DIRECT HEAT UTILIZATION OF GEOTHERMAL ENERGY

John W. Lund

Director
Geo-Heat Center
Oregon Institute of Technology
Klamath Falls, Oregon, USA

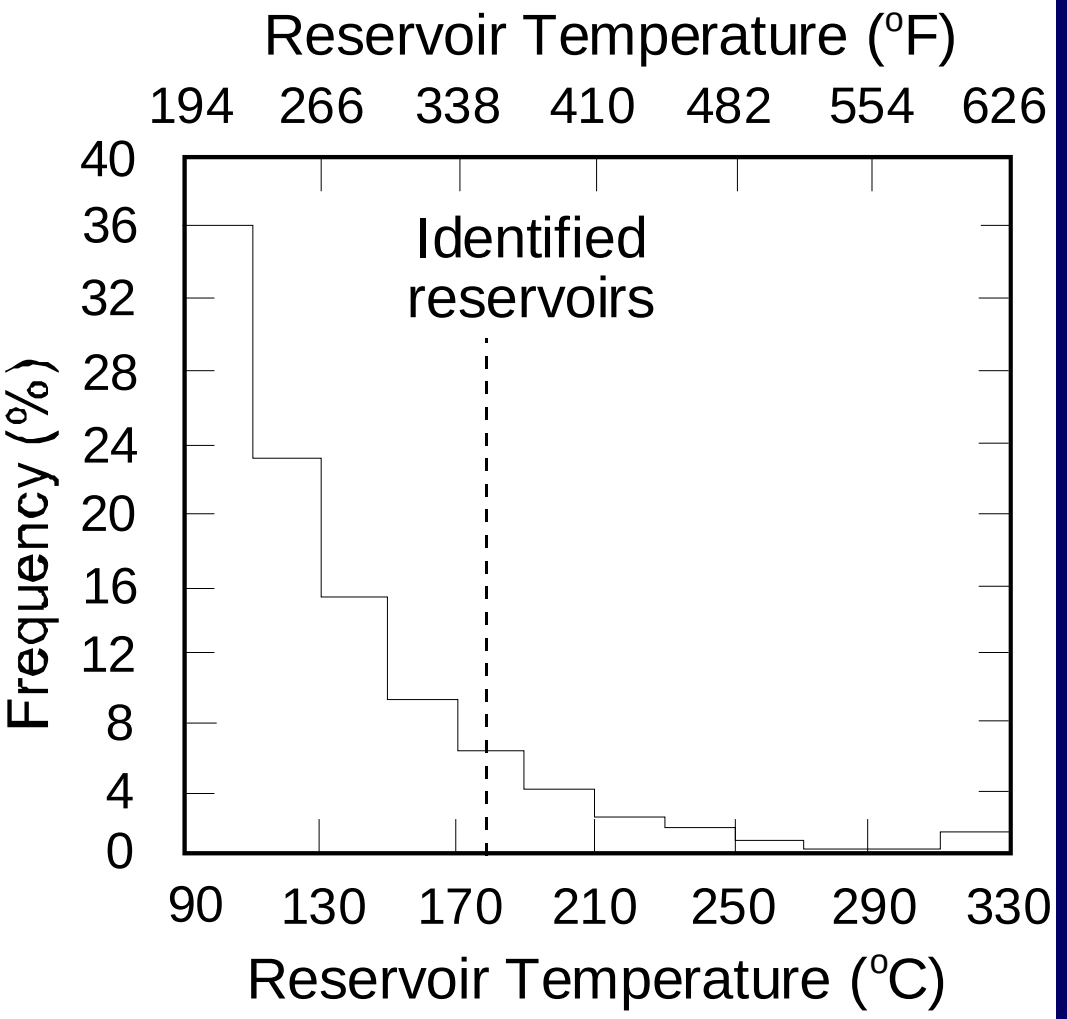
What is Direct-Use: Heating and Cooling

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

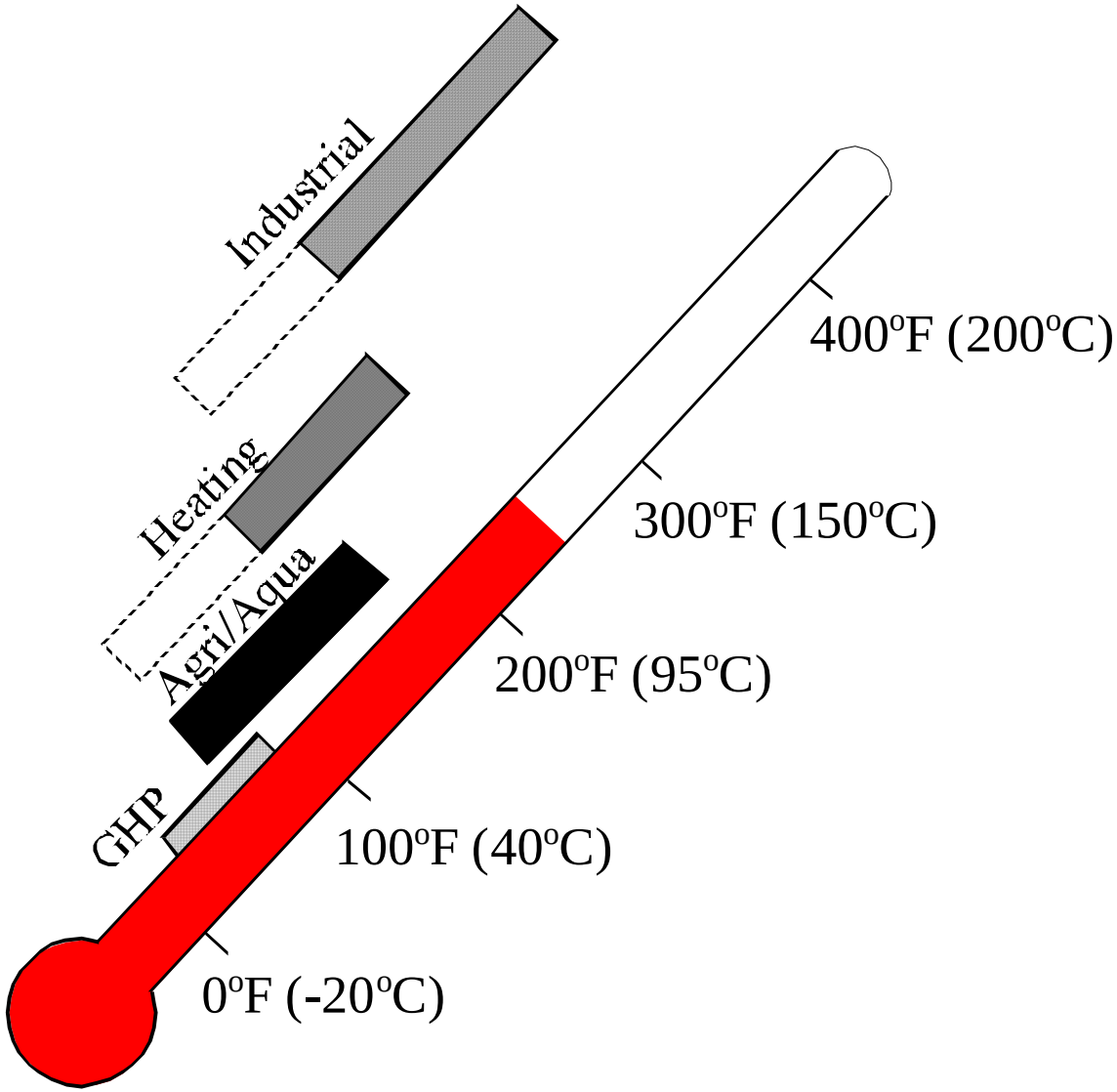
Advantages of Direct-Use of Geothermal Energy

- Can use low- to intermediate temperature resources (<300ºF)
- 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

