DIRECT HEAT UTILIZATION OF GEOTHERMAL ENERGY

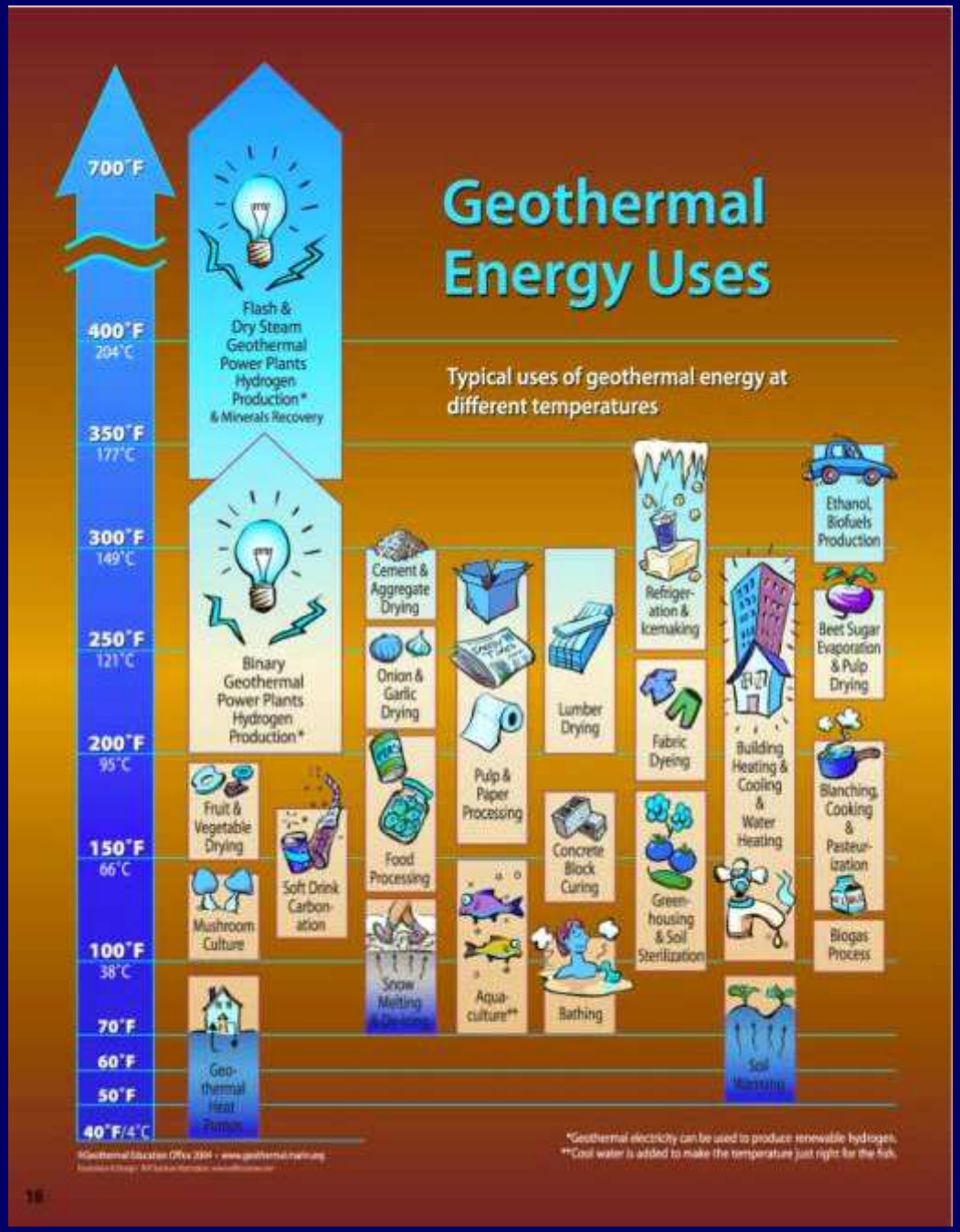
John W. Lund

Director

Geo-Heat Center

Oregon Institute of Technology

Klamath Falls, Oregon, USA


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*
Fruit & Vegetable Drying
Soft Drink Carbon-ation
Mushroom Culture
Geo-thermal Heat Pumps
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.

World Wide Direct Utilization (1)

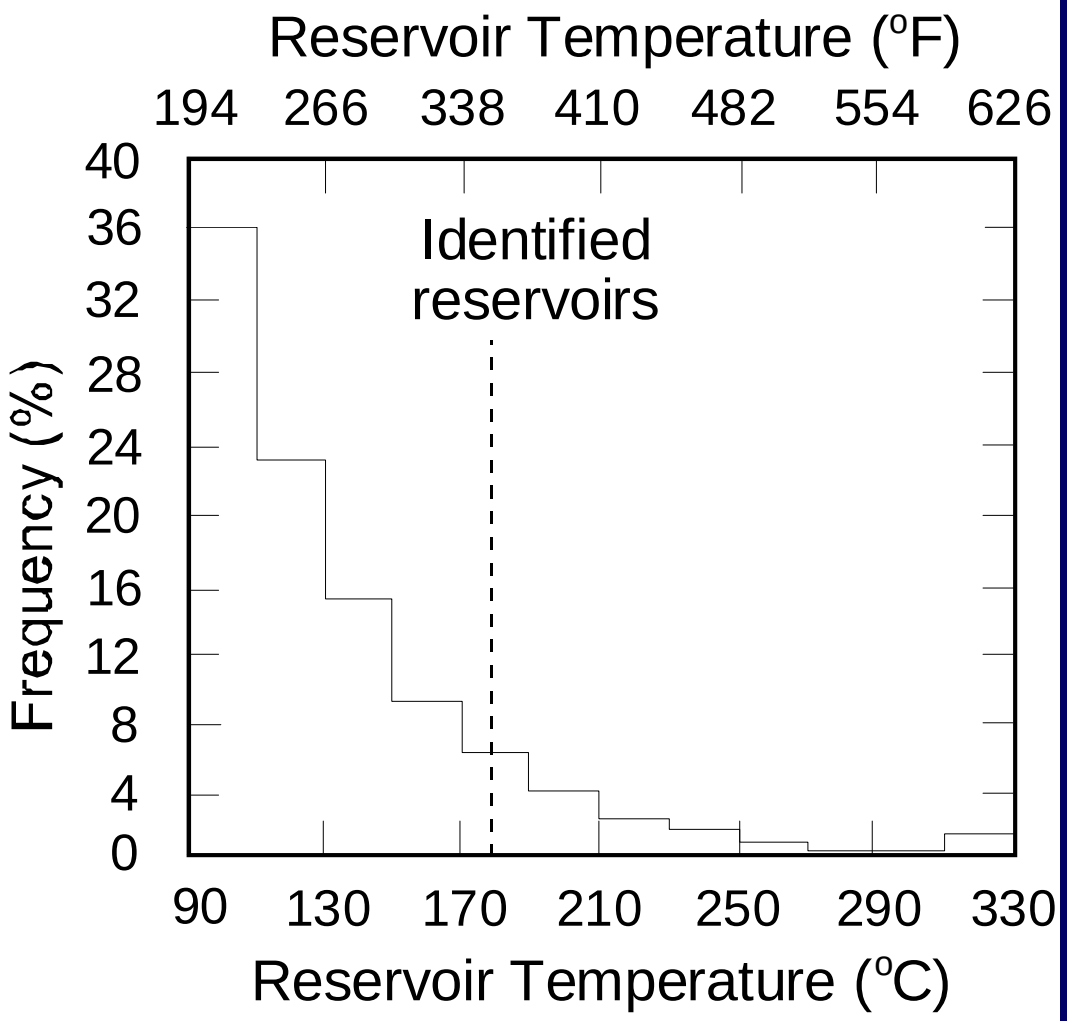
World Wide

- 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

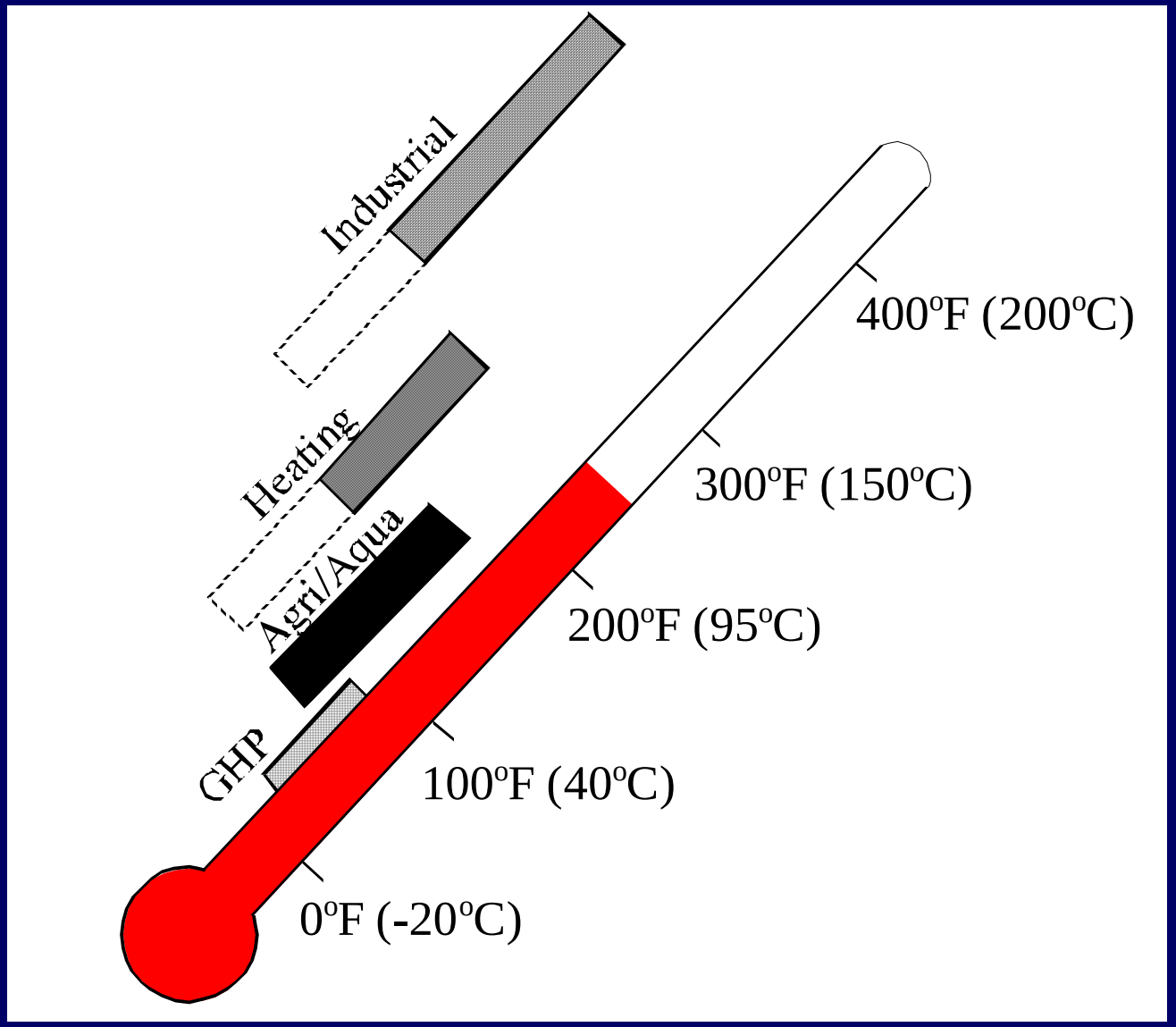
What is Direct-Use: Heating and Cooling

- 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



Temperature use for direct use applications

Advantages of Direct-Use of Geothermal Energy

- Can use low- to intermediate temperature resources (<150^{o}C)
- 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

