DIRECT HEAT UTILIZATION OF GEOTHERMAL ENERGY

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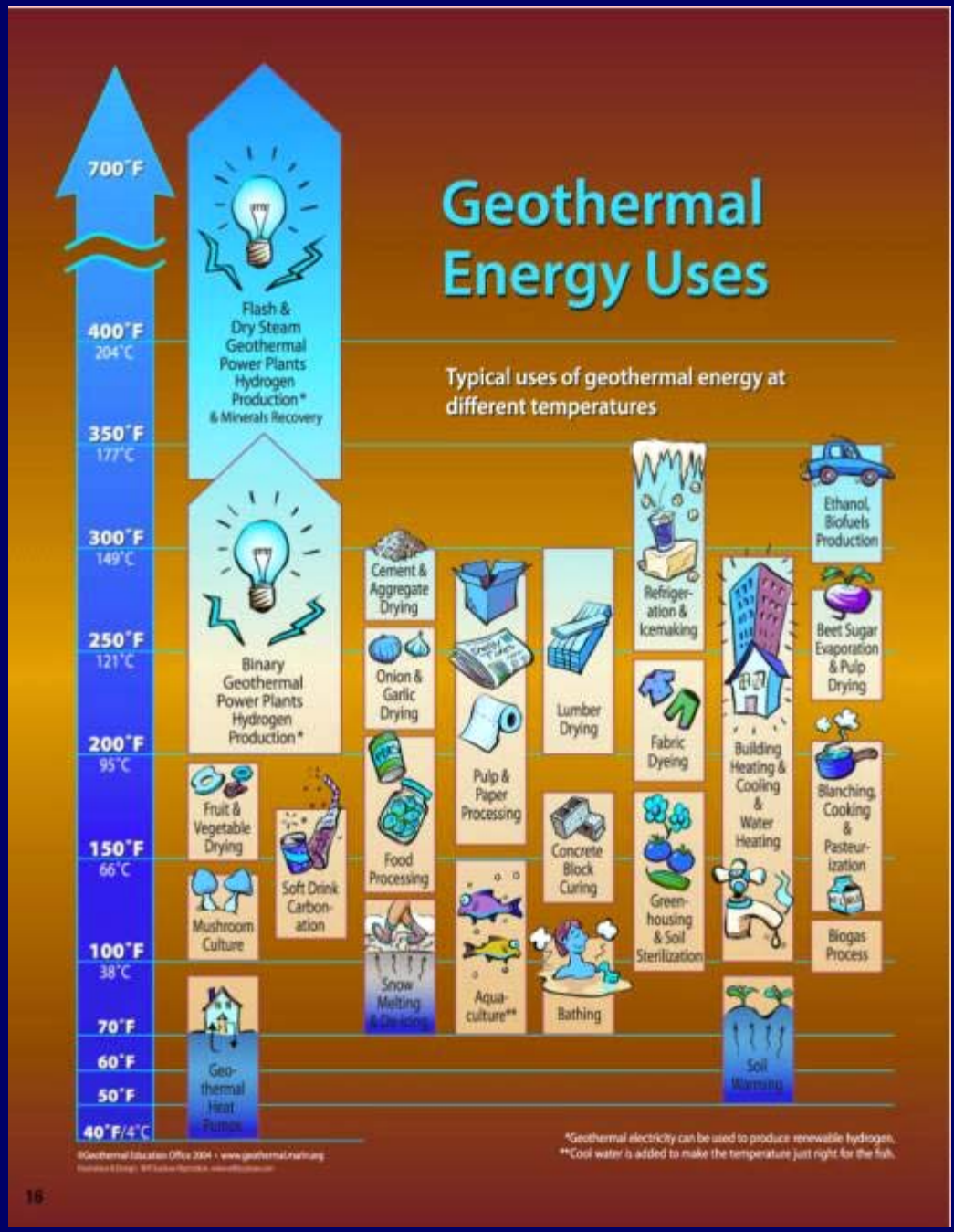
Geothermal Energy Uses
Typical uses of geothermal energy at different temperatures
700˚F
400˚F
204˚C
350˚F
177˚C
300˚F
149˚C
250˚F
121˚C
200˚F
95˚C
150˚F
66˚C
100˚F
38˚C
70˚F
60˚F
50˚F
40˚F/4˚C
Flash & Dry Steam Geothermal Power Plants Hydrogen Production* & Minerals Recovery
Binary Geothermal Power Plants Hydrogen Production*
Geo-thermal Heat Pumps
Fruit & Vegetable Drying
Mushroom Culture
Soft Drink Carbon-ation
Cement & Aggregate Drying
Onion & Garlic Drying
Food Processing
Snow Melting & Deicing
Pulp & Paper Processing
Aqua-culture**
Lumber Drying
Concrete Block Curing
Bathing
Refriger-ation & Icemaking
Fabric Dyeing
Green-housing & Soil Sterilization
Building Heating & Cooling & Water Heating
Soil Warming
Ethanol, Biofuels Production
Beet Sugar Evaporation & Pulp Drying
Blanching, Cooking & Pasteur-ization
Biogas Process
*Geothermal electricity can be used to produce renewable hydrogen.
**Cool water is added to make the temperature just right for the fish.
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World Wide Direct Utilization

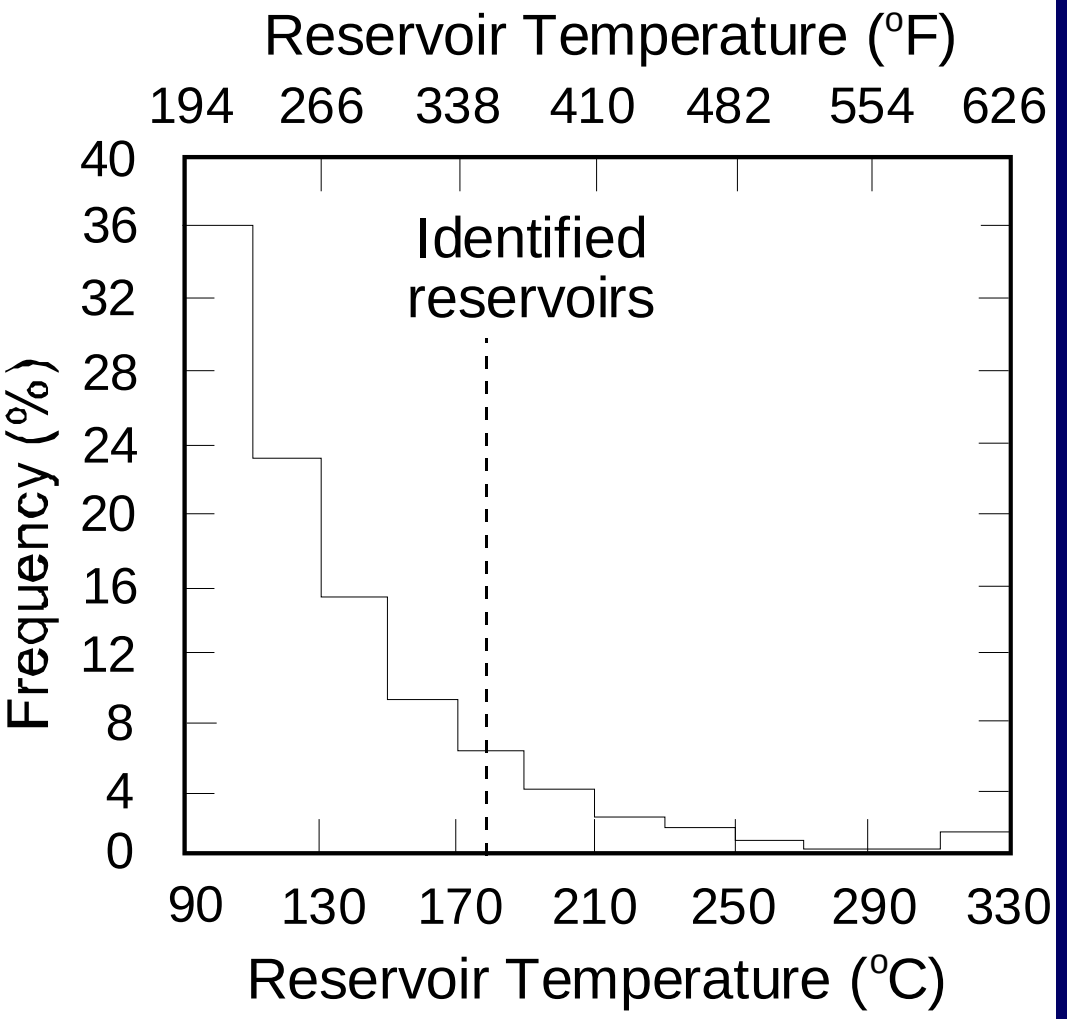
World Wide

- Approximately 72 countries
- Installed capacity: 28,268 MWt
- Energy Use: 273,372 TJ/yr (75,943 GWh/yr) (enough to heat 3.4 million homes)
- Saving 129 million bbl (19.2 mill. tonnes) of oil per year
- Largest use: geothermal (ground-source) heat pumps used for both heating and cooling

What is Direct-Use: Heating and Cooling

- Swimming, bathing and balneology
- Space heating and cooling
  - Including district energy (heating/cooling) systems
- Agriculture applications
  - Greenhouse heating
- Aquaculture applications
  - Fish pond and raceway heating
- Industrial processes
  - Including food and grain drying
- Geothermal heat pumps

Frequency vs Reservoir Temperature



Data taken from USGS Circular 790

Advantages of Direct-Use of Geothermal Energy

- Can use low- to intermediate temperature resources (<150ºC)
- These resources are more wide-spread (80 countries)
- Direct heat use (no conversion – high efficiency)
- Use conventional water-well drilling equipment
- Use conventional, off-the-shelf equipment
  - (allow for temperature and chemistry of fluid)
- Minimum start-up-time

Advantages of Direct-Use of Geothermal Energy

- Can be used on a small scale (“mom and pop operation”)
  - Individual home
  - Single greenhouse
  - Single aquaculture pond
- Can also be large scale operation
  - District heating
  - Food, lumber and mineral ore drying

