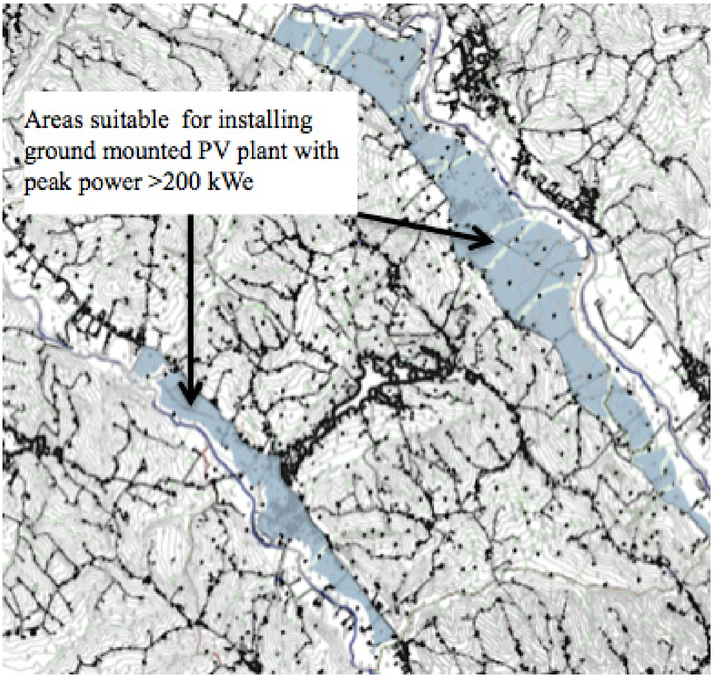

Figure 1: Map of Corinaldo.

In the same guidelines the PA, well aware of the need to attract private financial support to develop plants in public areas (which are of fundamental importance in the growth of renewable generation due to their demonstrative role) defined a compensation criterion according to which each 100 kWe of ground mounted PV power plant installed by a private investor required the installation of 1 kWe in public areas.

Thank to this rule 320 kW of PV plant have been installed in public areas so far (Table 4).

Table 4: Renewable production of PA.

PV power plant installed [kW]	Electricity production [GWh]	Percentage on electricity demand [%]
320 kWe	~0.4	50%

Furthermore, since Corinaldo is a very small urban area with less than 20’000 inhabitants, according to an Italian legislation, it can take advantage of ‘net metering’, which means that all the electricity produced by renewable plants can be used to satisfy the electricity demand of all the public ownerships, independently from the energy point of entry, using the grid as a sort of virtual electric energy storage. The consequence is a reduction in electricity need of 50% and an equal cutting in PA energy expenditures.

Another contribution to renewable production, as previously mentioned, derives from landfill gas. Since, at present, a large amount of waste is disposed in landfills -which produces biogas due to a natural anaerobic digestion process- the production of electric energy represents a classic situation where it is possible to turn a problem into opportunity.

As a matter of fact, the presence of landfill gas in the garbage dump can lead both to possible methane combustion or, even worst, to an auto-ignition, and a direct emission of methane has to be avoided, since its Global Warming Potential (GWP) is twenty-one times higher than carbon dioxide GWP.

Finally it is worth noting that electricity production from renewable provides money collection deriving from national energy policy mechanisms designed to support renewable generation, such as feed-in tariffs and Tradable Green Certificates (TGC).

Another important strategy adopted by the Municipality under study, which can be extended to large areas and also to metropolitan regions is the definition of clear short and medium/long-term targets, which have to be identified on the basis of the actual local potential of power generation from renewable.

With this aim, in 2010, Corinaldo Municipality began to develop the Energy Master Plan in collaboration with the present authors.

In the development of the Plan, particular attention has been paid to initiatives directly managed by the local administration, due to their exemplary role and their ability to attract both private and public funds.

In detail, the Energy Master Plan has provided: i) the identification of the main criticalities in the energy end-users, ii) the organizations of the work done so far by the local government in renewable energy field and iii) the planning of important initiatives in the area, which have been summed up in Table 5 together with their CO_2 emission reduction potential.

Table 5: Synoptic diagram of implemented policies.

