PPCR S.A. planning for the development of the high temperature geothermal potential of the Aegean volcanic arc islands.

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Geothermal & Biomass Department
Head Geothermal Section

October 2020
“PPC Renewables S.A.” is an 100% subsidiary of PPC S.A.. Founded in 1998 with a portfolio of 50 RES projects of a total installed power of about 200 MW. PPCR S.A. is the unique Greek RES company active in all RES technologies (wind, solar, hydro, geothermal, biomass).

PPC S.A. is the biggest electricity producer and provider in Greece (50% of energy production and about 70% energy supply) and one of the biggest energy utilities in Europe. PPC Renewables is the development branch of the group in the area of renewable energy sources, with an ambitious expansion plan in the near future.

**2020**
- 200 MW
- 450 GWh
- 495 kt
- 28 W/P
- 17 PV stations
- 17 SHPP
- 33 M€

- ~30 TWh by fossil fuel plants, hydro power plants and autonomous island oil plants
- ~11 GW of fossil fuel plants, hydro power plants and autonomous island oil plants
- ~4 bn € of total annual revenues

Personnel of PPC Group: ~15,000
Personnel of PPC Renewables S.A.: ~70
PPC Renewables - Mature Projects Portfolio

Operating

Constructing/tendering

Wind

Solar

SHPP

160MW

110MW

/350MW

2GW PV Mega projects

4GW Wind Mega projects
Fuel Mix, Greece [MW]
- RES: 28%
- Hydro: 15%
- NG: 26%
- Oil: 9%
- Lignite: 22%

Fuel Mix, PPC [MW]
- RES: 28%
- Hydro: 25%
- NG: 23%
- Oil: 15%
- Lignite: 36%
Electricity Transmission Network in Greece

Development of the Hellenic Electricity Transmission System (HETS)

Ten-year (2019 – 2028) Network Development Plan map


Source: Independent Power Transmission Operator S.A.
https://www.admie.gr/en
## Electricity generation cost – not interconnected islands

<table>
<thead>
<tr>
<th>Island</th>
<th>Installed Capacity [MW]</th>
<th>Costs €/MWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milos-Kimolos</td>
<td>20,60</td>
<td>146,20</td>
</tr>
<tr>
<td>Kos – Kalymnos</td>
<td>124,45</td>
<td>107,43</td>
</tr>
<tr>
<td>(Nisyros)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lesvos</td>
<td>84,41</td>
<td>115,60</td>
</tr>
<tr>
<td>Mykonos</td>
<td>62,16</td>
<td>262,06</td>
</tr>
<tr>
<td>Santorini</td>
<td>71,92</td>
<td>159,72</td>
</tr>
<tr>
<td>Crete</td>
<td>813,02</td>
<td>162,26</td>
</tr>
</tbody>
</table>
Electricity generation cost – not interconnected islands

Not interconnected islands
Data for 2016

Installed power
Oil-fueled Power Plants

Mean Production Cost
(€/MWh)

Interconnected by September 2020
Electricity generation cost – lignite

Lignite generation costs differ substantially across Europe with Greece exhibiting the highest cost of around 60 EUR/MWh, mainly due to structural differences (calorific value of lignite).

**Full Lignite Generation Costs (2012)**

<table>
<thead>
<tr>
<th>Country</th>
<th>EUR / MWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>Germany</td>
<td>67.85</td>
</tr>
<tr>
<td>Czech Republic</td>
<td>52.05</td>
</tr>
<tr>
<td>Poland</td>
<td>65.30</td>
</tr>
<tr>
<td>Romania</td>
<td>69.38</td>
</tr>
<tr>
<td>Bulgaria</td>
<td>41.63</td>
</tr>
<tr>
<td>Serbia</td>
<td>45.68</td>
</tr>
<tr>
<td>Turkey</td>
<td>92.62</td>
</tr>
<tr>
<td>Greece (PPC)</td>
<td>77.82</td>
</tr>
</tbody>
</table>

**System Average (EUR / MWh)**

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Germany</td>
<td>53.60</td>
</tr>
<tr>
<td>Czech Republic</td>
<td>38.97</td>
</tr>
<tr>
<td>Poland</td>
<td>38.60</td>
</tr>
<tr>
<td>Romania</td>
<td>54.19</td>
</tr>
<tr>
<td>Bulgaria</td>
<td>31.57</td>
</tr>
<tr>
<td>Serbia</td>
<td>40.32</td>
</tr>
<tr>
<td>Turkey</td>
<td>52.73</td>
</tr>
<tr>
<td>Greece (PPC)</td>
<td>59.93</td>
</tr>
</tbody>
</table>

