Introduction to Geothermal Energy

Summer School in Energy Economics 2016

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Introduction to Geothermal Energy:

1. Basics
2. Electricity generation
3. World/NZ resource
4. Regulation
5. Renewable/sustainable

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1. Geothermal Basics

Geothermal = Greek words

geo (earth)

therme (heat)

Geothermal system:

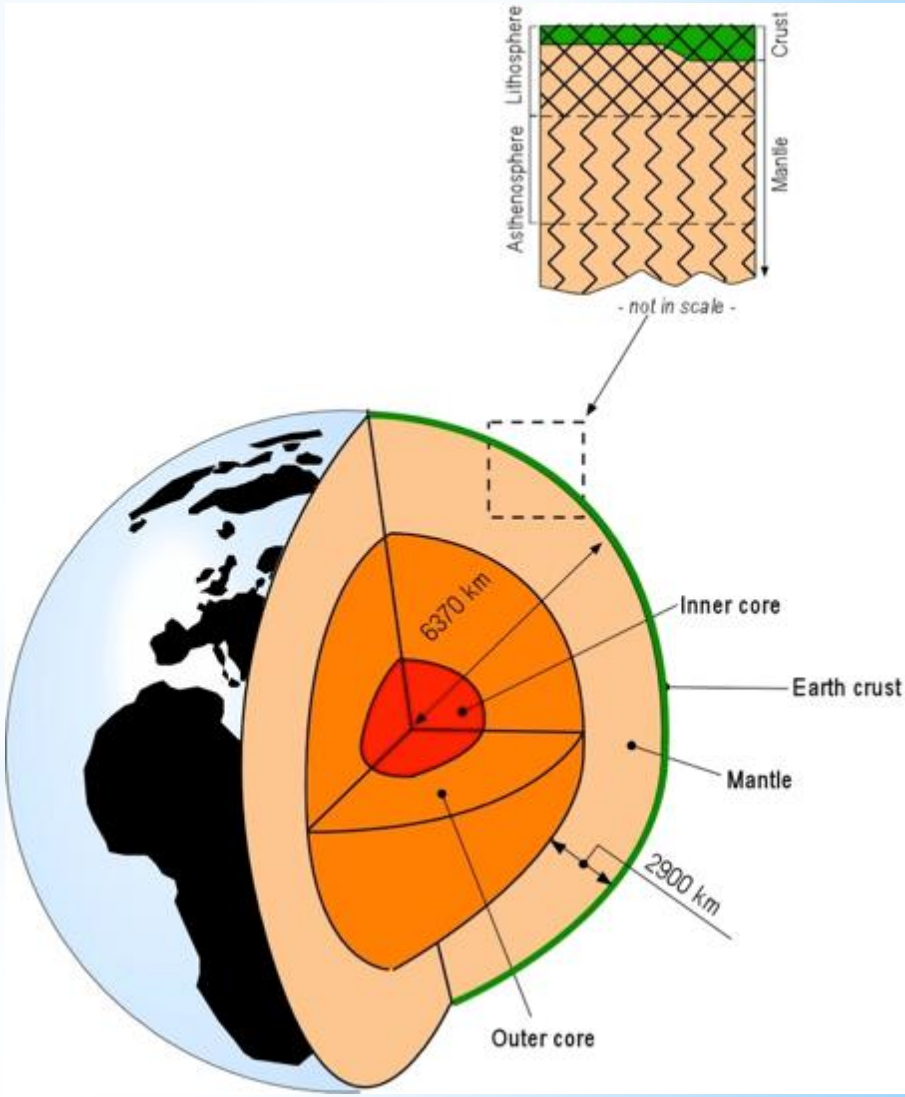
A system of processes involving heat transfer to the earth's surface (convection vs conduction)

Geothermal:

* Earth's interior : heat
* Heat: yields

  warmth and power
* 6,000 km deep:

  5,000 °C



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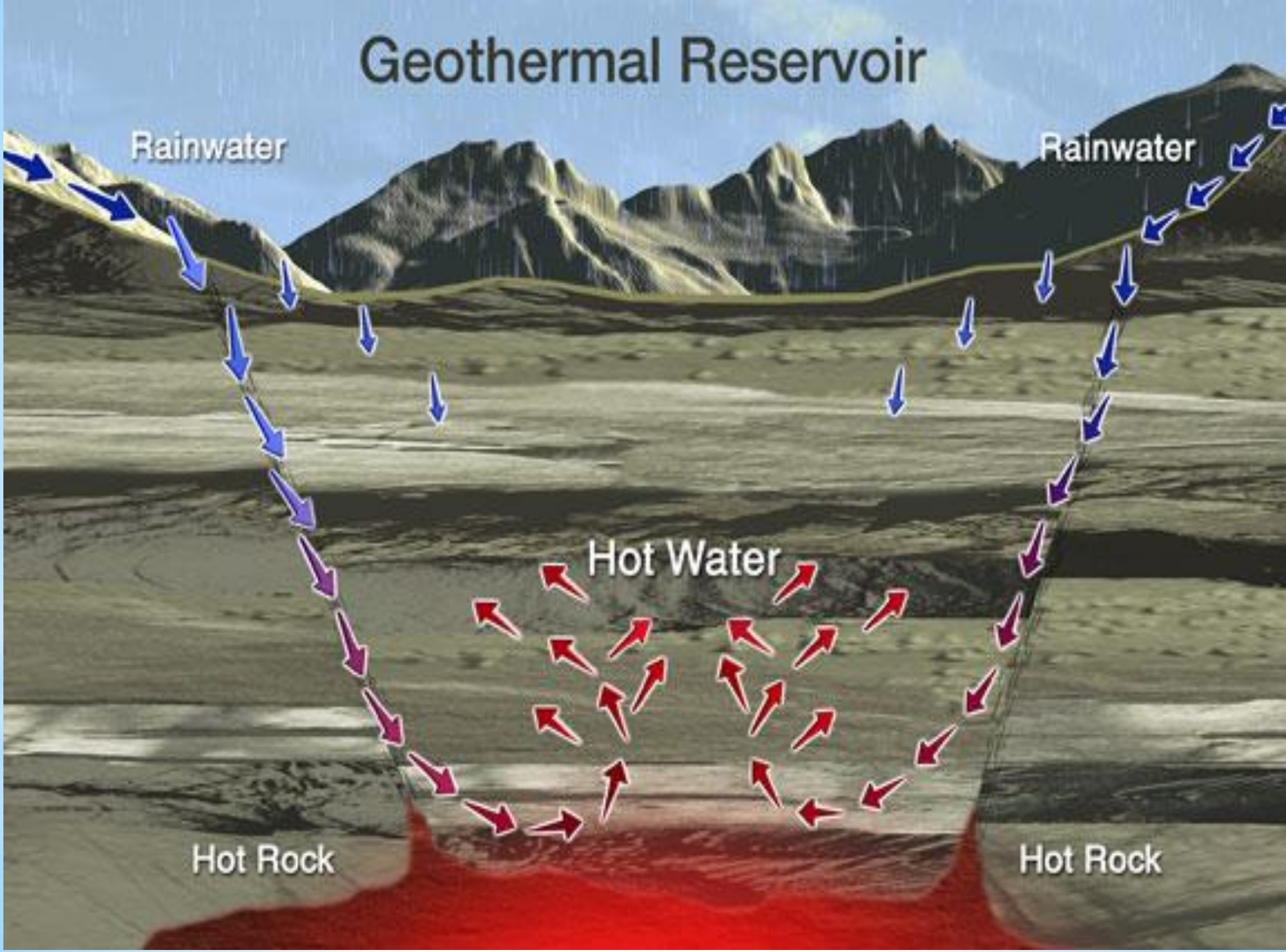
Transfer:

- Conducts rock
- High temp/pressure:
  - mantle rock melts and become magma
- Lighter/less dense than surrounding rock
- Move slowly toward the earth's crust

Reservoir:

- Magma may remain below the crust
- Heating nearby rock and water
- Geothermal water travels back up through faults and cracks
- If it reaches the earth's surface:

  springs/geysers
- Or trapped in cracks and porous rock (geothermal reservoir)


Geothermal Reservoir
Rainwater
Rainwater
Hot Water
Hot Rock
Hot Rock

Geothermal Reservoir:

The volume of hot rock surrounded by cold rock (both are hydraudically connected)

Geothermal System:

Heat source

Recharge (inflowing water)

Discharge (outflowing water)

