Clean and Just Energy Transition of Lesvos Week
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Geothermal energy in Italian islands

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EUROPEAN UNION

CLEAN ENERGY
FOR EU ISLANDS

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Geothermal Energy exploitation in Italy

1500BC: the oldest thermal bath over the Mediterranean sea.

In 1984, an ancient tholos of Mycenaean origin was discovered, which led archaeologists to suppose that these baths had been used since the 15th century BC.

The first historical document testifying the use of the baths is by the Greek Diodorus Siculus and dates back to around 50 BC. He told how those baths were very renowned and used by many people from Sicily for the treatment of numerous diseases.

Geothermal Energy exploitation in Italy

1818: Early industrial exploitation of the heat from the Earth

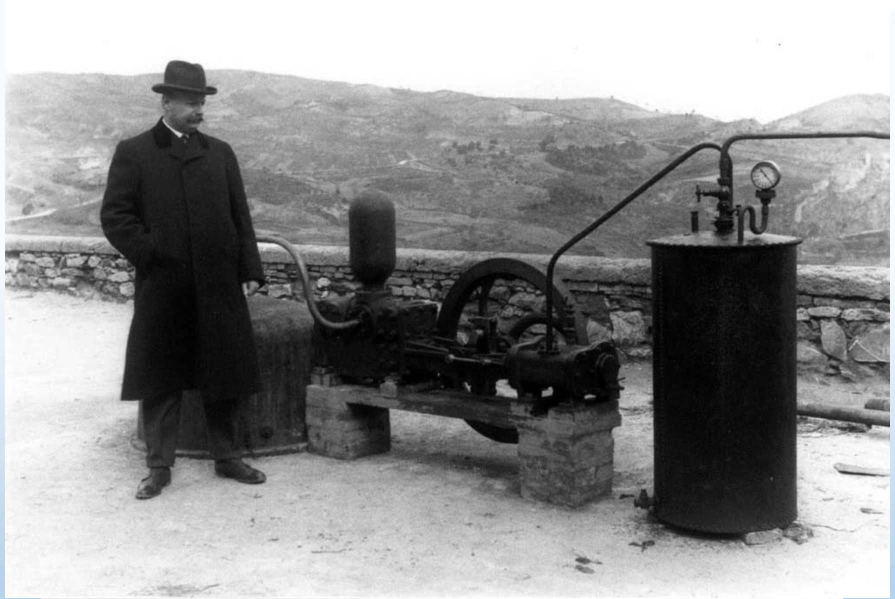
In 1818 eng. Francesco Giacomo Larderel built up the first industrial structure in the world to extract the boric acid from the geothermal steam and to use it for several chemical products (e.g. shampoo)

The "Soffioni" at the "Devil Valley" in Larderello

Geothermal Energy exploitation in Italy

1904: Electricity from geothermal energy

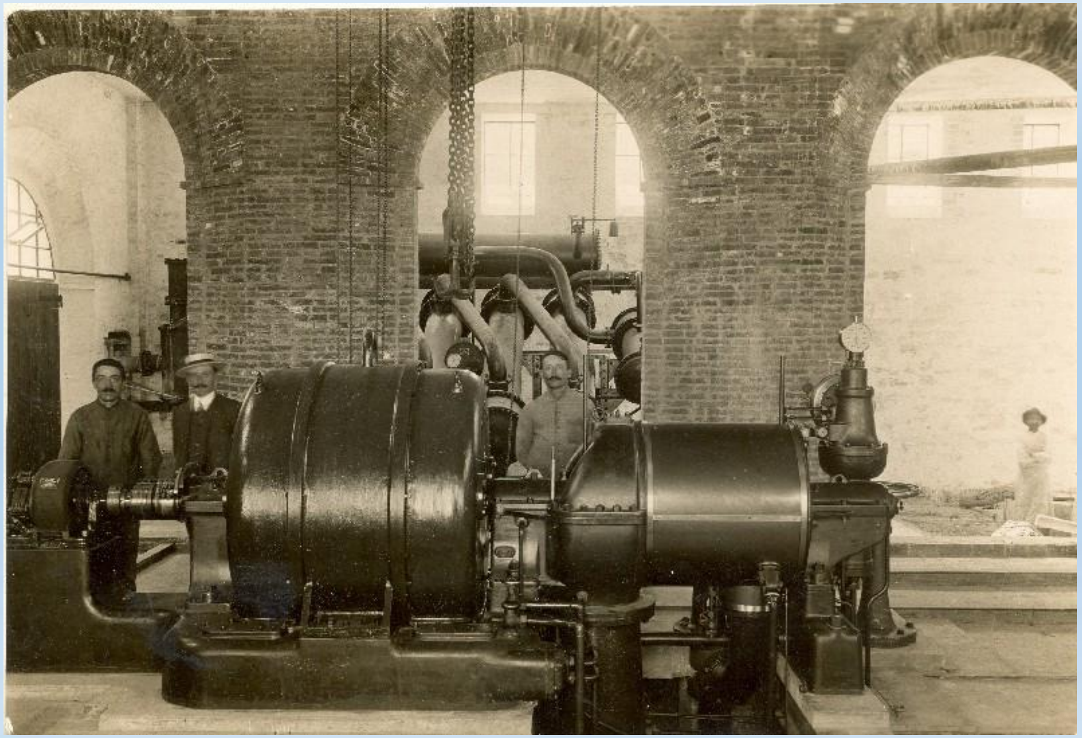
Prince Dr. Piero Ginori Conti started a program of technological innovation that allowed, on July 4, 1904, the first experiment in electricity production with geothermal fluids. For this purpose, it was decided to use pure steam obtained through a heat exchanger fed by a well located in **Larderello** in Tuscany. A piston engine was thus operated coupled to a 10 kW dynamo, to which 5 light bulbs of a few watts each were connected.



Geothermal Energy exploitation in Italy

1905: electricity from geothermal energy

In addition to its use for energy production, the resource is used in civil and industrial district heating systems, with technologies that allow the production of food-grade CO_2 and its use in the gastronomic sector.



The experiment worked, the light bulbs came on: geothermal energy was born.

In 1905, a geothermal engine was installed, powered by pure steam (also obtained with a heat exchanger according to the indirect cycle) and connected to a 20 kW dynamo that for about 10 years illuminated the Prince's Palace and other residences in Larderello.

Geothermal Energy exploitation in Italy

1905 - 1960s: electricity from the Larderello geothermal energy

From that time on, the Larderello geothermal power plant expanded, increased its geothermal power and remained the only geothermal power plant in the world until the 1960s.

Pictures from www.unionegeotermica.it/storia-della-geotermia/

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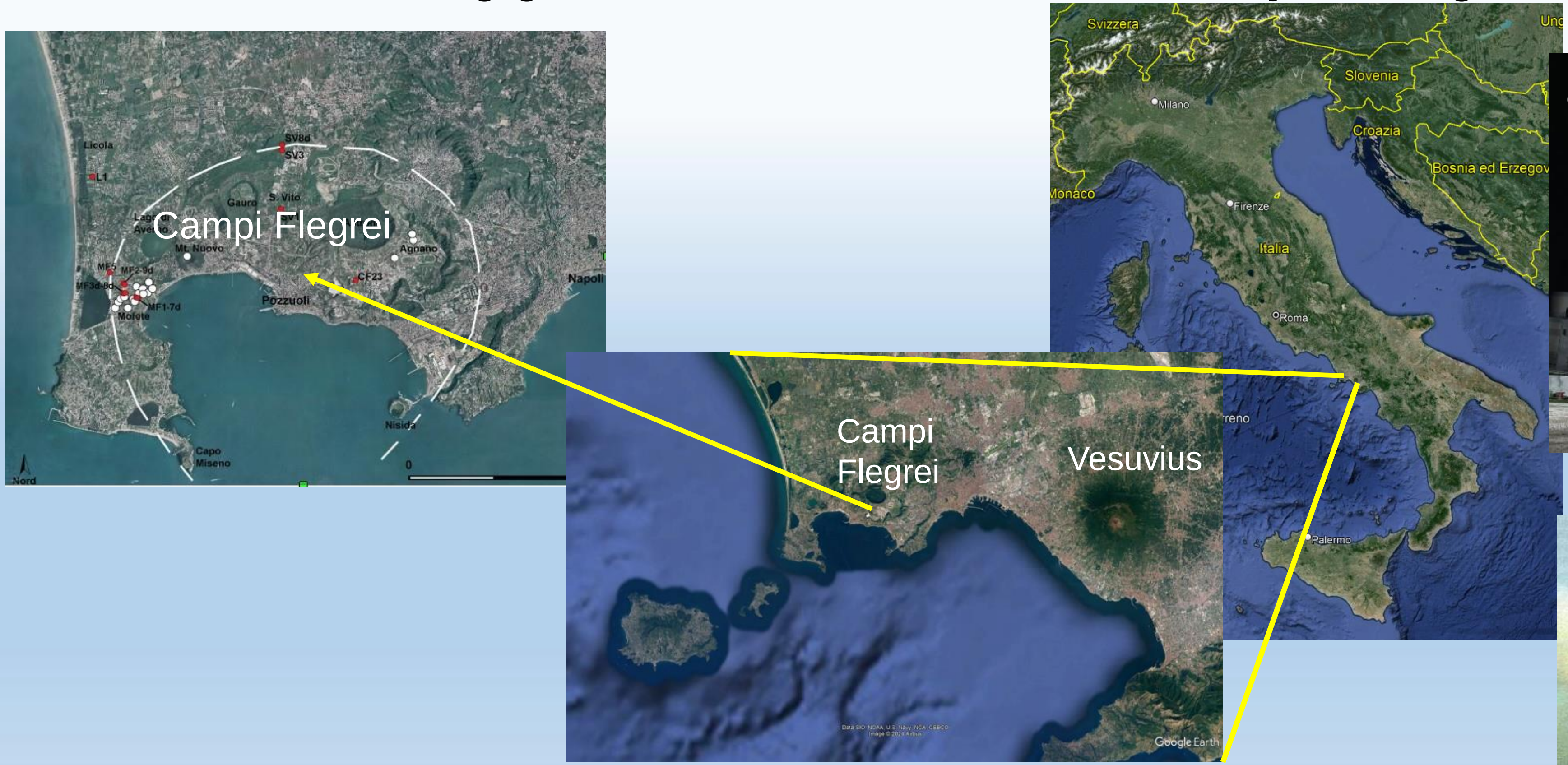
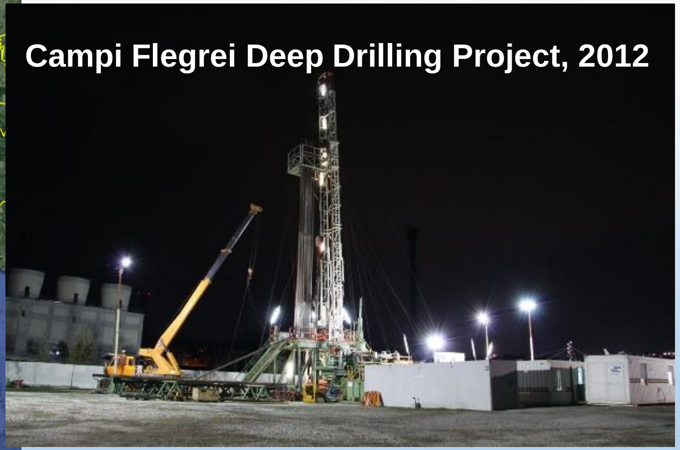
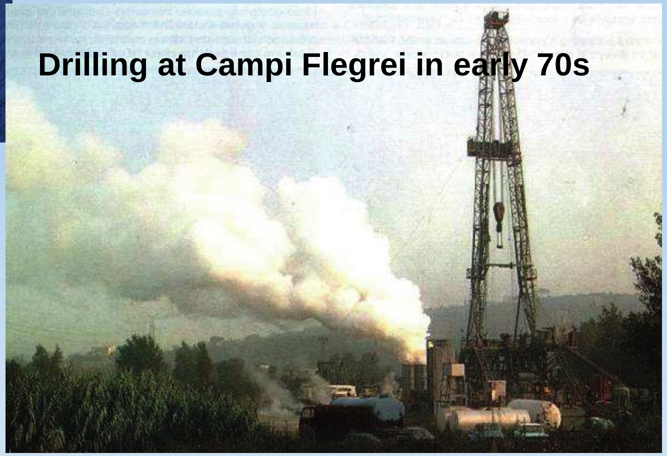
Geothermal power plants in Larderello producing about 6TW/h