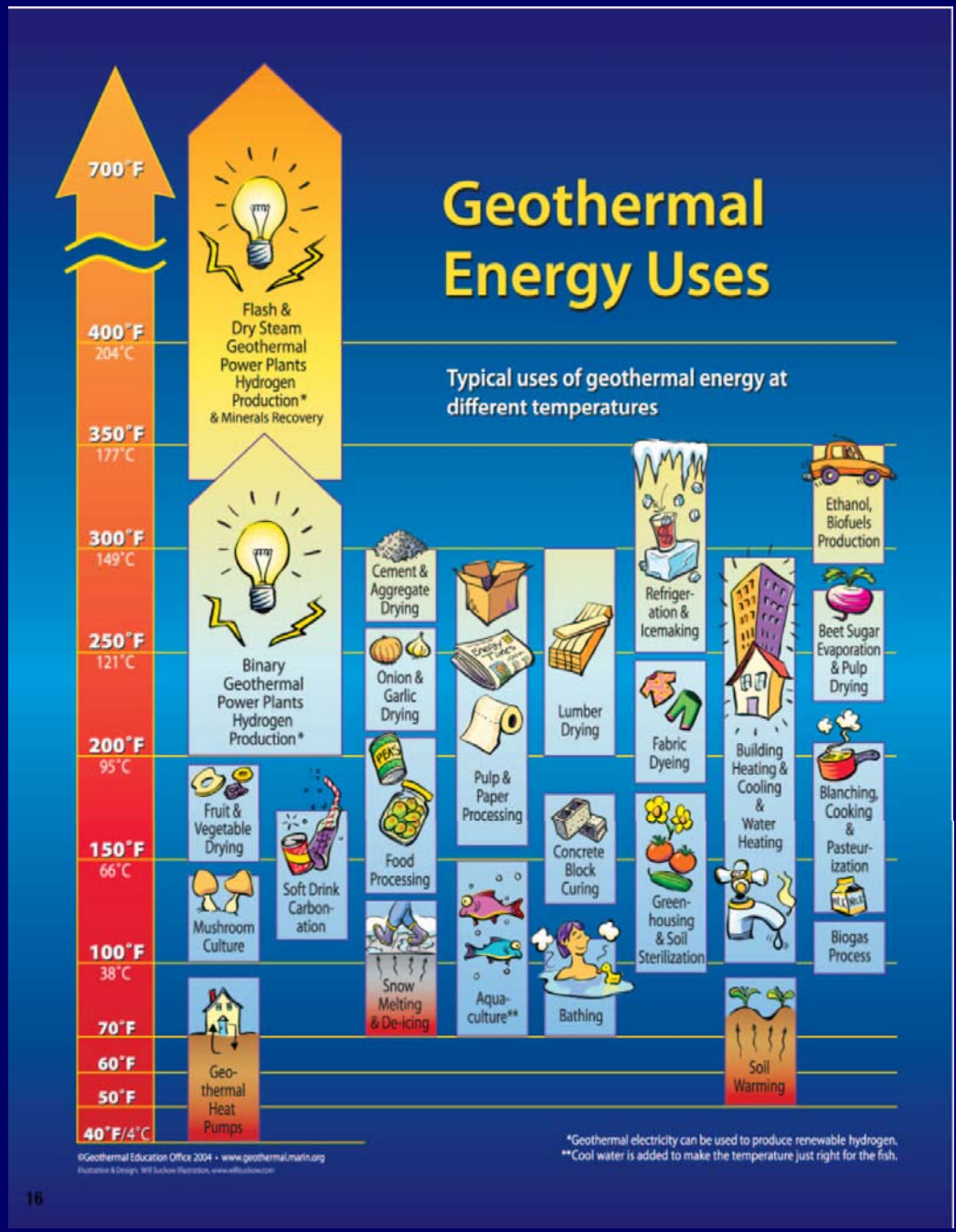
Frequency vs Reservoir Temperature



Data taken from USGS Circular 790



Temperature use for direct use applications

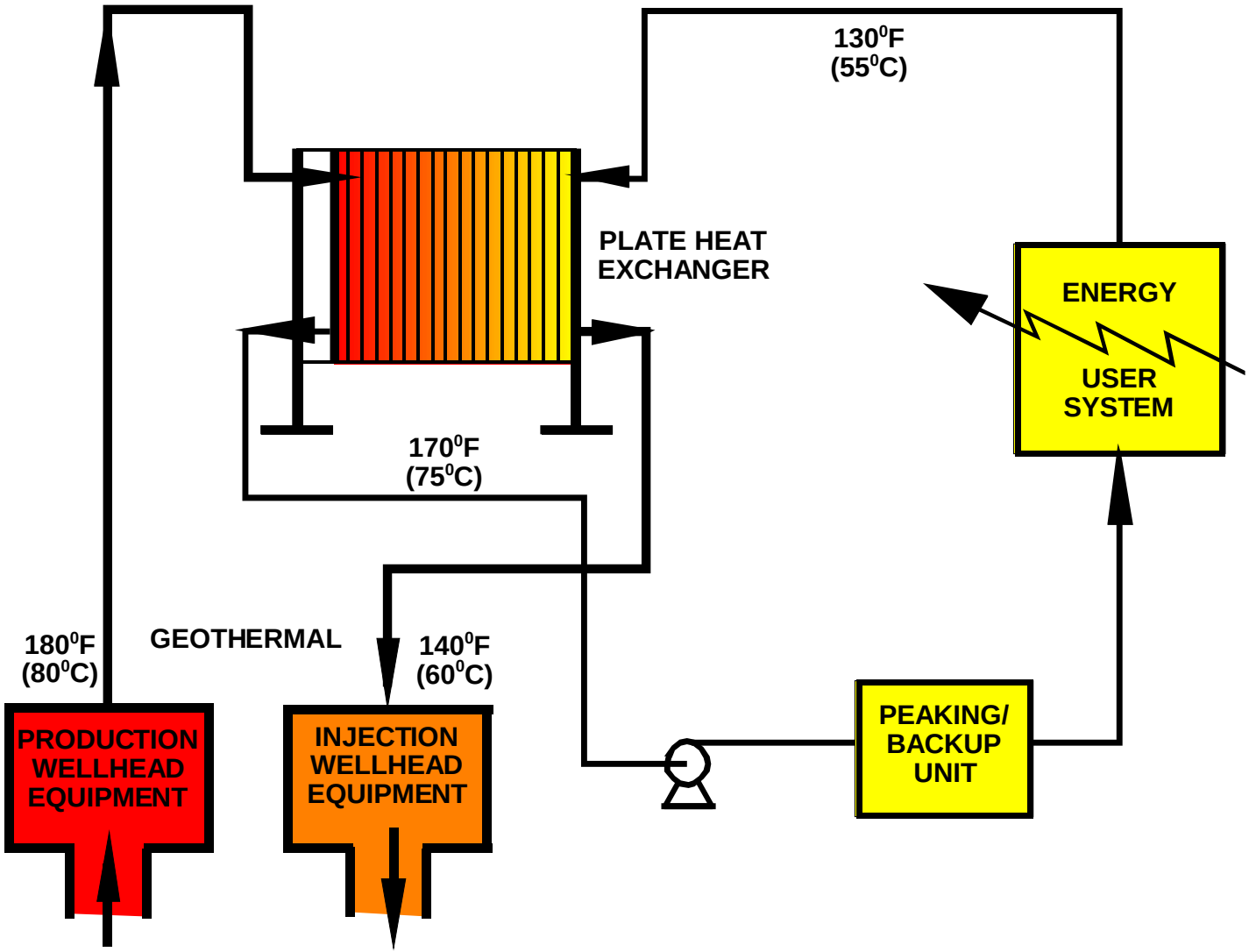

Geothermal Energy Uses
Typical uses of geothermal energy at different temperatures
700˚F
400˚F
204˚C
350˚F
177˚C
300˚F
149˚C
250˚F
121˚C
200˚F
95˚C
150˚F
66˚C
100˚F
38˚C
70˚F
60˚F
50˚F
40˚F/4˚C
Flash & Dry Steam Geothermal Power Plants Hydrogen Production* & Minerals Recovery
Binary Geothermal Power Plants Hydrogen Production*
Fruit & Vegetable Drying
Mushroom Culture
Soft Drink Carbon-ation
Geo-thermal Heat Pumps
Cement & Aggregate Drying
Onion & Garlic Drying
Food Processing
Snow Melting & De-icing
