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Original
Chasing Smart Communities standards: lesson learnt from Geothermal Communities project in Montieri (Italy) / Marino, V., Pagani, R.. - ELETTRONICO. - 78:(2015), pp. 681-686. (6th International Building Physics Conference, IBPC 2015) [10.1016/j.egypro.2015.11.064].

Availability:
This version is available at: 11583/2847127 since: 2020-10-01T08:16:39Z

Publisher:
Elsevier

Published
DOI:10.1016/j.egypro.2015.11.064

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10 October 2026

Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 78 (2015) 681 – 686

Energy Procedia

6th International Building Physics Conference, IBPC 2015

Chasing Smart Communities standards: lesson learnt from Geothermal Communities project in Montieri (Italy)

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Abstract

European Smart Cities and Communities initiative is asking cities to improve quality of urban life by developing actions aiming at better integrating infrastructures and rationalizing energy use. Lessons learnt from former European demonstration projects represent a valuable expertise on integrated actions aimed at developing innovative measures at urban level. The paper reports and discusses the first results of demonstration activities undertaken in the Italian site of Geothermal Communities project (European Commission, FP7 CONCERTO initiative) where best practices in geothermal energy use, integrated with other renewable energy sources and retrofitting measures, were implemented.

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Peer-review under responsibility of the CENTRO CONGRESSI INTERNAZIONALE SRL

Keywords: European demonstration project; district/community scale; geothermal district heating; energy retrofit; historic architecture

1. Introduction

In the run to the decarbonisation of Europe's economy, cities and their built environment have been assigned a major role to play, presenting high potential of improvements, if concerted actions are implemented.

Concerning urban energy issues, the Operational Implementation plan of the European Innovation Partnership on Smart City and Communities highlights "Districts and Built environment" as priority areas for implementing new technical building solutions and building automations, holistic measures for smart energy networks, energy storages and final energy use management. [1]

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Peer-review under responsibility of the CENTRO CONGRESSI INTERNAZIONALE SRL
doi:10.1016/j.egypro.2015.11.064

Several research studies investigate the possibility of extending the definition of zero energy building to neighbourhoods and districts [2]. Neighbourhood scale is identified as appropriate for defining energy patterns for demand and supply side and for implementing effective solutions [3]. It is widely recognised the need of an integrated approach that involves both the demand side and the whole energy supply chain to reach a zero energy target at district scale.

Within the CONCERTO initiative of the former European Research framework (FP6 and FP7) several pilot energy actions were implemented at community and district scale. The initiative aimed at combining energy demand and supply measures enhancing the share of renewable energy technologies in the built environment. Lesson learnt from the 58 communities involved in CONCERTO initiative constitute a valuable background of applied solutions for future Smart Cities and Communities projects.

This paper outlines the strategies implemented in Geothermal Communities project (afterword referred as GEOCOM project), funded in the third edition of CONCERTO initiative. The *fil rouge* of the project is the presence of geothermal resource in each demonstration site and its exploitation for direct thermal uses through district heating systems at urban scale. The main focus is dedicated to the Italian demonstration site: detailed description of strategies and measures implemented in Montieri are provided and projects results are discussed and compared to international research findings about the development of strategies for integrated supply and demand management actions at district scale.

2. Geothermal Communities project

GEOCOM project implements sustainable solutions for the exploitation of geothermal energy on a neighbourhood and community scale, combined with renewable energy resources and retrofitting measures for existing buildings. Solutions are implemented on three major pilot sites: the city of Galanta in Slovakia, the town of Morahalom in Hungary and the community of Montieri in Italy. Local existent uses of geothermal resource are implemented with new best practice solutions. In Morahalom a cascade system is designed to fully exploit the return water of the thermal bath at 28°C-35°C to produce heating and domestic hot water for several cultural and administrative facilities in the town centre. The cascade system is fuelled by a heat pump powered by a combined heat and power unit that burns the methane content of the naturally exhaled gas from the geothermal extraction well. In Galanta an existing geothermal cascade system fuelled by water at 90°C is extended to cover heating and domestic hot water demand of recently retrofitted buildings and a new system for re-injection of return water has been studied in order to extend the life span of the geothermal reservoir.