	GHG emission reduction ($tonCO_2$)
Thermal insulation in public and private buildings	536
Replacement of electric boiler with solar collector	49
Savings deriving from building new constructions according energy-saving criteria	19
Introduction of high efficiency equipment in dwellings	153
Introduction of high efficiency lamps in dwellings and public lighting	312
Introduction of micro-CHP in detached houses	60
Introduction of geothermal heat pump in dwellings	3
PV plant installation in public and private area	240
Introduction of high efficiency electric motors	1’213
TOTAL	2’585

A more detailed analysis of the measures planned, their cost and their potential in terms of primary energy savings can be found in a previous work developed by some of the authors, which have discussed the technical and economic aspects of municipal energy planning [9].

3 Energy strategies for increasing renewable energy generation

3.1 Adopted methodology

A specific tool [10], developed by the Aalborg University and widely used to assess concrete technical alternatives based on power generation from renewable has been used to better evaluate renewable energy strategies for the case under study [4].

The model, called EnergyPlan by its designers, is able to develop an integrated analysis of the energy system, taking into account the electricity, heat and transport sector. The mentioned model cab be applied both to large-scale and local-scale analysis and can also be used to evaluate the impact deriving from the introduction of specific technologies [11, 12].

The user is asked to introduce: i) electrical and thermal demand of industry, building and transport sector ii) energy production from both fossil fuels and renewable sources, iii) characteristics of the energy conversion technologies used to satisfy the energy needs (*i.e.* electric efficiency of CHP plants, boiler efficiency) and iv) characteristics of heat and electrical storages, if existing.

The electrical and thermal energy supply/demand mismatch is considered in the analysis by introducing the hourly-distribution of energy needs and production.

Furthermore the model allows the user to specify the regulation approach on the basis of which CHP systems and fluctuating renewable energy sources interact.

In the technical approach, which has been considered in the present work, CHP plants and fluctuating renewable energy sources are operated to ensure the best balance of heat and electricity production and demand.

The main outputs of the model are energy balances and resulting annual production, fuel consumption, import/export of electricity, and total costs.

3.2 Analysis of the energy system

The data used to develop the reference energy system of the municipality have been introduced in section 2.1; costs have not been considered in the present analysis.

As previously introduced the hourly-basis distribution of electrical and heat demand, as well as the hourly-basis distribution of the renewable production, have to be defined.

In the study the distribution of the electricity demand of the municipality has been considered equal to the Italian hourly load profile defined in [13], the thermal load has been built on the basis of the load profiles defined by [14] taking into account both the end-user typology and the climate condition of the area, the PV production as well as solar thermal production, as suggested by [15] derives from PVGIS (Photovoltaic Geographical Information System) data [16].

The outside world in terms of electricity production has been simulated as a power plant characterized by an efficiency of 46%, whose fuel mix is the Italian fuel mix (24.3% Coal, 12.3% Oil, 58.9% natural gas, 0.45% biomass [17]).

Table 6 shows results obtained for the reference scenario, in details: CO_2 emissions, fuel consumption, RES electricity production and RES share of, respectively, primary energy saving and electricity.

Table 6: The model results.

	Reference scenario	Scenario 1
CO_2 emissions [Mtoe]	19.8	18.5
Fuel consumption [GWh/year]	114.6	111.5
RES electricity production [GWh/year]	18.26	20.5
RES share of primary energy saving	27.4%	30.1%
RES share of electricity	68%	78.7%

Another important aspect, which comes from the analysis, is the problem related to the excess of electricity produced during the year by non-dispatchable renewable sources, which need to be balanced. Figure 2 shows the electricity demand and production of June, where it is pointed out the need to export part of the electric energy produced by renewable sources (black area).

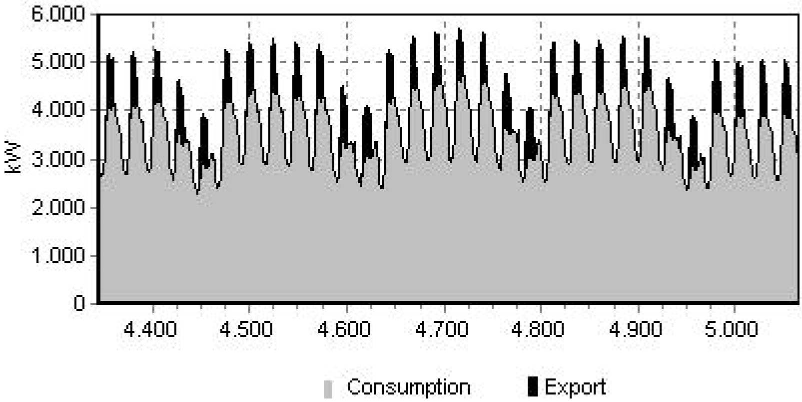

Figure 2: Electricity balance in June calculated by the model.