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 Education Office 2004 • www.geothermal.marin.org
*Geothermal electricity can be used to produce renewable hydrogen.
**Cool water is added to make the temperature just right for the fish.

Extent 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 and mineral ore drying**
  - **Large commercial greenhouse & aquaculture operations**

Equipment (1)

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

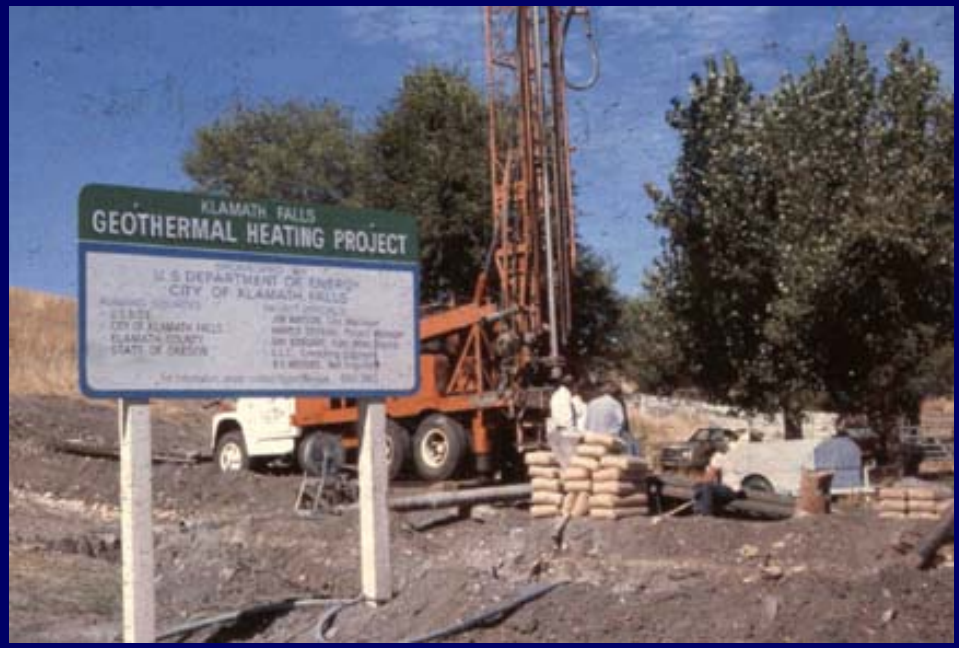

130⁰F
(55⁰C)
PLATE HEAT
EXCHANGER
ENERGY
USER
SYSTEM
170⁰F
(75⁰C)
180⁰F
(80⁰C)
GEOTHERMAL
140⁰F
(60⁰C)
PRODUCTION
WELLHEAD
EQUIPMENT
INJECTION
WELLHEAD
EQUIPMENT
PEAKING/
BACKUP
UNIT

