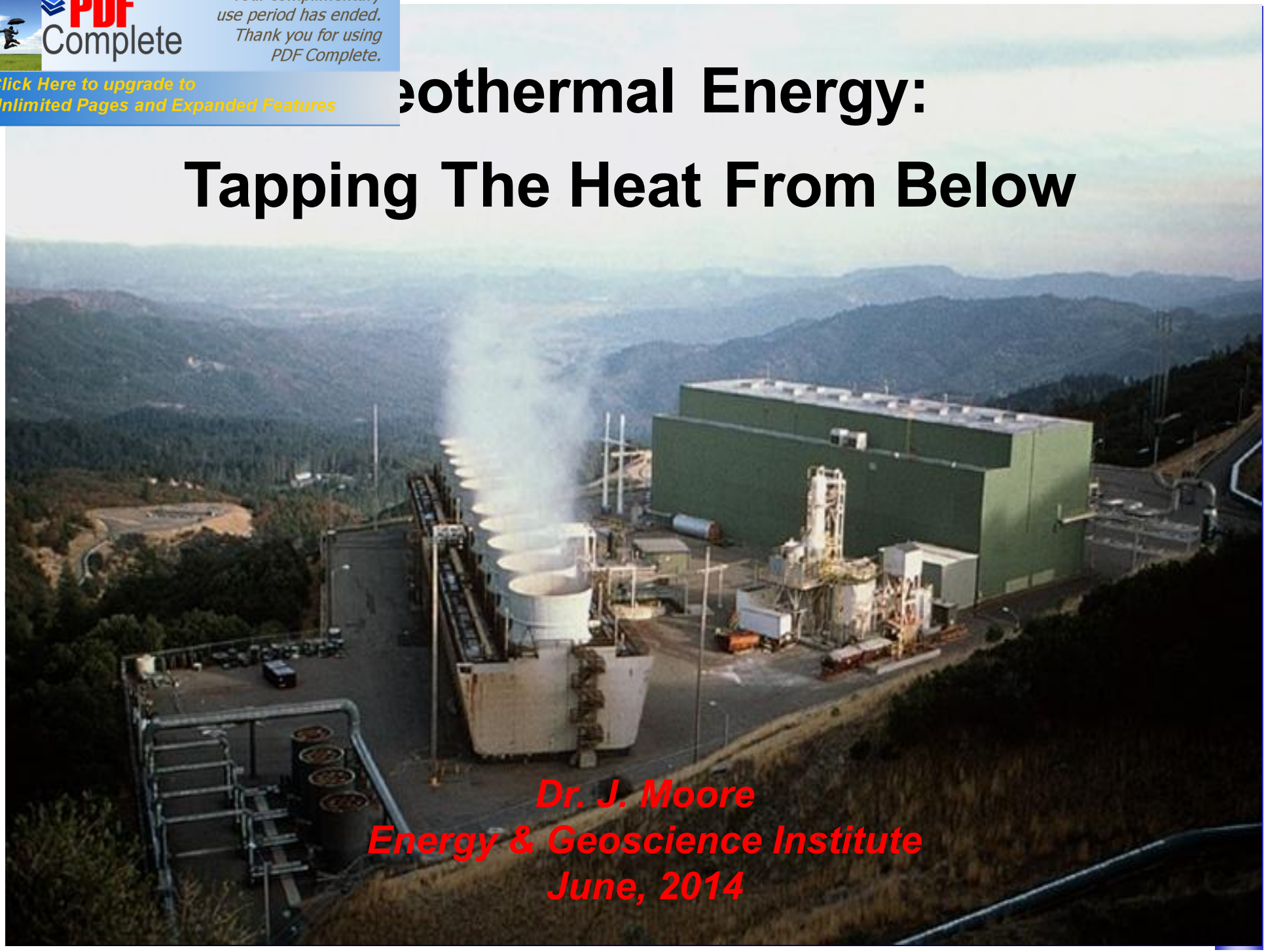
eothermal Energy:

Tapping The Heat From Below



Dr. J. Moore
Energy & Geoscience Institute
June, 2014

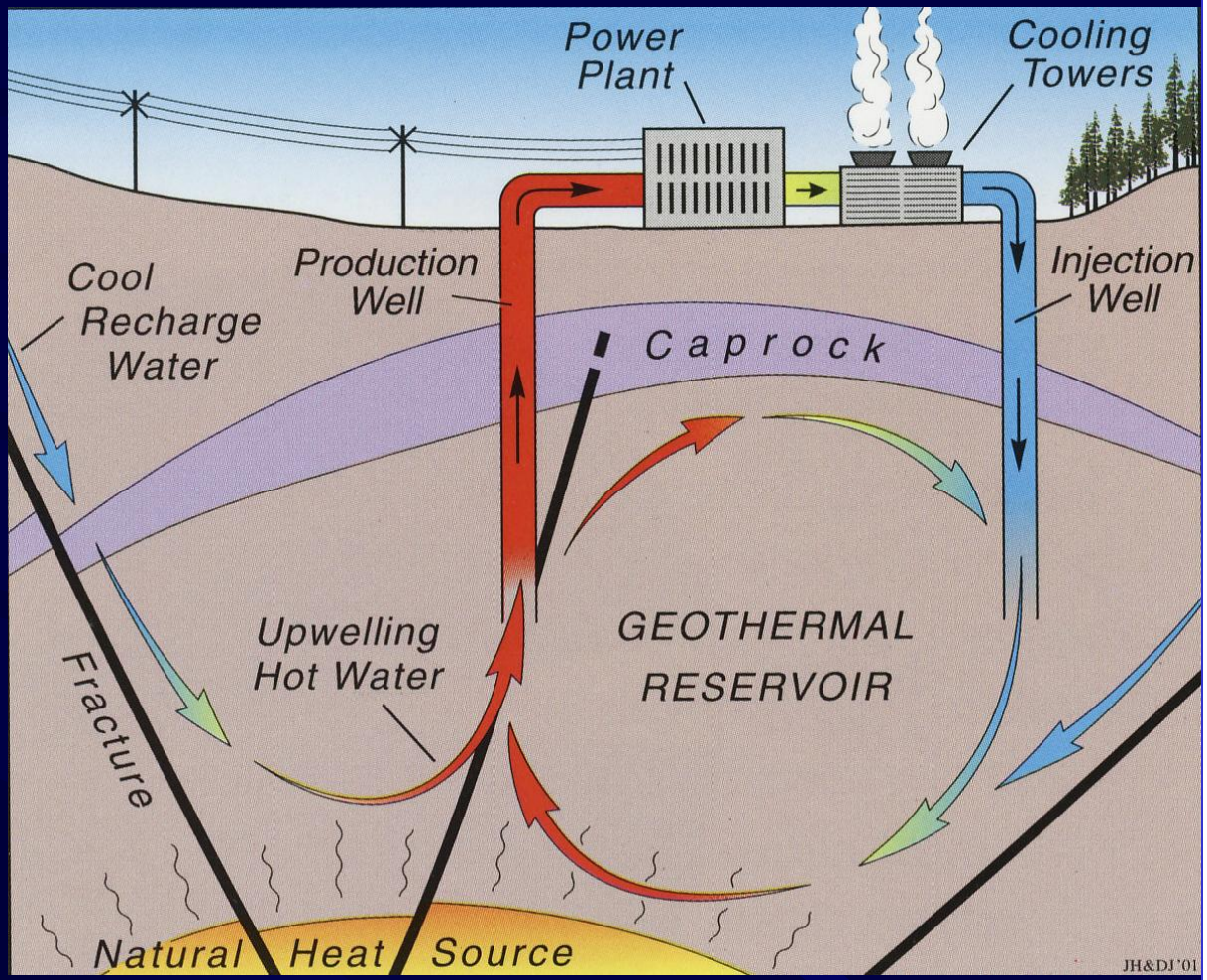
s of Geothermal Energy: The Forgotten Renewable?

