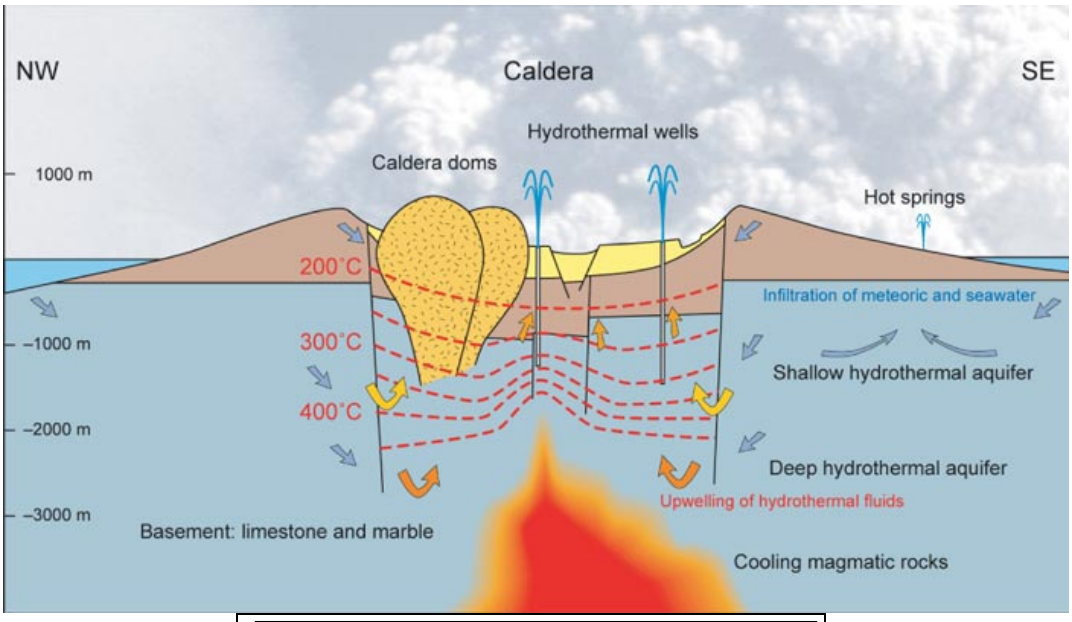
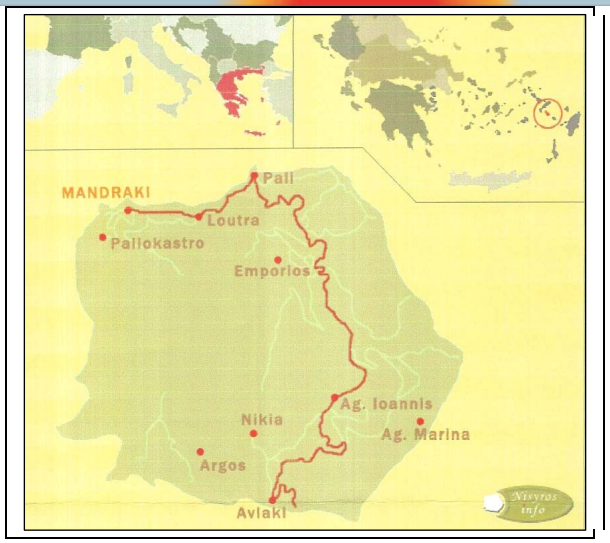
NISYROS GEOTHERMAL ENERGY UTILIZATION PREFEASIBILITY STUDY

A briefing paper
By Costas Karytsas CRES

Nisyros is a small island with an active volcano in the Eastern edge of the South Aegean volcanic arc. It covers an area of 41.2 square kilometers and reaches a height of 698 meters. It is surrounded by 4 other small uninhabited volcanic islets. Nisyros is the youngest volcanic cone in the Aegean. Major volcanic activity is roughly estimated to have ended about 30,000-15,000 years ago. Since then superheated geothermal fluids triggered hydrothermal explosions, blasting the covering formations. Ten impressive craters of hydrothermal explosions with a diameter up to 300 m decorate the southeast part of the caldera floor. The most recent was created in 1887.

