Can the Hydrocarbons Industry be a Strong Driver to the Growth of the Geothermal Energy Sector?*

Claudio Alimonti¹, Elena Sodlo¹, and Davide Scrocca²

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Abstract

Global changes urge a radical transformation and improvement of the energy producing systems to meet the decarbonisation targets of the European economy by 2050 and a reduction of greenhouse gas emissions. In this context, a key point for the geothermal sector is the need to reduce uncertainties on profitability and to design sustainable solutions for large-scale development out of the conventional assets. The large knowledge accumulated in the oil and gas industry should be highly profitable to the understanding of the possible ways of growth in the relatively young geothermal industry. Since ’90, American and Chinese oil companies have studied the possibility of co-producing geothermal energy from oil and gas wells. Those projects were the first trials in making cross-over knowledge between the two energy sectors. Today a key issue in the oil industry is the management of produced waters. In fact, the oil and gas production in its mature stage is often associated to a large amount of brines or formation waters which must be treated continuously. Since these formation waters could not be released to the environment they are reinjected in the subsurface. The analogies with the doublet geothermal plant are clear. A possible way to accelerate the implementation of complementary geothermal- hydrocarbon production opportunities is to proceed to an evaluation of the available thermal potential ready to use. The selection of the final utilization and the potential of geothermal production depends on the temperature, pressure, and flow rate of water, which are function of local geothermal gradient, well depth, and poro-perm properties of the reservoir rocks. Therefore, well information available in the databases of the oil and gas industries can give a real idea of the potential successful projects. The oil and gas fields in the Italian territory are
distributed in thrust belt, foredeep basin, and foreland geological settings. Hydrocarbon occurrences are related to at least five major petroleum systems which are associated to both carbonate and siliciclastic reservoir rocks ranging in age from Triassic to Paleogene and from Oligocene to Pleistocene, respectively. At the end of 2017, the total number of productive wells on the Italian territory was 1594, 881 wells are onshore and 771 are offshore. The possibility of a synergic integration of geothermal energy in these oil and gas fields represents a chance for Italy to increase the share of renewable energy production and to reduce the waste heat. Furthermore, the conversion of hydrocarbons fields into geothermal ones may be an opportunity to create a positive social response in the area where the oil and gas wells are located. The use of existing wells is a benefit for the oil companies, which avoid the cost of mining closure of the wells and for the geothermal companies, which avoid the cost of drilling new wells. A major obstacle is constituted by the administrative procedures to achieve a transfer from a hydrocarbon license to a geothermal one.
Can the hydrocarbons industry be a strong driver to the grow of the geothermal energy sector?

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Global changes urge a radical transformation and improvement of the energy producing systems to meet the decarbonisation targets of the European economy by 2050 and a reduction of greenhouse gas emissions.

<table>
<thead>
<tr>
<th></th>
<th>Greenhouse emissions</th>
<th>Energy from renewables</th>
<th>Energy efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Europe 2020</td>
<td>-20%</td>
<td>20%</td>
<td>+ 20%</td>
</tr>
<tr>
<td>Europe 2030</td>
<td>-40%</td>
<td>27%</td>
<td>+ 27%</td>
</tr>
<tr>
<td>Europe 2050</td>
<td>-80-95%</td>
<td>75%</td>
<td>+ 41%</td>
</tr>
</tbody>
</table>

Current heating and cooling system is a major contributor to EU’s greenhouse gas emissions.

- 47% of the final energy consumption in the EU is due to heating and cooling (domestic & industrial)
- 81% of heating produced through the combustion of fossil fuels while cooling predominantly produced from electricity-driven processes (today largely generated burning coal and gas).

Geothermal energy can significantly contribute to the diffusion of low carbon technologies for the generation of electricity, heating and cooling
In this context, a key point for the geothermal sector is the need to reduce uncertainties on profitability and to design sustainable solution for large-scale development out of the conventional assets as well as to be deployed more rapidly.

The possibility of a crossover from oil & gas to geothermal energy production represents a chance for Italy to increase the share of renewable energy production and to reduce the waste heat.

At the end of 2017, the total number of productive oil & gas wells on the Italian territory was 1594 (881 wells onshore and 771 offshore).
Today a key issue in the oil industry is the management of produced waters. In fact, the oil and gas production in its mature stage is often associated to a large amount of brines or formation waters which must be treated continuously.

Since these formation waters could not be released to the environment they are often reinjected in the subsurface. The analogies with the doublet geothermal plant are clear.

A possible way to accelerate the implementation of complementary geothermal-hydrocarbon production opportunities is to proceed to an evaluation of the available thermal potential ready to use.