- ✓ Low emission
- ✓ Useful over broad temperature range
- ✓ Base load power
- ✓ Peaking
- ✓ Renewable
- ✓ Vast resource
- ✓ Low costs once established
- ✓ Small geographic footprint
- ✓ Modular
- ✓ Suitable for a wide range of climates

EGI

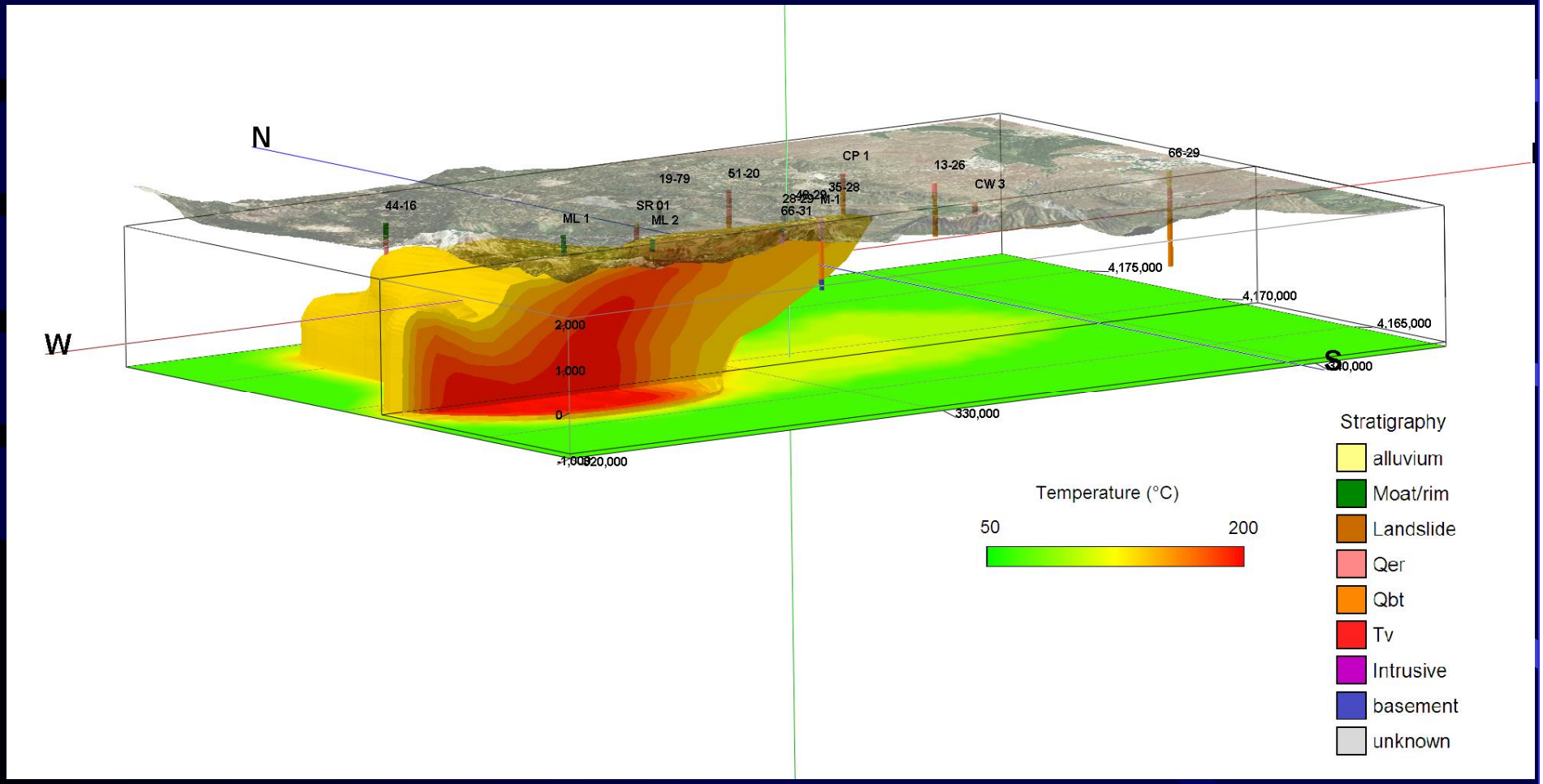
Of A Geothermal Resource

- A heat source
- Convective upflow of liquid and/or steam
- A low permeability conductively heated cap
- Recharge by meteoric waters
- Outflow of the deep fluids to the surface or other hydraulic base level



