

# Geothermal Energy: Status and Scope

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Summary

Introduction

Energy demand and environmental issues

Geothermal energy: Heat pumps

Geothermal power generation

Conclusion

Acknowledgement

References

# Summary

Worldwide energy demand is growing:

Population growth

Rapid industrialization or development of Asian countries

Increasing demand for oil and natural gas

Pollution

Greenhouse gas emissions

Global warming

# Electricity Generation\*

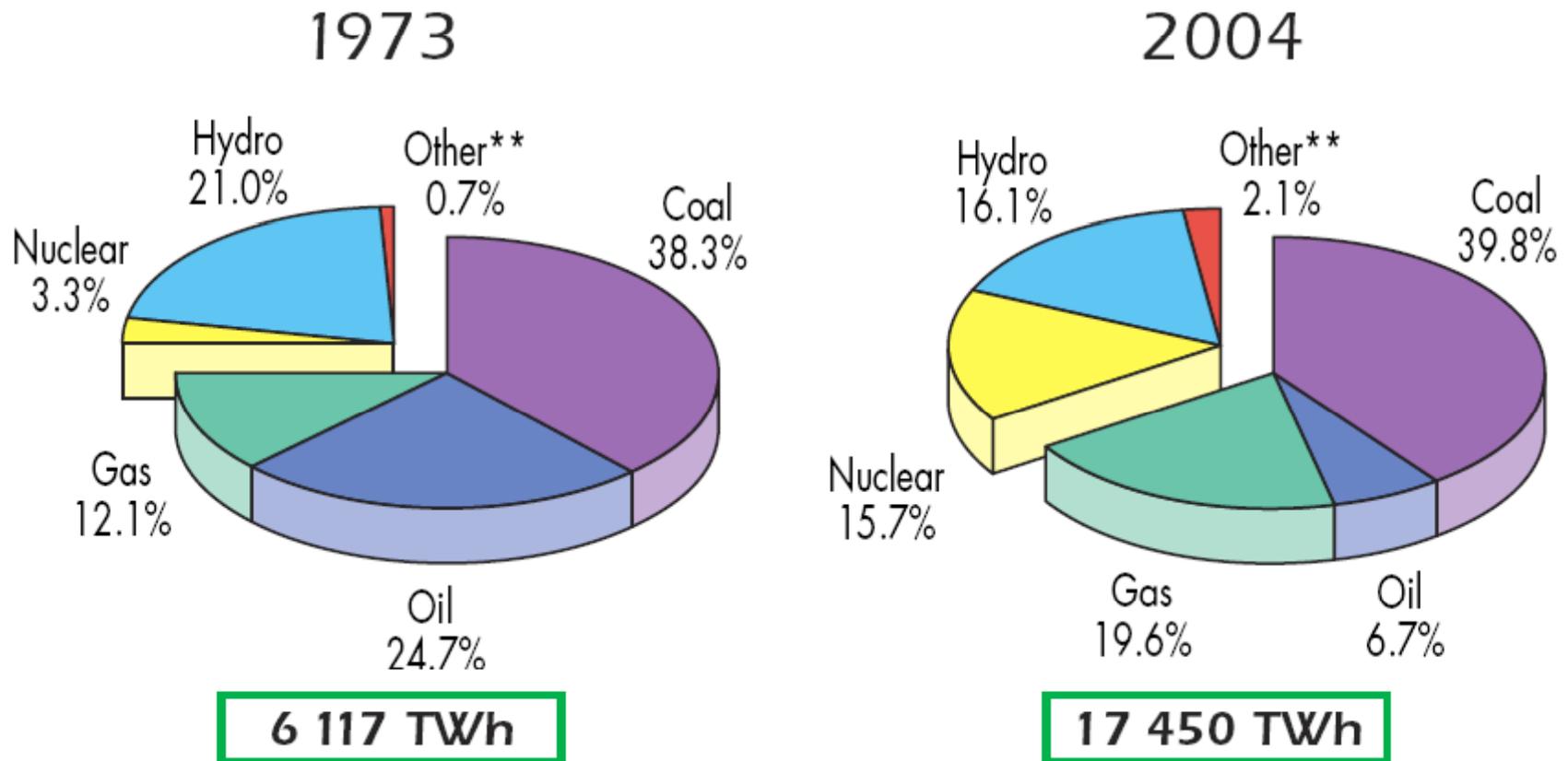


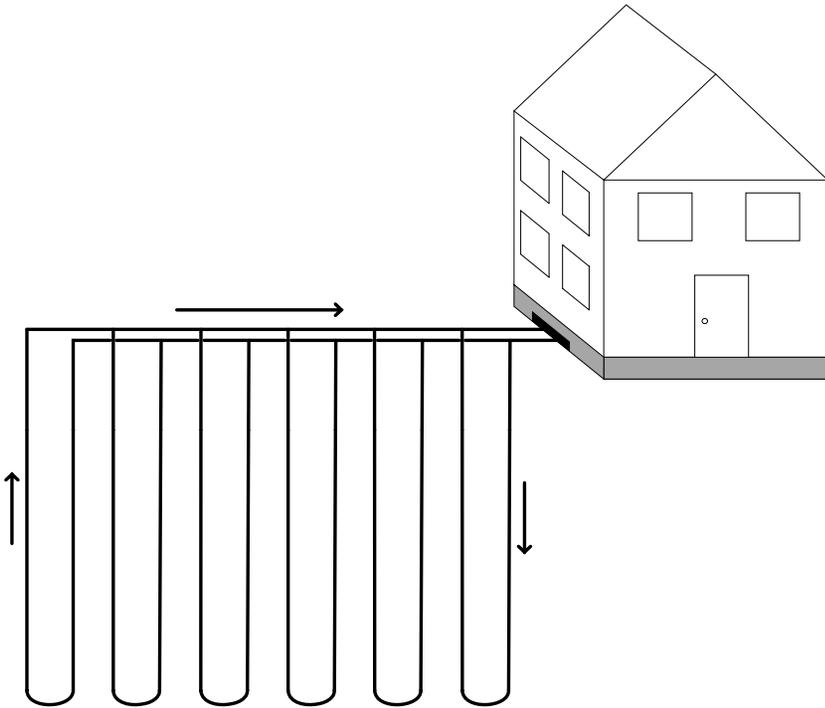
Figure 1. Ref: World Energy Outlook 2006 - iea.org

# Geothermal Heat Pumps

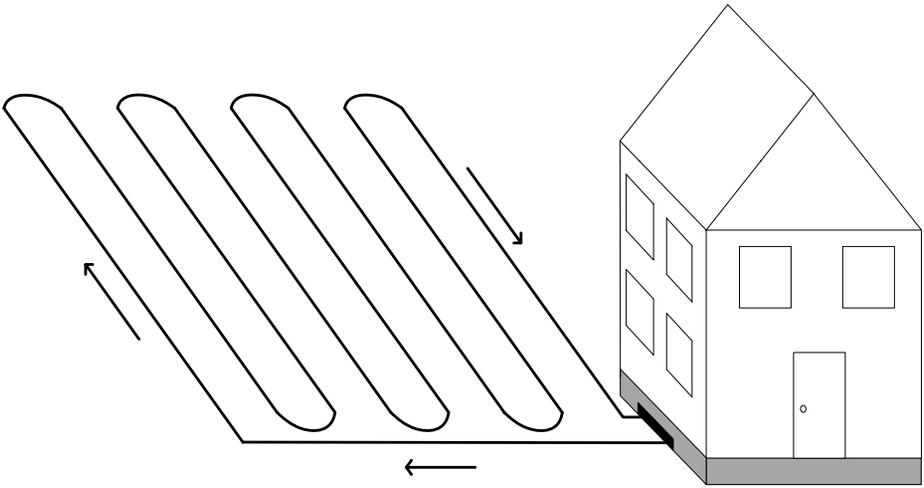
Geothermal heat pump concept since 1800's

Moves heat between building and ground and modifies its temperature

Facilitates heat extraction from the ground via a heat exchanger loop.



