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INTEGRATION OF GEOTHERMAL DISTRICT HEATING, ENERGY EFFICIENCY AND RES IN MONTIERI DEMO-SITE WITHIN GEOTHERMAL COMMUNITIES PROJECT OF CONCERTO EUROPEAN INITIATIVE (FP7)

ABSTRACT

This paper sets out the objectives of Geothermal Communities project for the demo-site of Montieri (Italy). The realisation of the geothermal district-heating network is combined with energy efficiency measures on buildings and the integration of other renewable energy sources within the historic town. Specificity and innovation of geothermal energy use in Montieri are outlined together with the designed retrofit interventions. The adoption of an integrated approach that combines the use of different resources and measures demonstrates to be a priority to preserve the geothermal resource for future generations.

KEY WORDS

Geothermal district heating, building retrofit, system integration, historic town centre

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1. GEOTHERMAL COMMUNITIES PROJECT IN THE ITALIAN DEMO-SITE OF MONTIERI

The Geothermal Communities Project is part of CONCERTO initiative co-funded by the European Commission within the FP7.

GEOCOM project aims at demonstrating the best available technologies in the use of geothermal energy combined with innovative energy efficiency measures and integration of other renewable energy resources in three different pilot sites located in Hungary, Slovakia and Italy respectively.

This paper analyses GEOCOM project in the Italian pilot site of Montieri.

The projects has three main objectives:

The realisation of a highly innovative geothermal district heating system by using high enthalpy fluid

The energy retrofit of selected dwellings among the building estate of Montieri town centre with materials and methods in conformity with their historical value

RES integration: 8.5 kWp of PV panels and 42,5 m^2 of solar collector for sanitary hot water production

A preliminary investigation highlighted the feasibility of a geothermal district heating network, exclusively devoted to the city of Montieri, to be served by the system, with a total heated volume of 110,000 m^3 and a value of energy required estimated around 5,500 kW (20,000 GJ). The GEOCOM project covers the cost of buildings' connection to district heating network and, when necessary, the upgrading of the existent heating system of private homes.

Montieri also represents a challenging site for defining and testing a qualitative architectural integration of retrofitting measures on culturally-valuable buildings where the potential for intervention on building envelope is quite limited. Only materials and methods in conformity with the medieval city structure are considered acceptable. Retrofit solutions are asked to reach an ambitious objective of reduction of current energy demand.

2. GEOTHERMAL DISTRICT HEATING NETWORK

The Montieri pilot site is setting a new, ambitious example of exploitation of medium enthalpy geothermal resources by the help of innovative technological solutions. Challenges include the development of best practice in the use of geothermal resources characterised by high pressure (15–20 bar) and temperature (200–215°C). The solution chosen for the realisation of the district heating system of Montieri, mainly financed by Regional and local funds, is technologically innovative and it is going to be applied in the field of geothermal district heating for the first time.

Due to the need of reducing the temperature of geothermal steam to one feasible for the hot water heat exchangers of building heating systems and to the need of bring the geothermal heat up to a difference in altitude of about 170 m, the geothermal pipeline is subdivided into two main circuits: a primary one to bring superheated water to the altitude of Montieri and a secondary one to distribute hot water within the district heating of the village. Two heat exchanger plants are therefore needed: the first to exchange heat from geothermal steam to superheated water (200°C/120°C), the second to exchange heat from superheated water to hot water (120°C/80–90°C).

Particular care was put in choosing the location of the two thermal exchange plants. The first is being placed near the geothermal well (A on map), at an altitude of 530 m a.s.l. for solving problems related to pumping condensate return. The second is being placed outside the town centre of Montieri (B on map) at 700 m a.s.l. Given the height difference between the two exchangers, to keep in the circuit the superheated water at a pressure of 2 bars is sufficient to pressurise the circuit share of the central exchange, where expansion vessels will be installed (B on fig. 2).