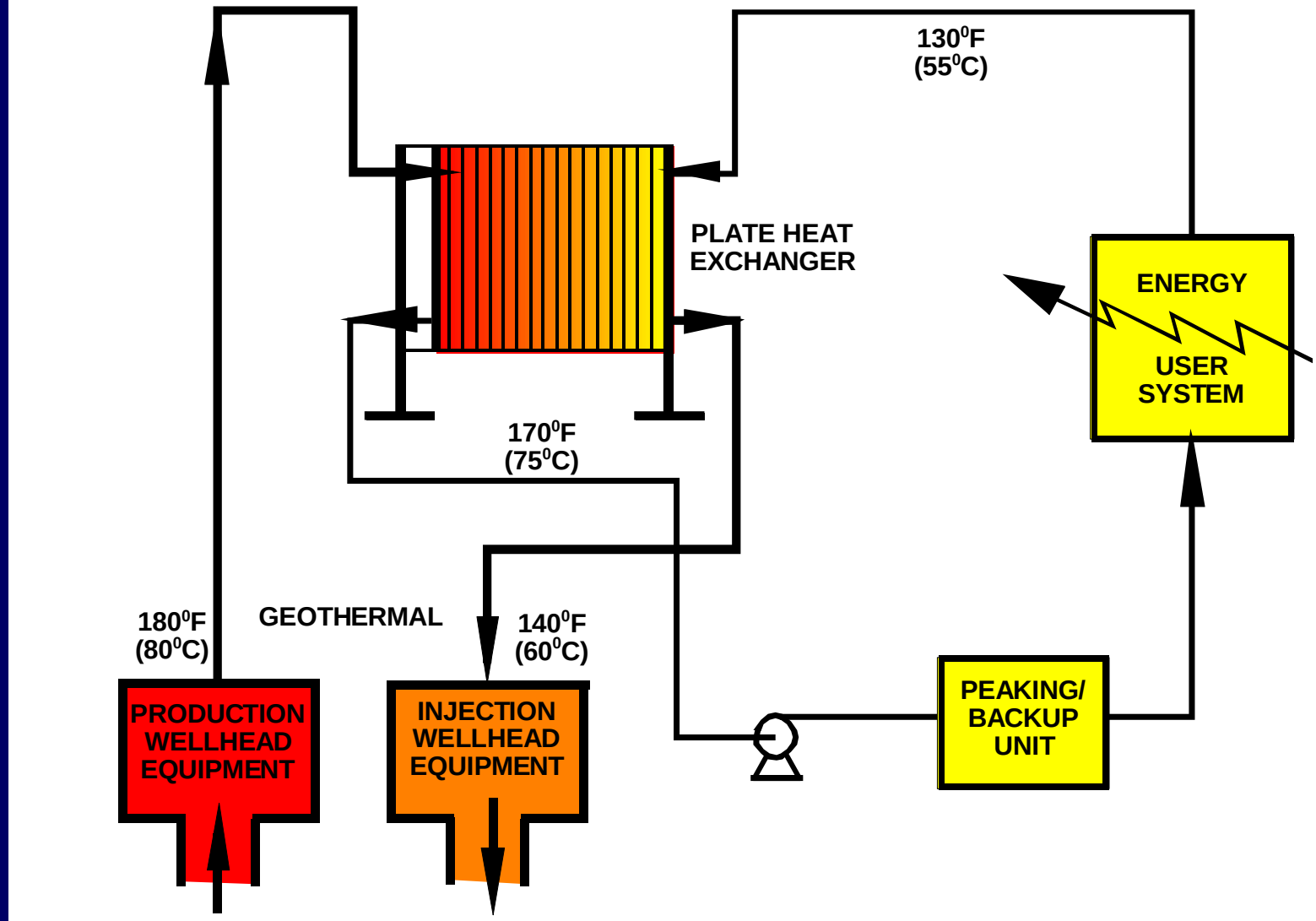
Equipment (1)

- 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:

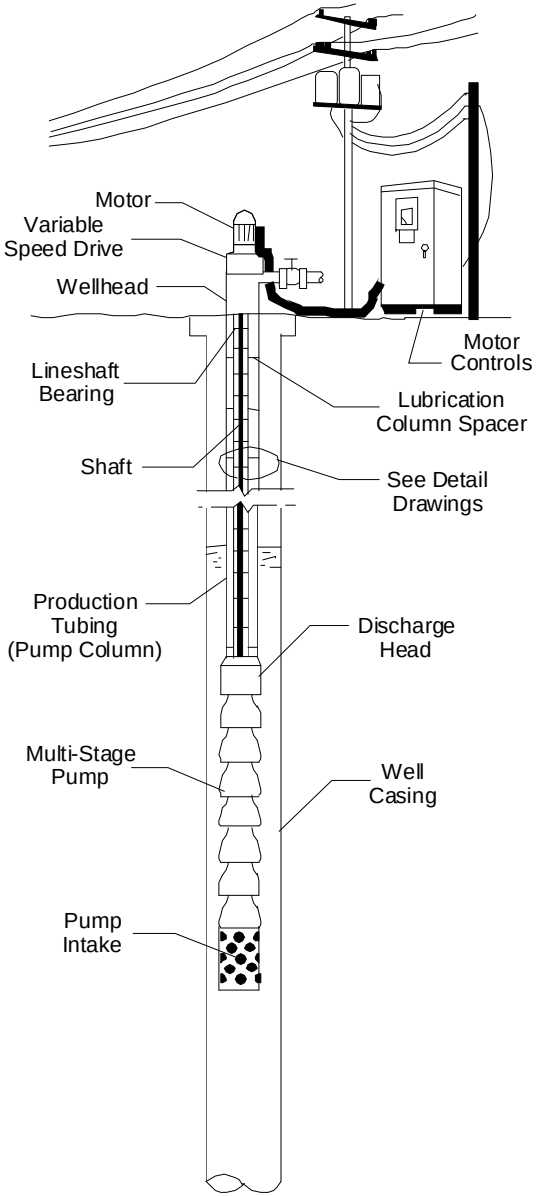
- Downhole and circulation pumps
- Heat exchangers
- Transmission and distribution pipelines
- Heat extraction equipment
- Peaking or back-up plants
- Fluid disposal system

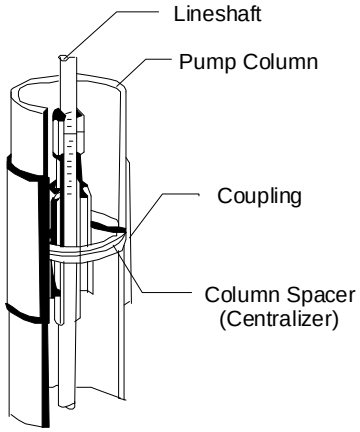

130⁰F
(55⁰C)
PLATE HEAT
EXCHANGER
ENERGY
USER
SYSTEM
170⁰F
(75⁰C)
180⁰F
(80⁰C)
GEOTHERMAL
140⁰F
(60⁰C)
PRODUCTION
WELLHEAD
EQUIPMENT
INJECTION
WELLHEAD
EQUIPMENT
PEAKING/
BACKUP
UNIT

Wells Pumps

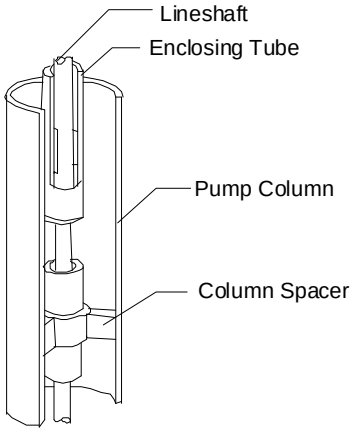
Two types used:

- 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)