Active solar technologies as well as demand side management measures at building level are implemented on the same urban sites. Project goals for the central district in Morahalom foresaw the implementation of retrofit strategies for the two buildings of Mora Cultural Center, School and Gymnasium and the Nursery to reduce heat demand by 30-35%. Solar thermal and photovoltaic panels were integrated to cover hot water and electricity demand. In Galanta, three residential blocks underwent large retrofitting works to both reduce winter heating demand by 40% and improve building quality. A small photovoltaic array was integrated to cover electricity demand of common lighting appliances. Inefficient windows were substituted on an elementary school and nursery, solar panels were installed as well.

2.1. The Italian demonstration site of Montieri

Montieri is a medieval small historic town located at 700 m a.s.l. on a North-East oriented hillside in the southern part of Tuscany. The geographical area is classified as cold climatic zone with 2500 heating degree-days. The urban structure has not expanded very much over the centuries. Buildings are characterised by local traditional construction systems such as load bearing stone and brick masonry, wooden horizontal floor and roof structures with clay cover units. Windows and external wall finish, together with roofs, are the elements that undergo regular maintenance and repair works therefore are rarely original on buildings. Before the construction of the district-heating network each dwelling had individual heating system with separated electric or gasoil boilers for domestic hot water production. Typical fuels for indoor heating were burning wood, gasoil and methane.

The main objective of the GEOCOM project in Montieri demo-site is the connection of 425 dwellings of the city centre (the whole historic area) to a district-heating network fuelled by geothermal steam available in the territory.

2.2. A brand new geothermal district heating system

The basic idea of the project is the exploitation of a part of the steam extracted from Montieri 4 geothermal well that is unsuitable for electricity production but appropriate for thermal uses. The geothermal district-heating network is made up of the following parts: a first pipeline conveys the steam to the heat exchanger A. This first heat exchanger transfers heat from the steam to a first circuit of super-heated water. This circuit is about 2*2200 m long. It conveys superheated water to the heat exchanger B, located at the edge of the town, where heat is transferred to a second circuit. From heat exchanger B begins the main pipeline that reaches the town centre. Here five branch circuits spread to reach all dwellings of the built up area. The whole second circuit is about 5100 m long. All circuits are sealed to prevent emissions of steam and water leakage in the environment. The network doesn't deplete clean water but re-uses it within each circuit, with a consequent saving of residual energy.

Each dwelling is connected to the network by a heat exchanger unit that provides hot water for indoor heating and sanitary water production.

Inside exchange station A, four heat exchangers (two of 4000 kWp and two of 800 kWp) are installed to transfer heat from steam to water. These two couples of heat exchangers work in parallel: the first couple at 73% of nominal power, the second at 50%. In each couple one heat exchanger is the back-up of the other to guarantee the service in case of malfunctioning. Inside exchange station B, two heat exchangers of 4000 kWp are installed to transfer heat from super heated water to heated water. These heat exchangers work in parallel at 78% of nominal power. One heat exchanger is the back-up of the other, as provided in plant A. Exchanges of heat among fluids and temperature variations are highlighted in table 1.

Water of the first circuit, between heat exchanger A and B, is pumped by a circulation group of 11 kWp made up of 2 pumps + 1R (back up). A similar circulation group of pumps (11 kWp) is placed in heat exchanger B to move water within the second circuit.

The following table highlights the heat exchanges within the two plants, figure 1 reports the scheme of the fluxes from the collection of the system to the delivery of the hot water to the village.