Photo credits: NASA/GSFC/METI/ERSDAC/JAROS, and U.S./Japan ASTER Science Team





Map of Nisyros

This prefeasibility study was conducted in order to examine the possibility of exploiting geothermal energy on the island. This prefeasibility study considered 4 different scenarios: two of them utilizing low enthalpy geothermal fields and two with medium enthalpy fields. With the exception of one scenario (the one utilizing geothermal energy with relatively low temperature which only considers thermal uses of the geothermal field), all others consider electricity production as well, using an OCR technology option.

The **four scenarios** include:

LOW ENTHALPY GEOTHERMAL ENERGY APPLICATIONS

A.1. Nisyros Case 1: Available geothermal energy 200 m^3/h at 72^oC
A.2. Nisyros Case 2: Available geothermal energy 250 m^3/h at 99^oC

MEDIUM ENTHALPY GEOTHERMAL ENERGY APPLICATIONS

B.1. Nisyros Case 3: Available geothermal energy 120 t/h at 120^{o}C
B.2. Nisyros Case 4: Available geothermal energy 150 t/h at 180^{o}C

A.1. Based on geological, geochemical, geophysical, drilling logging data and the geothermal reservoir conceptual model of Nisyros Isl. (Geotermica Italiana-PPC 1984) **the temperature of 72ºC** for the entering geothermal temperature (well-head temperature) **seems to be feasible at any point of the island at a depth of 200-250m.** Therefore 2 shallow boreholes (simple hydrogeological boreholes of at least 250 m) with final diameters of 11-14" should be drilled. However**,** the possibility of the utilization of hot-spring waters should also be examined in this case.

The production wells, the reinjection well (-s), the heat exchangers and the piping conveying geothermal water compose the geothermal circuit and will be located either near "Paloi" village or near the location "Loutra". The Greenhouses will be located near "Paloi" village and the district heating system near "Loutra" in order to cover the heating/cooling needs for the spa centre.

A.1.– Nisyros Case 1 - Summary Table Case of 200 m^3/h at 72^{o}C

CATEGORY	THERMAL DESALINATION	GEOTHERMAL GREENHOUSES	GEOTHERMAL HEAT PUMP SYSTEM	TOTAL
NOMINAL POWER	2,3 MW_{th}	5,1 MW_{th}	2,1 MW_{th} COP 4,2 (Heating)	**9,0 MW_{th}**
PRODUCTION OF APPLICATION	480 m^3 per day or 157.680 m^3 per year of desalinated water TDS<50 ppm	30.000 m^2 for heating or equivalent	21,000 m^2 of space heating/cooling	**n/a**
COST OF APPLICATION (EURO)	**700.000**	**550.000***	**900.000**	**2.150.000**
TOTAL ENERGY PRODUCED SUBSTITUTED in MWh_{th}	**18.133**	**8.935**	**7.359**	**34.427**
TOTAL ANNUAL PRODUCTION COST in EURO	**129.546**	**91.770**	**236.632**	**454.948**
ANNUAL REVENUES BASED ON RECOMMENDED PRICES in EURO	**197.100**	**268.047**	**294.360**	**759.507**
ANNUAL PRE-TAX PROFITS	**67.554**	**176.277**	**57.728**	**304.559**
ANNUAL CAPITAL RECOVERY (50% of INITIAL INVESTMENT at 5% for 20 years)	**28.084**	**22.066***	**36.108**	**86.258**

Please note:
Annual Revenues are based on the following assumptions:

a) 1 kWhe purchased by PPC at 0,08 EURO (based on Greek Law)
b) 1 m^3 desalinated water sold to users at 1,25 EURO (based on private agreements)
c) 1 kWh_{th} (thermal energy for greenhouse or equivalent energy for space heating) sold at 0,03 EURO or 280 EURO/TOE (based on private agreements)

d) 1 $kWht_h$ or 1 kWh_c (heating/cooling) for heat pumps sold at 0,040 EURO (based on private agreements)

* Only the cost for the greenhouse geothermal energy supply system estimated at 5 € per m^2 of greenhouse, the cost for the construction of greenhouses is **not** included

A.2. Based on geological, geochemical, geophysical, drilling logging data and the geothermal reservoir conceptual model of Nisyros Isl. (Geotermica Italiana-PPC 1984) **the temperature of 99ºC** for the entering geothermal temperature (well-head temperature) **seams to be feasible especially in the region of the crater and possibly at numerous points of the rest of the island at depths of 350-400 m.** Therefore 2 boreholes (geothermal boreholes of at least 350m) with final diameters of 12-14" should be drilled. However, the possibility of the utilization of hot-spring waters should also be examined in this case.