Geothermal Energy exploitation in Italy

1920s - 1980s: drilling geothermal wells in Southern Italy – Phlegraean fields




Campi Flegrei Deep Drilling Project, 2012


Drilling at Campi Flegrei in early 70s

Geothermal drillings at the Campi Flegrei between 1939 al 1984. White dots show wells with deph less than 200 m.,red dots > 200 m. The white dotted line shows the Campi Flegrei caldera rim

Geothermal Energy exploitation in Italian islands

1939 - 1954: drilling geothermal wells in Ischia Island

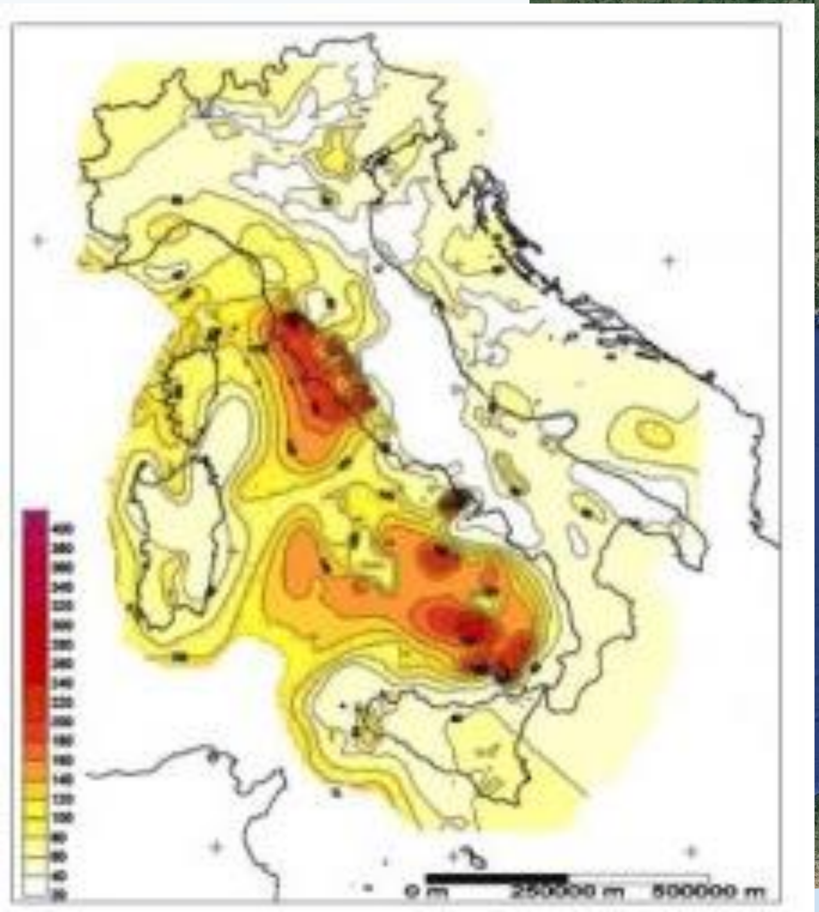
Between 1934 and 1942 it was planned and tested the first binary cicle power plant

Further activities stopped by political decisions supported by "authoritative" opinions of scientists and full professors from local institutions

Geothermal drillings at Ischia island. White dots show wells with deph less than 200 m.,red dots > 200 m. A well drilled at 1150m produced heated steam at 225°C

Geothermal Energy exploitation in Italian islands

Italian islands and the heat-flow map



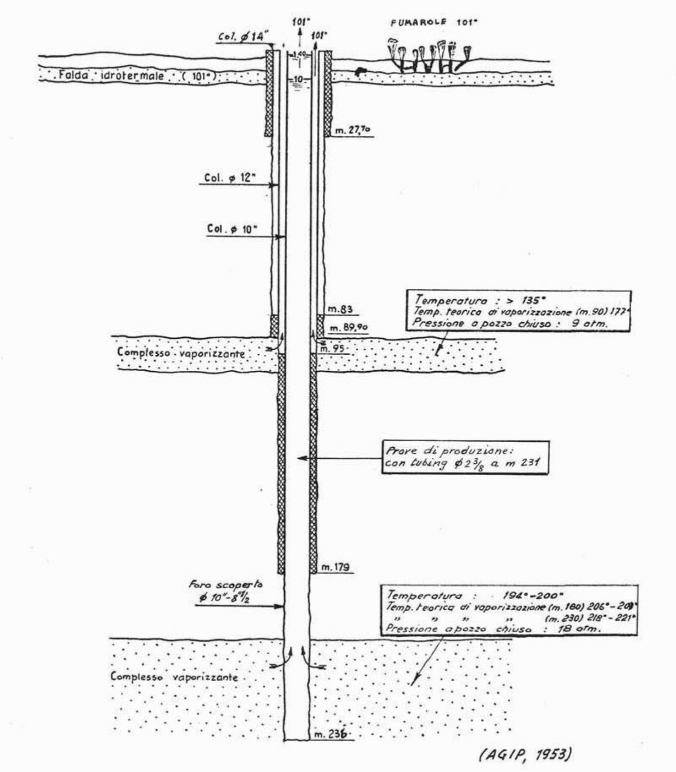
Geothermal Energy exploitation in Italian islands

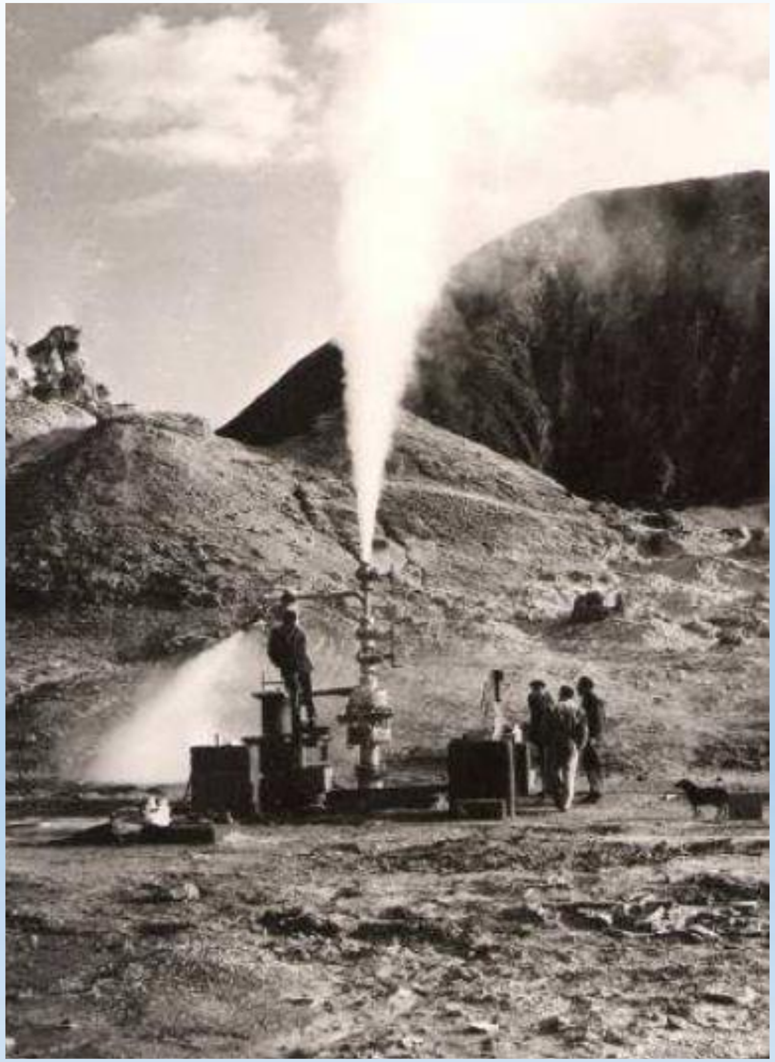
1953-1956: the geothermal energy at Vulcano (Aeolian Islands)

