Introduction to Geothermal Energy

Summer School in Energy Economics 2018

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Introduction to Geothermal Energy:

1. Basics
2. Resources and locations
3. End-uses
4. Electricity generation technologies
5. Regulation & exploration

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1. Geothermal Basics

Geothermal = Greek words

geo (earth)

therme (heat)

Geothermal system:

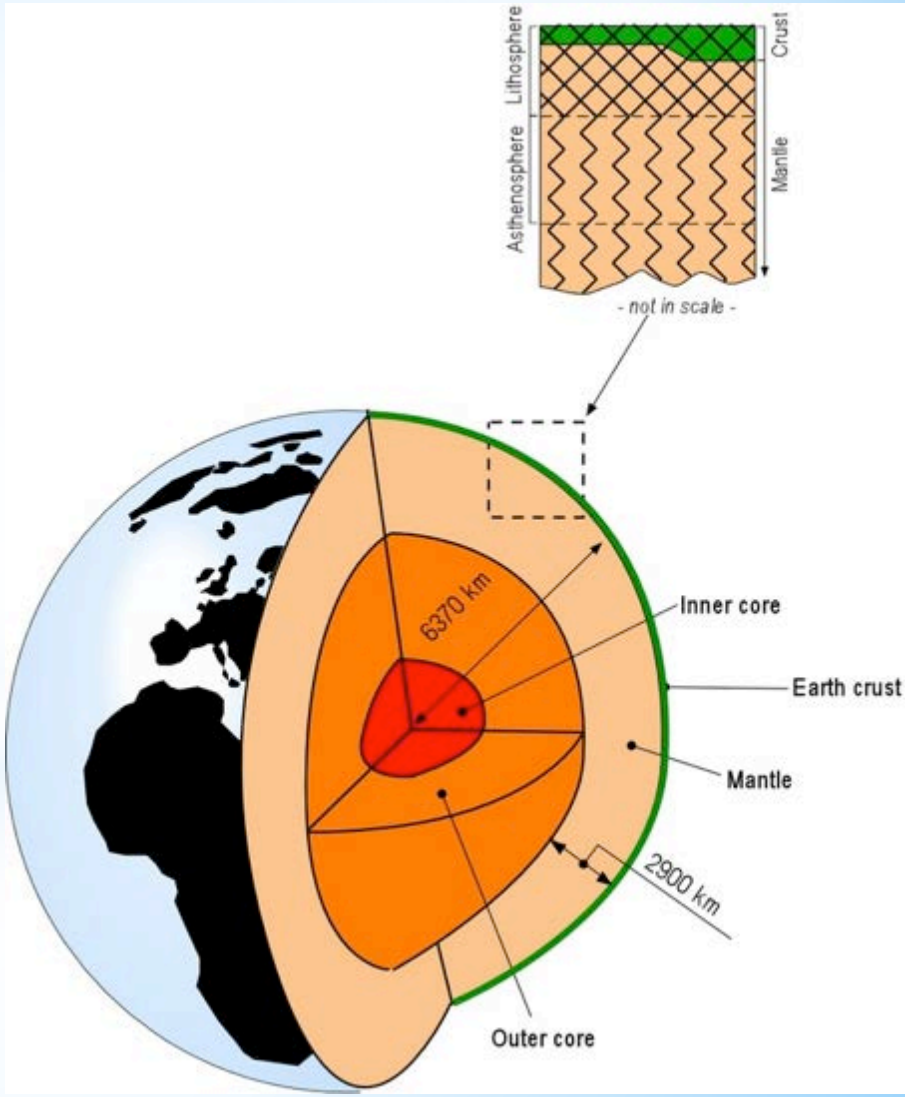
A system of processes involving heat transfer to the earth's surface (convection vs conduction)

1. Geothermal:

* Earth's interior : heat
* Heat: yields

  warmth and power
* 6,000 km deep:

  5,000 °C



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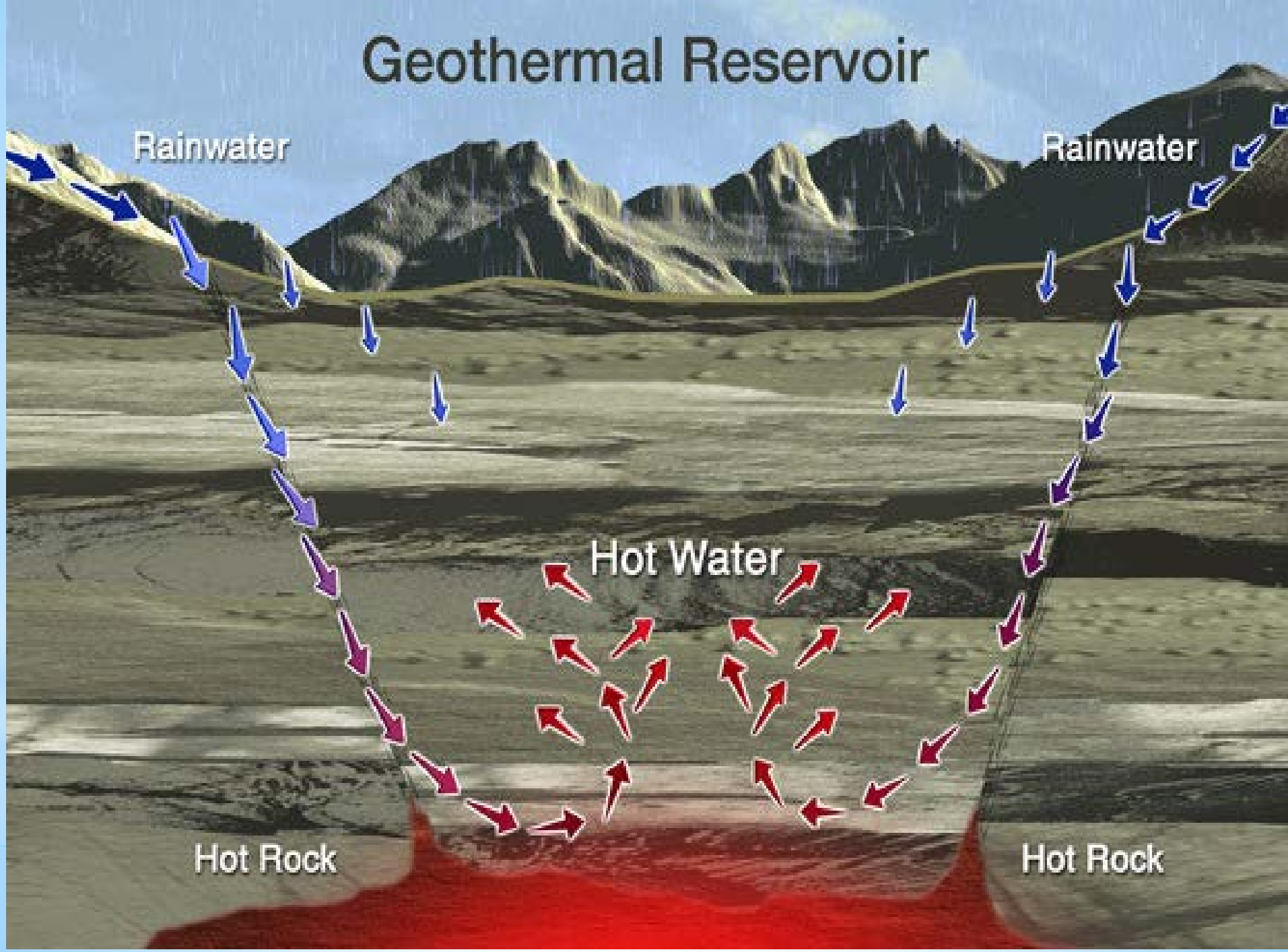
1. Heat Transfer:

