SUSTAINABLE, AVAILABLE BASE-LOAD ELECTRICITY & HEAT : GEOTHERMAL ENERGY

Network of Expert Energy Technology (NEET)
Integrated Approaches to Energy Technologies
27 November 2012, Ministry for Science and Technology, Beijing, China

Chris Bromley, GNS Wairakei, IEA-GIA Chairman
Mike Mongillo, IEA-GIA Executive Secretary

Outline of Presentation

- History of geothermal growth
- Opportunities for future growth in Asia-Pacific Region
- Novel geothermal applications
- Role of the IEA-GIA
- Geothermal deployment efforts
- Example from New Zealand
- Example from Tibet

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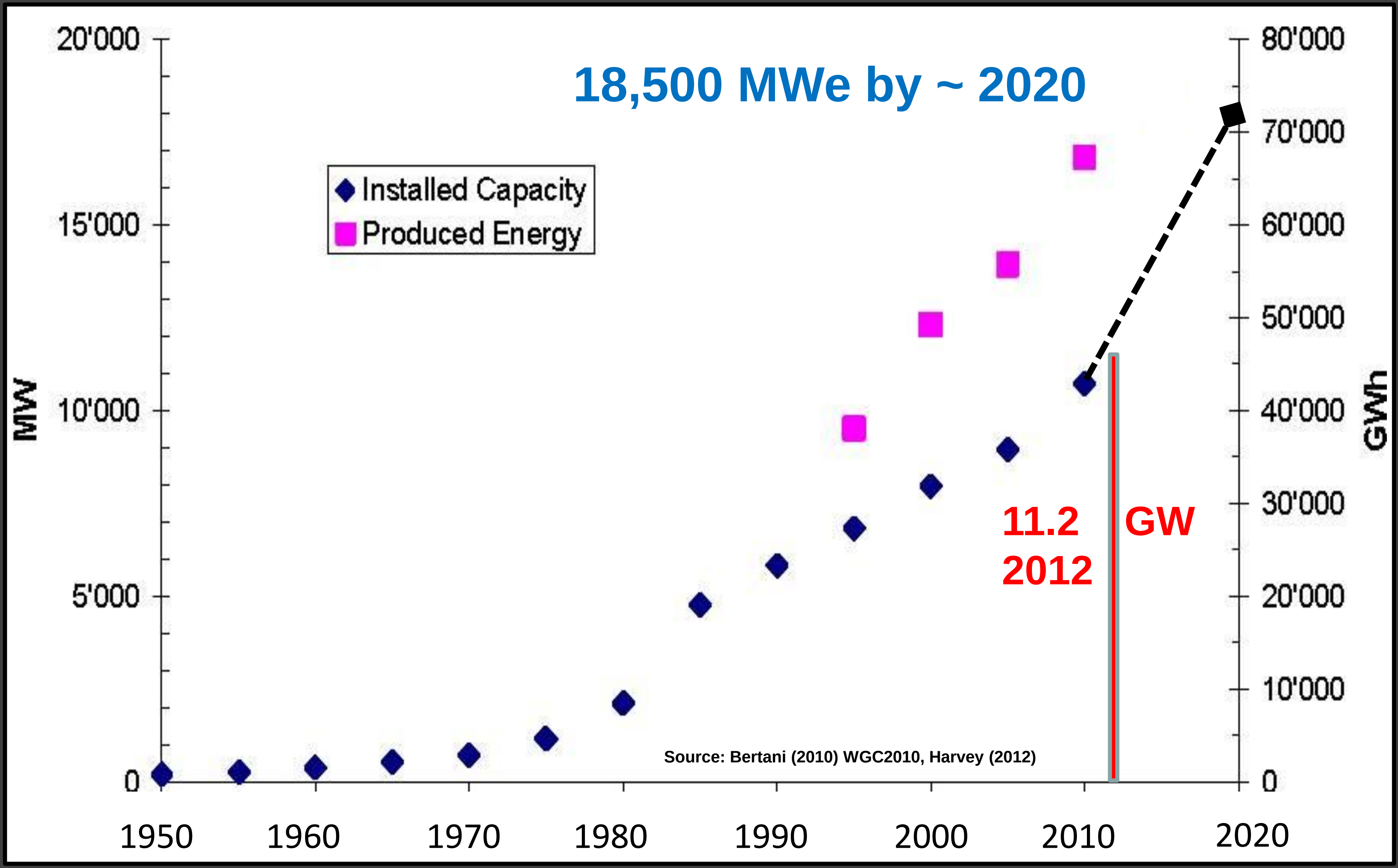
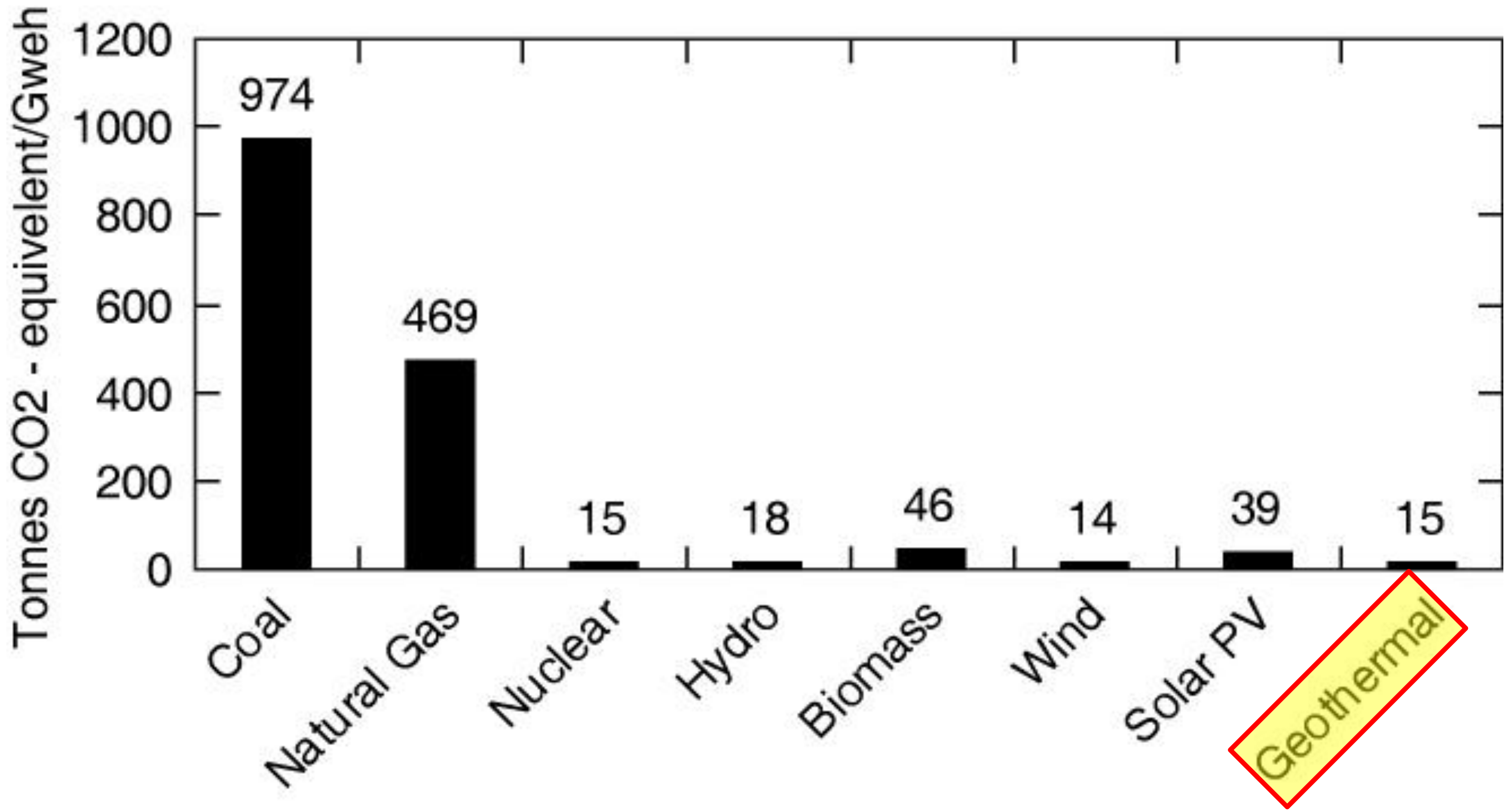
World Geothermal Electricity, 1950 to 2020



Life Cycle CO_2(equiv) Emissions



Comparison of Life Cycle Emissions in Metric Tonnes of CO_2e per GW-hour for various modes of Electricity Production; P.J. Meier, *Life-Cycle Assessment of electricity Generation Systems with Applications for Climate Change Policy Analysis,* Ph.D. dissertation, University of Wisconsin (2002); S. White, *Emissions form Helium-3, Fission and Wind Electrical Power plants,* Ph.D. Dissertation, University of Wisconsin (1998); M. K. Mann and P. L. Spath, *Life Cycle Assessment of a Biomass Gasification Combined-Cycle System*, (1997), www.nrel.gov/docs/legosti/fy98/23076.pdf *(ref 33).*

Source: Richter(2012)

