Geothermal Energy - how does it stack up in the Future Energy Mix?

Veli Losinj - August - 2014
World Future Energy Mix

- For starters - A Look around the World:
  - How do we fuel our future energy needs?
  - Is the world running out of oil or natural gas?
  - What is the favored form of energy?
World Risks

- Ukraine-Russia Tensions
- Middle East Unrests
- Libya Conflicts
- Fundementalist Uprising
- Yemen-Tribal Conflicts
- Argentina Financial Crisis
World Risks

- How can we secure sufficient, affordable energy supply in a world of economic crisis and political unrest?

- ... but is the world really affected by it?
Oil prices have been **essentially stable** at around the 100 – 115 USD/bbl bandwidth for the last 5 years.

Major oil price spikes like the one in 2008 **have not reoccurred** as a consequence of past and present political uncertainties.
Capex on the rise...

- With oil prices largely flat over the last 5 years, costs are rising faster than revenues
- E+P Capex per barrel are on a 11% p.a. increase
- A number of projects are consequently deferred, shelved or in for re-assessment

**Compound Annual Growth Rate of E+P Capex/bbl**

- 0.9% CAGR (1985-1999)
- 10.9% CAGR (1999-2013)

*Source: IEA, Barclays Research*
Major oil and gas firms cutting on Capex ...

- Capital discipline became now a key issue for Majors
- Cash flow growth supersedes production growth
- Substantial downward revision since Oct-13 outlook
- Oil majors face challenging investment climate
- → impact obvious: supply shortening!
Global gas price developments

- Over a decade, prices for natural gas markets around the world were essentially following an identical, converging development.
- Then, in mid 2008, different markets developed into a large spread between Japan’s prices being highest (16 USD/Mcf), closely followed by Europe (12 USD/Mcf) and depressed prices in North America (4 USD/Mcf at Henry Hub).
- ... what happened?
US Unconventional Gas

- A rush has set in at ~2008 in the US to develop the resource ‘Tight Gas Sands’ and ‘Shale Gas’
- While this continues to succeed in the US, other parts of the world have so far not been able to duplicate the story despite large resources are believed to exist elsewhere
- The downside: prices collapsed in North America (Henry Hub Spot – USD/Mcf)
What first looked too good to be true has meanwhile become a fact, which will make the US not only fossil fuel independent, but will also allow them in future to export natural gas (as LNG) and eventually even crude oil.

Source: ExxonMobil
World Production Forecasts

- Including all type of energy (fossil, nuclear and renewables), in a span of 50 years (1990-2040) the world is expected to double its energy production (and demand) from **175 to almost 350 BOE per day**

Source: ExxonMobil
World Production Forecasts (by regions)

- Within these 50 years, the largest energy growth is expected to occur in Asia (lead by China), followed by the Middle East and Africa, while the OECD countries will have stagnating or dropping energy demands.

Source: ExxonMobil
World Production Forecasts

- While fossil fuels will continue to provide the bulk of the energy supply, renewable energies are expected to show only a moderate increase from 12% (1990) to 15% (2040) in the overall energy production.

*Source: ExxonMobil*
World Production Forecasts (by types)

- With crude oil production presently (2014) just shy of the **100 MM boepd**, natural gas will show the strongest increase in energy contribution, while coal supply will peak around 2025

**World Energy Production (separate by type)**

Daily Total Energy Production
[in MM BOE per day]

Source: ExxonMobil
World Gas Reserves and Resources

- With ‘Peak Oil’ for crude being a myth and Reserves Life Index (RLI) on gas > 60 years for Proven Reserves only, their seems no imminent danger of shortage in fossil hydrocarbon fuels.

- The before mentioned generalized statements need to be analysed in more granularity for different areas and markets, as North America (US/Canada) and Europe (EU28) behave differently.

Source: ExxonMobil
Regional energy mix trends – the USA

Even gains across the entire energy mix

Growth in nuclear and hydro power are slower

US Energy Consumption - 2008-2035

Source: EIA Energy Outlook
Oil remains strong in the US
Fossils remain strong in EU28 energy mix

- Fossil fuels strong but are losing
- Renewable are strongly gaining
  *(unfortunately, also nuclear rising...)*
... but renewables are on the rise!
Recent geopolitical events have rekindled the quest for energy independence of Europe.

At present (2014), Russia still provide over 1/3 of the gas supply to EU28.

What are the options for an alternate energy supply for EU28, (if any)?

Source: WoodMacKenzie
Central Asian Gas for Europe?

- 30+ B m³/yr will try to get to Western markets by 2020
Central Asian Gas for Europe?