Source: Euracoal, IEA, EEX, Eurostat, Annual reports, Debriv, UDI, Statistical Office of Serbia, Turkish Statistical Institute, Niemann-Deilus et al, Achlada, M.E.T.E, PPC, Booz & Company Analysis

Booz & Company
Prepared for PPC
LCOE of geothermal power projects by technology and project size, 2007-2021

Development and distribution of the volcanic intrusions;
A is showing the age data of the orogenic volcanics and plutonics while B shows the age data of the alkaline volcanics. 
C-A = calc-alkaline, 
Sho = shoshonitic, 
U-K = ultra potassic, 
SAAVA = South Aegean Active Volcanic Arc.
Stars mark the occurrence of U-K magmas.
Volcanism development in the Aegean area

Distribution and different types of magmatism reveal the trend in volcanic activity over time and the change from N to S.

**Black-grey arrows** = subduction-related products; **Blue** = potassic alkali basalts; **Red** = sodic alkali basalts; **Green** = crustal related magmas. **C-A** = calc-alkaline; **HK C-A** = high potassium calc-alkaline; **Sho** = shoshonitic; **U-K** = ultra potassic; **Rhy** = rhyolites

Geothermal regions in Greece

1. Milos – Kimolos – Plyaigos island group
2. Nisyros island
3. Lesbos island
4. Methana region
PPC/PPCR’s Major Geothermal Milestones

- 1973: Beginning of exploratory drilling for Geothermal Fields
- 1998: Founding of PPC Renewables S.A.
- 2006: Transfer of all PPC’s RES assets to PPC Renewables S.A.
- 2011: Transfer of geothermal rights from PPC to PPCR

Pic.1: Milos - Zefyria 1986
Pic.2: Milos - Zefyria 2011
A 5 MW geothermal plant is planned. With the full field development, and after connecting to Syros, this plant can cover most of the Cyclades’ energy demand. PPCR has leased the right to explore and develop the field until 2025 – The license can be extended for an additional 20-year period.

Capacity in MW (based on the relevant Ministerial Decisions)/ Production output: 5 MW/ 41,600 MWh

Maximum Temperature: 323°C

Maximum Depth of wells drilled: 1,381 m

Number of deep wells drilled: 5

Estimated depth of exploitable fluid: 1,000 – 1,500 m

Interconnection infrastructure: Interconnection Milos-Kimolos with aluminum cables 4X50 (max 5MW)

1) Verified by magnetotellurics and production tests
Current situation

- Since 1973, there have been:
  - More than 130 studies performed
  - 5 productive wells of 1,000 – 1,800 m depth were drilled
  - Installation (in 1986) of a 2 MW pilot geothermal unit, which operated for 2 years (generated 6 TWh)

- Over the two years of the plant’s operation, there were no signs of decay in the drillings

- Current activities include:
  - Informing the local community and obtaining formal social consensus which is not yet achieved
  - Promoting a 5 MW geothermal power unit

- An AMT/MT study has been completed in 2010 by “MANVIT S.A.”

Next steps

- For the full development of the field, connection to the grid of the Cyclades is required
Measured Temperature 280° C – 320° C
- Reservoir depth 1000 – 1380 m
- Production 339 ton/h Fluid:
  - 200 ton/h gas phase (saturated steam)
  - 139 ton/h liquid phase (hot water)
- Pressure 11 – 29 atm

<table>
<thead>
<tr>
<th>Sample</th>
<th>El. Conductivity μS/cm</th>
<th>pH</th>
<th>T.D.S</th>
<th>Ca</th>
<th>Mg</th>
<th>Na</th>
<th>K</th>
<th>CO3</th>
<th>HCO3</th>
<th>Cl</th>
<th>SO4</th>
<th>SiO2</th>
<th>Al</th>
<th>B</th>
<th>Fe</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>M-1</td>
<td>135.000</td>
<td>4.3</td>
<td>120.000</td>
<td>4750</td>
<td>14</td>
<td>33500</td>
<td>8700</td>
<td>0</td>
<td>68000</td>
<td>60</td>
<td>1000</td>
<td>0</td>
<td>87</td>
<td>47.3</td>
<td>3</td>
<td></td>
</tr>
</tbody>
</table>
Overview of Kimolos geothermal area (1/2)

**Geographic position**

**Overview**

- The possibility of a 5 MW power plant is under investigation
- PPCR has leased the right to research and develop the field until 2025. The license can be extended for an additional 20-year period

**Field characteristics**

| Capacity in MW (based on the relevant Ministerial Decisions)/ Production output | 5 MW/ 41,600 MWh |
| Maximum Temperature$^{1)}$ | Temperature is expected to be higher than 160°C |
| Number of deep wells drilled | - |
| Shallow exploration wells drilled | PPCR has drilled 8 temperature gradient slimholes and 2 shallow wells to feed desalination facilities (wells’ depth ~200m, max temperature 70 °C) – Temperature for the deep reservoir is estimated to be higher than 160 °C |
| Estimated depth of exploitable fluid$^{1)}$ | 1,200-1,400 m |

$^{1)}$ Magnetotellurics’ estimate
Overview of Kimolos geothermal area (2/2)

Current situation

- Currently the island is under exploration
- Social consensus is not yet achieved
- An application license has been submitted to RAE for a 5MW plant
- An AMT/MT study has been completed in 2010 by “MANVIT S.A.”

