Geothermal Energy (Week 12, 16 Nov)
- Enhanced Geothermal System

민기복

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Field trip (석모도 지열개발 프로젝트)

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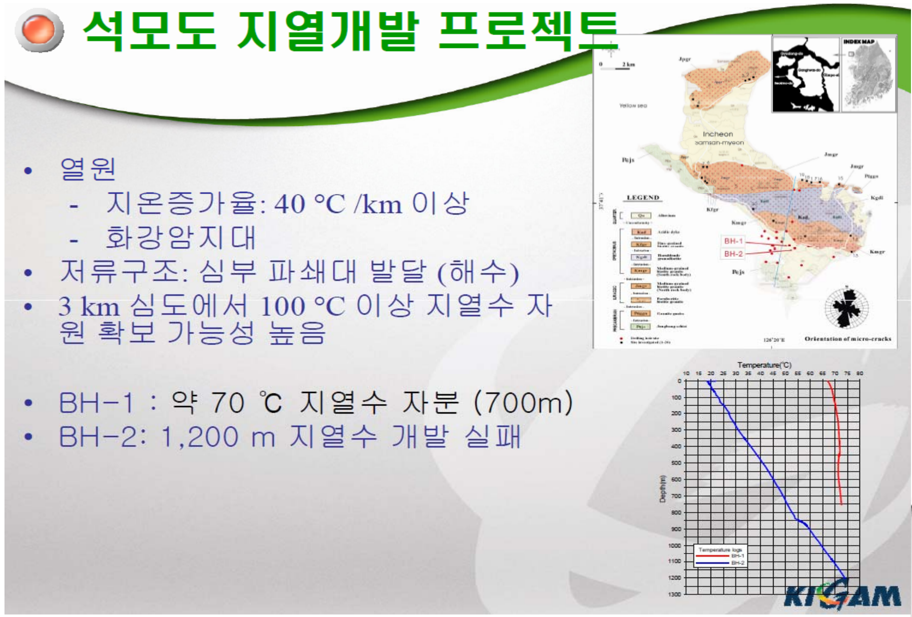
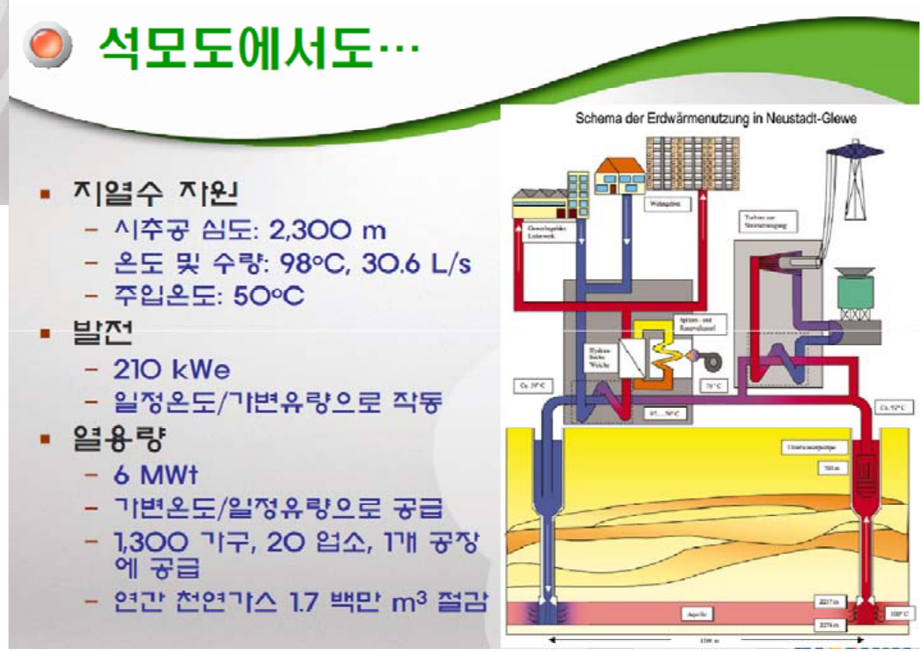


Tae Jong Lee, 2009



• 20 Nov 2009 (10:00 ~ 18:00)

Next week
Invited lectures

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- 16:00 – 18:00, Mon 23 Nov 2009
  - Geothermal Energy Development in Korea
  - Dr Yoon Ho Song (송윤호), Korea Institute of Geoscience and Mineral Resources (KIGAM, 한국지질자원연구원)

- 09:00 – 10:15, Wed 25 Nov 2009
  - Direct Use of Geothermal Energy
  - Mr Hyung Jun An (안형준 차장), KOLON E & C (코오롱 건설 기술연구소)

Progress report
a few comments

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- You need to be very specific on the purpose of your project.
- Proper citation
  - 1) gives a credit to the people who have done previous study
  - 2) supports your argument.
- Copy and Paste is not allowed.
  - It is often out of context. If you have to use wordings from other people, add citation.
- Read instruction

Past two weeks

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- Geothermal Power Generation
- Design consideration: Separator, Gathering system, Pressure losses, Turbine blade integrity, condenser
- Type of Geothermal power generation
- Status