• By 2050, it will be 60-80 B m3/yr
• Turkmen gas will go East – not West!
• With EU28 importing 150 B m3/a from Russia (2014), the gap is 70 B m3/a...
So much about the **Energy Supply to the World** (which is obviously not yet running out of fossil fuels)

But how do the **Renewable Energies** perform in this competition?
Germany on track for a new record in 2014

Press Release 12-Aug-2014:

- Germany’s renewable energy sector touched a new record in the first half of 2014, according to the Fraunhofer institute.

- Renewable energy sources generated 81 TWh in the first half of 2014, accounting for 31% of the nation’s electricity. Solar and wind power had a contribution of 45 TWh or 17%, spurring production by 28% respectively 19%. The again happening record in Germany’s renewables proves the incredible success of Germany’s EEG legislation. In total, renewable energy production certainly surpassed power production from lignite (69.7 TWh), the single most important energy source. Electricity exports increase one more time by 27% to 18.3 TWh. If this trend is continuing, Germany would hit the third electricity export record in 2014 after already touching records in 2012 and 2013. Its main customers have been the Netherlands, followed by Austria, Switzerland, and Poland.
Effect and Efficiency of FITs - Germany

- **The Rise and Rise**
  - After the adoption of Feed-In Tariffs (FIT) including their revisions the Renewable Power Industry is increasingly investing and will soon exceed 100,000 MW installed capacity;
  - Germany produces some 32% of its energy demand from renewable sources; over 300,000 people are employed in the renewables industry which has an annual turnover of ~40 Billion EUR.
  - The Nuclear Exit strategy has provided a large boost to renewables, although coal power generation plants were also on the comeback.

![Installed Capacity Graph](Image)

*Source: BP Statistical Review of World Energy 2013*
Effect and Efficiency of FITs - Denmark

- The Rise, Fall... and Rise
- Development of Feed-In Tariffs (FIT) helped the Renewable Power Industry to progressively invest into over 3,200 MW installed production capacity; with the abolishment of the FIT in 2004 (due to changes in the political landscape), investment stagnated... as adverse developments were obvious, policy was revised, causing revival of investments
- Denmark supplies 28% of its energy from renewable sources; 21,000 people are employed in this industry which has an annual turnover of 37 Billion USD.
- For 2030, Denmark plans installation of 10,000 MW PV+Wind plants

Source: John Farrell (2009) ‘Feed-In Tariffs in Amerika’ Heinrich Böll Foundation
Selected Feed In Tariffs

- After unsuccessfully toying with tax cuts, grants and subsidies, many countries around the world have adopted **Feed-In Tariff (FIT)** systems to entice small Private Power Plants (PPPs) and renewable energy generation.

- Solar (photovoltaic) seems to be favoured with high FITs while geothermal remains at an average (except in few countries, where indicated).
Feed-In (FIT) vs Renewable Electricity Standard (RES)

- Europe (FIT) and USA (RES)
- A single source of revenue for energy makes the financing of renewable energy projects in Europe much simpler:

A typical energy sales and purchases contract between an industrial power provider and a utility company has 85 pages in the US – in Germany, it has between 2 and 4...

Source: John Farrell (2009) ‘Feed-In Tariffs in Amerika’ Heinrich Böll Foundation
Feed-In (FIT) vs Renewable Electricity Standard (RES)

- **Project Financing and Economics**
  - An FIT based project is much simpler to finance and decision making is straightforward – the paper trail for other cases is quite complex:

- **Feed-In Tariff (FIT):**

- **Renewable Electricity Standard (RES):**

Source: John Farrell (2009)  
‘Feed-In Tariffs in Amerika’  
Heinrich Böll Foundation
Cost - Benefit

FIT based energy supply shows a very robust cost vs benefit ratio: Germany benefits from the continued support of renewable energy producer with a net benefit by a factor of 3

Source: John Farrell (2009) ‘Feed-In Tariffs in Amerika’ Heinrich Böll Foundation
Energy Market Access – FIT vs RES

- Feed-in Tariffs (FIT):
  - Prices are **politically** determined
  - Quantities are **market** determined

- Renewable Electricity Standard (RES):
  - Prices are **market** determined
  - Quantities are **politically** determined

→ purely market oriented contracting is a myth!