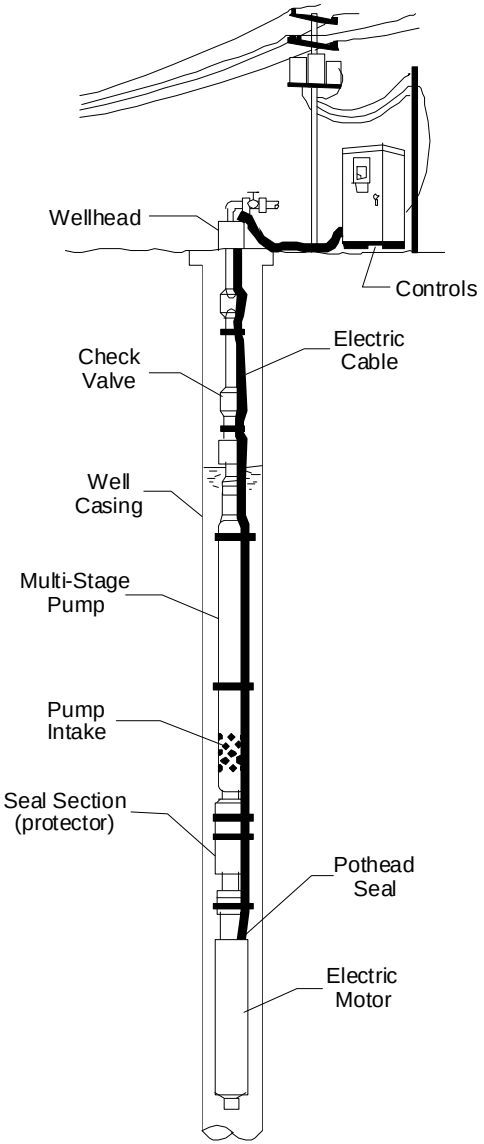




Open Lineshaft Bearing Lubrication



Enclosed Lineshaft Bearing Lubrication



Heat Exchangers

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

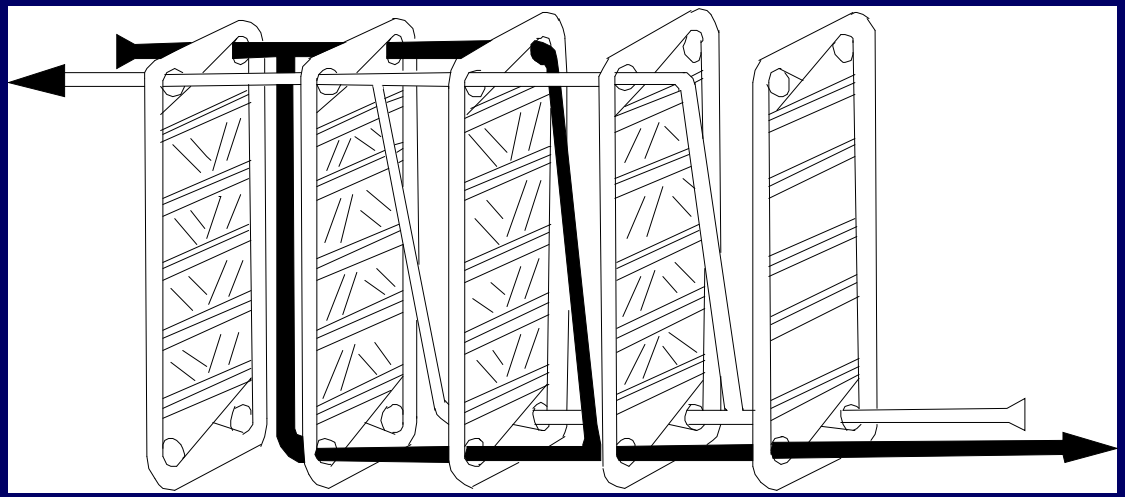
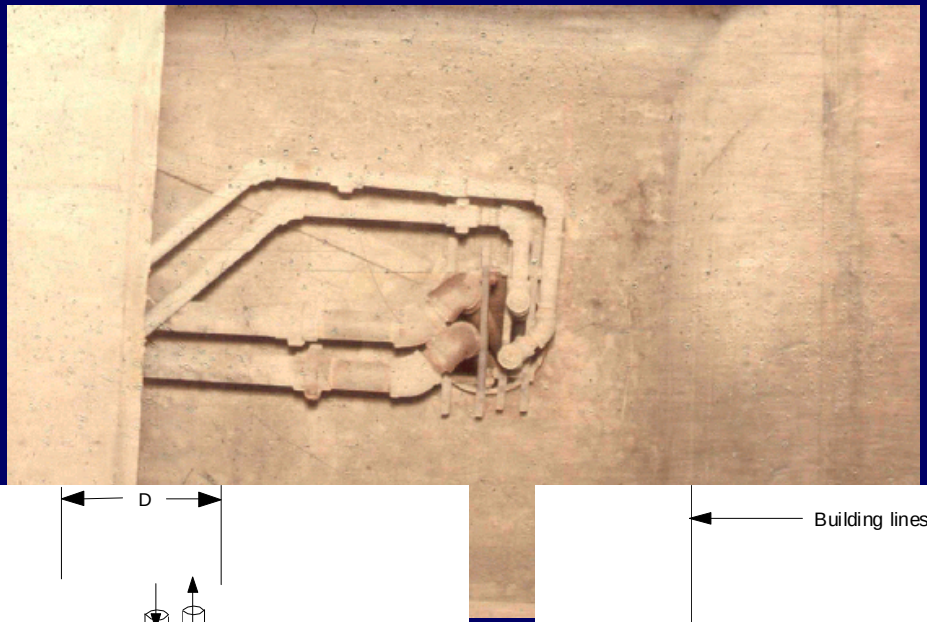
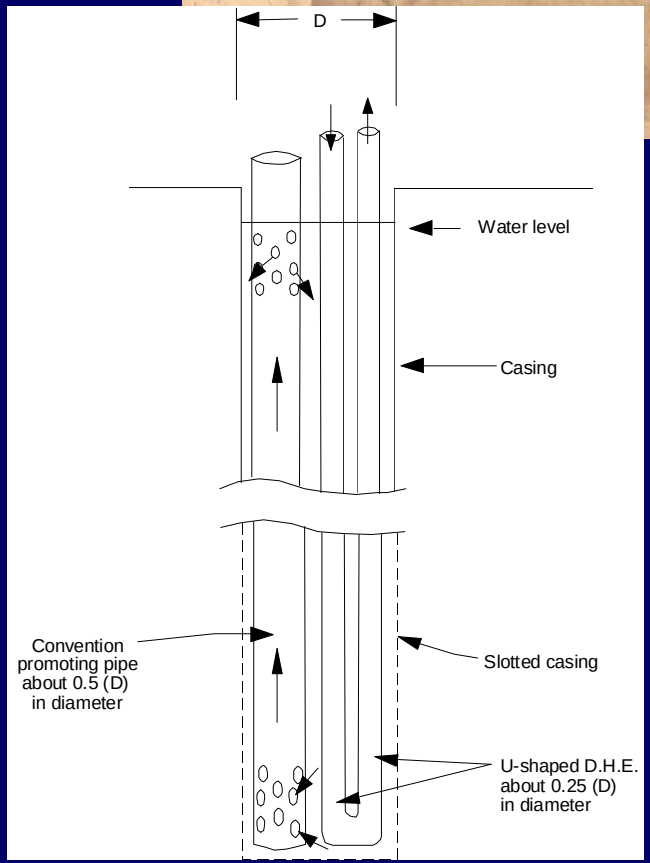
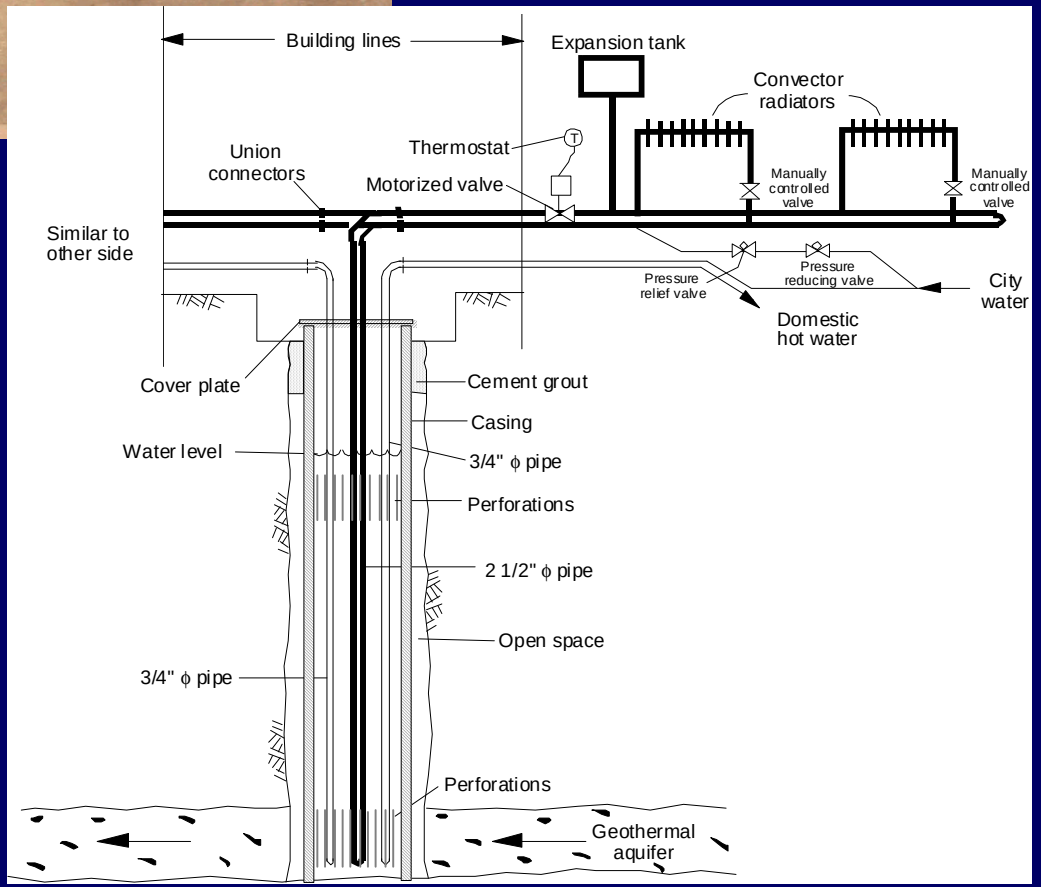


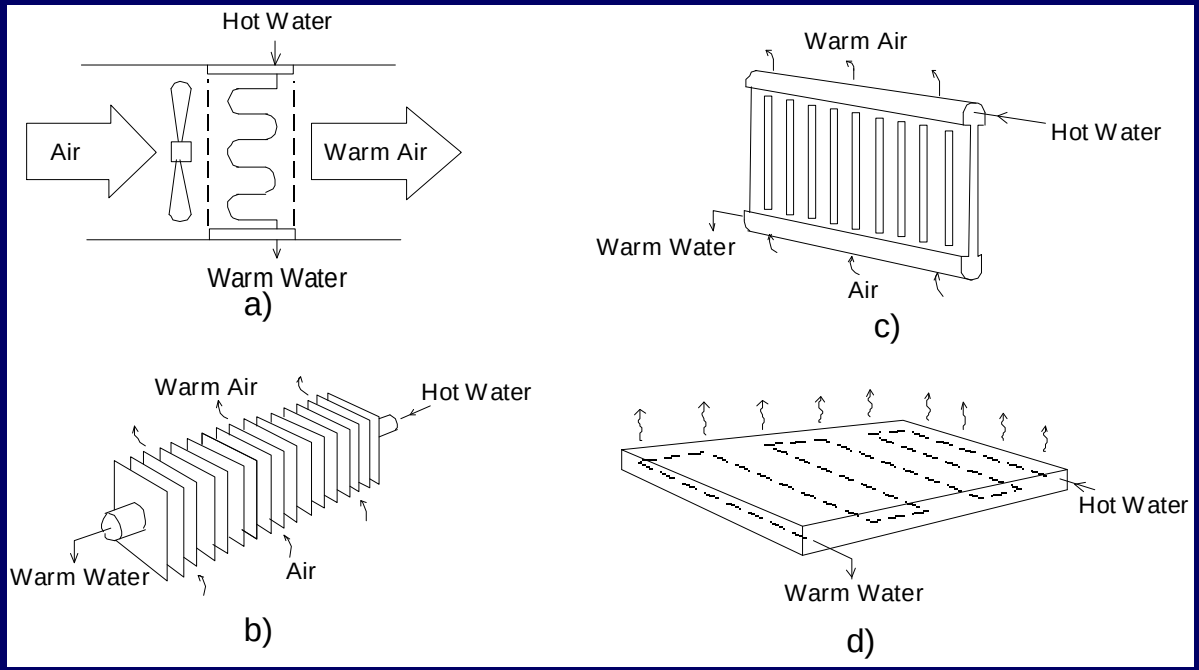
Plate heat exchanger

Downhole heat exchanger








Hot Water
Air
Warm Air
Warm Water
a)
Warm Air
Hot Water
Warm Water
Air
c)
Warm Air
Hot Water
Warm Water
Air
b)
Hot Water
Warm Water
d)

Piping (1)

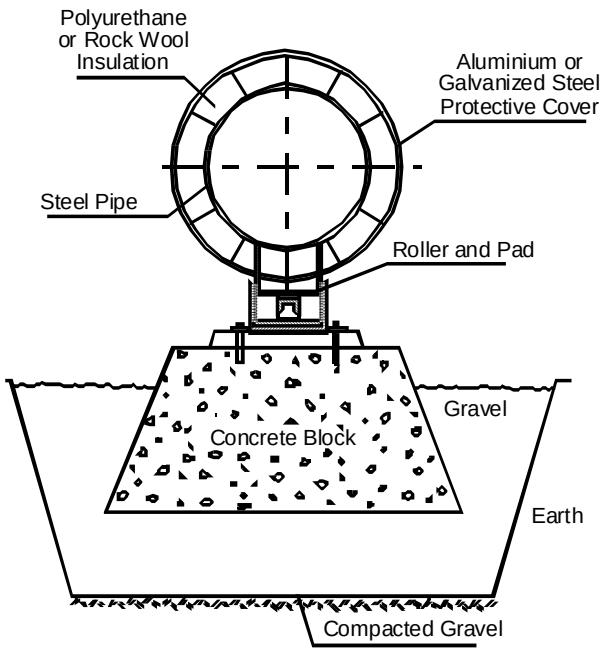
Location

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

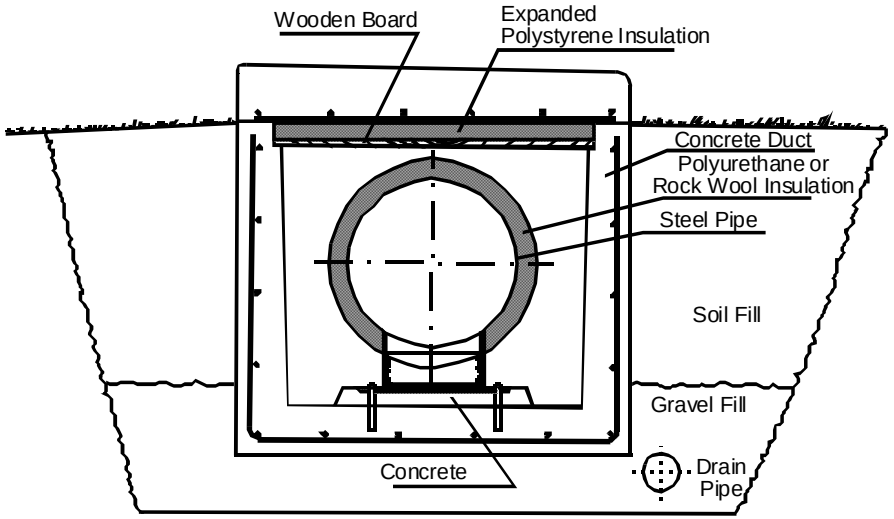
Piping (2)