- EBS video on Geothermal Energy

Status

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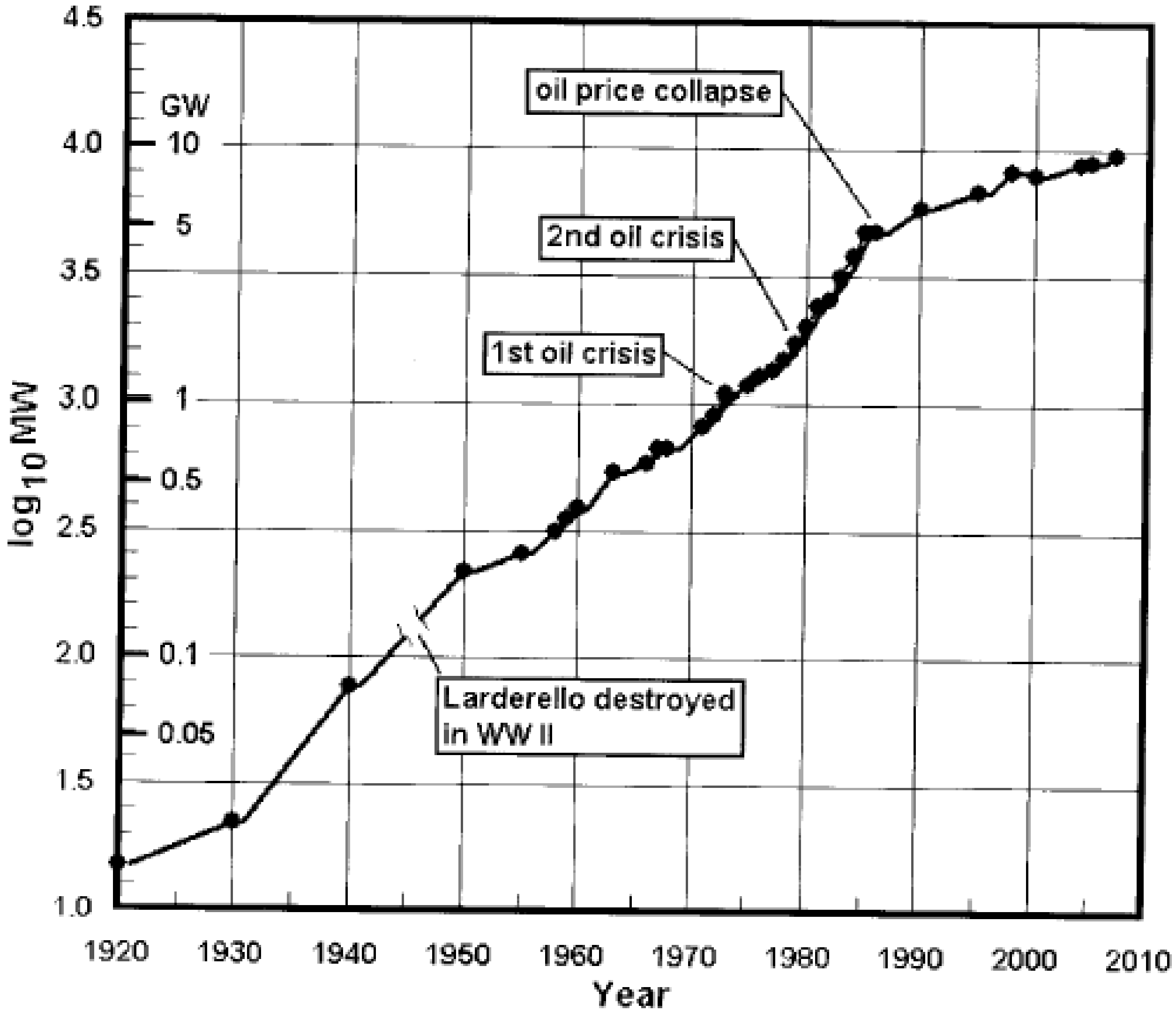

DiPippo, 2008

Today
Enhanced Geothermal System

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- Definition
- Status
- What we know
- Remaining issues
- Feasibility
- Geothermal Energy in Korea