Next steps

- Construction of deep exploration – production drill holes
Overview of Nisyros geothermal area (1/4)

Geographic position

Overview

> Nisyros has the second largest geothermal field (enthalpy-wise) in Greece
> At this phase, a 5 MW plant will be developed at Aghia Eirini
> PPCR has leased the right to explore and develop the field until 2026 – The license can be extended for an additional 20-year period

Field characteristics

- **Capacity in MW (based on the relevant Ministerial Decisions)/ Production output**: 5 MW/ 41,600 MWh
- **Maximum Temperature**: 350° C
- **Depth of wells drilled**: 1,816 m
- **Number of deep wells drilled**: 2
- **Estimated depth of exploitable fluid**: 1,500 – 2,500 m

Interconnection infrastructure

Interconnection of 9 islands (Lipsi-Leros-Kalimnos-Tenedos-Pserimos-Kos- Giali-Nisyros-Tilos)
Nisyros-Kos coppers cable 3X 35 (max 10 MW)

1) Verified by geophysical survey and production tests
Current situation

- An application license has been submitted to RAE for a 5 MW plant
- The land-owners are in agreement with the idea of long-term lease contract
- The local community could accept a project of this scale
- No social consensus achieved yet
- New wells will be drilled to the known reserve from the projected new plant position

Next steps

- Signing of contracts for the long-term lease of the required land
- 3D geophysical study (MT/AMT)
Overview of Nisyros geothermal area (3/4)

- Fault zones
- Deep geothermal wells
- Fault
- Planned 5 MW Geothermal Power Plant
Chemical composition of the Nisyros geothermal fluids (mg/l)

### Liquid Phase

<table>
<thead>
<tr>
<th>Sample</th>
<th>El. Conductivity $\mu$S/cm</th>
<th>pH</th>
<th>T.D.S</th>
<th>Ca</th>
<th>Mg</th>
<th>Na</th>
<th>K</th>
<th>CO3</th>
<th>HCO3</th>
<th>Cl</th>
<th>SO4</th>
<th>SiO2</th>
<th>Al</th>
<th>B</th>
<th>Fe</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>N-2</td>
<td>135.000</td>
<td>4.9</td>
<td>117.000</td>
<td>9670</td>
<td>103</td>
<td>28470</td>
<td>3783</td>
<td>-</td>
<td>-</td>
<td>66390</td>
<td>32.6</td>
<td>842</td>
<td>-</td>
<td>55</td>
<td>8.2</td>
<td>1.4</td>
</tr>
</tbody>
</table>

### Gas Phase (Steam)

<table>
<thead>
<tr>
<th>Sample</th>
<th>$%_v$ vol</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$H_2$</td>
</tr>
<tr>
<td>N-2</td>
<td>0.1</td>
</tr>
<tr>
<td>N-1</td>
<td>1.4</td>
</tr>
</tbody>
</table>

- Measured Temperature > 350$^\circ$ C
- Reservoir depth 1400 – 1900 m
- Production 75 ton/h Fluid
  - Ratio Gas/Liquid: 27/73
- Pressure 12 atm
Overview of Lesvos geothermal area (1/3)

Geographic position

Overview

> PPCR has leased the right to explore and develop the geothermal potential of the leased area until 2027
> The license can be extended for an additional 20-year period

Field characteristics

<table>
<thead>
<tr>
<th>Capacity in MW (based on the relevant Ministerial Decisions)/ Production output</th>
<th>8 MW/ 66,500 MWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Temperature measured / estimated</td>
<td>105° C / 160° C</td>
</tr>
<tr>
<td>Maximum Depth of wells drilled</td>
<td>1,410 m</td>
</tr>
<tr>
<td>Number of deep wells drilled</td>
<td>2</td>
</tr>
<tr>
<td>Estimated depth of exploitable fluid</td>
<td>2,500-3,500 m</td>
</tr>
</tbody>
</table>

Interconnection infrastructure

Not interconnected

1) Estimate from Magnetotellurics and exploration drilling results
Current situation