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**

DRILLING

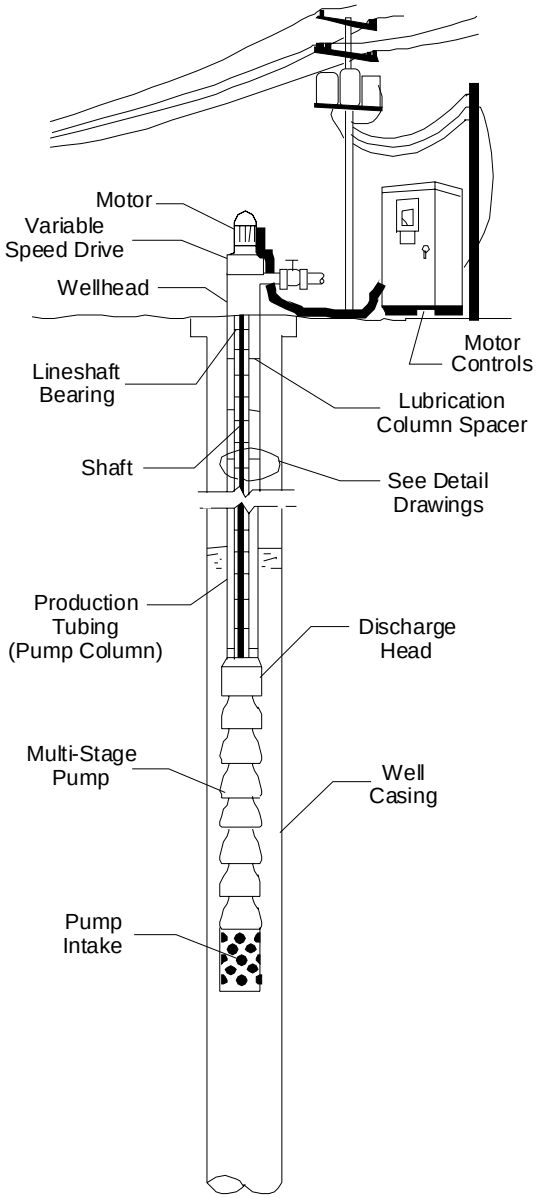


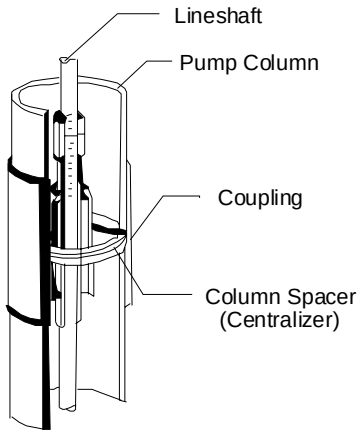
Rotary vs cable (percussion)

Wells Pumps

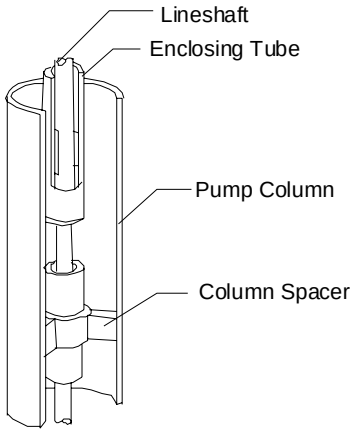
Two types used:

- **Lineshaft – motor on surface (most common in the US) (often used with variable frequency drive) <800 ft.**
  - **Less expensive – enclosed line shaft**
- **Submersible – motor below water (most common in Europe) – high temp. expensive**
  - **Deeper setting – best for small/low temp.**