EGS

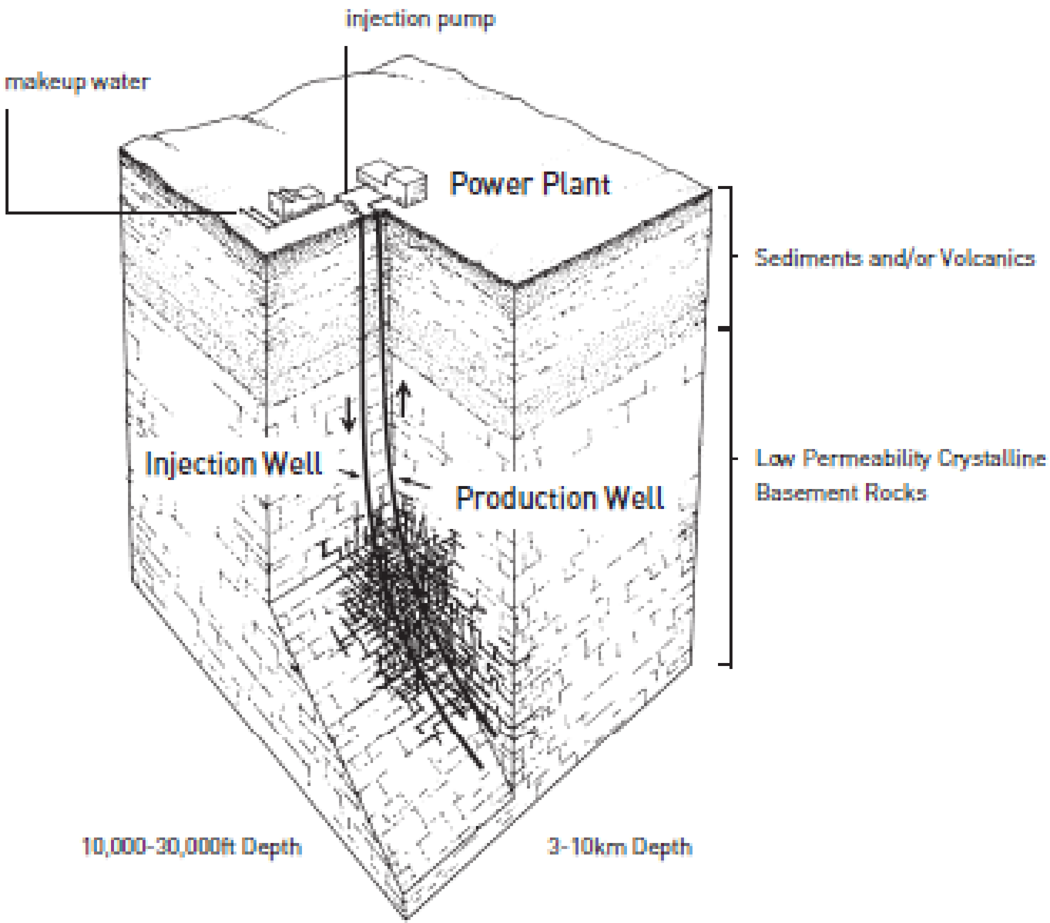

Figure 1.1 Schematic of a conceptual two-well Enhanced Geothermal System in hot rock in a low-permeability crystalline basement formation.

Tester et al., 2006

Enhanced Geothermal System
Definition

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- EGS: Enhanced (or Engineered) Geothermal System
- Broader definition: A system designed for primary energy recovery using heat-mining technology, which is designed to extract and utilize the Earth's stored thermal energy (Tester et al., 2006)
- Narrower definition (also called HDR, Hot Dry Rock, or HFR, Hot Fractured Rock): A geothermal system that requires hydraulic stimulation to improve the permeability.

Classification of geothermal
Australian Perspective

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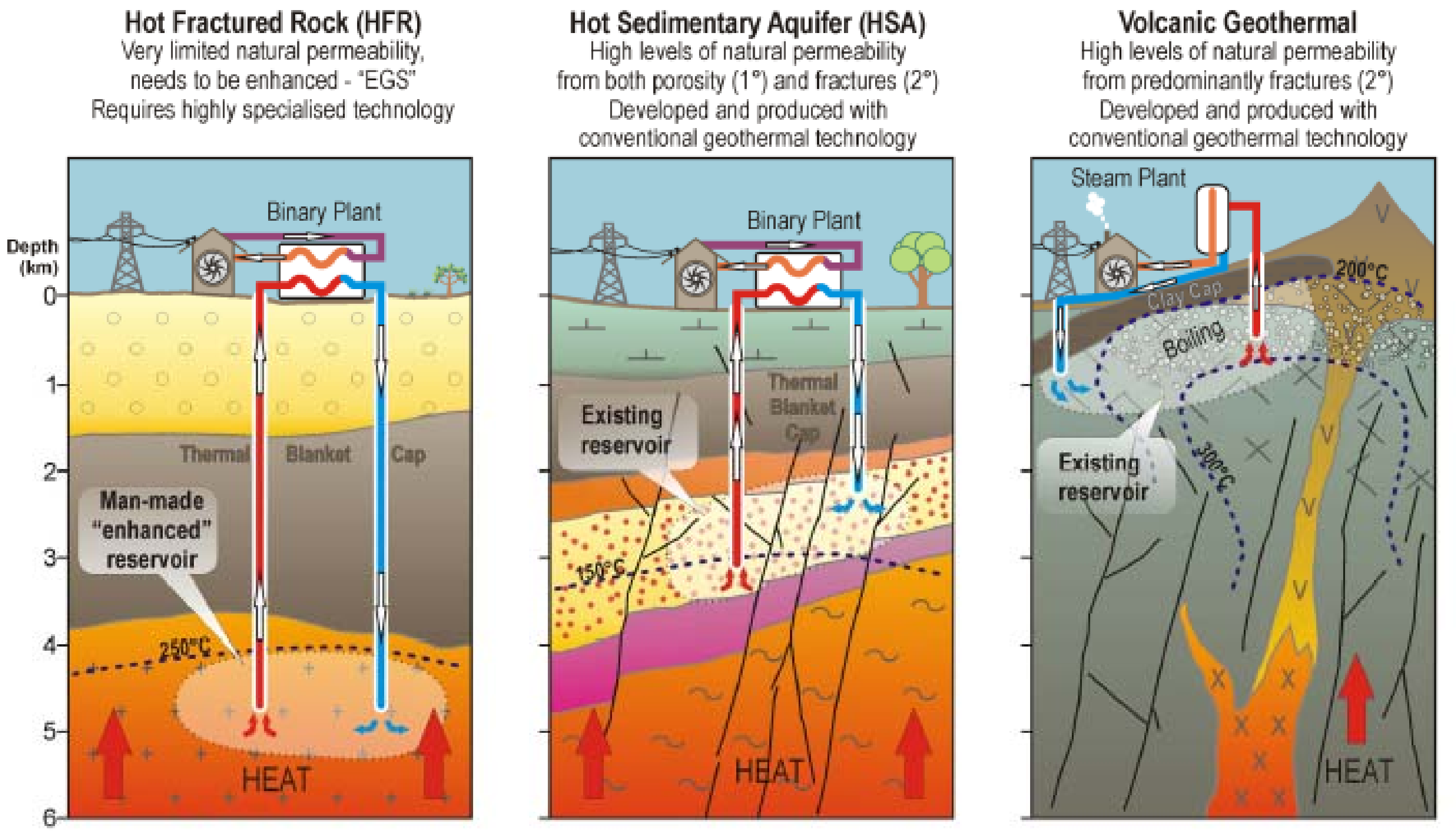

heat | e | Heat + permeability | Op | Heat + permeability + water

installed generation capacity

.hotrockltd.com

Enhanced Geothermal System
Definition

- Indirect use (electricity)
  - Volcanic geothermal : heat + permeability + water
  - Hot Sedimentary Aquifer (HSA) : heat + permeability
  - Enhanced Geothermal System (EGS) : heat
  - Geopressurized
  - Magma Energy