Electricity grid constrains are an important issue, which have to be considered to identify the best strategies to increase the penetration of energy production from renewable. As a matter of fact, the growth of fluctuating renewable energy production requires energy system design improvements, such as, for instance: i) improvement of transmission interconnection, ii) introduction of storage facilities (*i.e.* centralized or load side-storage), iii) demand-side management, iv) introduction of innovative mobility solutions based on electrical or hydrogen vehicles.

These aspects suggest, furthermore, the need to coordinate local, regional and national energy policy. As a matter of fact, long-term targets, although based on the actual potential of the territory and properly encouraged by local energy policies might not give the expected results if important initiatives to improve the energy system are not undertaken at regional and national level.

A second scenario, called ‘scenario 1’, has been built considering all the measures studied in the Energy Master Plan (see Table 5). It has been assumed an increasing in the electricity and heat demand of about 0.8% per year and ten years to put all the initiatives planned into action.

The energy saving measures identified can be translated into a reduction of electric energy demand (*i.e.* the substitution of electric boilers with solar collectors, the replacement of low efficiency electric equipments and lamps, the energy saving measures in public lighting) a reduction of fuel consumption in individual buildings (thermal insulation) and an increase in renewable energy production.

The scenario 1 also considers the contribution coming from 776 kWe run-of-river mini-hydro plant that has been recently identified, with a potential yearly electricity production of about 2,51 GWh. In order to assess its hourly distribution, raining data that are characteristic of the Central Italy have been considered [18].

Table 6 sums up the results coming from the energy scenario implemented. As shown, it results a reduction in fuel consumption, an increase in electricity renewable energy production and a consequent reduction in carbon dioxide emissions.

The introduction of a further fluctuating renewable energy source in the energy system increases the value of electricity to be exported, suggesting the importance to improve and modify the current energy system.

In the present paper it has been analyzed the introduction of Electric Vehicles (EVs) in the current energy system, to cover respectively, from the 5% to 20% of the kilometres currently covered by internal combustion engines. It has been assumed a constant recharge of EVs at night, from 10 p.m to 7 a.m.

As shown in table 7, the introduction of EV provides a reduction in energy consumption and a slightly increase in electricity from renewable directly used by the municipality.

Table 7: Effects EVs introduction.

	Fuel consumption [GWh/year]	RES electricity production [GWh/year]	RES share of PES
5%	112.23	22.23	31.5%
10%	111.72	22.25	31.7%
15%	110.26	22.26	32.1%
20%	109.44	22.27	32.4%

4 Conclusion and remarks

Small urban areas have shown a higher ability to develop renewable energy strategies able to increase the percentage of RES with respect to the local energy demand.

Apart from the obvious reason coming from the easiest target to be achieved with respect to larger urban areas and metropolitan region (*i.e.* the high incidence of transportation sector in big cities would be hardly satisfied by renewable energy sources with the current technologies) a so high penetration of RES, in authors' opinion, can be explained by the nearer connection between the local governance and citizens, which is able to improve communication.

Consequently, local governance of small areas can more easily persuade citizens to convert the current energy system from fossil fuel to renewable sources energy generation system, making people aware of the actual economic, technical and social benefits.

However, although small urban areas have the advantage of a more direct link between citizens and government, the motivation of the municipal government and especially of the Mayor, other than his/her ability to be convincing, appears to be the most important and fundamental reason at the basis of a high penetration of renewable sources.

To sum up, the main strategies for the development of renewable energy systems suitable for both small and large urban areas as well as for big cities and metropolitan regions, results to be the following:

- stress on the exemplary role plaid by local governance
- indentify the actual potential of energy generation from renewable energy production
- develop guidelines for the simplification of RES implementation
- attract private investors to exploit the local renewable energy potential
- find private and public loans to support municipalities in the development of pilot power plant to make aware citizens of benefits deriving from renewable energy production
- develop local Energy Master Plan to identify clear short, medium and long-term targets on the basis of an integrated analysis of the energy system
- consider the constrains of the current energy system in order to coordinate each policy with regional and national energy policies
- focus on the development of demand side management policies which is the most immediate solution that can be developed at local level to cope with the fluctuations of renewable energy production.

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