The production wells, the reinjection wells, the heat exchangers and the piping conveying geothermal water compose the geothermal circuit and will be located either near "Paloi" village or near the location "Loutra". The Greenhouses will be located near "Paloi" village and the district heating system near "Loutra" in order to cover the heating/cooling needs for the spa centre.

A.2. – Nisyros Case 2 - Summary Table Case of 250 m^3/h at 99ºC

CATEGORY	BINARY CYCLE KALINA or ORC	THERMAL DESALINATION	GREENHOUSES (COST OF HEATING SYSTEM)	HEAT PUMP SYSTEM	TOTAL
NOMINAL POWER	700 kWe	2,3 MW_{th}	5,1 MW_{th}	2,1 MW_{th} COP 4,2 (Heating)	**700 kWe**
PRODUCTION OF APPLICATION	5.825.400 kWhe per year	480 m^3 per day or 157.680 m^3 per year desalinated water TDS<50 ppm	30.000 m^2 for heating	21,000 m^2 of space heating/cooling	**n/a**
COST OF APPLICATION (EURO)	**1.750.000**	**800.000**	**550.000***	**900.000**	**4.000.000**
TOTAL ENERGY PRODUCED SUBSTITUTED in MWh_{th}	**74.989**	**18.133**	**8.935**	**7.359**	**109.416**
TOTAL ANNUAL PRODUCTION COST in EURO	**183.120**	**132.546**	**91.770**	**236.632**	**644.068**
ANNUAL REVENUES BASED ON RECOMMENDED PRICES in EURO	**466.032**	**197.100**	**268.047**	**294.360**	**1.225.539**
ANNUAL PRE-TAX PROFITS	**282.912**	**64.554**	**176.277**	**57.728**	**581.471**
ANNUAL CAPITAL					

RECOVERY (50% of INITIAL INVESTMENT at 5% for 20 years)	**70.210**	**32.097**	**22.066***	**36.108**	**160.481**

B.1. Based on geological, geochemical, geophysical, drilling logging data and the geothermal reservoir conceptual model of Nisyros Isl. (Geotermica Italiana-PPC 1984) **the temperature of 120ºC** for the entering geothermal temperature (well-head temperature) **seams to be feasible to reach in the region of the crater and possibly at several points of the rest of the island at depths of 500 m.** Therefore a borehole (geothermal borehole of at least 500m) with final diameters of 12-14" should be drilled.

The production wells, the reinjection wells, the heat exchangers and the piping conveying geothermal water compose the geothermal circuit and **will be located in a position determined by a detailed geological-geophysical study**.

B.1. – Nisyros Case 3 - Summary Table Case of 120 t/h at 120 ^{o}C

CATEGORY	BINARY CYCLE KALINA or ORC	THERMAL DESALINATION	GREENHOUSES (COST OF HEATING SYSTEM)	HEAT PUMP SYSTEM	TOTAL
NOMINAL POWER	800 kWe	2,3 MW_{th}	5,1 MW_{th}	2,1 MW_{th} COP 4,2 (Heating)	**800 kWe**
PRODUCTION OF APPLICATION	6.657.600 kWhe per year	480 m^3 per day or 157.680 m^3 per year desalinated water TDS<50 ppm	30.000 m^2 for heating	21,000 m^2 of space heating/cooling	**n/a**
COST OF APPLICATION (EURO)	**2.800.000**	**800.000**	**550.000***	**900.000**	**5.050.000**
TOTAL ENERGY PRODUCED SUBSTITUTED in MWh_{th}	**58.060**	**18.133**	**8.935**	**7.359**	**92.487**
TOTAL ANNUAL PRODUCTION COST in EURO	**196.420**	**132.546**	**91.770**	**236.632**	**657.368**
ANNUAL REVENUES BASED ON RECOMMENDED PRICES in EURO	**532.608**	**197.100**	**268.047**	**294.360**	**1.292.115**
ANNUAL PRE-TAX PROFITS	**336.188**	**64.554**	**176.277**	**57.728**	**634.747**
ANNUAL CAPITAL RECOVERY (50% of INITIAL INVESTMENT at 5% for 20 years)	**112.336**	**32.096**	**22.066***	**36.108**	**202.606**