Permeability structure

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Craters of the Moon (Taupo)

Geothermal Usage:

- Electricity
- Hot springs/bath
- Cooking
- Medicine
- Heat buildings (ground source heat pump)
- Agriculture: glass houses (plants)
- Aquaculture: fish/shrimp farming
- Dairy: pasteurize milk
- District heating: Russa, China, France, Sweden, Hungary, Romania, Japan, Iceland, Netherlands and USA

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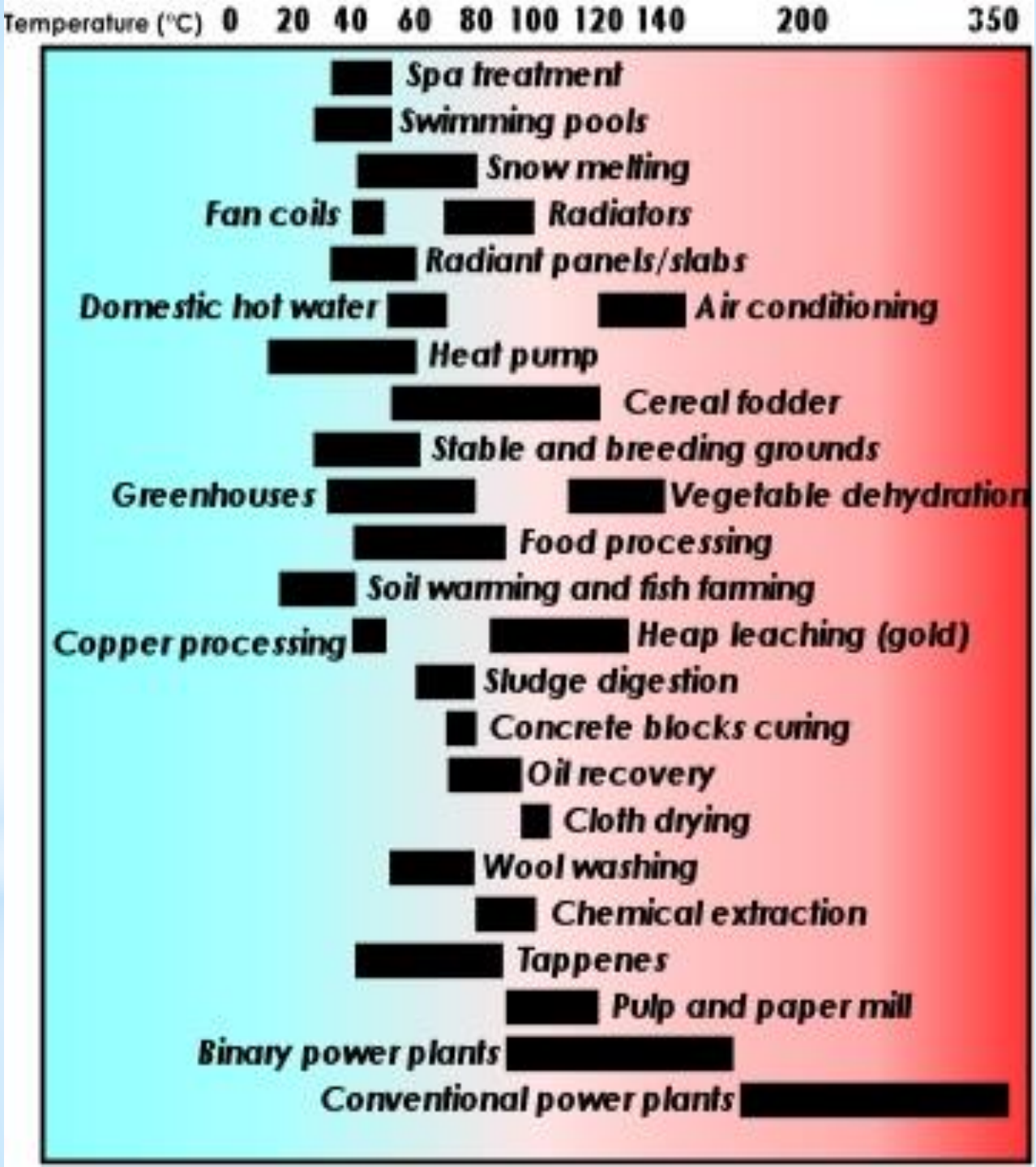
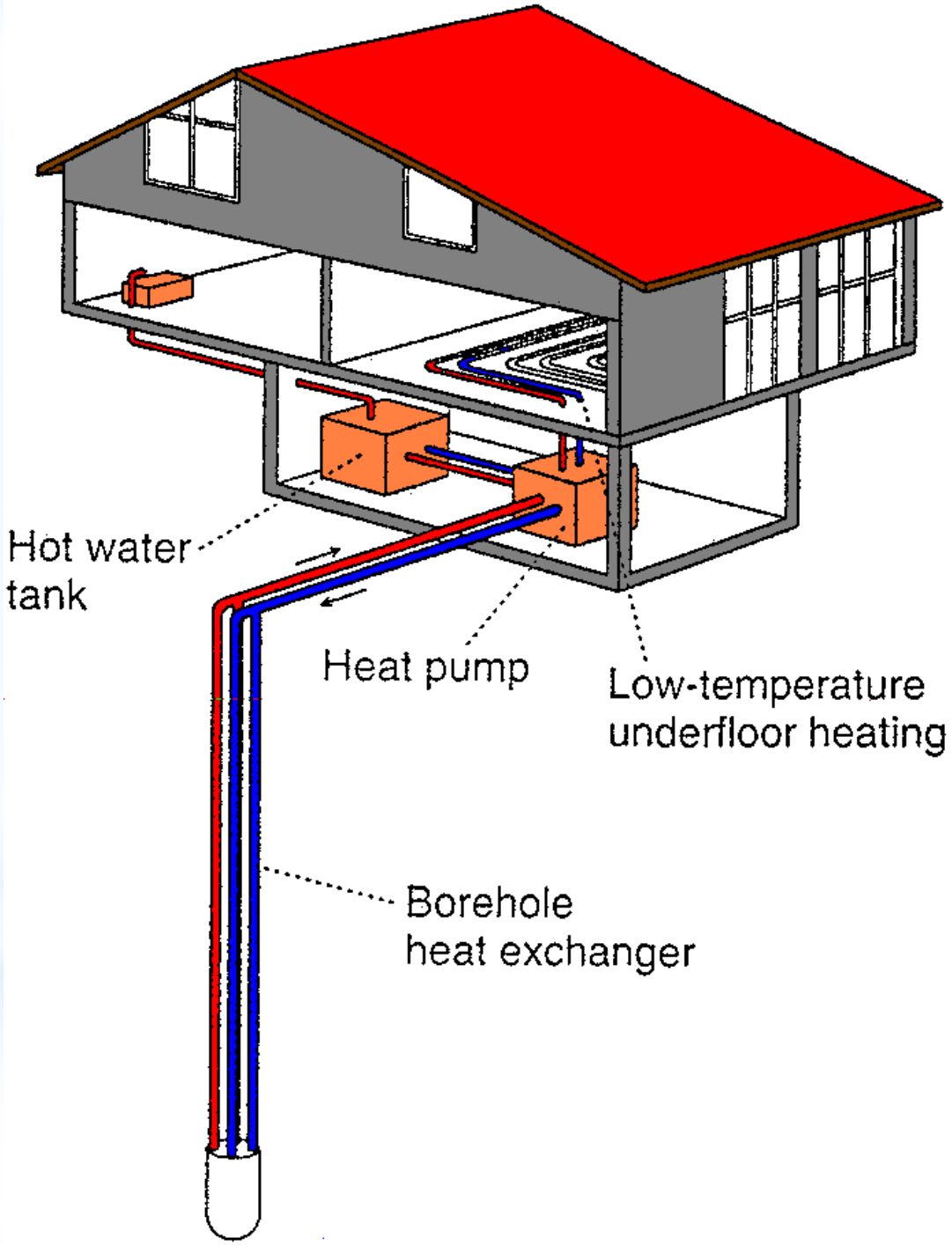


Lindal Diagram

Heat Pump system:



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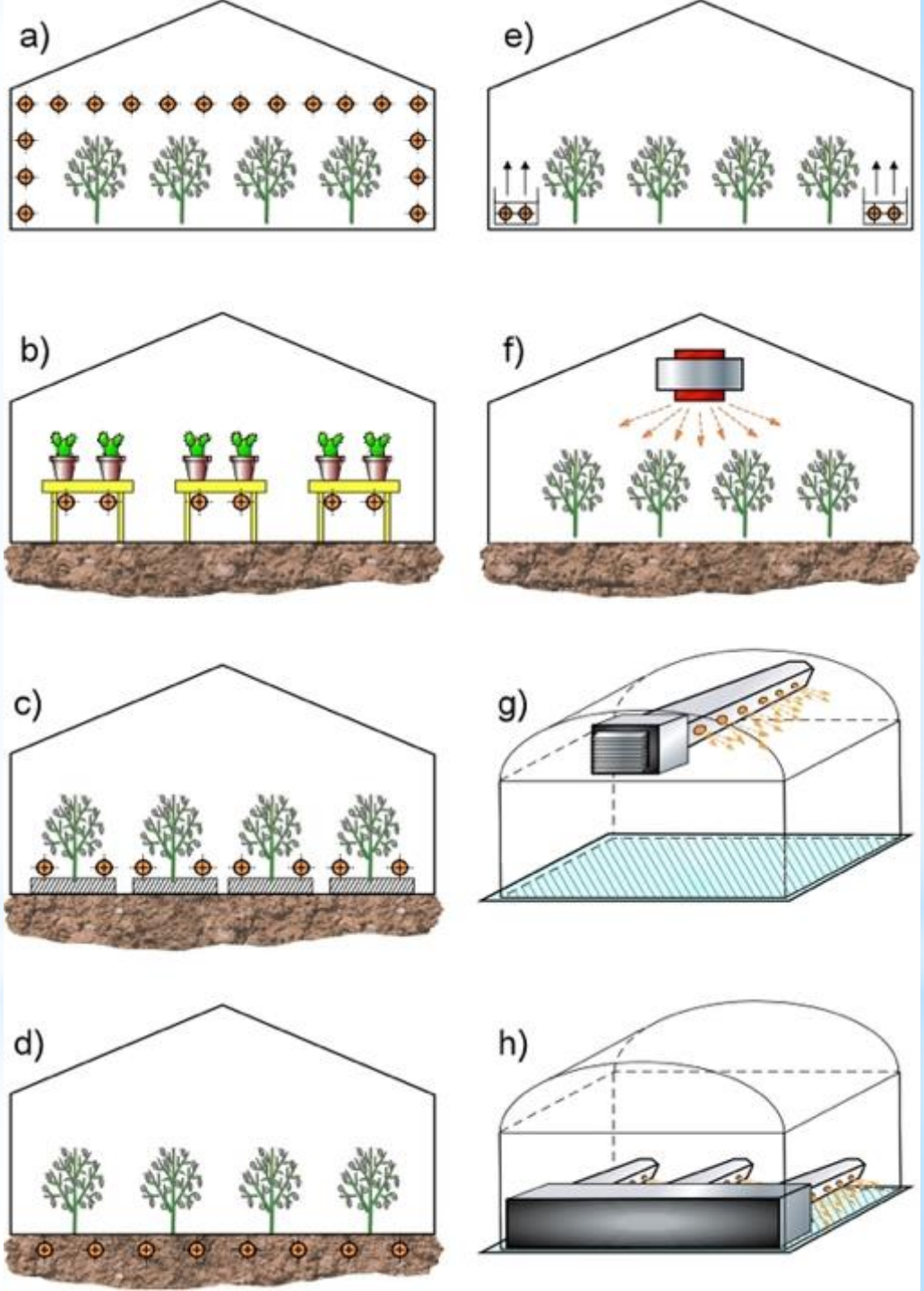
Heating systems in geothermal greenhouses:



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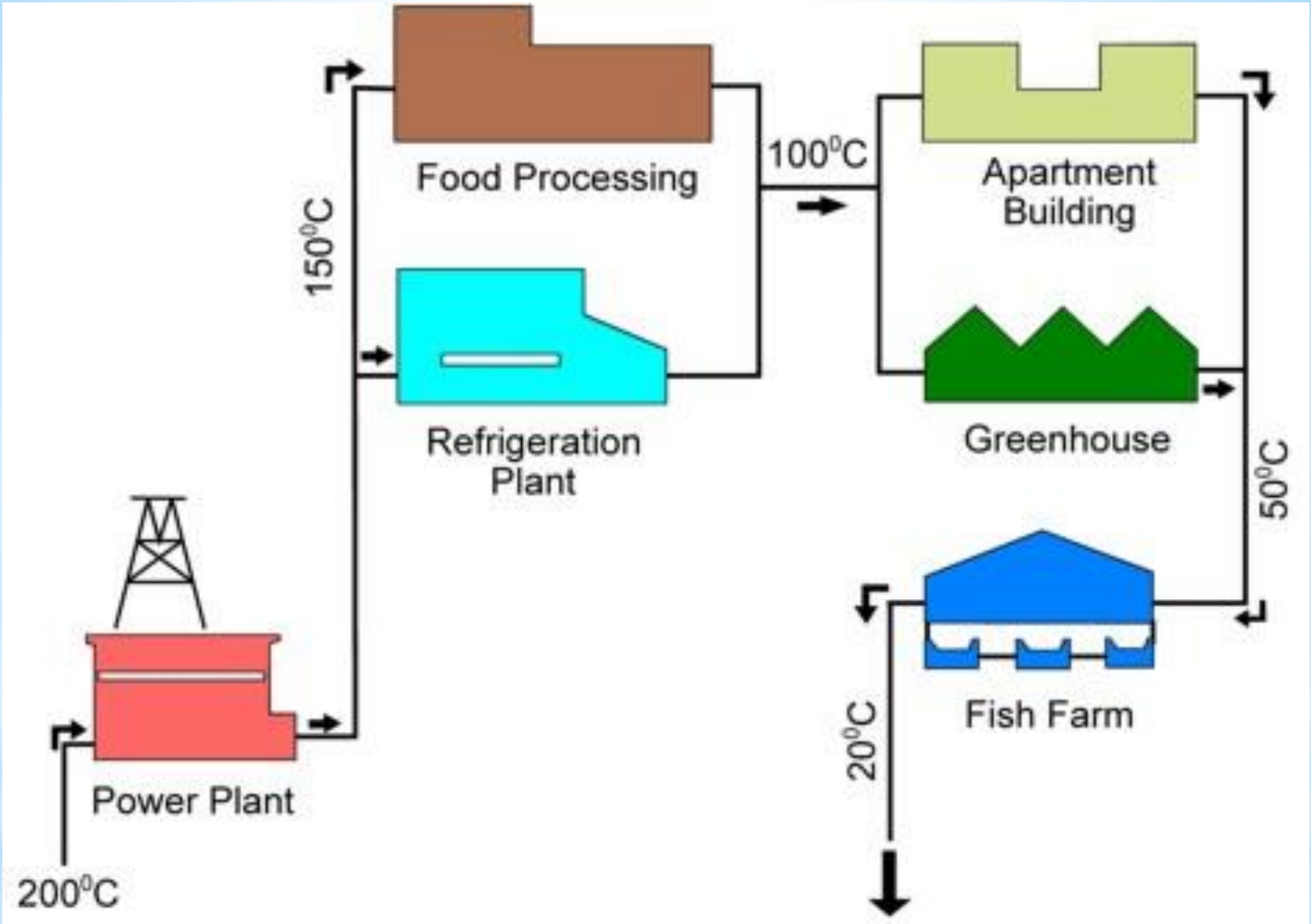