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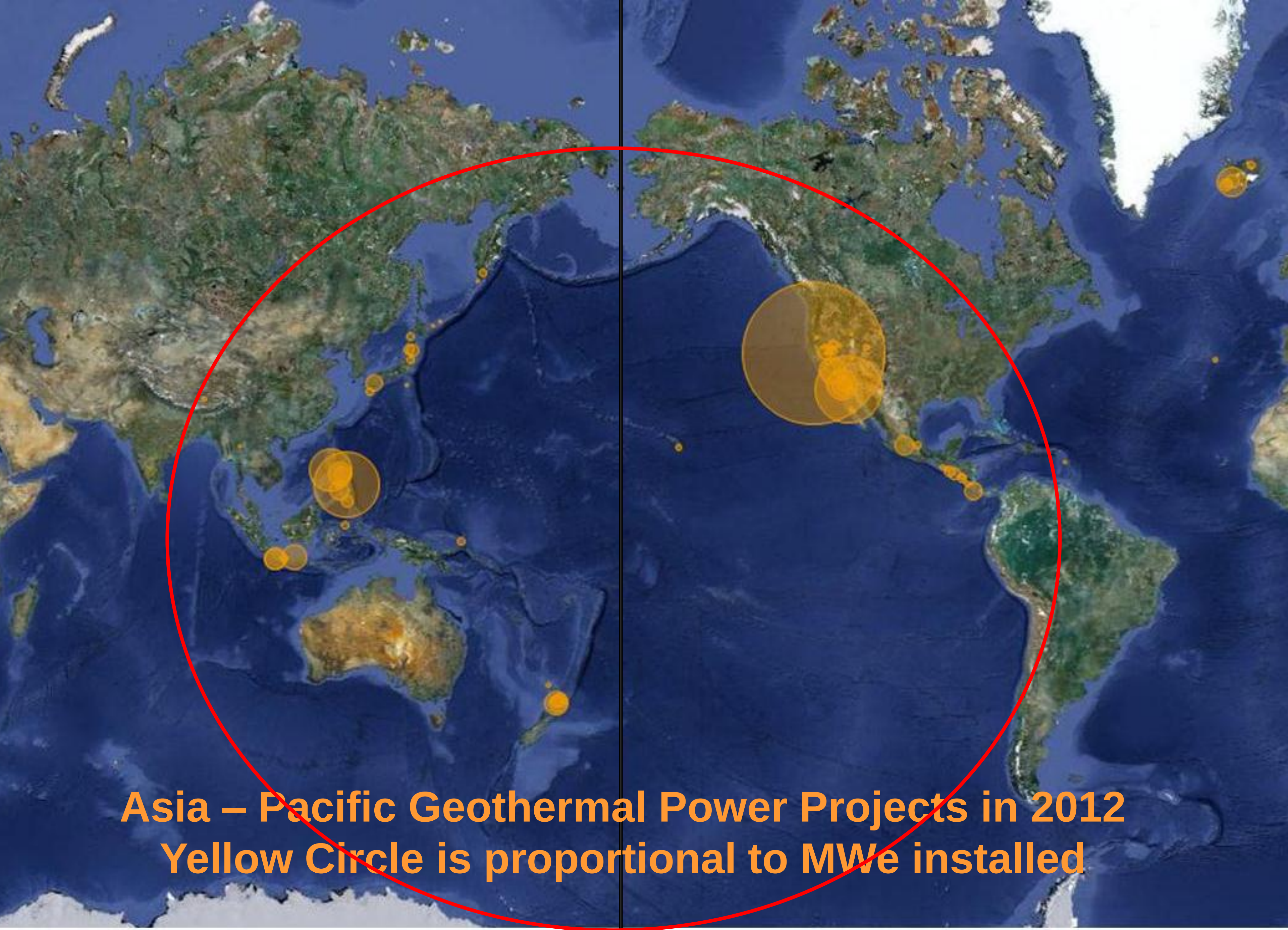

Asia – Pacific Geothermal Power Projects in 2012
Yellow Circle is proportional to MWe installed

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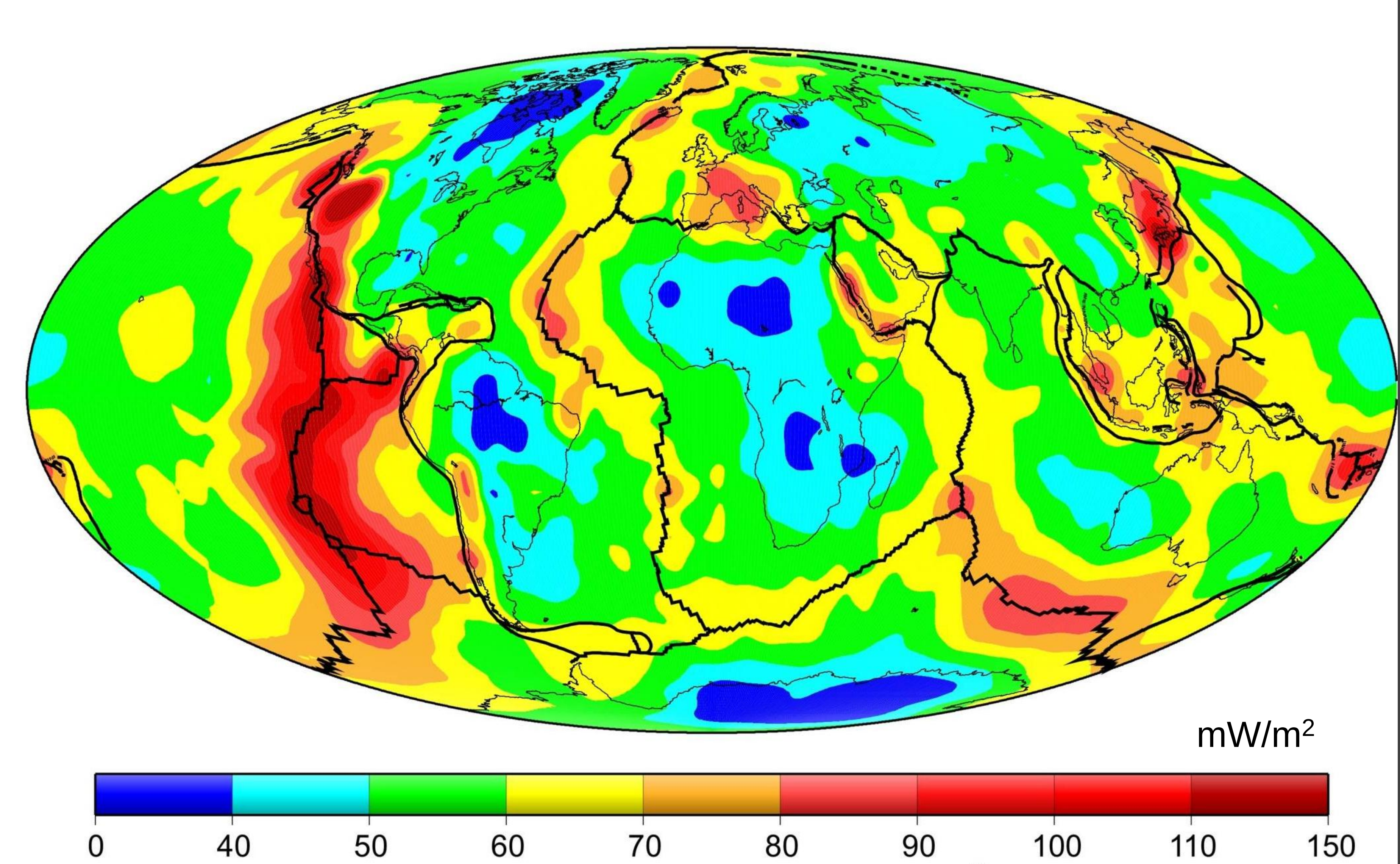
Global conductive heat-flow anomalies….



(IPCC SRREN, 2011)

… heat-flow is greatest near plate boundaries

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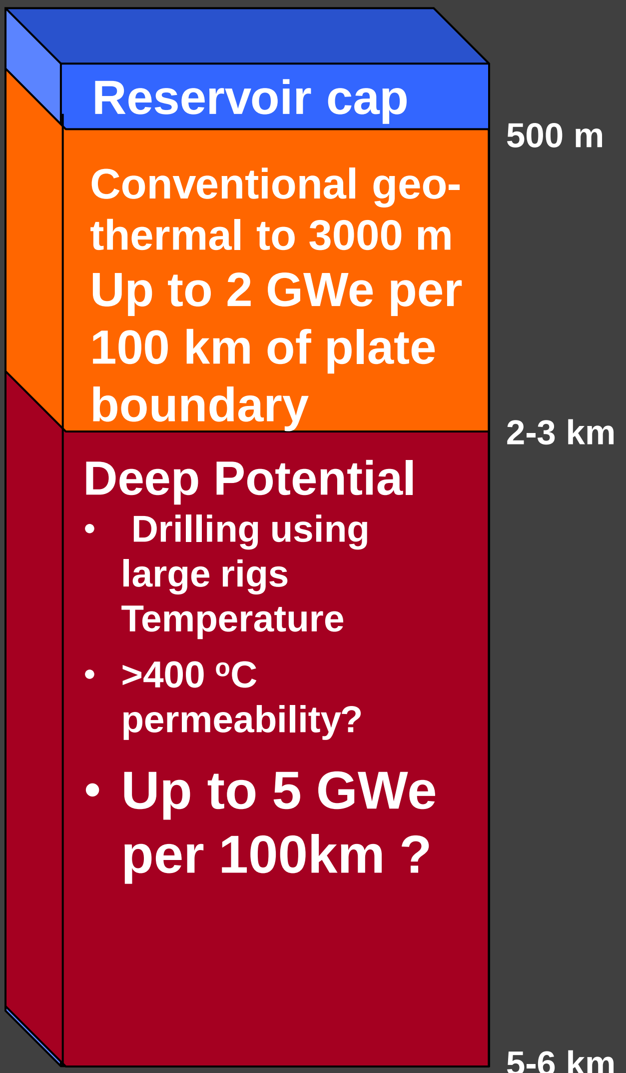
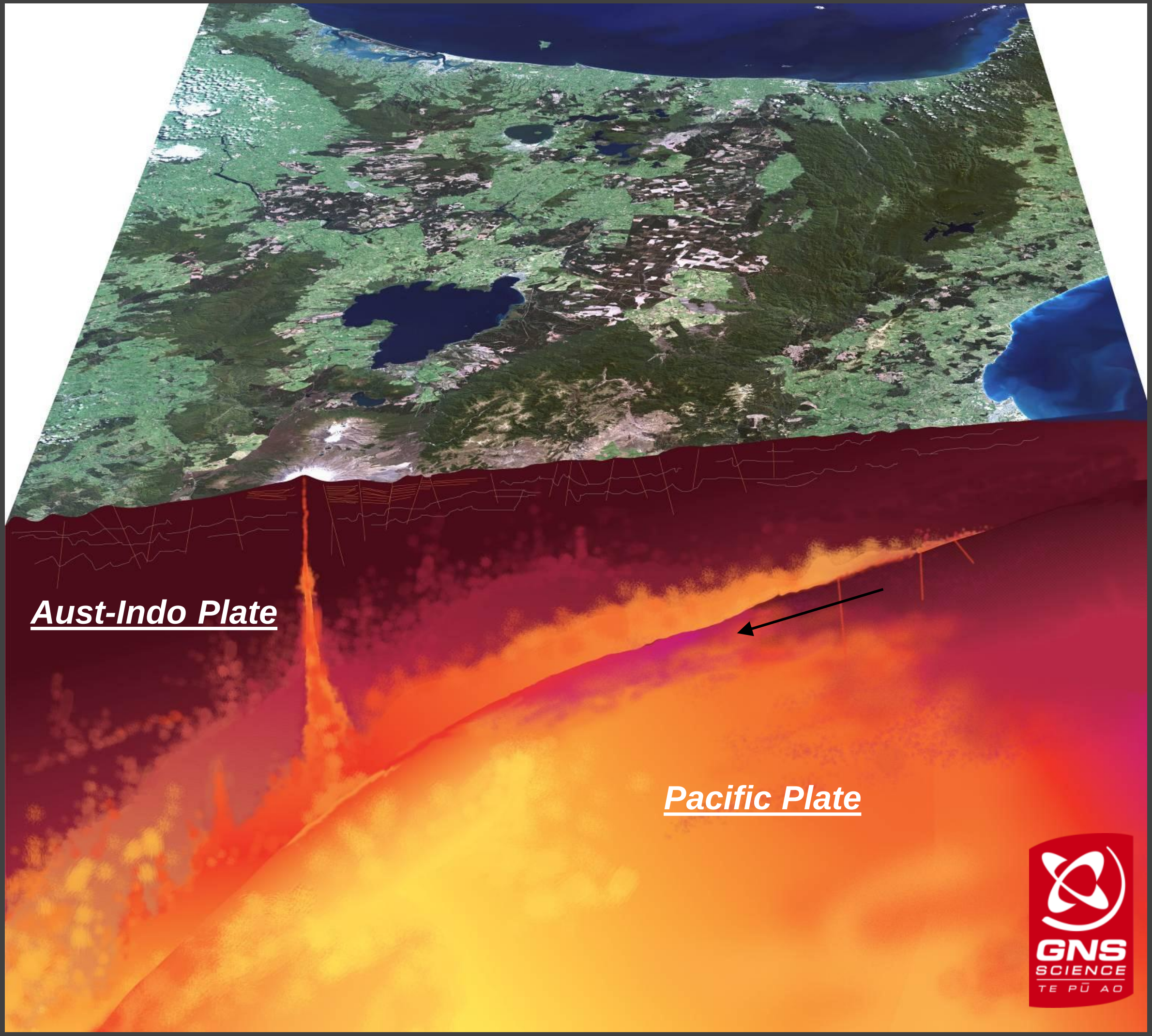
Circum-Pacific plate-tectonic boundaries & intra-plate hotspots provide a vast Natural Energy Source in the form of Convective Hydrothermal Systems