Home cooker – Rotorua, New Zealand

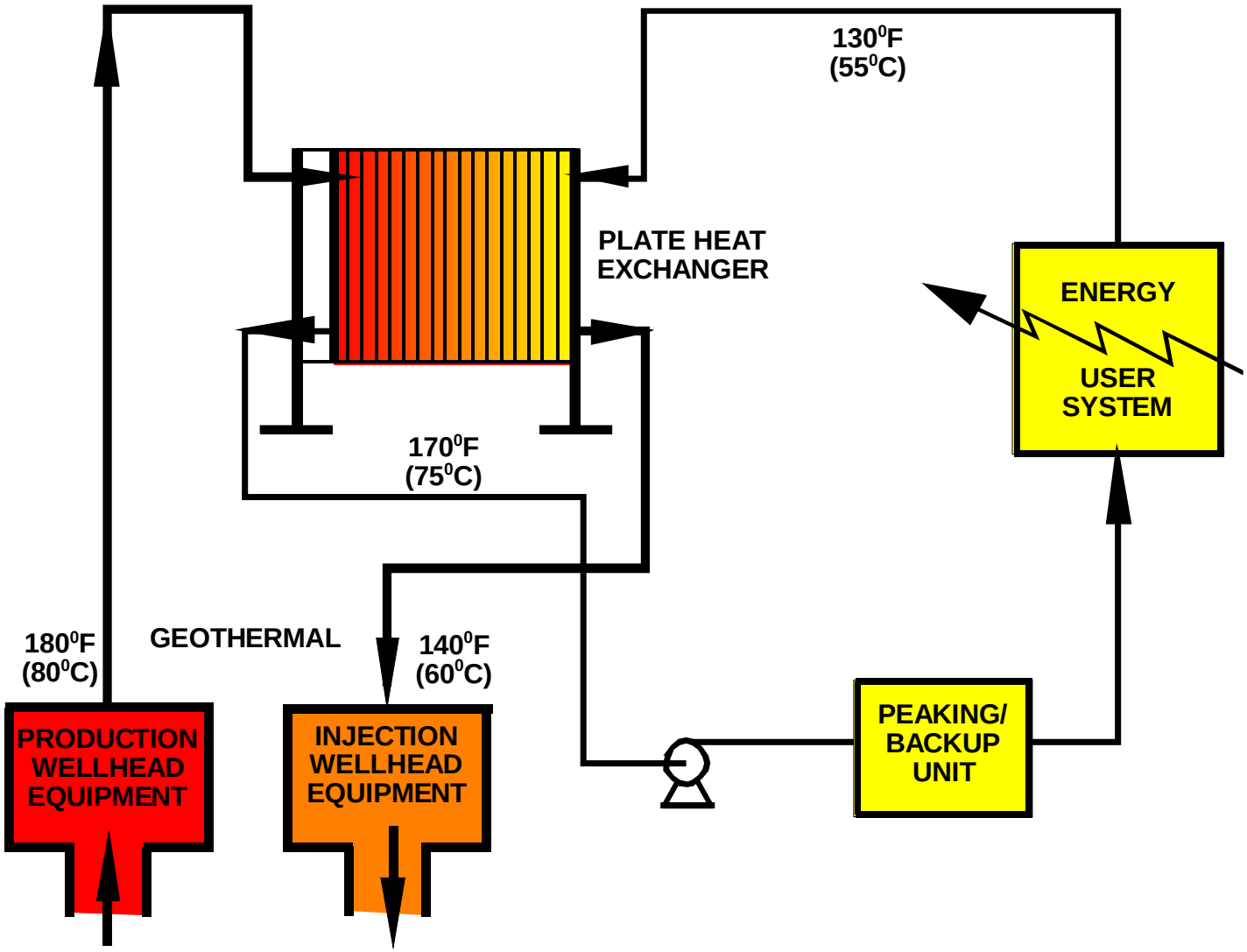
Equipment (1)

- Often necessary to isolate geothermal fluid to prevent corrosion or scaling
- Care taken to prevent oxygen from entering system
- Dissolved gases and minerals (boron, arsenic, hydrogen sulfide, etc.) may be harmful to plants and animals

Equipment (2)

Typical equipment includes:

- **Downhole and circulation pumps**
- **Heat exchangers**
- **Transmission and distribution pipelines**
- **Heat extraction equipment**
- **Peaking or back-up plants**
- **Fluid disposal system**


130⁰F
(55⁰C)
PLATE HEAT
EXCHANGER
ENERGY
USER
SYSTEM
170⁰F
(75⁰C)
180⁰F
(80⁰C)
GEOTHERMAL
140⁰F
(60⁰C)
PRODUCTION
WELLHEAD
EQUIPMENT
INJECTION
WELLHEAD
EQUIPMENT
PEAKING/
BACKUP
UNIT

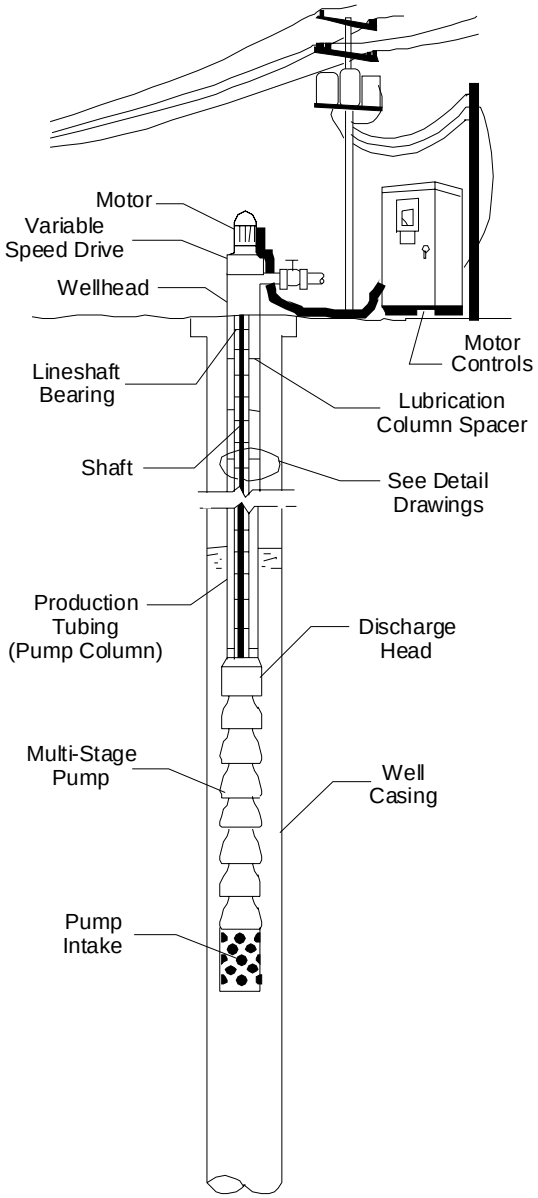
Rotary drilling

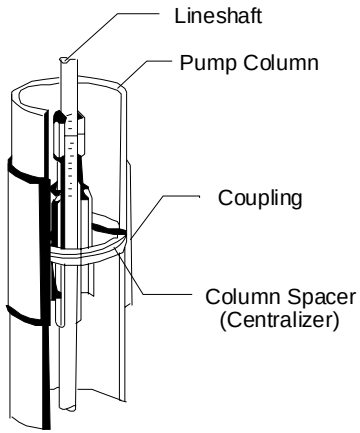
Cable drilling

Wells Pumps

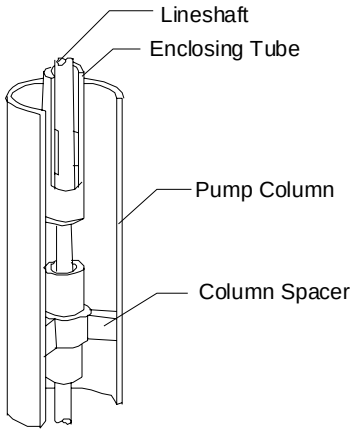
Two types used:

- **Lineshaft – motor on surface (most common in the US) (often used with variable frequency drive) <250 m**
- **Submersible – motor below water (most common in Europe) <4,000 m – lower temperature tolerance**