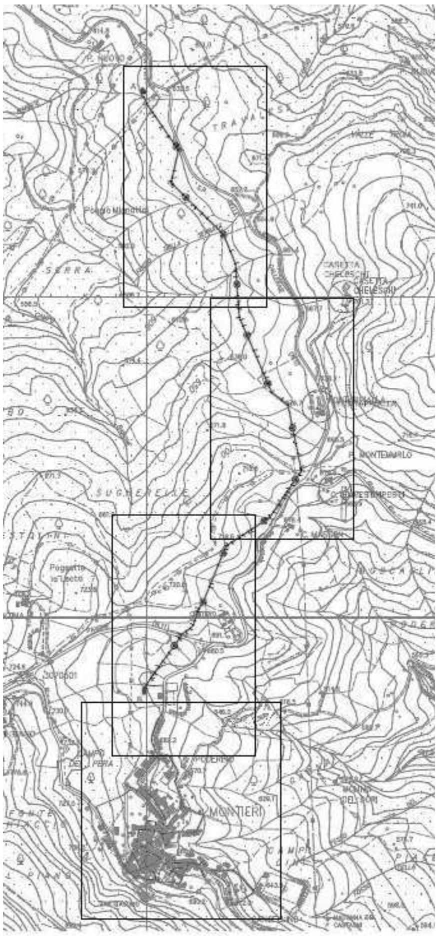

Fig. 1. The development of geothermal heat pipeline form Montieri 4 well (A) and the town (B)

Rys. 1. Przebieg rurociągu geotermlanej sieci ciepłowniczej z otworu Montieri 4 (A) do centrum miasta (B)

Since the installation of a geothermal heating has to limit the thermal peak power on equal energy output, and maintain the network operating conditions as stable as possible, over time, by adopting thermoregulation equipment, the plant is supposed to operate even during the night.

The innovative aspects related to this geothermal district heating network relay mainly in the reuse of heat that remains at the end of the treatment of fluids in both circuits. Within the primary circuit the condensate will be put in the way back of the fluid in order to avoid waste of heat, for the same reason on the secondary circuit the remaining heat from the district heating will integrate the exchange of heat at exchanger plant B (see the map in Image 1). This second recover of heat will be mainly useful in summer when the geothermal plant will be used at lower rate to cover only the sanitary hot water need of the village.

2.1. Heat source management and benefits due to geothermal district heating

The Geothermal district heating system will provide heating and domestic hot water for users in the historic town centre (including 8 public buildings).

Energy analysis of the town shows an energy demand for annual heating season quantified in 13.605.212,07 kWh.

Annually, from the environmental point of view the use of geothermal resource (steam + two-phase) will generate a saving of 1172.6 TEP (tonnes of equivalent oil 1TEP = 11.6 MWh) and a reduction of the CO_2 and NO_x emissions estimated about 3440000 kg and 7660 kg, respectively.

The geothermal district heating system will be fully automated and it will be controlled by a dedicated automatic and remote control, which will include heat flux metering on single heated units.

The control system will manage all main parameters of the whole system, pressure and temperature at set-point. It will operate quickly on the system by alarm management and it will be linked to the ENEL network to improve synergy of system and data exchange. This innovative technical solution for the remote control of whole system will improve management and control of real thermal consumption and benefits of the system in real time.

Fig. 2. Path of the geothermal district heating within the historic town

Rys. 2. Ścieżka geotermalnej sieci ciepłowniczej w historycznym centrum miasta

3. ENERGY RETROFIT OF TOWN CENTRE

The improvement in energy performance of buildings due to geothermal district heating system will be increased by the integration of energy efficiency measures on building envelopes.

A series of technologies were studied to improve the energy efficiency of existent buildings taking into account cultural and historic value of local architecture. The Geothermal Communities projects set a challenging target: to reduce by the 50% the energy performances required by the Italian norm on energy efficiency in 2006 for new building constructions.

4. INTEGRATION OF SOLAR ENERGY SOURCES

Solar renewable energy sources as photovoltaic and solar thermal will be integrated in the system to give a further contribution in the reduction of fossil fuel demand for basic energy needs of the town. Design of these systems starts by the choice of an appropriate location in order to not overlap their function with geothermal district heating (solar thermal for DHW only) and to not ruin the landscape view of the village with invasive integrations on historic buildings.