How does EGS works?
Principles

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- Animation from Geodynamics Limited.
- www.geodynamics.com.au

History

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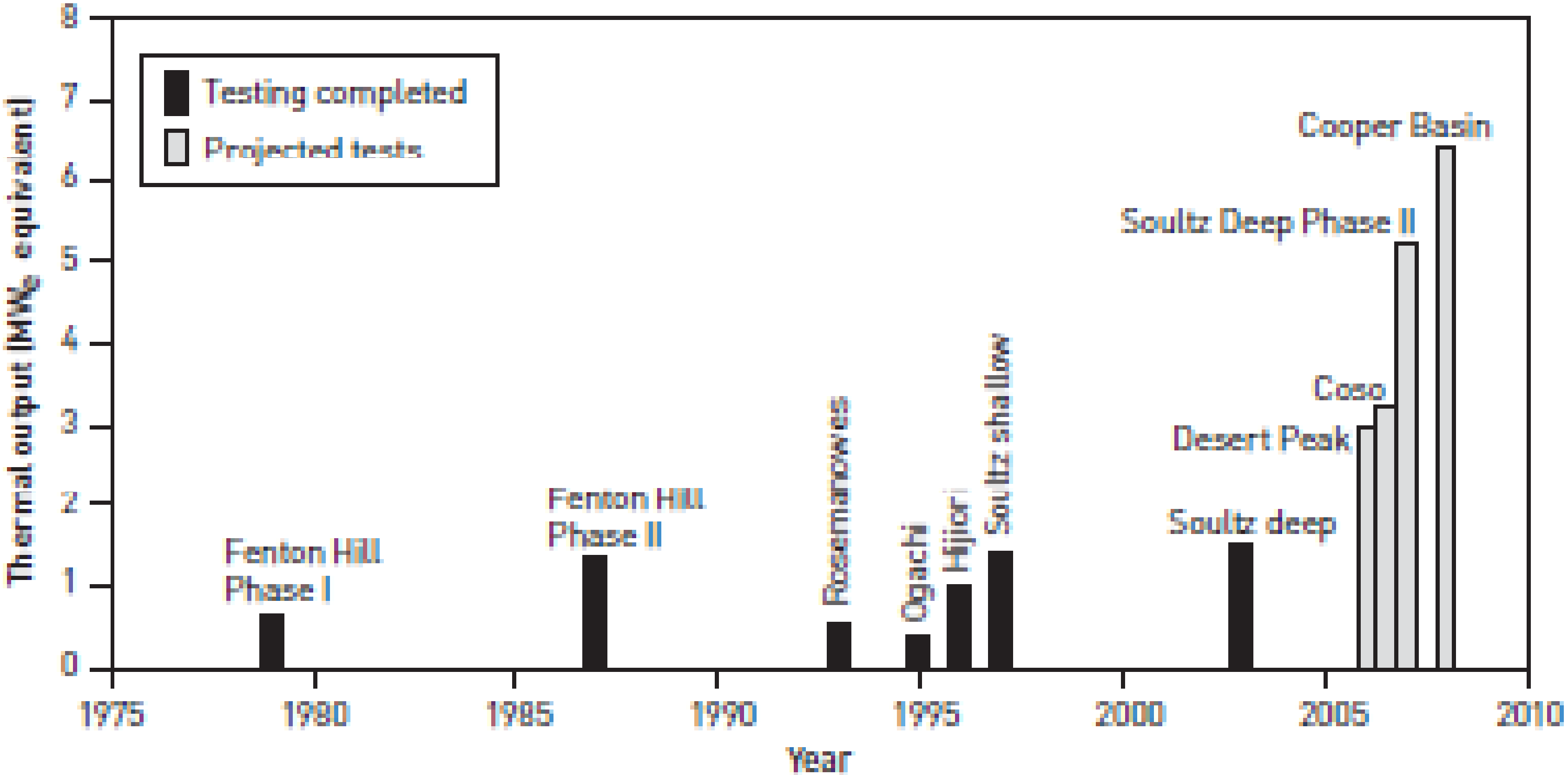

Figure 4.16 Evolution of estimated electrical power output per production well, with time from EGS projects. The Fenton Hill, Coso, and Desert Peak projects received, or are receiving, major funding from the U.S. DOE.

Tester et al., 2006

The things that we know

– High flow rates with long path lengths are needed
– Stimulation is through shearing of pre-existing fractures
– Monitoring of acoustic emission is our best tool for understanding the system
– Rock-fluid interactions may have a long-term effect on reservoir operation

The things that we know

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- Pumping the production well for high flow rates without increasing overall reservoir pressure → reduce the risk of short circuiting
- Drilling technology being improved
  - Drill bits last ~ 50 hours in deep high temperature environment
- Circulation for extended time periods without temperature drop is possible
- Models are available for characterizing fractures and for managing the reservoir
- Induced seismicity concerns

Remaining technical issues

- Preventing short circuit
  - Short circuit reduce the effective heat-exchange area of the system
  - We cannot stimulate specific fractures
- Better understanding the influence of major fractures and faults as subsurface barriers or conduits to flow
  - Barriers or conduits
  - Method of characterising these features are needed

Remaining technical issues

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- Site selection
- Equipment and Instrumentation
  - Downhole pumps
  - High-temperature packers/well-interval isolation systems
- Rock property quantification
- Fracture design model/Fracture mapping method
- Reservoir connectivity

Remaining technical issues

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- Understanding the seismic event and its impact on environment
- Characterizing rock fluid interactions
  - Will mineral deposition occur over time that will diminish connectivity and increase pressure drop?
  - Is mineral dissolution going to create short circuits or improve pressure drop?