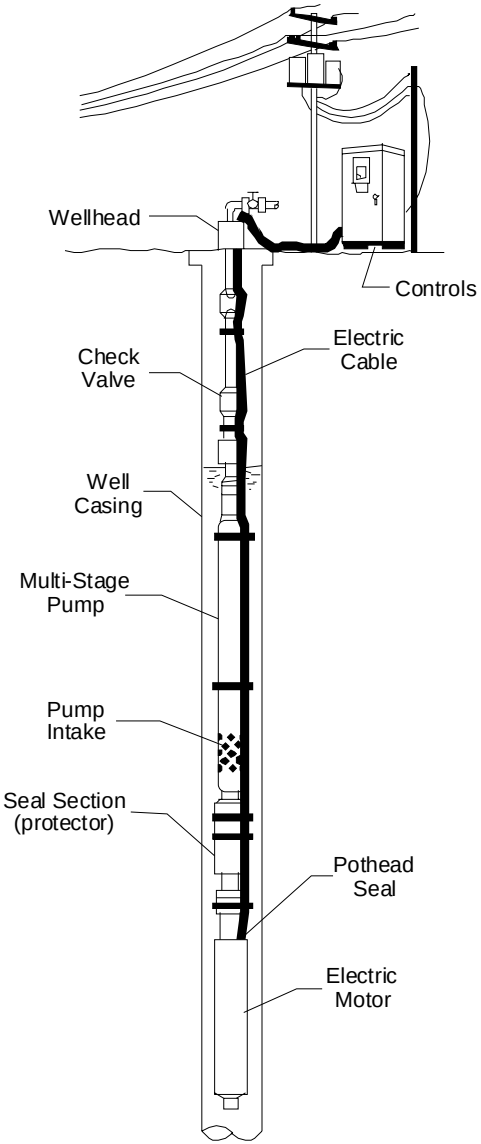




Open Lineshaft Bearing Lubrication



Enclosed Lineshaft Bearing Lubrication



Heat Exchangers

- Shell and tube
- Plate
- Downhole
- Room heat convectors

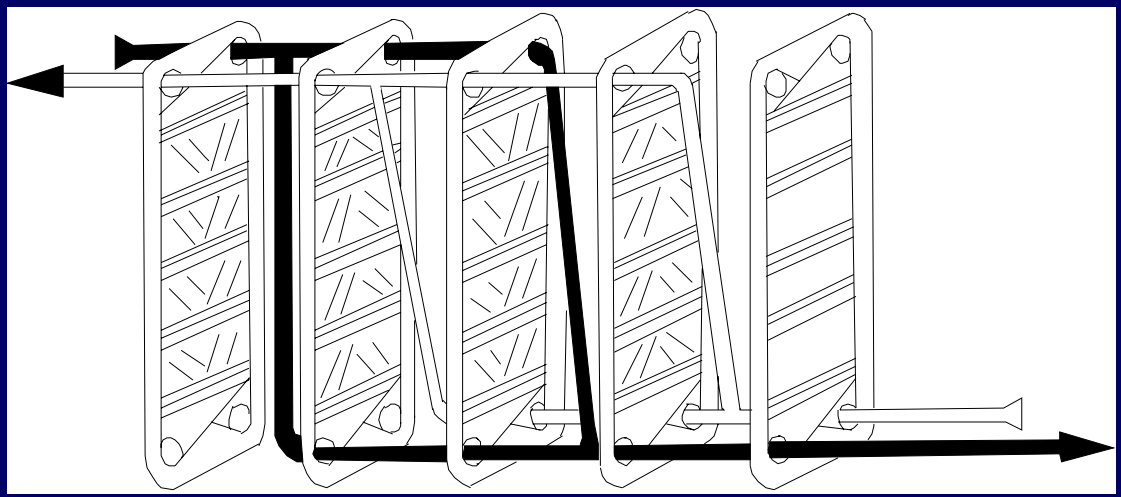
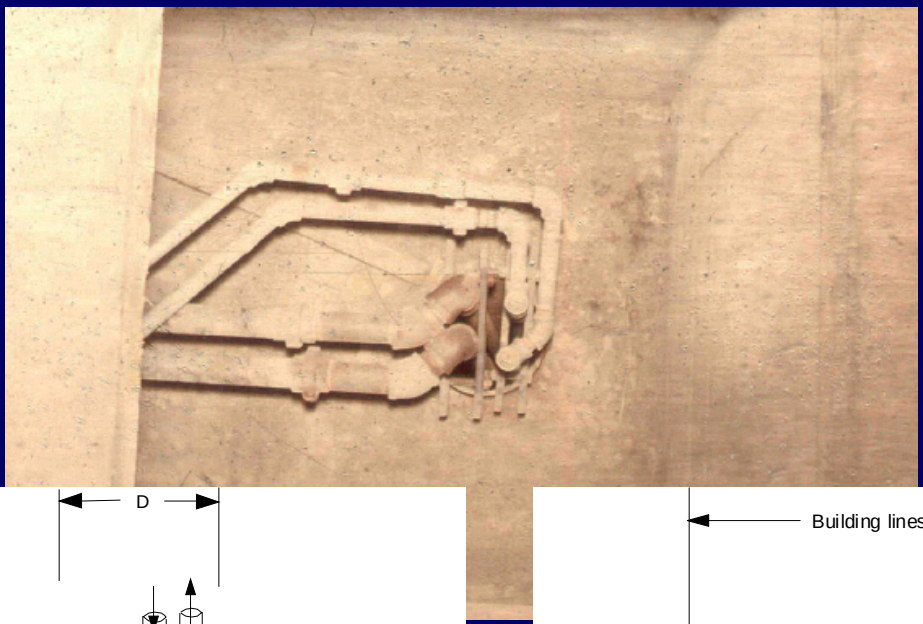
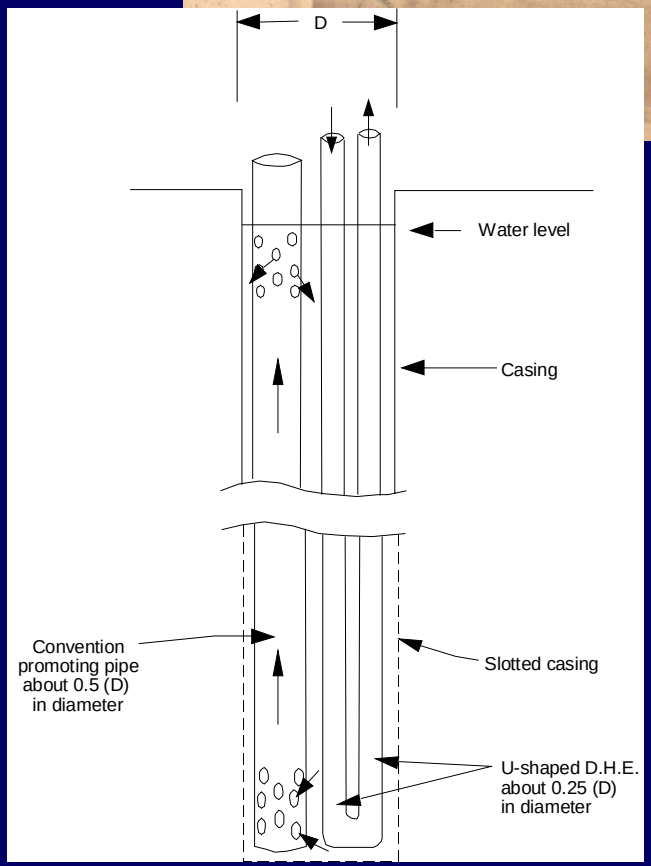
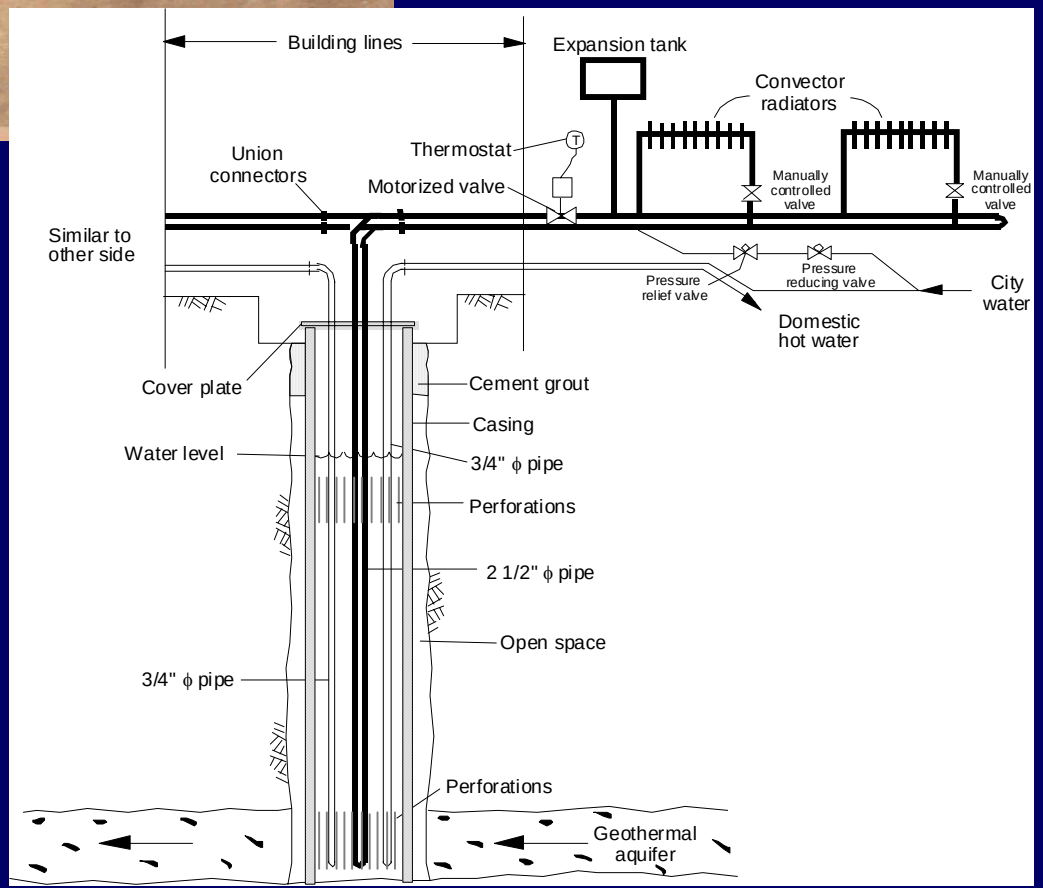


Plate heat exchanger

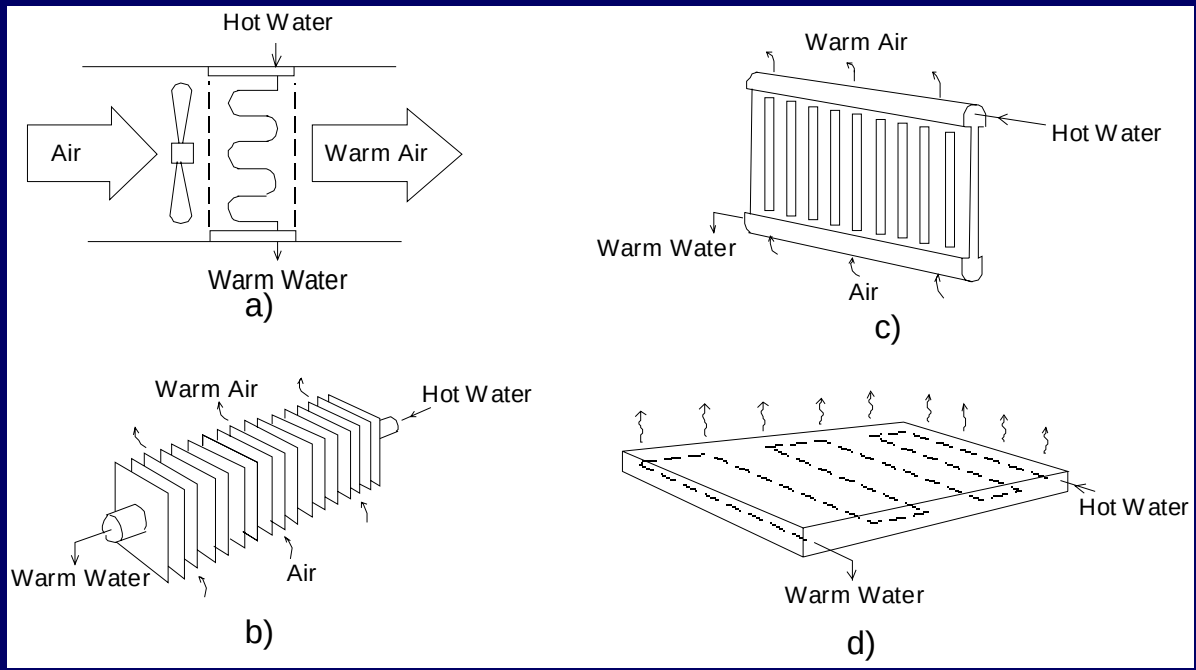
Downhole heat exchanger







Room heat convectors



Piping (1)

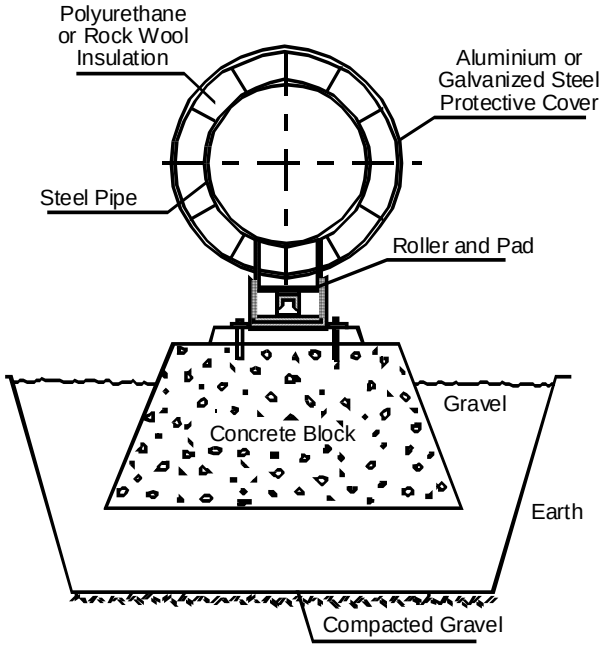
Location

- Above ground
- Below ground
- Problems
  - Metallic - external corrosion – if direct buried
  - Non-metallic <100°C

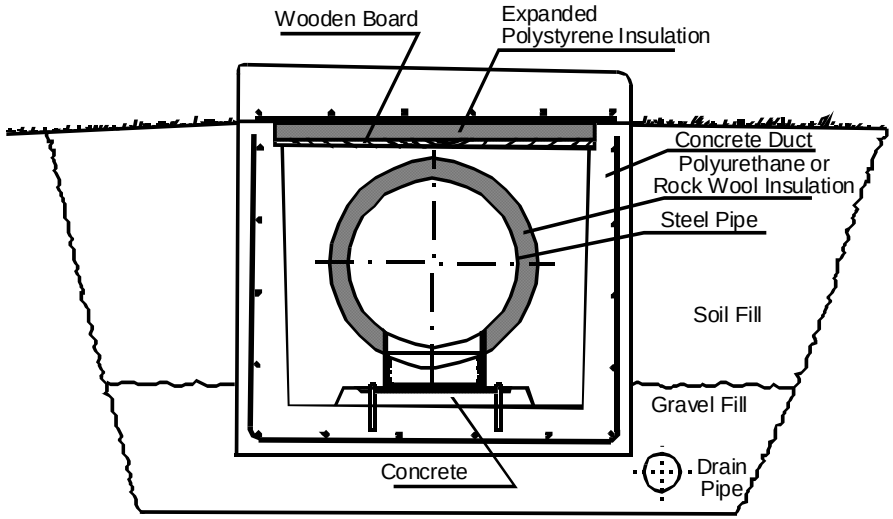
Piping (2)