Harvey and Bignall, 2012

Opportunities & Benefits of Geothermal Energy

- Geothermal energy deployment is rapidly progressing in many countries of the Asia-Pacific region (especially Philippines, Indonesia, New Zealand, Mexico and the USA)
- Future deployment projections of this abundant energy resource are very promising.
- In volcanic and plate-boundary settings, high-temperature geothermal is often the least-expensive renewable-energy option, in terms of long-run marginal cost.
- Geothermal has the added benefits of being a source of base-load power, with low life-cycle CO_2 emissions, low environmental impact & low surface footprint.
- Geothermal efficiently provides on-demand heating and cooling for buildings, and for industrial and agricultural direct process-heat applications.
- Novel geothermal applications are creating many additional opportunities for growth

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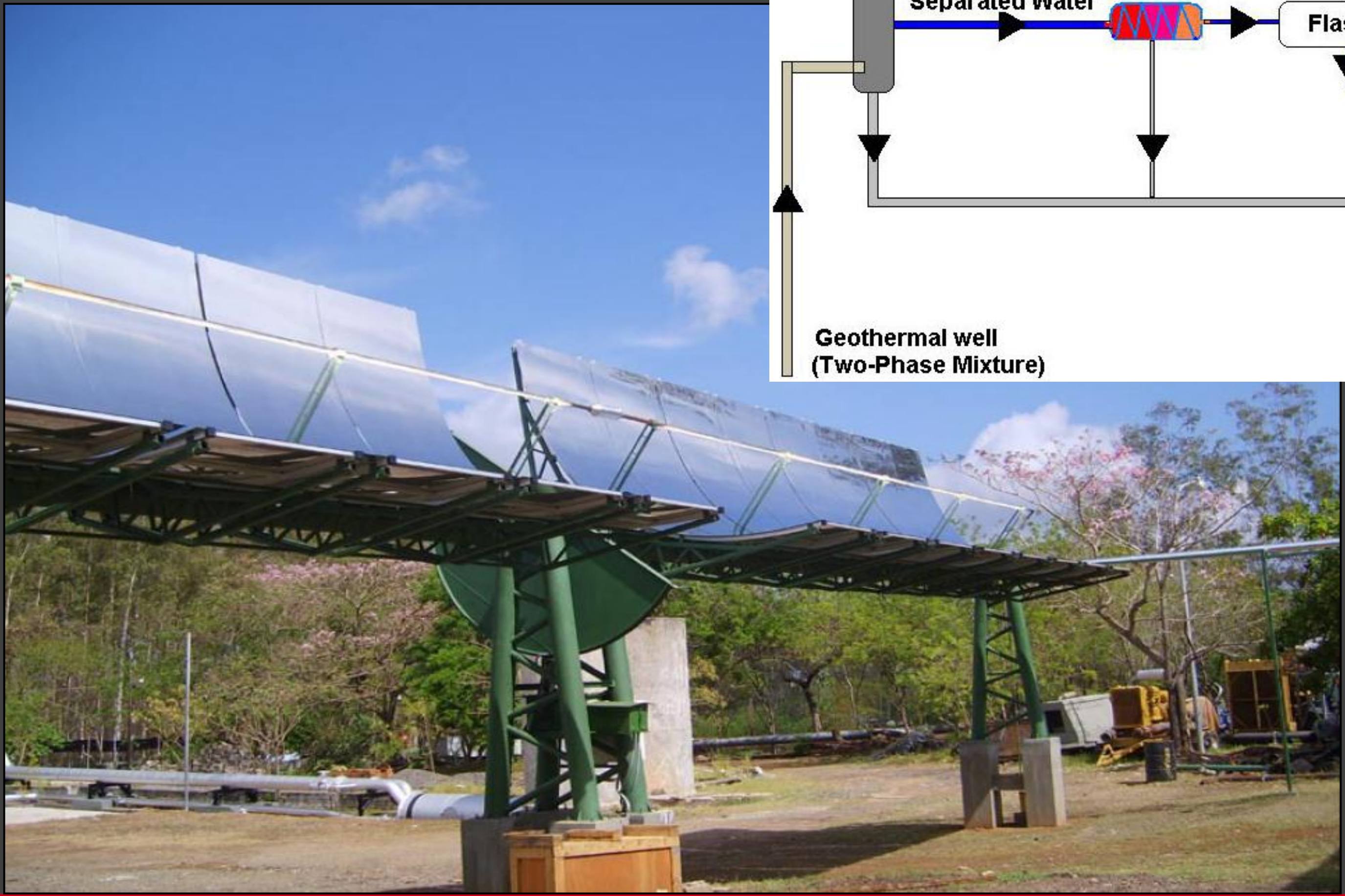
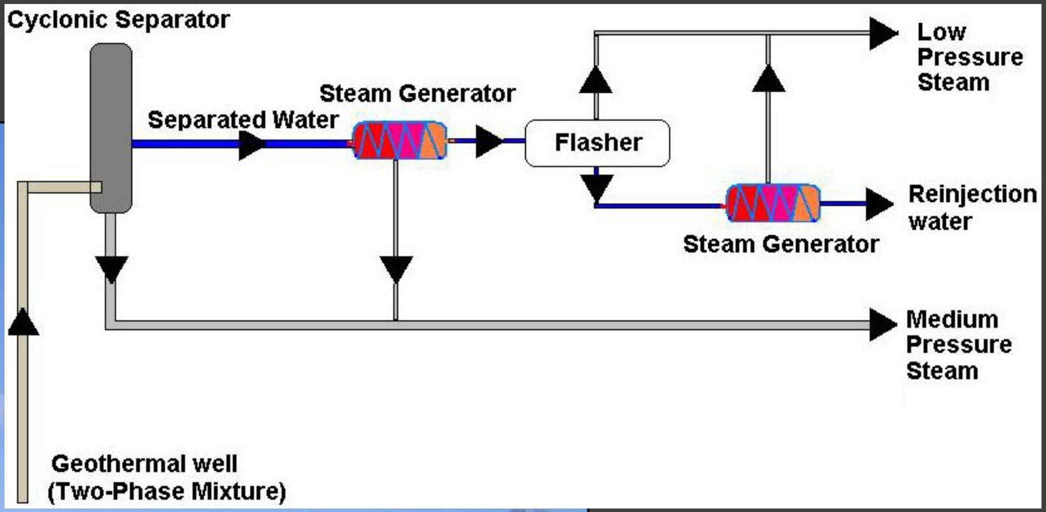
Novel Geothermal Applications :

Combinations of geothermal & other technologies

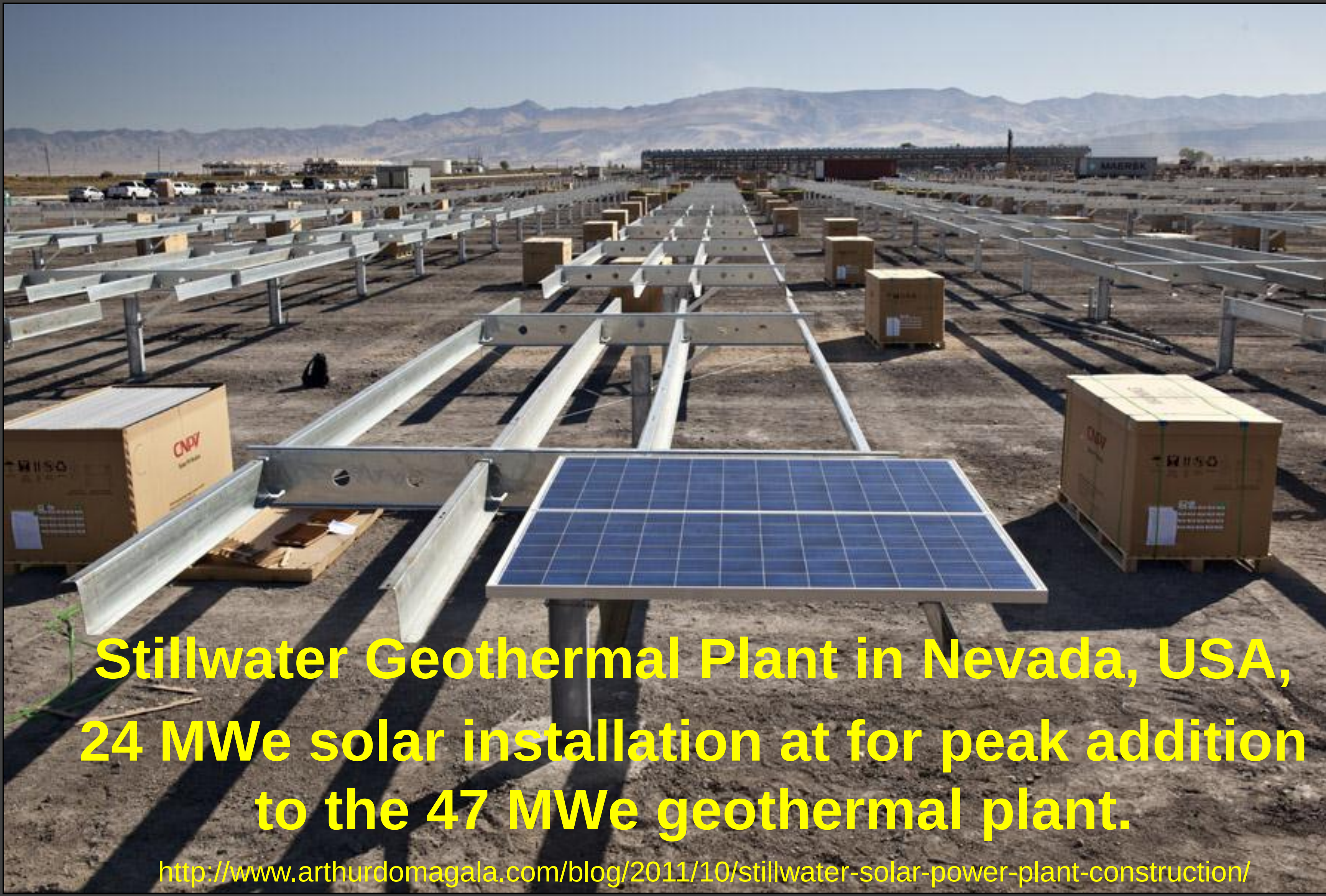
Geothermal and Solar Thermal Hybrid at Ahuachapán, El Salvador





