Status of Geothermal Resource Classification & Key Stakeholders

Prof. Dr. Gioia Falcone
Institute of Petroleum Engineering
Dept. of Geothermal Engineering & Integrated Energy Systems

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Outline

- Need for Geothermal Classification Standards
- Updated Review of Geothermal Classification Schemes
- Lessons Learnt from the Oil & Gas Sector
- Geothermal Hand-in-Hand with Renewables?
- Conclusions
Need for Geothermal Classification Standards
Is it Possible to Enforce ‘THE GOAL’?

Standards?
Rules?
Guidelines?
Codes?
Protocols?

Flexibility increases uncertainty

Greater uncertainty = greater risk to investor

Less confidence in geothermal development
Multiple End-Users … Can They Agree?

- Governments
- Policy Makers
- Field Owners, Operators
- Investors
- Reserves Auditors
- Insurance Companies
- International Energy Associations, Agencies, Councils
What is the Geothermal Target?

- Source?
- Reservoir?
- Fluids?
- Stored heat?
- Recoverable volume?
- Recoverable heat?
- Recoverable power?
- ....or simply the net $$$?
Review of Geothermal Classification Schemes
McKelvey diagram for geothermal energy (Muffler and Cataldi, 1978)
### Status of Geothermal Resource Classification & Key Stakeholders

By Temperature, Use, Type & Status

<table>
<thead>
<tr>
<th>Low Temperature Resources</th>
<th>High Temperature Resources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct Use</td>
<td>Electricity</td>
</tr>
<tr>
<td>Distinct Heating</td>
<td>Hydrothermal</td>
</tr>
<tr>
<td>Pools &amp; Spas</td>
<td>Hot Dry Rock (HDR)</td>
</tr>
<tr>
<td>Desalination, Greenhouses, Other</td>
<td>Hydrothermal Conventional &amp; Binary</td>
</tr>
<tr>
<td>Binary</td>
<td>Hot Dry Rock (HDR)</td>
</tr>
<tr>
<td></td>
<td>Supercritical</td>
</tr>
<tr>
<td></td>
<td>Geopressed</td>
</tr>
<tr>
<td></td>
<td>Offshore</td>
</tr>
</tbody>
</table>

- **Existing**
- **Planned**
- **Potential**
- **Market**

*(after Bromley, 2009)*
By “Potential”

(Rybach, 2010)
By “Potential”

**Theoretical potential** = physically usable energy supply (heat in place).

**Technical potential** = fraction of theoretical potential that can be used with current technology.

**Economic potential** = time & location dependent fraction of technical potential that can be economically used.

**Sustainable potential** = fraction of economic potential that can be used by applying sustainable production levels.

**Developable potential** = fraction of sustainable potential that can be developed under realistic conditions (regulations, environmental restrictions).

*(Rybach, 2010)*
By Exergy

Mollier diagram (Lee, 2001)
2 independent properties necessary to define thermodynamic status of a fluid.

Exergy defines:

Resource’s ability to generate thermodynamic work (like calorific value for fossil fuels).

Quality of energy content within the geothermal fluid.
“The geothermal resource is the estimated recoverable thermal energy relative to defined base and cut-off temperatures. If there is reasonable basis for doing so, convertibility into electricity may be assessed and an additional estimate of the recoverable, converted electrical energy may be stated [...]. The recovery and conversion factors used must be separately stated alongside the geothermal resource estimate, whenever it is quoted in a public report.”
Other Geothermal Classification Schemes

- The New Geothermal Terms and Definitions, by the Geothermal Energy Association (GEA, 2010).

→ The geothermal community is not new to the problem!
Lessons Learnt from the Oil & Gas Sector
**Analysis of Geothermal Resources**

**Status of Geothermal Resource Classification & Key Stakeholders**

(PRMS, 2007)

*Project Maturity Sub-classes*
- On Production
- Approved for Development
- Justified for Development
- Development Pending
- Development Unclarified or On Hold
- Development not Viable

*Increasing Chance of Commerciality*
- Prospect
- Lead
- Play

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**Range of Uncertainty**

Not to scale
Recent Oil & Gas Reserves “Train Wrecks”

2004 – A Bad Year for Reserves Reporting
- **Shell** writes down over 4 Bn BOE
  - Chairman, CFO, & CEO resign
  - Over 150 MM$US in SEC fines
- **El Paso** writes down 1.8 TCF
  - Chairman & President resign, new board elected, extensive technical staff turnover