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District heating system

2. Geothermal Electricity Generation:

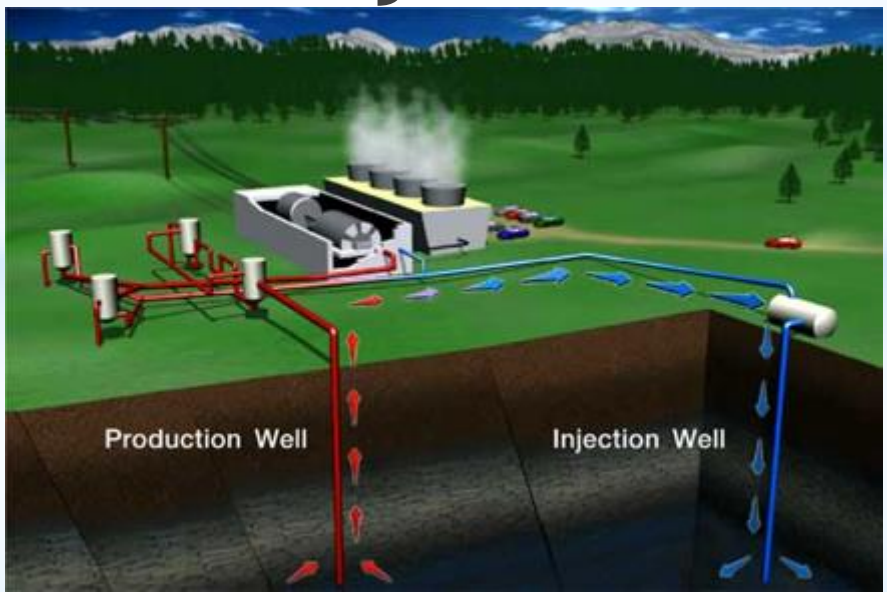
Production wells

Natural steam

Turbine generator

Condensed in cooling tower

Reinjection



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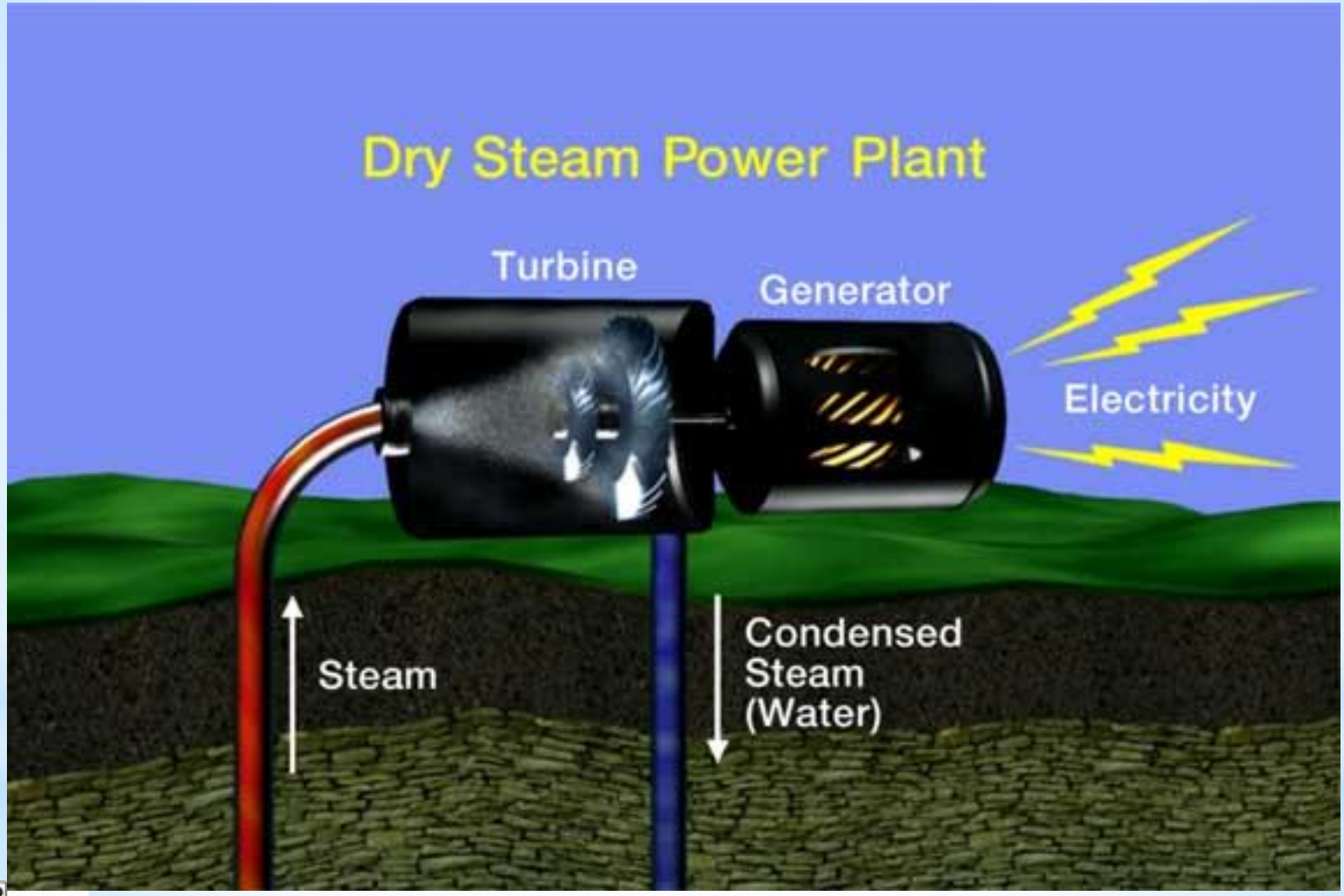
Electricity generation



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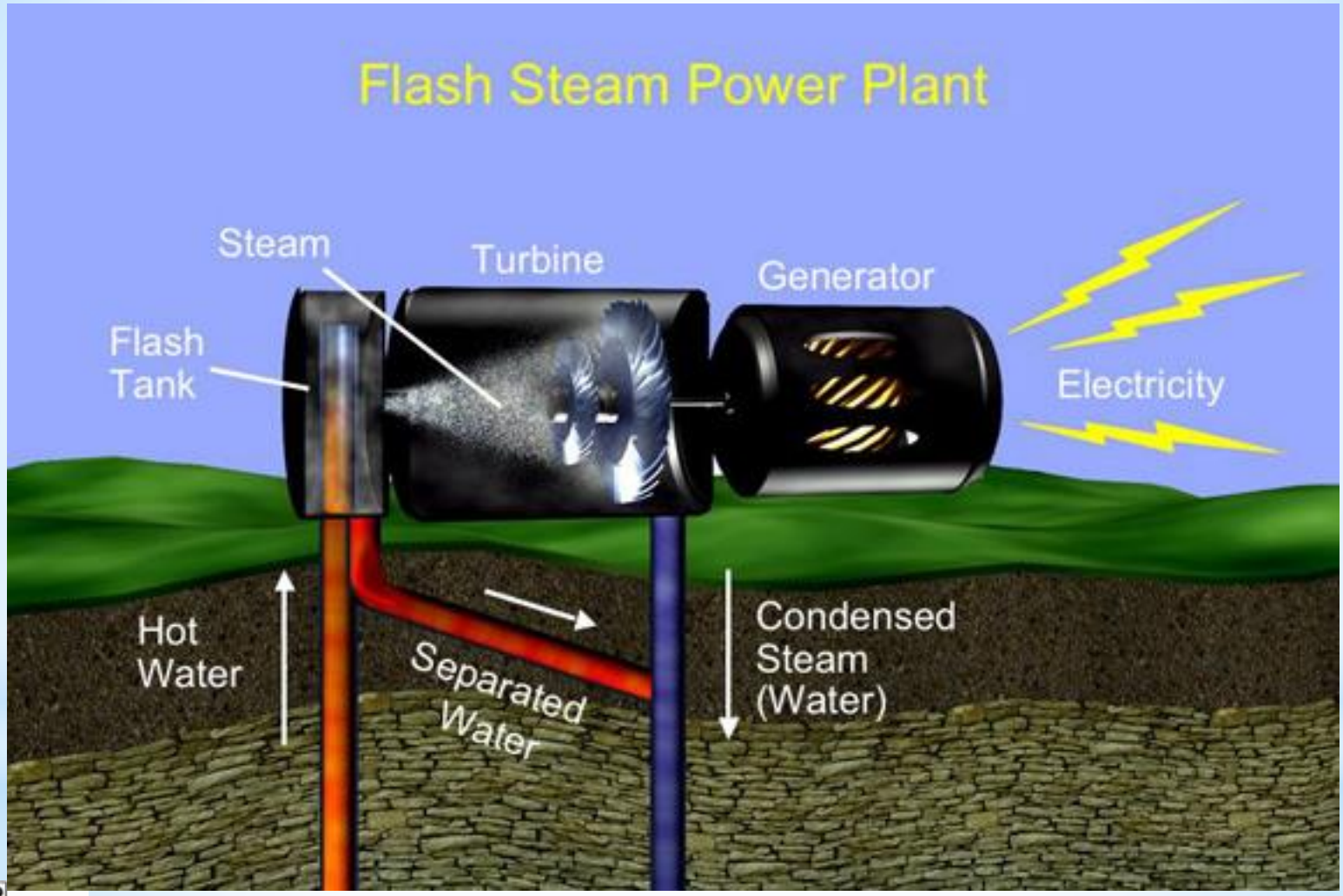
Electricity generation