Material

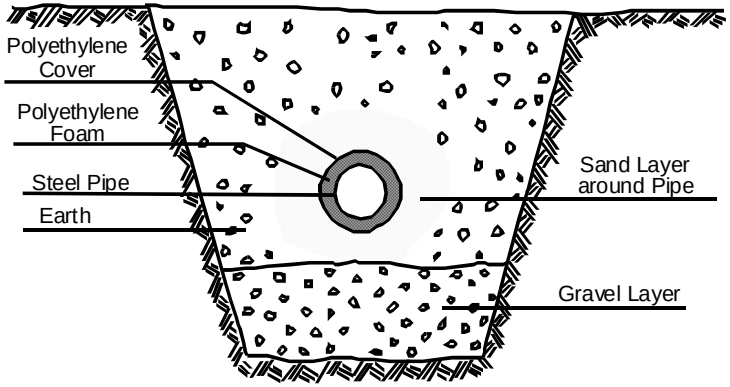
- Carbon steel >100^{o}C
  - Expansion loops or bellows
- FRP or PVC <100^{o}C – Fiberglass reinforced plastic and polyvinylchloride
- AC – Asbestos cement
  - Environmental limitation
  - Longest = Deildartunga – Akranes, Iceland at 62 km
- Cross-linked polyethylene (PEX) good to 90^{o}C and 550 Pa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

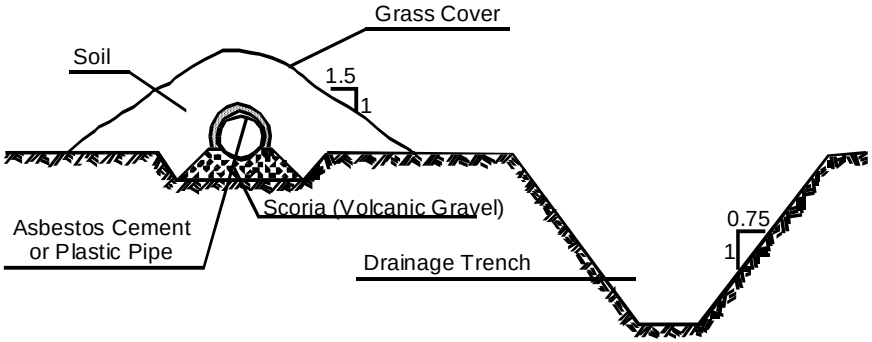
a)


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

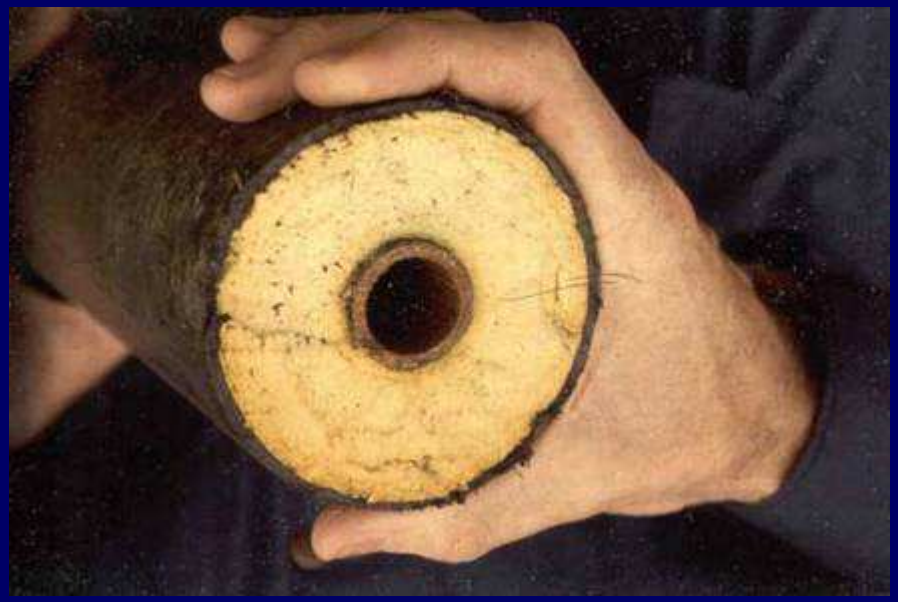
b)


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)



Swimming, Bathing and Balneology (1)

- Main Users (past and present)
  - Romans
  - Chinese
  - Ottomans (Turks)
  - Japanese
  - Central Europeans
  - American Indians (Mexico and USA regions)

Swimming, Bathing and Balneology (2)

- Spa, Belgium
  - Originator of the name
  - Resort town
- Japan
  - 2200 hot springs
  - 100 million guests per year
  - Beppu
    - Most famous hot springs city
- New Zealand – Rotorua
  - WWII – Queen Elizabeth Hospital

Swimming, Bathing and Balneology (3)

- Former Czechoslovakia
  - 1000 years of use (Romans)
  - 60 resorts
  - 460,000 patients/year
- USA – used by Indians for 10,000 years
  - The “Great Spirit”
  - Neutral ground
  - Recuperated from battle
  - Today – 115 major geothermal spas
  - Hot Springs National Park, Arkansas


Collection of George Bolz


the amazing BLUE LAGOON in ICELAND
a pool with power

Glenwood Springs, Colorado

Space Conditioning (1)

- Individual wells for a building or several buildings using pumps or downhole heat exchangers
- Klamath Falls, Oregon
- Reno, Nevada
- Rotorua, New Zealand
- Taupo, New Zealand
- Several Places in Turkey

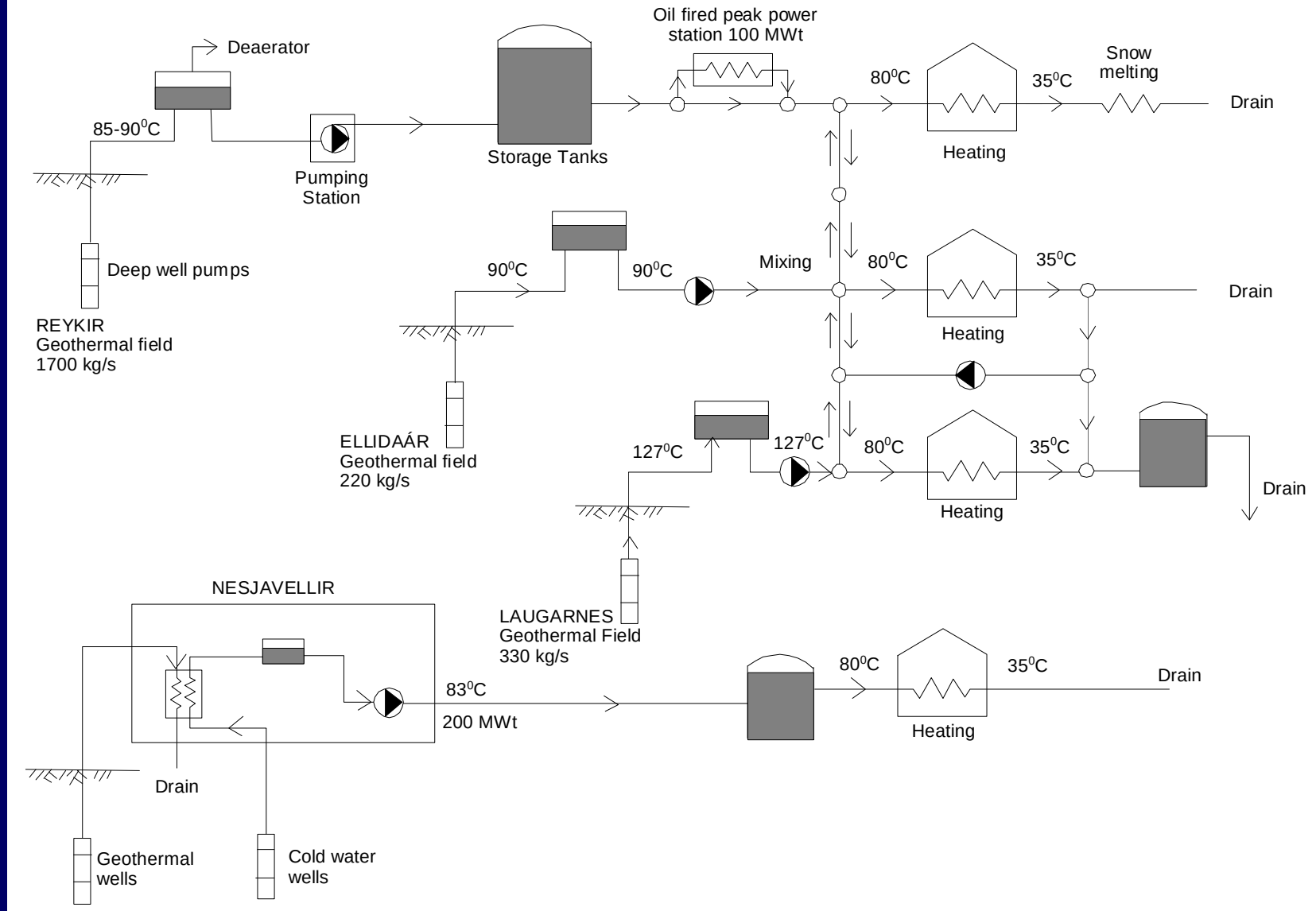
Space Conditioning (2)

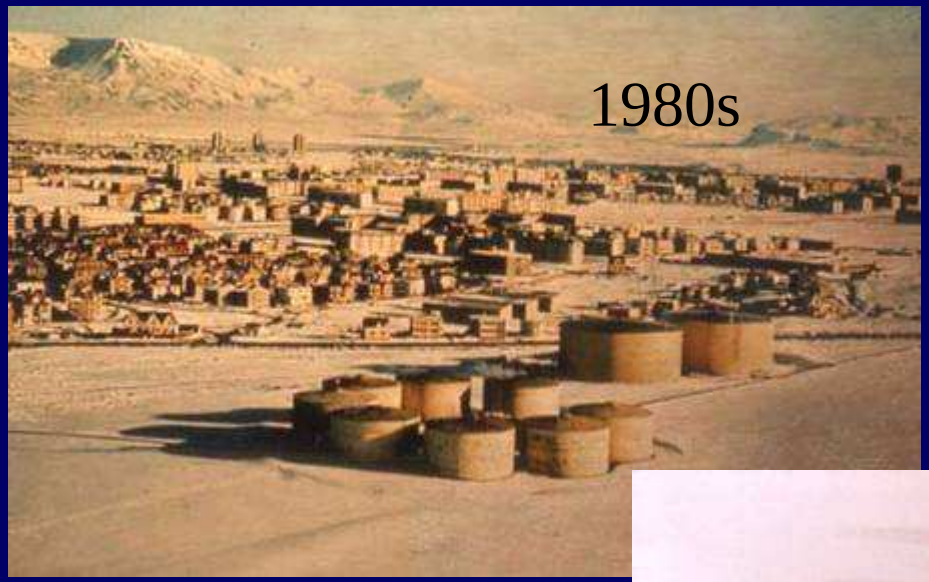
- District heating in at least 12 countries
- Piping system
  - Single pipe – once through system – disposal
    - Environmental problems
  - Two pipe – recirculation – residual heat conserved
    - 20 to 30% more expensive

