

ENGINE- *Geothermal Lighthouse Projects in Europe*

Information gathered during the ENGINE co-ordination action (ENhanced Geothermal Innovative Network for Europe)

<http://engine.brgm.fr/>

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Project Name:

Project Institute/Company Leader: ENEL, Italy

Contact Person:

Web-site: http://enelgreenpower.enel.it/en/green_tour/larderello.html

Country: Italy

Location: Southern Tuscany

Type(s) of resource [High/Low Enthalpy / EGS]: High Entalpy

Main on-site operators: Drilling, Monitoring, Power plants

Number of wells [w. Total Depth pr. well]: 202 (180 in Larderello + 22 in Travale/Radicondoli; 11 deep wells of 3000-4000 m are programmed for 2003-2007)

Type of wells [Exploration, Production, Injection]: Exploration, Production, Injection

Well configuration [Single well, Doublet, Triplet]: All types

Distance between well at Depth [Horiz. Dist at Depth]: variable (in general <500 m)

Temperature at total depth: 300-350°C (deep reservoir)

Combination with other energy sources [Gas, Waste, Biomass etc.]:

Potential of the geothermal resource [TJ/yr at Date]: 1680 GW_{yr} as a *resource* for electrical production (temperature > 130°C) and 4640 GW_{yr} as a total *resource* (T> 60°C); 550 GW_{yr} as a *reserve* for electrical production and 1940 GWh as a total *reserve* (in Central and Southern Tuscany; Cataldi et al., 1978)

Average flow rate [kg/s at Date (if expected)]: 850 kg/s at Larderello; 300 kg/s at Travale/Radicondoli

Main production [Heat or Power]: Power (Heat as secondary)

Installed/Expected capacity [MWe or MWt at Date (if expected)]: 722 MWe (562 Larderello + 160 Travale/Radicondoli, until December 2005)

Running/Expected capacity [MW/time at Date (if expected)]: 583 MW

Co-generated production [Heat or Power]: Heat

Installed/Expected capacity [MWe or MWt at Date (if expected)]: 36.3 Gcal/h

Running/Expected capacity [MW/time at Date (if expected)]:

Short description of *Exploration History* (Limit this section; no more than 200 words):

Possible keywords (non-exhaustive list):

- Objective of project
- Important dates

In 2004 the celebration of the centenary of the first experiment carried out at Larderello in 1904 took place. After the first pioneer age, the first industrial power plant (250 kW) was put into operation in 1913 in the same area; and geothermal power production has since increased continuously up to the present value of 722 MW installed capacity. Electricity generation reached the historical maximum of 5340 GWh in 2003. Ten new power plants (254 MW installed capacity) have been commissioned and placed on-line in the last five years, both for replacing old and obsolete units and as new capacity due to the extension of the explored area at depth beneath the old shallow fields.

- Main geological context [stratigraphy, sedimentary formations, volcanism, granite intrusions, faults, graben etc.]

The geothermal areas are geologically characterized by late-to-post-orogenic basins filled with Neogene, continental to marine sediments and separated by ridges where the Oligocene-Middle Miocene Apenninic tectonic pile of nappes crops out. The tectonic pile includes the Tuscan Complex where the shallow reservoir is located in cataclastic levels of carbonate and evaporitic rocks of Mesozoic age. The deeper reservoir is situated within Palaeozoic metamorphic units, intruded by Pliocene to Quaternary granites.

- Expected CO₂ emission saving
- Project funding [state, communities, private etc.]
- Distribution network

Reservoir Characteristics (Limit this section; no more than 200 words):

Possible keywords (non-exhaustive list):

- Type of reservoir [fractured, porous or both]
- Hosted lithology/rock/mineralogy/fluids [composition]
- Fracture system
- Stress field
- Temperature range or temperature profile
- Main reservoir characteristics [porosity, (natural) permeability etc.]
- Occurrence of natural brines
- Stimulation types [hydraulic, thermal, chemical]
- Wells characteristics [injectivity, productivity etc.]
- Connectivity between wells
- Storage capacity

A shallow steam dominated reservoir is hosted at depths of 500-1500 m in the carbonate Tuscan Nappe Units and evaporitic Tectonic Wedges formations. This reservoir is characterised by medium-high permeability, temperature of about 270°C and reservoir pressure of 6 MPa. Approaching the sedimentary basins, these same lithologic units host the reservoir at variable depth (1000-2500 m) and are usually referred as "Horst" and "Graben" reservoirs.

Larderello and Travale/Radicondoli are two adjacent parts of the same deep field, covering a huge areal extension of approximately 400 km². This deep reservoir is hosted in the metamorphic rocks of the basement and thermometamorphic rocks located to a depth of approximately 4000 m. It shows highly anisotropic permeability distribution given by fractures and has the same temperature (300-350°C) and pressure (7 MPa) everywhere.

Exploitation (Limit this section; no more than 200 words):

Possible keywords (non-exhaustive list):

- Type of exploitation/power plant [direct, binary or combined cycle] direct
- Type of binary cycle [ORC, Kalina cycle etc.]
- Nature of working fluid Superheated steam
- Cooling system [water, air] ???
- Injection fluid [water, salty water etc.] condensed water
- Annual production [GWh_e or GWh_t at Date (if expected)] 5 340 GWh_e in 2003

- Seasonal production
- Capacity factor (%)???

- Need for special tools [pumps, turbine etc.] ???
- Development/improvement of methods (chemical fracturing, new tracers, seismic etc..) 3D seismic
- Monitoring and optimising of field/area using computer models yes (THOUGH2)
- Assessment of environmental impact yes

On-going or future works planes (Limit this section; no more than 200 words):

Possible keywords (non-exhaustive list):

- Next important event [major hydraulic test, new geophysical measurements etc.]
- Future plans? e.g.:
 - o New wells
 - o Optimizing of existing or building new power plants..
 - o Implementation of new tools..
 - o Implementation of new methods..
 - o New exploration phase..

Ten new power plants (254 MW installed capacity) were commissioned and placed on-line in 2000-2005, both for replacing old and obsolete units and as new capacity due to the extension of the explored area at depth beneath the old shallow fields. An additional new deep exploration programme during 2003-2007 has been launched with a 3D seismic survey and 11 deep wells (3 000-4 000 m). A total of 21 wells have been drilled during 2000-2005 for a total of 64 km.

ENGINE partners involved in the Project:

- Use list of partners from ENGINE Web-site <http://engine.brgm.fr/partners.asp>

IGG, Italia

Main References (no more than 5 references):

Bertani, R. “World Geothermal Generation 2001-2005: State of the Art”. Proceedings World Geothermal Congress 2005, Antalya, Turkey, 24-29 April 2005.

Bertini, G., Casini, M., Gianelli, G. and Pandeli, E. “Geological structure of a long-living geothermal system, Larderello, Italy”. Terra Nova, v. 18, pp. 163-169. 2006.

Cataldi, R., Lazzarotto, A., Muffler, P., Squarci, P. and Stefani, G. “Assessment of Geothermal Potential of Central and Southern Tuscany”. Geothermics, v. 7, pp. 91-131. 1978.

Manzella, A., Gianelli, G., Manetti, P., Ruggieri, G., Bellani, S., Giolito, C. and Mayorga, C. “TRAVALE TEST SITE (Italy) The electrical resistivity variation in crystalline rocks hosting a geothermal system”. Internal report for I-GET project. 2006.



Figure 1