2005 – More Bad News
- **Stone Energy** writes down 161 BCF
  - 1 Director + 1 Officer + 1 Snr Mgr resign
  - SEC investigation

2006 – The Story Continues
- **Repsol YPF** writes down 1.3 Bn BOE

(Adapted from SPE short course 2010)
Recent Oil & Gas Reserves “Train Wrecks” 2

• 2007 – Not Again
  - Cairn Energy writes off 213 BCF
  - Hydro writes down Front Runner & 9 other GOM Fields
  - Shell agrees to 353 MM$US settlement with US shareholders
  - Enterra Energy writes down PUD gas reserves
  - Parallel Energy removes 100’s of horizontal PUD locations

• 2008 – Still More?
  - Shell agrees to 117 MM$US settlement with European shareholders
  - Shell writes off 1.3 bn BOE due to government contract changes in PSC agreements in Nigeria & Russia
  - Lawsuits & government investigations continue
  - Shotgun mergers & Property Fire Sales continue
  - 5 Former El Paso employees fined by SEC for fraud & reserves reporting violations
Subjectivity of Oil & Gas Reserves Auditing

Same data, 2 auditors, 2 answers….

Outer diagonal lines show a range of 80%

Nearly a half order of magnitude of uncertainty, even when you have all the data you want.

Reserve Estimates of U.S. Onshore Oil Properties by Two Estimating Groups

(McLane, 2009)
# Miscommunicating Reserves & Resources

Our estimates of reserves & resources are made based on known best estimates of geological, engineering & economic data.

<table>
<thead>
<tr>
<th>Category</th>
<th>Descriptive Term</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proved</td>
<td>Reasonable certainty</td>
</tr>
<tr>
<td>Probable</td>
<td>More likely than not</td>
</tr>
<tr>
<td>Possible</td>
<td>Less likely than probable</td>
</tr>
<tr>
<td>Contingent Resources</td>
<td>Discovered, not committed</td>
</tr>
<tr>
<td>Prospective Resources</td>
<td>Undiscovered</td>
</tr>
</tbody>
</table>

**WORDS CAN BE A PROBLEM!**
Geothermal Hand-in-Hand with Renewables?
Quantifying Global Exergy Resources

(Hermann, 2006)
Exergy approach already applied for comparing on equal grounds different energy resources of different quality.

Focus not on the raw quantity of the resource, but rather on how the way it is exploited impacts on the global system, so as to better identify and evaluate options for an energy sustainable future.
Why Not BOE? – Conversion Factors

- The BOE system compares the heating capacity of 1 bbl of oil (~5,800,000 BTU) vs. that of 1 scf gas (~1028 BTU). However, BOE conversion factors are not unique and depend on the quality of the oil & the gas. Reported ranges are from 1 bbl oil equal to 5.6 to 6 Mcf gas, a 7\% discrepancy, which can be significant when dealing with multi-million BOE deals.

- Consider Bloomberg on 11-April-2013: crude oil (WTI) is trading at $93.5/bbl and natural gas (NYMEX) at $4.2/Mcf, which represents a "value conversion factor" of 22 Mcf/BOE, some 4 times greater than that suggested by heat equivalence.
Why Not BOE? – Emissions Equivalency

(ESMAP, 2012)
Why Not BOE? – Transportability

Geothermal is resource location dependent

“I load a truck with oil, but not with heat”
Segneri et al. (2013) already mentioned the possible implementation of the UNFC framework to include geothermal classification.

Beardsmore (2013) recently issued a report commissioned by the IEA-GIA, on the inter-relationships between the UNFC and a range of existing geothermal classification schemes.
Conclusions -1

- Geothermal classification standards needed to reduce risk to investor & increase confidence in geothermal development.

- Currently, no universally recognised standards exist for classifying and reporting geothermal resources.

- Difficult to standardise workflows while minimising freedom of interpretation → Learn from oil & gas sector.
Conclusions -2

- Multiple parallel efforts within the geothermal community have lead to duplication of the efforts and independent reference documents which still cannot be put under the same umbrella.

- Potential need for a common platform to embrace solid minerals, hydrocarbons & renewables.

- However, the energy community should not rush into a system that is too generic and neglects fundamental commodity-specific aspects that have already been identified by the individual sub-communities.
Acknowledgements

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