A model proposal for evaluating thermal demand of industrial process to be supplied by low geothermal enthalpy

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ABSTRACT

The aim of the research is to provide an interdisciplinary approach, on the basis of geological, technological, energy demand and economical aspects, to optimize the exploitation of geothermal resources for thermal use in industrial processes. Therefore, a conceptual model (Mo.nalis.a) that identifies the most suitable geothermal technology to satisfy the thermal industrial demands in four regions, located in south of Italy, has been proposed. This is based on the interaction and integration of different actions able to associate industrial thermal energy request with the local shallow/deeper geothermal resources. These ones were mapped by a methodological approach able to synthesize the geological, hydrogeological and thermodynamic properties influencing the geo-exchange potential of the subsoil. The comparison between the obtained thematic (potential) maps and the possible final users distribution provides an overview of the possible development of the geothermal solution in the investigated area. The Mo.nalis.a model should be used as a tool to define the distribution of heat demands in the reference territory and to find the most suitable local geothermal resource to satisfy the industrial thermal needs.

1. INTRODUCTION

Currently, almost 50% of the total energy consumed in Europe is used for the generation of heat for either domestic or industrial purposes. A thorough investigation, based on data for the year 2006, identified the different ways in which heat is used in EU 27, putting in evidence that the mayor heat demands, about 70% of the global heat market, come from low temperatures demands (Weiss and Biermayr 2009; www.estif.org). The mayor sectors of low heat energy consumption are: industry, services, transport and households with a thermal request up 100 °C generally. Many potential thermal industrial processes can be supplied by the low enthalpy geothermal source. However, in Italy the geothermal sector is technologically behind with respect to other renewable resources due to the lack of a comprehensive policy and regulatory frameworks at regional and national level. This is partly related to the unawareness of: 1) the best exploitation systems for optimum development of low enthalpy; 2) economic planning (Goumas et al. 1999). An analysis revealed that the uncertainty of various input variables influences critically the choice of geothermal technology: temperature, depth, distance user/resource, lowest annual temperature value, system size (Houldsworth and McDevitt, 1982).

Part of these issues have been considered in the frame of the VIGOR Project (www.vigor-geotermia.it), aimed at assessing the geothermal potential of the four Convergenza Regions in southern Italy (Fig. 1). Mo.analis.a energetic analysis model is capable to identify the thermal industrial demands at regional level and match it with the most suitable local geothermal sources.

Figure 1: The “Convergenza Regions” on southern Italy.

Mo.analis.a should be a support for the political regional government to prepare and deliver an effective Environmental Energy Regional Plan (P.E.A.R) to facilitate the process of promoting the use of heat coming from the ground, as well as any local policy support for Heating&Cooling renewable technologies. The geothermal energy potential, especially the low-medium enthalpy resources for the direct heat use, is poorly known, and a clear methodology for energy analysis of supply and demand on an industrial level doesn't exist. The proposed method should be retained in response to particular situations of different geographical context.

2. CONCEPTUAL MODEL PURPOSE

Mo.nalis.a is based on the interaction and integration of different actions / methods in order to obtain the regional maps of thermal needs and to elaborate the "Error map" to achieve the depht satisfying the energy needs of a territory (Fig. 2).

Three categories of input data have been used in the Mo.nalis.a: 1) Data users: known within a reasonable degree of accuracy, the number of local units and process temperatures; 2) Data planning: estimated by technical sizing; 3) Data resource: introduced in the model as values of different algorithms by laboratory test and measures in situ.

2.1 Data users

The fist step begins by identifying three ranges of temperature (20-40 °C; 40-80 °C; 80-120 °C) related to the main chosen direct uses.

Then, the regional background and the main area features, such as history, traditions, and economic and industrial development in the recent years have been considered. The results of this initial investigation provided a list of industrial processes, which in Italy are classified by ATECO codes, which were filtered off the industrial activities not eligible for renewable resources funding by the European Economic Community Council as on Article 1, N. 7/bis of 18/12/1959 (National Gazette, 1961). Starting from these processes, the statistical "weight" of each process at provincial and regional level has been made. In particular, the research has been carried out using a series of keywords related to the product or service of a particular process and repeating this action for all provinces of each region. After a statistical analysis, the results have been processed through ArcMap 9.3 (ESRI), obtaining a distribution of all local units.