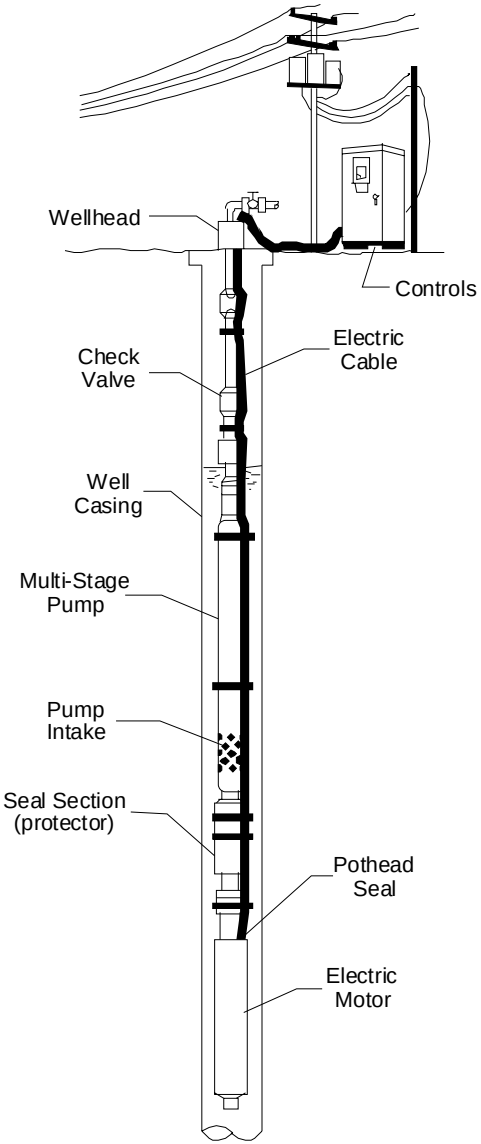




Open Lineshaft Bearing Lubrication



Enclosed Lineshaft Bearing Lubrication



Heat Exchangers

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