Photovoltaic plant will consist in 8.5 kWp to be integrated on the roof of Boccheggiano's theatre, a recent building that had already undergone major renovations.

Solar thermal collectors will be installed on the roof of sport facilities of Montieri, with a total area of collectors of about 42.5 m^2, to directly supply sanitary warm water to the showers. This sport facility is located out of the town centre and it is not connected to the geothermal district-heating network. By this choice there will be no visual impact issues and designers will choose best orientation and irradiation for solar thermal system.

5. SYSTEMS INTEGRATION

Montieri is a medieval village that still preserves historical characteristics of traditional architecture.

The town centre is made up of narrow paved streets sided by two/three storey buildings terraced or isolated. Older buildings are made up of stone and brick masonry and wood “coppi” tiles). The openings have external timber shading devices called “finestra alla fiorentina”.

Some very old buildings are recognisable among the urban texture because of stone masonry walls (“filaretto” stonework) and peculiar arches and openings. Local authority for cultural heritage and landscape listed those buildings as symbols of culture and history of Montieri. Some modern buildings filled in the voids of the urban pattern respecting geometrical proportion of existent architecture even by the use of modern technologies. In the historic area a relevant portion of buildings needs to be renovated, in some cases critical decay is visible.

Today constructions of the village of Montieri are fuelled by a variety of fuel types: for residential energy needs these range from firewood (gathered from private sectors of wood that still are owned by the most of local population), to LPG and methane gas network (few dwellings connected), to the use of gas cylinders and fuel gas stoves. According to data collected by the municipality the main part of dwellings use wood burning stoves for heating and LPG and methane gas for cooking, hot water is mainly provided by methane gas or electric boilers. Public buildings instead are connected to both gas and LPG networks. Moreover according to the same data half of the private buildings are vacant or are holiday homes, and for the rest of buildings the combination of fuel use for different needs is hardly uniform.

Due to the variety of fuel used for heating and domestic hot water and due to the vacancy of many flats for the most of months of a year, it was very difficult to do a proper survey of dwellings energy demand at current state before the connection to the geothermal district-heating network. An attempt of estimating current energy needs for residential sector in Montieri is given by the analysis of the urban estate and the definition of selected case studies representative of typical building types.

In the table below (Table 1) are represented the selected case studies chosen for the assessment of present state and retrofit design energy performances of buildings.

Table 1

Selected case studies

Tabela 1

Wybrane studia przypadków

Selected case studies identified by census number		
n. 115 	n.274 	n.269 
n.327 	n.380 	n.350 

The present energy performance of case studies has been calculated by a software for the energy certification of buildings tested by CTI (the Italian Committee for national normalisation of norms on energy use). Some assumptions were made to supply lack of specific information on each building, therefore the results cannot be considered representative of the exact energy consumption of case studies, but they express well the energetic behaviour of local architecture.

Table 2

Assumptions for energy performance calculation

Tabela 2

Założenia obliczeń wydajności energetycznej

Assumptions for energy performance of buildings assessment	
Occupancy	All dwellings are considered fully occupied for the whole year, as well as contiguous buildings
Horizontal structures	To first floor, roof and last ceiling towards unheated space the same structures are repeated in all buildings
Windows	Modular size of openings and single glazing system
Natural ventilation air changes	0,3 air changes/hour
Air changes by infiltration	0,5 air changes/hour
Heating and DHW systems	To each building is attributed a central heating system fuelled by methane gas that provides both heating that DHW, the efficiency of the system is always around $\rho \cong 0{,}7\%$

The energy performance of each case study at current state was estimated as shown in the following table.

Table 3

Heating energy demand of case study buildings

Tabela 3

Zapotrzebowanie na energię do ogrzewania budynków

Case studies identified by census number	Heat losses through the building envelope [kWh/y]	Heating energy demand [kWh/m^{2}y]
115	42 482	361
274	57 415	118
269	30 153	207
327	119 998	340
6 380	16 060	166
350	16 681	181

5.1. Technological solutions

The control of energy demand of the village of Montieri consists in a combination of actions that sums up the benefits due to the connection of buildings to the geothermal district-heating network with specific technical measures to reduce building energy demand.