EGI

A Geologic Model



EGI

Suemnicht, 2011

Fault Zones

Productive Fracture

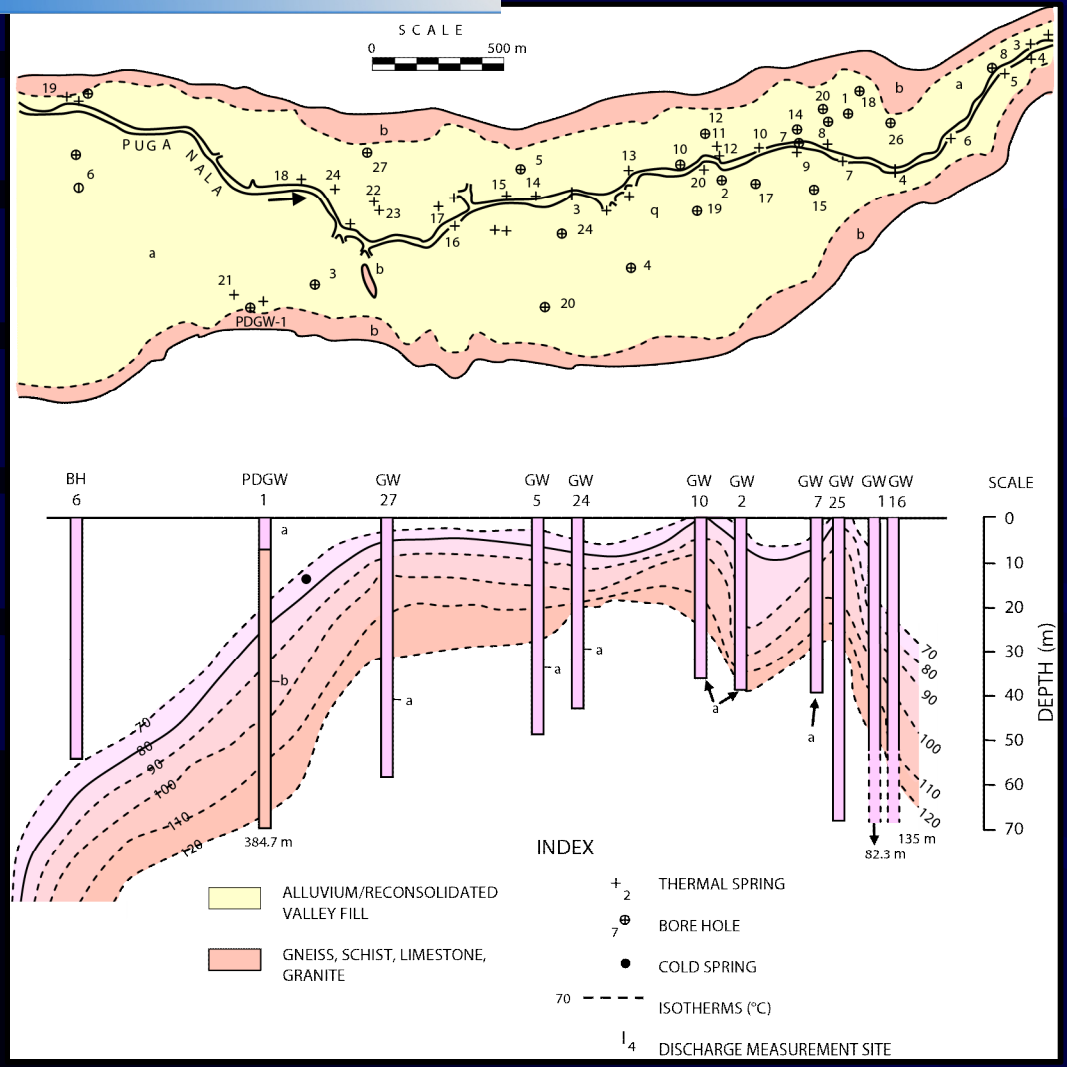
othermal Provinces

Craig and others, 2013

India estimated potential >10, 000 MWe

- Yangbajing, Tibet
- Elevation = 4300 m
- Air temp 2.5C (mean); -30C (winter)
- 2 reservoirs; 150-170C (180-280 m) and 250-329C (at 1000-2007 m)
- 25 MWe (installed)

Geothermal System

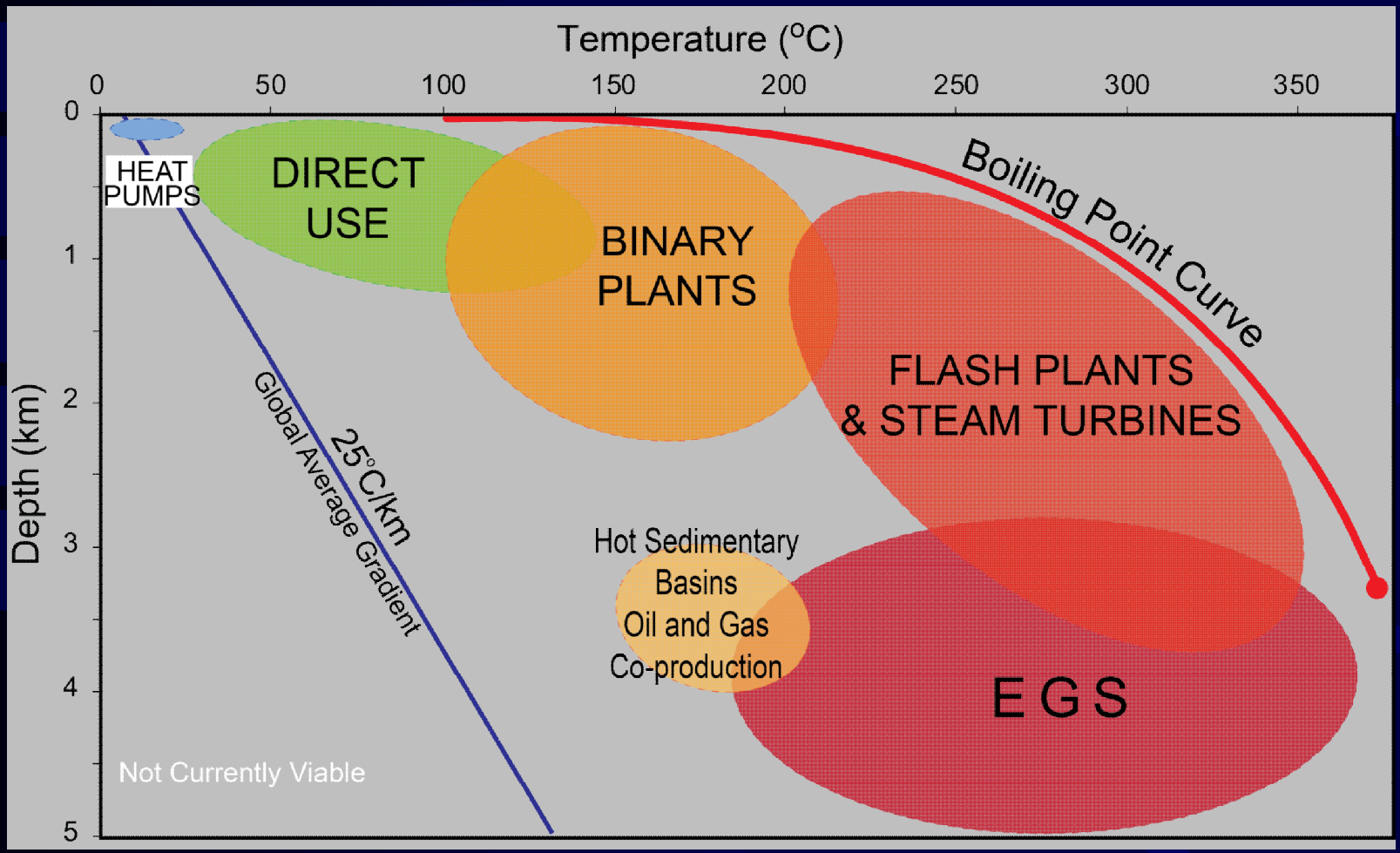


34 wells (max 385 m)
Max temp = 130C
Geothermometer temp = ~160-180C
Pilot studies-extract borax and sulfur, poultry and mushroom farming