Table 1. Exchanges of heat within the two plants A and B and each distribution circuit

	direction	fluid	Temperature
Heat exchanger A	IN	Steam	150°C
final increase of water temperature:	OUT	Steam	100 °C
50 °C	IN (from B - return circuit)	Water	80 °C
	OUT	Super heated -water	130°C
Heat exchanger B	IN (from 2nd circuit - return)	Water	64.15 °C
final increase of water temperature:			
31°C	OUT	Water	95.19 °C

The geothermal district-heating network is designed to serve 425 units, eight of which are public buildings. The following data summarize the size and the main characteristics of the system. According to design evaluation, the integration of the geothermal district heating leads to important fossil energy and CO_2 savings, as shown in table 2.

Construction works started in November 2012 and were concluded at the end of October 2014.

Table 2. Features of the geothermal district heating

Geothermal district heating - design parameters	
Total heated volume (425 dwellings)	111,354 m^3
Estimated average energy demand	122.18 kWh/m^3y
Total annual energy demand	13,605,212.07 kWh/y
Estimated total power demand (heating)	5451.56 kW
Estimated total power demand (domestic hot water)	712.8 kW
Total power installed	6,164 kW
Fossil energy saved (geothermal steam)	1172.6 TOE/y
CO_2 saved	3,440 ton/y

Being the historic town mainly made up of narrow pedestrian streets, no more than three excavation yards could be made at time to allow access to citizens' homes. The need for deep excavation of street floors was seen as an opportunity for the renovation of obsolete urban infrastructures, such as water-main pipes, sewage system, optical

fibre and electric wire embedding and street re-paving. Dwelling heating systems were connected to the district-heating network through small heat exchangers installed in a niche at the base of each building with access from the public street for maintenance purposes.

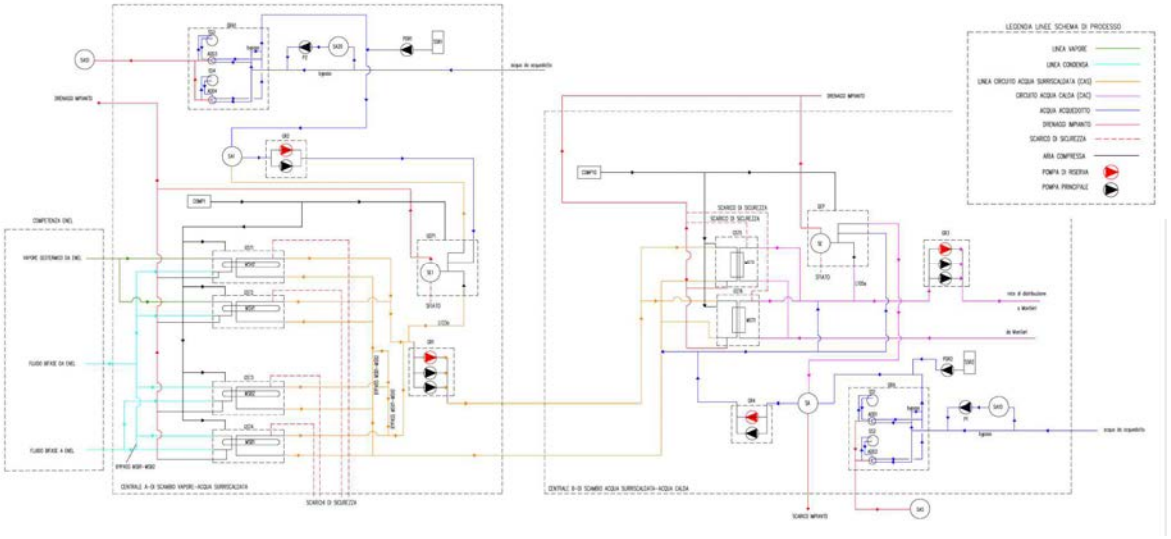

Fig. 1. Diagram of the district heating plant, from left to right: steam inlet from the geothermal well, heat exchanger A and heat exchanger B