B.2. Based on geological, geochemical, geophysical, drilling logging data and the geothermal reservoir conceptual model of Nisyros Isl. (Geotermica Italiana-PPC 1984) **the temperature of 180ºC** for the entering geothermal temperature (well-head temperature) **seams to be feasible to reach in the region of the crater and possibly at a few points of the rest of the island at depths of 800 m.** Therefore 2 boreholes (geothermal boreholes of at least 800m) with final diameters of 12-14" should be drilled.

The production wells, the reinjection wells, the heat exchangers and the piping conveying geothermal water compose the geothermal circuit and **will be located in a position determined by a detailed geological-geophysical study**.

B.2. – Nisyros Case 4 - Summary Table Case of 150 t/h at 180ºC.

CATEGORY	BINARY CYCLE KALINA or ORC	THERMAL DESALINATION	GREENHOUSES (COST OF HEATING SYSTEM)	HEAT PUMP SYSTEM	TOTAL
NOMINAL POWER	2000 kWe	2,3 MW_{th}	5,1 MW_{th}	2,1 MW_{th} COP 4,2 (Heating)	**2.000 kWe**
PRODUCTION OF APPLICATION	16.644.000 kWhe per year	480 m^3 per day or 157.680 m^3 per year desalinated water TDS<50 ppm	30.000 m^2 for heating	21,000 m^2 of space heating/cooling	**n/a**
COST OF APPLICATION (EURO)	**6.000.000**	**800.000**	**550.000***	**900.000**	**8.250.000**
TOTAL ENERGY PRODUCED SUBSTITUTED in MWh_{th}	**116.058**	**18.133**	**8.935**	**7.359**	**150.485**
TOTAL ANNUAL PRODUCTION COST in EURO	**414.770**	**132.546**	**91.770**	**236.632**	**875.718**
ANNUAL REVENUES BASED ON RECOMMENDED PRICES in EURO	**1.331.520**	**197.100**	**268.047**	**294.360**	**2.091.027**
ANNUAL PRE-TAX PROFITS	**905.950**	**64.554**	**176.277**	**57.728**	**1.215.309**
ANNUAL CAPITAL RECOVERY (50% of INITIAL INVESTMENT at 5% for 20 years)	**240.720**	**32.096**	**22.066***	**36.108**	**330.990**

PERMITTING PROCEDURES

According to Framework Law 3175/2003 and Ministerial Decision Δ9Β/Φ166/οικ8411/ΓΔΦΠ2373/117 (May 6th 2005), a public tender should take place before any investor is authorized to proceed with an investment in geothermal energy. This authorization is needed both for field research as well as for field exploitation.

In the case of Scenario A1, the public tender is announced by the Secretary General of the Region. The process can be initiated after an interested investor files a letter of intent to the regional authorities. The successful bidder has 25-30 years rights to the assigned fields.

In the case of all other scenarios (which include electricity production), the tender is announced by the Development Minister. Every two years, the Minister receives a catalogue by the Regulatory Agency for Energy (RAE) with all candidate areas available for investments in geothermal power. Taking account of this catalogue, the Minister announces open bids for each area. Once again, the successful bidder has 25-30 years rights to the assigned fields. With regard to the research phase, the maximum timeframe is 5-7 years, and once the field proves to be exploitable, the bidder files a detailed feasibility study in order to proceed with the investment.

In the case of Nisyros, a critical detail is the exact coordinates of the field which has already been assigned to PPC (Public Power Corporation). PPC holds the rights to the crater area (caldera), and if any other investor wants to exploit this field, he has to cooperate with PPC. If one is interested in a field outside the jurisdiction of PPC, he has to follow the process that we described above (i.e. file a letter of intent to RAE and wait for an open bid).

It seems that nobody holds the rights to the fields on the four islets which are adjacent to Nisyros. However, since these islets are uninhabited, there is no way to utilize most of the thermal energy (i.e. one can only produce electricity and proceed with a thermal desalination unit. The advantage of thermal energy consumers is no longer valid).