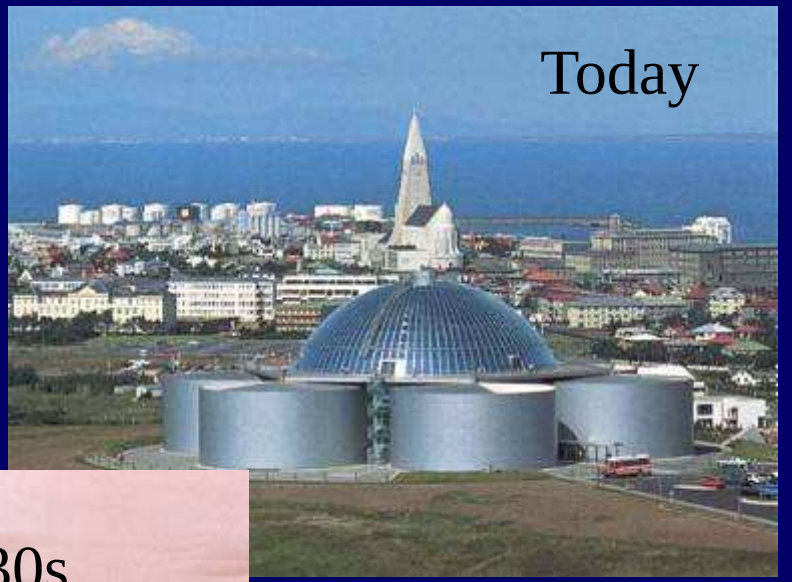
Examples of Geothermal District Heating System

Hitaveita Reykjavikur, Iceland (1930)

- 200,000 people
- 80 million m^3 of fluid/year – 91 wells
- 60,000 homes (58 $X10^6$ m^3)
- 80^oC water supplied
- 3,846 km of pipelines
- 3850 GWh/yr (13,840 TJ/yr)
- 924 MWt peak power (1264 MWt capacity)
- 5258 L/s (peak) – 2332 L/s average)
- LF = 0.44


Deaerator
85-90^{0}C
Pumping Station
Storage Tanks
Oil fired peak power station 100 MWt
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
Heating
Drain
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

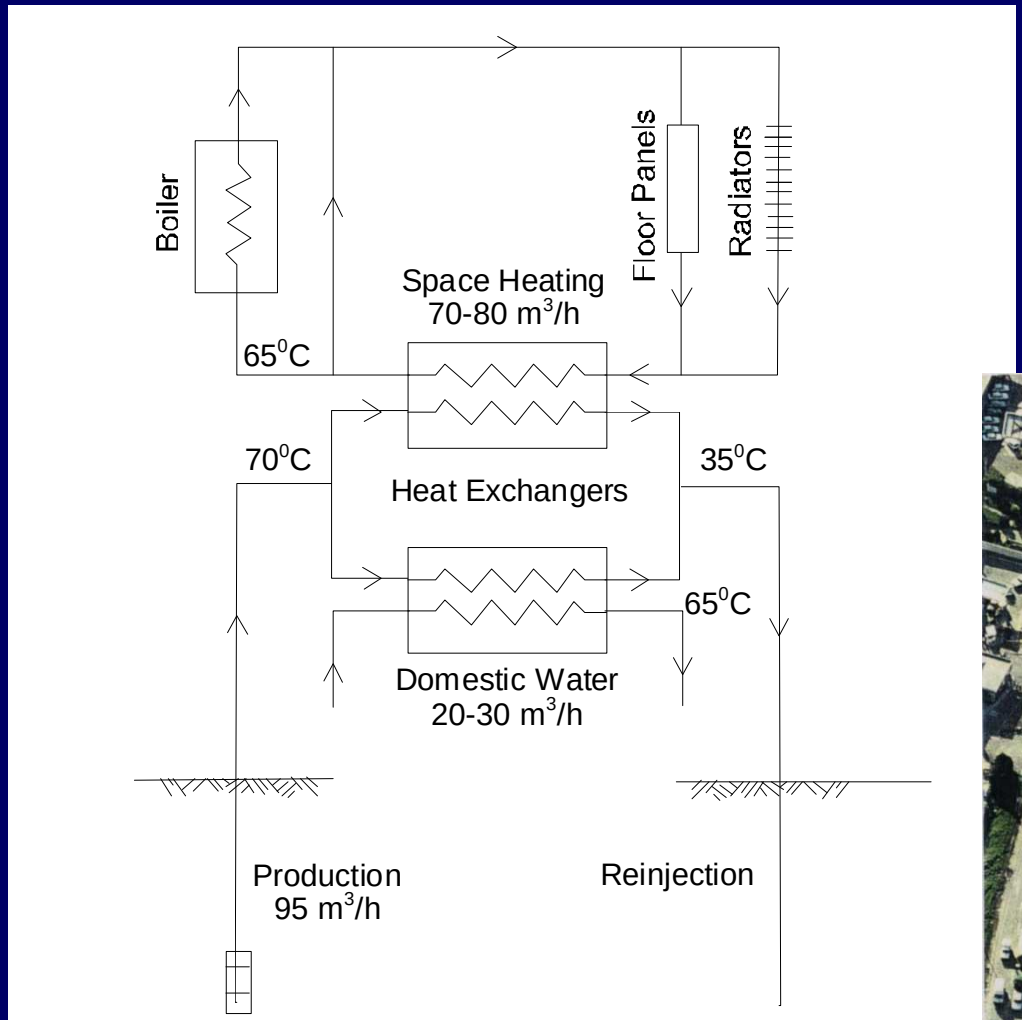

Today


1930s

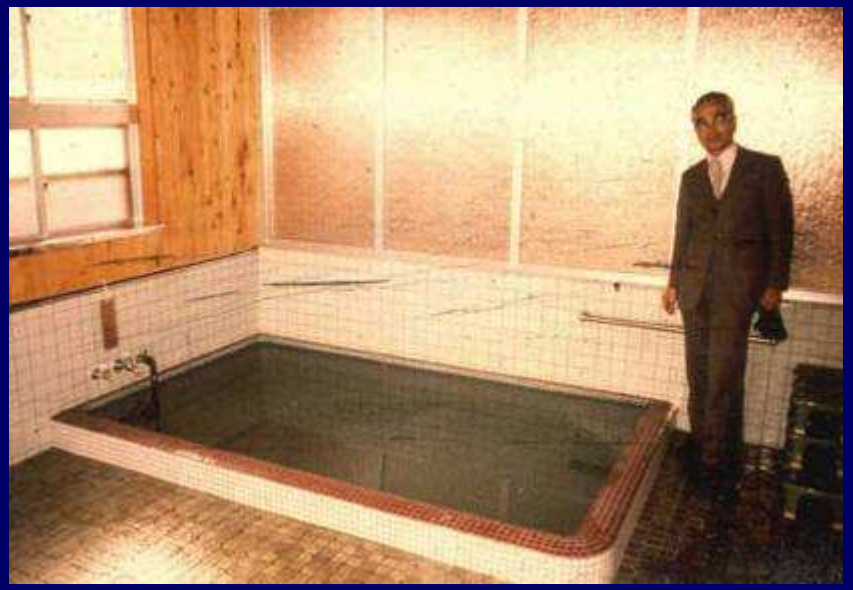
District Heating – Examples (2)

Paris Basin (Melun), France

- 60^{o} to 100^{o}C
- Doublet wells 1,500 to 2,000 m deep
- 500,000 people – 40 projects
- Heat pumps and fossil fuel boilers assist to provide 70^{o}C water to user



AEREAL VIEW OF THE MELUN l'ALMONT DRILL SITE



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
- Wairakei, New Zealand
  - Malaysian prawns
  - 30 tonnes per year
  - Selling for US$37 to 60/kg