Craig and others, 2013
Photos by J. Thurow

EGI

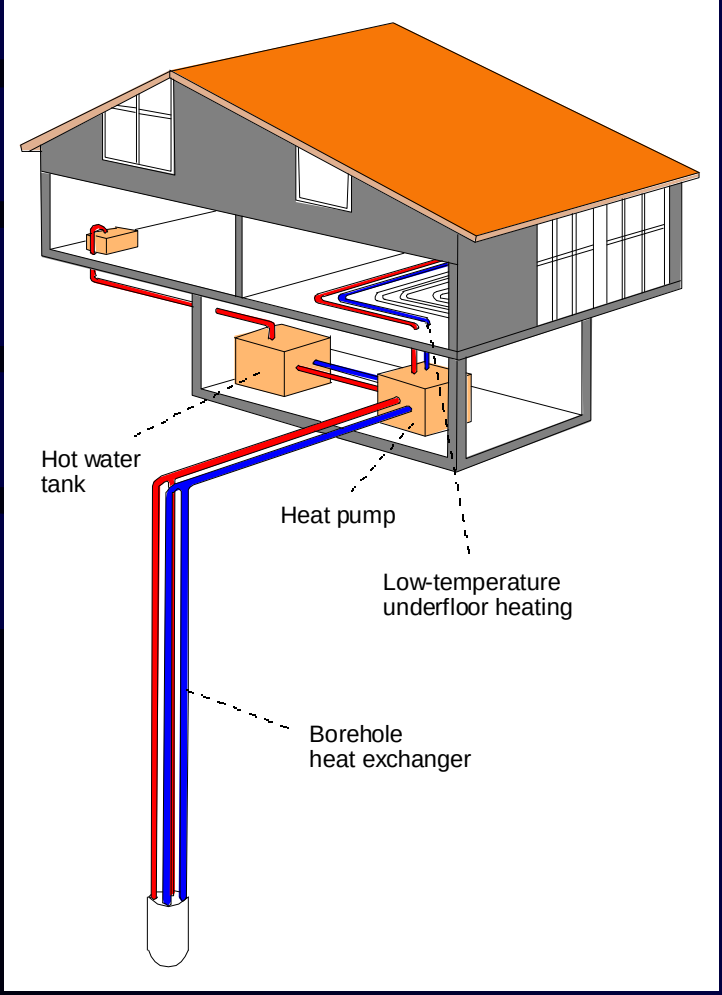
thermal Applications



Moore and Simmons, 2013

EGI

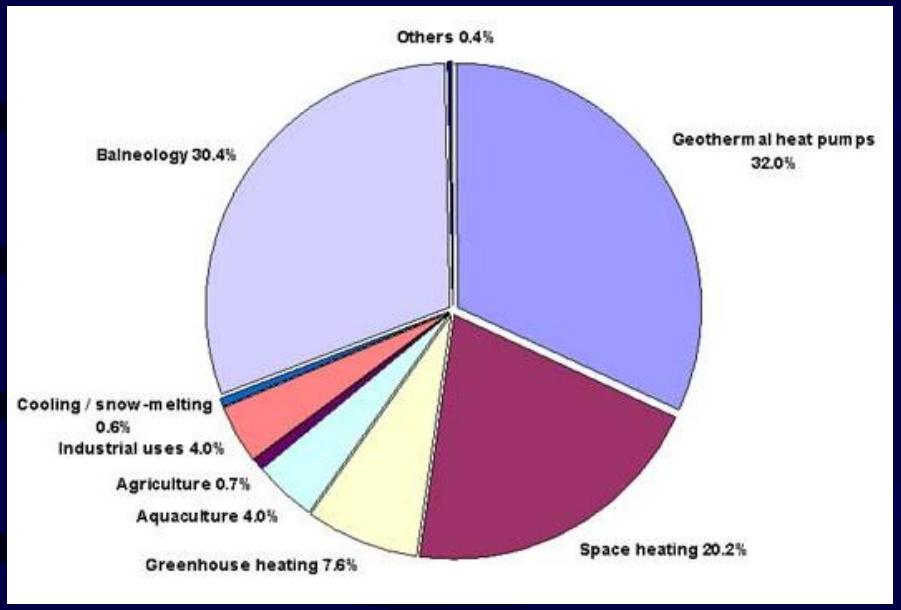
Heat Pumps

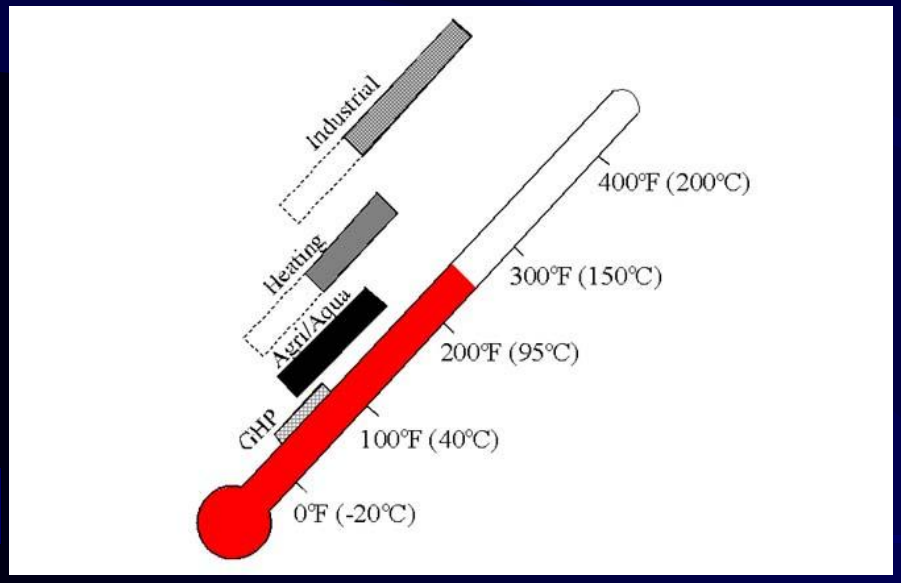


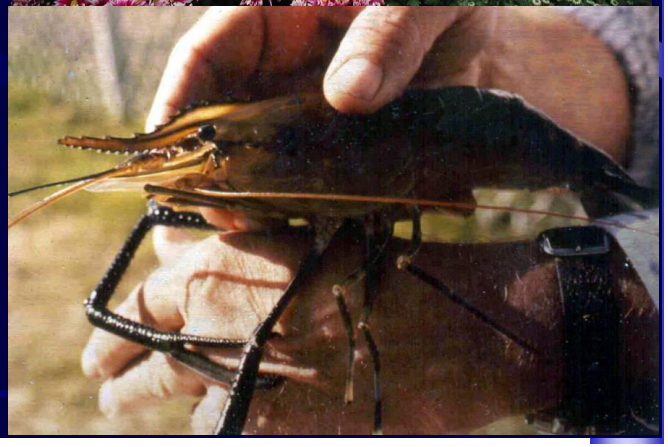
>1,500,000 units world-wide
Growing at the rate 25%/year
Savings of 30-70% when heating and 20-50% when cooling

EGI

# of Geothermal Energy







ric Power Generation

- 24 countries produce electricity from geothermal energy
- Total of 11,131 MWe of installed
  - US = 3151 Mwe
  - Philippines = 1907 MWe
  - Indonesia 1307 MWe
- Operating with a capacity factor of 73%; in US > 90%
- 270 million barrels, or 41 million tonnes of oil/yr (about 3.5 days or 1% of world's production)

1904 – Larderello, Italy