1985-1987: the last attempts

Vulcano Island: AGIP geothermal drillings at the Levante Bay

Depth 230m; Temp. = 198°C; 1 ton/h dry steam

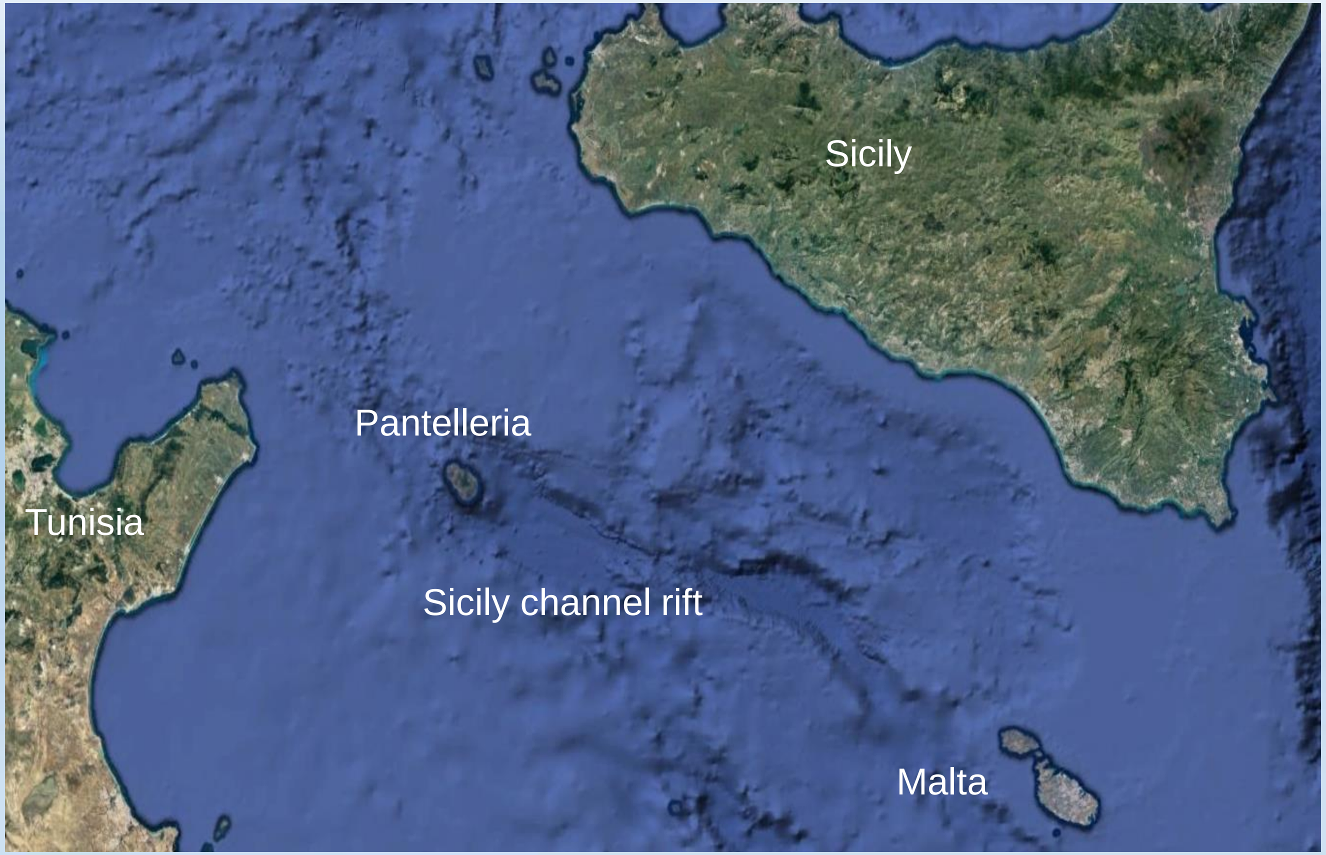


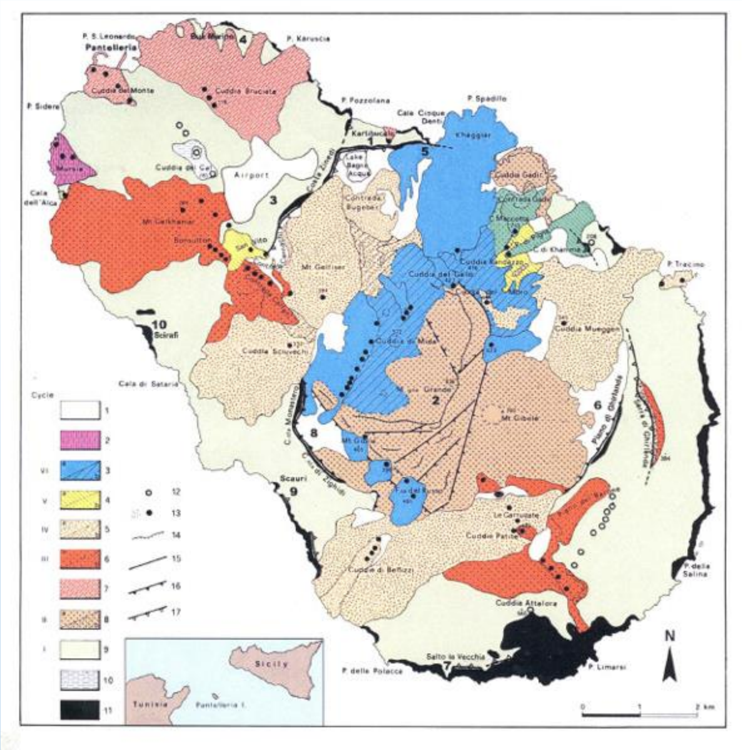


Geothermal Energy exploitation in Italian islands

1991-1993: the geothermal drillings at Pantelleria island

Active volcano – Last eruption (submarine) in 1891 7km to the North of the island





- Two wells drilled at a depth >1000m
- Hi-enthalpy steam production
- No further activities

Improving the knowledge of geothermal fluids availability

The geochemical approach

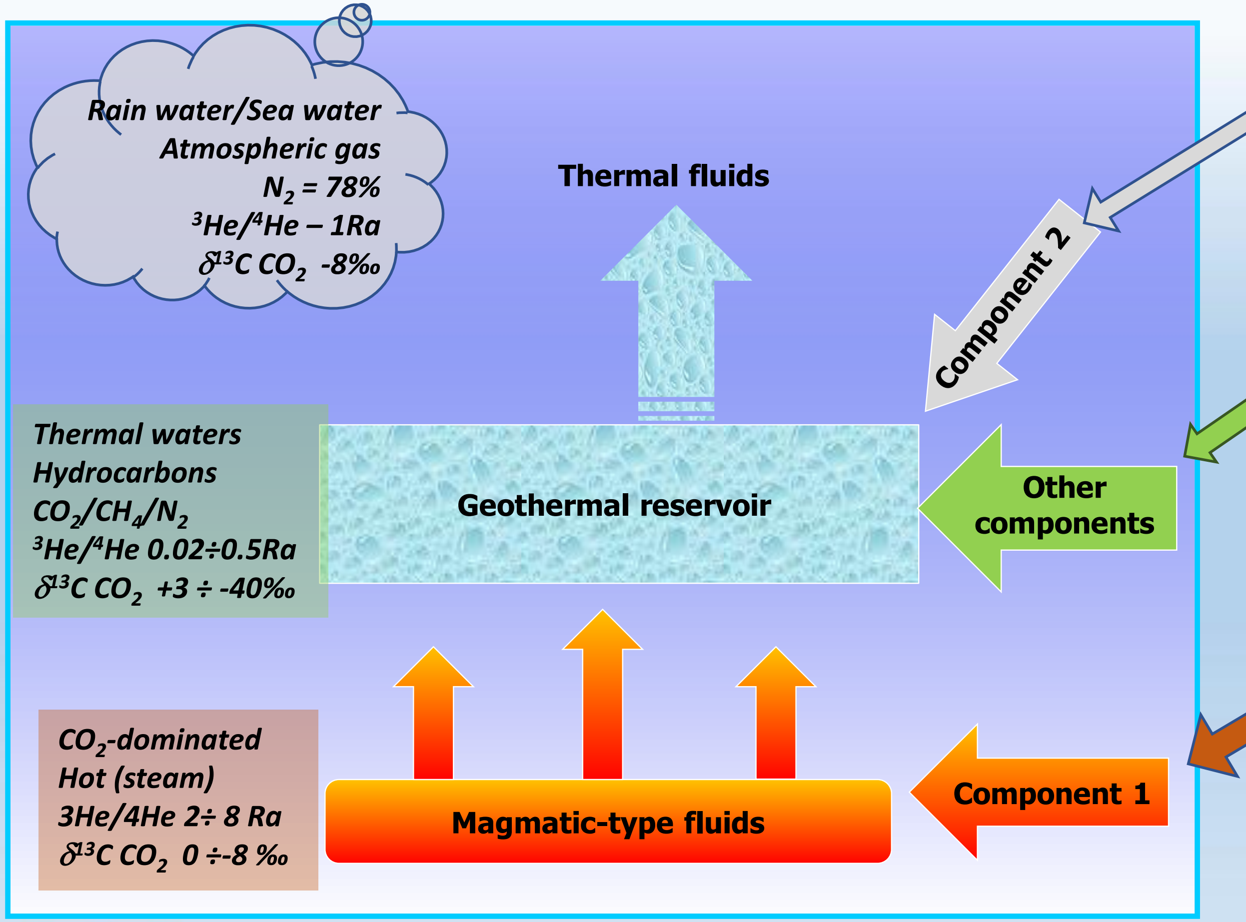
Although both drilling activities and new exploitation activities stopped during the last 30-40 years, the knowledge about the presence of geothermal sources over the italian islands has been improved mainly by using a geochemical approach

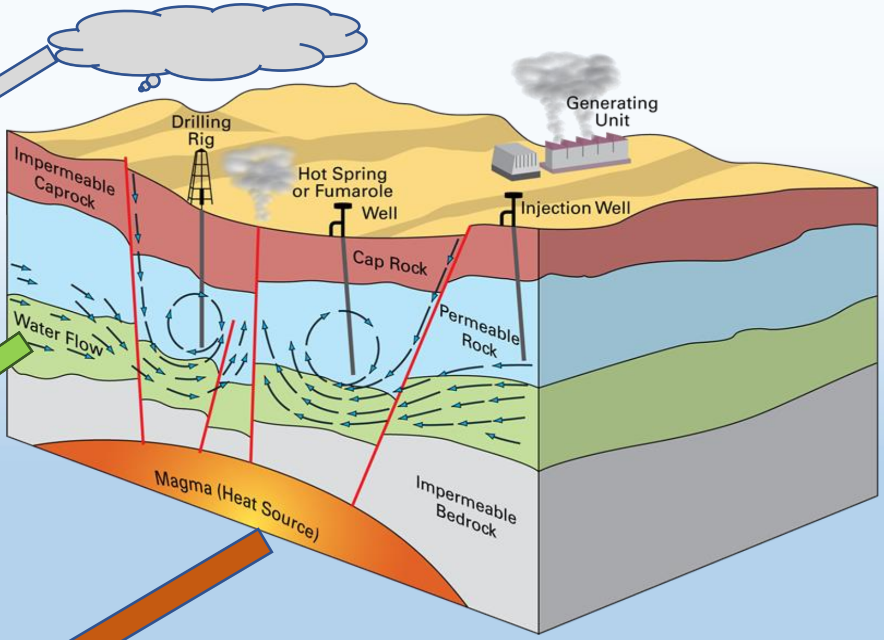
Fluids geochemistry provides:

- information on origin and interactions of the thermal fluids
- quick and low-cost data during exploration
- Preliminary estimations of the deep temperatures