The final utilization and the potential of geothermal production depends on the temperature, pressure and flow rate of water, which are function of local geothermal gradient, well depth, and poro-perm properties of the reservoir rocks.
Hydrocarbon occurrences in Italy are related to at least 5 major petroleum systems, which are associated to both carbonate and siliciclastic reservoir rocks ranging in age from Triassic to Paleogene and from Oligocene to Pleistocene, respectively, distributed in thrust belt, foredeep basin, and foreland geological settings.

Three mainly oil-prone petroleum systems
Mid Triassic, Late Triassic-Early Jurassic and Mid Cretaceous

Two gas-prone systems
Plio-Pleistocene foredeep basins (Biogenic)
Late Eocene-Miocene foredeep basins (Thermogenic)
Discovered in 1984. At the end of 2000 produced 188 Mbo of 43° API oil and more than 2000 MSTm3 of gas.

Two reservoirs made up by dolomitized shelf carbonates producing from fracture network: upper reservoir Upper Triassic-Lower Liassic units (5700 m deep), lower one Anisian (6300 m deep).

Two source rock characterised by Type II kerogen: Besano Shales (Anisian/Ladinian) and Meride Limestone (Ladinian).

Seal: marly and volcanoclastic units.

Trap: thrust-related folds.

Charge: main hydrocarbon expulsion phase during the Plio-Pleistocene burial after the Oligocene-Messinan trap formation.
**VILLAFORTUNA-TRECATE: RESERVOIRS & SOURCES**

### Upper Reservoir

<table>
<thead>
<tr>
<th>Formation</th>
<th>Porosity</th>
<th>Permeability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conchodon Dolomite</td>
<td>Mean value = 3.2%</td>
<td>Mean value = 27 mD</td>
</tr>
<tr>
<td>Subtidal to peritidal facies, coarse grained dolomite. Multiphase deep burial dolomitization and diagenesis. Intercrystalline, vuggy and moldic porosity and dissolution enlarged fractures.</td>
<td>Max. Values = 12%</td>
<td>Max. Values = 1000 mD</td>
</tr>
<tr>
<td></td>
<td>Min. Values = 1%</td>
<td>Min. Values = 0.01 mD</td>
</tr>
<tr>
<td>Campo dei Fiori Formation</td>
<td>Limestone Porosity</td>
<td>Limestone Permeability</td>
</tr>
<tr>
<td>Limestone Unit - Lagoon to shoal facies in shallowward upward cycles. Fresh water dissolution below the soil. Moldic porosity and dissolution vugs.</td>
<td>Mean value = 3.2%</td>
<td>Mean value = 0.9 mD</td>
</tr>
<tr>
<td>Dolomite Unit - Subtidal facies, coarse grained dolomite. Burial dolomitization. Intercrystalline and vuggy porosity.</td>
<td>Max. Values = 11%</td>
<td>Max. Values = 10 mD</td>
</tr>
<tr>
<td>Dolomia Principale</td>
<td>Porosity</td>
<td>Permeability</td>
</tr>
<tr>
<td>Subtidal to peritidal facies, fine grained dolomite. Early diageneric to shallow burial dolomitization. Vuggy porosity and dissolution enlarged fractures.</td>
<td>Mean value = 2.7%</td>
<td>Mean value = 4.1 mD</td>
</tr>
<tr>
<td></td>
<td>Max. Values = 8%</td>
<td>Max. Values = 100 mD</td>
</tr>
<tr>
<td></td>
<td>Min. Values = 0.5%</td>
<td>Min. Values = 0.01 mD</td>
</tr>
</tbody>
</table>

### Source Rocks

- **Meride Limestone**
  - Thin bedded, dark grey limestone with marly and shaly laminae.
  - At the base a volcanoclastic unit, few tens of meters thick, is present.
  - Kerogen type II
  - HI 500-550 mg HC/g T.O.C.
  - T.O.C. 0.6 %
  - PP mean value 3 Kg HC/t rock

- **Besano Shales**
  - Thin bedded, dark grey laminated dolostones with intercalations of organic rich black shale laminae. The dolomite is fine grained.
  - Chert nodules and pelagic bivalve accumulations are present.
  - Kerogen type II
  - HI 500-550 mg HC/g T.O.C.

- **Black Shales**
  - T.O.C. 26 %
  - PP 150 Kg HC/t rock

- **Formation Mean Values**
  - T.O.C. 4%
  - PP 21 Kg HC/t rock

### Lower Reservoir

- **Monte San Giorgio Dolomite**
  - Subtidal lagoon to peritidal facies, fine to medium grained dolomite.
  - Shallow burial dolomitization.
  - Vuggy porosity and fractures.
  - Porosity
    - Mean value = 3%
    - Max. Values = 7.3%
    - Min. Values = 0.9%
  - Permeability
    - Mean value = 4.1 mD
    - Max. Values = 8.5 mD
    - Min. Values = 0.01 mD

Note: the petrophysical data of the reservoir Formations belongs to continuous coring of a Trecate well. The geochimical data of the source rock Formations come from outcrop series.