Carbon Dioxide emissions range from 0 - 4% per megawatt of the CO_2 emitted by a fossil fuel power plant – most new geothermal plants produce 0% CO_2

EGI

Do We Need To Know

Resource Questions

- Depth?
- Quality?
- Permeability?
- Size?
- Productivity?
- Longevity?

Exploration Techniques

Geology

Geochemistry

Geophysics

Reservoir Engineering

EGI

G. Suemnicht, 2011

n Drilling: Ultimately must demonstrate the resource

- Typically 100 -1000 m for measuring temperature
- Can be rotary or core holes-need 3-6 inch holes for flow testing
- Can be designed and sized to be converted to production, if successful.

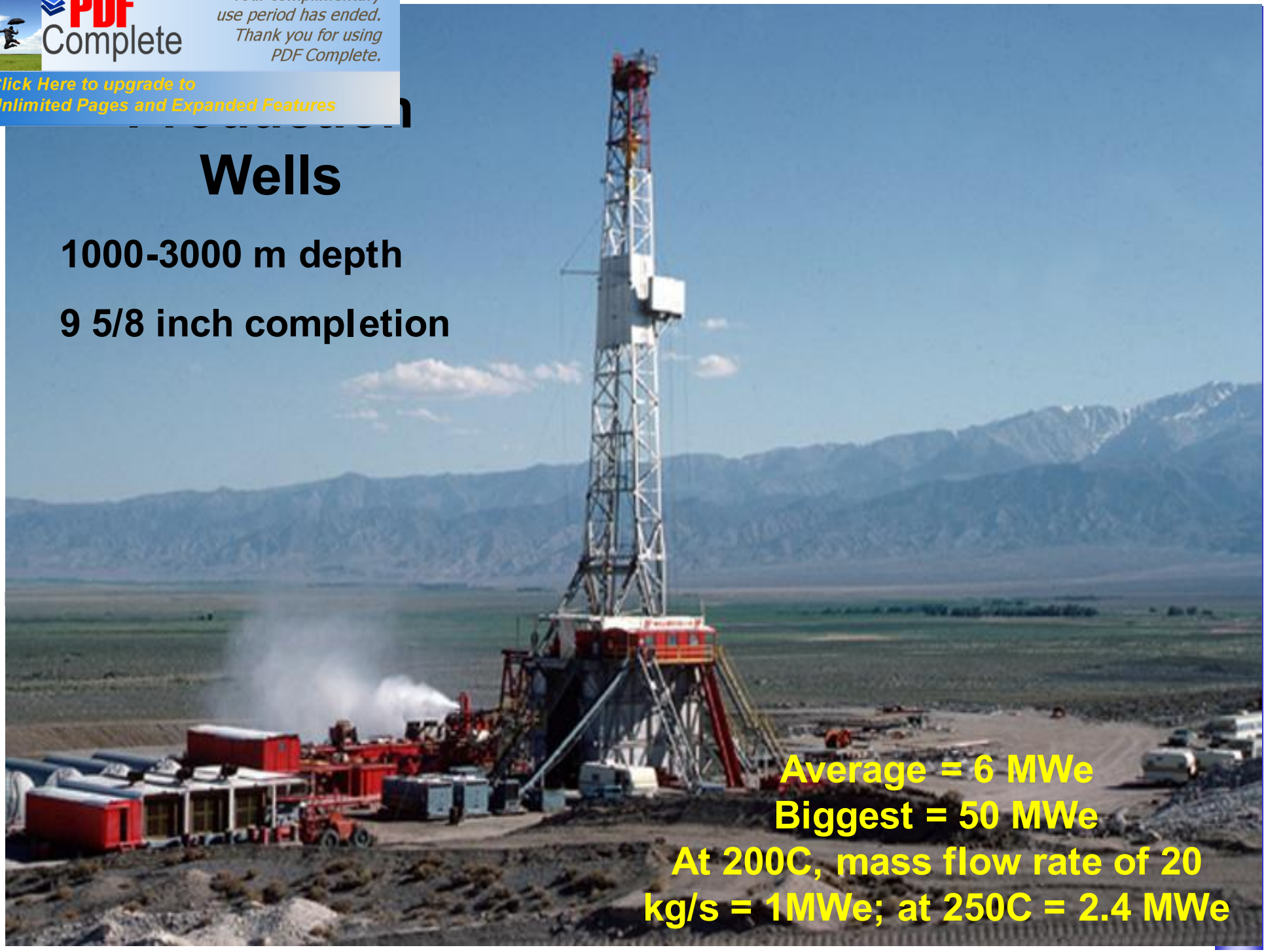
Courtesy West Indies Power

EGI

Wells

1000-3000 m depth

9 5/8 inch completion



Average = 6 MWe
Biggest = 50 MWe
At 200C, mass flow rate of 20 kg/s = 1MWe; at 250C = 2.4 MWe