A weighted average has been achieved, considering for each individual process the various percentages of the local units with the corresponding temperature value. To distinguish the processes according to the heat demand for each region, the "Energy Needs" maps have been produced for each temperature range related to the various chosen processes of low-medium-high temperature for each territory. The elaborated maps allow to evaluate the thermal requirements for the different production processes in the regions.

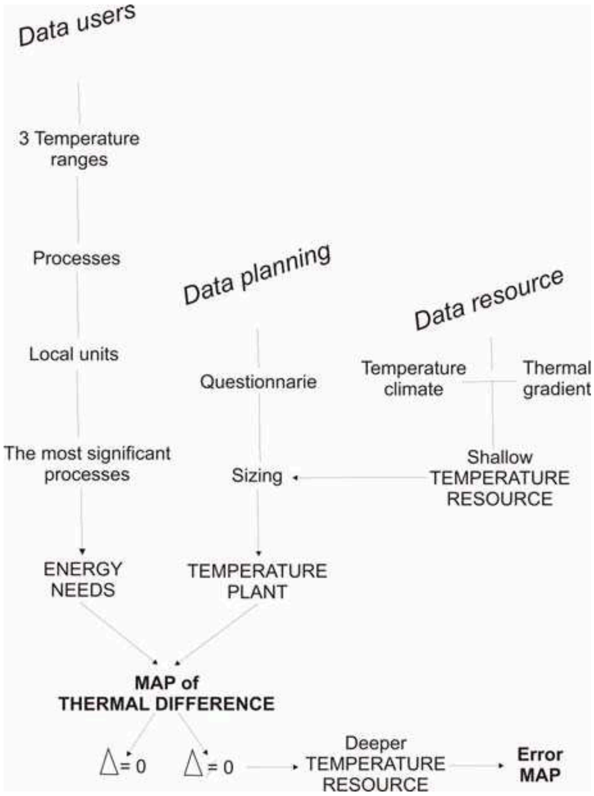

Figure 2: Conceptual model of the Mo.nalis.a method.

2.2 Data planning

Starting from the typical temperatures production processes in the four regions, some types of plants have been identified for multiple processes and/or multiple areas of interest. To obtain further information, some specific "interviews" have been achieved in some areas chosen in the four regions, after the identification of the most interesting companies. On the basis of the selected plants, it is worth to note that an increase of geothermal fluid temperature corresponds to a large versatility to satisfy different production processes. In this regard, the table 1 shows some of major industrial and/or agricultural activities present in the Convergenza Regions. The process temperature ranges have been associated to each process, as well as the corresponding geothermal technology for their application.

Table 1: Processes and thermal needs.

Processes	*T (°C)*
Distilling, rectifying and blending of spirits	80 - 100
Tanning and dressing of leather and fur	20 - 40
Paper and paperboard manufacture	120 - 140
Manufacture of plastic packing	60 - 140
Pasta and flour production	120 - 140

Soaps and detergents manufacture	80 - 120
Production of biscuits, cookies, etc.; production of confectionery	0 - 60
Production of fresh pastries	0 - 10
Brick manufacturing	120 - 140
Swimming pools management	20 - 40
Wastewater treatment - Sludge digestion	60 - 140
Wine preparation	10 - 30
Desalination	60 - 140
Manufactures of diodes, transistors, etc.	0 - 10
Concrete, plaster, cement manufacture	100 - 120

2.3 Data resource

The plant dimensioning has been managed on the base of the local geothermal shallow resource. To prepare an evolution map of this parameter, a bibliographic research aimed at the recovery of all wells data (up to 150 meters) and existing sources in the four regions has been conducted. In fact, this is only representative of the water surface temperature. Following the Fourier's Law, the ground temperature map at 50 m depth has been derived from different types of maps, as average annual air temperature and thermal conductivity and heat flux map (Galgaro et al., 2012). So, the map of distribution of "Shallow geothermal temperature" was compared to the "Temperature request of plants" map.