To improve the energy efficiency of building's envelope heat losses and uncontrolled air infiltration have to be reduced.

The retrofit strategy is based on the concept that on old local architecture just minimal retrofit intervention on the building envelope are suitable due to the small dimensions of indoor rooms, to the large thickness of masonry walls and to restrictive urban norms for the preservation of the town centre. Since old architecture characterises the main part of the building estate, the new energy efficiency standards are set to enhance largely feasible retrofitting actions requiring minimum thicknesses of insulating material of defined thermal conductivity for each key technology. This is possible because the Italian energy norm states that on buildings belonging to city centres or historic nucleus the fulfilment of national standards is not required if the measure affects their cultural value. The amount of funding provided by Geothermal Communities project is tailored on minimum retrofit standards and it is the same for all buildings within the village. In this way the retrofit technologies are suitable for all building types and can be widely adopted by building owners.

The choice of retrofit technologies required a thorough study of local building construction in order to define all the restraints to retrofit interventions.

In older buildings installing thermal insulation on external walls is usually not possible either to preserve the original aesthetic of façades or to not reduce rooms' size with internal insulation. Moreover every kind of internal insulation of walls would reduce the effect of thermal mass of walls on controlling and delaying peaks of outdoor temperature. For these reasons the retrofit of external walls has mainly the aim of protecting the masonry from water and moisture infiltration by laying protective plaster on surfaces.

Instead the insulation of loft space and basement ceiling is recommended where it is technically possible. This measure will reduce the heat losses in winter and the overheating in summer. A natural ventilation of the loft space must be provided to avoid moisture deposit on insulating layer.

The improvement of windows performances can be provided by the substitution of the glazing system when the thickness of the existent timber frame allows it or by the substitution of the whole window. The former solution must be extremely careful to not ruin historic window frame, the latter requires a proper design to not change proportion and appearance of the whole façade. Low emitting double-glazing systems with air or argon filling represent a big improvement of insulating performance of windows. The choice of timber frame is always advisable because of its efficiency and its similarity to original windows.

The list of suitable retrofit technologies, evaluated from efficiency, cost and quality point of view, is published as an attachment of the public call for assigning GEOCOM funding in order to assist local authority and local designers during design process. A catalogue of solutions, integrally estimated on each technological and morphological building type is worked-out, in order to predict the most appropriate technology and configuration for local architecture. The result is a matrix of technologies, components, equipments and materials to be tested in the whole town centre, qualified and quantified in terms of energy benefits, environmental impact reduction, and gas emission control. The key result is a set of exemplar retrofit interventions for the existing building stock of Montieri that are going to be tested by local inhabitants during the future development of the project.

5.2. Simulation of systems integration

On the base of defined retrofitting measures the energy efficiency and the CO_2 savings due to technological upgrade for the proposed case studies are estimated. Results expressed in the next table represent the installation of retrofit technological measures suitable for each building type.

Table 4

Energy and CO_2 savings obtained by the integration of selected key technologies on case studies

Tabela 4

Oszczędności w zużyciu energii i emisji CO_2 uzyskane dzięki integracji kluczowych technologii dla wybranych studiów przypadków

Case studies identified by census number	Key retrofit technologies	Energy savings [kWh/m^{2}y]	Energy savings [%]	CO_2 savings t CO_2/y (due to EE measures, based on CO_2 emissions of natural gas)
115	Connection to geothermal district heating installation of thermal plaster, loft insulation, first floor insulation	165	45%	4
274	Connection to geothermal district heating installation of thermal plaster, loft insulation, windows substitution	42	35%	4
269	Connection to geothermal district heating loft insulation, first floor insulation, substitution of windows	61	29%	2
327	Connection to geothermal district heating loft insulation, first floor insulation, substitution of windows	127	37%	9
380	Connection to geothermal district heating internal insulation of walls, substitution of windows	66	40%	1
350	Connection to geothermal district heating loft insulation, first floor insulation, substitution of windows	55	30%	1

From the analysis of the effects of retrofit actions on cases study buildings can be stated that technological measures tailored for Montieri's architecture are able to reduce consistently the heat losses of the building envelope and the winter energy demand of buildings.