Handal et al., 2007

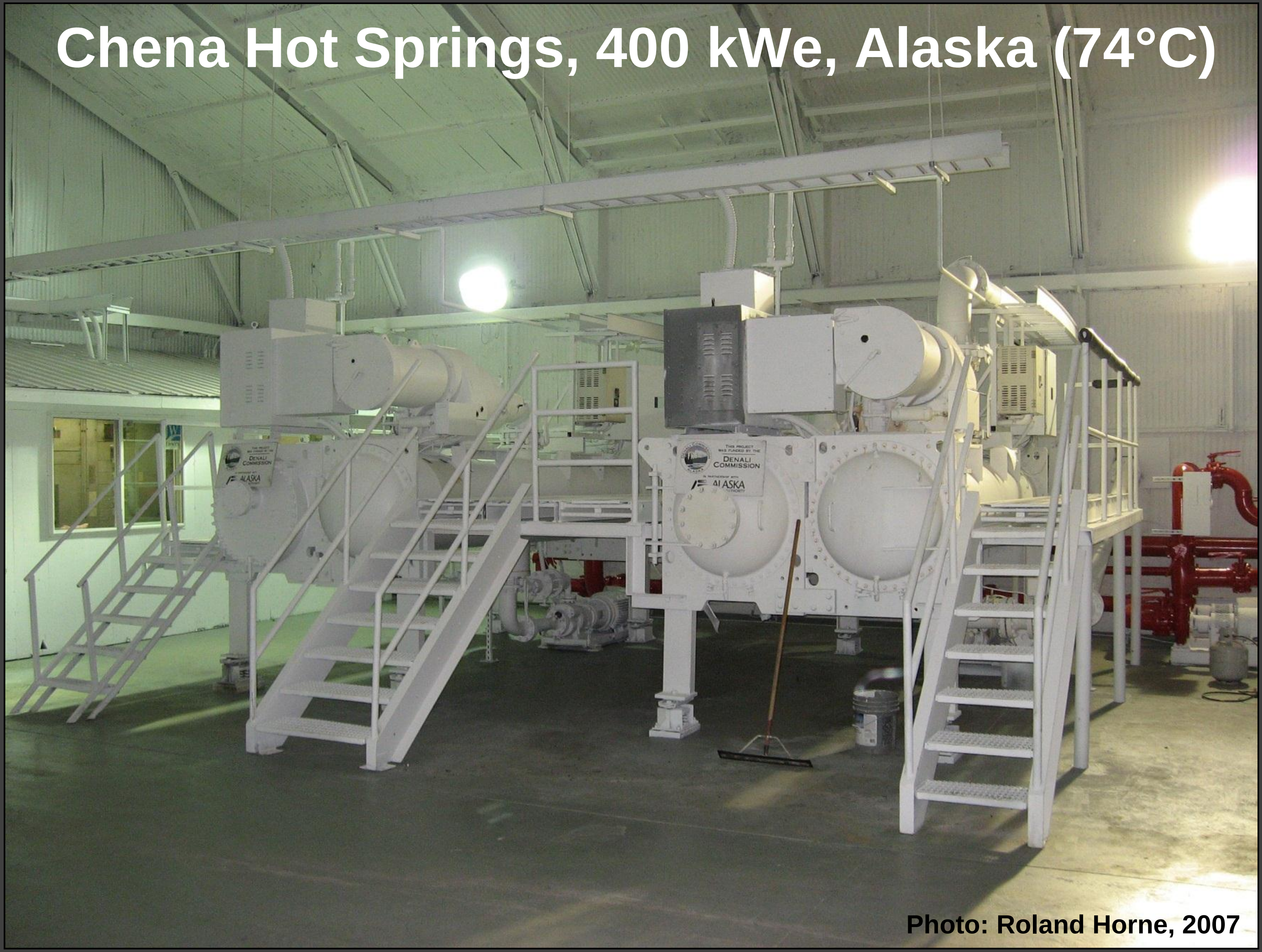
Geothermal and Solar PV Hybrid



Stillwater Geothermal Plant in Nevada, USA, 24 MWe solar installation at for peak addition to the 47 MWe geothermal plant.

http://www.arthurdomagala.com/blog/2011/10/stillwater-solar-power-plant-construction/

Electricity from Lower Temperature Springs



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Geothermal for Isolated Island Communities

2010.

Geothermal from Co-produced Fluids (oil and hot water)

Rocky Mountain Oilfield Testing Center
46 kg/s flow, 92^{o}C, 216 kWe

Huabei oil field, China
110 - 120^{o}C, 400 kWe

Xin, Dong, Liang and Li, SGW 2012

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Role of the IEA-GIA (Geothermal Implementing Agreement)

IEA-GIA :

- includes 10 members from the Asia-Pacific region
- assists decision makers with future policy development and investment decisions
- assists in generating geothermal deployment projections and technology ‘road-maps’ through multiparty collaboration
- participates in renewable energy initiatives such as the geothermal chapter of the IPCC special report on renewable energy (2011)
- provides a venue for sharing research results & best practices and facilitates collaboration
- produces & disseminates authoritative information
- Secretariat at GNS Science, Taupo, New Zealand

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IEA-GIA Achievements

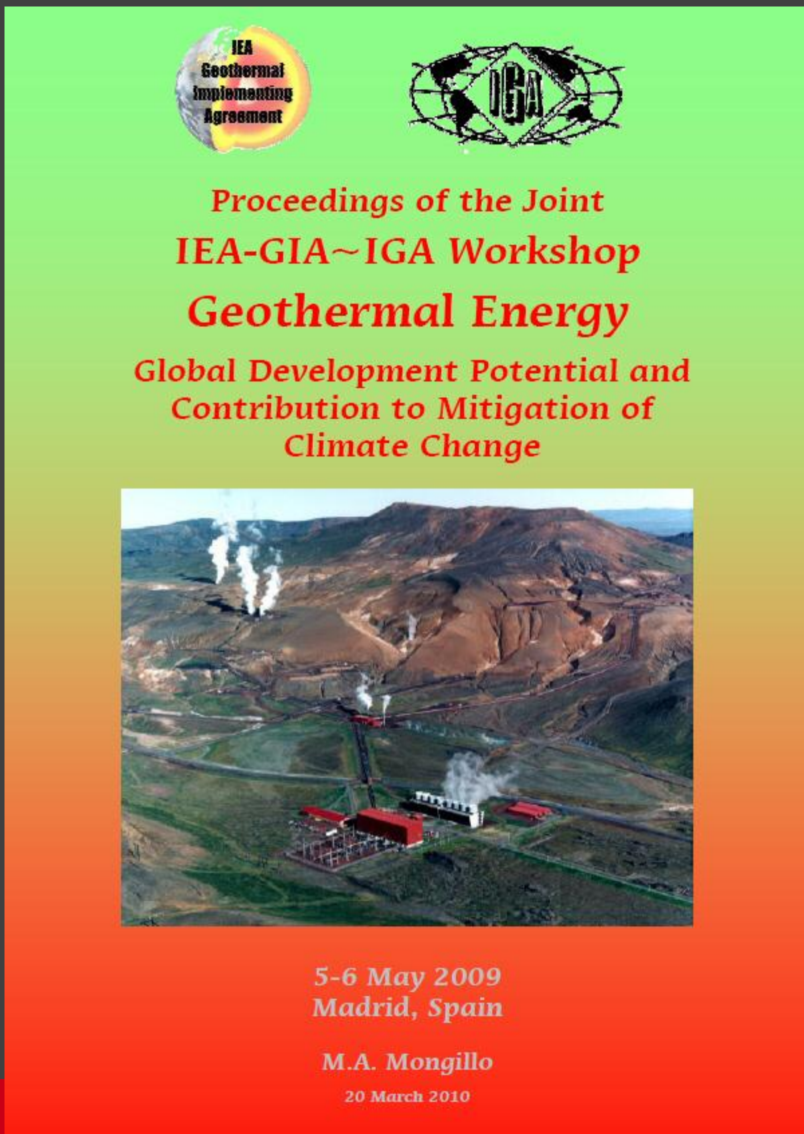
Significant Information Dissemination

- website: www.iea-gia.org
- Database on global geothermal resource
- Environmental mitigation workshop (Taupo, NZ, June 2012)
- Extensive annual and trend reports
- Participation at renewable energy and geothermal conferences (Posters, Papers Presentations

  - RE2008 (Busan, Korea)
  - WGC2010 (Bali, Indonesia)
  - GRC (2008, 2009, 2010); Stanford Geothermal Reservoir Workshop (2007-10, New Zealand Geothermal Workshop (2007-2012), European Geothermal Congress (2007)

Highlighted Efforts

Climate Change Mitigation



- **IPCC (2011) Renewable Energy Special Report (SRREN)**
- **Geothermal Chapter**
  - **Scoping study review**
  - **Joint GIA~IGA Workshop on resource potential**
  - **GIA members as Lead & Contributing Authors and Reviewers**