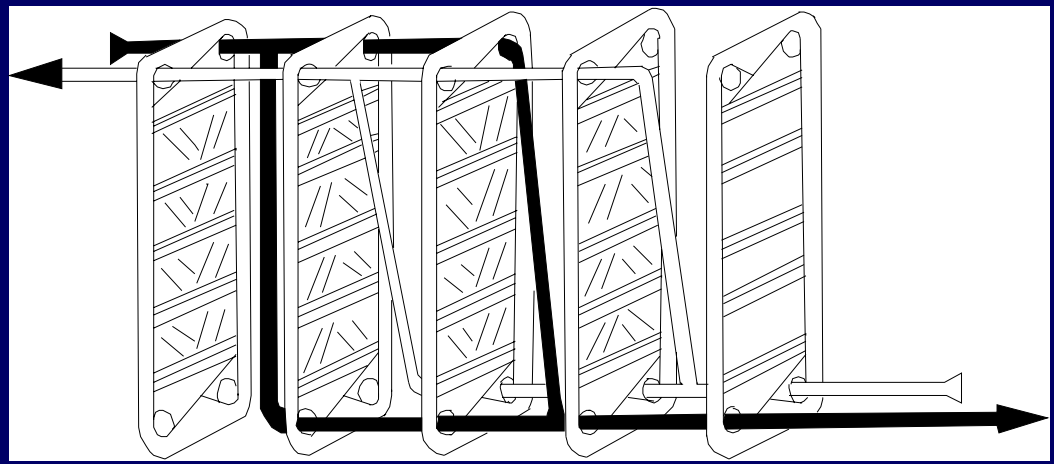
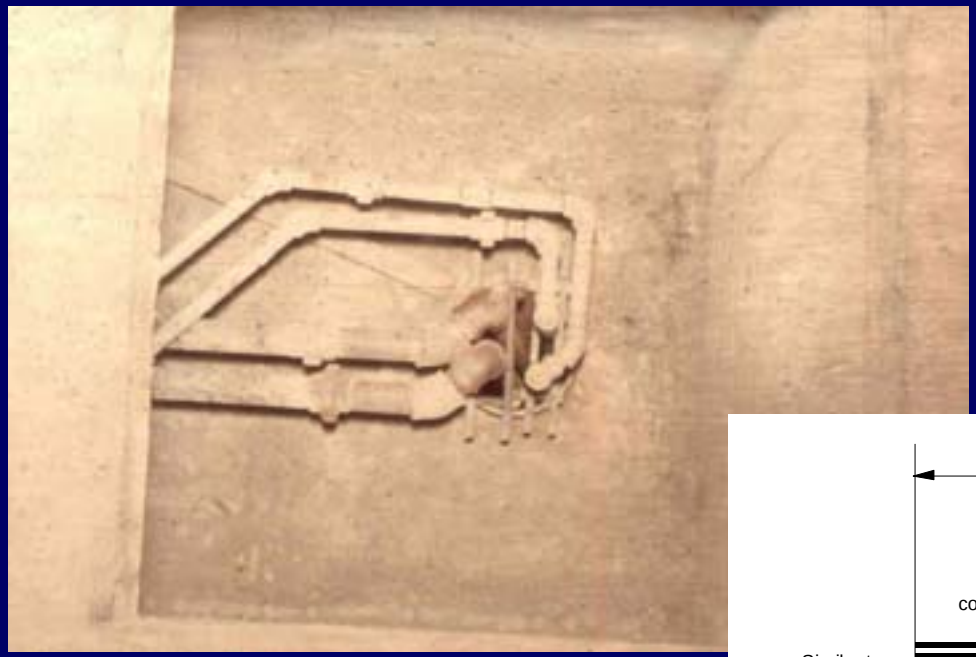
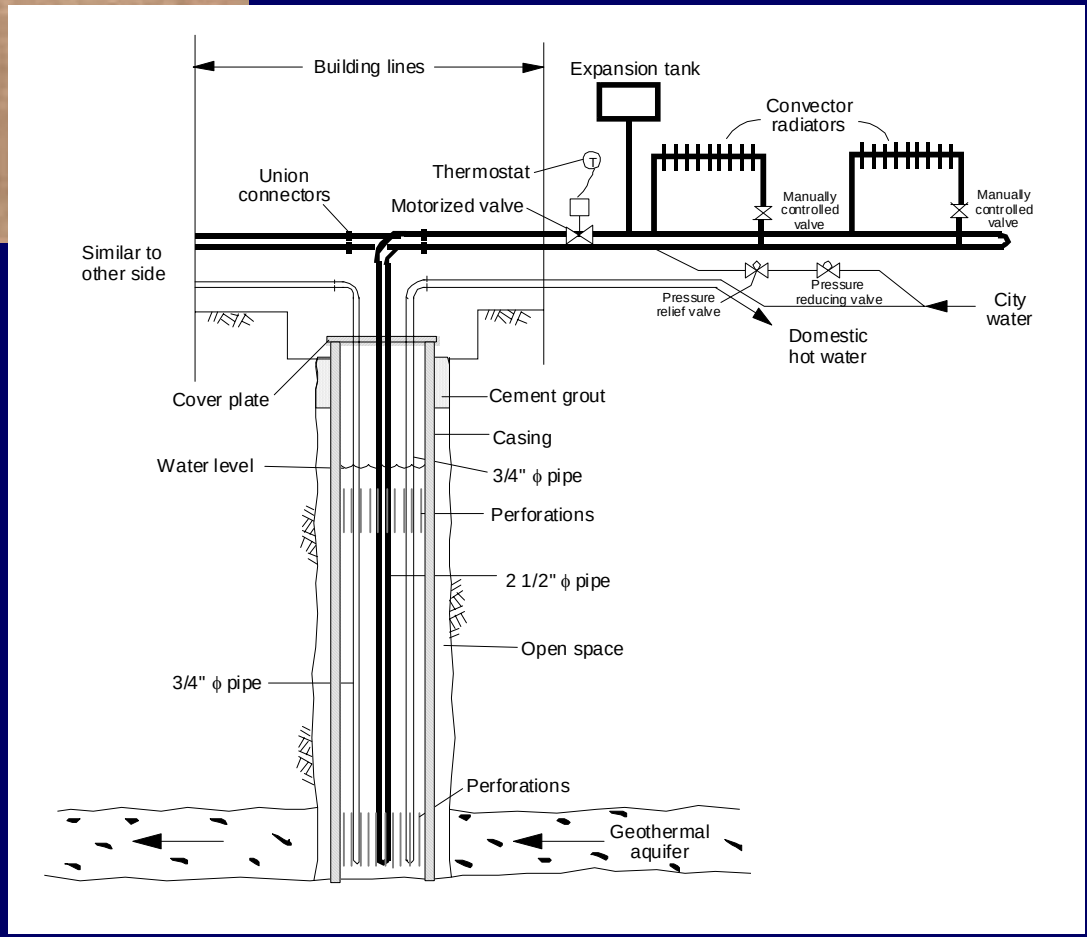
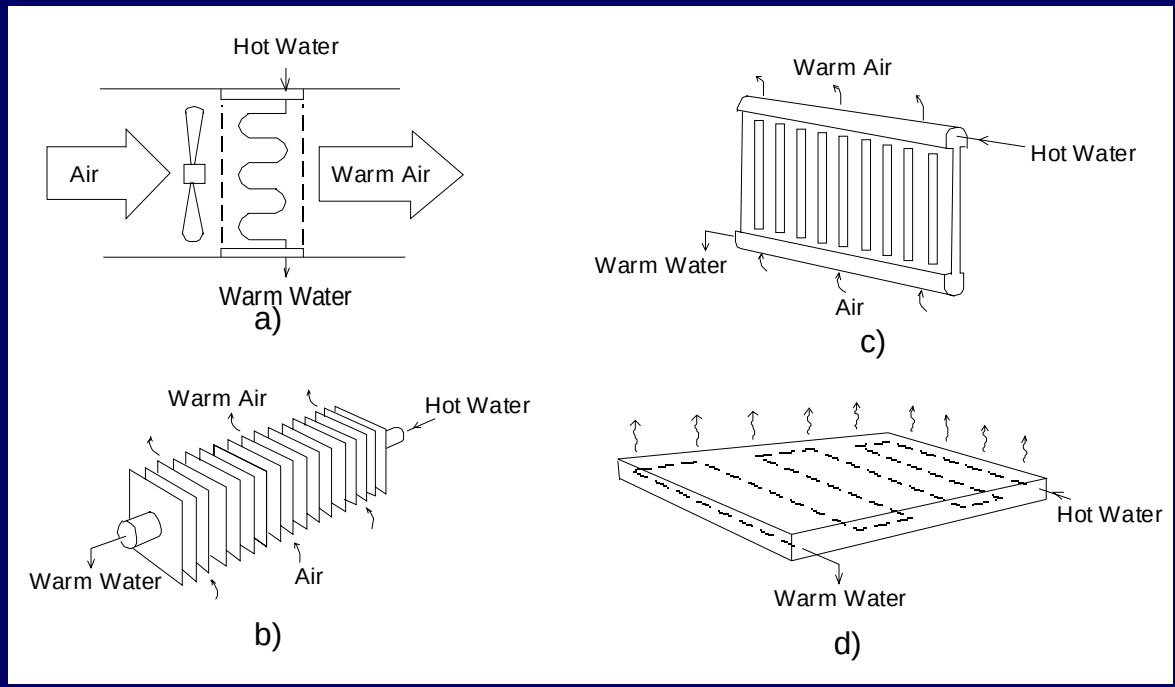