EGS development
Cooper Basin

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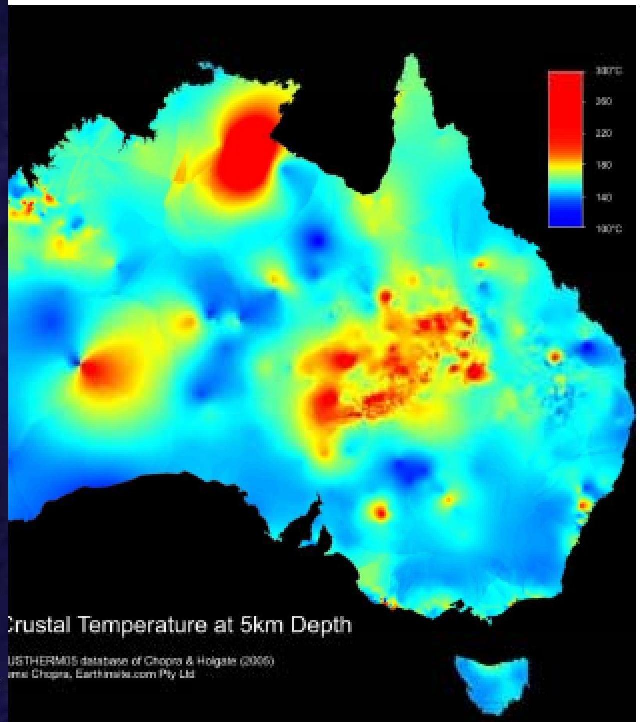

Long term goal of the Joint Venture with Origin Energy remains to bring this considerable energy resource to market

EGS development
Cooper Basin

EGS development
Cooper Basin

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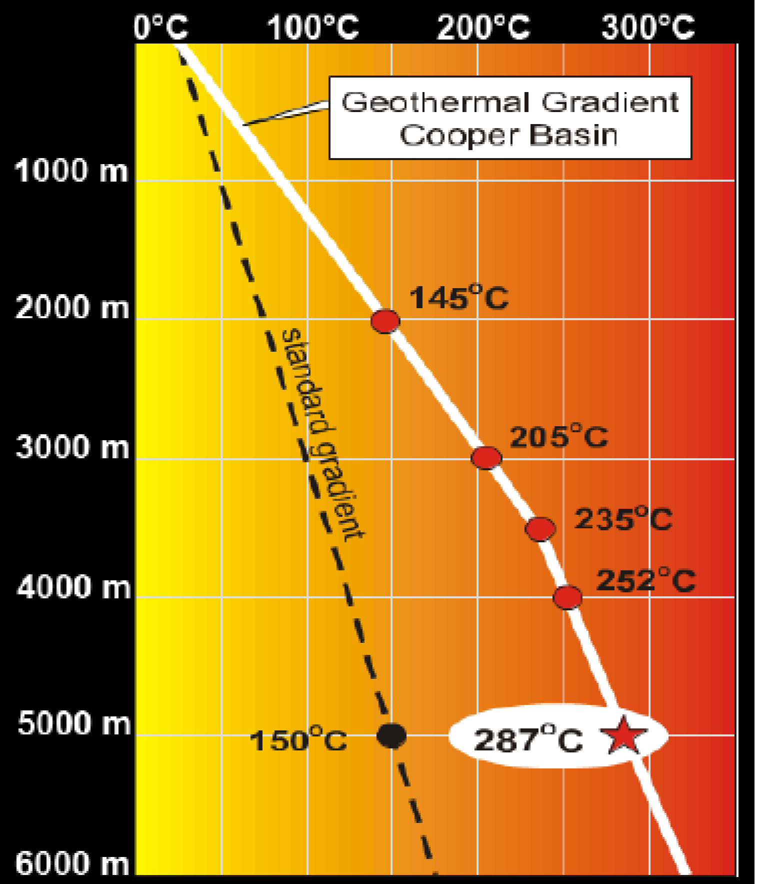
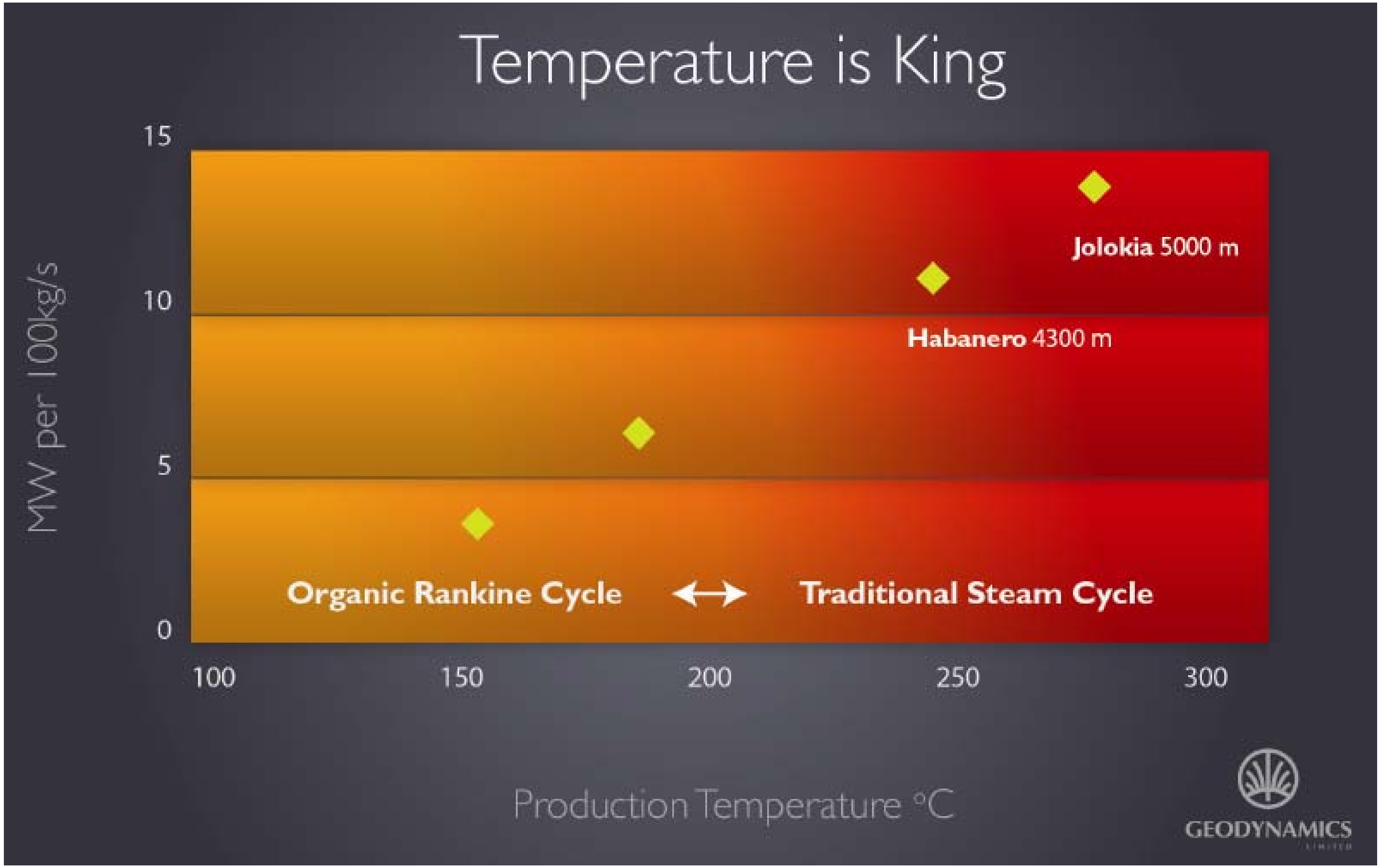
TEMPERATURE IS KING!