A comparison (Fig. 3) between the geothermal resource (T_0) temperature and the temperature required by the processes (T_i) has been made. The resulting temperature difference (Δ) can be referred to two situations, which define different technological approaches:

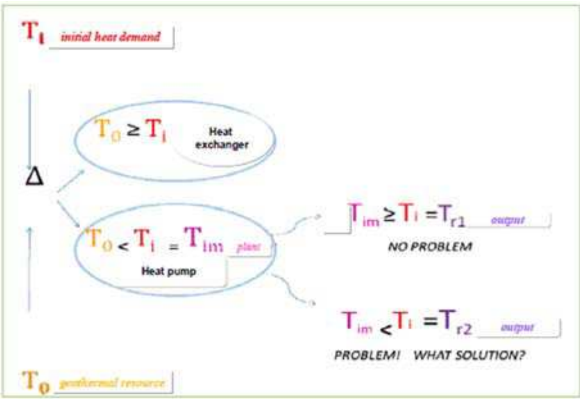

Figure 3: Relationships between heat demand, resource and plant temperatures.

1) If the resource temperature (T_0) is equal to or greater than the one required by the process (T_i) a traditional heat exchanger is enough;

2) If the required temperature (T_i) is less than the initial resource temperature (T_0) it is necessary to supply additional heat by heat pumps.

In this second case, the heat pump meets the energy demands only if the plant Temperature (T_{im}) is greater (or equal) than the initial heat demand (T_i), otherwise it is necessary to suggest another additional heat resource to meet the industrial requirements. The areas where the initial needs (T_i) are fully met by reaching of restitution temperatures plant (T_r) are then mapped to highlight the provinces where this condition is or is not verified. Areas requesting a system integration may use a different renewable energy sources to fill the difference in rerquired temperature, or intercept the geothermal fluid at greater depths.

To fulfill the energy demand of medium-high temperature processes, the deep temperature field has therefore to be evaluated. The temperature distribution at selected depths (i.e. 500 and 1000 m b.g.l.) are computed by thermal modelling, based on evaluating an extensive database of raw geophysical and geological information from deep hydrocarbon exploratory wells released by drilling companies. To obtain an accurate 3D geological representation of the buried geometries, an approach based on surface and subsurface data integration with the interpretation of geophysical survey and lithological logs is applied. Since the boreholes are not homogeneously distributed on the territory, to map the geothermal gradients a geostatistical interpolation method (kriging) has been applied. Then the computed temperatures at selected depths can be extracted from the model, pleasing the energy needs of industrial processes.

3. DISCUSSION

The goal of this model is examine the current energy consumption of some direct uses and explore possibilities for geothermal energy in four regions of Italy. This should provide insight in the heating demand of some industrial sector in these regions and the role geothermal energy could play in the preservation of the heating supply (Alfrink, 2011).

For economic and technical reasons, in the Mo.nalis.a analysis energy the chosen processes include different sectors: washing, boiling, heating, distilling, drying, various chemical process, etc. requiring temperature ranging from 0 to 140 °C. Mo.nalis.a is based on the geothermal resource data and thematic maps of thermal needs that could be met, through the sizing planning.

In some areas, the model shows that the shallow geothermal resource is not sufficient to meet the thermal needs by heat pumps and exchangers. In these cases deep resources are necessary ,and an estimate of depth at which the temperature request can be satisfied is provided. This latter information is, however, only an rough estimate, and further analyse are necessary in order to define the thermal and hydraulic conditions at depth. Only by detailed exploration the planning and designing of the energy projects and the related economic analysis can be completed. By Mo.nalis.a approach, however, we may have a quick view of places having good possibility, and that deserve further investigation.

4. CONCLUSIONS

The objective of this research is to promote the use of geothermal resources and improve the role of geothermal energy among renewable sources. To this aim, it is important to consider the thermal needs of industrial uses and sizing geothermal plants able to satisfy the request, therefore contributing to energy efficiency and greenhouse emissions reduction. To meet the industrial thermal needs, the low-to medium enthalpy geothermal energy is suitable, as proved by the many forms of utilization of geothermal energy in the world (e.g., Dickson and Fanelli, 2003).

In the frame of the VIGOR project, Mo.nalis.a, a new model of energy analysis, was implemented to estimate the thermal needs of some industrial sectors sizing the most appropriate plants using low geothermal energy. This method provides an evaluation of the geothermal supply merely on the base of the thermal industrial request, the temperature source and access depth, and supplements this information by means of maps. Where the underground temperature at 0-150 m is too low to provide the required temperature, the model extracts the estimated depth at which the needed temperature can be found.

This model aims to be a innovative planning tool by integrating the participation of companies in the regional/provincial energy analysis, providing a valid support to stakeholders and planners for better developing the future energy plans, also as a function of the geothermal answer to thermal needs.

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