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


Geothermal Reservoir
Rainwater
Rainwater
Hot Water
Hot Rock
Hot Rock

1. Heat Transfer

- 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)

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1. Geothermal Reservoir:

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

Geothermal System:

Heat source

Water (recharge = inflowing;discharge =outflowing water)

Permeability structure

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

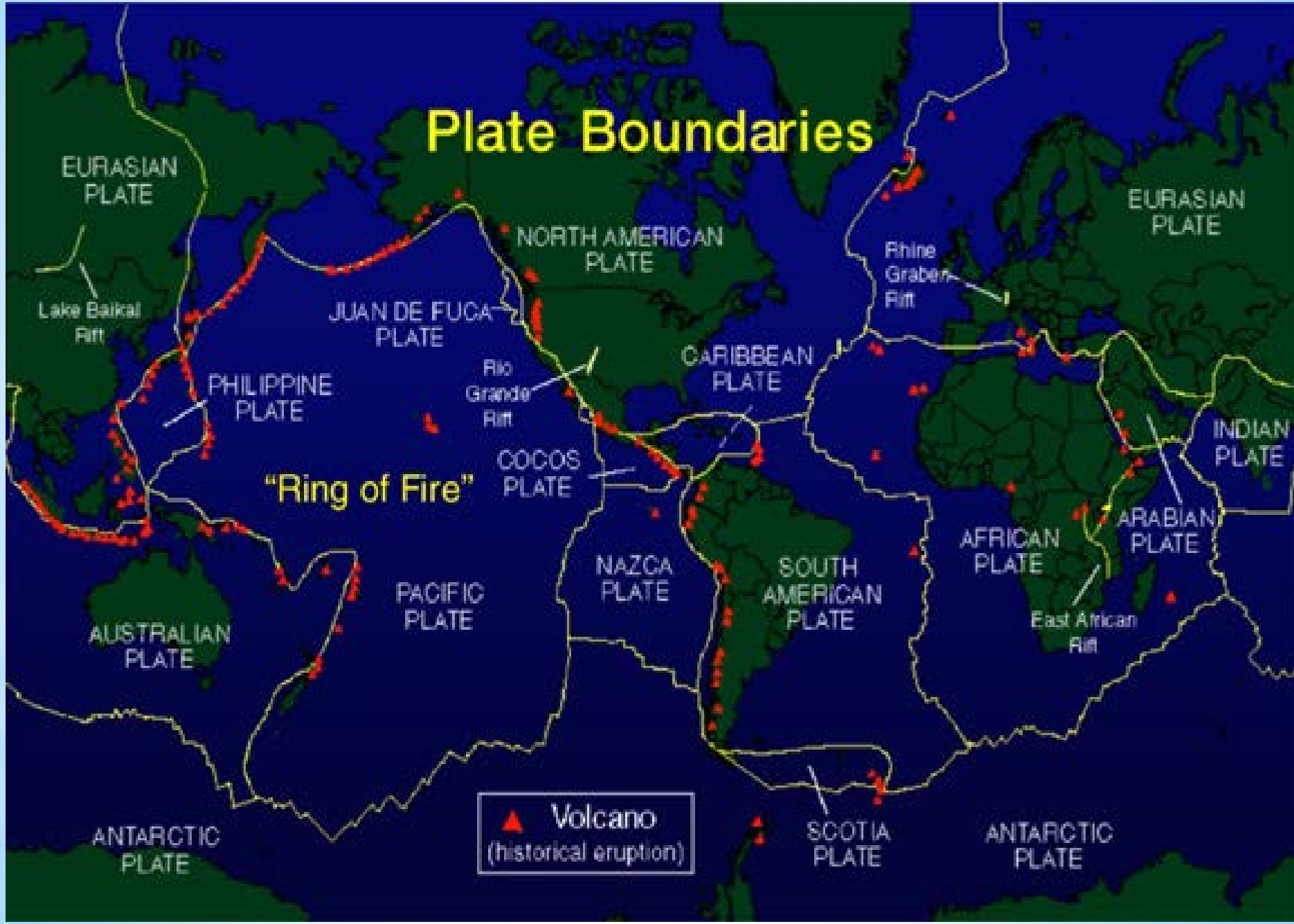
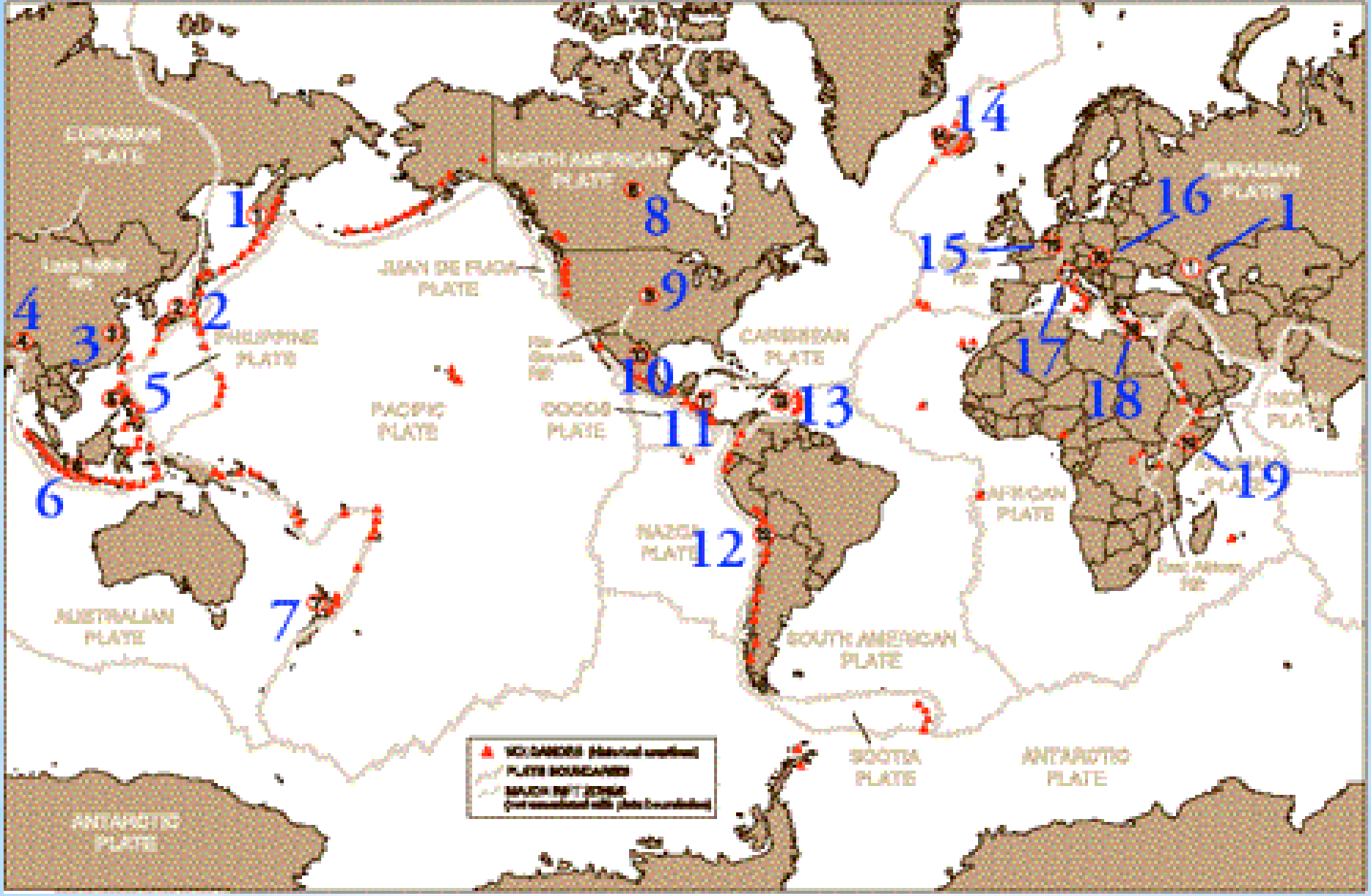
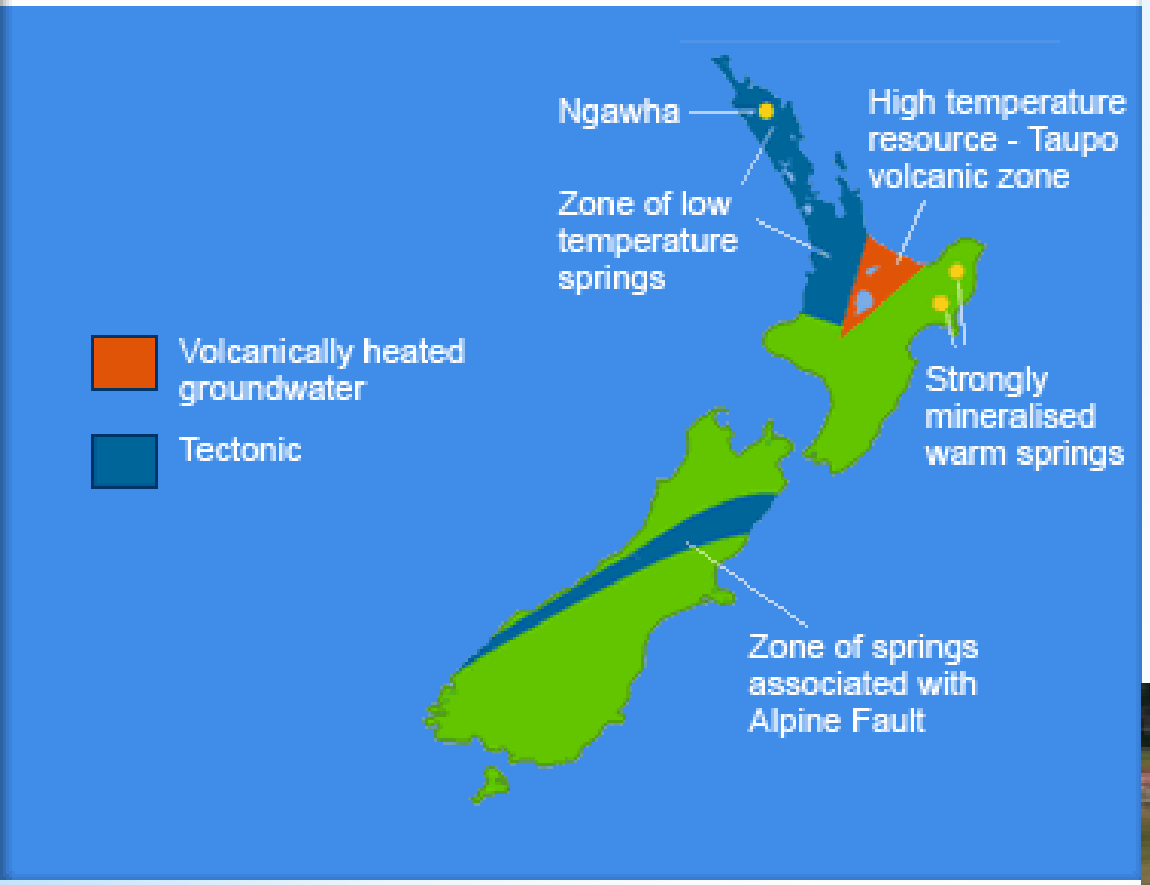