- Cooper Basin has hottest known rocks of its type in the world
- Commercial viability of all renewable sources will come down to the most efficient use of capital
- Lowest Capex per unit of useful energy will be most competitive
- Geodynamics believes the Cooper Basin EGS resource will be the lowest cost renewable source in Australia – delivered sub $100 / MWh



EGS development
Cooper Basin



Geothermal industry
An example in Australia

- Currently only 120kW geothermal power plant in Birdsville
- GEL (Geothermal Exploration License)
  - first in 2001, now 385 licenses in 360,000 km2
- 48 geothermal companies with 10 ASX (Australian Security exchange) listed
- Expenditure more than 1,500 million A$ from 2002 – 2013 (700 million A$ in the US for 3 years)
- 5.5 GW (6.8%) by 2030
- 17,000 new employment expected

Growth in Australian EGS and Hot Sedimentary Aquifer

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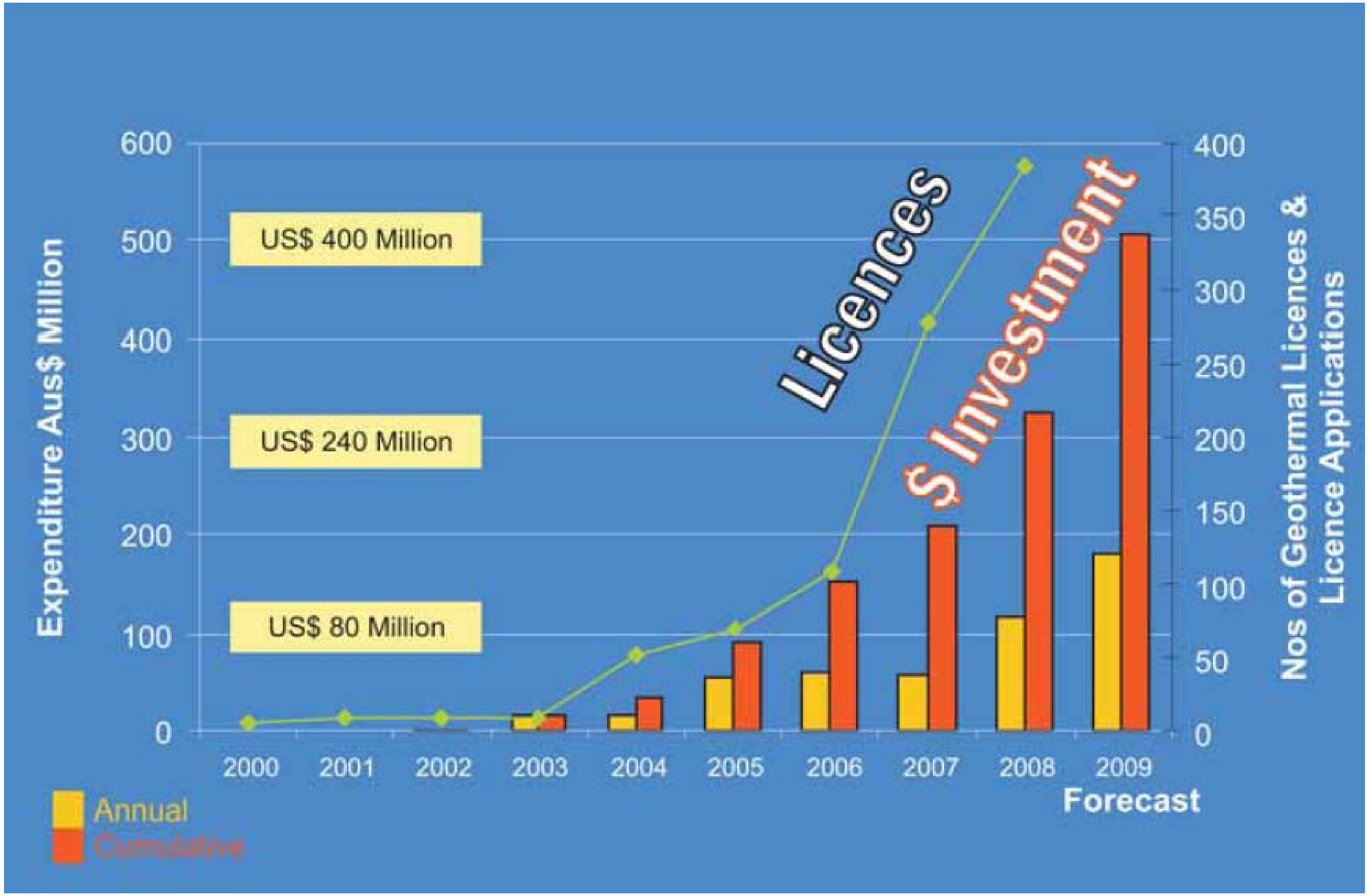