Improving the knowledge of geothermal fluids availability

The geochemical approach



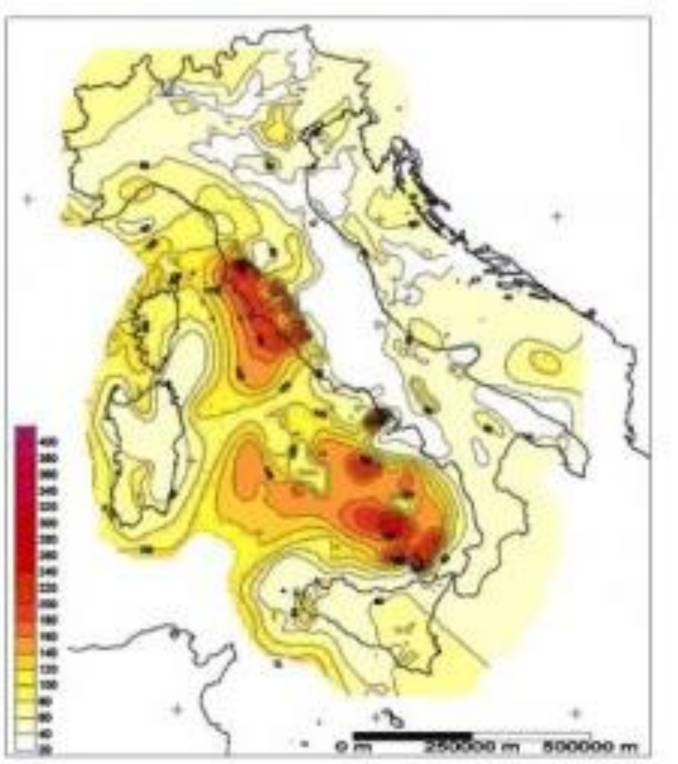


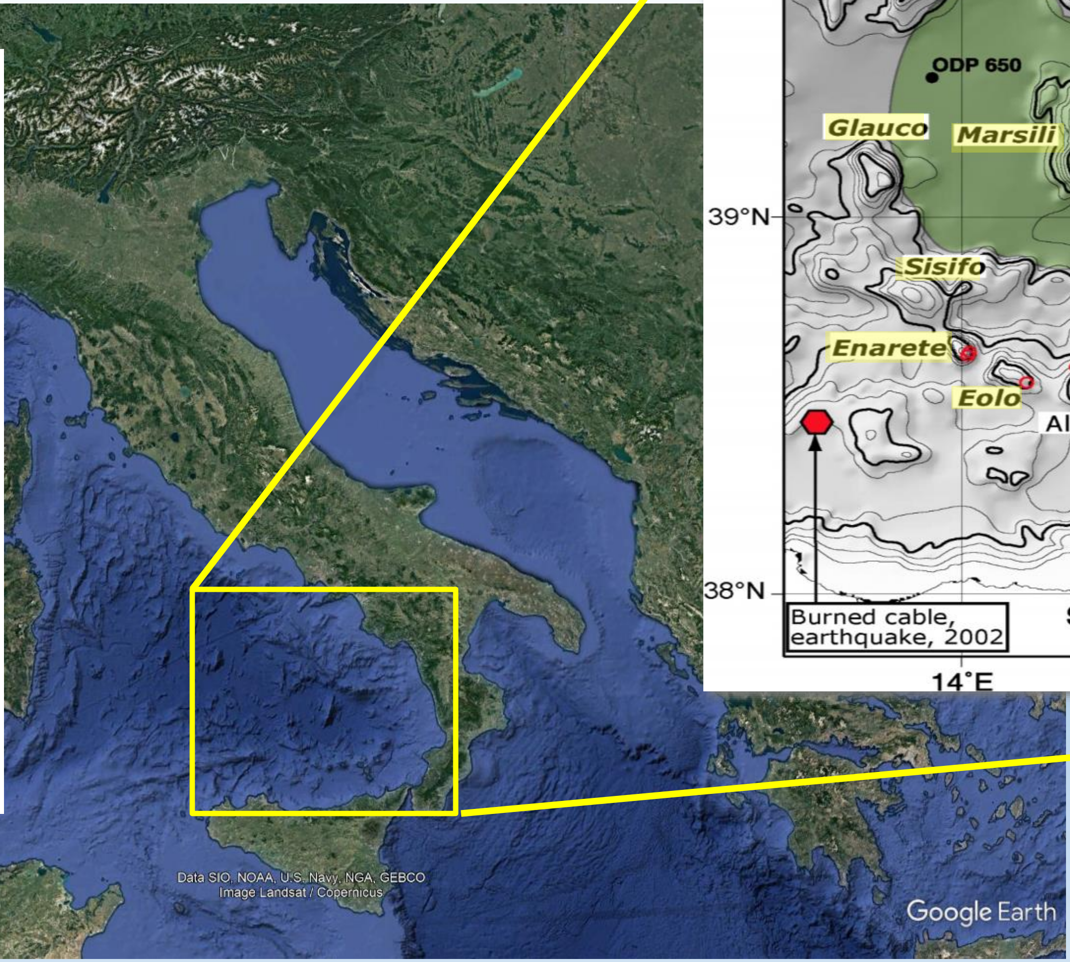
Every fluid is a result of a mixing of some components

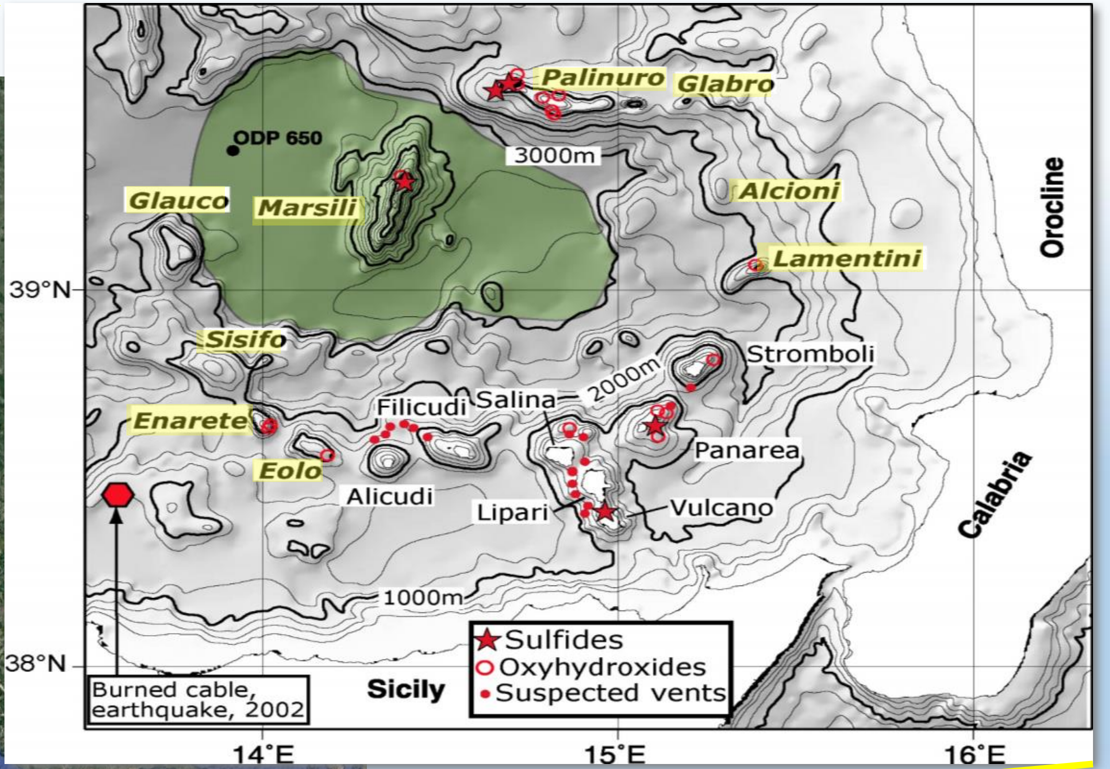
Highly important to pay attention to changes in the mixing proportions

Improving the knowledge of geothermal fluids availability

Tyrrhenian offshore



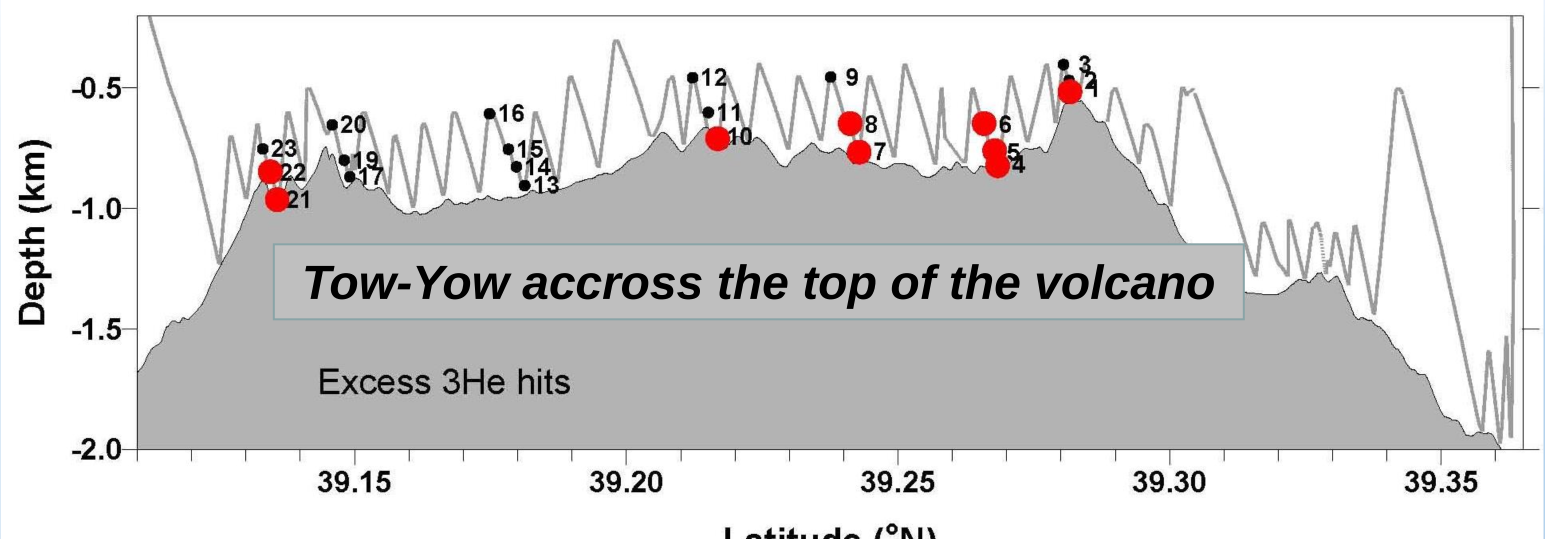




Improving the knowledge of geothermal fluids availability

Tyrrhenian offshore

Marsili seamount



After Lupton et al, JGR 2011

Water-column studies carried out across the whole sea-mount

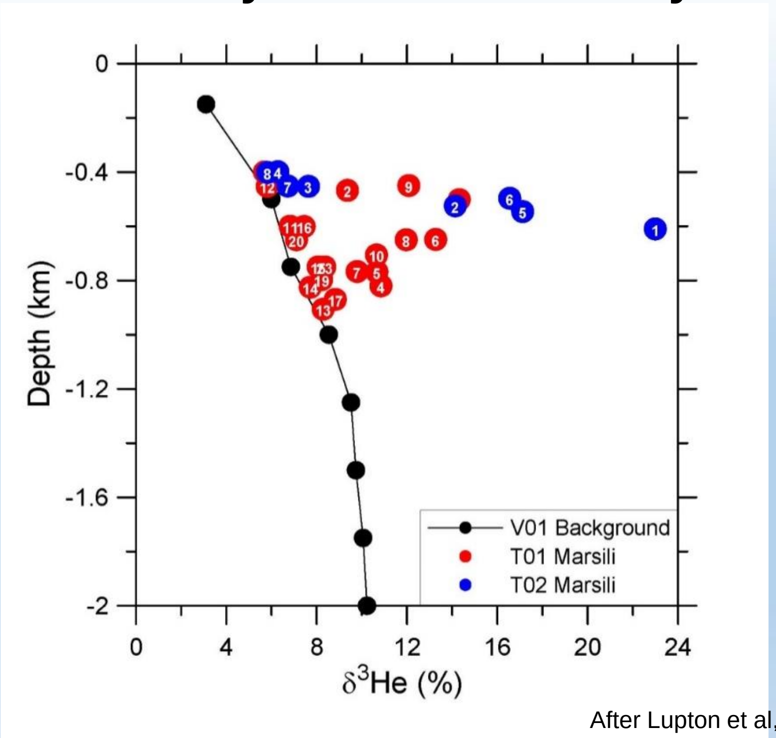
Improving the knowledge of geothermal fluids availability