Material

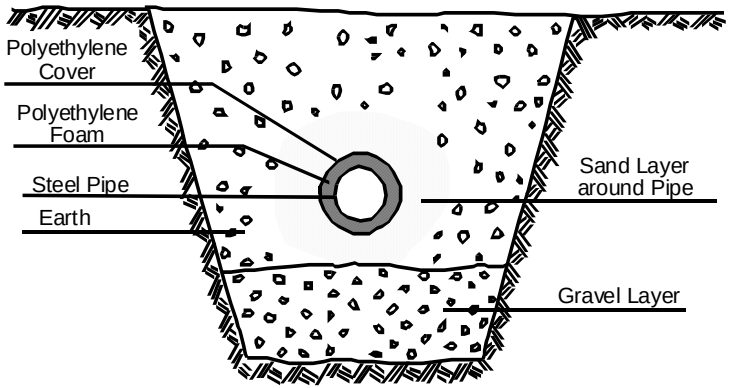
- Carbon steel >100^{o}C
  - Expansion loops or bellows
- FRP or PVC <100^{o}C – Fiberglass reinforced plastic and polyvinylchloride
- AC – Asbestos cement
  - Environmental limitation
  - Longest = Deildartunga – Akranes, Iceland at 62 km
- Cross-linked polyethylene (PEX) good to 90^{o}C and 550 Pa (5.5 bar) – used for snow melting


Polyurethane
or Rock Wool
Insulation
Aluminium or
Galvanized Steel
Protective Cover
Steel Pipe
Roller and Pad
Gravel
Concrete Block
Earth
Compacted Gravel

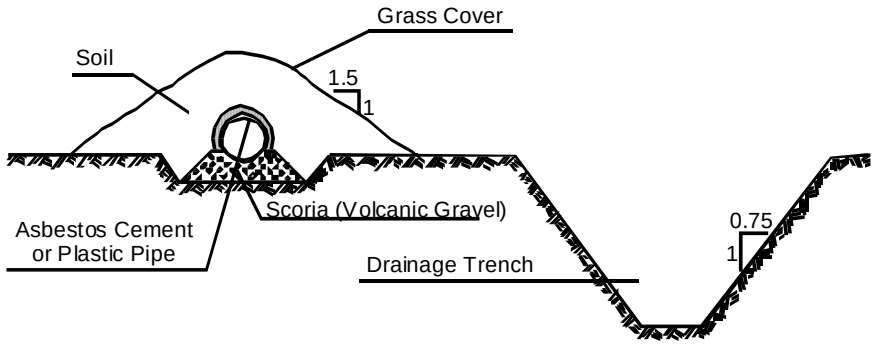
a)


Wooden Board
Expanded
Polystyrene Insulation
Concrete Duct
Polyurethane or
Rock Wool Insulation
Steel Pipe
Soil Fill
Gravel Fill
Concrete
Drain
Pipe

b)


Polyethylene
Cover
Polyethylene
Foam
Steel Pipe
Earth
Sand Layer
around Pipe
Gravel Layer

c)

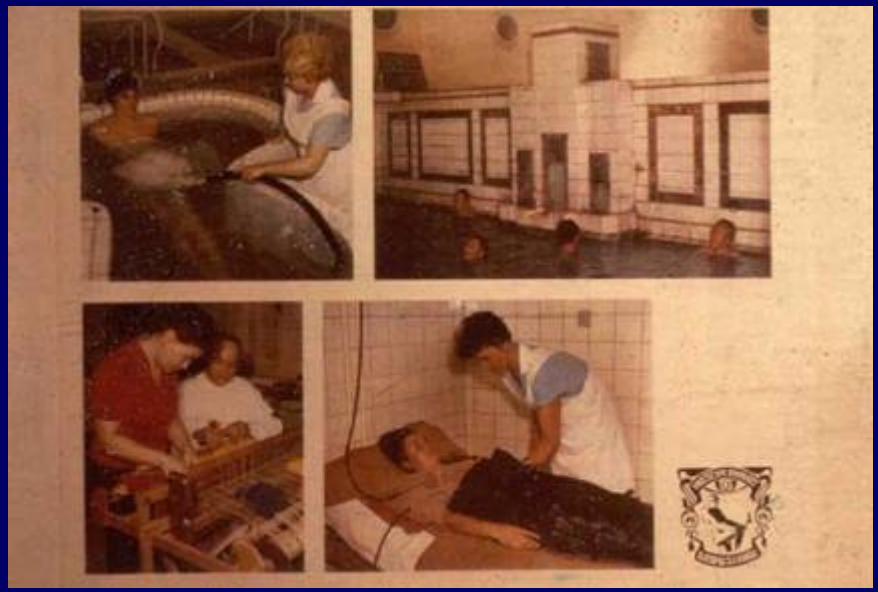

Grass Cover
Soil
1.5
1
Scoria (Volcanic Gravel)
Asbestos Cement
or Plastic Pipe
Drainage Trench
0.75
1

d)

Iceland

Swimming, Bathing and Balneology - Spas

- These are normally provided for:
  - exercise and fitness
  - medical reasons - health
  - get away from stress to relax
- Typical range of temperature = 24 to 40^{o}C
- Geothermal resource 10 to 15^{o}C above pool temperature

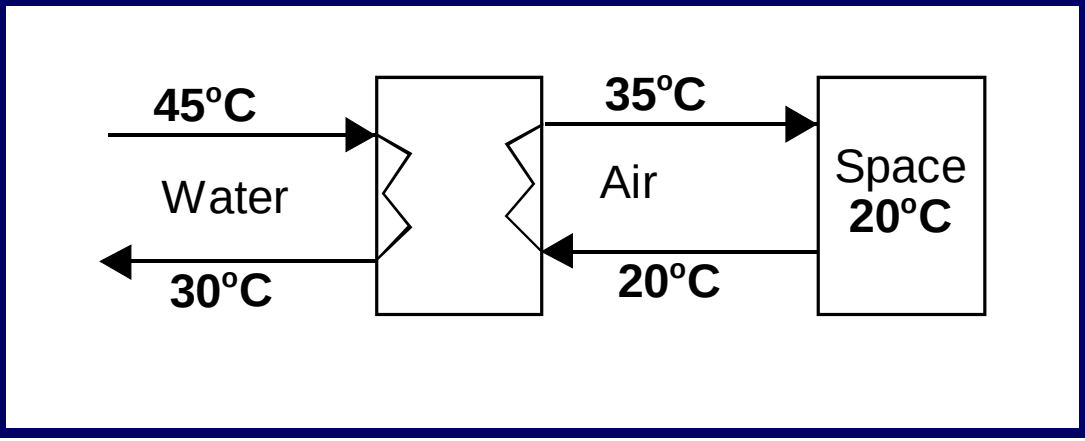


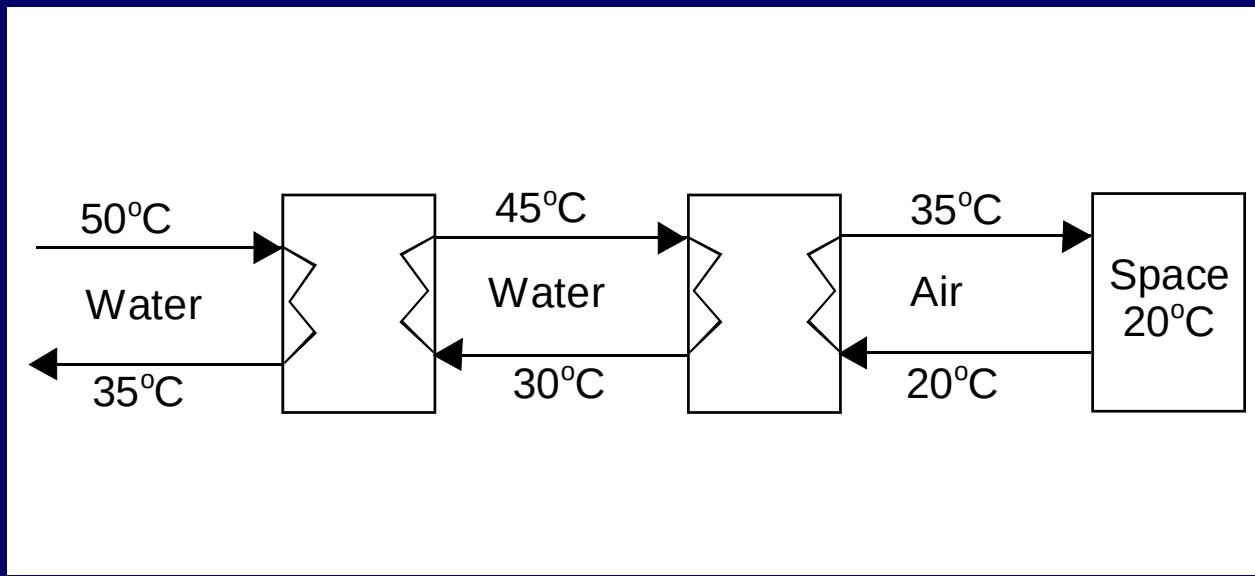

the amazing BLUE LAGOON in ICELAND
a pool with power

Space Conditioning (1)

- Both water-to-water and water-to-air heating systems used
- Space heating – need 20^{o}C room temperature
- Normally need >45 to 50^{o}C geothermal temperature

Temperature Requirements Space Heating





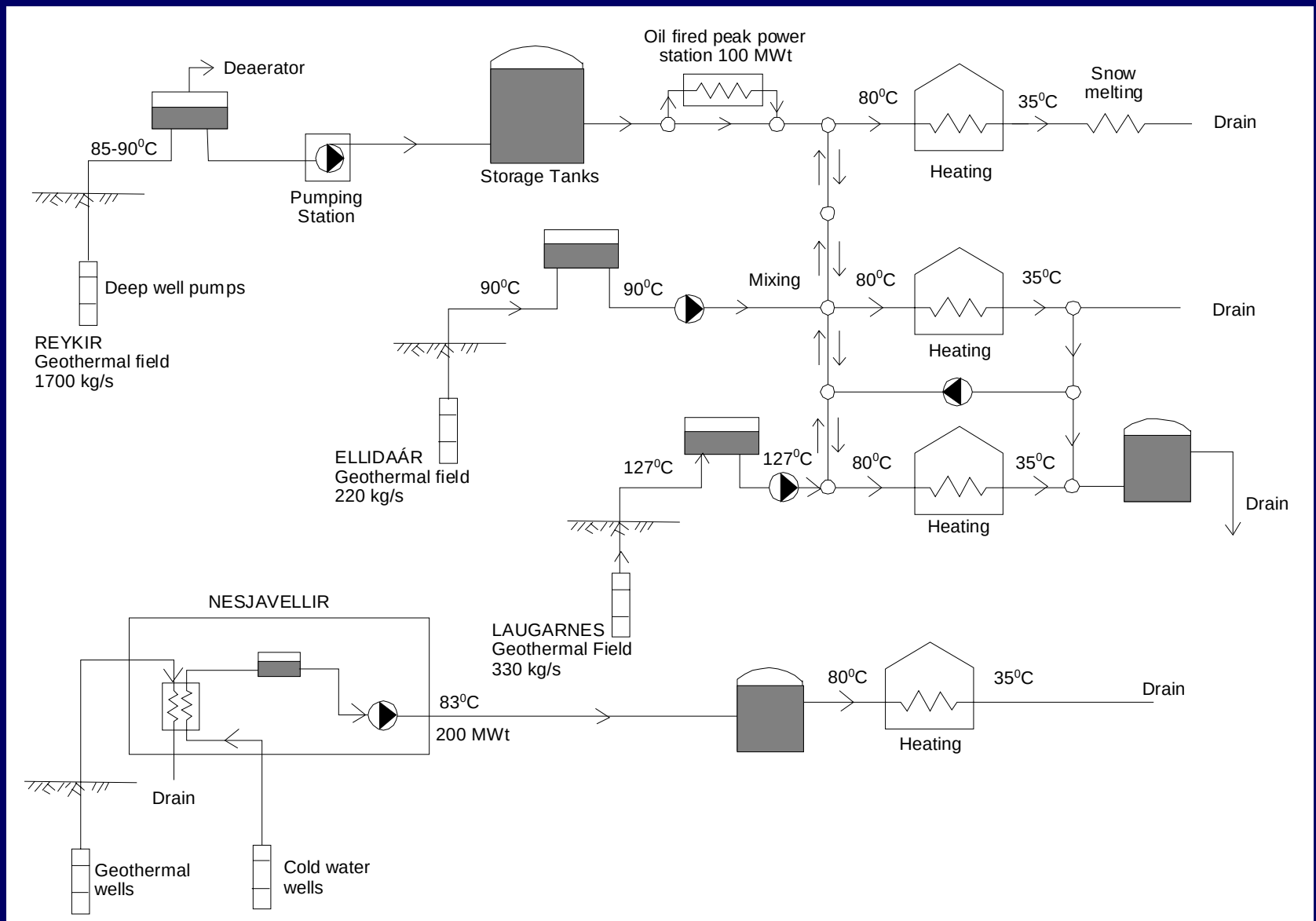
Space Conditioning (2)