**Figure 2: Vertical closed loop heat exchange system for a geothermal heat pump [2]**



**Figure 3: Horizontal loop piping in series for a geothermal heat pump[2]**

# Geothermal Heat Pumps: Global Status

Table 1: Leading countries using geothermal heat pumps as of 2004 [1]

| Country     | Installed thermal capacity ( $\text{MW}_{\text{th}}$ ) | Annual energy use (GWh) | Number of GHP installations |
|-------------|--|-------------------------|-----------------------------|
| U.S.        | 6300   | 6300                    | 600,000                     |
| Sweden      | 2000   | 8000                    | 200,000                     |
| Germany     | 560  | 840                     | 40,000                      |
| Switzerland | 440  | 660                     | 25,000                      |
| Canada      | 435  | 300                     | 36,000                      |
| Australia   | 275  | 370                     | 23,000                      |

# Geothermal Thermal Energy Storage Systems

- Store thermal energy in underground soil mass
- Use heat transport fluid and heat exchangers to
  - Transfer thermal energy to soil/Ground
  - Recover thermal energy from soil/Ground

# Geothermal Thermal Energy Storage Applications

- Often large
- Used for heating and/or cooling complexes of buildings

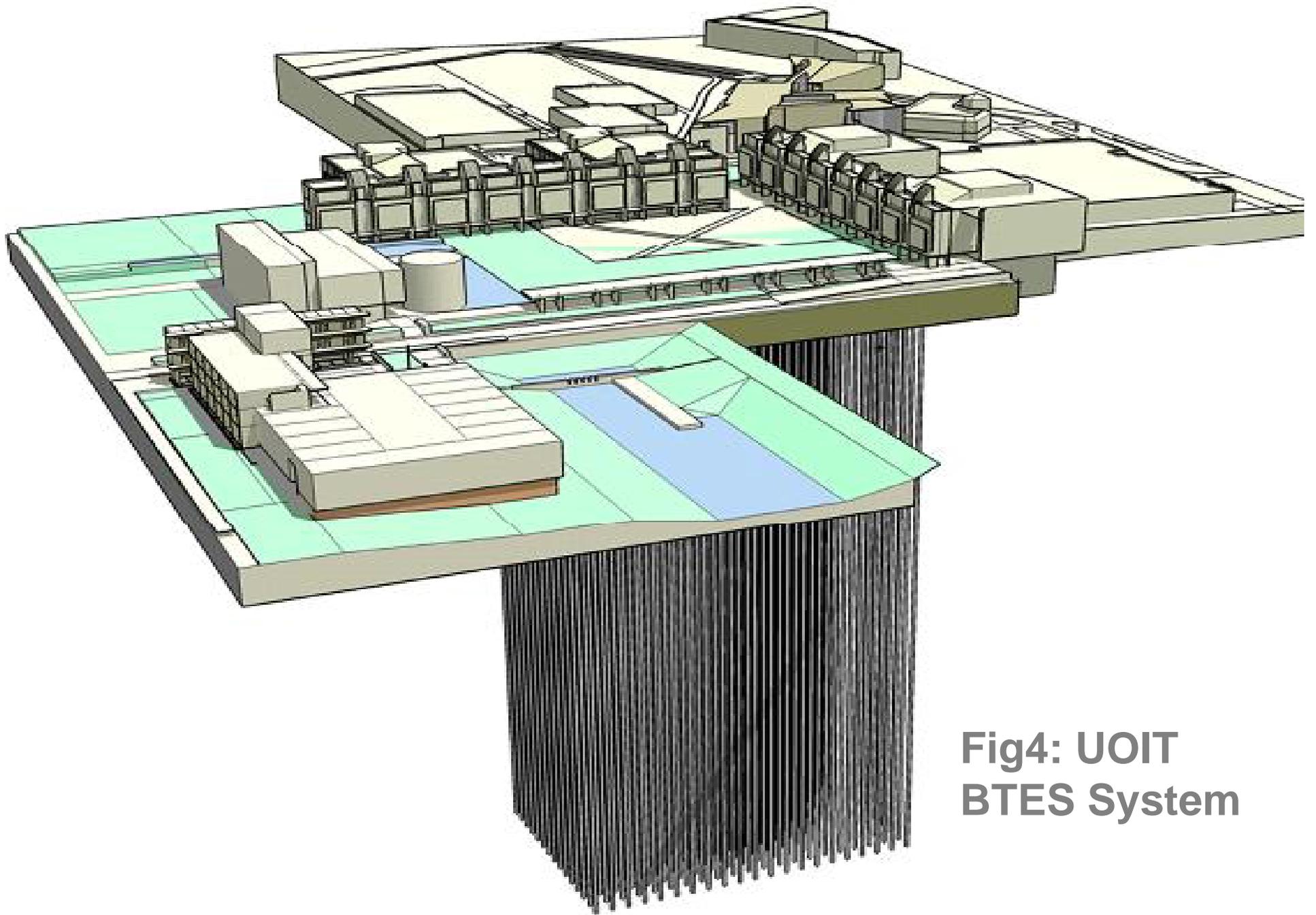


Fig4: UOIT  
BTES System

# Geothermal Heat Pumps: Recent Developments

Auxiliary component cooling

Ground Frost Loop

Standing Column well heat exchangers

# Analysis and Comparison of Heating Systems

**Table 2: Comparison of CO<sub>2</sub> emissions for various heating systems in several locations[2]**

| Heating system        | Annual fuel use (kWh) | Alberta                                     |                               | Ontario                                     |                               | Nova Scotia                                 |                               |