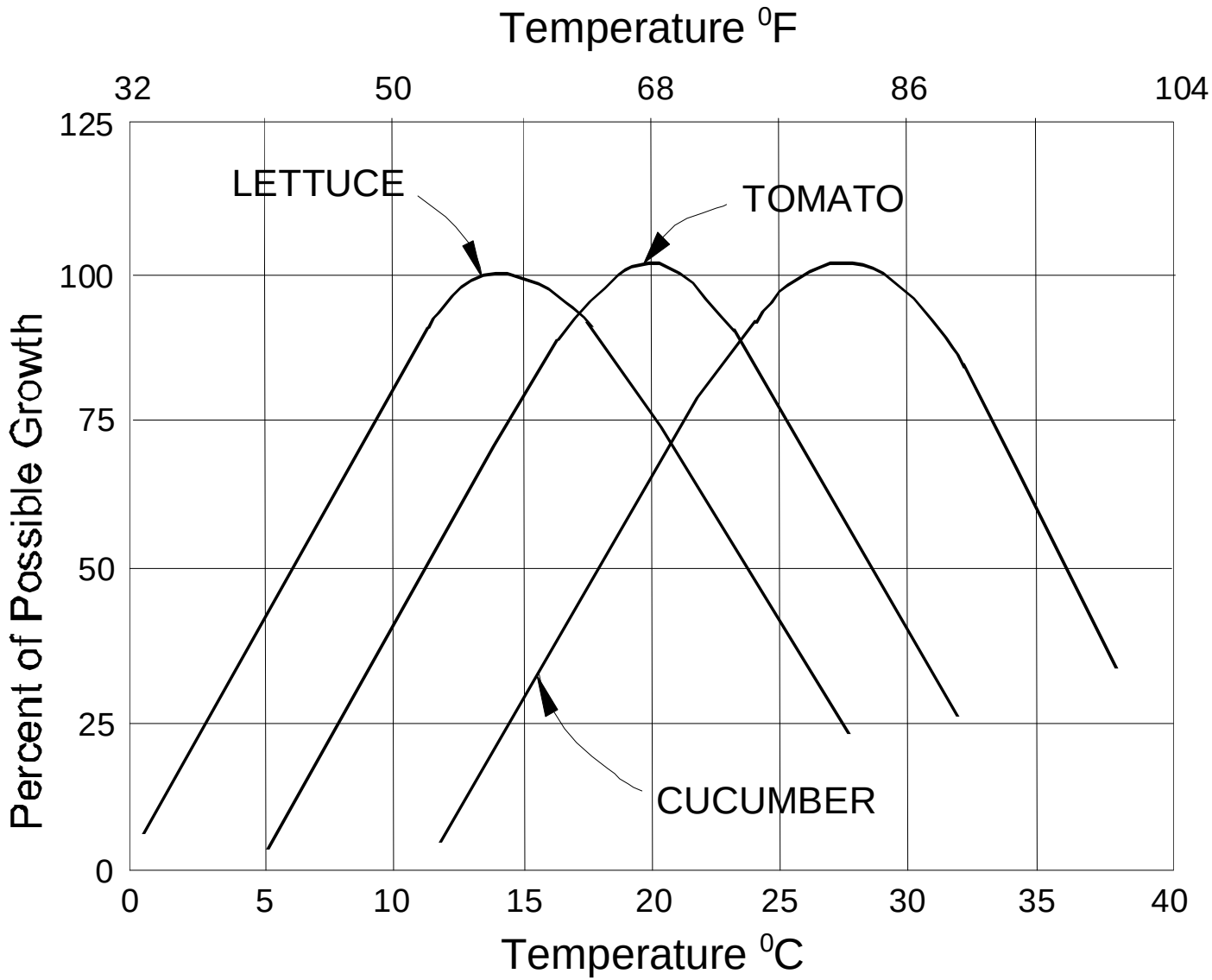
Tianjin, China

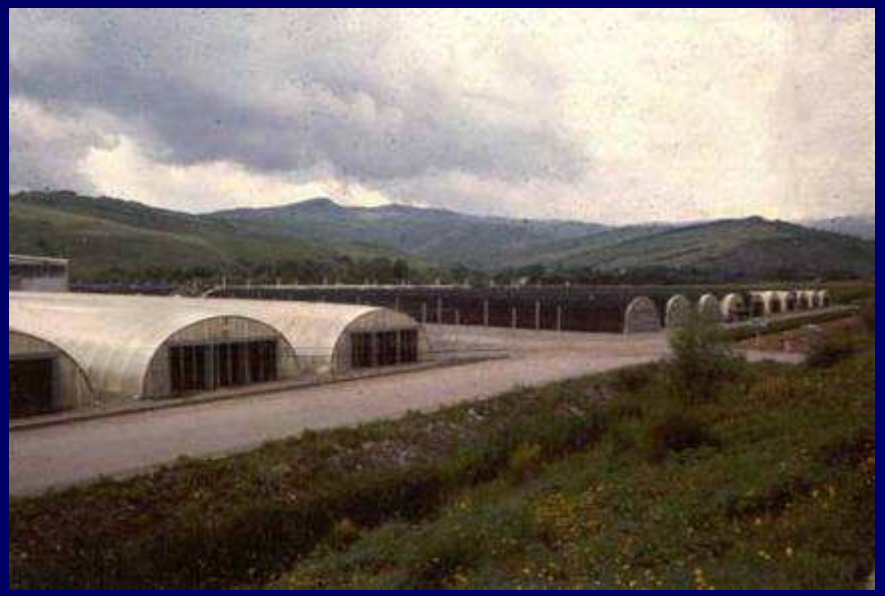
Peking Duck

59°C
geo.

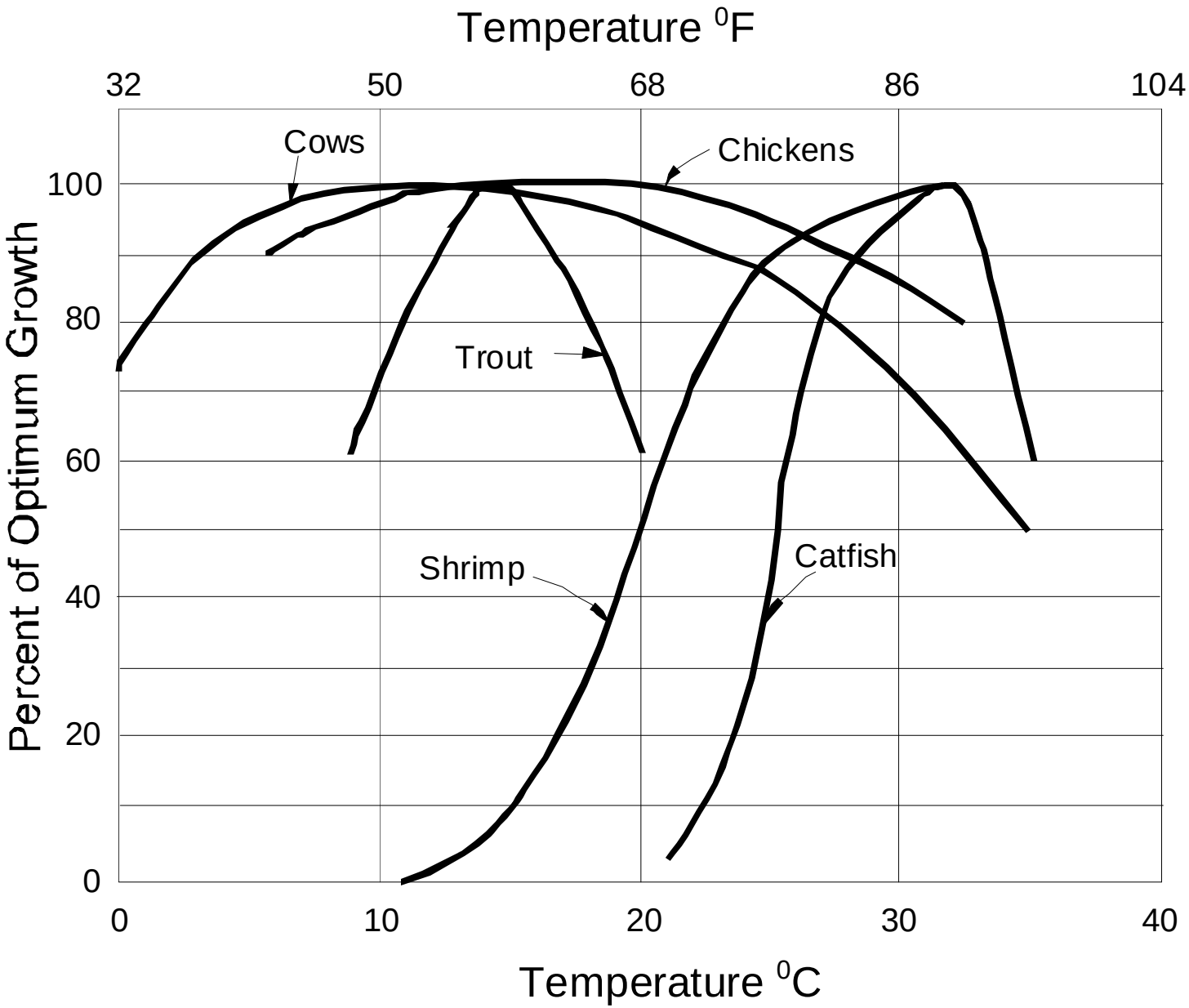
14 kg/h
4 t/yr
dried

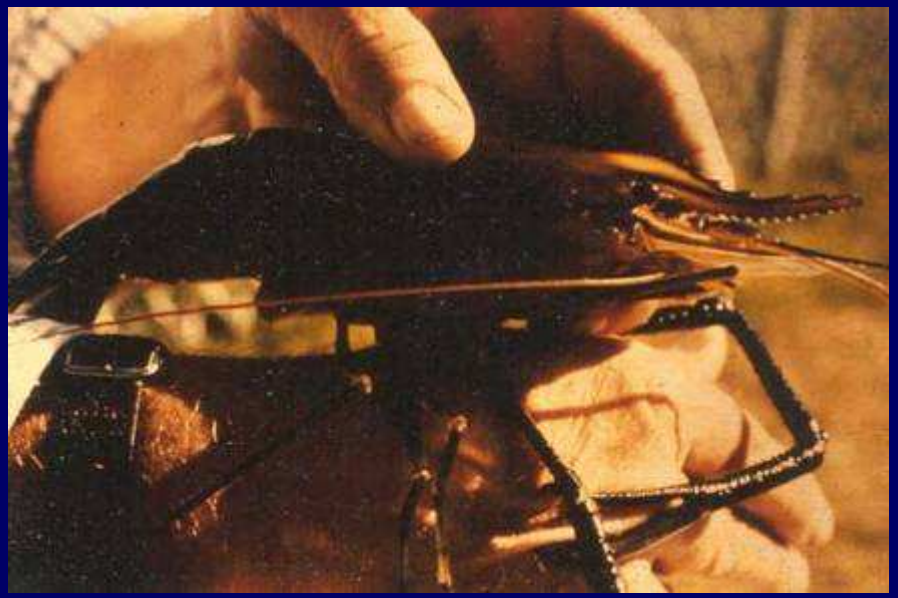
Tomato drying - Greece


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
100
80
60
40
20
0
Percent of Optimum Growth
0
10
20
30
40
Temperature ^{0}C



Aquaculture examples

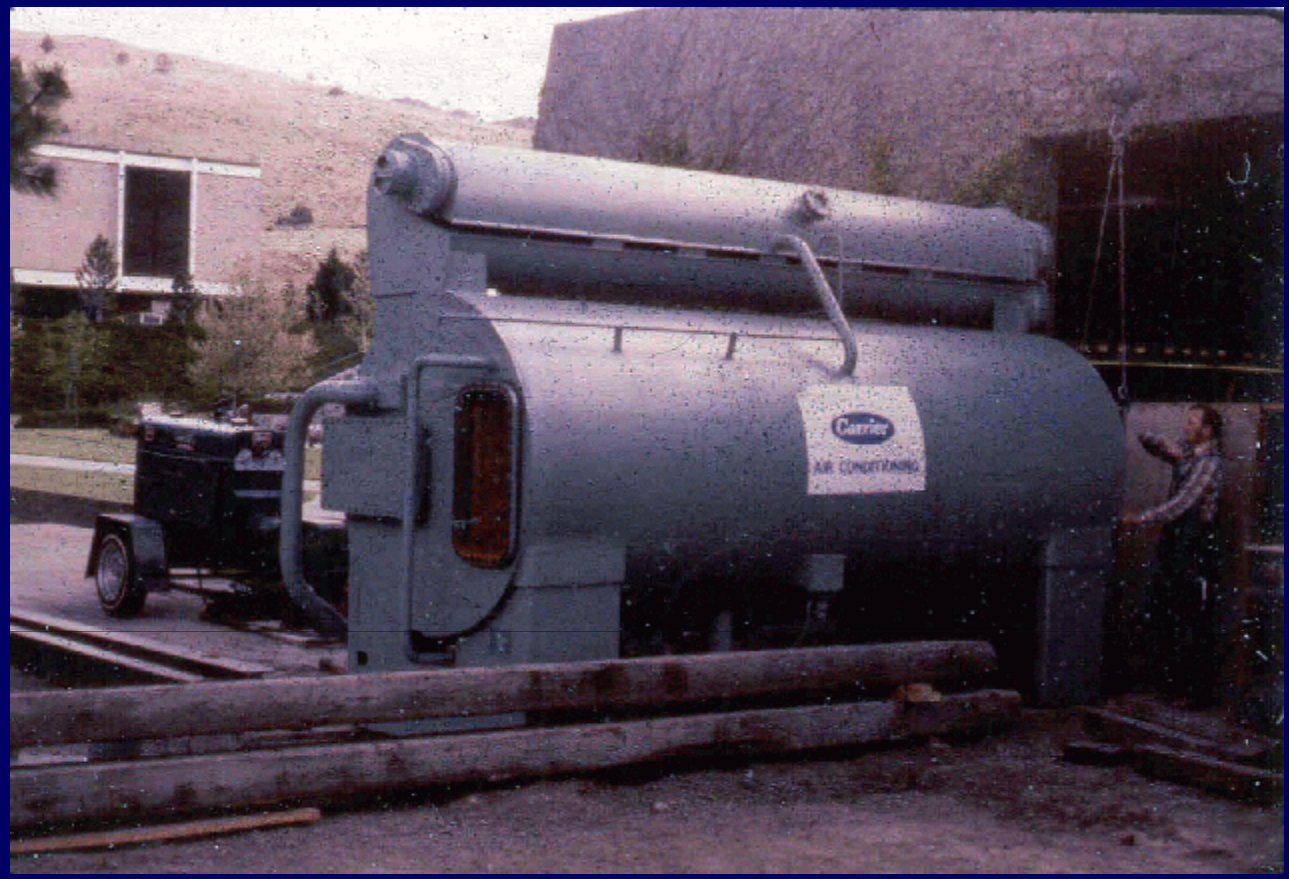
Aquaculture – Example

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$60/kg retail
- 90% sold to restaurant on the property
- 25,000 tourists/yr
- Future expansion to 40 ha and will produce 400 tonnes/yr – income of US$ 6.7 million