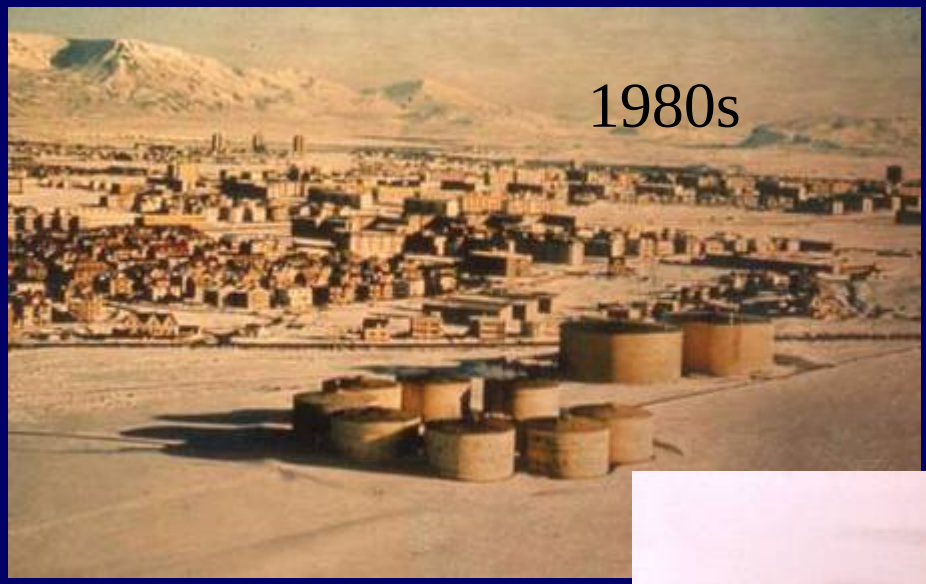
- District heating in at least 12 countries
- Piping system
  - Single pipe – once through system – disposal
    - Environmental problems
  - Two pipe – recirculation – residual heat conserved
    - 20 to 30% more expensive

District Heating – Example

Reykjavik, Iceland

- **Started 1930**
- **190,000 people**
- **89^{o} to 125^{o}C water – supplied at 80^{o}C**
- **Adequate to –26^{o}C**
- **830 MWt**
- **62 wells**
- **Large storage tanks for peaking**
- **Oil fired booster station**


Oil fired peak power station 100 MWt
Deaerator
85-90^{0}C
Pumping Station
Storage Tanks
80^{0}C
35^{0}C
Snow melting
Drain
Heating
Deep well pumps
REYKIR
Geothermal field
1700 kg/s
90^{0}C
90^{0}C
Mixing
80^{0}C
35^{0}C
Drain
Heating
ELLIDAÁR
Geothermal field
220 kg/s
127^{0}C
127^{0}C
80^{0}C
35^{0}C
Drain
Heating
NESJAVELLIR
LAUGARNES
Geothermal Field
330 kg/s
83^{0}C
200 MWt
80^{0}C
35^{0}C
Drain
Heating
Drain
Geothermal wells
Cold water wells


1980s


Today


1930s

Suwa, Japan

Agribusiness Applications (1)

- Greenhouse heating (flowers, vegetables, tree seedlings)
  - Up to 35% savings due to heating costs
- Animal pen heating and cleaning
- Soil warming
- Crop irrigation
- Mushroom raising
- Soil and mulch sterilization
- Aquaculture
  - 50% increase in growth rate
  - Catfish, shrimp, tilapia, eels, tropical fish

Agribusiness Applications (2)

- Must consider heavy metals, fluorides, chlorides, arsenic and boron in fluid
- Can produce CO_2 for greenhouses to improve growth
  - Iceland, New Zealand
- Low geothermal temperature needed - >40^{o}C

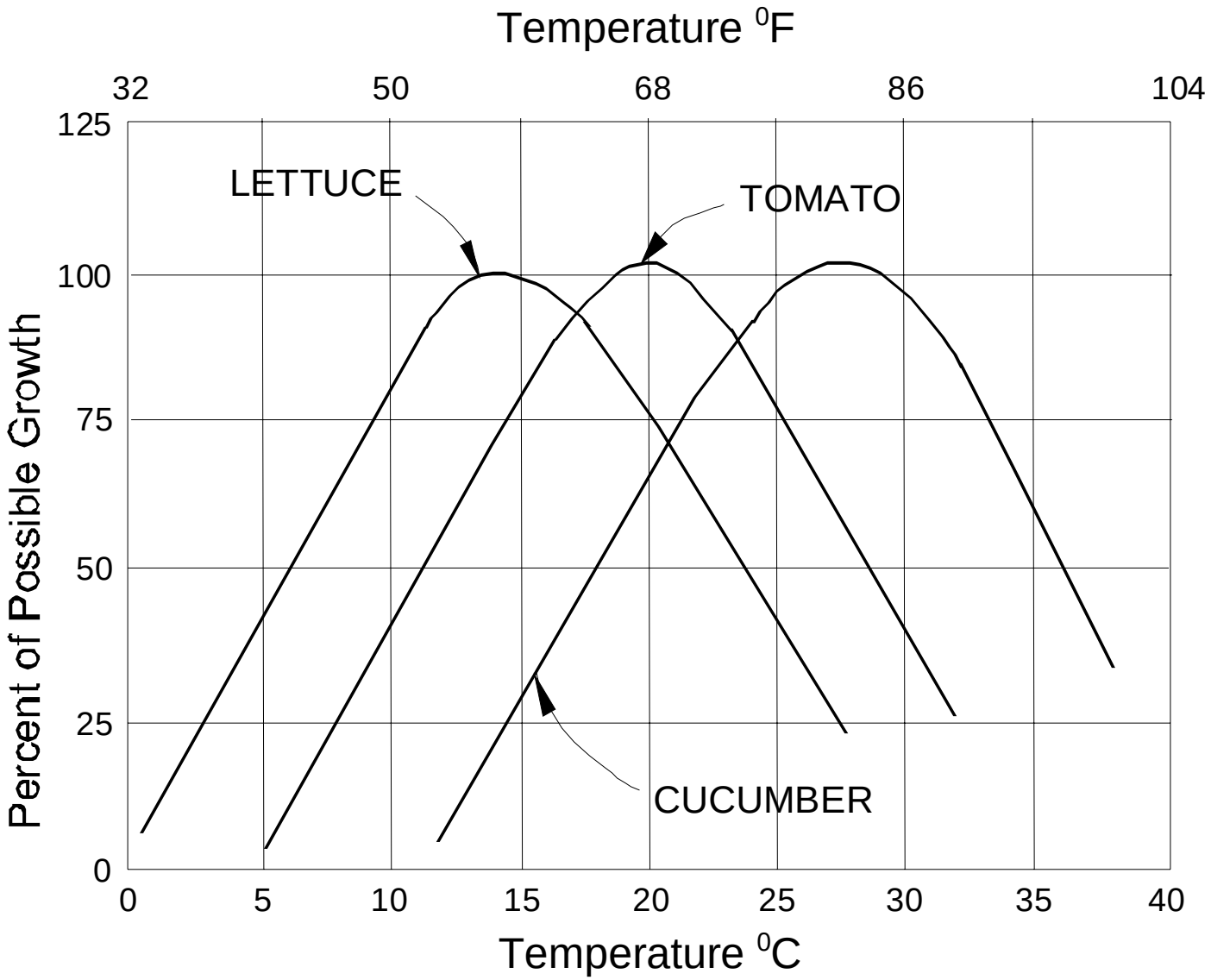
Tianjin, China

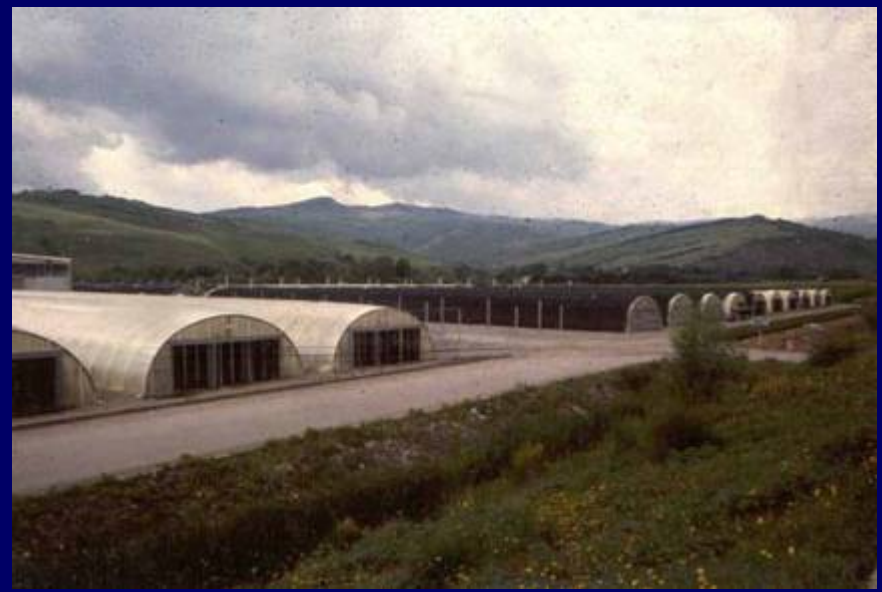
Peking Duck

59°C
geo.