|-----------------------|-----------------------|---|-------------------------------|---|-------------------------------|---|-------------------------------|
|                       |                       | Emission intensity (kg <sub>CO2</sub> /kWh) | CO <sub>2</sub> emission (kg) | Emission intensity (kg <sub>CO2</sub> /kWh) | CO <sub>2</sub> emission (kg) | Emission intensity (kg <sub>CO2</sub> /kWh) | CO <sub>2</sub> emission (kg) |
| Geothermal HP         | 6080                  | 1.12  | 6826                          | 0.188                                       | 1143                          | 1.04  | 6346                          |
| Air source HP         | 8214                  | 1.12  | 9222                          | 0.188                                       | 1544                          | 1.04  | 8573                          |
| Electric baseboard    | 22280                 | 1.12  | 25015                         | 0.188                                       | 4188                          | 1.04  | 23255                         |
| Natural gas furnace*  | 28475                 | 0.190                                       | 5410                          | 0.190                                       | 5410                          | 0.190                                       | 5410                          |
| Natural gas furnace** | 24655                 | 0.190                                       | 4684                          | 0.190                                       | 4684                          | 0.190                                       | 4684                          |

# Geothermal Power Generation

1<sup>st</sup> Geothermal Power Plant: Larderello dry steam field,  
Italy

## **Geothermal Resources:**

Hydrothermal resources

Geopressured resources

Hot dry rock resources

Magma resources

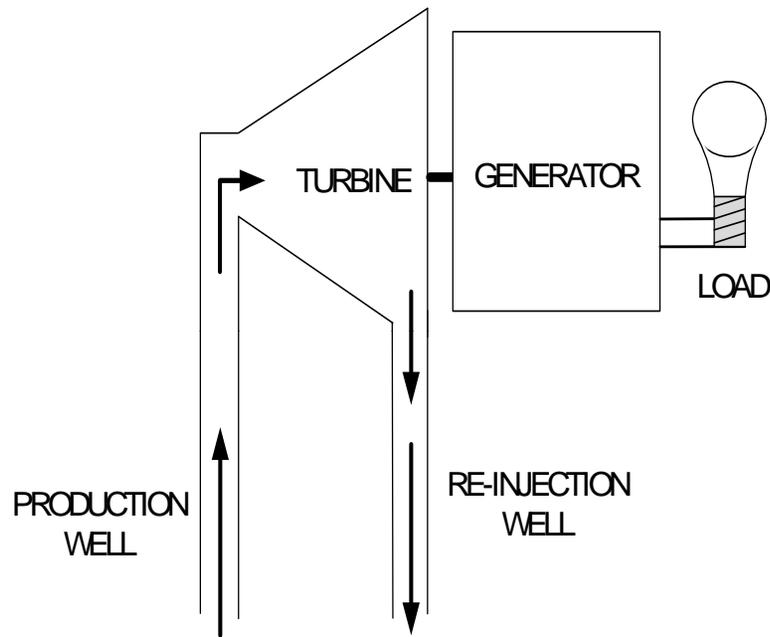


Fig. 5. Basic layout of a dry-steam geothermal power plant [2]