Highlighted Efforts

Sustainability

- **Workshop on Geothermal Sustainability Modelling**
  - **International Workshop with Wairakei (NZ) 50th Anniversary Covered: case histories of power and direct use**

Led to the preparation of :

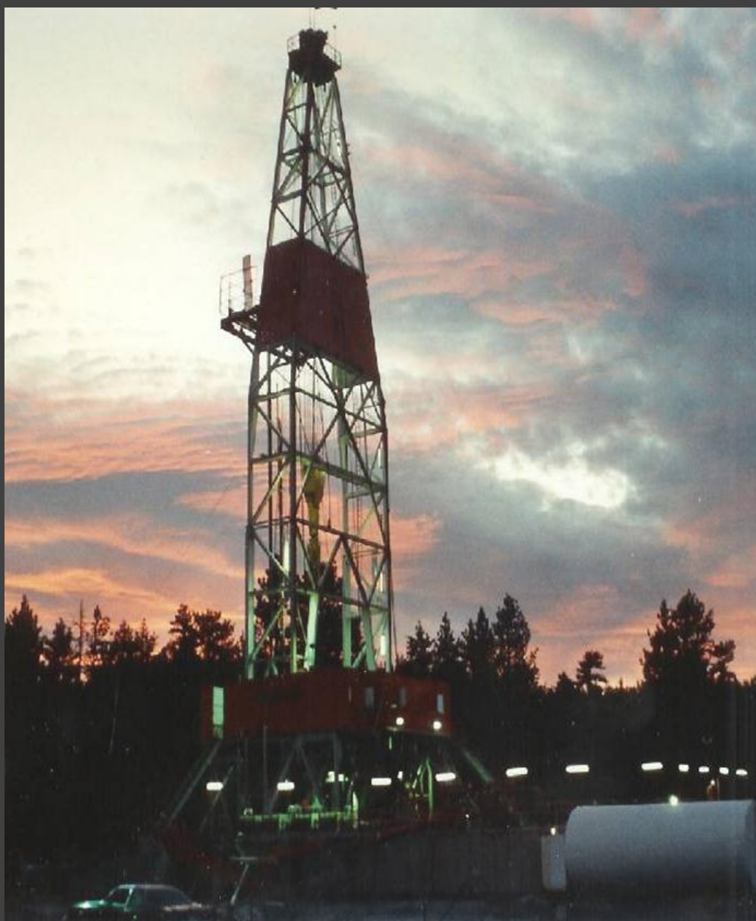
Geothermics Special Issue- Sustainable Utilization of Geothermal Energy

Issue 39/4: December 2010

Highlighted Efforts

Reducing Drilling Costs

- Well drilling costs/performance database
- Well costs simulator
- Drilling best-practices handbook



SAND2010-6048
Unlimited Release
Printed December 2010

Handbook of Best Practices for Geothermal Drilling

John Finger and Doug Blankenship

Prepared for the International Energy Agency,
Geothermal Implementing Agreement, Annex VII
by
Sandia National Laboratories
P.O. Box 5800
Albuquerque, New Mexico 87185

Abstract

This Handbook is a description of the complex process that comprises drilling a geothermal well. The focus of the detailed Chapters covering various aspects of the process (casing design, cementing, logging and instrumentation, etc) is on techniques and hardware that have proven successful in geothermal reservoirs around the world. The Handbook will eventually be linked to the Geothermal Implementing Agreement (GIA) web site, with the hope and expectation that it can be continually updated as new methods are demonstrated or proven.

3

Highlighted Efforts

IEA Technology Roadmap- Geothermal Heat and Power

- **3 international workshops**
- **Several GIA contributors**
- **Published June 2011**

Ormat Binary Geothermal Power-plant Central America

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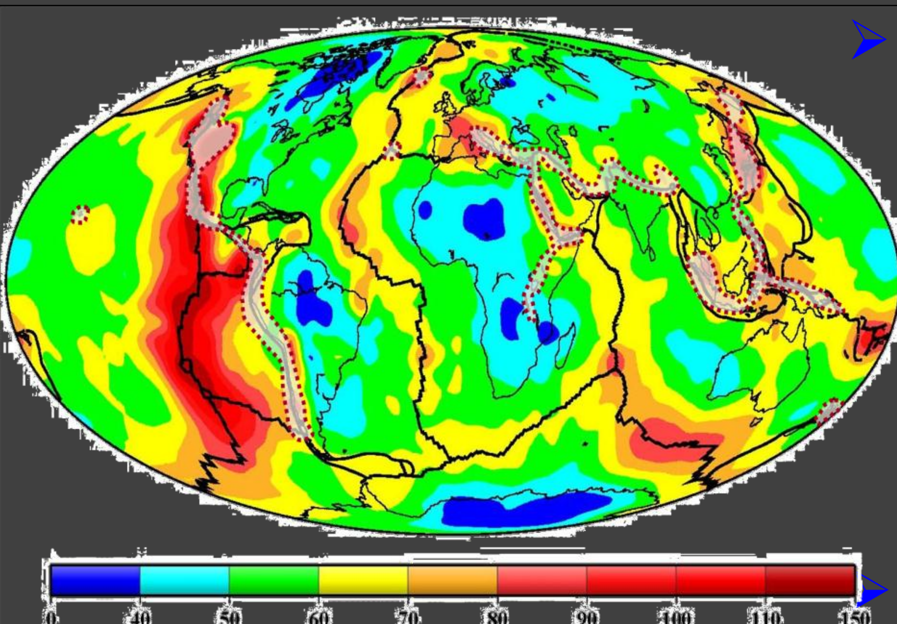
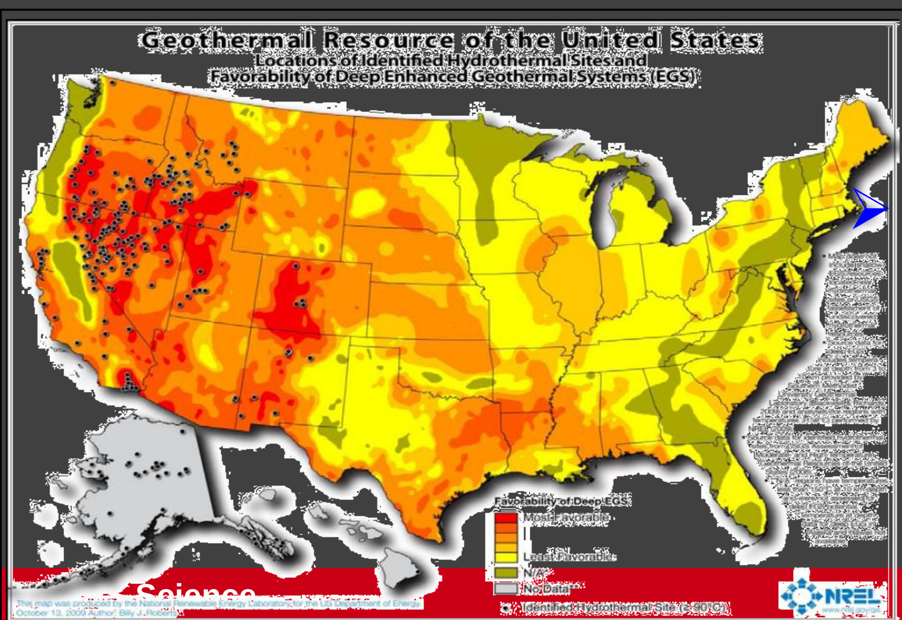
IEA Geothermal Roadmap





