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Energy Networks in Sustainable Cities: Polycity Project and the Case Study of Turin-Arquata

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***Abstract*-The European Commission is supporting many projects intended to improve the use of renewable energy sources and a special attention has been devoted to the case of large scale urban areas. The project POLYCITY represents a significant demonstration of this energy policy which is applied to 3 cities: Barcelona, Stuttgart and Turin. The case of Turin appears of particular relevance because it is dedicated to the improvement of existing building and installations which is in our opinion the most frequent situation.**

In particular the most qualifying characteristic of Turin project is the installation of a new combined heat and power generator (CHP) coupled with an absorption chiller in order to supply energy more efficiently in a district which include the Housing Authority of the Province of Turin (ATC) and 30 council buildings. The trigeneration is able to supply electricity and cooling power to the main office building and, thanks to the coupling to the existing district heating system, it provides thermal energy for space heating and hot water to the council buildings in the district.

The paper will give the description of this project highlighting the use of renewable sources and the initial results. The preliminary assessment of our experiment will be discussed according to socio-economic, environmental and energetic indicators. instructions give you basic guidelines for preparing camera-ready papers for conference proceedings.

INTRODUCTION

Arquata is a quarter in Turin built at the beginning of XX century which involves about 87,500 m^2 and dedicated to social purposes (social houses, Fig. 1).



Fig. 1 Arquata district.

The building construction standards were very simple and no heating system was initially installed.
In proximity of this quarter the general office of the organization (ATC, see Fig. 2) which manages all the social houses of the Region Piedmont has been built in first 70's; this building needs both heating and cooling systems and it exhibits a lot of problems of energy consumption to get satisfactory ambient conditions due to its wide glazed facades and poor insulations.
The surface of this building is about 11,350 m^2.



Fig. 2 ATC building

In recent years this set of buildings received many interventions of rehabilitation. In particular a district heating was installed which allows to heat all the dwellings of the district and to distribute hot water in most of them; the same plant supplies heat to the office building .
The POLYCITY, supported by the European Commission (Sixth Framework Programme – Priority 6.1 Sustainable Energy Systems), allowed to introduce further developments by installing a CHP which produces electric energy released to the medium voltage grid and heat which enhances the thermal power produced by the existing heat plant in winter and which is used for hot water production and for supplying an absorption chiller during Summer. Some photovoltaic systems were also installed both in the office building (50 kWp) and in some district buildings (120 kWp), Fig. 3.
A digital metering and control system allows to manage the plant, to collect experimental data and to evaluate the system performances. A possible use of this system as a "continuous energy laboratory" which use RES technologies available both to population and to students of Politecnico di Torino is also expected.



Fig. 3 Arquata district and ATC building PV panels.

The preliminary study to predict possible interactions between the new electric system and the existing grid has been done and the most significant results are published in [1]. A possible optimization of the system has also been developed in [2]. The following paper gives more information on the metering and control system with some preliminary experimental results obtained after the first months of activity and monitoring.

STRUCTURE OF THE ENERGY SYSTEM

The energy production in the Arquata project is synthesized in the scheme of Fig. 4.
The thermal plant, that is placed in the second floor underground of the ATC building, includes:

a. the CHP
   - thermal power: 1176 kW
   - electric power: 976 kW
b. two traditional gas boilers: 2 x 2600 kW
c. a condensing boiler: 895 kW
d. an absorption chiller, thermally coupled by the CHP: 190 kW
e. an electric chiller: 476 kW

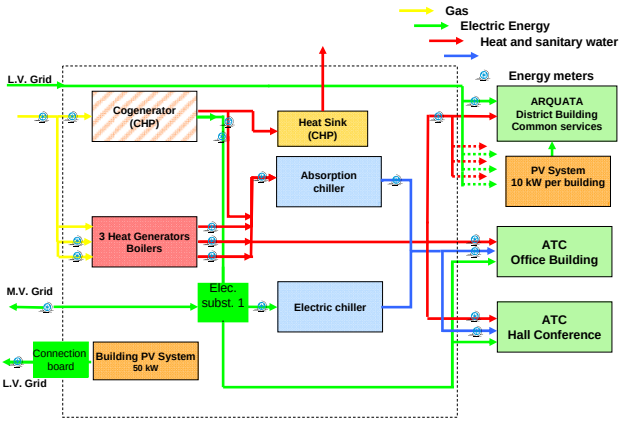


Fig. 4 Arquata energetic and metric system

In range of the project some photovoltaic plants were installed:

a. a PV plant (50 kWp) was installed on two façades of the ATC building;
b. 12 PV plants were installed on the roofs of 12 buildings of the district (10 kWp for each plant).

In the ATC buildings the panels are installed above the windows, so they produce a shading effect of the offices (with an expected saving on summer cooling of the building). It was chosen to connect the PV generation set directly to the low voltage grid without any connection to the building electric power system giving up the possible advantage to reduce the electric power absorbed from the grid.
The PV production of the district plants is used to supply the common loads of the buildings (stairs light, lift). The surplus of energy flows toward the network and when the production is not enough to supply the load the missing power is absorbed by the network.