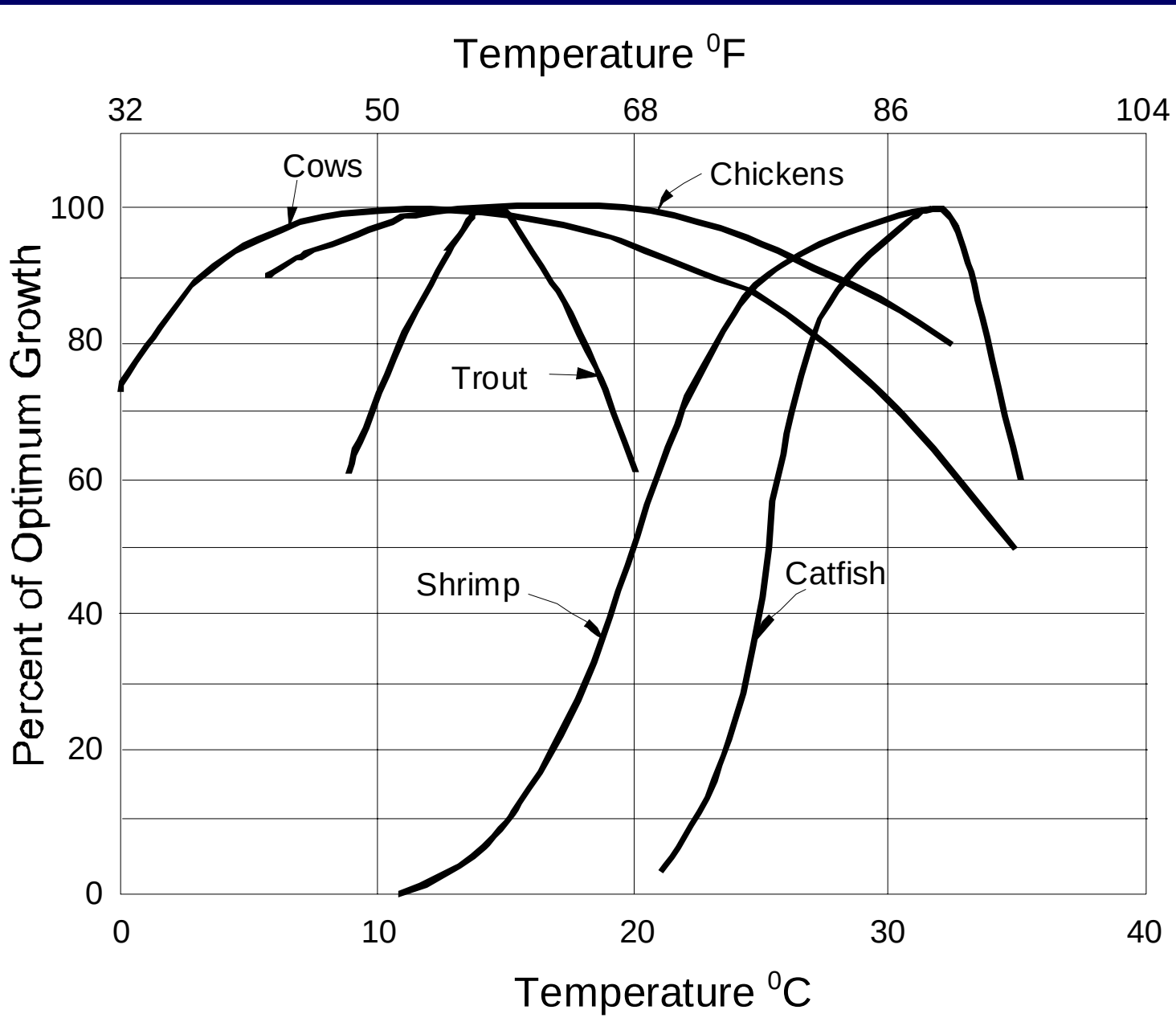
14 kg/h
4 t/yr
dried

Tomato drying - Greece


Temperature ^{0}F
32
50
68
86
104
125
100
75
50
25
0
Percent of Possible Growth
LETTUCE
TOMATO
CUCUMBER
0
5
10
15
20
25
30
35
40
Temperature ^{0}C

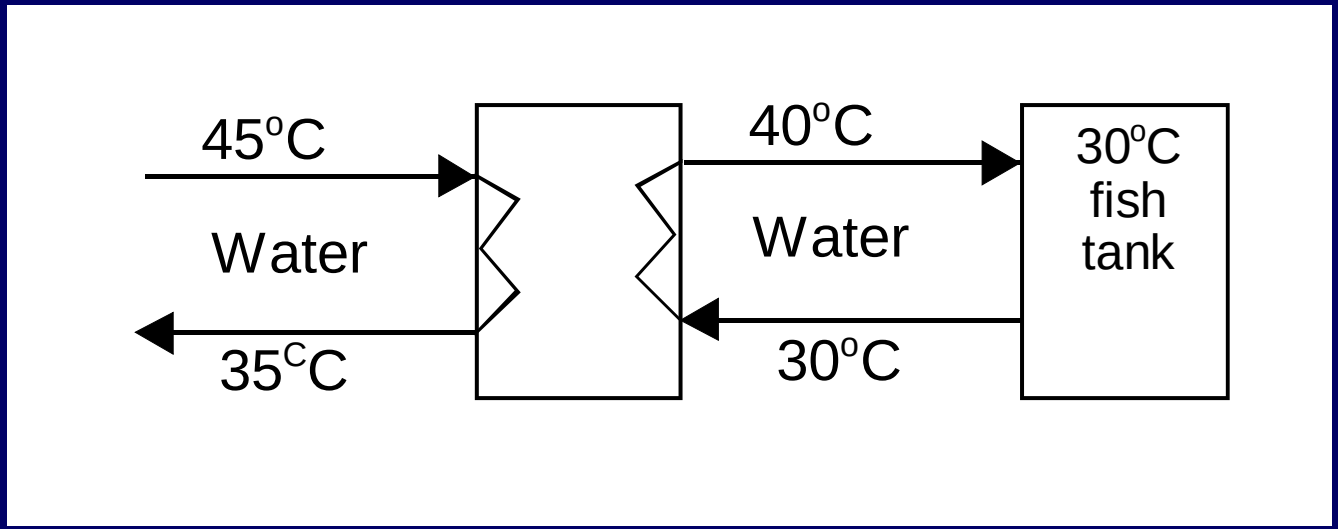


Greenhouse in Greece


Temperature ^{0}F
32
50
68
86
104
Cows
Chickens
Trout
Shrimp
Catfish
Percent of Optimum Growth
100
80
60
40
20
0
0
10
20
30
40
Temperature ^{0}C

Aquaculture examples

Aquaculture Pond Heating Temperature Requirements

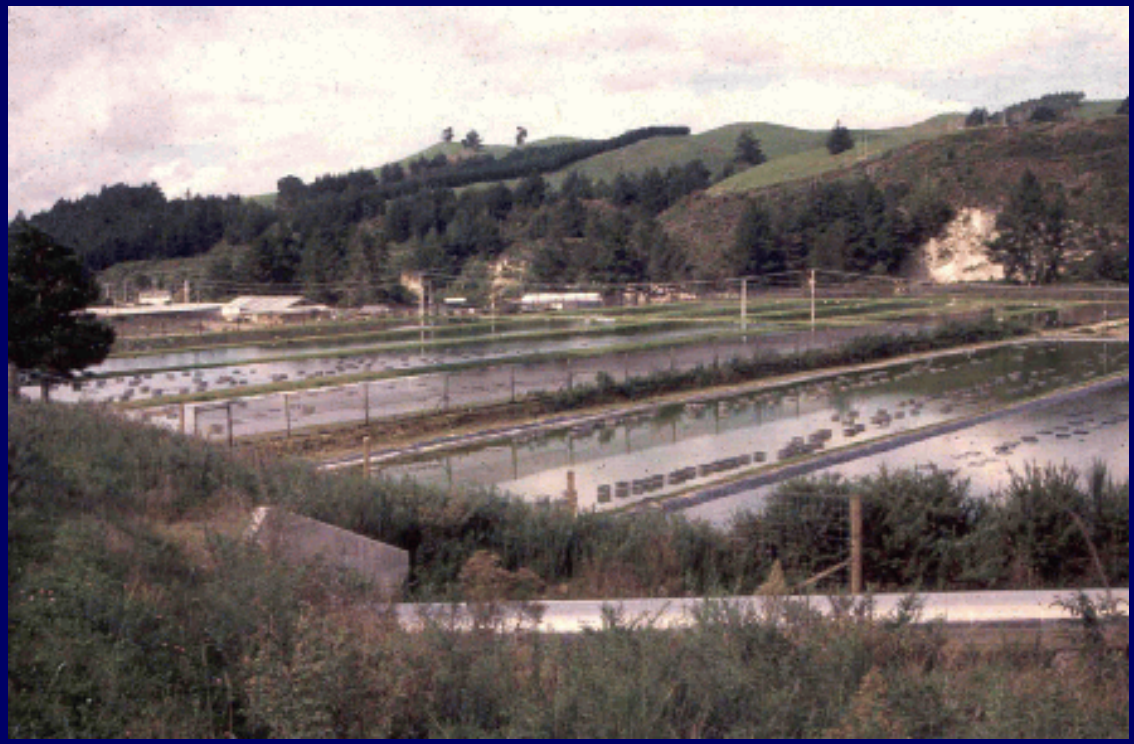


Geothermal resource 10 to 15°C above pond or tank temperature

Aquaculture – Example

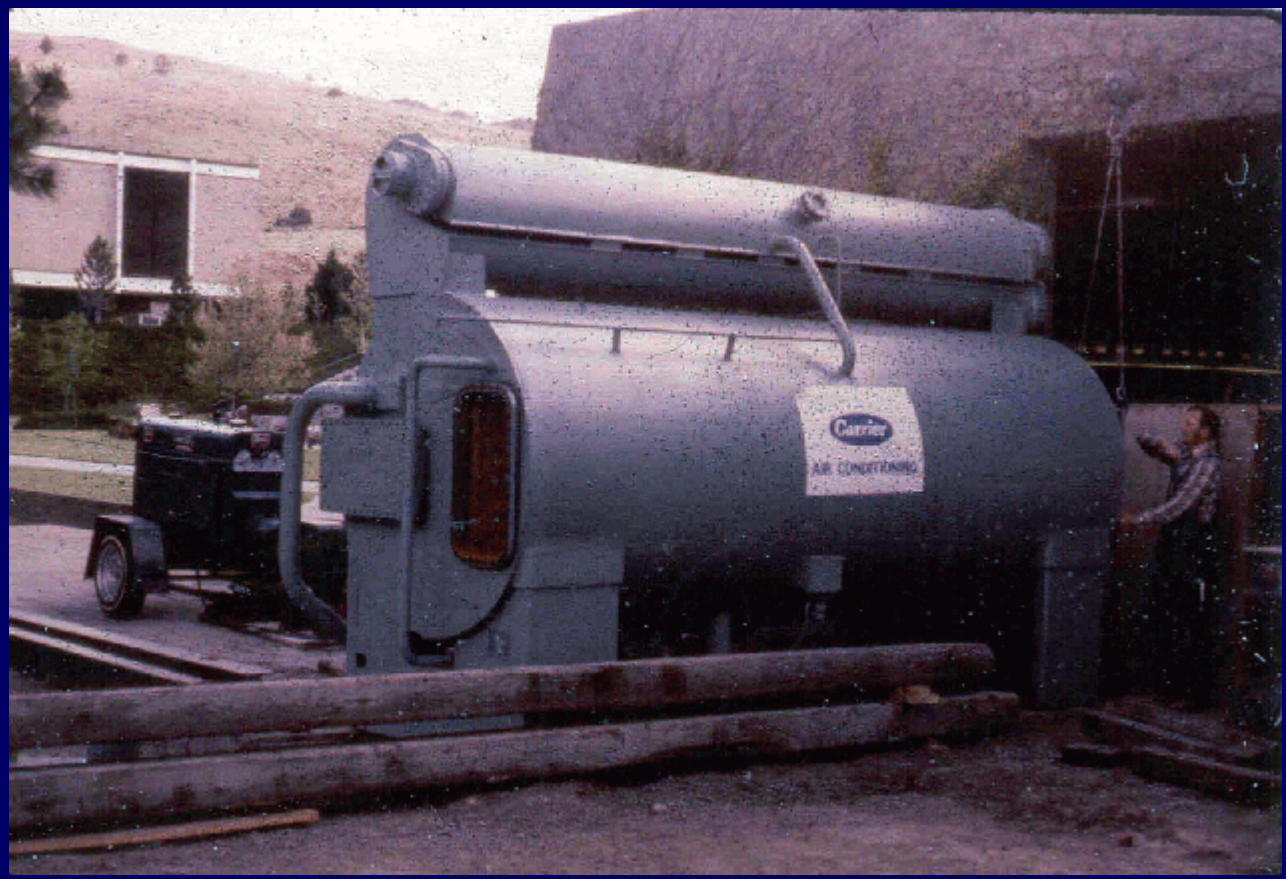
Wairakei, New Zealand – freshwater prawns