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^{o}C – however, >115^{o}C better for 100% efficiency)
- Ammonia absorption used for refrigeration below freezing normally large capacity and require geothermal temperatures above 120^{o}C



Oregon Institute of Technology – chiller

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

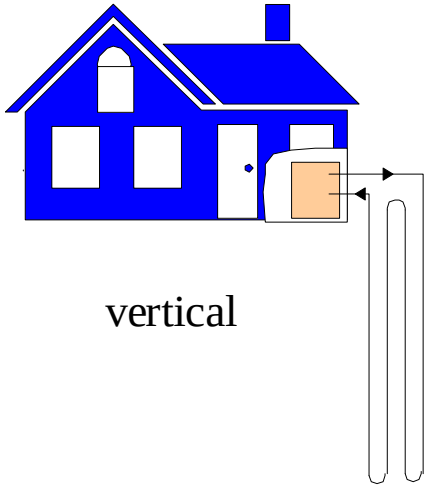
1 MWt installed – 500 kW net

Heat Pumps (1)

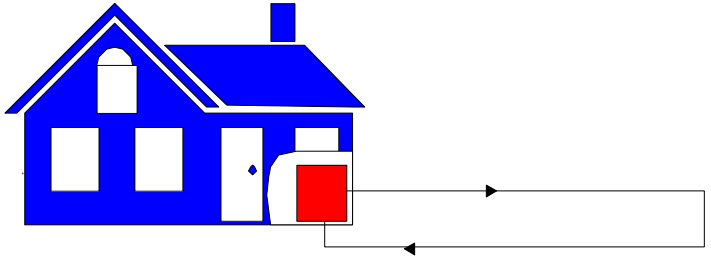
- Used for both heating and cooling
- Heated capacity of 3 kW to 1,500 kW
- 43 countries
- 2,800,000 units installed world-wide
- Growing at the rate 17 to 18 %/year
- COP of 4 (75% savings in electricity)

Heat Pumps (2)

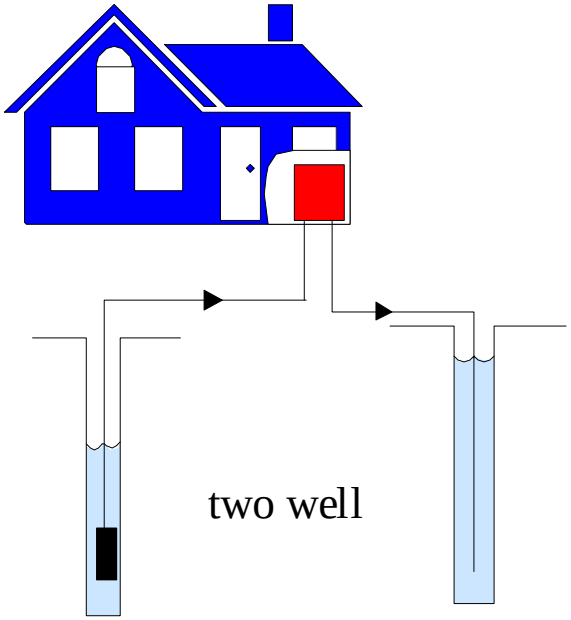
- Ground source and geothermal heat pumps (GSHP or GHP) – uses 5 to 30˚ C ground temperature
- 50 to 100% more efficient than air source, since uses constant temperature resource
- Ground coupled
  - Horizontal in trenches 1 – 3 m deep
  - Vertical in 10 cm diameter 50 – 60 m deep drillholes
  - Others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



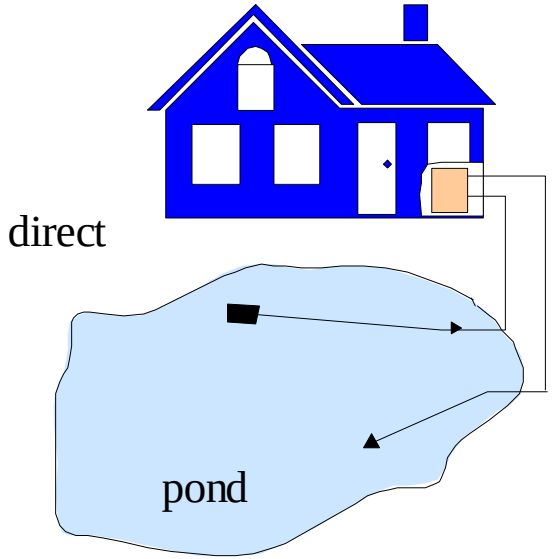
vertical



horizontal



two well

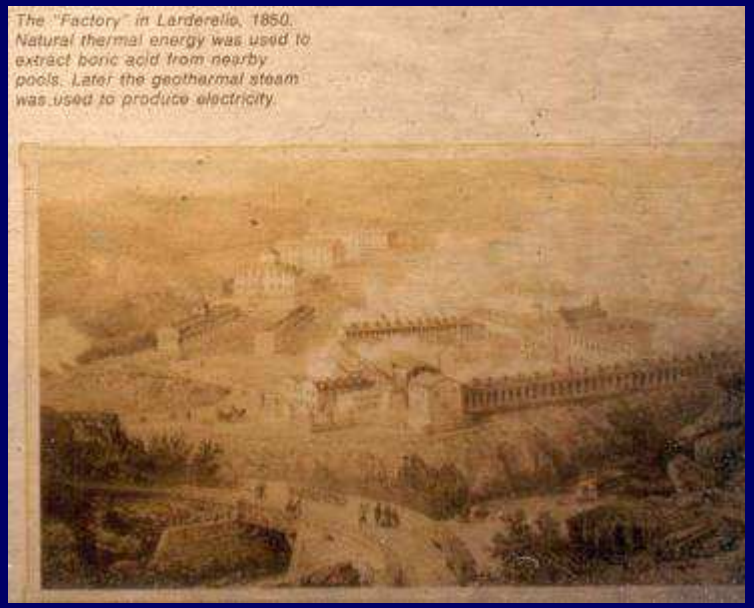


direct

pond

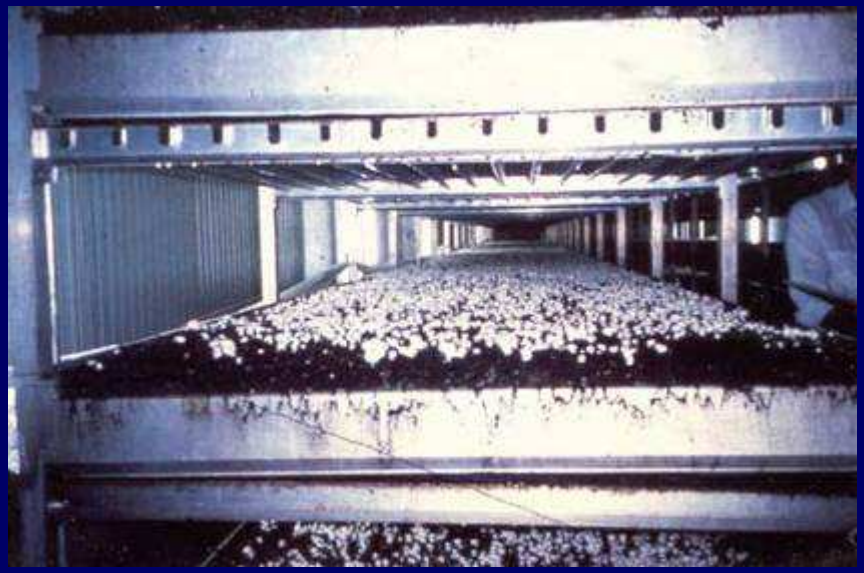
Industrial Applications

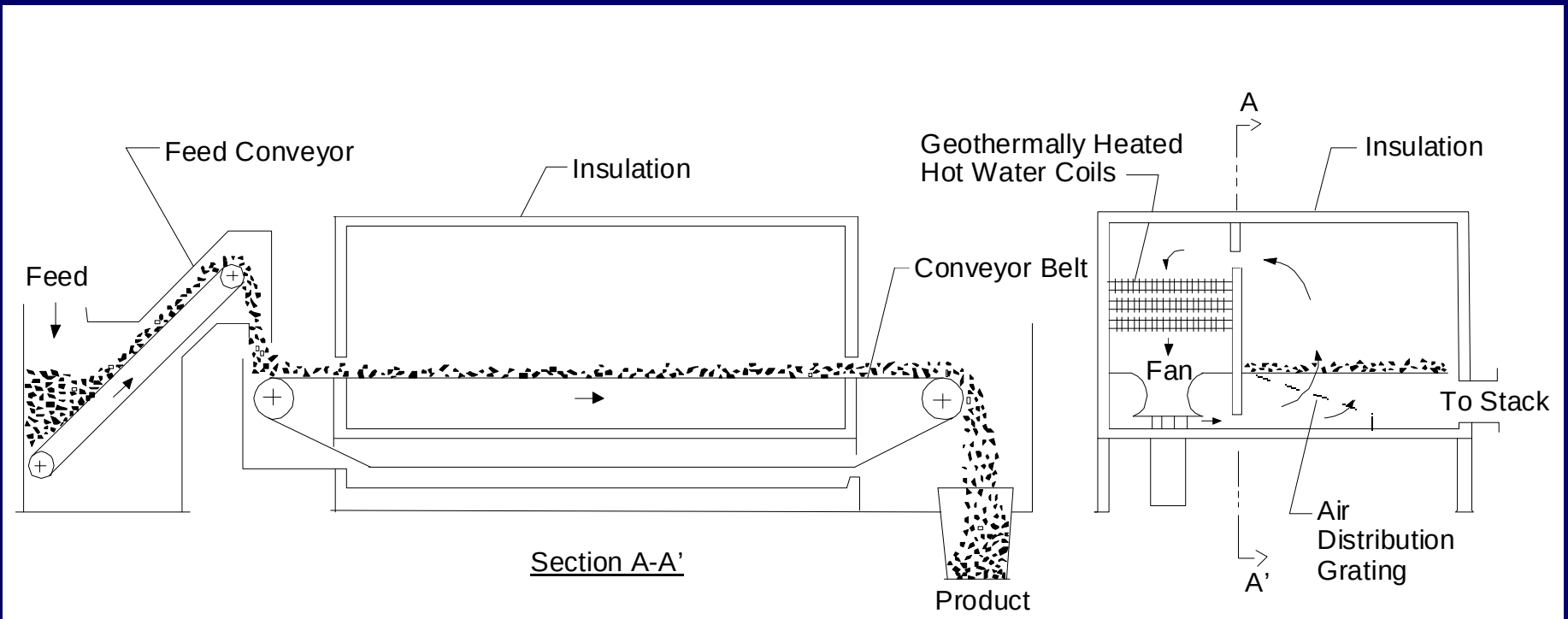
- Oldest: Larderello, Italy – boric acid and borate compounds processed since 1790
- New Zealand: pulp, paper and wood processing at Kawerau
- Iceland: diatomaceous earth drying – Myvatn
- USA: vegetable dehydration (onion) – Nevada
  gold extraction (heap leaching) - Nevada