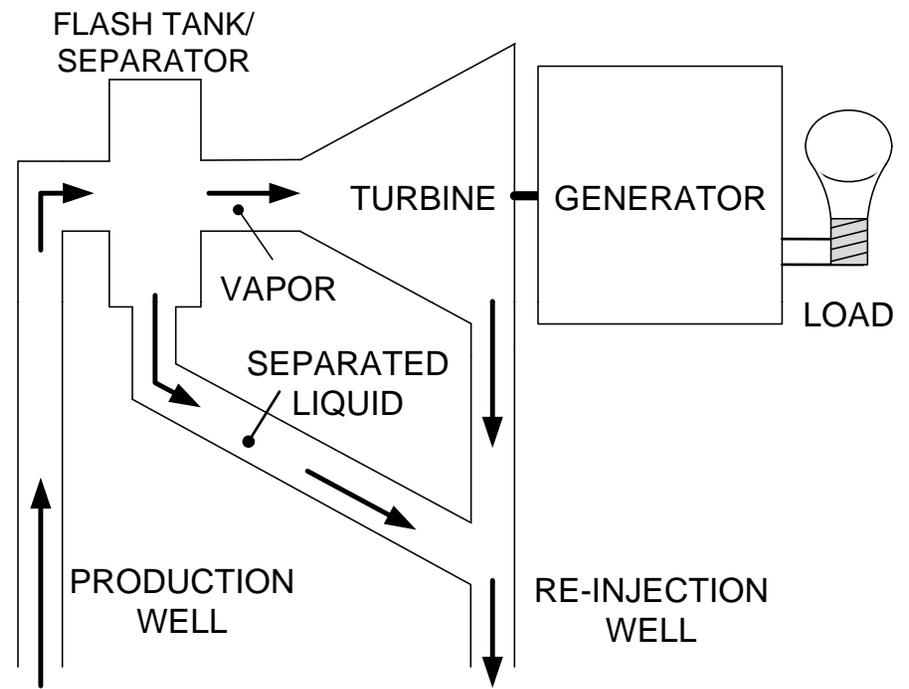


Fig. 6. Basic layout of a single flash-steam geothermal power plant [2]