- 19 ponds – 0.2 to .35 ha – 1.0 to 1.2 m deep
- 24^{o}C – effluent from power plant
- Produces 30 tonnes/yr
- Harvested after 9 months at 30 to 40/kg
- Sold for US$37/kg wholesale and US$60/kg retail
- 90% sold to restaurant on the property
- 25,000 tourists/yr



Refrigeration

- **Lithium bromide system (most common – uses water as the refrigerant)**
  - **Supplies chilled water for space and process cooling – above the freezing point**
  - **The higher temperature, the more efficient (can use geothermal fluids below 100°C – however, >115°C better for 100% efficiency)**
- **Ammonia absorption used for refrigeration below freezing normally large capacity and require geothermal temperatures above 120°C**



Oregon Institute of Technology – chiller

89°C producing 7°C chilled water @ 38 l/s

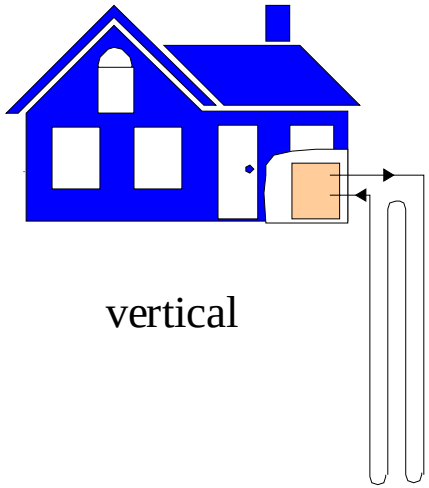
1 MWt installed – 500 kW net

Heat Pumps (1)

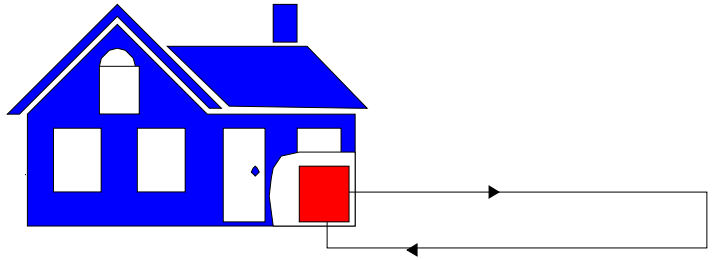
- Used for both heating and cooling
- Heated capacity of 3 kW to 1,500 kW
- 27 countries
- >1.,500,000 units installed world-wide
- Growing at the rate 20 to 30%/year
- COP of 4 (75% savings in electricity)

Heat Pumps (2)

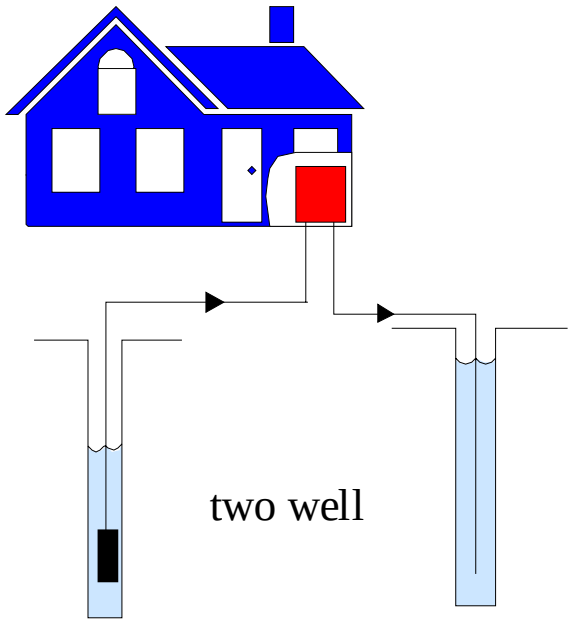
- Ground source and geothermal heat pumps (GSHP or GHP) – uses 5 to 30°C ground temperature
- 50 to 100% more efficient than air source, since uses constant temperature resource
- Ground coupled
  - Horizontal in trenches 1 – 3 m deep
  - Vertical in 10 cm diameter 50 – 60 m deep drillholes
  - Others
- Ground water
  - Using well water



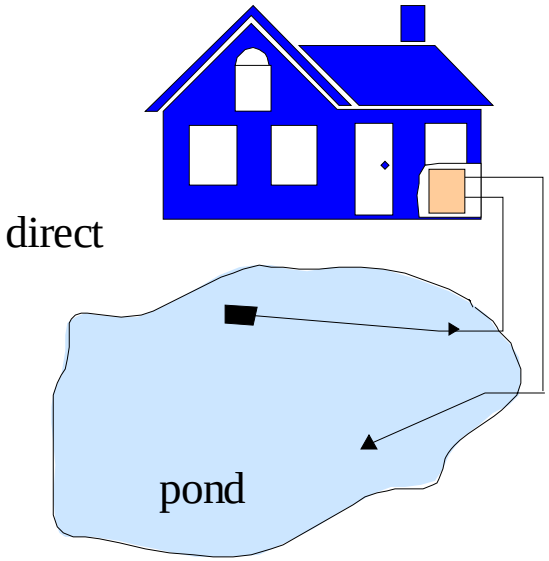
vertical



horizontal



two well

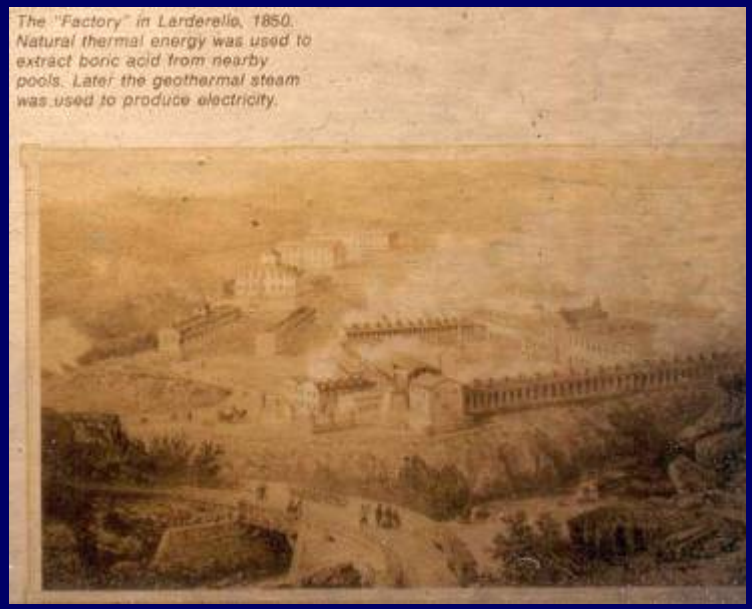


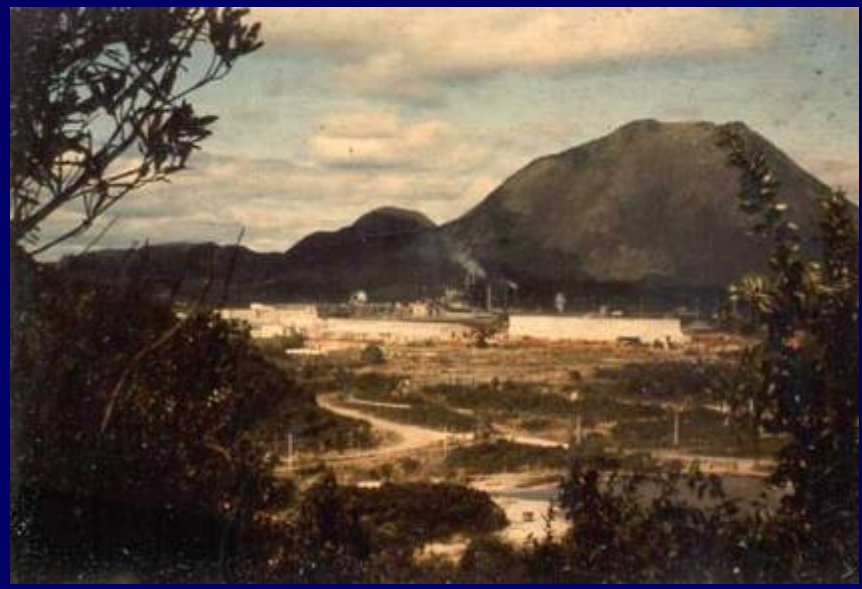
direct

pond

Industrial Applications

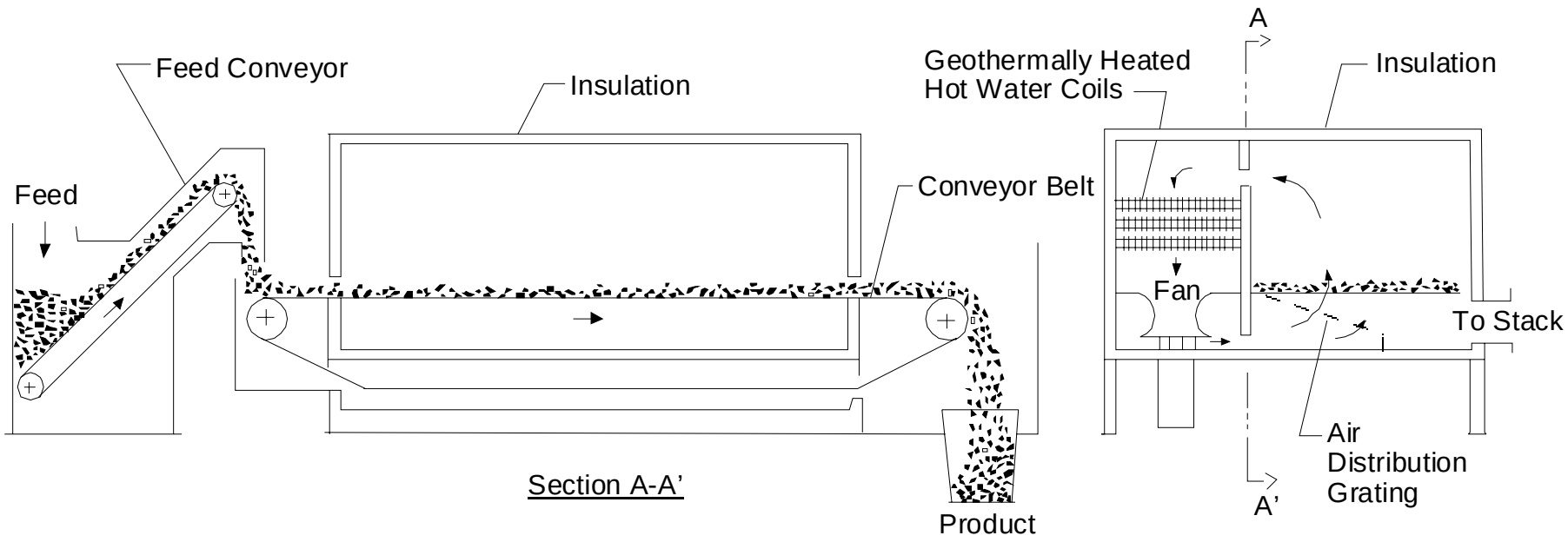
- **Oldest: Larderello, Italy – boric acid and borate compounds processed since 1790**
- **New Zealand: pulp, paper and wood processing at Kawerau**
- **Iceland: diatomaceous earth drying – Myvatn**
- **USA: vegetable dehydration (onion) – and gold extraction (heap leaching) - Nevada**