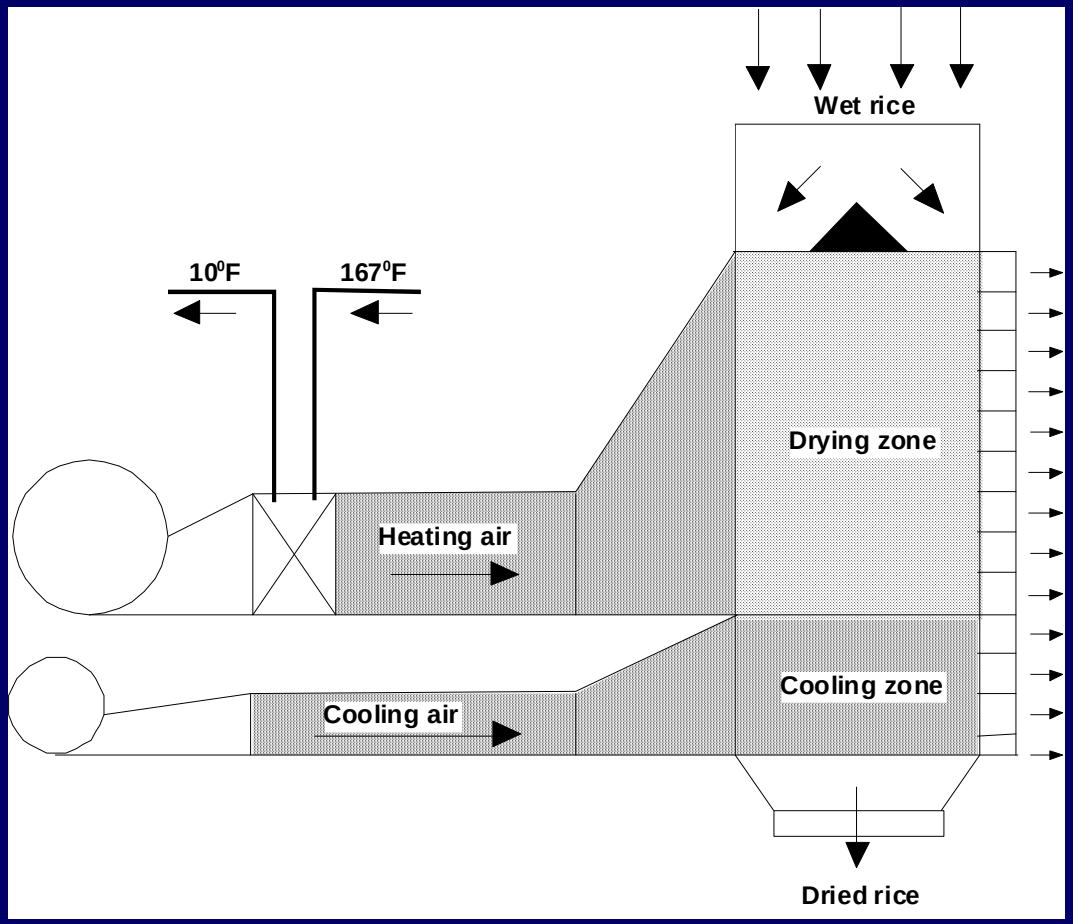
Industrial application examples

More industrial application examples





Food dehydration belt dryer

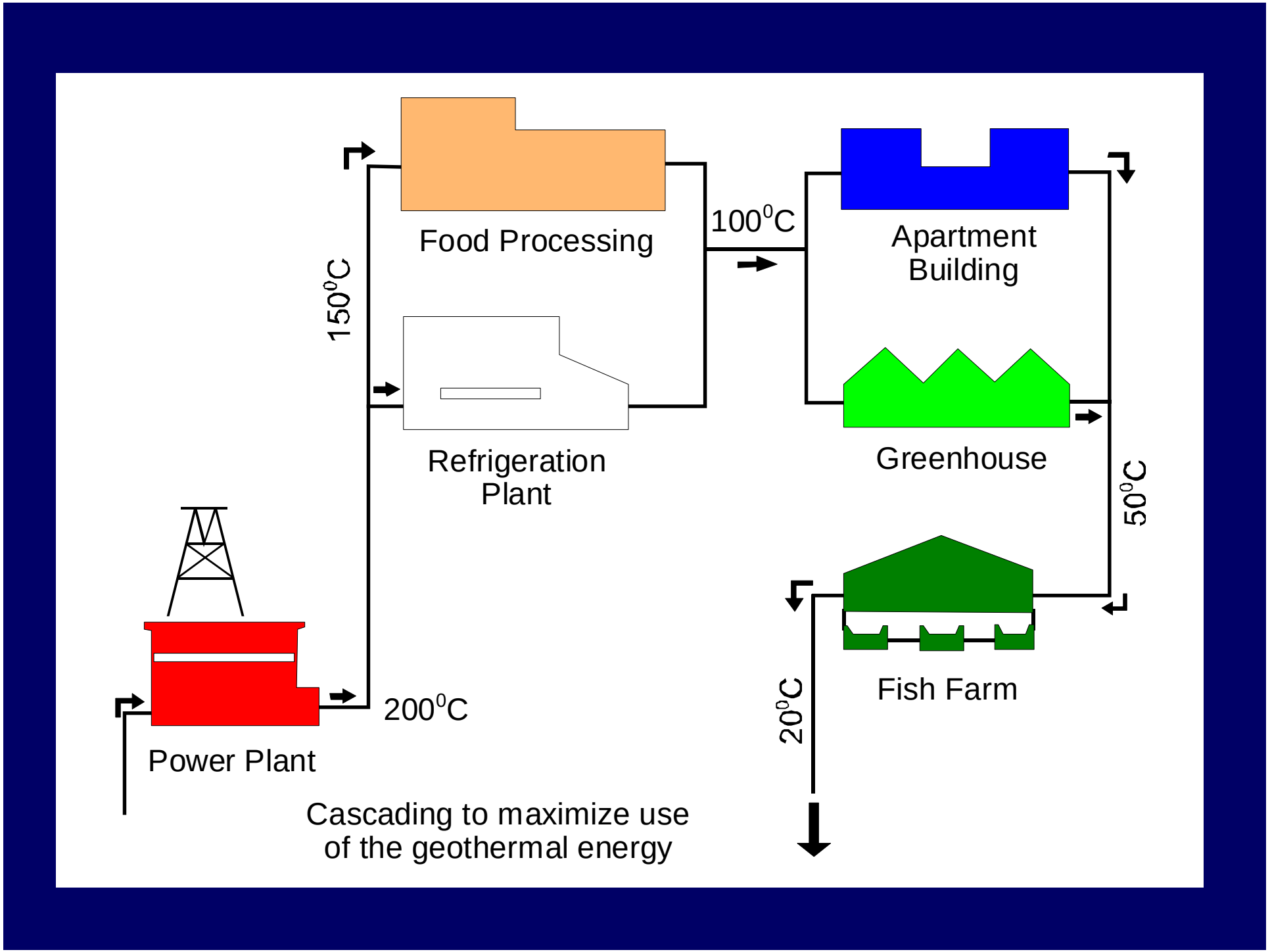


Rice dryer – Macedonia

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

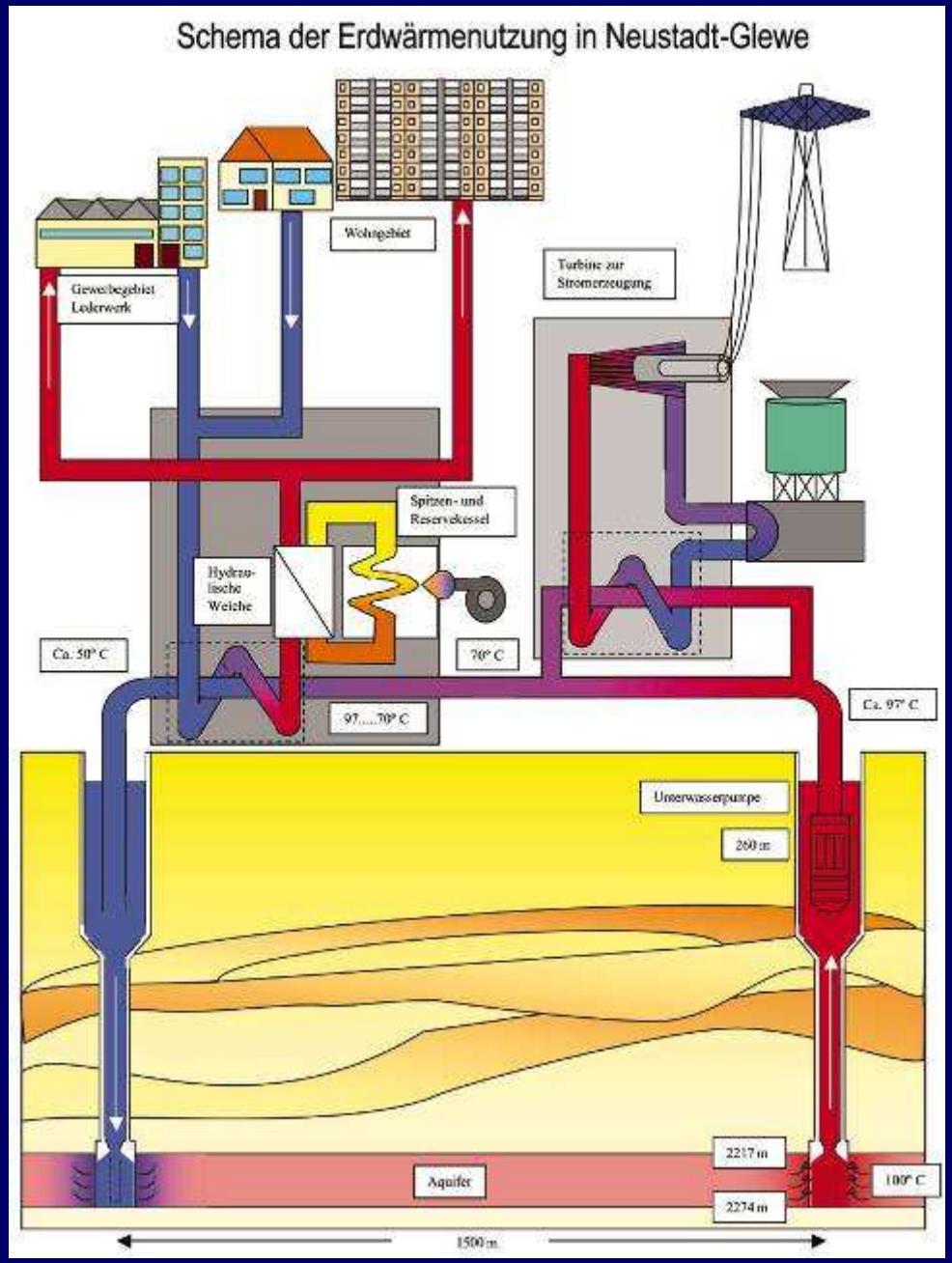
NEW TRENDS

- **COMBINED HEAT AND POWER PLANTS**
  - **Low temperature resources used for binary power production and cascaded for direct use**
  - **Temperatures as low as 98ºC are being used**
  - **Makes efficient use of the resources**
  - **Improves economics**
- **See GHC Quarterly Bulletin 26/2 (June 05)**


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

COMBINED GEOTHERMAL HEAT AND POWER PROJECT NEUSTADT GLEWE, GERMANY

- Wells drilled 1986 and 1989 – 2,300 m
- Geothermal water at 98ºC – 1,700 l/s
- Heat plant provides basic load for district heating network – 11 MW (thermal)
  - 6 MW geothermal – 95% of energy
- 210 kWe binary power plant added meeting the electricity demands for 500 households


Schema der Erdwärmenutzung in Neustadt-Glewe
Wohngebiet
Gewerbegebiet Lederwerk
Turbine zur Stromerzeugung
Spitzen- und Reservekessel
Hydrau-lische Weiche
Ca. 50° C
70° C
97....70° C
Ca. 97° C
Unterwasserpumpe
200 m
2217 m
2274 m
Aquifer
100° C
1500 m

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
  - Optimize growth – even in warm climates
- Ground coupled and groundwater heat pumps
  - For both heating and cooling
- Combined heat and power projects - cascading

Thank You