Tyrrhenian offshore – Aeolian arc

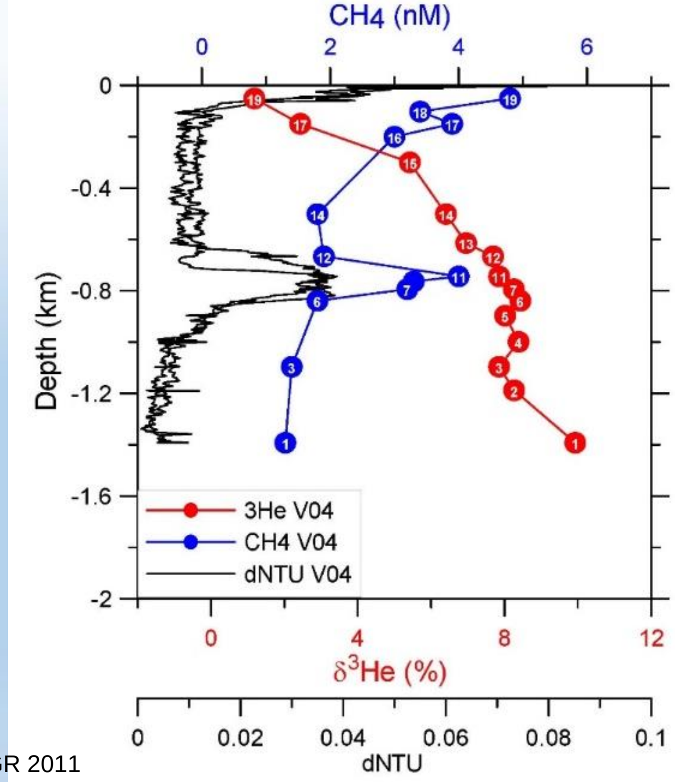
Excess of hydrothermal-derived gases (CO_2, CO, CH_4) with respect to the background due to geothermal fluids vented from the seamounts

Helium isotope analyses of the dissolved gases evidenced $^3He/^4He$ isotope ratios significantly higher than the background

Marsili hydrothermal activity



Palinuro seamount



After Lupton et al, JGR 2011

References:

Paltrinieri D., Favali, P., Italiano F., Signanini P., Caso C., and Armani F.B. (2022). The Marsili Seamount Offshore Geothermal Reservoir: A Big Challenge for an Energy Transition Model Energies 15, 5: 1900. https://doi.org/10.3390/en15051900

F. Italiano, A. De Santis, **P. Favali**, M.L. Rainone, S. Rusi, **P. Signanini**. (2014) The Marsili Volcanic Seamount (Southern Tyrrhenian Sea): a potential offshore geothermal resource. Energies, 7, 4068-4086; doi:10.3390/en7074068

Antonelli U., **Paltrinieri D, Favali P., Italiano F.,** Rainone M.L., **Signanini P.** (2014) Renewable energy from a natural system: the MARSILI offshore geothermal project. Scientific progresses, technology innovation, industrial exploitation and monitoring. SET PLAN Conference 2014 - Driving the Energy Transition Together Research & Innovation for the Energy Union. Rome 10-11 December 2014

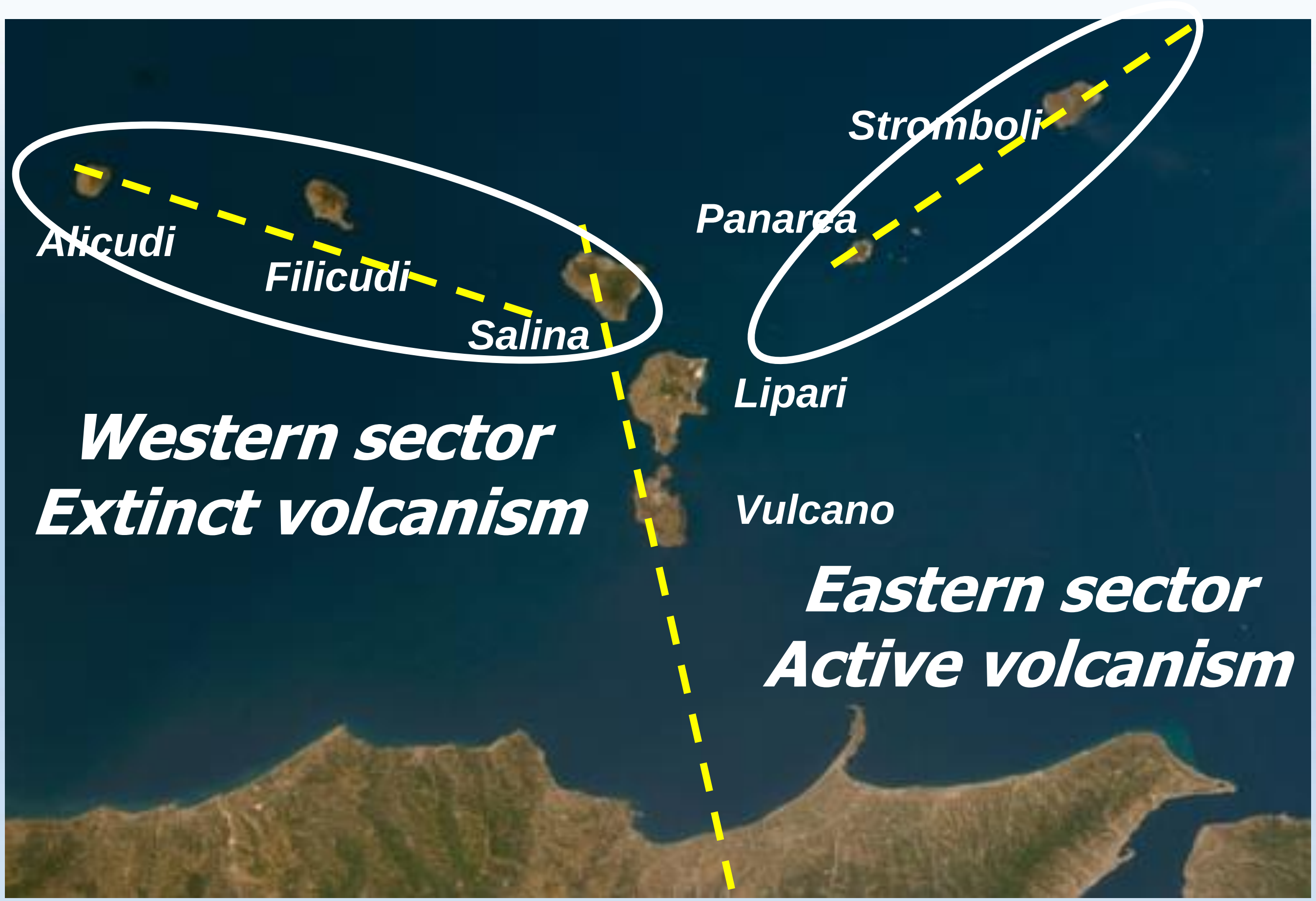
The Aeolian islands

- **7 islands; 6 belonging to the Lipari municipality and one (Salina island) managed by 3 municipalities**
- **All of them involved in the EU Clean Energy program** (*100% carbon free by 2050*)

- Panarea and the planned geothermal well
- Regulatory aspects (italian prescrictions)
- Risks evaluation and monitoring
- Geothermal small scale backyard development

The Aeolian islands

Main tectonic settings



The Aeolian islands

Short volcanological information

Alicudi Island – Extinct volcanism - Submarine hydrothermal activity

Filicudi Island – Extinct volcanism - Submarine hydrothermal activity

Salina Island – Extinct volcanism - Terrestrial and submarine hydrothermal activity

Lipari Island – Historical volcanism - Terrestrial and submarine hydrothermal activity

Panarea Island – Extinct volcanism - Terrestrial and submarine hydrothermal activity – Submarine explosion in November 2002

Vulcano Island – Active volcanism – Last eruption 1888-1890 – Last volcanic unrest 2021 - Terrestrial and submarine hydrothermal activity

Stromboli Island – Active volcanism – Continuous explosive activity with some lava flows – Weak clues of submarine activity