ative Production Rates

Water well – 200 gpm

Oil well – 200 gpm

Geothermal well
2000 gpm

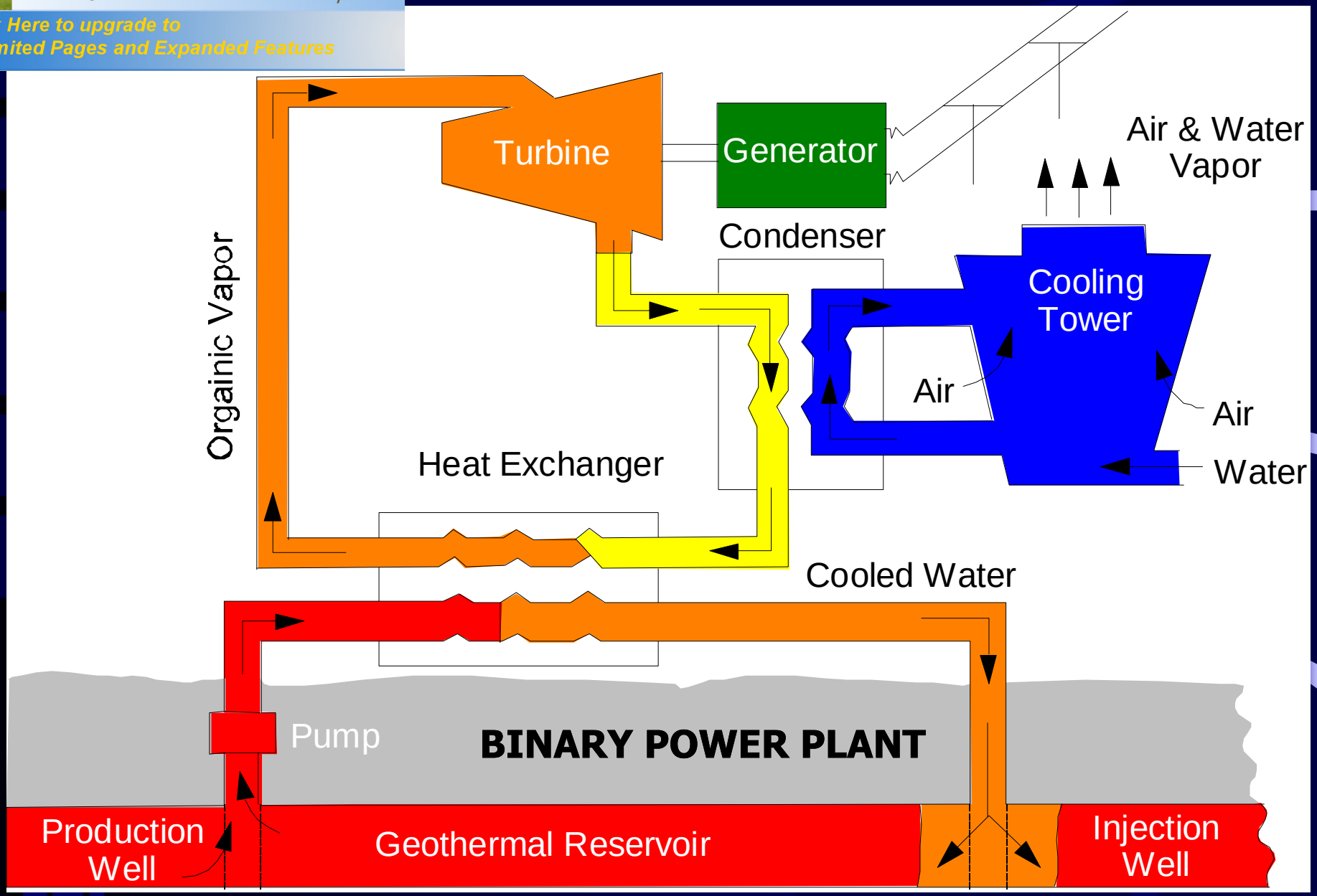
EGI

G. Suemnicht, 2011

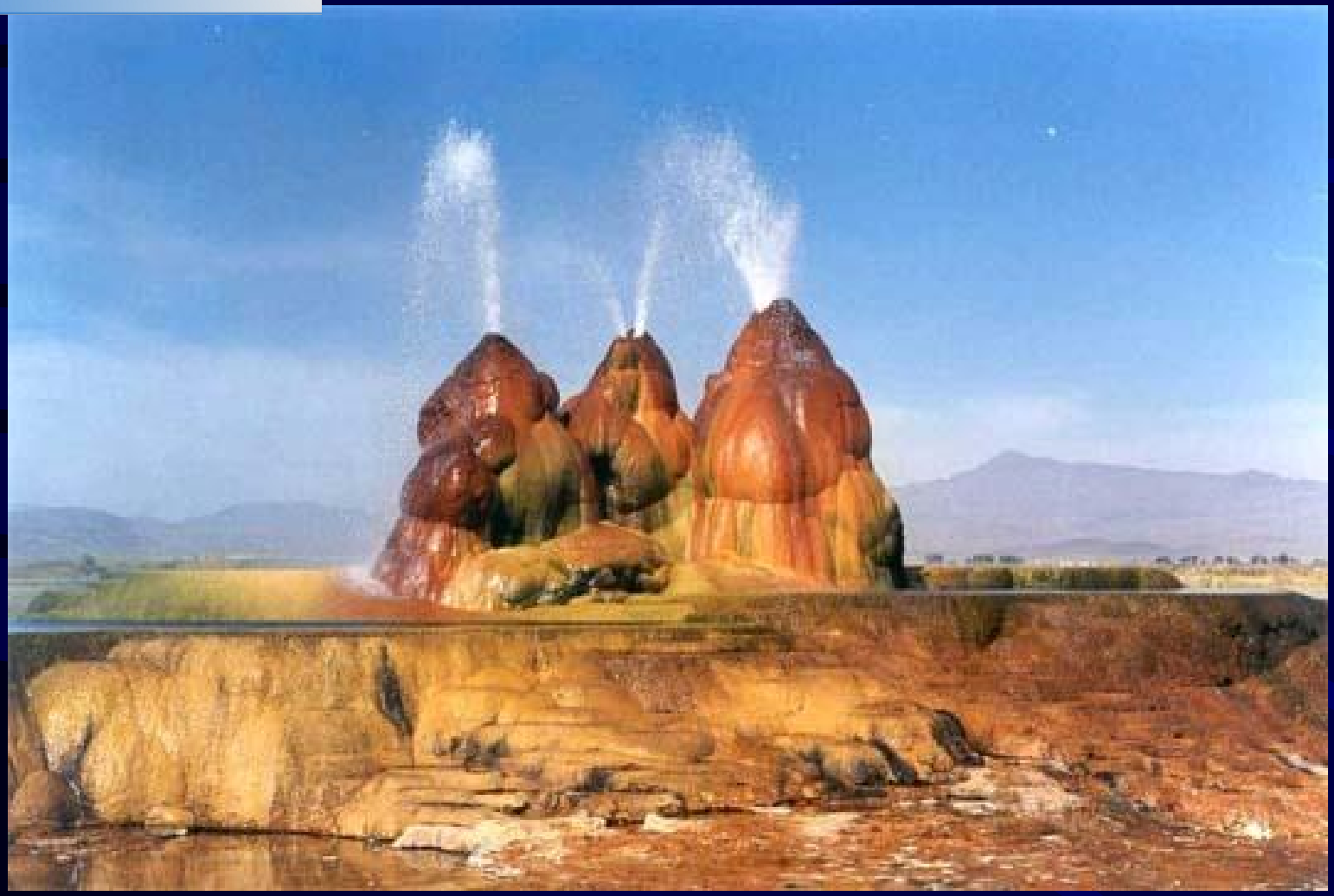
y Power Plant :Raft River, Idaho

- Maximum T ~150°C
- 4 Production; 3 Injection Wells
- Production: ~ 5,000 gpm
- Produces ~10-11.5 Mw_e
- Capacity Factor >90%

0.25 Mwe UTC Generator



QUESTIONS?