Fantoni et al. (2002)
<table>
<thead>
<tr>
<th>Well Name</th>
<th>Depth (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TRECATE 019 X</td>
<td>6330</td>
</tr>
<tr>
<td>CASCINA CARDANA 001 DIR A</td>
<td>6113</td>
</tr>
<tr>
<td>TRECATE 005 DIR A</td>
<td>5807</td>
</tr>
<tr>
<td>TRECATE 008</td>
<td>6250</td>
</tr>
<tr>
<td>TRECATE 020 OR A</td>
<td>5430</td>
</tr>
<tr>
<td>TRECATE 027 DIR A</td>
<td>6078</td>
</tr>
<tr>
<td>VILLAFORTUNA 001 BIS</td>
<td></td>
</tr>
<tr>
<td>VILLAFORTUNA 011 DIR A</td>
<td>5670</td>
</tr>
<tr>
<td>TRECATE A (injection)</td>
<td>2502</td>
</tr>
<tr>
<td>TRECATE B (injection)</td>
<td>2061</td>
</tr>
<tr>
<td>TRECATE C (injection)</td>
<td>2030</td>
</tr>
<tr>
<td>TRECATE 004 DIR (monitor.)</td>
<td>6282</td>
</tr>
</tbody>
</table>
VILLAFORTUNA-TRECATE DISTRICT HEATING

Production well: 3
Injection well: 1
Flowrate: 100 m³/h
Wellhead temp. 130 °C
Thermal power 21 MW

Heat exchanger section
130 °C → 60 °C → 90 °C → 70 °C

| Specific thermal power | 20 W/m³ |
| Heated volume          | 1.046.500 m³ |
| Equivalent inhabitants | 10.465 |
| Population covered    | 67% |

| Specific yearly heat demand | 40 kWh/m³ |
| Annual energy demand       | 41.8 MWh |
| Avoided emissions          | 8.400 t CO₂eq |

Galliate (15700 ab.)
VILLAFORTUNA-TRECATE DISTRICT HEATING

Production well: 2
Injection well: 1
Flowrate: 100 m³/h
Wellhead temp. 130 °C

Thermal power 14 MW

<table>
<thead>
<tr>
<th>Specific thermal power</th>
<th>20 W/m³</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heated volume</td>
<td>700,000 m³</td>
</tr>
<tr>
<td>Equivalent inhabitants</td>
<td>6,900</td>
</tr>
<tr>
<td>Population covered</td>
<td>125%</td>
</tr>
</tbody>
</table>

Heat exchanger section
130 °C
60°C  90 °C
70 °C

Specific yearly heat demand 40 kWh/m³
Annual energy demand 27,9 MWh
Avoided emissions 5,580 t CO₂eq

Romentino (5600 ab.)
GAGGIANO FIELD

- GAGGIANO 001 BIS DIR: 4613 m
- GAGGIANO 001: 5009 m
- GAGGIANO 004 DIR: 4853 m
- GAGGIANO A (injection): 2371 m
GAGGIANO DISTRICT HEATING

Production well: 2
Injection well: 1
Flowrate: 50 m³/h
Wellhead temp. 125 °C

Thermal power 6.4 MW

Specific thermal power 20 W/m³
Heated volume 320,000 m³
Equivalent inhabitants 3,200
Population covered 123%

Heat exchanger section

125 °C
60°C  →  →  →  →  →  →  →  →  → 90 °C
70 °C

Noviglio (1751 ab.)
1.5 km from OC

Mainate (795 ab.)
2 km from OC

Tainate (60 ab.)
0.6 km from OC

Specific yearly heat demand 40 kWh/m³
Annual energy demand 12,8 MWh
Avoided emissions 2,560 t CO2eq
The conversion of hydrocarbons fields into geothermal ones may be an opportunity to create a **positive social response** in the area where the oil and gas wells are already located.

The use of existing wells is a **benefit** for the oil companies, which avoid the cost of mining closure of the wells and for the geothermal companies, which avoid the cost of drilling new wells.

A major **obstacle** is constituted by the **administrative procedures** to achieve a transfer from a hydrocarbon license to a geothermal one.

A preliminary evaluation of the existing potential **is on going**. The applied method suggests the suitable range of temperatures, depth, pressure and flow rate for the technologies and uses of geothermal sector.

Therefore, starting from the temperature maps of Italy and the available data of the wells, a **second life** for the existing wells will be identified.