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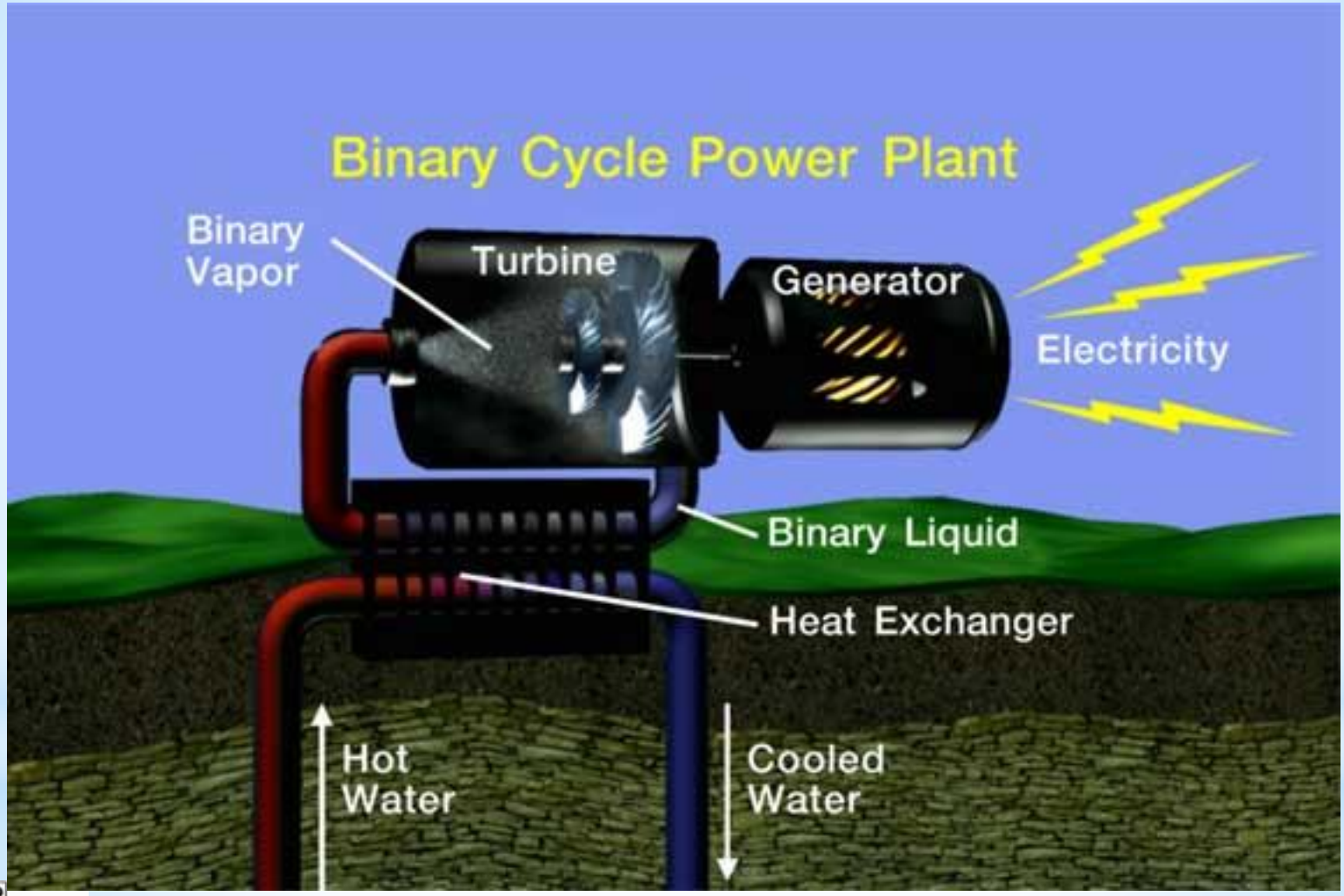
Electricity generation



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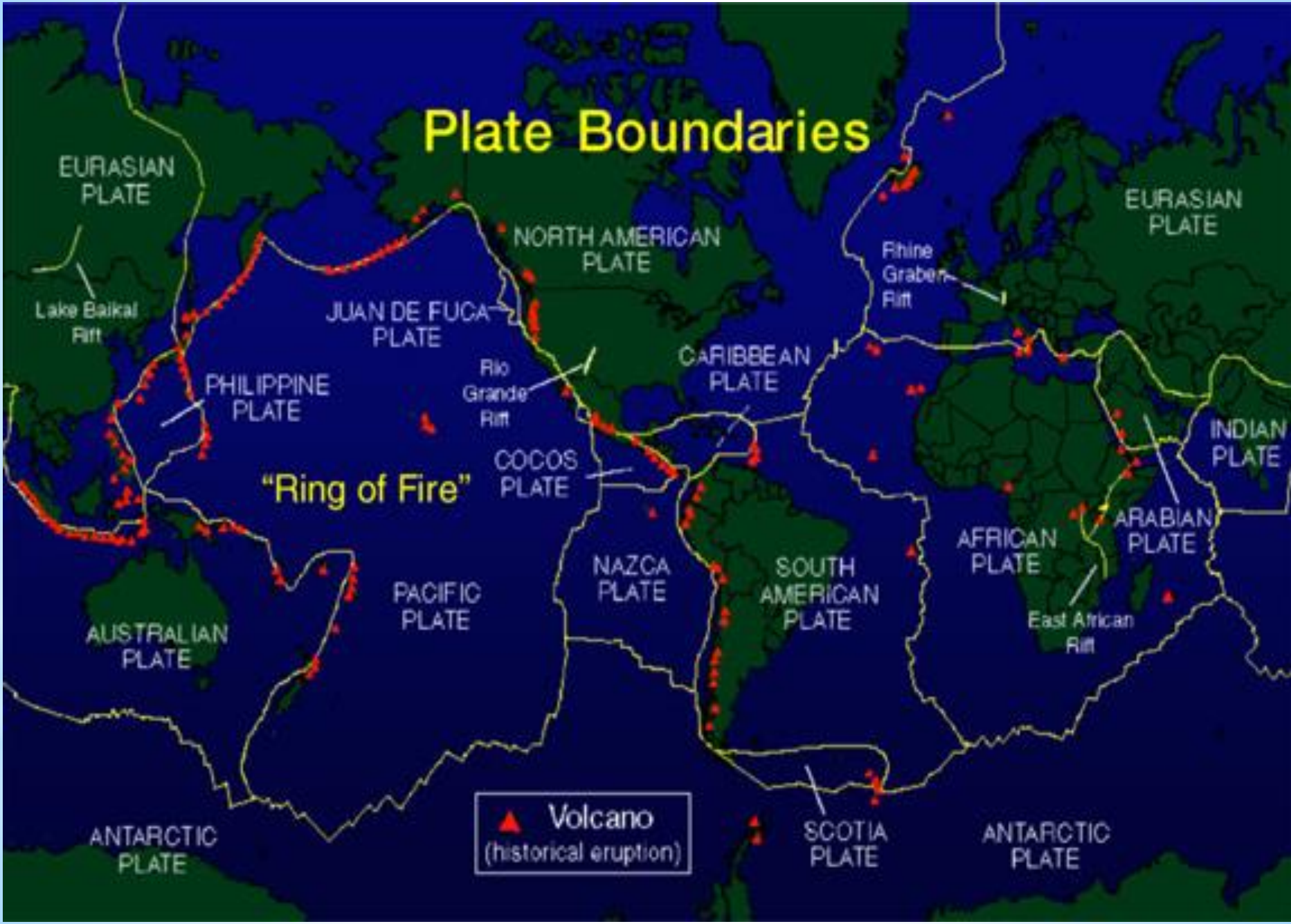
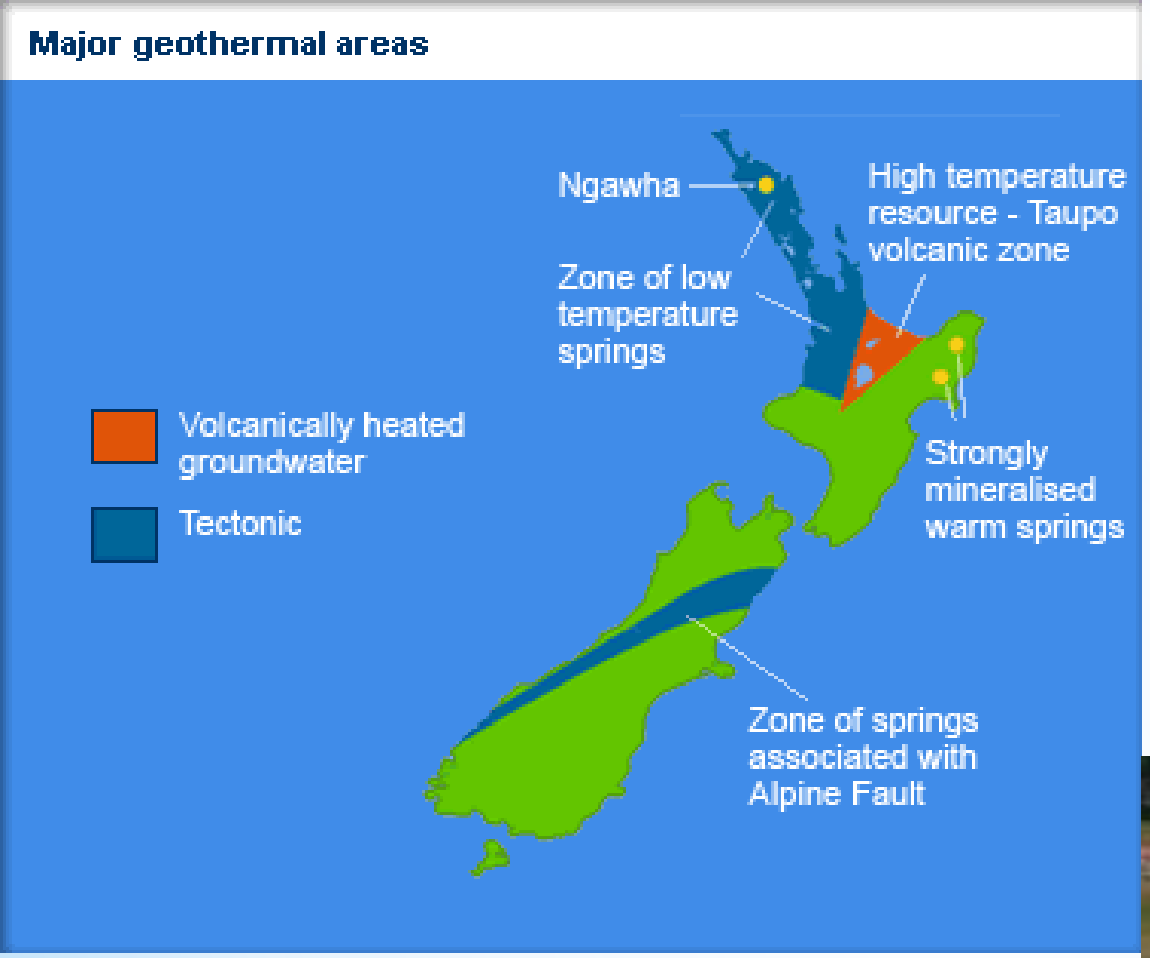