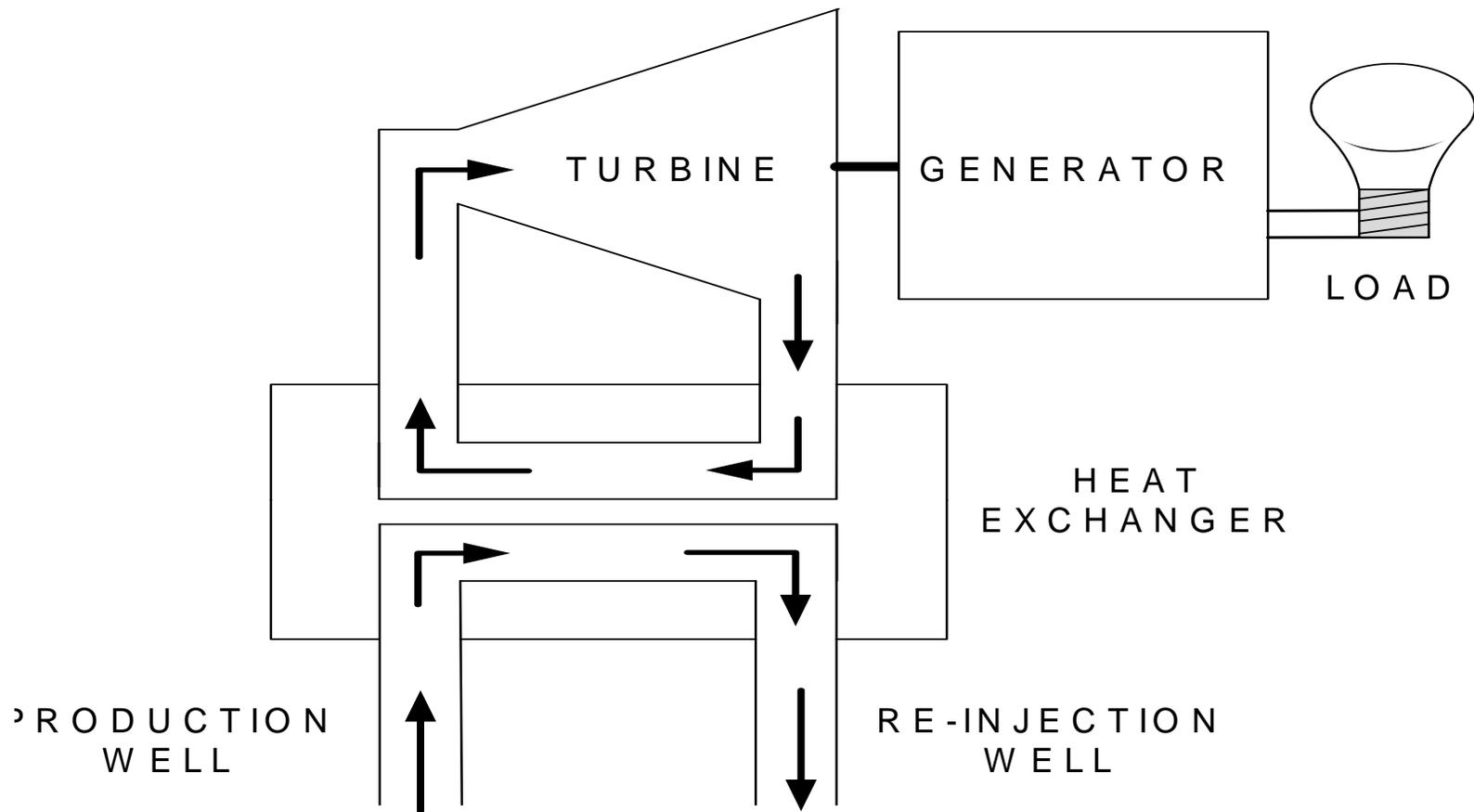


Fig. 7. Basic layout of a binary cycle geothermal power plant [2]

Table 3. Installed geothermal generating capacities worldwide [3, 4, 5]

| Country          | Number of Commercial Units | Power Production Capacity (MW <sub>e</sub> ) |
|------------------|----------------------------|--|
| U.S.A            | 187                        | 2534   |
| Philippines      | 57                         | 1931   |
| Mexico           | 37                         | 953  |
| Indonesia        | 15                         | 807  |
| Italy            | 33                         | 791  |
| Japan            | 22                         | 537  |
| New Zealand      | 33                         | 453  |
| Iceland          | 17                         | 202  |
| Costa Rica       | 6                          | 163  |
| El Salvador      | 5                          | 162  |
| Kenya            | 8                          | 127  |
| Russia           | 8                          | 82   |
| Nicaragua        | 4                          | 78   |
| China            | 13                         | 32   |
| Guatemala        | 8                          | 29   |
| Turkey           | 1                          | 20   |
| Portugal         | 5                          | 16   |
| France           | 2                          | 15   |
| Ethiopia         | 1                          | 7  |
| Papua New Guinea | 2                          | 6  |
| Austria          | 1                          | 1.3  |
| Thailand         | 1                          | 0.3  |
| Germany          | 1                          | 0.2  |
| Australia        | 1                          | 0.2  |
| <b>Total</b>     | 468                        | 8947   |

# Recent Research and Developments

Geothermal power plants:

Mixed working fluids (Binary plants)

Equipment lining

Air cooled condensers

Alternative non-condensable gas removal methods

## Advanced Geothermal Energy Conversion Systems [7]

Combined flash-binary system: Combines a flash steam plant and a binary cycle, which results in reduced losses and increased power.

Integrated flash-binary system: Similar to combined flash binary system, the separated liquid provides heat to drive a binary cycle.

Fossil fuel-superheat systems: Involves the use of a fossil fueled superheater to superheat the vapor.