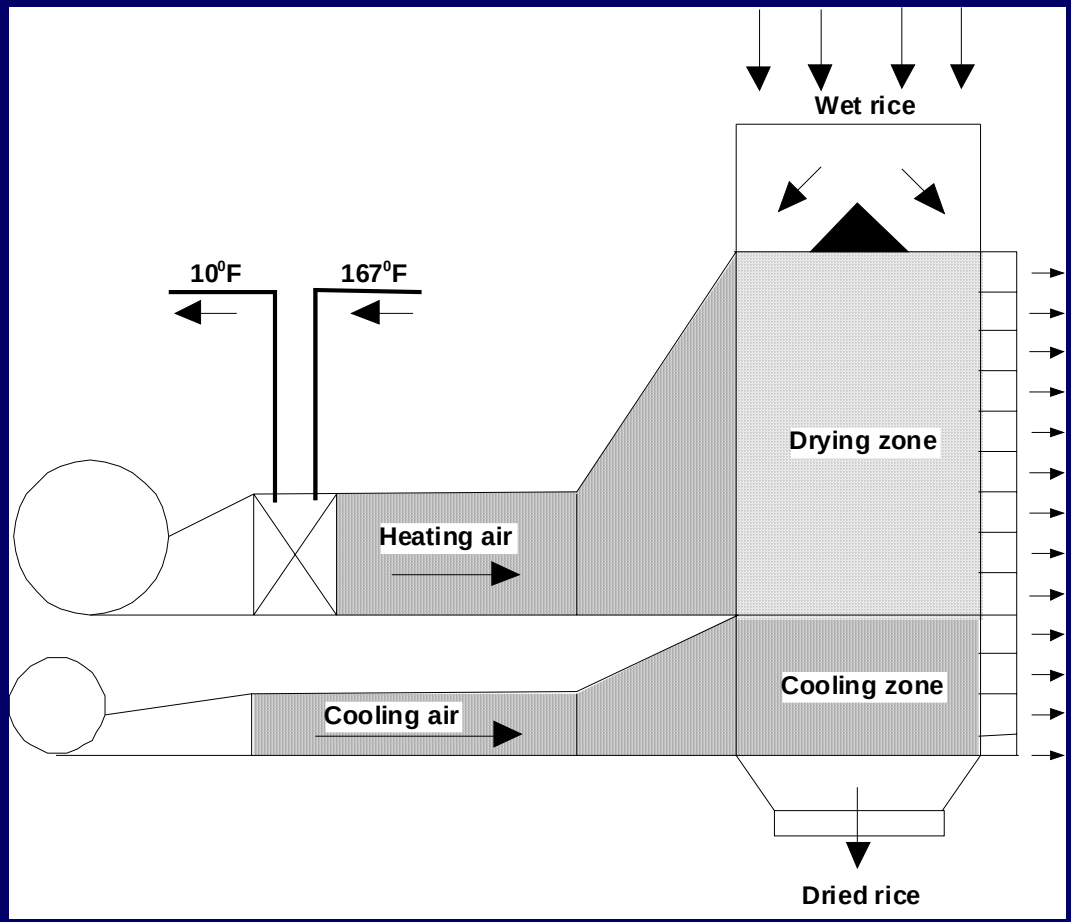


Industrial application examples

More industrial application examples



Food dehydration belt dryer

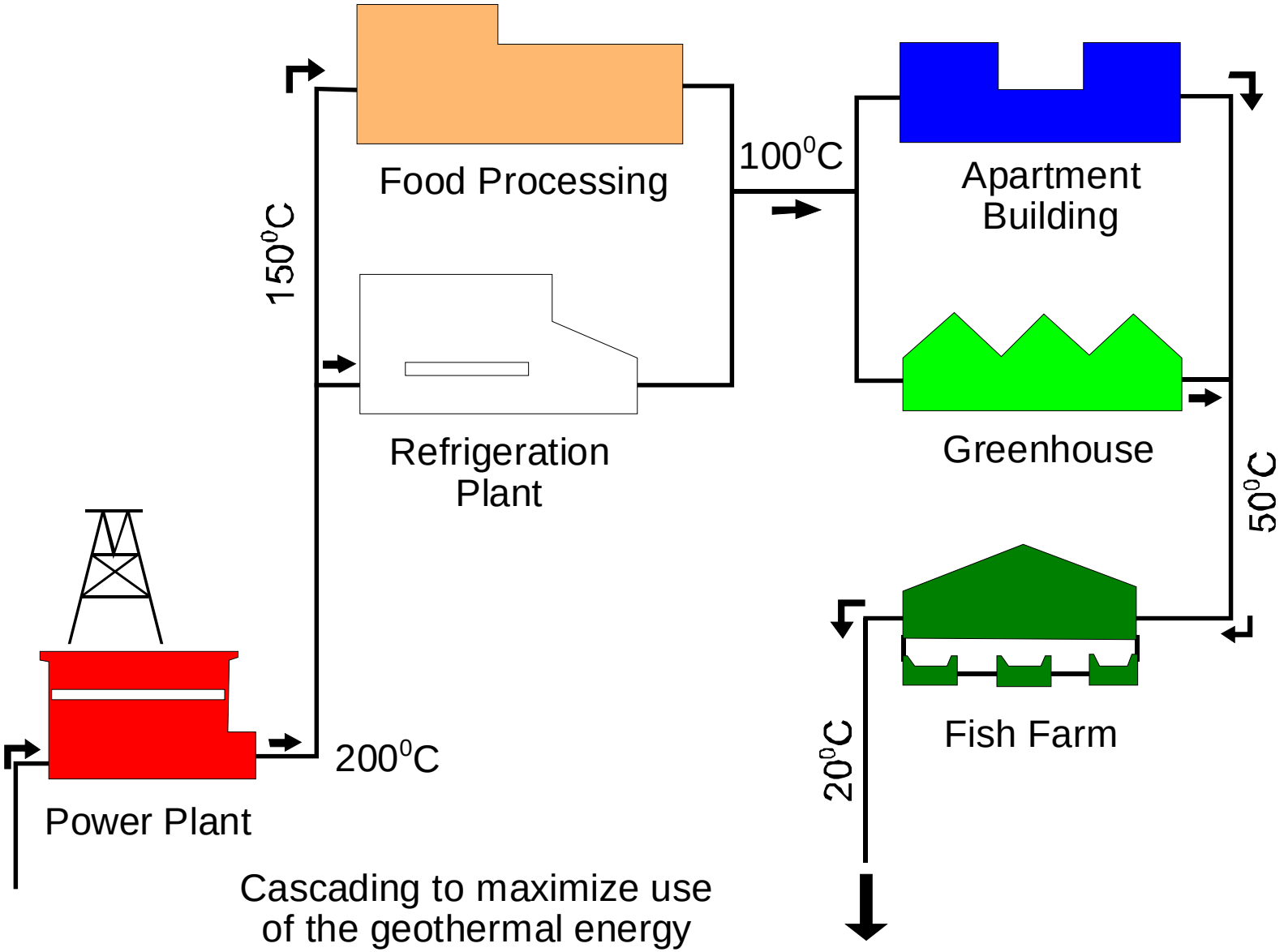


Rice dryer – Macedonia

75ºC resource – 35ºC air – 10 t/h – 1,360 kWt

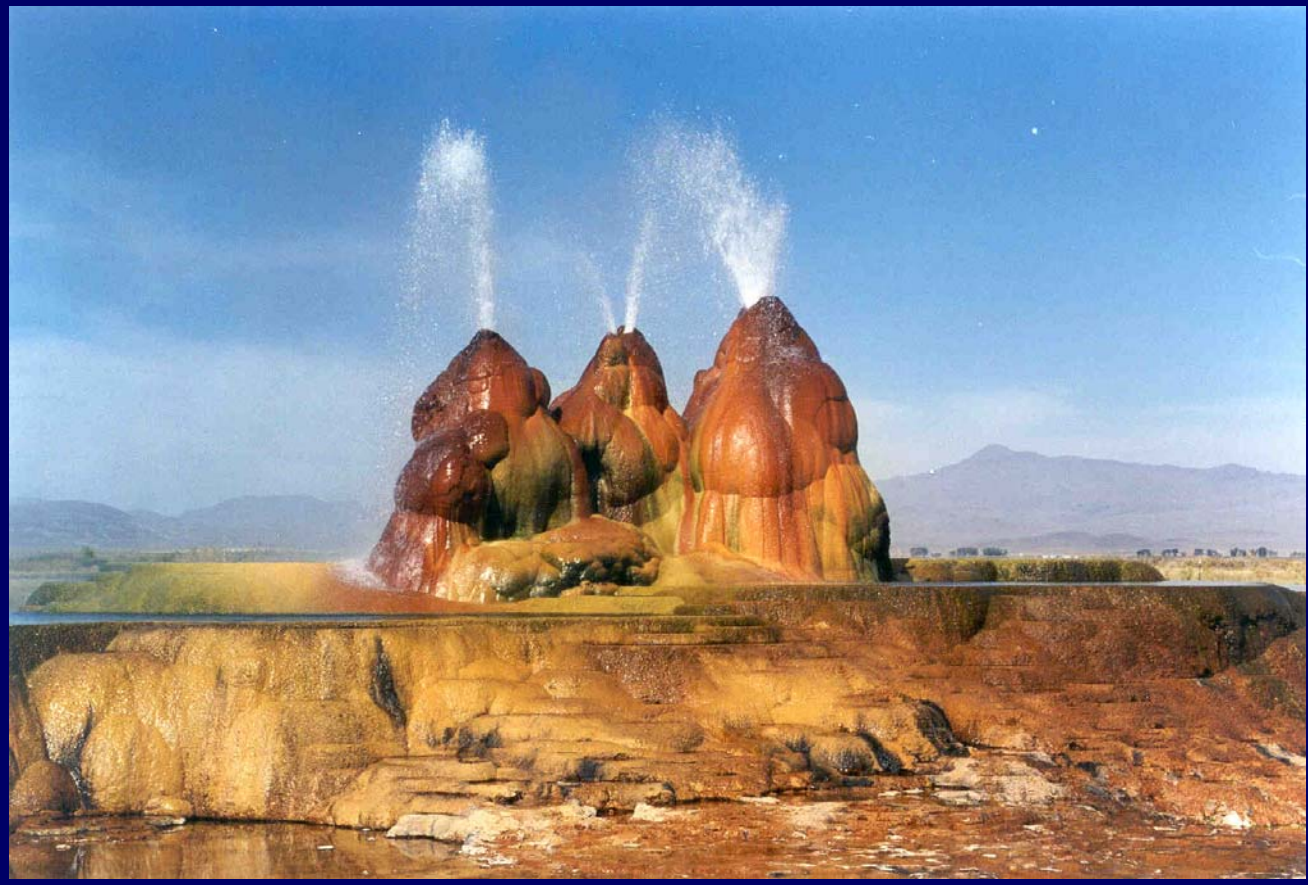
NEW TRENDS

- **COMBINED HEAT AND POWER PLANTS**
  - **Low temperature resources used for binary power production and cascaded for direct use**
  - **Temperatures as low as 98^{o}C are being used**
  - **Makes efficient use of the resources**
  - **Improves economics**
  - **Increases employment**


Food Processing
100^{0}C
Apartment Building
150^{0}C
Refrigeration Plant
Greenhouse
50^{0}C
Fish Farm
20^{0}C
200^{0}C
Power Plant
Cascading to maximize use of the geothermal energy

Future Developments

- **Collocated resources and use**
  - **Within 8 km apart**
- **Sites with high heat and cooling load density**
  - **>37 MWt/km^2**
- **Food and grain dehydration**
  - **Especially in tropical areas where spoilage is common**
- **Greenhouses in colder climates**
- **Aquaculture – to optimize growth**
- **Ground coupled and groundwater heat pumps – for both heating and cooling**
- **Combined heat and power projects - cascading**



Thank You