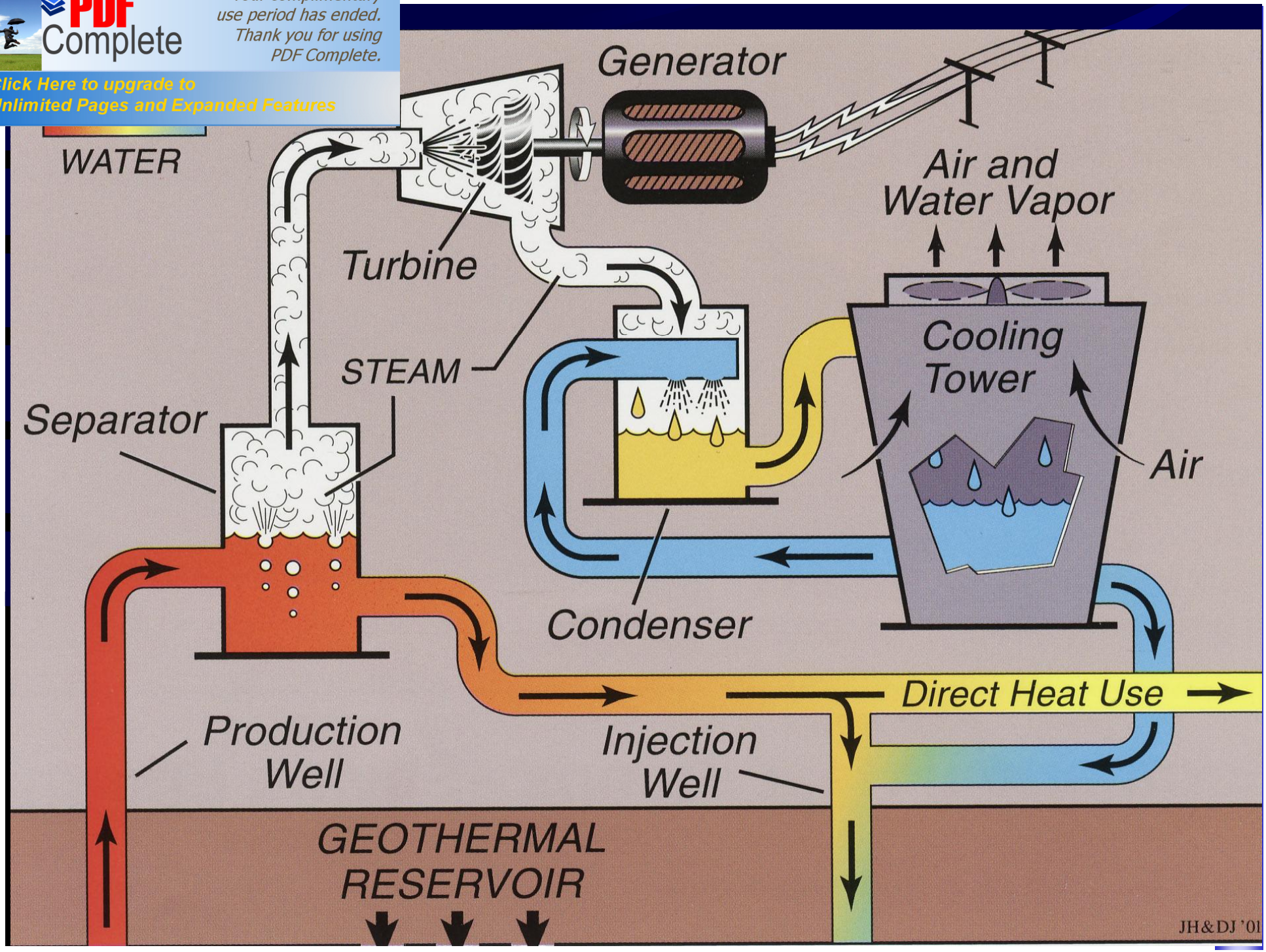


THANK YOU

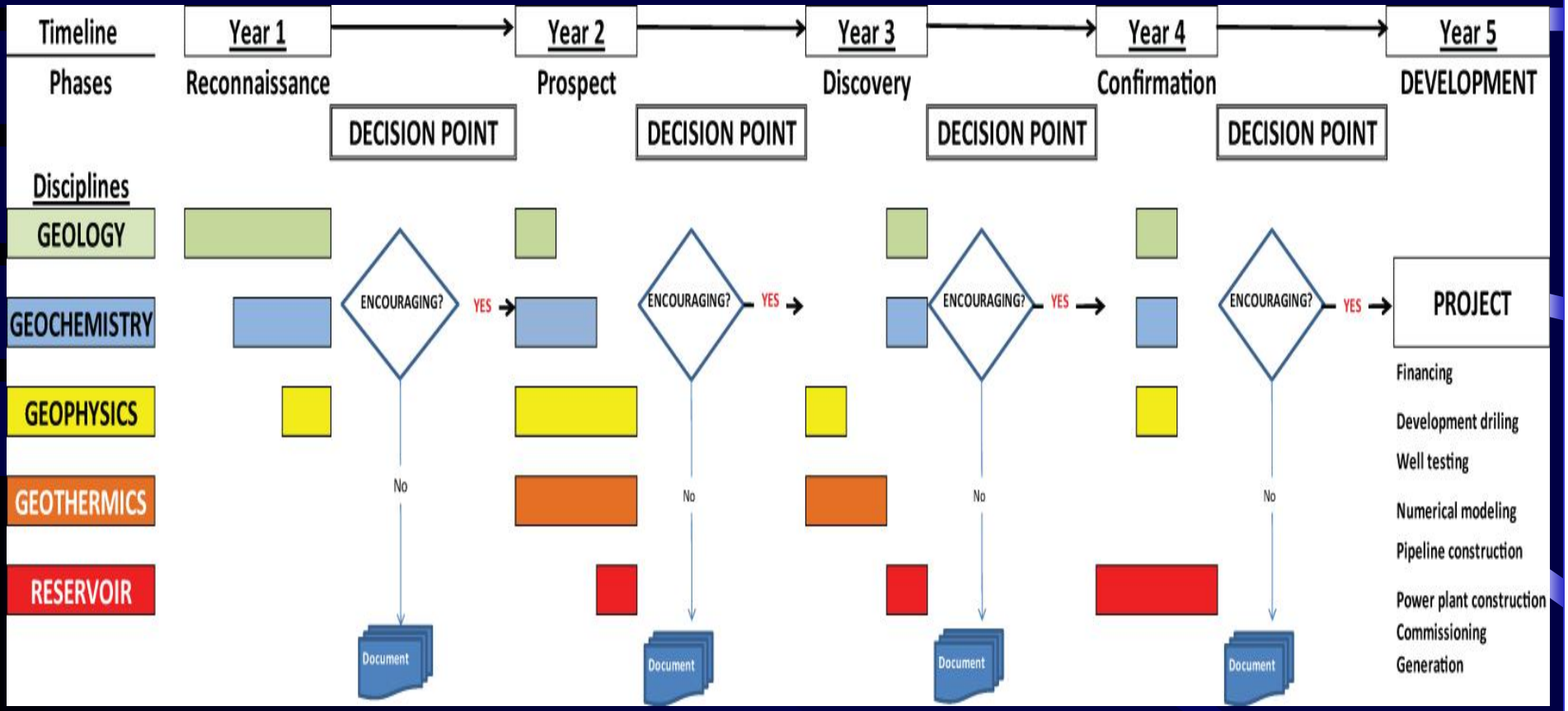
EGI

36 MW Blundell Plant, UT

EGI



xploration Timeline



EGI

G. Suemnicht, 2011

TOP DIRECT-USE COUNTRIES

Country	GWh/yr	MWt	Main Application
China	12,605	3,687	bathing
Sweden	10,000	3,840	GHP
U.S.A.	8,678	7,817	GHP
Turkey	6,900	1,495	district heating
Iceland	6,806	1,844	district heating
Japan	2,862	822	bathing (onsens)
Hungary	2,206	694	spas/greenhouse
Italy	2,098	607	spas/space heating
New Zealand	1,969	308	industrial uses