Plate heat exchanger



Downhole heat exchanger





Room heat convectors

Piping (1)

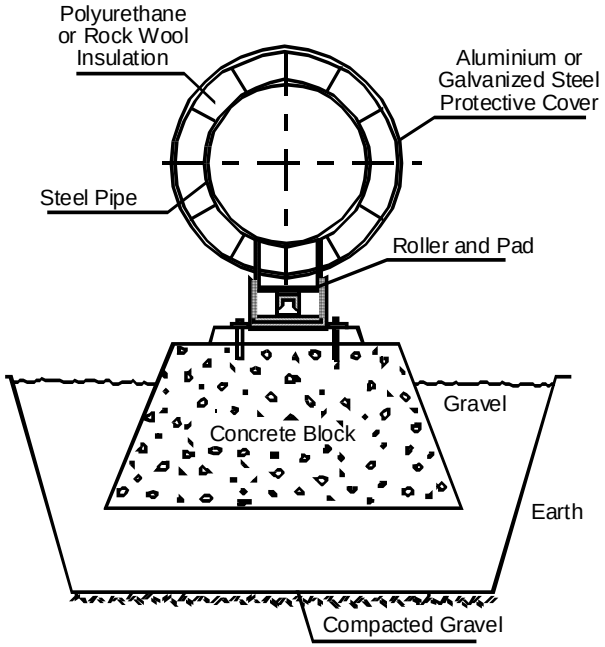
Location

- Above ground
- Below ground
- Pre-insulated with urethane foam + cover
- Problems
  - Metallic - external corrosion – if direct buried
  - and expansion/contraction must be considered
  - Copper attacked by H_2S – and solder
  - Non-metallic <200°F