In November 2014 about half of the households were connected to the district heating. The metering system was operating for about 70 units, the first data on energy demand for heating and domestic hot water registered by the individual heat exchangers are reported in graph 1. The period of data collection refers to 5 months from December 2014 to April 2015. A very low rate of energy consumption is registered. This is not representative of the efficiency of the system but it is due to the fact that very few dwellings fully exploited the new resource for indoor heating and domestic hot water in the whole period. To study the potential reduction of energy demand, the thermal behaviour of 13 case studies was evaluated by asset rating with steady state method, (UNI/TS 11300 part 1, 2 and 4), Results of the scenarios before and after the connection to the district heating are presented in table 3.

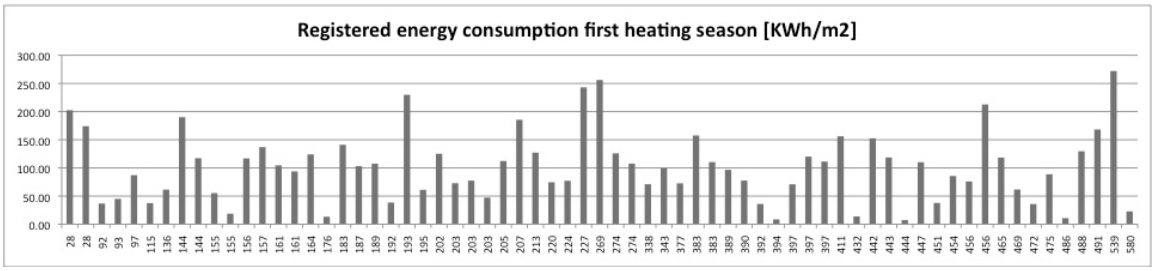

Fig. 2. Registered energy demand of a sample of dwellings connected to the district heating from December 2014 to April 2015

From the results of the evaluation is evident that the connection of units to the district heating averagely reduces the initial energy demand for heating and domestic hot water by about 23%. On the other hand the same measure is able to cut CO2 emissions by about 70%. The CO2 emission rate of the district heating system considers emissions

Table 3 Evaluation of energy demand and CO_2 emissions before and after the connection to the district heating system

Code	Heated floor area	Before district heating system				With district heating	
		Heat source	DHW source	Primary energy consumption [kWh/m²y]	CO_2 [ton Co_2/year]	Primary energy consumption [kWh/m²y]	CO_2 [ton Co_2/year]
273	205.52	wood-gasoil	Electricity	279.3	13.9	213.7	4
263	548.61	gasoil	Electricity	200.6	24.4	148.4	6.8
335	55.8	gasoil	Electricity	521.6	7.3	421.3	6.1
250	82.32	wood	Electricity	423.2	0.9	394.5	0.1
248	96.78	wood-gasoil	Gasoil	354.1	8.4	298.8	2.6
329	467.4	wood-gasoil	Electricity	206.3	23.4	152.2	6.4
380	528.72	wood gasoil	Electricity	196.7	20.6	144.1	6.3
269	95	wood gasoil	Electricity	350	8.1	273.5	2.3
254	83.7	wood gasoil	Electricity	386	7.8	303.8	2.3
350	291.96	gasoil	Gasoil	204	16.2	173.4	4.6
123	200.72	wood-gasoil	Electricity	266.8	13	203.2	3.7
390	319.68	Wood-gasoil	Electricity	217	16.8	161.2	4.6
191	231.66	Wood-gasoil	Electricity	252.8	14.2	191.4	4

produced at the extraction of geothermal steam, while the power demand of the plant is not taken into account because in the area the electricity is produced by the exploitation of the geothermal steam. A rate of 0.09 kg CO_2/kWh produced by geothermal steam is considered. Table 3 highlights the importance of the realisation of the geothermal district heating from environmental point of view, while the reduction of energy demand is not sufficient for reaching relevant saving standards.