*Neither the FITs nor the Green Certificate/Renewable Electricity Standard (RES) approach are inherently more “market oriented”*

- **However:**
  The Green Certificates/RES approach favors corporate ownership structures, which may lead to NIMBYism (or even BANANA) *)

*) **NIMBY = not in my back yard**
   **BANANA = build absolutely nothing anywhere near anyone**
Geothermal vs Other Power Generation Systems

- at present, only **small plant sizes** possible (limited by mass flow)
- electrical efficiency **still low** but in range of small steam turbines
- *Technical Improvements? → Technology S-Curves...*
Technology S-Curves (theory)

- Technology S-Curves represent the “learning curve” of an industry
- **Effort** (=cumulative expenditure) is plotted vs a **Performance Indicator** (=efficiency, cost per unit produced, etc.)
- Deviations from the S-Shape can be caused by onset of a Second (Generation) Technology indicated either by
  - an offset, similar shaped S-curve with an improved final performance or
  - a steeper inclination of the S-curve (faster “learning”, less effort)

Source:
Technology S-curves in renewable energy alternatives: Analysis and implications for industry and government
Melissa A. Schilling, Melissa Esmundo
(Stern School of Business – Feb-2009)
Technology S-Curves in Renewable Energy

Wind Energy

Geothermal Energy

Geothermal energy has **largest potential** of all renewable energies for fast and further improvement of technological efficiency

Source:
Technology S-curves in renewable energy alternatives: Analysis and implications for industry and government
Melissa A. Schilling, Melissa Esmundo
(Stern School of Business – Feb-2009)
Valuation of Geothermal Projects

- A **risked valuation** of (geothermal) projects provides a method to
  - model contractual conditions
  - valuate reserves
  - assess risks expressed as economic indicators (NPV, PO, ROR, etc)

- Proven and Probable Reserves can be **valued and financed**
- Possible Reserves and Resources can be **valued but not financed**
Reserves and Resources Definition

- Society of Petroleum Engineers (SPE) has developed a Hydrocarbon Reserves and Resource Classification, which is meanwhile globally adopted by the industry, banks and stock exchanges.
- It is suggested, that the Geothermal Industry should adopt a similar classification for its Geothermal Reserves and Resource base.

Source: SPE - Guidelines for Application of the Petroleum Resources Management System November 2011
Reserves and Resources - Example

- Drilling technology and costs largely dictate cut-off between Geothermal Reserves and Resources (presently at +/- 7,000 m). Changes in energy cost environment shift limits up or down!
Example - Well Costs and Resource Temperature

- Estimate of Well Costs
- Depending on depth, wells represent ~50% of CAPEX...

**Well Cost and Temperature**
(normal geothermal gradient; avg 2012 costs)

- **Depth [m]** vs. **Temp [°C]** vs. **Cost [MM USD]**

*Example*
Well Costs and Other Project Costs Assumptions

- Well Costs are **dominating cost element** (~50%)
- Capital Expenditures will vary with project type, location
- Used example is for an average geothermal power project with well depths at ~3,500 m well
## Geothermal Project Economics – Assumptions (1)

<table>
<thead>
<tr>
<th>Base Assumptions</th>
<th>Fill in value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Parameter</strong></td>
<td><strong>Calculated</strong></td>
</tr>
<tr>
<td>Depth of the well</td>
<td>3,500 [m]</td>
</tr>
<tr>
<td>Geothermal gradient</td>
<td>0.038 [K/m]</td>
</tr>
<tr>
<td>Reservoir temperature</td>
<td>133.0 [°C]</td>
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<tr>
<td>Flow of the well</td>
<td>115.0 [l/s]</td>
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<tr>
<td>Well head temperature</td>
<td>128.1 [°C]</td>
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<tr>
<td>Reinjection temperature</td>
<td>55.1 [°C]</td>
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<tr>
<td>Conversion efficiency thermal power</td>
<td>96.0 [%]</td>
</tr>
<tr>
<td>Full load hours per year</td>
<td>8,000 [h]</td>
</tr>
<tr>
<td>Thermal Power</td>
<td>33.7 [MW]</td>
</tr>
<tr>
<td>Thermal Energy</td>
<td>269.8 [GWh]</td>
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<tr>
<td>Heating hours per year</td>
<td>3,200 [h]</td>
</tr>
<tr>
<td>Heating energy per year</td>
<td>107.9 [GWh]</td>
</tr>
<tr>
<td>Annual growth heat sales</td>
<td>2.0 [%p.a.]</td>
</tr>
<tr>
<td>District heating wholesale price per MWh</td>
<td>55.0 [EUR]</td>
</tr>
<tr>
<td>Electricity per year</td>
<td>19.4 [GWh]</td>
</tr>
<tr>
<td>Received price per MWh electricity sold</td>
<td>190.0 [EUR]</td>
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<tr>
<td>Size of electric power station</td>
<td>3.5 [MW]</td>
</tr>
<tr>
<td>Total Investment</td>
<td>31.2 [MM EUR]</td>
</tr>
<tr>
<td>Conversion efficiency electric power</td>
<td>12.0 [%]</td>
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<tr>
<td>Price increase for electricity bought</td>
<td>4.0 [%p.a.]</td>
</tr>
<tr>
<td>Price increase general costs</td>
<td>3.0 [%p.a.]</td>
</tr>
<tr>
<td>Price of CO₂ Emission</td>
<td>5.0 [EUR]</td>
</tr>
</tbody>
</table>