Goldstein et al., 2008

Geothermal drilling and downhole measurements (end of 2008)

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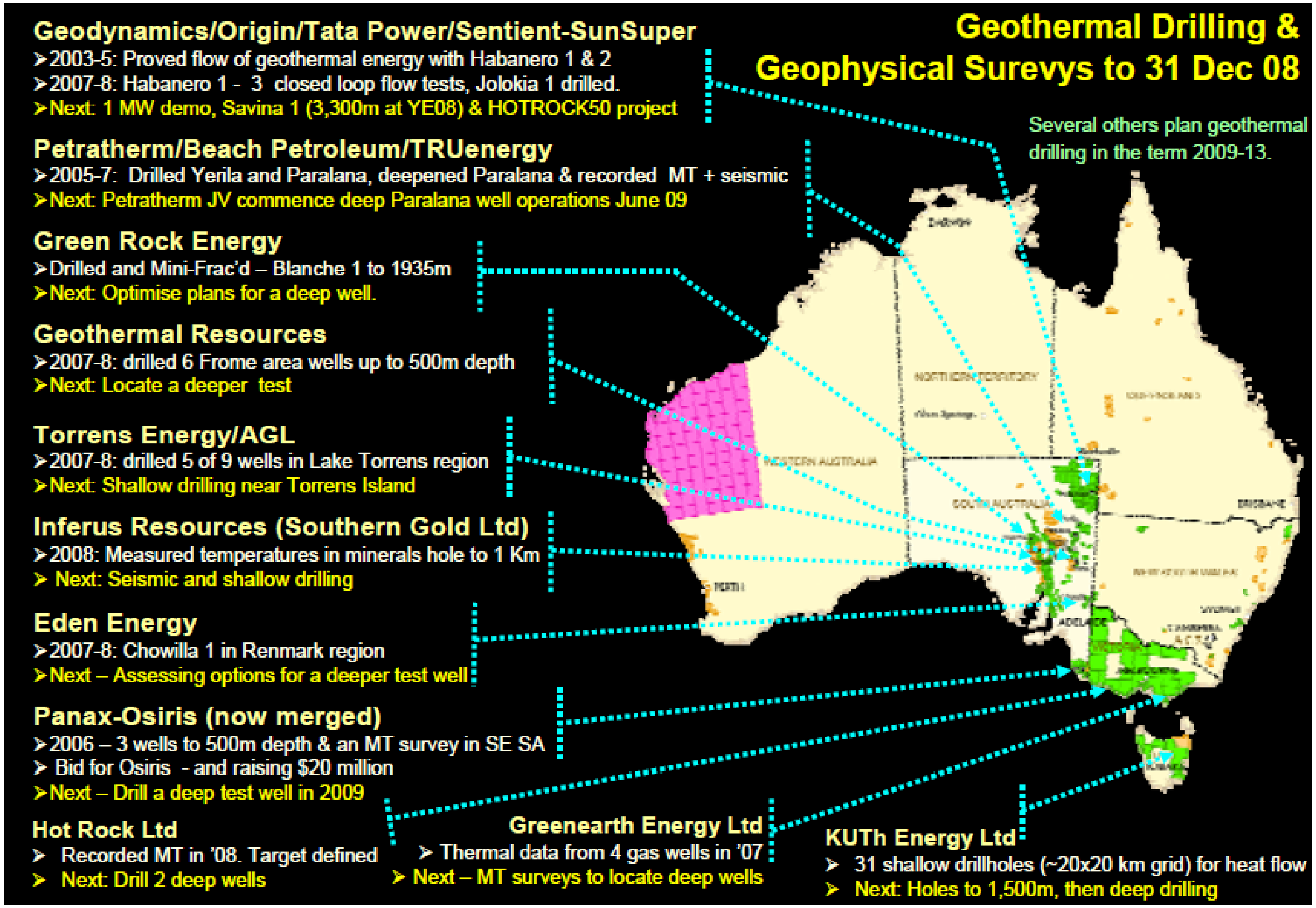