CONCLUSIONS

The Geothermal Communities project in Montieri demo site contributes to the realisation of a geothermal district-heating network that applies innovative solutions for the reduction of waste in the exploitation of geothermal heat. Montieri is one of the last municipalities of Larderello area to start using geothermal resource for domestic heating and hot water production. The experience of Montieri demo-site will be an interesting pilot example for Eastern European countries that also have geothermal resources characterised by high/medium enthalpy.

Beside energy and CO_2 savings due to the exploitation of a geothermal resource characterised by a good efficiency in extraction and distribution process, the connection of dwellings of town centre to the district heating network will solve the problem of "heating security" that nowadays affects the inhabited dwellings heated by more discontinuous systems. Thus, improvement of comfort level of dwellings is expected as one of the results of GEOCOM project. Hopefully this would lead to an increased liveability of the village with consequences in economic and social system too.

The exploitation of geothermal energy resource for heating and domestic hot water must be integrated with actions aimed at reducing building energy demand in order to preserve geothermal resource for future generations. Thus the efforts for studying feasible energy retrofit interventions on buildings characterised by cultural value. The proposed case studies represent possible improvement of energy performance of building envelopes obtained by the adoption of tailored retrofit technologies according to the architectural characteristics of chosen buildings. Reductions of energy demand span from 30% to 45% and reduction of CO_2 emissions from 1 to 9 ton/year. Even if compared to other retrofit actions realised on non-listed buildings these results would be considered not satisfactory, for buildings belonging to a historic town centre they represent a good target, taking into account all limitations to technical intervention due to the high value of building fabrics.

The choice of locating solar systems as photovoltaic and solar thermal collectors far from the historic town is mainly due to landscape protection choices and to serve common facilities otherwise excluded from the project's benefits. A further proposed solution for the integration of PV system with the geothermal district heating network is to place PV modules on buildings dedicated to heat exchange stations of the geothermal pipeline in order to partially cover power demand of electric appliances.

The project sets the objective of connecting 425 dwellings to the geothermal district heating network and to complete the energy retrofit of at least a 20% of buildings of the town centre: this would lead to a overall reduction of global energy demand for heating and domestic hot water of about 20% of current demand according to simulation made for the whole village.

The realisation of Geothermal Communities project's objectives in Montieri demo-site will reduce the overall environmental impact of the historic town due to the energy demand and will also improve the economic and social liveliness of the village with the expected consequence of strengthening the relationship between population and territory.

The article was prepared Geothermal Communities – demonstrating the cascading use of geothermal energy for district heating with small scale RES integration and retrofitting measures", 7th Framework Programme, IEE, kontrakt nr: TREN/FP7EN/239515/"GEOCOM).

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INTEGRACJA GEOTERMALNEGO CIEPŁA SIECIOWEGO, EFEKTYWNOŚCI ENERGETYCZNEJ I ODNAWIALNYCH ŹRÓDEŁ ENERGII W MIEŚCIE PILOTOWYM MONTIERI W RAMACH PROJEKTU „SPOŁECZNOŚCI GEOTERMALNE" (GEOCOM) FINANSOWANEGO W RAMACH 7 PROGRAMU RAMOWEGO (UE)

STRESZCZENIE

W ramach projektu Społeczności Geotermalne (GEOCOM) we włoskim mieście Montieri realizowany jest innowacyjny system geotermalnej sieci ciepłowniczej wraz z integracją z innymi OZE połączony z modernizacją budynków przy równoczesnym zachowaniu średniowiecznej struktury miasta. Takie innowacyjne połączenie w systemie ciepłowniczym różnych OZE, wykorzystanie ich zasobów ma na celu przede wszystkim ochronę zasobów geotermalnych dla przyszłych pokoleń.

SŁOWA KLUCZOWE

Geotermalne ciepło sieciowe, modernizacja budynków, integracja systemu, historyczne centrum miasta