2.3. Solar renewable energy technologies

The integration of solar energy technologies was designed to complete the renewable energy supply made by the district heating. A photovoltaic roof-pitch was installed on the building of the heat exchanger A of the geothermal district heating to cover part of the total electricity demand (40kW) of the pumping system. The installed power is 12 kWp, grid connected and controlled by a net metering service. The plant location was chosen not only for exploiting a South-East orientation of the roof pitch but also to avoid PV installations in the small historic town centre, thus to preserving the overall aesthetic character of the place. The integration of solar thermal collectors was enhanced for private touristic and productive facilities such as hotels, restaurants and farms located in areas outside the boundaries of the town centre, where the geothermal district heating cannot reach.

2.4. The strategy for demand side management

The initial objective of the project was to balance the actions on the supply side with an equal effort for the reduction of energy consumption at building level. The initial planning of retrofitting the 20% of the historic built environment led to articulate appropriate retrofit measures to integrate insulation technologies on building envelopes. A guideline document was set up to suggest suitable energy retrofit measures affordable for homeowners and feasible for old building fabrics. Energy efficiency improvements were outlined to meet minimum energy requirements. This would have been further coupled with a total renewable energy supply through the connection to the district heating system. Indeed, the suitability of retrofit measures with old building fabrics, in the respect of the cultural value of buildings, was put as primary requirement. The implementation phase did not end up with the expected outcome, a very small number of intervention was carried out, whose results are negligible for the project success. Citizens perceived retrofit works on buildings as an extra cost over those related to the connection to the network, instead as useful means to reduce heat demand at building level. However, to compensate this weakness, the municipality decided to retrofit a local public school, where important energy saving measures will be coupled with structural interventions. This retrofit work will be done in the upcoming months.

3. Discussion and conclusion

The paper reported the experience of Geothermal Communities project of FP7 CONCERTO initiative, focusing on actions related to the small historic town of Montieri in Italy. The construction of the geothermal district heating represents a milestone in the energy use for the local community. The original scattered and individual supply system is turned into a full renewable system, in which security of supply and remote management of heating and DHW systems are provided and controlled at municipal level.

The main benefit of geothermal resource exploitation is seen as the consistent reduction of the CO_2 emissions in the atmosphere due to the replaced fossil fuels in heating and DHW uses [4] [5] [6]. Despite the initial investment costs, geothermal district heating proves to generate economic benefits for end users in the long run due to the lower cost of the resource [5]. This effect is the main reason of the high acceptability of public investments on geothermal energy from public perception. [7] In the case of Montieri, the scale of the energy transition to a renewable supply system represents a step forward the resilience of the community to climate change and energy shortage, being able to count upon local resources, potentially infinite and totally manageable at local level. The first months of operation of the system already revealed an improved comfort inside dwellings, whereas data registered by the metering system are not representative yet for provide proof of the efficiency of the district heating. The steady state evaluation of the energy performance of buildings, before and after the connection to the system shows an average reduction of about 23%. Data collected in the next heating season, when the metering system will be complete, will provide reliable data on the efficiency of the district heating.

The low level of penetration of the retrofitting strategy on private dwellings of the historic centre is mainly due to its complex energy-economic relation with district heating system. Nevertheless, the increased share of the use of renewable energy sources provides an almost total cut of CO_2 emissions at the community level. This partly compensates the lack of demand side management actions. Recent studies support this hypothesis demonstrating that in presence of large penetration of district heating networks fuelled by renewable energy sources, deep retrofit actions at building level may counteract the efficiency of district systems and become less cost effective due to the lower costs of energy supply. [8] [9] This outcome is relevant for future implementations of energy strategies in historical towns and districts, where deep retrofits on building fabrics are potentially harmful for the preservation of the cultural value of buildings, whereas the integration of renewable district heating network can represent a suitable solution because the visual impact of the intervention, mainly represented by the installation of the individual heat exchanger, can be reduced. Further research is needed to prove the long-term advantages, cost effectiveness and final environmental benefits of this approach.

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