Plate Boundaries
EURASIAN PLATE
Lake Baikal Rift
NORTH AMERICAN PLATE
JUAN DE FUCA PLATE
Rio Grande Rift
PHILIPPINE PLATE
"Ring of Fire"
COCOS PLATE
CARIBBEAN PLATE
Rhine Graben Rift
EURASIAN PLATE
INDIAN PLATE
ARABIAN PLATE
AFRICAN PLATE
East African Rift
NAZCA PLATE
SOUTH AMERICAN PLATE
PACIFIC PLATE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



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

Major geothermal areas



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

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Geothermal resources located in Environment Waikato boundaries

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3. Geothermal Uses:

- 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

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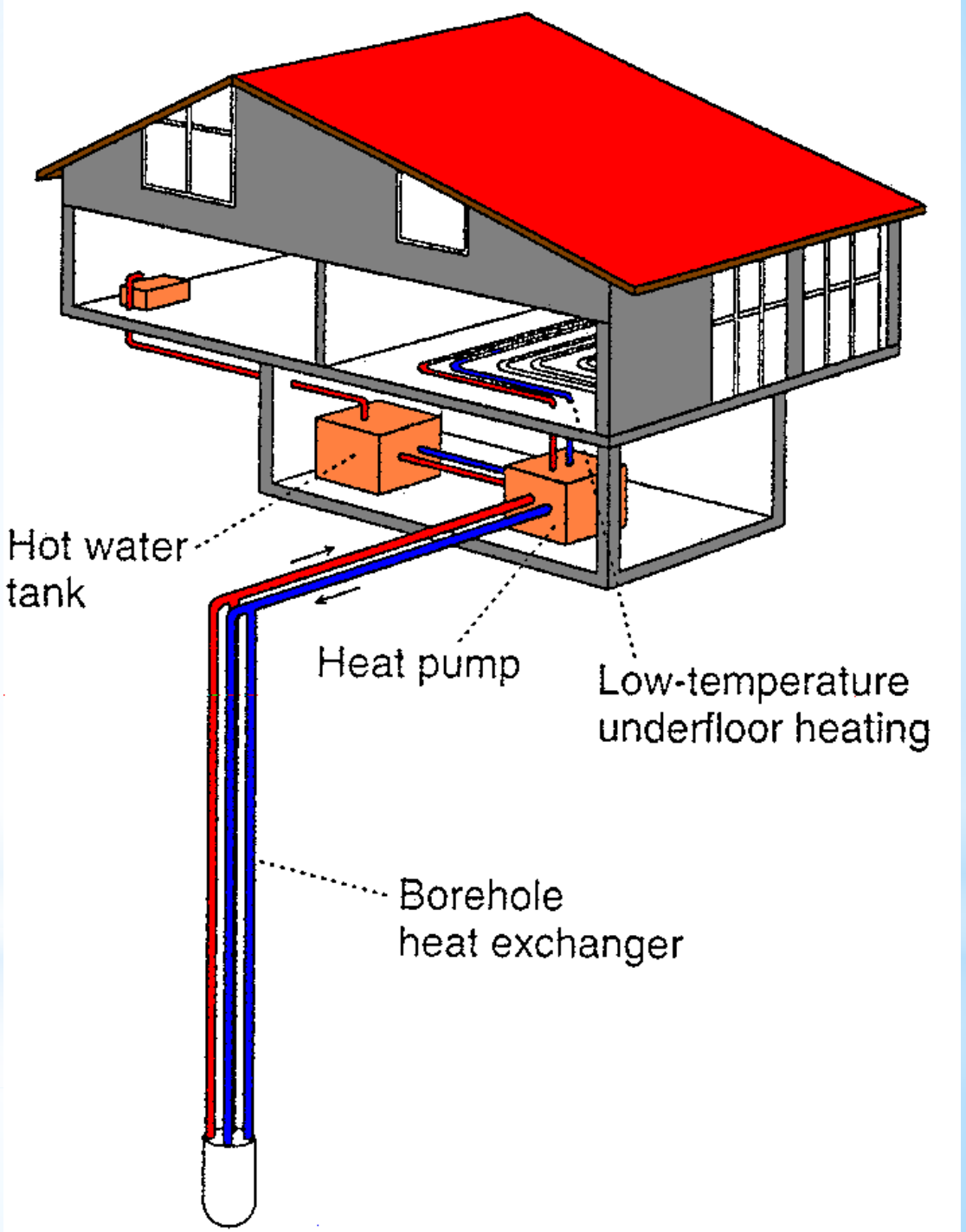
Heat Pump system:



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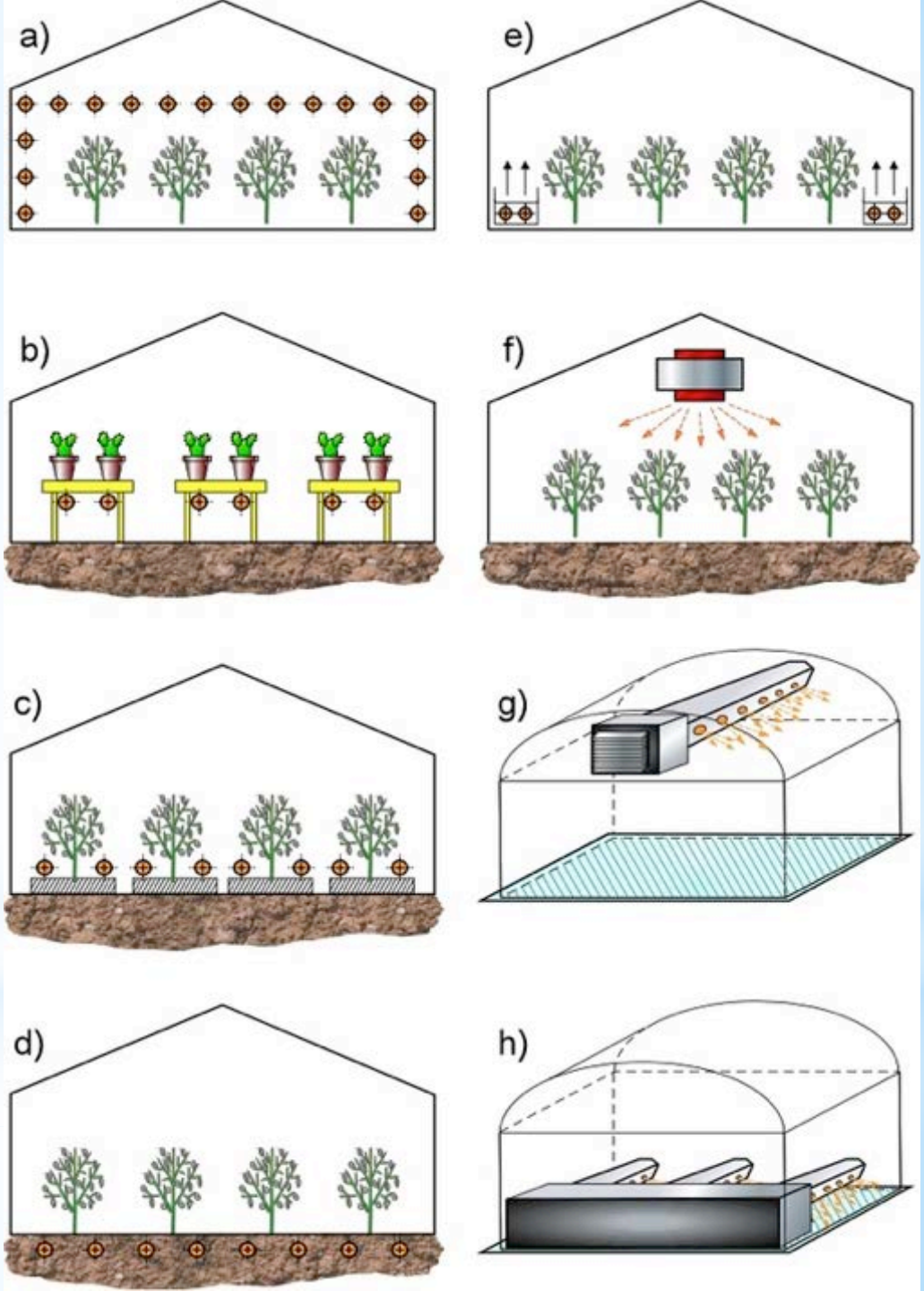
Heating systems in geothermal greenhouses:



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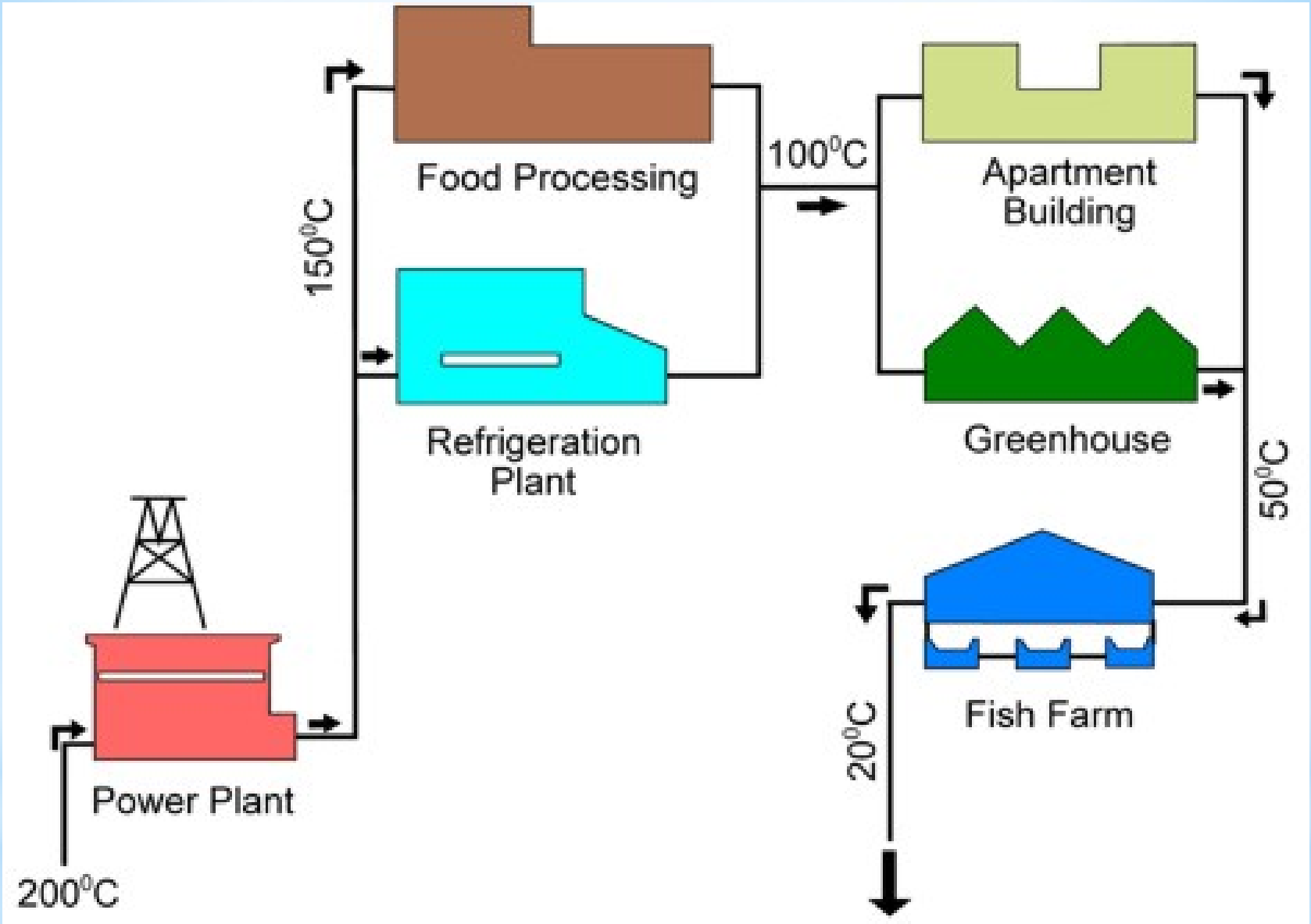

District heating system

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Craters of the Moon (Taupo)