Potential Global Contribution of Geothermal for Power & Heat

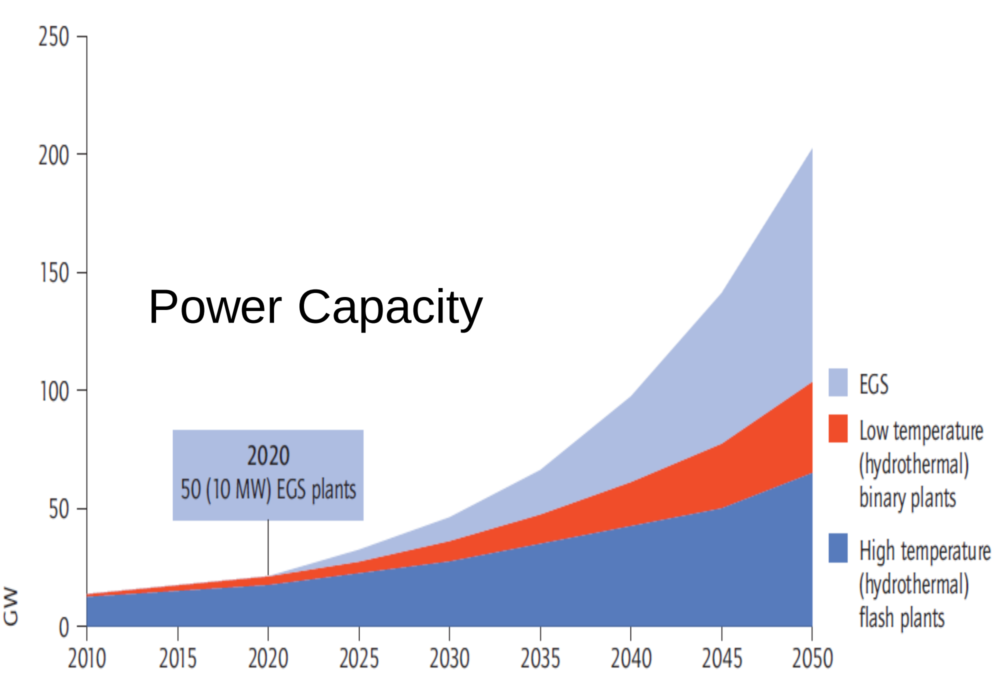
Hydrothermal Resources

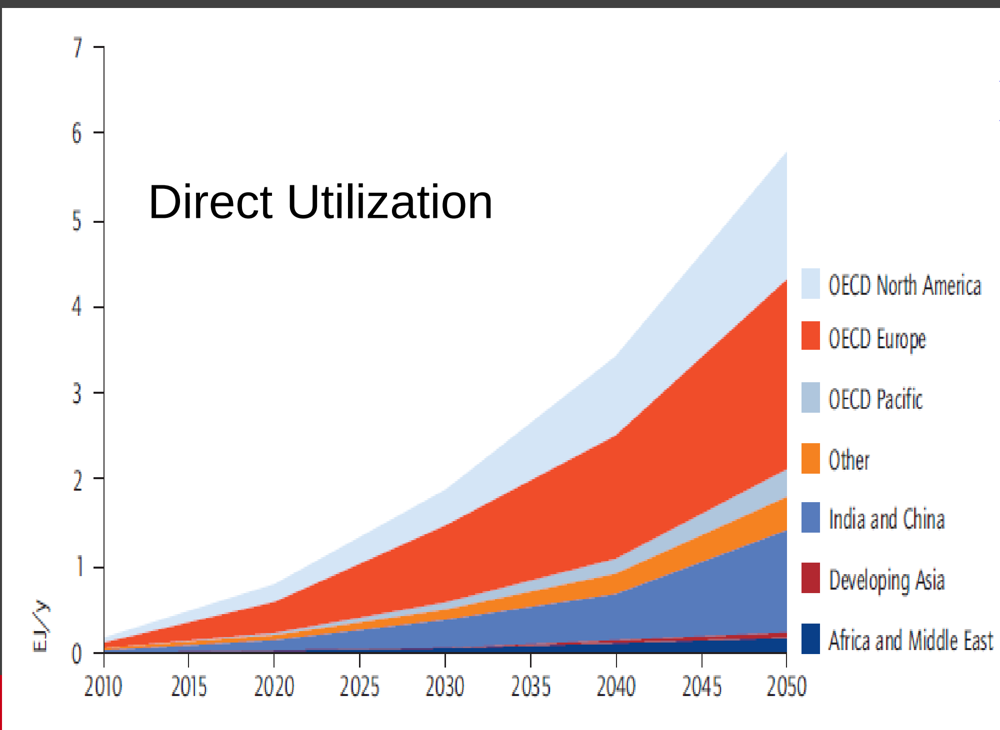
- Long experience use for power & heat
- Technologies conventional & mature
- Identified as renewable resources
- Can be sustainably utilized
- Produce very low CO_2 emissions

Hot Rock Resources- Enhanced (Engineered) Geothermal Systems

Global Theoretical Potential Estimates (upper 10 km)

- Power: 45 EJ/yr
- Direct Heat: 1,000 EJ/yr





IEA Geothermal Roadmap Projections

- **Provides Clear Pathway Analysis**
- **Shows Geothermal's Potential to Help Mitigate Climate Change Effects via CO_2 Avoidance**
- **Deployment Projections, Approaches, and Tasks :**
  - **Research & Development**
  - **Financing mechanisms**
  - **Legal & regulatory frameworks**
  - **Engaging public**
  - **International collaboration**

IEA Geothermal Implementing Agreement

Key Findings

Landau Power Station, Germany

- **Geothermal can provide low-carbon base-load power & heat from :**
  - **Hydrothermal Systems**
  - **Deep Aquifer Systems (low-medium temperatures)**
  - **Hot rock resources stimulated for energy extraction**
- **By 2050 Power Generation :**
- **~ 200 GW_e (1,400 TWh/yr)**
  - **3.5 % global total**
  - **~50% from hot rock resources (EGS)**
- **However, incentives are required to attain these goals**

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Key Actions and Incentives Required

- **Increase Investor Confidence & Accelerate Growth in Geothermal Deployment**
- **By 2030**
  - attractive economics accelerate deployment of conventional, high-temperature hydrothermal resources near plate-boundaries (~15% of land-surface)
  - deep aquifer, medium-T hot-water resources will expand
    - use for power & heat
- **By 2050 - deploy advanced technologies**
  - Hot rock (EGS)
  - Geo-pressure
  - Off-shore hydrothermal
  - Super-critical & magmatic fluids
  - Co-produced hot water from oil & gas wells

IEA Geothermal Implementing Agreement

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To Find Out More About The GIA

Visit the GIA Website

at

www.iea-gia.org

or

Contact the IEA-GIA Secretary

mongillom@reap.org.nz

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Geothermal deployment efforts

Asia-Pacific deployment projections

- **By 2050, geothermal could contribute 2-3% of electricity and heat demand for non-volcanic countries in Asia-Pacific region using Enhanced Geothermal System technologies (eg. Australia and Korea).**
- **By 2050, geothermal could contribute 10-30% of demand in volcanic countries (eg. Indonesia, Japan & New Zealand).**
- **In some countries, rapid geothermal deployment over the past five years is already displacing coal-fired power generation.**
- **With a concerted collaboration effort, the Asia-Pacific region can lead the way internationally in geothermal deployment by :**

a) helping out neighbours that are relatively inexperienced in geothermal development, especially in South America (Chile, Peru, etc.) and the South Pacific (e.g. Papua New Guinea),

b) assisting fellow nations to reach their huge geothermal energy development potential.

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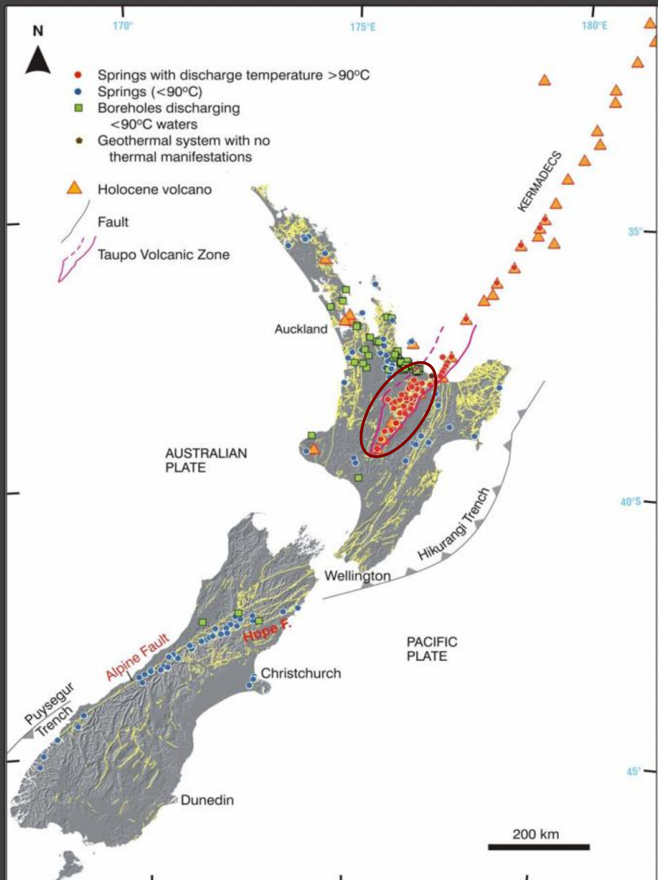
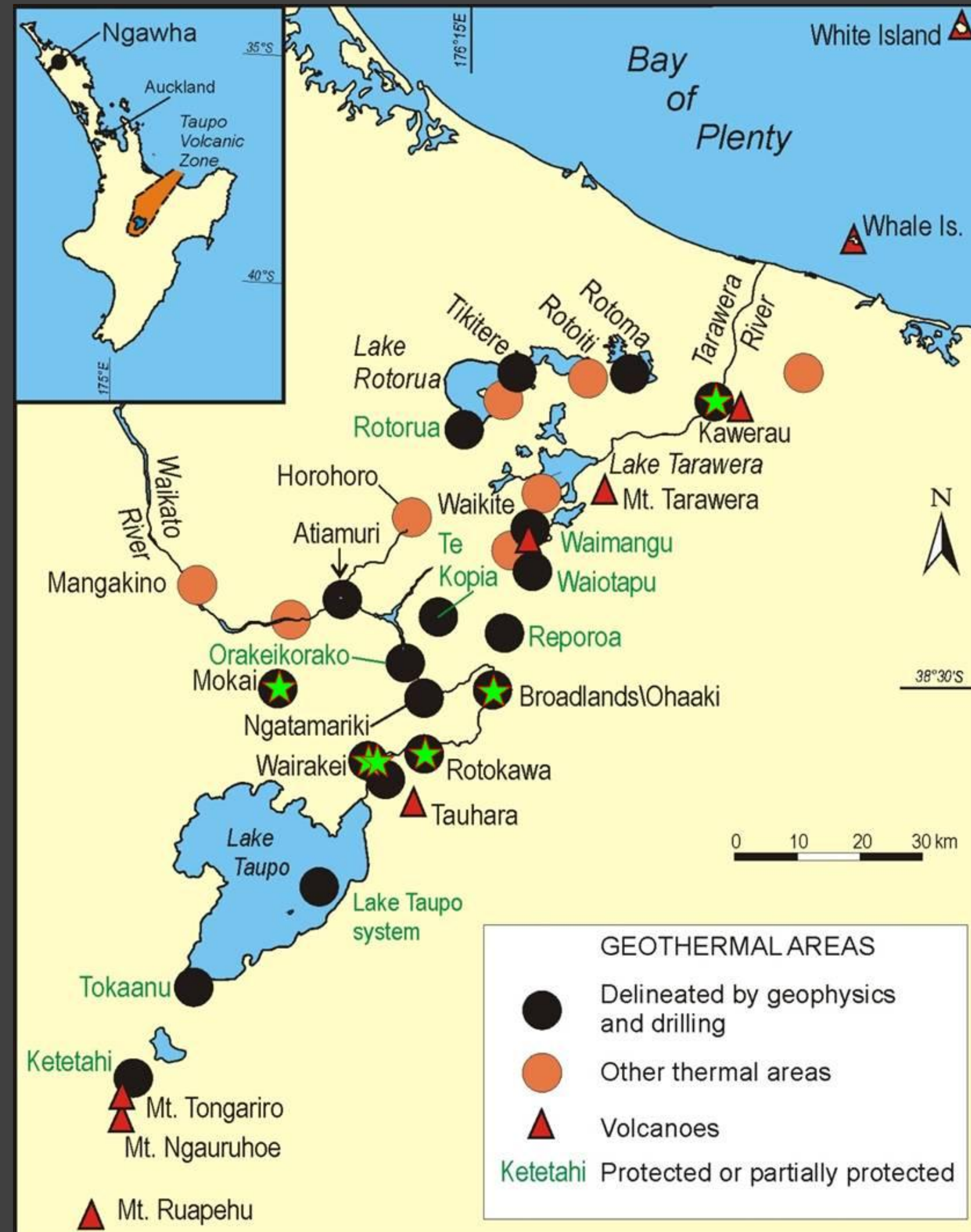
Geothermal Example from New Zealand





758 MWe installed (running)
+ 637 MWe planned
~ + 1000 MWe (1 GW) available
~ + 1600 MWe protected
Total ~ 4 GWe
+10 GWe >3-5km depth?

Geothermal Development Trends :

Doubled from 7% of total power supply in 2006 to 14% in 2012
Projected to rise from 758 to 1400 MW_e (24% of total) by 2025 ?
4-fold or 10-fold future expansion potential possible ?