Volcanic activity at Stromboli island

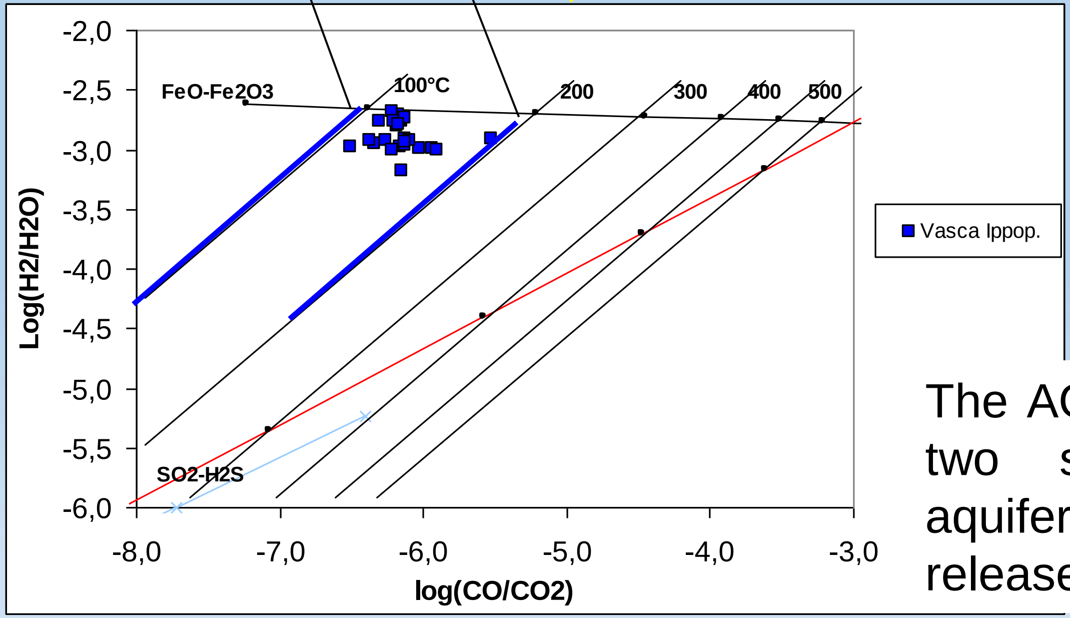
The Aeolian islands

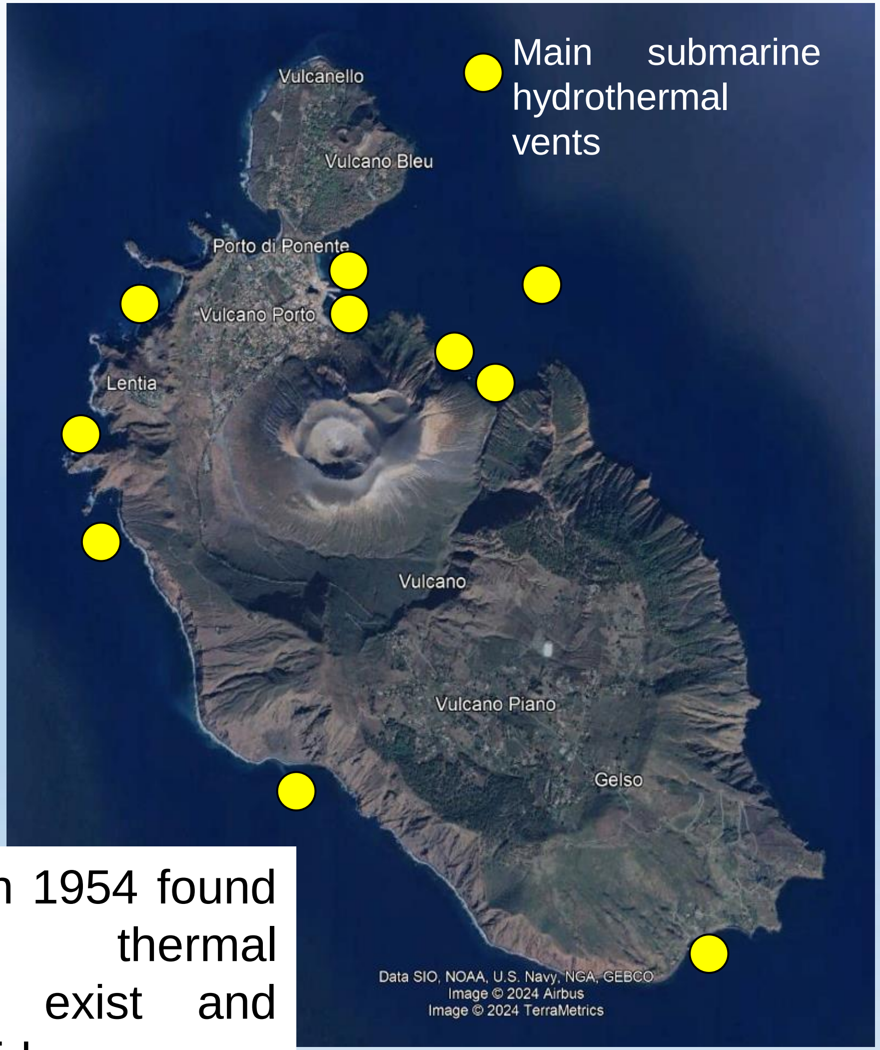
Examples from some of the islands

VULCANO Island

Gas geothermometry

135°C 195°C



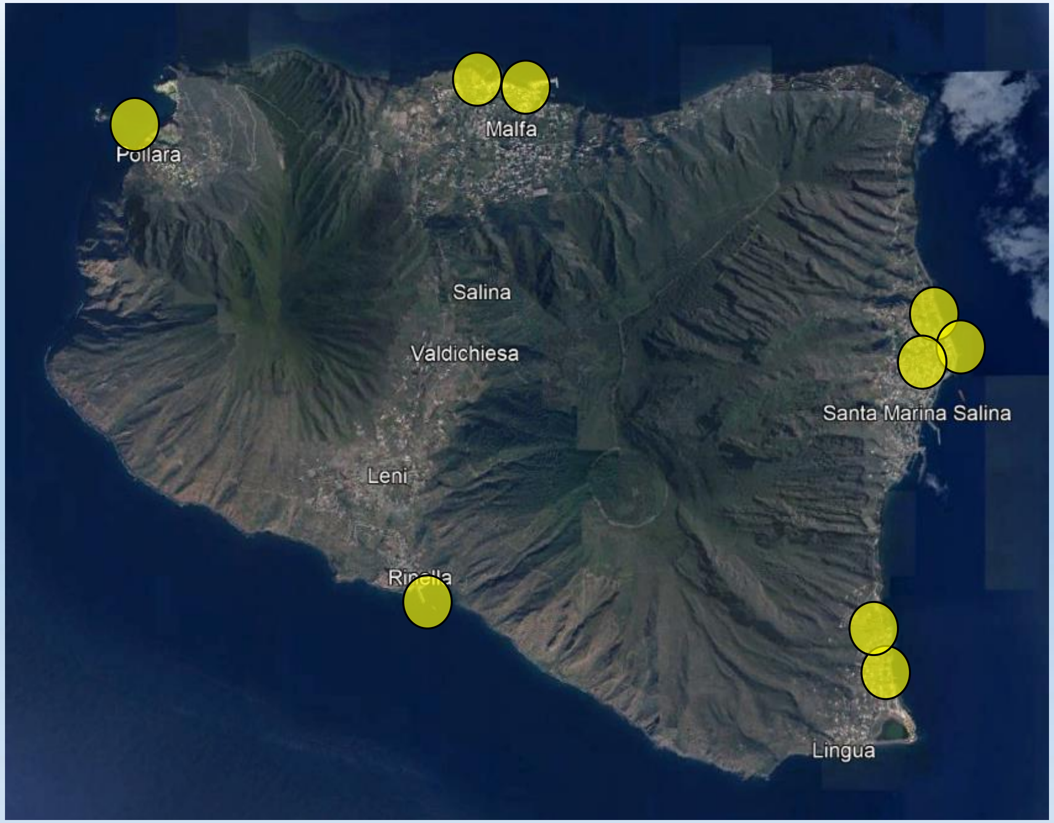


The AGIP drillings in 1954 found two superimposed thermal aquifers that still exist and release the same fluids

The Aeolian islands

Examples from some of the islands

SALINA Island



On the main land, a number of wells have been drilled at shallow depth for agriculture, for agriculture, construction and tourist purposes. They display water temperatures in the range of 19-39°C with sea-water contamination at various extents

Shallow submarine hydrothermal vents are known at the sites of Pollara, Rinella, Malfa

The Aeolian islands

Examples from some of the islands

SALINA Island

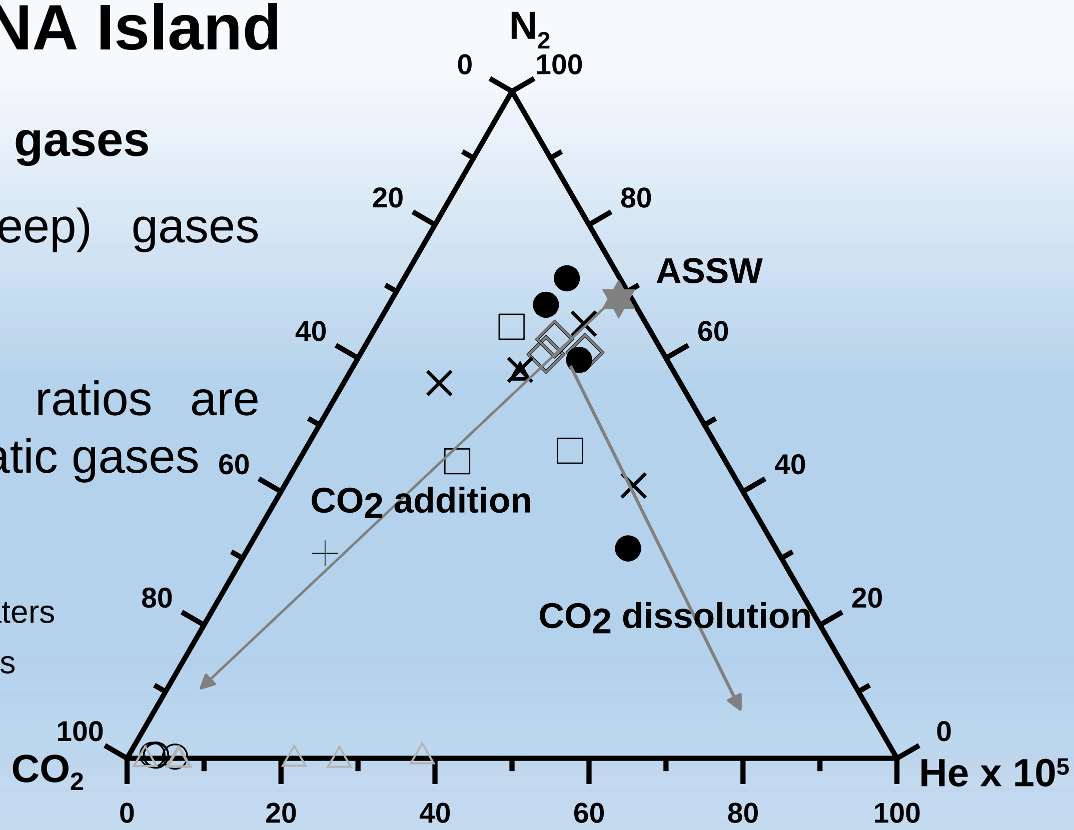
The dissolved gases

Mixing CO_2 (deep) gases with atmosphere

Helium isotopic ratios are typical of magmatic gases

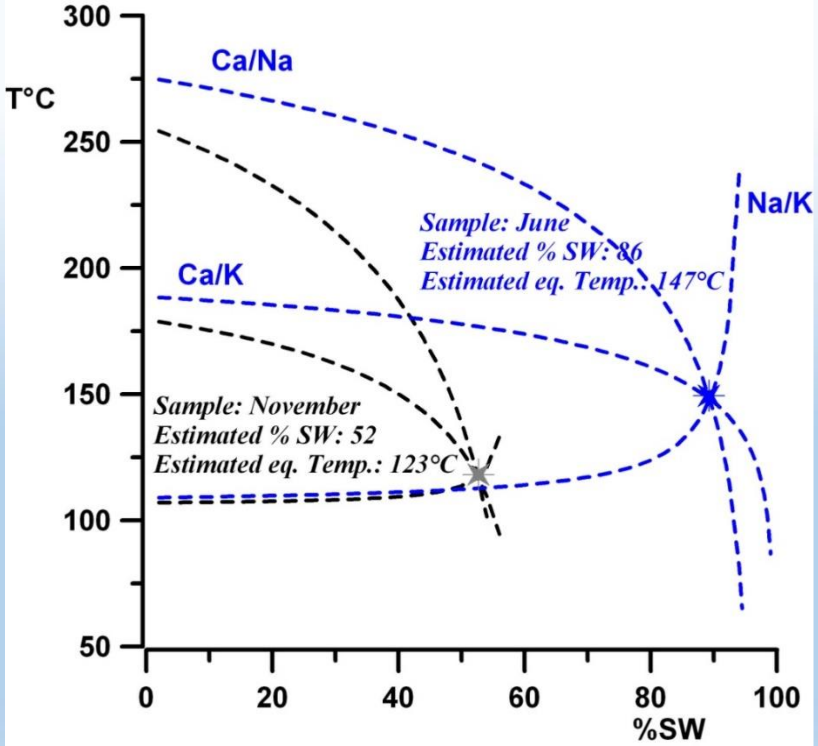
Grey marks = thermal waters

Black marks = cold waters



Equilibrium temperatures estimates

Liquid phase geothermometry



120°C <Temperature <180°C

10% < Sea water contamination < 90%

References:

F. Italiano, P. Signanini (2011) Geothermal fluids and extinct volcanism: the study case of the Island of Salina Aeolian arc, Italy, 30°GNGTS, Trieste, 14-17 November 2011. Abstract volume173-174

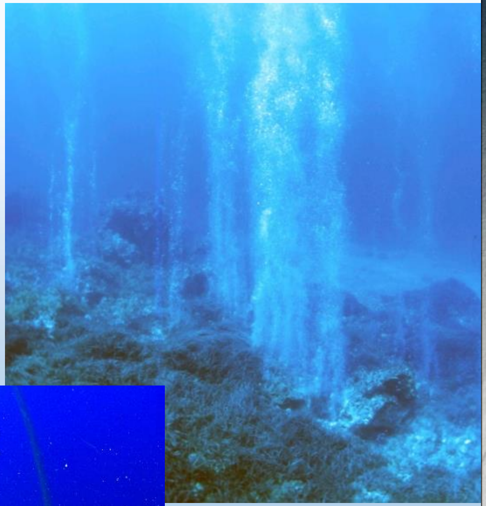
Italiano F, Caruso C. (2011) Detection of fresh and thermal waters over an island with extinct volcanism: the island of Salina (Aeolian arc, Italy) Procedia Earth and Planetary Science 4 (2011) 39 – 49