**Olympic Pool** 3,125 [m³]

**Capacity of 1 W = 1.16222 [kcal/h]**
### Geothermal Project Economics – Assumptions (2)

#### CAPEX

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Depreciation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drilling</td>
<td>15.0 [MM EUR] 30 [yrs]</td>
</tr>
<tr>
<td>Drilling reserve</td>
<td>0.5 [MM EUR] 30 [yrs]</td>
</tr>
<tr>
<td>Building &amp; land</td>
<td>1.0 [MM EUR] 15 [yrs]</td>
</tr>
<tr>
<td>Pump</td>
<td>1.6 [MM EUR] 5 [yrs]</td>
</tr>
<tr>
<td>Heating redundancy</td>
<td>1.0 [MM EUR] 5 [yrs]</td>
</tr>
<tr>
<td>Heating pipeline</td>
<td>3.0 [MM EUR] 30 [yrs]</td>
</tr>
<tr>
<td>Electric power station</td>
<td>8.0 [MM EUR] 20 [yrs]</td>
</tr>
<tr>
<td>Other</td>
<td>1.1 [MM EUR] 5 [yrs]</td>
</tr>
<tr>
<td><strong>Total CAPEX € million</strong></td>
<td><strong>31.2 [MM EUR]</strong></td>
</tr>
</tbody>
</table>

#### OPEX

<table>
<thead>
<tr>
<th>Parameter</th>
<th>[M EUR p.a.]</th>
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<tbody>
<tr>
<td>Increase in provisions</td>
<td>48.0</td>
</tr>
<tr>
<td>Material and third party costs</td>
<td>2,000.0</td>
</tr>
<tr>
<td>thereof electric power</td>
<td>1,000.0</td>
</tr>
<tr>
<td>thereof oil</td>
<td>0.0</td>
</tr>
<tr>
<td>Personnel costs</td>
<td>100.0</td>
</tr>
<tr>
<td>Other operating expenses</td>
<td>500.0</td>
</tr>
<tr>
<td>Other operating</td>
<td></td>
</tr>
<tr>
<td>Start up costs</td>
<td>1,000.0</td>
</tr>
<tr>
<td>Maintenance</td>
<td>2.0</td>
</tr>
<tr>
<td><strong>Total OPEX</strong></td>
<td><strong>4,650.0</strong></td>
</tr>
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</table>
Geothermal Project Economics – Results

<table>
<thead>
<tr>
<th>Results</th>
<th>BT</th>
<th>AT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Internal rate of return (ROR)</td>
<td>20.4%</td>
<td>17.2%</td>
</tr>
<tr>
<td>Net present value (NPV)</td>
<td>52.1</td>
<td>39.3</td>
</tr>
<tr>
<td>Pay back period</td>
<td>6.6</td>
<td>7.8</td>
</tr>
</tbody>
</table>

- Detailed Economics include inflation, depreciation, before (BT) and after tax (AT) results
- Example shows very satisfactory economics → **but don’t forget assumptions made!**
Geothermal Project Economics - Sensitivities

Sensitivities Geothermal Projects

- most sensitive parameter: temperature difference across process (inlet vs outlet temperatures)
What is Geothermal Energy up against?

- Globally, **coal will remain dominant** on short term
- **Gas will eventually replace oil** – but ‘Peak Oil’ is a myth
- Despite Fukushima, **nuclear returns** (selective amnesia!)
- “**CCC” - Carbon Credit recovering** (a good chance to clean air)
- **Renewables will grow** – some places faster than others
- **Energy efficiency** is on the rise (car mileage, heating)
- Regionally, differences depend on geographic location, infrastructure, distance to resource → **no uniform picture!**
Geothermal in the Future Energy Mix - Summary

- Geothermal Energy has large potential to increase efficiency by technological advancements → technological developments can (and will) improve situation
- Low Enthalpy geothermal energy needs cascading heat recovery to be economic → pure electricity generation (without direct heat use) will likely result in marginal economics
- Electricity generation requires favorable investment environments → supportive FIT schemes are growing globally
- Projects must become and remain financeable → clear and de-mystified definition of reserves and resources
- Comparison to nuclear power generation needs transparency and fairness → full cycle economics for nuclear fuels to include spent fuel storage and plant dismantling costs
- Rise and maintain reputation of Geothermal Energy → no corner cutting and ‘cheap solutions’
Rise and maintain reputation of Geothermal Energy ➔ no corner cutting and ‘cheap solutions’
Thank You