Plate Boundaries
EURASIAN PLATE
Lake Baikal Rift
NORTH AMERICAN PLATE
JUAN DE FUCA PLATE
PHILIPPINE PLATE
Rio Grande Rift
CARIBBEAN PLATE
Rhine Graben Rift
EURASIAN PLATE
INDIAN PLATE
"Ring of Fire"
COCOS PLATE
ARABIAN PLATE
AFRICAN PLATE
NAZCA PLATE
SOUTH AMERICAN PLATE
PACIFIC PLATE
East African Rift
AUSTRALIAN PLATE
Volcano
(historical eruption)
ANTARCTIC PLATE
SCOTIA PLATE
ANTARCTIC PLATE

Major geothermal areas



New Zealand's first geothermal generator was commissioned at Wairakei in 1958 (Te Mihi)

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* Compare world installed capacity & resources?
* => Mike

4. Geothermal Regulation

Similar issues as Oil/Gas Regulation

- Underground resource => step-wise exploration
- Ownership/access to resource
- Environmental aspects (+sustainability)
- Financial viability (incl power prices & royalties/subsidies)

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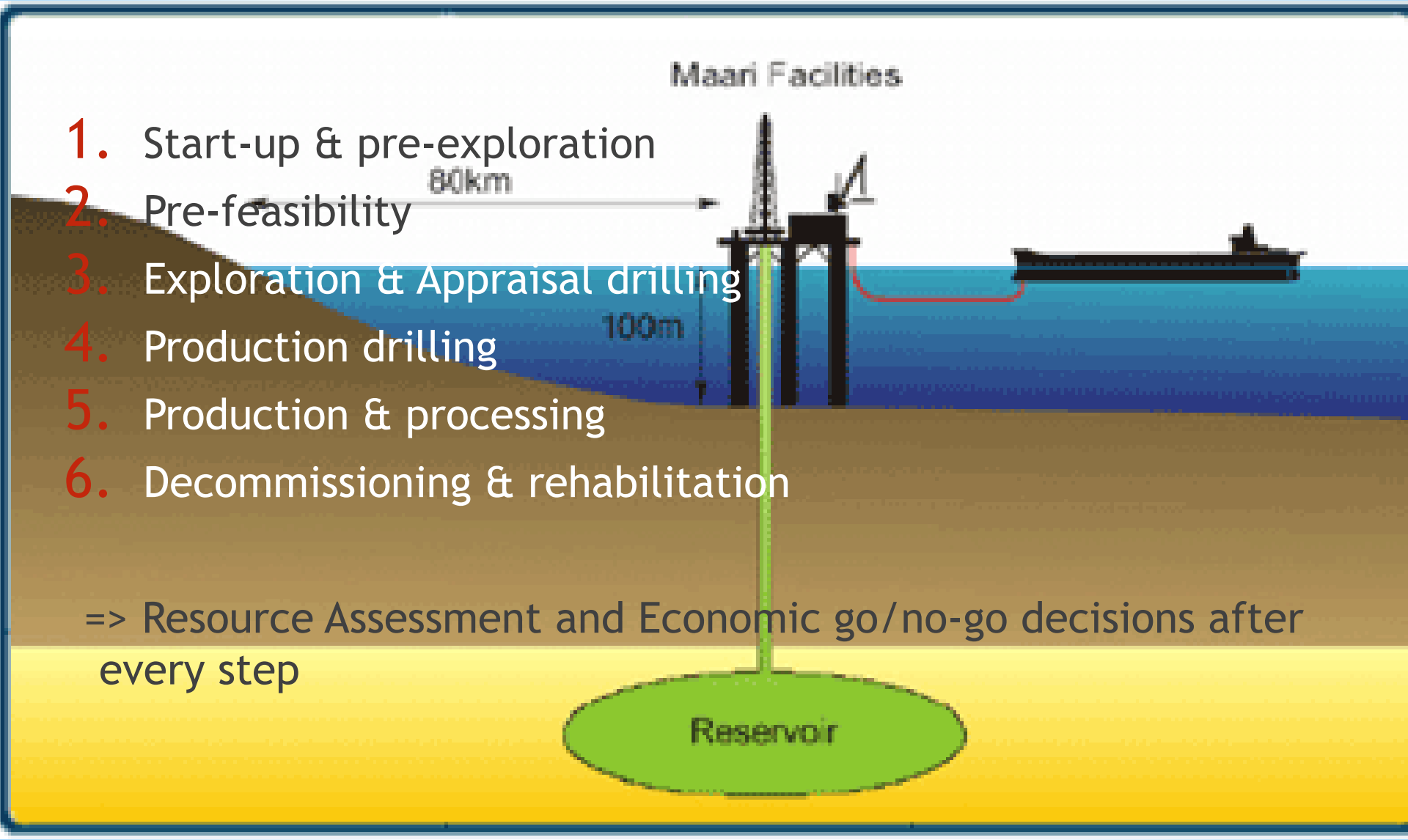
*Typical E&P process

1. Start-up & pre-exploration
2. Pre-feasibility
3. Exploration & Appraisal drilling
4. Production drilling
5. Production & processing
6. Decommissioning & rehabilitation

=> Resource Assessment and Economic go/no-go decisions after every step



Stage 1: Start-up & pre-exploration

* Project identification and reconnaissance:
* Desktop research (existing info & exploration studies)
* Reconnaissance/physical inspection
* Apply for exploration license and land-owner permit