Beyond to improve the energy sources, other interventions have been done to reduce the energy demand:

- insulation of the office building interested: new glazed façade;
- insulation of concrete external structure;
- substitution of 500 windows of district buildings: new windows with low emittance glazing and frame.

A reduction of 25% of energy demand is expected both by the office building and by the buildings of the district. The generation of electric energy both by means of CHP and by the PV systems together with the consumption reductions will give rise to an expected reduction of primary energy of 43% and greenhouse gas emissions 52% lower than in the existing situation.

PRELIMINARY RESULTS

Arquata project started on May 2005 and all the interventions were completed at the end of 2008. The project will be completed the next year 2011, anyway some preliminary considerations can be done which can give useful suggestions in the case of a renovation of complex existing installations and buildings.

A. Environmental preliminary results

The overall CO_2 emissions are calculated considering the local emissions and the global emissions.
The local emissions are produced by the CHP and by the three boilers. So it is necessary to consider the total gas consumption.

TABLE I
CO_2 EMISSIONS

			2007/2008	2008/2009
Local Emissions	Emission factor for stoichiometric gas combustion *(1)*	(kg CO_2/kWh)	0.202	0.202
	Total natural gas import	(kWh)	16,615,707.04	14,603,478.08
	Local CO_2 emissions	(t/y)	3,356.37	2,949.90
Global Emissions	Emission factor for Italian electrical system *(2)*	(kg CO_2/kWh)	0.614	0.614
	Electricity import	(kWh)	1,030,200.00	1,030,200.00
	Electricity export	(kWh)	3,195,829.37	2,334,087.88
	Imported electricity related CO_2 emissions	(t/y)	632.54	632.54
	CO_2 reduction related to electricity export	(t/y)	-1,962.24	-1,433.13
TOTAL CO_2 EMISSIONS		(t/y)	2,026.68	2,149.32

The local emissions are calculated considering the emissions due to the production of imported electricity and the CO_2 reduction due to the electricity export. The electricity export is equal to:

$$Export = E_{CHP} + E_{PV} - E_{ATC} \quad (1)$$

where:

- E_{CHP} is the CHP electrical production;
- E_{PV} is the production of ATC building PV system;
- E_{ATC} is ATC building electrical consumption.

The emission factor for stoichiometric gas combustion and the emission factor for Italian electrical systems are quoted respectively in [3] and [4].

B. Energetic preliminary results

One of the indicators used for the analysis of the results is the Conventional Energy. The Conventional Energy was calculated considering the formula proposed in [5]:

$$CE = FF + \left[0.01(100 - RES\%)(E_{consumer} + E_{aux}) - E_{RES}\right] \quad (2)$$

where:

- *FF* is the fossil fuel used in the respective area;
- *RES%* is the share of RES in national electricity mix;
- $E_{consumer}$ is the electricity consumption by regular customers;
- E_{aux} is the electricity consumption by CHP plant;
- E_{RES} is the electricity production by RES.

Two types of conventional energy have to considered:

- natural gas, that supplies the CHP and the three boilers;
- electricity import (ATC building and council buildings).

Only the PV systems can be considered as Renewable Energy Sources: the CHP can not be considered as RES because it is supplied by fossil fuel.

TABLE II

CONVENTIONAL ENERGY

			2007/2008 *(a)*	2008/2009 *(a)*
Fossil Fuel Consumption	Boilers	(kWh)	4,712,578.91	5,354,594.64
	CHP	(kWh)	11,903,128.13	9,248,883.44
	Total	(kWh)	16,615,707.04	14,603,478.08
Electricity Consumption	ATC building	(kWh)	1,446,860.63	1,227,366.12
	Council buildings	(kWh)	1,155,000.00	1,155,000.00
	Auxiliary CHP	(kWh)	155,055.00	137,150.00
	Total	(kWh)	2,756,915.63	2,519,516.12
Electricity RES Production	ATC building PV system	(kWh)	*(b)* 54,000.00	54,964.00
	District PV systems	(kWh)	*(b)* 124,800.00	*(b)* 124,800.00
	Total RES	(kWh)	178,800.00	179,764.00
RES share *(c)*	National data	(%)	15.7	18.7
CONVENTIONAL ENERGY *CE*		(kWh)	18,759,837.35	16,471,743.06

(a) The period analyzed runs from October to September.

(b)These data are a prediction. About this variable are available measured values only by August 2009.

(c) The RES share were calculated considering the data in the document of Terna "Statistical data on electricity in Italy 2008".

The data about the electricity consumption of council building are derived by the analysis on bills done in [6].

Some measures about the PV systems production are not available. Then some data in TABLE II are prediction calculated considering the installed power.