New geothermal plants : Kawerau (100 MW_e), Rotokawa (140), Te Huka (23)
Under construction : Te Mihi (166), Ngatamariki (82)
Planned: Tauhara (250), Kawerau (50), Tikitere (45), others (80)

Incentives for Geothermal Development in NZ

- **Substantial Information Available**
- **Public Awareness High**
- **Extensive Experience with Geothermal**
- **Education & Training Well Regarded Worldwide**

Recent capital costs :

Kawerau (100 MWe flash):
~ $3 M / MWe
Tauhara Te Huka (23 binary):
~ $3.4 M / MWe
Rotokawa NAP (140 flash):
~ $3.6 M / MWe
Te Mihi (166 flash):
~$3.8 M / MWe
Ngatamariki (82 binary):
~$5.7 M / MWe

- **Most Important-**

  Geothermal Lowest Cost New Generation Option

- **Economics Key Driver for Geothermal Deployment and Investment – Expect Continued Rapid Growth**

- **HV DC interconnection to Australia ?**

IEA Geothermal Implementing Agreement

Direct use innovation

- Direct use growth is steady (11 PJ/yr), 60% industrial/heating, 40% bathing & tourism
- Novel engineering : 2-phase heat exchanger at Taupo , steam stripping for high-grade feed-water at Mokai & Kawerau, biological treatment for H_2S reduction at Wairakei & Mokai; artificial geyser and sinter terrace & pools at Wairakei

Miraka Dairy Factory (Mokai) world's first geothermal-steam, dairy-milk drying-plant, 270 TJ/yr, 210 M litres/yr, 8 tonnes/hr milk powder (2011)

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Nga Awa Purua

(Rotokawa) 140 MW_e* power plant, the world's largest triple flash single geothermal turbine (commissioned April 2010).

IEA Geothermal Implementing Agreement

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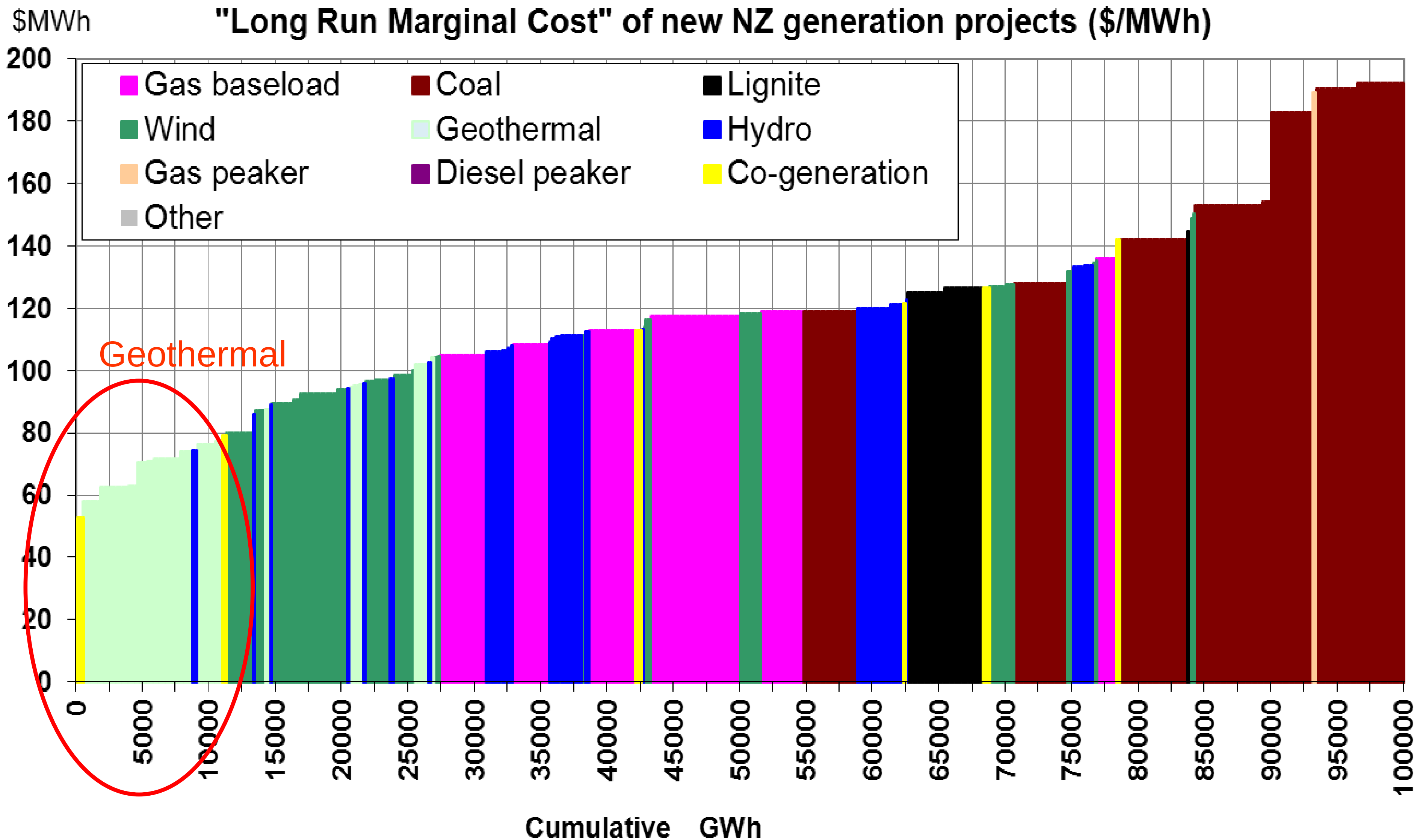
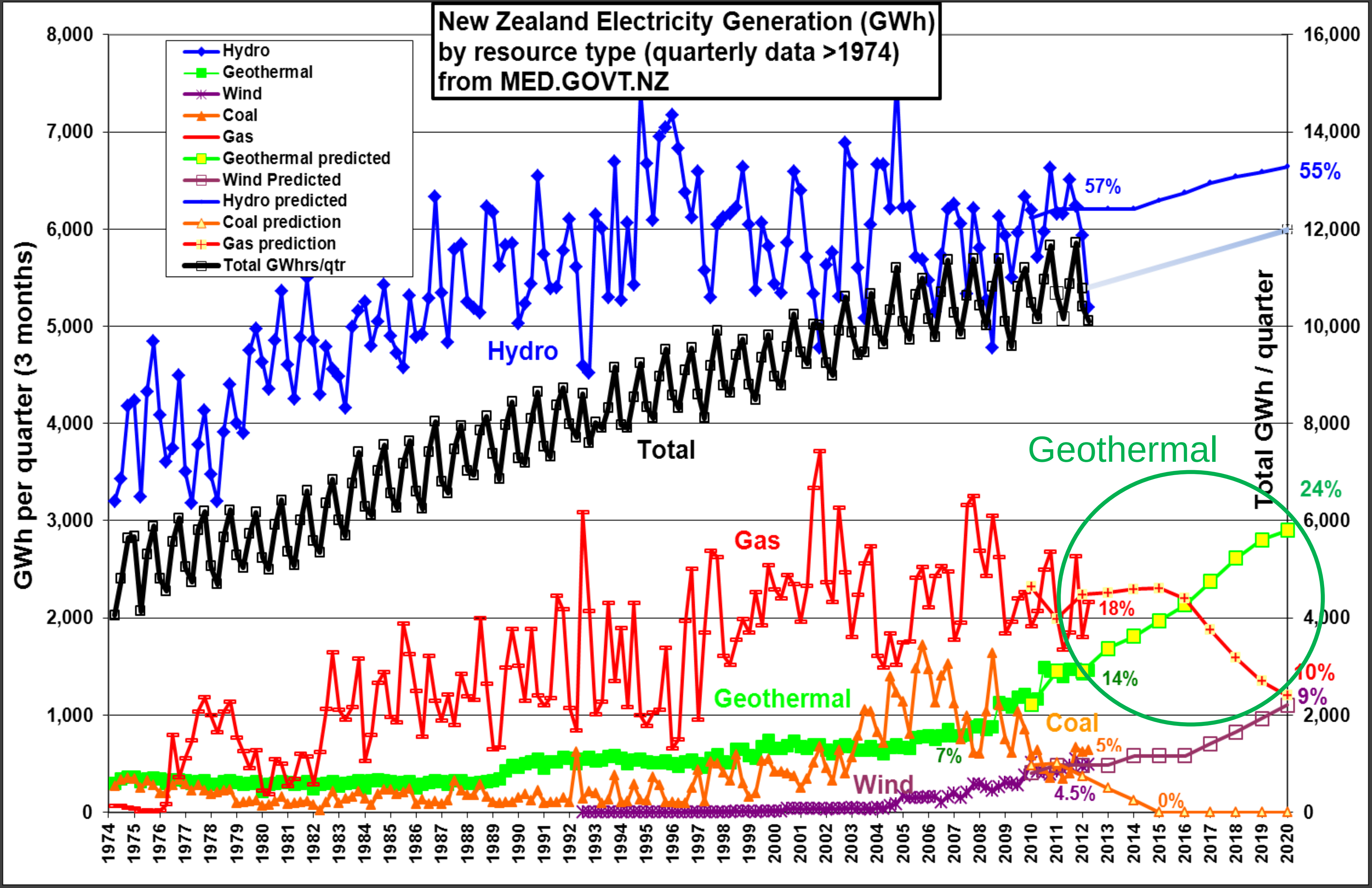


Electricity generation – LRMC for new projects in lowest cost order (MED.GOVT.NZ) updated March 2012. Assumes: 1.5% annual growth rates; $25/tonne carbon tax; 8% discount rate; +5,000 GWh required over 10 yrs. Geothermal predominates up to 11,000 GWh (~1.2 GWe or ~20 years new base-load capacity). These long-run marginal new generation costs include the costs of interest on capital, operations and maintenance, and make-up drilling.