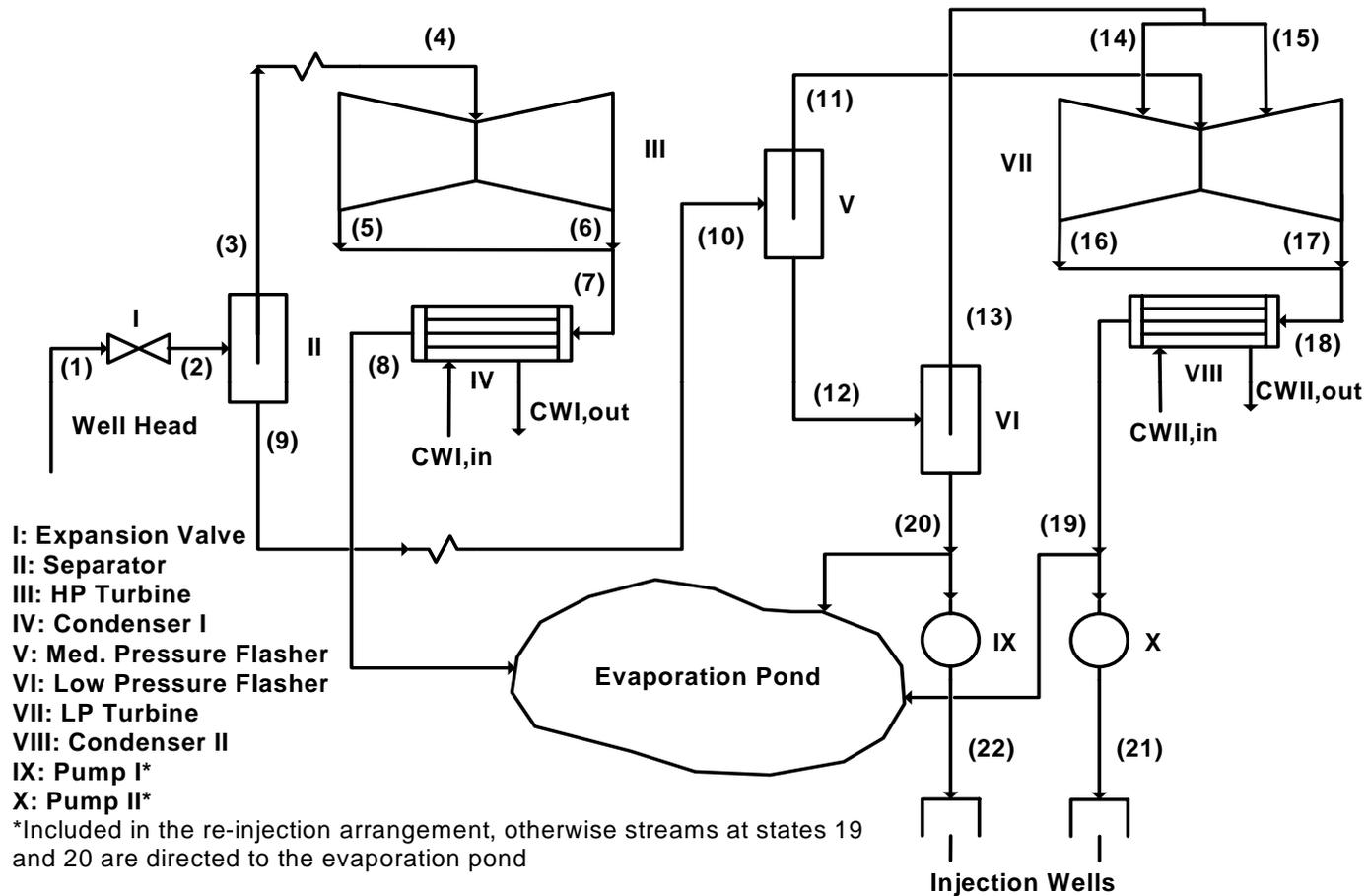


Fig. 8 State diagram for the Cerro Prieto I geothermal power plant. Modified from Reference [6, 8]

# Energy and Exergy Analyses

## **Energy Analysis**

First law: Energy balance

## **Exergy Analysis**

Second law: Irreversibilities, quality

Provides the details on the role of operating conditions  
on performance from quality point of view

Exergy losses, exergy destruction, exergetic efficiency

# Research Work at UOIT

Geothermal heat pumps

Geothermal thermal energy storage and applications

Geothermal power generation

Hybrid systems

Thermal energy storage

# Conclusions

**Geothermal heat pumps:** Good scope for heating and cooling applications

Component efficiencies

**Geothermal power generation:**

Growing attention for power generation

Binary cycle geothermal plants

Working fluids

Exergy analysis

**Cerro Prieto I geothermal power plant:** In the standard system most of the energy and exergy was being wasted through the use of direct discharge. With re-injection that amount is almost cut in half and the main source of exergy waste or destruction is the evaporation valve at the well head.

## Acknowledgements

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UOIT

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