4. Geothermal Electricity Generation:

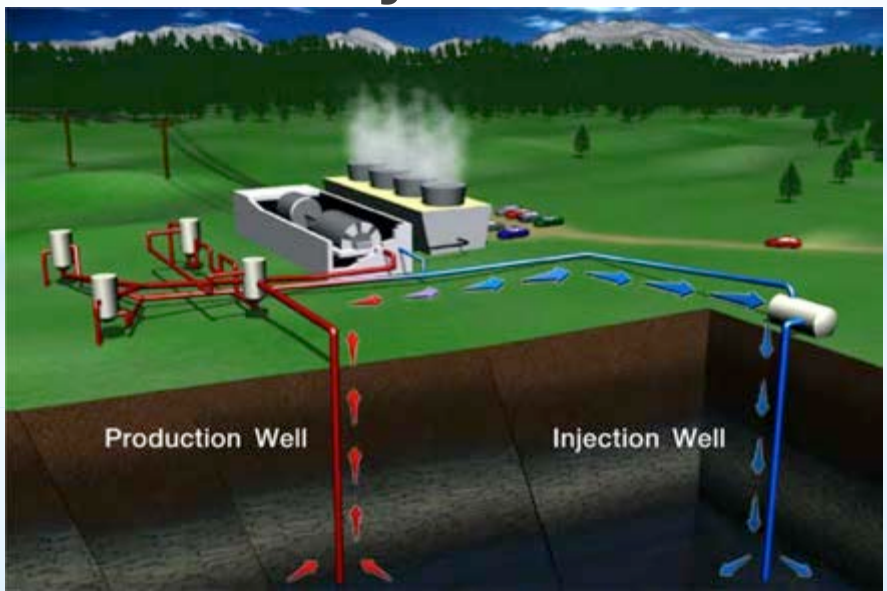
Production wells

Natural steam

Turbine generator

Condensed in cooling tower

Reinjection



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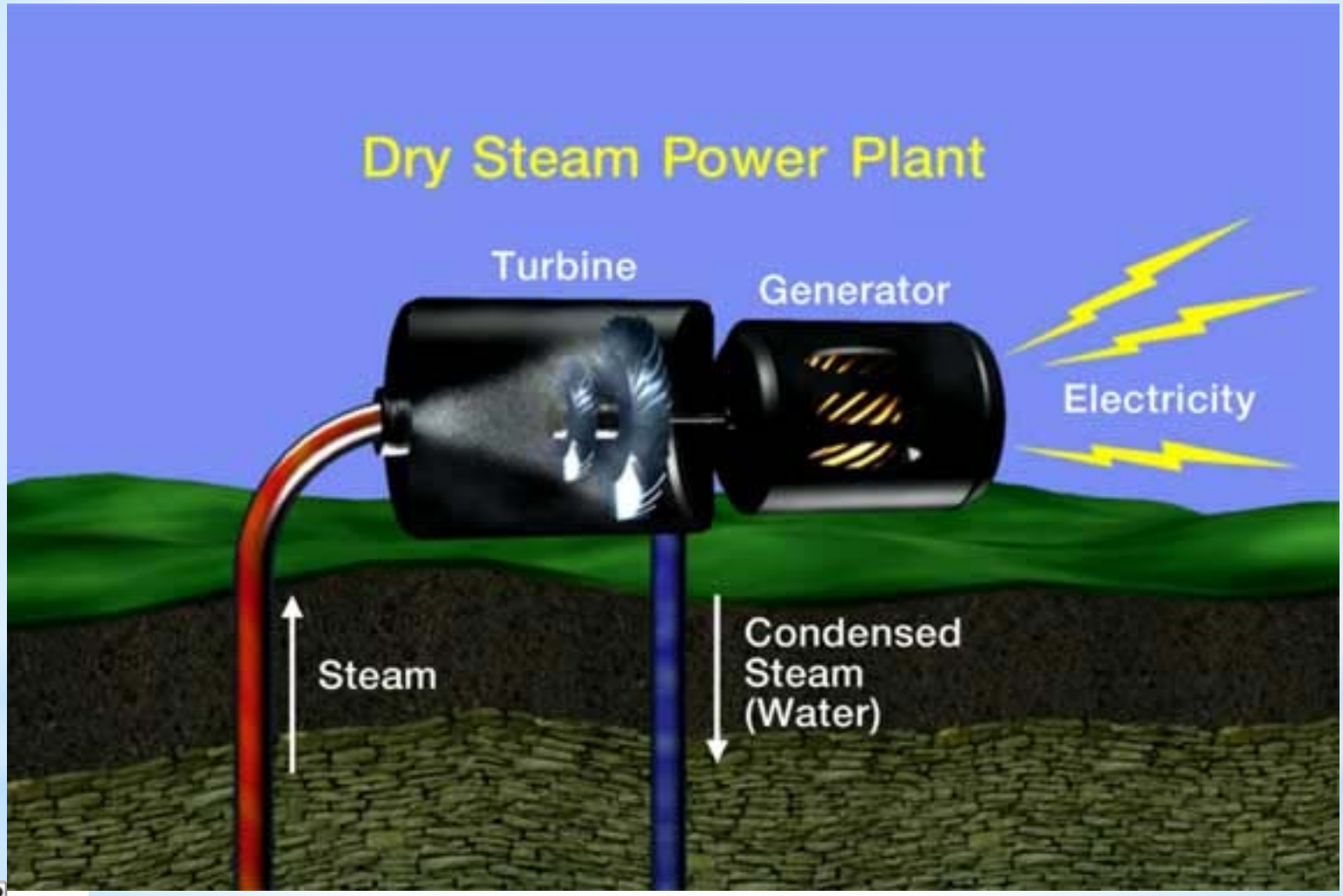
4. Dry steam plant generation



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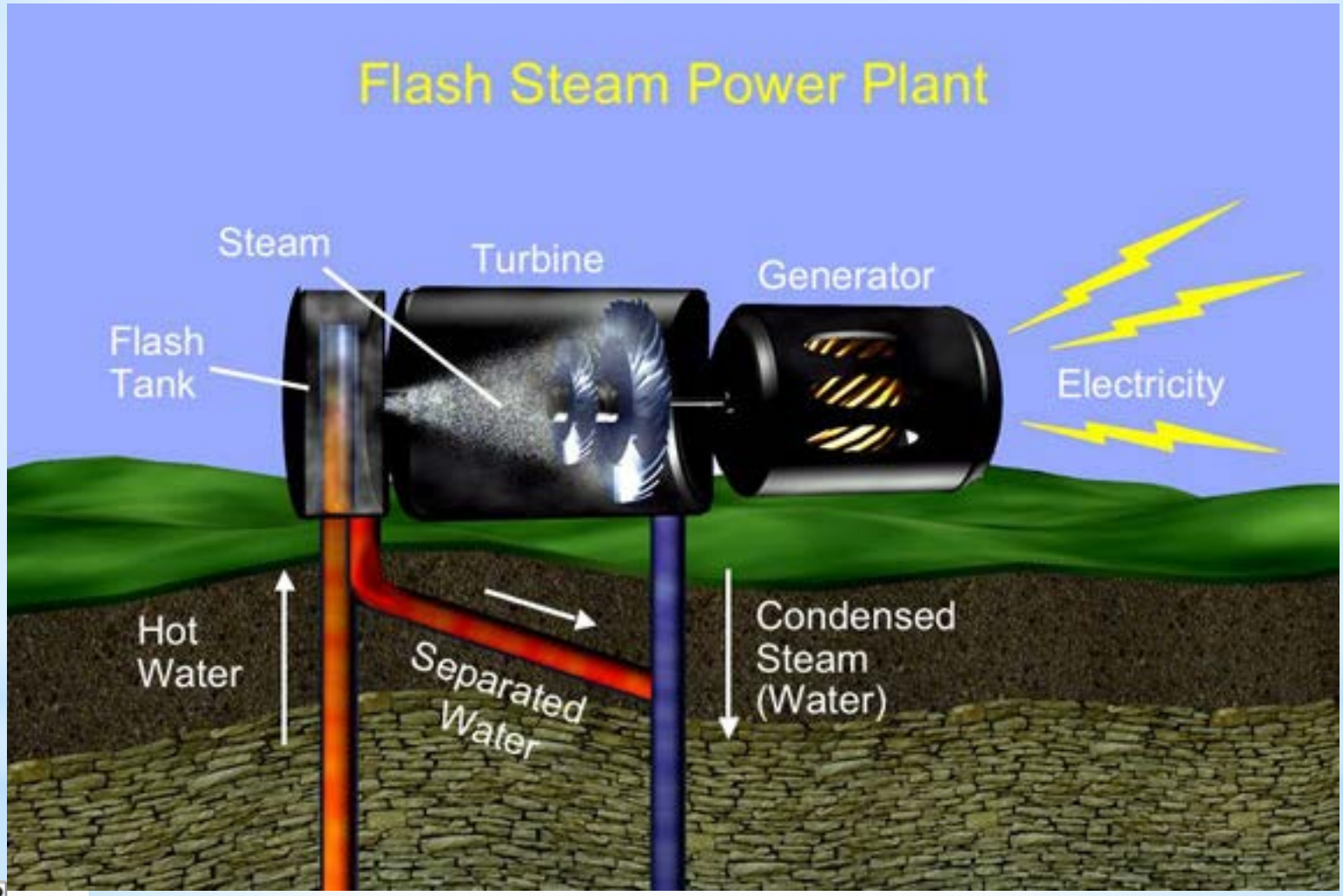
4. Flash steam plant