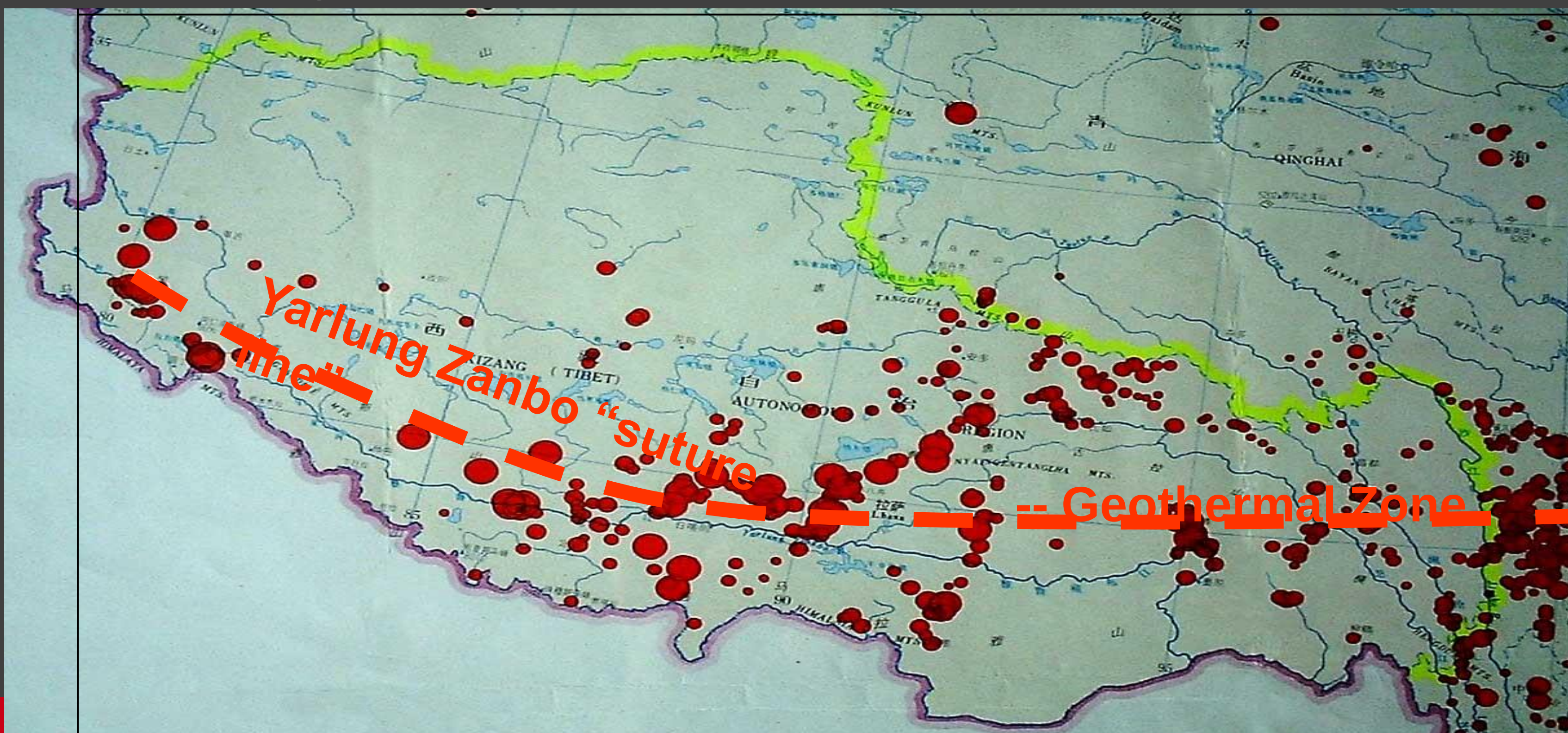


Electricity generation projections

Geothermal Example Tibet

Keyan Zheng & Meihua Wang
Geothermal Council of China Energy Society (GCES),
China Institute of Geo-Environment Monitoring

- 2- 3 GWe potential for geothermal, 57 systems
- 137.5 MWe of reserves explored
- Yangbajain : 24 MWe, 140 GWh/yr
- New Yangyi Power Plant : 2×16 MWe started

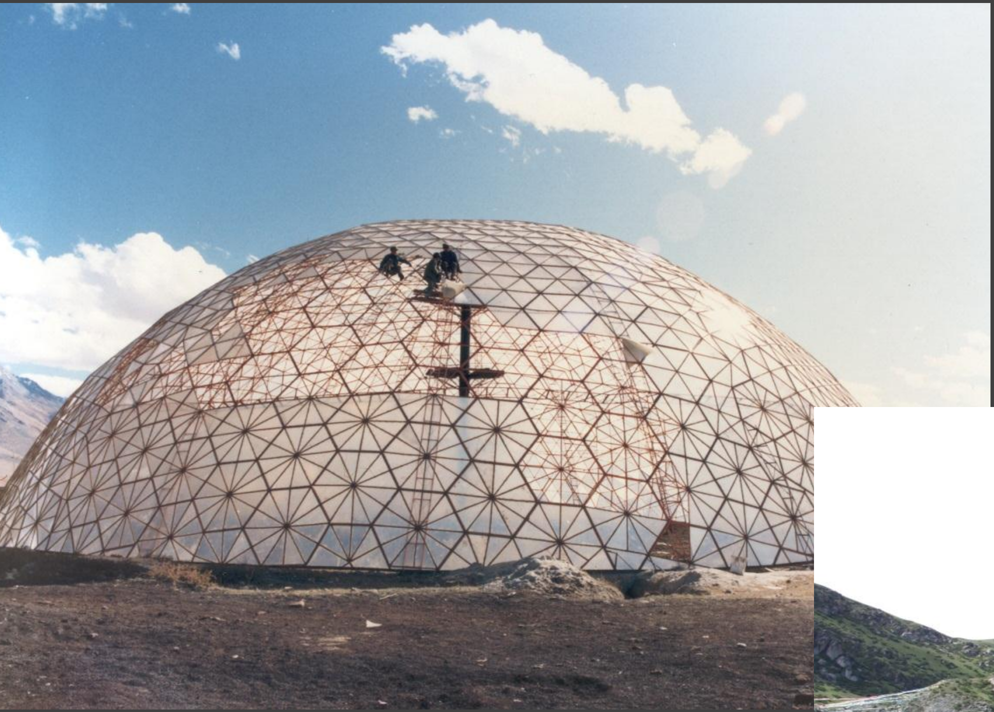


YANGBAJAIN GEOTHERMAL POWER PLANT

- The first high temp. geothermal power plant in China
- Started running in 1977
- South plant 10MWe; North plant 15MWe
- Uses shallow reservoir only

2×1MW screw expander units at Yangbajain, 2009/2010 (Longyuan Co.)

Direct use : Geothermal Greenhouses



Use waste thermal water from Yangbajain Power Plant

Washing of sheep's wool

Yangyi production well drilling and 2×16MW power plant site

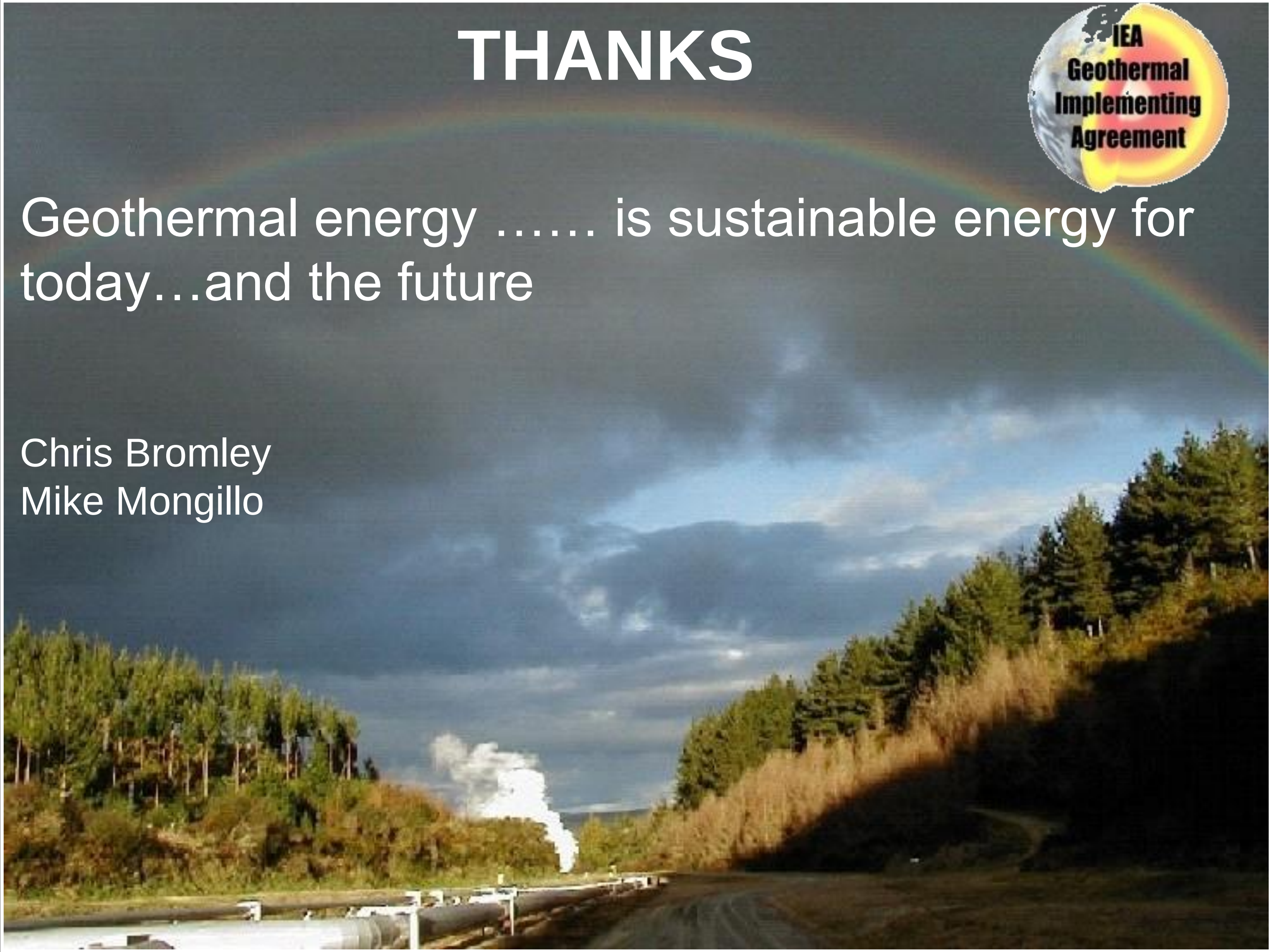
"Countrywide Symposium on Pushing and Accelerating Geothermal Power Generation in China"

- **"The Second Spring of Chinese geothermal development has come": Mr. Mao Rubai, former president of the Environmental and Resources Committee of National People's Congress**

THANKS

Geothermal energy …… is sustainable energy for today…and the future

Chris Bromley
Mike Mongillo



Special Thanks to: IEA-GIA, IPGT, & IGA collaborators, Colin Harvey & Roland Horne
Keyan Zheng & Meihua Wang