The Aeolian islands

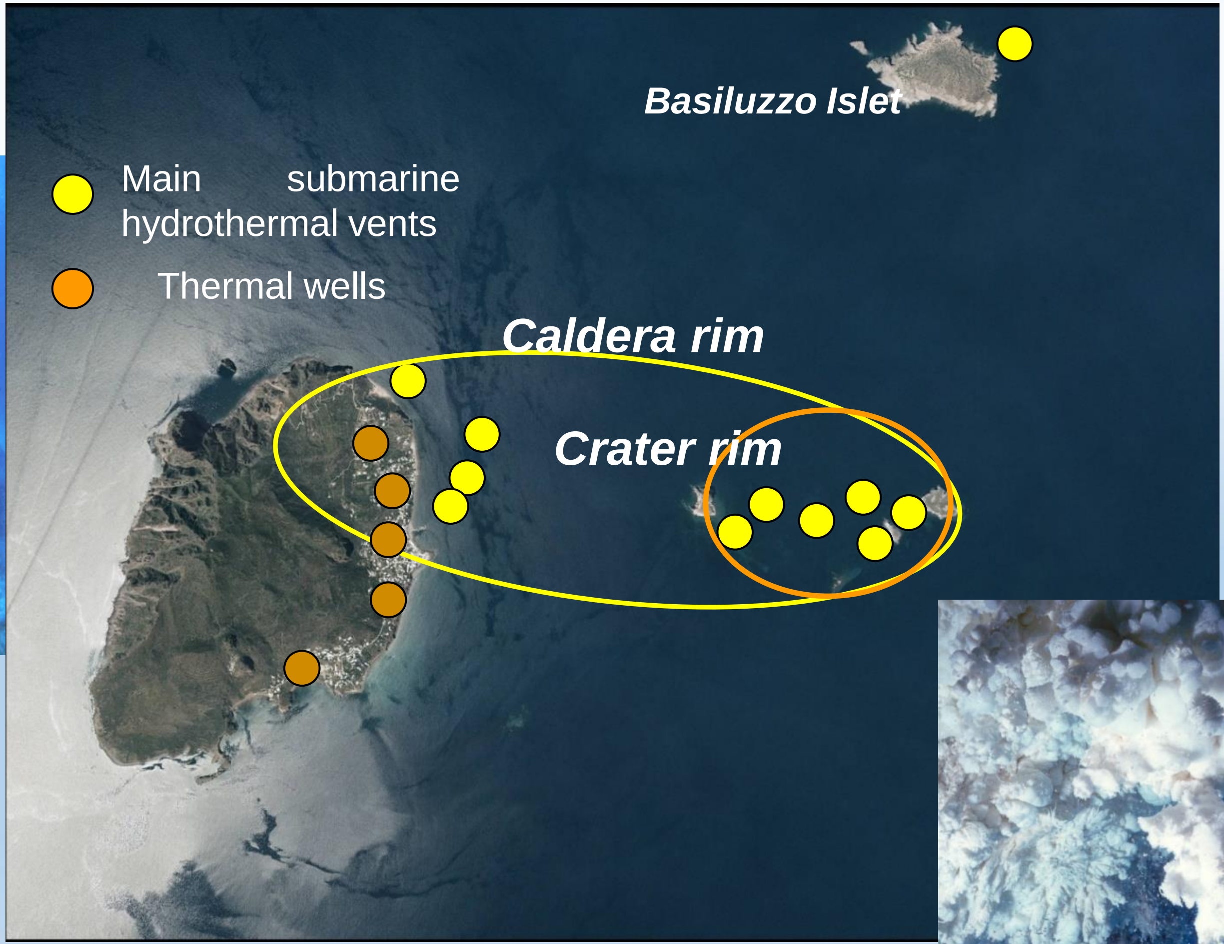
Examples from some of the islands

PANAREA Island

The largest submarine hydrothermal system of the Mediterranean sea



Sampling of thermal fluids (135°C) at a depth of 24m



The discharged fluids consist of both gases and thermal waters with temperature up to 140°C. They are normally surrounded by deposits mainly composed of sulphur

The Aeolian islands

Examples from some of the islands

PANAREA Island

More than 200 chimneys located over a submarine valley at a depth between 65 and 85 m release gases and thermal waters

The chimneys show that the Panarea geothermal system is much wider than it was stated before and it has still be investigated

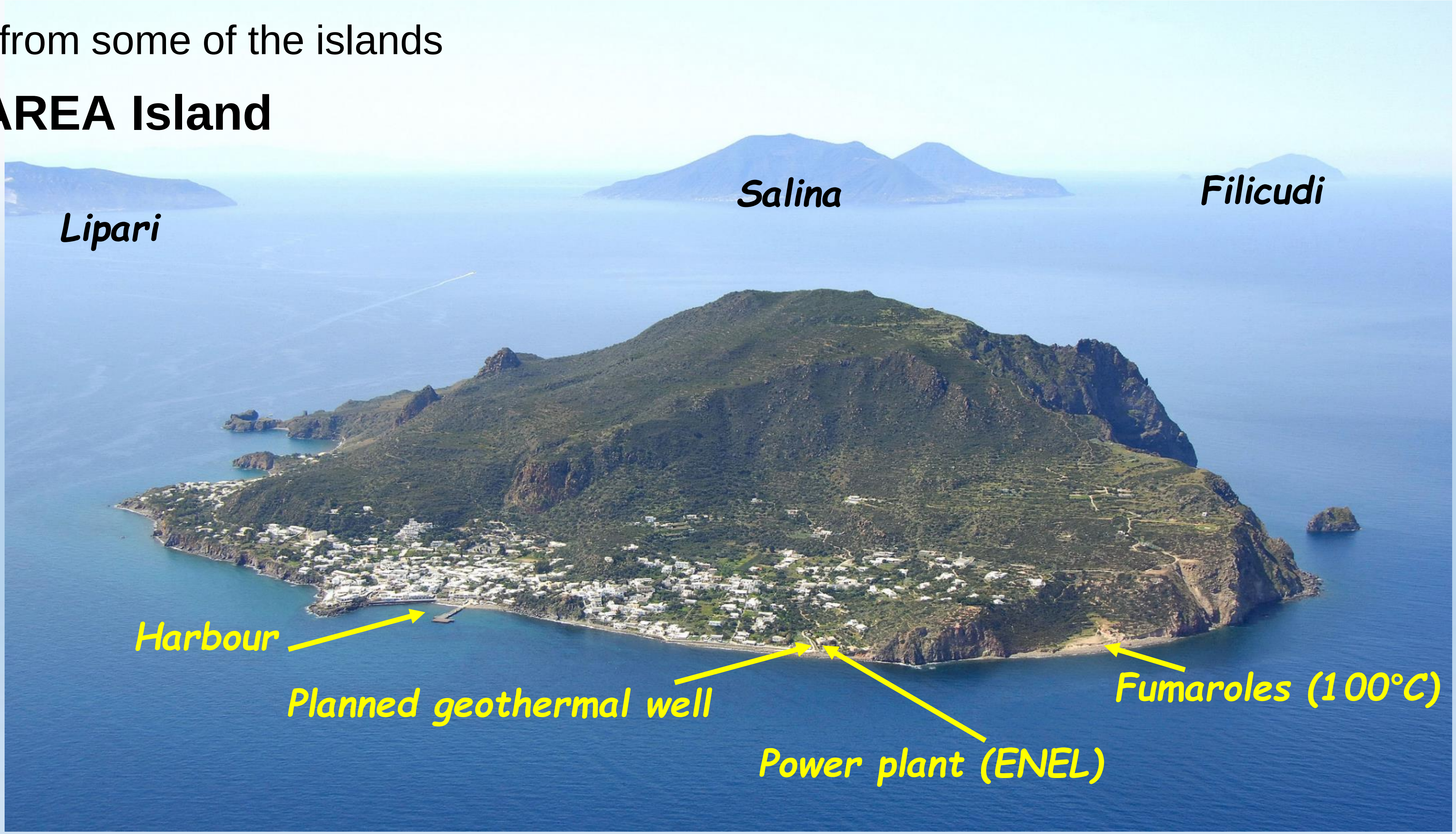
References:

Italiano F. and Nuccio P.M. (1991) Geochemical investigations on submarine volcanic exhalations to the East of Panarea, Aeolian Islands, Italy. Jour. Volc. and Geoth. Res., 46, 125-141

The Aeolian islands

Examples from some of the islands

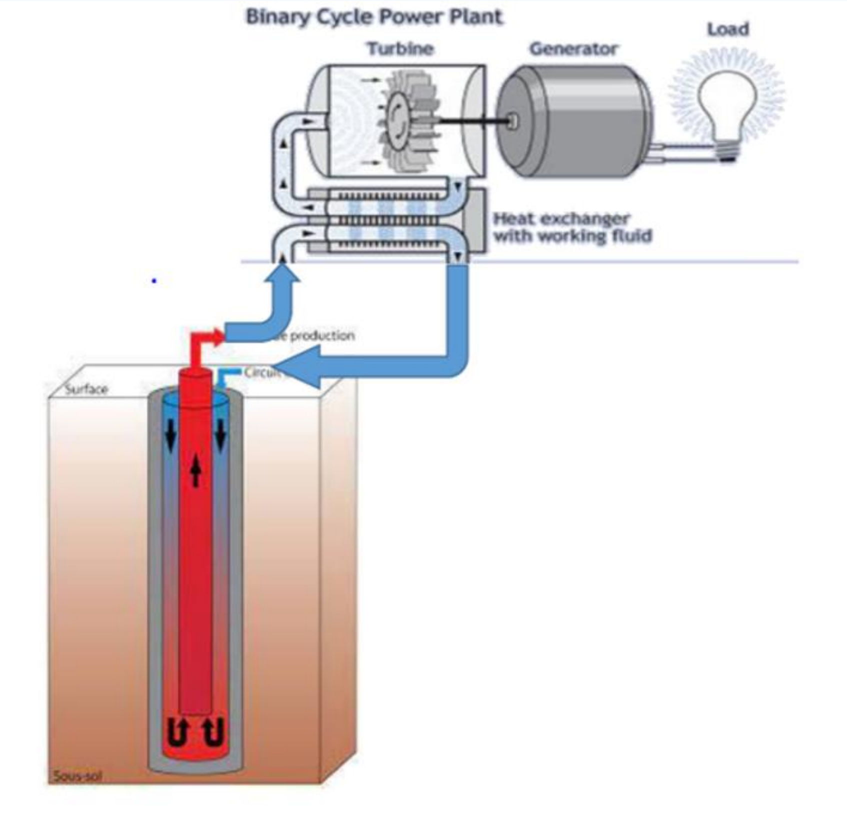
PANAREA Island

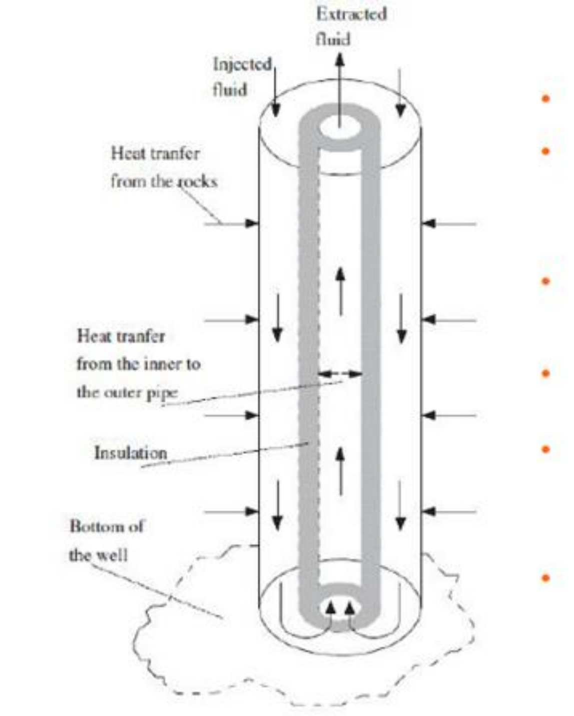


Reducing the environmental impact: Coaxial closed loop technology

Impact on the island's energy balance: A small-scale plant, 100 – 150 kW, would allow a production of approximately 1,000,000 kWh/year equal to 44.84% of the island's overall needs.