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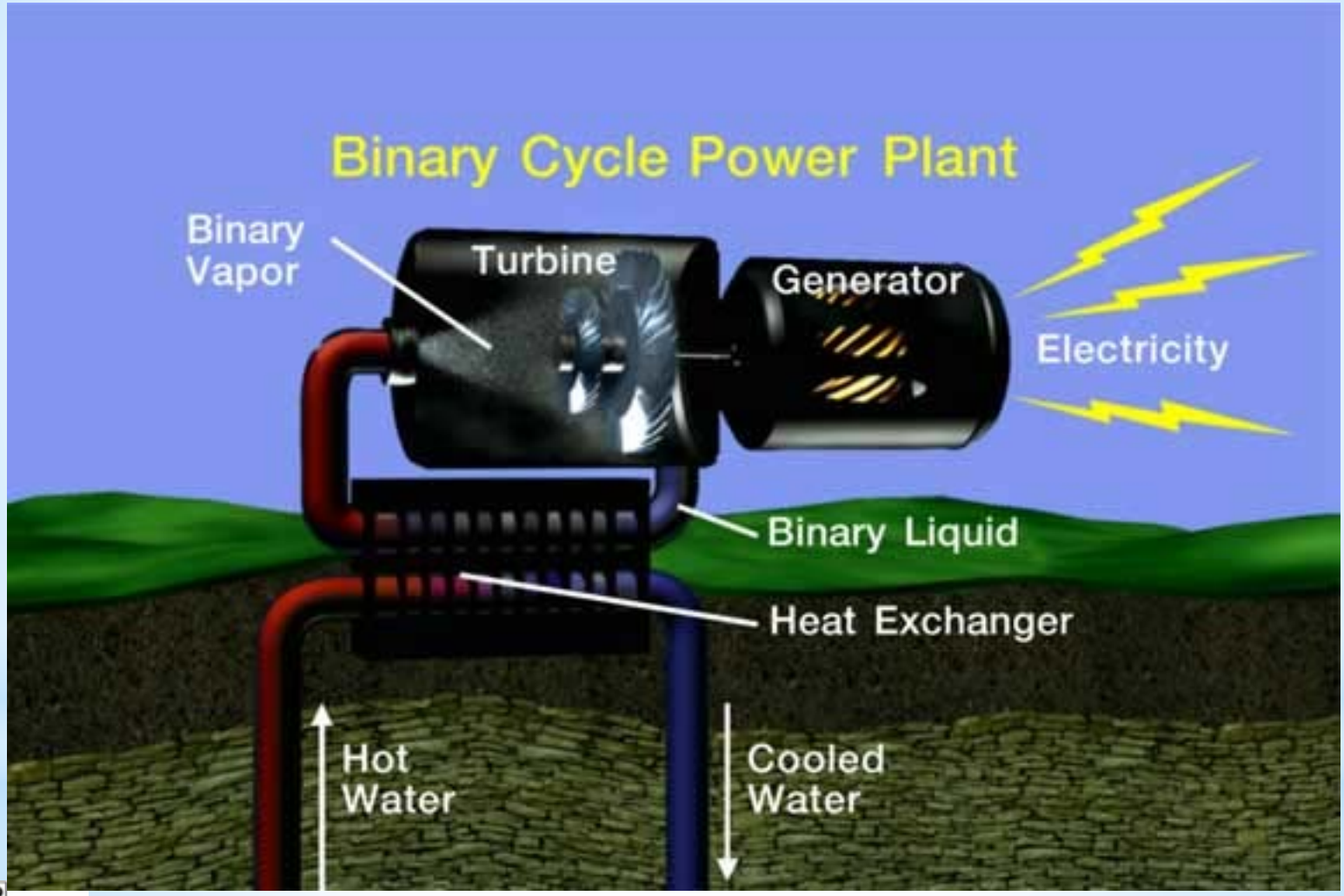
4. Binary plant



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5. Geothermal vs Oil/Gas

- Many similarities to Oil&Gas
- But renewable/sustainable (if done well)
- Source regenerates (in human timeframes)
- Low CO2-content (generally)