* Geoscientific exploration:
* Geological, Geochemical and Geophysical Studies
* Aerial studies/mapping
* Often geophysical is separated out (Go/No-Go)

Stage 2: pre-feasibility

* Conceptual model:
* integrating all information into a 3-D diagram to get a total picture of the resource

* Pre-feasibility study:
* On the basis of the above create a first estimate of the resource and approx cost of installations (ca 50% error margin) to assess economic sense;
* Necessary before making million-$ drilling decisions

Stage 3: Exploration drilling and appraisal/feasibility

* (pre)-Permitting
* In most countries one or more permits (environmental and sometimes a separate exploration/ appraisal) are necessary to do exploration drilling. Such permits are generally simpler and faster than full permits .
* Exploration drilling and well-testing
* Feasibility Study:
* With above info, make more accurate resource assessment + installation cost estimate (ca 25% margin)
* Including risk/sensitivity analysis
* Generally necessary to acquire project financing (bank loans) & production permits

Stage 4: Design, permitting and production drilling

- Preliminary design
- Project permitting
- Environmental, Health & Safety, exploitation/production license
- Production drilling

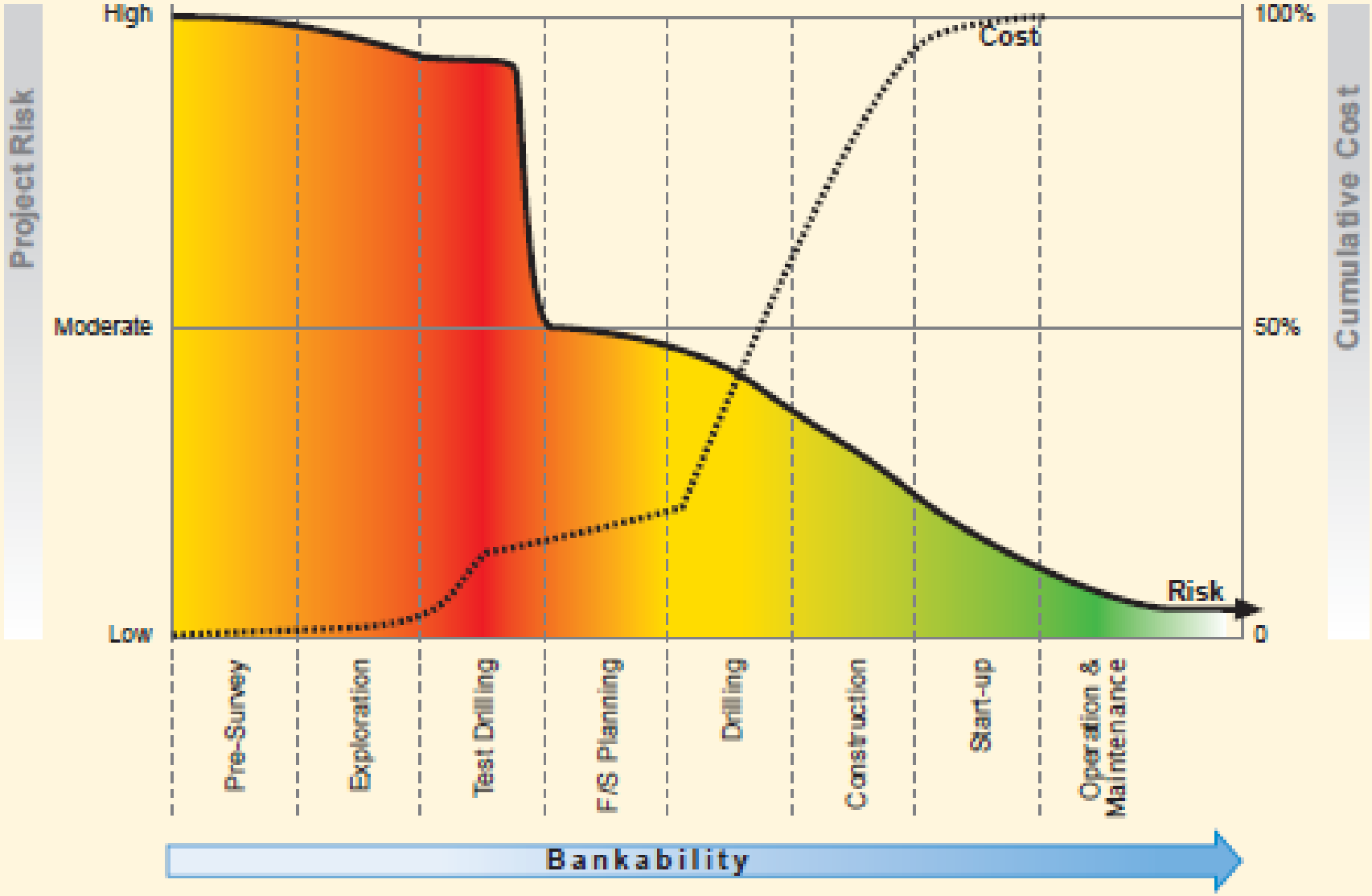
Stage 5: Production & Processing

* 25 to 50 years involving activities such as:
* Operation and maintenance
* Reservoir management to understand the performance of reservoir;
* Environmental monitoring
* Additional studies to improve efficiency, drill additional wells, etc;

Stage 6: Decommissioning & Rehabilitation

Project Phases, Investment, Risk

Source: World Bank/ESMAP, 2012



NZ Regulation slightly different:

- Based on water & common law: state doesn't own the resource
- Government manages the resource on behalf of 'common good'
- Resource Management Act
- Puts Sustainable Management at the Centre:
  - External effects; and
  - Resource available for 'future generations'

4. Geothermal Generation

Renewable? Sustainable?

Heat extraction

Natural heat transfer

Sustainability:

- Pressure
- temperature
- Geothermal features

- Subsidence

Lower temperature/pressure:

1. Inefficeincy in production
2. Lower quality resources for future generations

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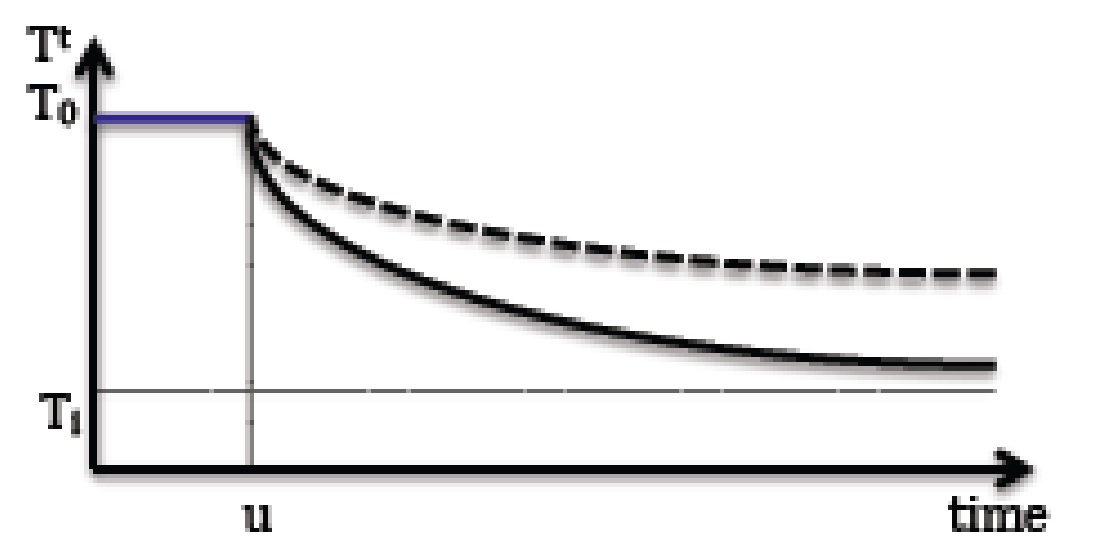
Sustainability:



Wairakei: 300 years to recover after 100 years of extraction

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60 years

Ohaaki – 114 Mwe (1989) to 30/60 Mwe (2007)

Rotorua

The Geysers, California

Internalise externalities:

Selected policies to balance the costs and benefits

Careful planning and management

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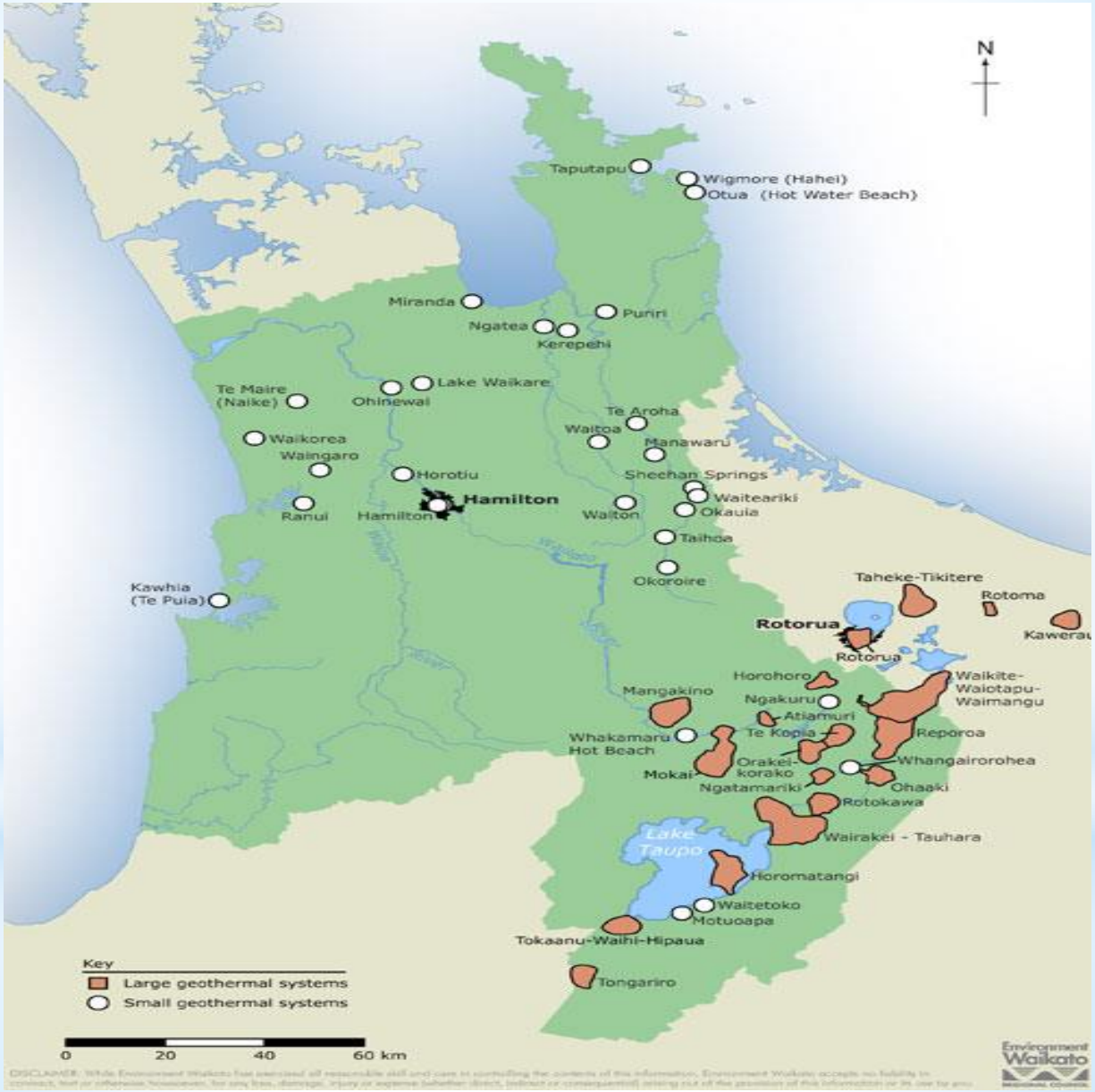
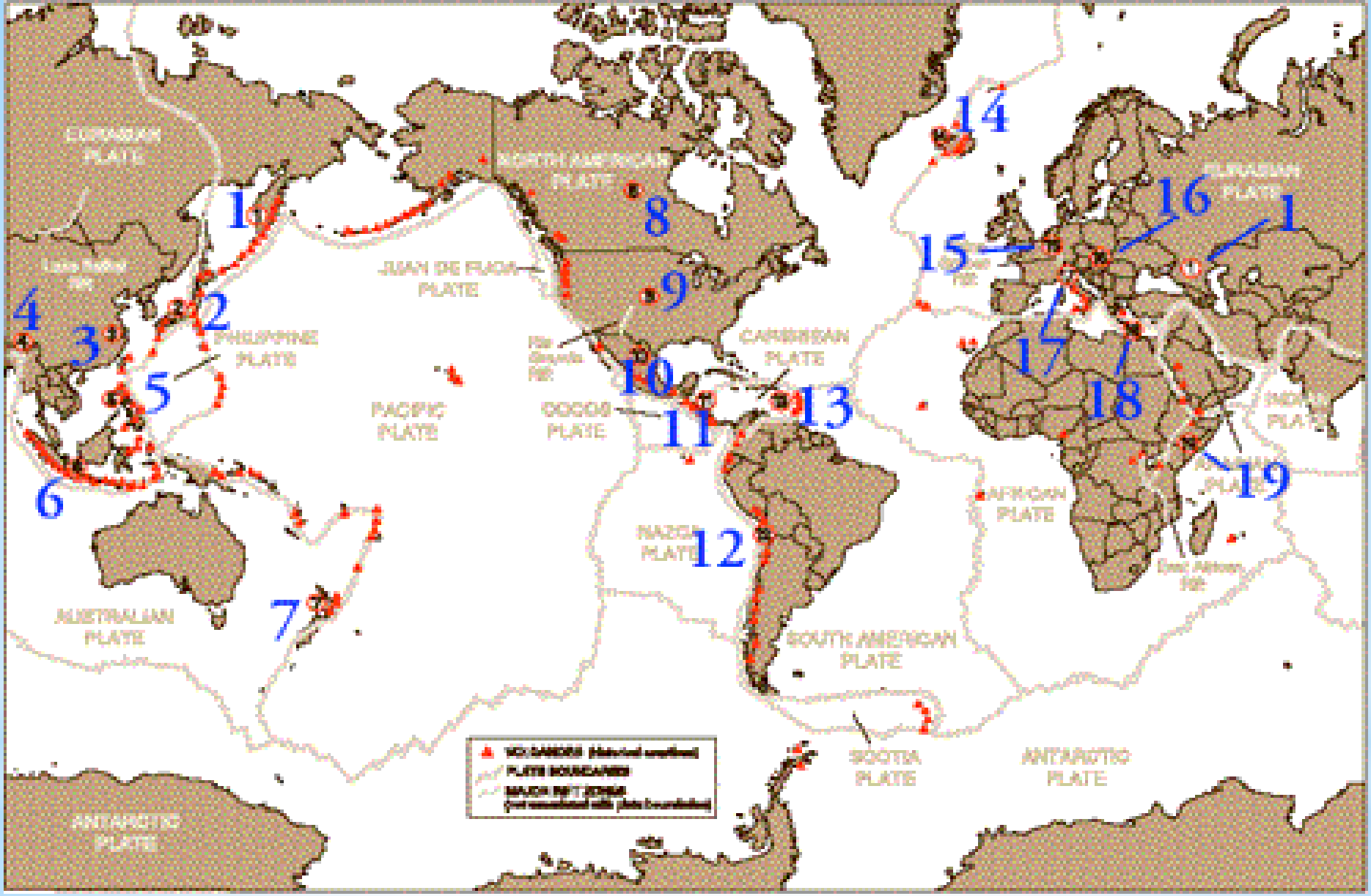
Wai O Tapu Loop Rd (Rotorua)
Thank You

Geothermal resources located in Environment Waikato boundaries





1. Russia, 2. Japan, 3. Eastern China, 4. Himalayan, 5. The Philippines, 6. Indonesia, 7. New Zealand, 8. Canada, 9. United State, 10. Mexico, 11. Central American Volcanic Belt, 12. Andean Volcanic Belt, 13. the Caribbean, 14. Iceland, 15. Northern Europe, 16. Eastern Europe, 17. Italy, 18. Eastern and Southern Mediterranean, 19. East Africa Rift System

Geothermal Power:

MidAmerican Energy Geothermal Plant Virtual Tour (4.46 mins)

www.youtube.com/watch?v=FKXcLa88GhQ

Energy 101: Geothermal Energy (3.47 mins)

www.youtube.com/watch?v=mCRDf7QxjDk