- An exploration well (Σ-1) of 1,410 m was completed, without detecting satisfactory temperature values
- Approval of environmental terms for exploration drilling works has been granted
- Specifications for exploration drilling works (deep geothermal wells) have been prepared

Next steps

- New additional geophysical survey (MT/AMT, gravity and high-resolution DC-Resistivity)
- Composite tectonic study and 3D modeling with emphasis on tectonic structures, to determine positions of the new exploration wells
- Deep well drilling, selection of contractor
Overview of Lesvos geothermal area (3/3)

Lesvos Island

Legend
- Geothermal Concession
- Favourable areas
- Current exploration area
Overview of Methana geothermal area (1/2)

**Geographic position**

The geothermal area of Methana is not yet fully explored – No geothermal field has been proven yet, however there is strong evidence (from geophysical survey) for high geothermal potential.

**Field characteristics**

- **Capacity in MW (based on the relevant Ministerial Decisions)/ Production output**: 5 MW/ 41,600 MWh
- **Maximum Temperature**
  - Temperature is expected to be higher than 150°C
- **Number of deep wells drilled**
  - 
- **Shallow exploration wells drilled**
  - PPCR has drilled 10 temperature gradient wells (depth approx. 200 – 250 m; temperature of 60 °C)
- **Estimated depth of exploitable fluid**
  - 2,000-3,000 m
- **Interconnection infrastructure**
  - The Geothermal Power Plant can be connected directly with mainland’s grid (400 kV)

1) Magnetotellurics’ estimate
Current situation

> 8 exploration studies have been conducted since 2000
> PPCR received required approval of environmental terms
> 11 shallow exploratory slimholes (max. depth 250 m) have already been drilled
> 2D magneto telluric (MT) study and Approval of Environmental Terms for drillings up to 300m
> A re-evaluation of the geophysical (AMT / MT) studies by Prof. E. Lagios (Univ. of Athens) was conducted for the precise location of the boreholes
> The Local Authorities are aware of PPCR plans and have a positive attitude
> Characterization as archaeological site has postponed development and additional licenses are required

Next steps

> An exploration well (depth approx. 1,000 m) will be drilled
> Construction of an exploration well of 2,000 m depth will follow
In June 2017 PPCR has published a call (Eoi) to find a partner to co-develop the Geothermal Power Plants that will be installed at the leased geothermal areas (Milos-Kimolos-Polyegos, Nisyros, Lesvos and Methana).

Seven (7) Expressions of Interest were submitted, indicating the strong interest of the international and local market to partner with PPC Renewables S.A. (PPCR) in this unique project for Greece, one of the few untapped high-enthalpy Geothermal projects in Europe.

During Phase B, eligible partners were granted access to the terms and conditions of the Selection Process as well as available information about the Geothermal Power Plants Project and the Transaction.

In April 2018, the eligible partners were called to submit Binding Offers (Request for Proposals)

Only HELECTOR S.A. and TERNA ENERGY – TERNA AIOLIKI XEROVOUNIOU submitted offers.
After evaluating the offers, in August 2018, HELECTOR S.A. was declared the Preferred Partner.

In March 2020 the Ministry of Energy and Environment approved the establishment of the Company “Geothermal Target II”, as a 100% subsidiary of PPCR.

HELECTOR S.A. will acquire 51% of “Geothermal Target II”

The geothermal rights (construction of production and reinjection wells as well as management of the geothermal reservoirs) remain the sole responsibility of PPCR.

Geothermal Target II will plan, finance, construct and operate the geothermal power plants on the above areas.

The agreement will enter into force after approval by the Greek Competition Committee.
Challenges

> Geothermal potential sufficient for electricity production is proven only on Milos and Nisyros

> On Lesvos there are strong indications for a high temperature reservoir, which has not been yet confirmed by exploration wells

> On Methana exploration is still on an early stage, no deep exploration wells have been drilled

> The main issue on Milos and Nisyros is the lack of social acceptance for the projects

> Energy demand on the not interconnected islands can be very low in the winter months
Initial 5 MW geothermal power plants are planned on each one of the above regions.

The interconnection of Milos island to the main grid will solve the low demand problem of the winter period. Estimated date for the interconnection of Milos is the year 2025.

At a later stage, the installed power can be increased, as the operation of the initial power plants will provide a deeper knowledge of the local geothermal systems.
Implementation plan

> Development of a communication policy involving the local community from the initial stages of the project and addressing problems with participation of the residents.

> In addition to electricity generation, thermal energy will be available for direct use in a number of applications such as agricultural, spa, heating/cooling, etc.

> Geothermal desalination could be a solution to the freshwater scarcity on the islands.

> In order to achieve social consensus, thermal applications are sought to be developed in collaboration with local municipalities.
Thank you for your attention!
Any questions?

Energy is in our nature