It has been a reduction of consumption of conventional energy (12%) in the second period analyzed respect to the first. Fig. 5 shows the quantity of electric energy produced by the ATC building's plant in the period from April 2008 to June 2010.

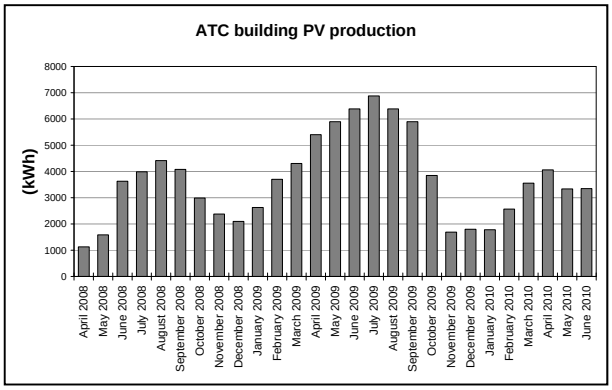


Fig. 5 Arquata energetic and metric system

C. Economic preliminary results

Arquata is an old district in the city of Torino and Polycity project aims to improve the energy efficiency of the whole district. It is important to highlight that energy efficiency is just one of the main goals of the project, since Arquata district is characterized by council Housing.

Because of the composition of Arquata district population, energy price represents one of the most important success key of the project. Therefore a very careful cost/benefit analysis is needed.

In this respect, a general methodology was developed in order to evaluate the social, energetic and economic impact of POLYCITY project:

1. Monitoring of social participation before and after POLYCITY interventions in terms of perceived quality, expectations, attitudes, services usability, perceived added value,…
2. Measurement and analysis of economic parameters (i.e.. cost services, housing costs, employment , …) related to the district;
3. Development of a communication plan at different levels, in order to involve, inform and form "Arquata citizens" and, more generally, Torino city.

As mentioned above, the measures, carried out from 2007 to 2009, include a "tri-generation supply system" operated on natural gas, an extensive integration of photovoltaic in the buildings and several measures to reduce the buildings energy consumption such as improved insulation and utilization of low emitting glazing.

According to the economic analysis, the simple payback period of the "tri-generation supply system" is estimated in 5 years, and the pay-back period of the all project is expected in 10 years. The discounted pay- back period is expected in 12 years. Of course the time to recover the initial investment is a function of the fuel cost and of the sale price of the energy services provided by the plant, and a sensitivity analysis is required. As an example the following figure 5 presents effects on the payback period of the variation of "Arquata thermal revenues", that is the sum of the bills charged to the Arquata inhabitants for the heating service. The total investments to analyze are reduced of the European contribution (35% for CHP and 15% for PV systems) so the effects of the European policy to sustain Renewable Energy Sources.

The effects of variation of thermal revenues are analyzed in the range ±20% with respect to the value obtained applying market prices to the thermal bills. These variations affect the payback period reducing or increasing its predicted value of about 2-3 years. This analysis shows the possibility of choosing tariff plans for the heating service which take into account possible discount like subsidies on the basis of the economic and social status of inhabitants.

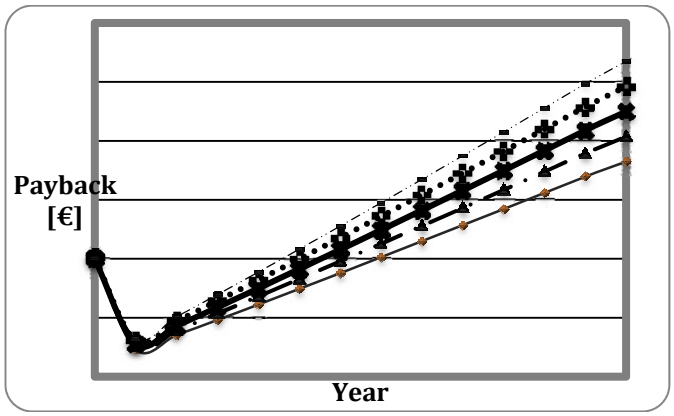


Fig. 6 Sensitivity analysis: Polycity project payback (Arquata revenues variation)

We can conclude that Polycity project seems to achieve its goals in terms of reduction of energy consumptions and of their costs for the weakest citizens.

The first effects of these investments are expected at the end of 2010 because after the realization of the most important investments (between 2007 and 2008) it is necessary an accurate tuning (2009-2010) of the complete energy system.

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The Arquata project is based on the contribution of other Italian partners which we intend to cite and to acknowledge:

ATC (Agenzia Territoriale Casa) is the owner of the Office building and of the district buildings and designed and directed all the renovation and installation of new components.

CRF (Centro Ricerche FIAT) is a partner which contributed to the installation of the ARQUATA measuring and control system.

AEM is the utility which is connected to the Arquata electric system and which is giving data on electric consumption both of the district users and of the office building.

Comune di Torino is the town municipality which supported the improvement of Arquata district with technical (district heating in 2000) and social initiatives (quarter contract in 2005).

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