5. Geothermal Regulation

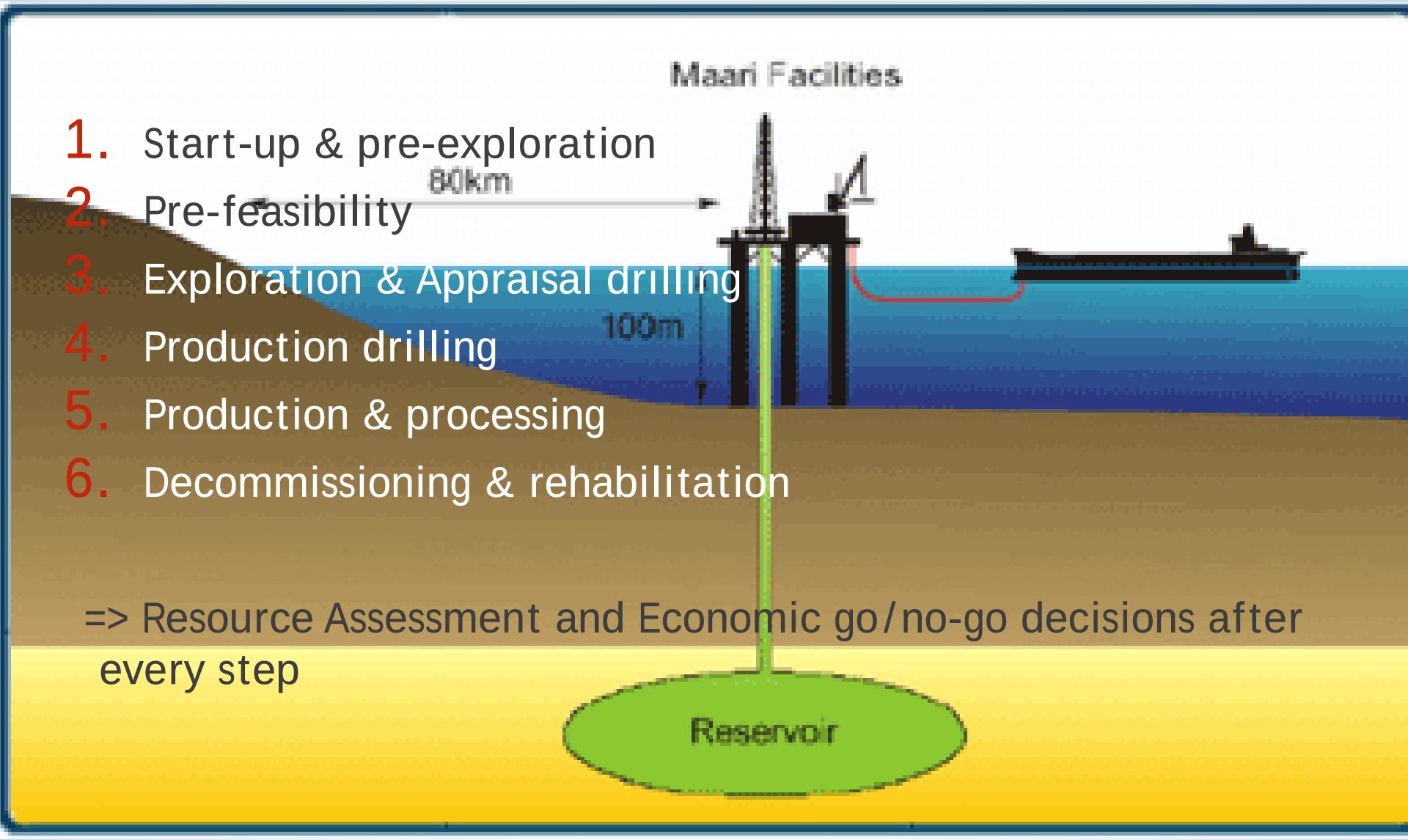
Similar issues as Oil/Gas Regulation

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

*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

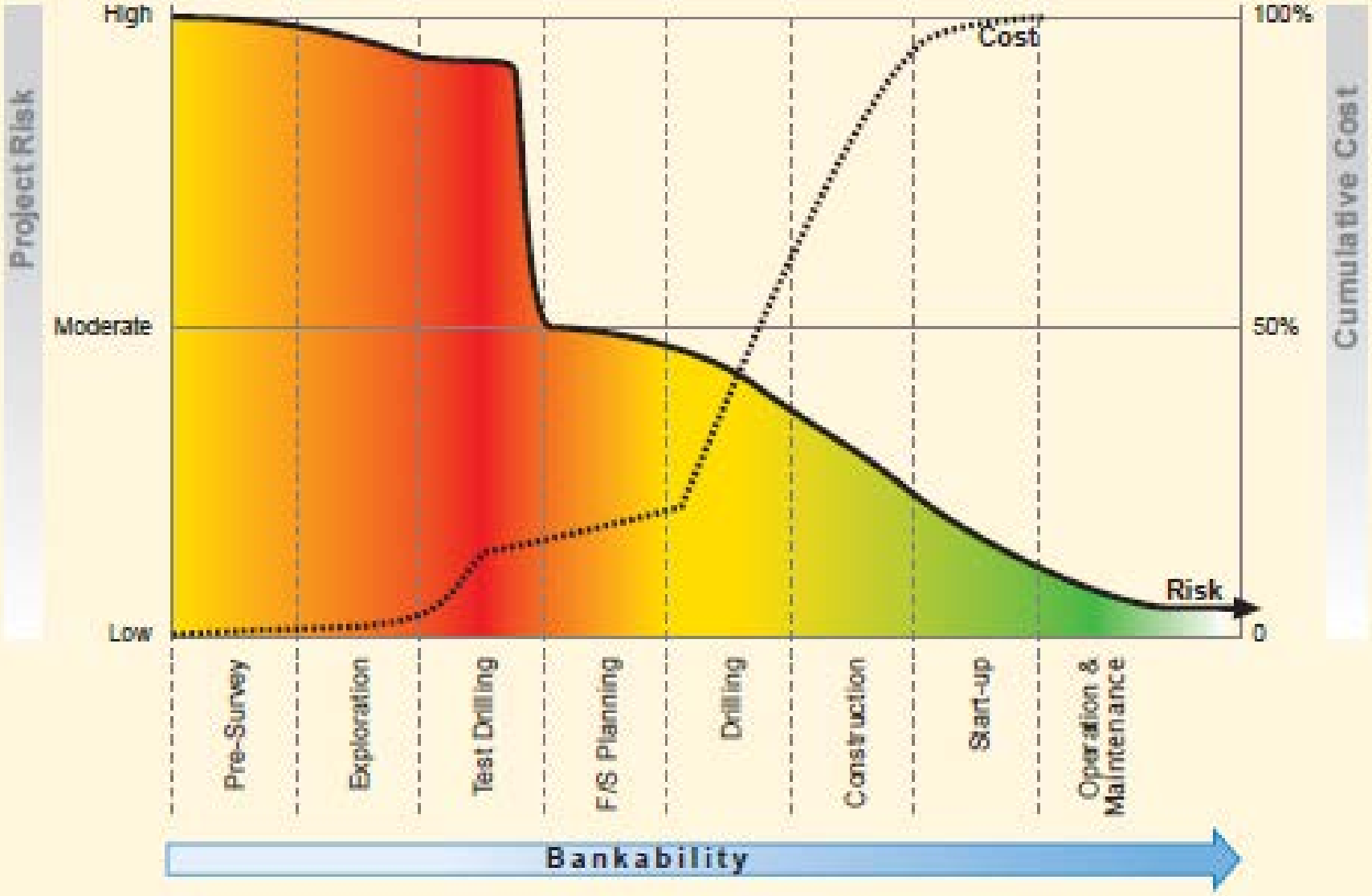
Stage 5: Production & Processing

* 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



5. NZ Geothermal 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'

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5. Geothermal Sustainability:

a) External Impacts/effects:

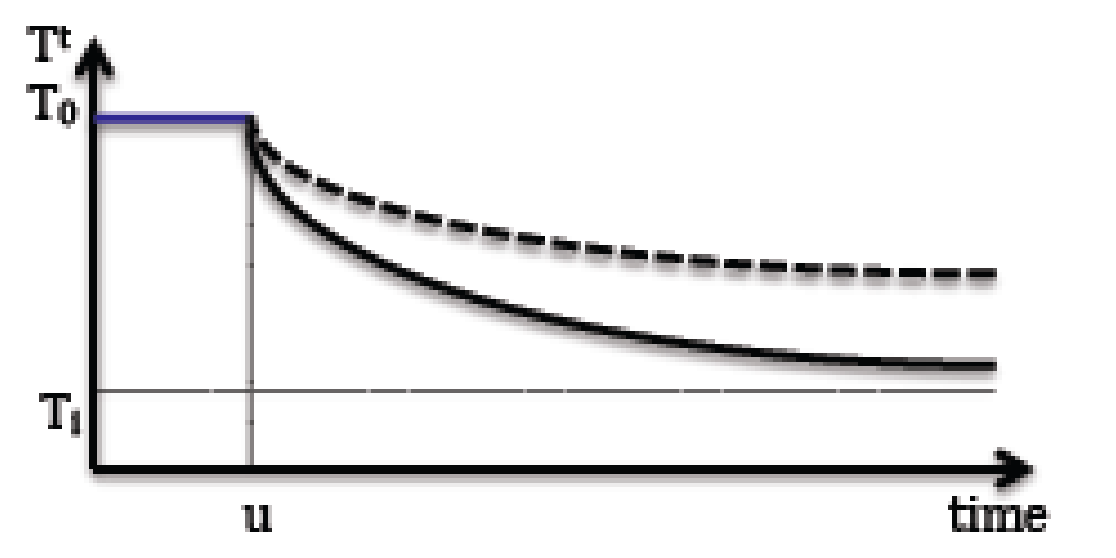
Pressure/Temp changes => affects geothermal features, subsidence

b) Resource itself:

-Often faster draw-down than regeneration => controlled depletion (50-100 yrs)

- Conserve other resources/fields for future generations

5. Example Sustainability:



Wairakei: 100-200 years to recover after 100 years of extraction

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


Wai O Tapu Loop Rd (Rotorua)
Thank You