Goldstein et al., 2008

Geothermal industry
An example in Australia

- The Geothermal Reporting Code
  - First published in 2008
  - Second edition in 2009
- Covers a minimum, mandatory set of requirements for the pubic reporting of exploration results, geothermal resources and geothermal reserves.
- Governing principles
  - Transparency
  - Materiality
  - competence

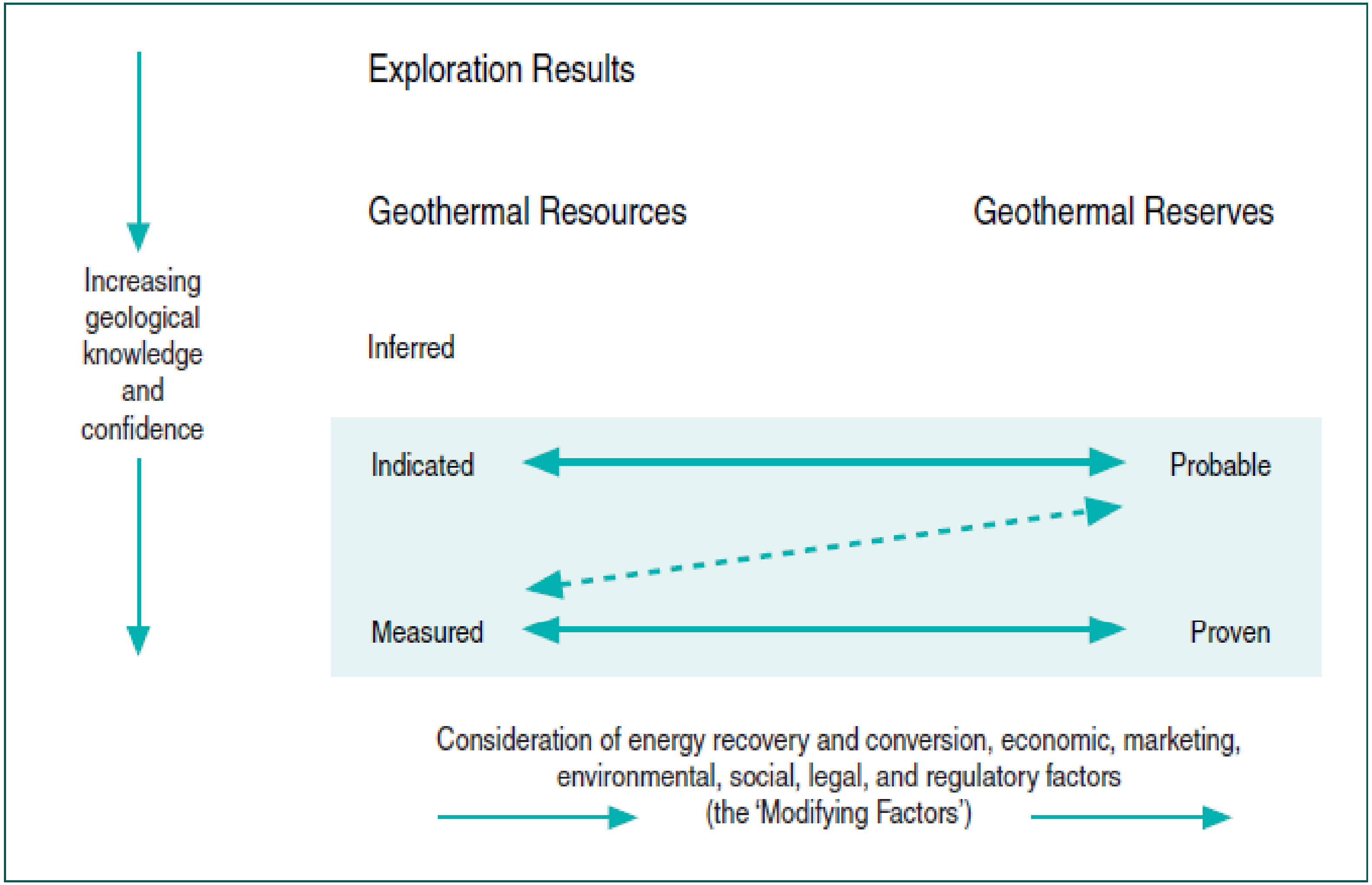

Figure 1. Relationship between Exploration Results, Geothermal Resources and Geothermal Reserves. The Geothermal Code recognises three levels of Geothermal Resource (Inferred, Indicated and Measured) based upon increasing levels of geological knowledge and confidence which directly affect the assessment of the probability of occurrence. Geothermal Reserves are further estimated from Geothermal Resources by consideration and application of "Modifying Factors" which directly affect the likelihood of commercial delivery (e.g. production, economic, marketing, legal, environmental, land access, social and governmental factors). Two categories of Geothermal Reserve are recognised (Probable and Proven) based upon confidence in both the underlying Geothermal Resource estimate and the Modifying Factors. General relationships and pathways between the various Geothermal Resource and Reserve categories that are permitted under the Geothermal Code are as shown.

- Greenearth Energy introduction

Today

- Enhanced Geothermal System
  - History & status
  - remaining issues
  - example
- The Geothermal Reporting code

Next week

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- 16:00 – 18:00, Mon 23 Nov 2009
  - Geothermal Energy Development in Korea
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- Week 14
  - Report writing guide
  - Feasibility of geothermal energy development

References

- MIT, 2006, The future of geothermal energy - Impact of Enhanced Geothermal Systems (EGS) on the United States in the 21st century, US Department of Energy, http://www1.eere.energy.gov/geothermal/future_geothermal.html
- Goldstein BA, Hill T, Long A, Australian Geothermal Implementing Agreement Annual Report – 2008, Australian Geothermal Energy Group, 2008