To produce the same amount of electricity from photovoltaic, it is necessary to install photovoltaic panels for approximately 800 kW with a commitment of approximately 8,000 m2 of surface area.

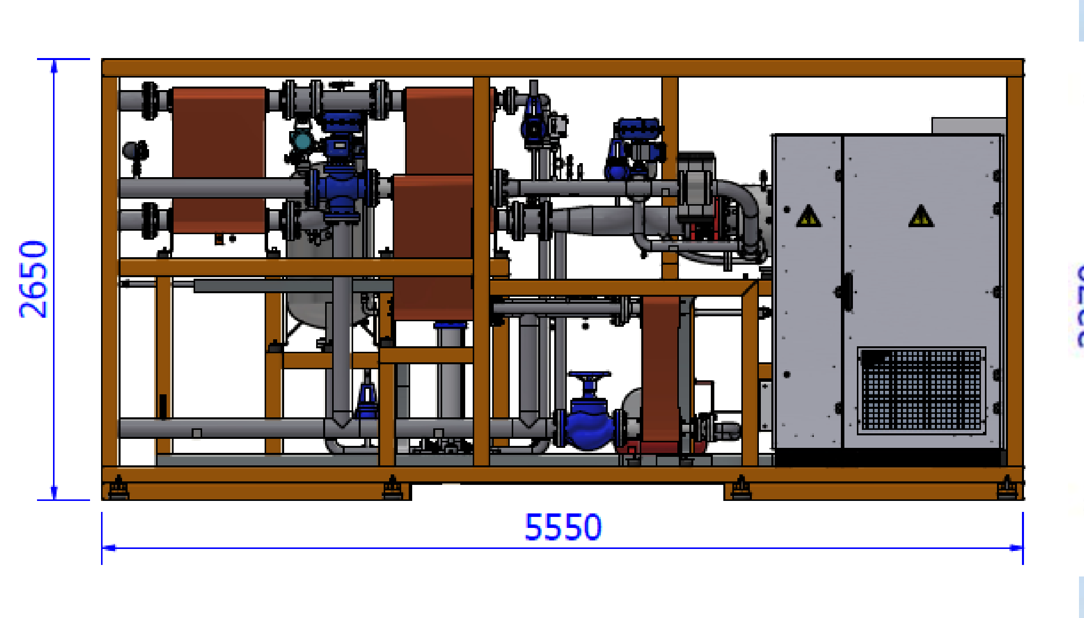


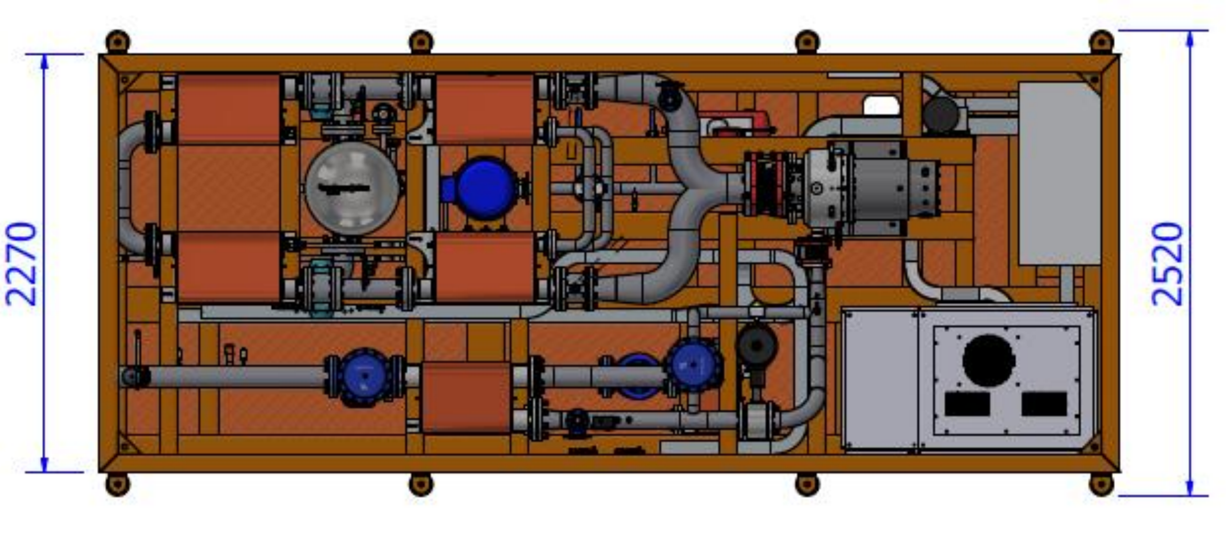


scambio termico nel pozzo singolo

Reducing the environmental impact: Coaxial closed loop technology

A geothermal plant of the proposed size has a practically zero environmental impact as it occupies a total surface area of just 150 m2. Furthermore, by using the coaxial closed loop technique, there is no extraction of geothermal fluid, but only heat exchange between the heat transfer fluid and the geothermal heat in a closed circuit, therefore the plant will have zero emissions in compliance with Legislative Decree 22/2010.





Regulatory aspects

REGULATIONS ON THE USE OF GEOTHERMAL RESOURCES" in particular regarding SMALL LOCAL USES

-thermal power less than 2 MW

-well less than 400 m deep for electricity production with zero-emission binary cycle plants.

The competent authorities for administrative functions are the Regions or bodies delegated by them. Small local uses are subject to the Simplified Authorization Procedure (PAS).

Since the plant has an electrical power of less than 1 MW, for this type of application they are also excluded from the Environmental Subjection Verification

Monitoring activities for hazards evaluation and mitigation

- During drilling
- During geothermal fluids exploitation

Coupling laboratory and deployable equipments

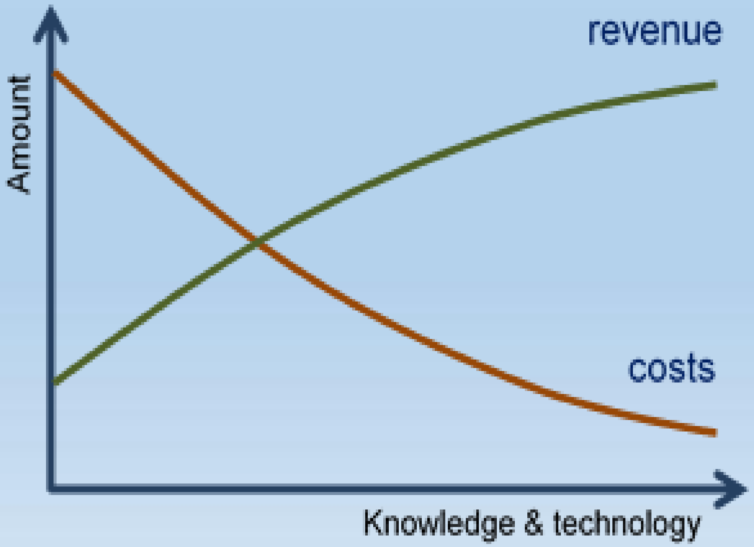
Automatic and continuous monitoring of chemical and isotopic composition of both the liquid and the gas phase.

Data from remote stations transmitted to dedicated processing centers

GEOTHERMAL SMALL SCALE BACKYARD DEVELOPMENT

Small-size power plants (less than 2 MW installed capacity - wells less than 400 m deep) built on the EU volcanic islands (e.g. Aeolian Islands, Greek Islands, Canary Islands, Azores), for more resilient and scalable island infrastructures.

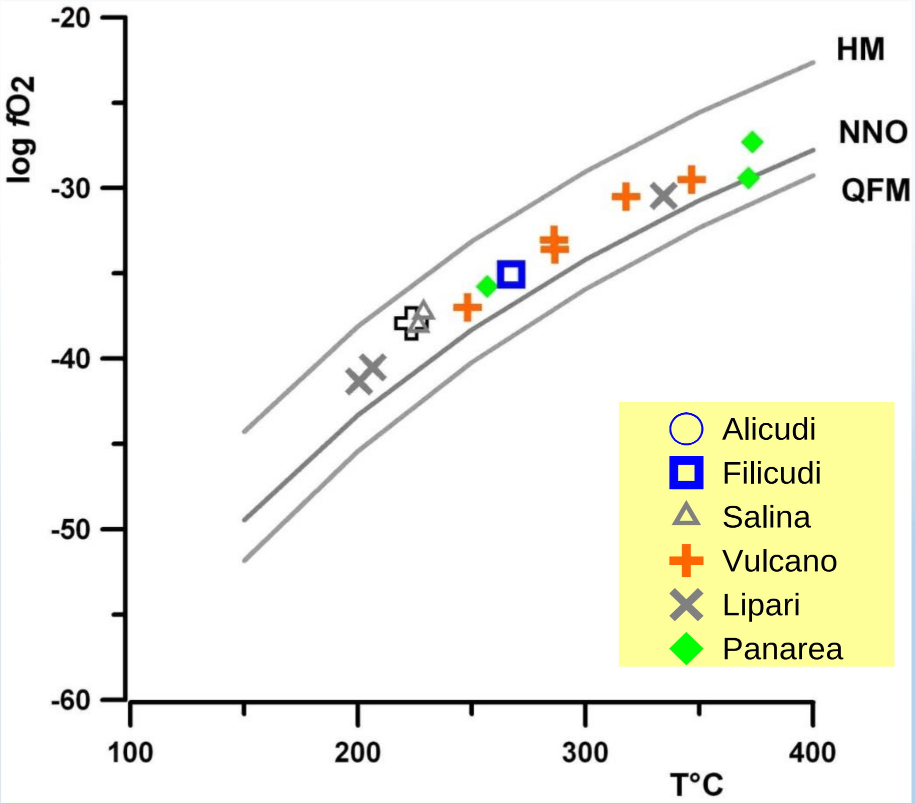
Compared to previous attempts on geothermal exploitation, small plants, may cut the set-up costs, reduce production risks and increase the revenues



Basic assumptions to make the Aeolian islands autonomous with the cultivation of geothermal energy

Estimated capacity – 7.5 Mwe
Production (year) – 58 GWh
Enthalpy – Medium/High
Plant location – nearshore
Wells – 4/6

Conclusions



- Geothermal bodies beneath all of the islands
- Estimated deep equilibrium temperatures in the range of 200-400°C
- The geothermal well planned at Panarea will be the first attempt to exploit geothermal energy on a volcanic island and the first well drilled after a long lasting stop

- We need to deeply revise the prescrictions required nowadays
- Move towards the integrated use of different forms of renewable energy to activate and support other infrastructures (desalination plants, waste treatment, spa, tourist activities)

Thank you for your kind attention

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