ochemical Sampling

Chemical analyses provide information on:

- **Reservoir temperatures (based on content of SiO2 and ratios of Na-K-Ca and K-Mg)**
- **Reservoir salinity**
- **Scaling potential**
- **Extent of the Resource**
- **Fluid Origins**
- **Reservoir monitoring**

ohysical Techniques

Electrical Methods

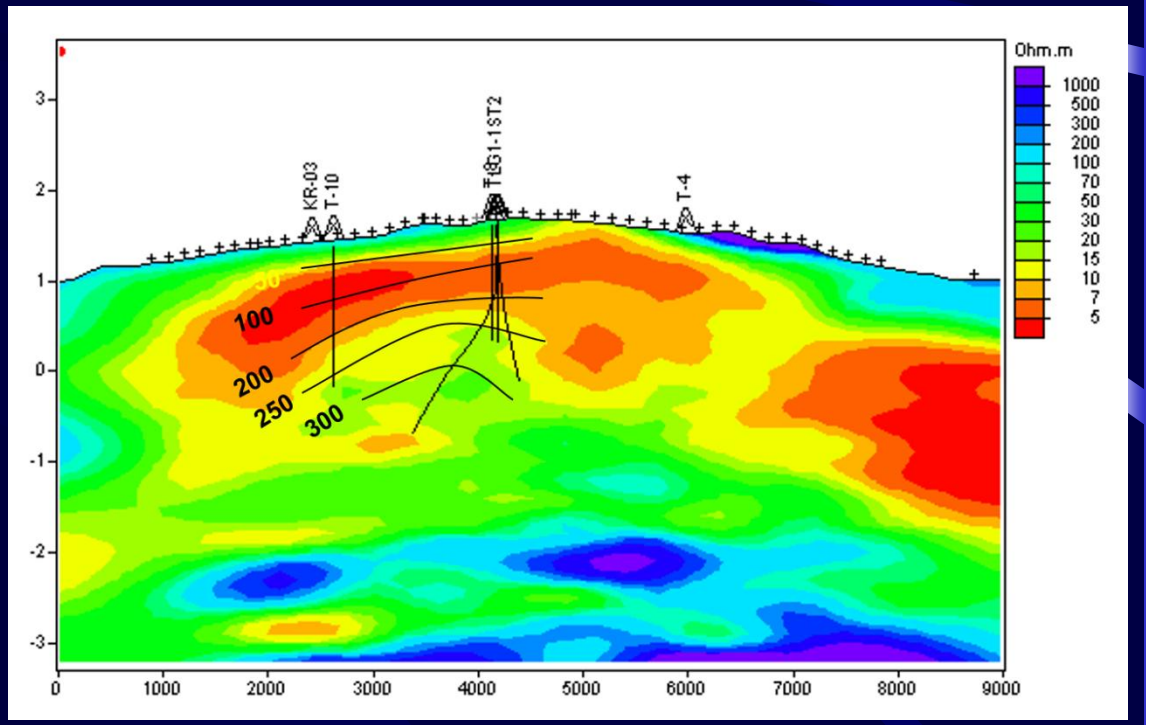
- Magnetotelluric (MT)

Potential Field Methods

- Gravity
- Magnetics
- Seismic reflection

Information on:

- Reservoir Depth
- Extent
- Geometry
- Permeabilty



Ussher, 2007