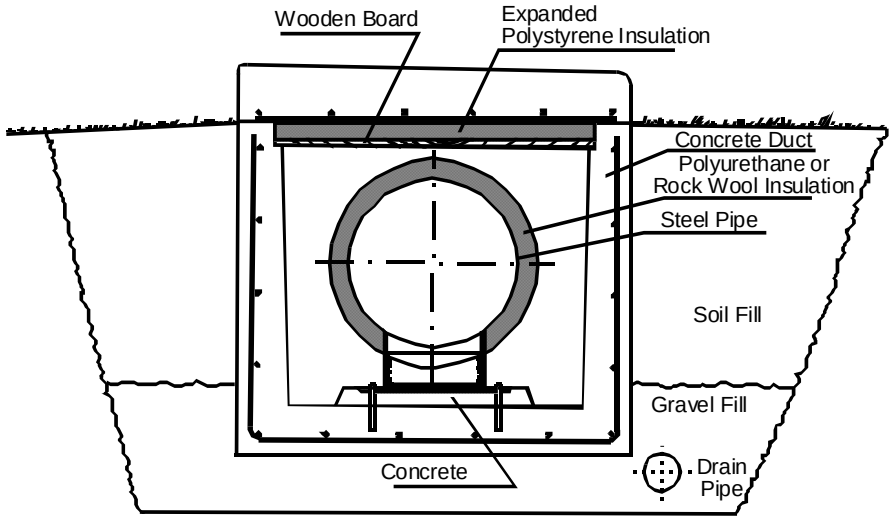
Piping (2)

Material

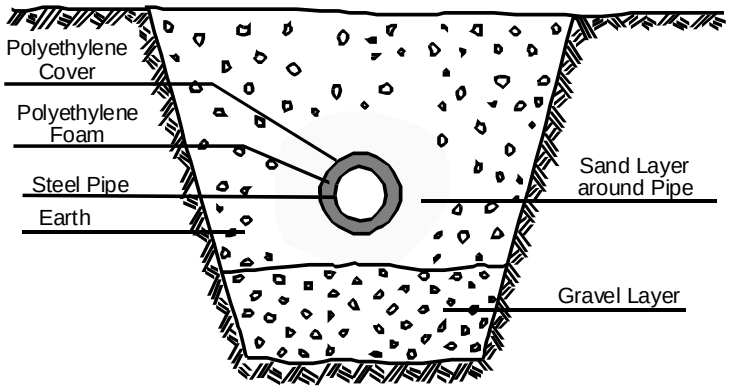
- **Carbon steel** >200ºF
  - Expansion loops or bellows
- **FRP or PVC** <200ºF – Fiberglass reinforced plastic and polyvinylchloride
- **PEX** (200ºF @ 80 psi) cross-lined polyethylene
  - 2.5 x cost of PVC – only small sizes available
- **Fiberglass** < 300ºF – expensive 3.5x PVC
- **AC** – Asbestos cement
  - Environmental limitation
  - Longest = Deildartunga – Akranes, Iceland at 38 miles


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

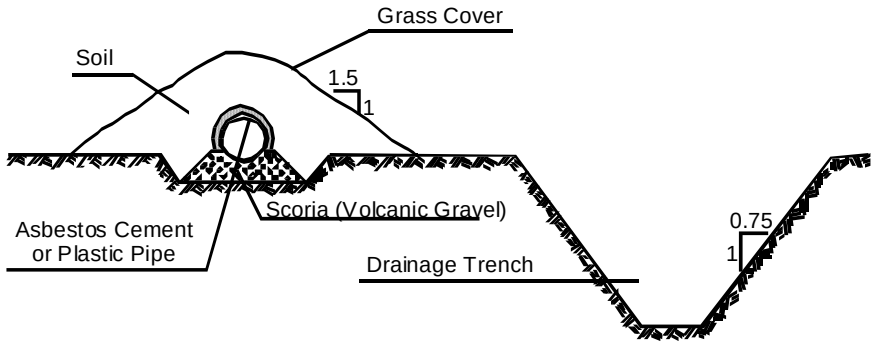
a)


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 (1)

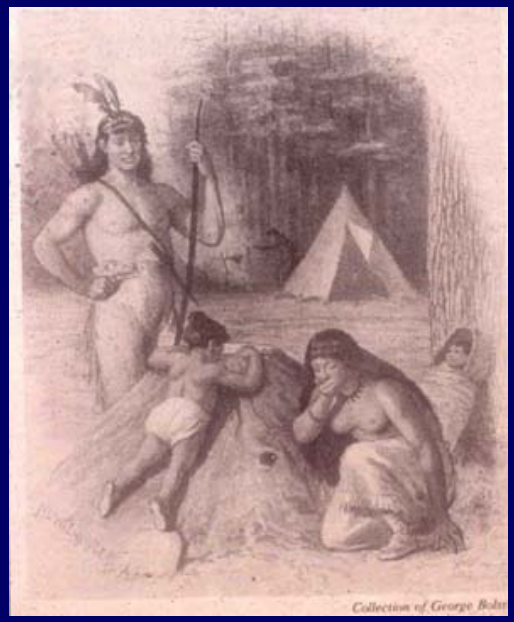
- **Main Users (past and present)**
  - **Romans**
  - **Chinese**
  - **Ottomans (Turks)**
  - **Japanese**
  - **Central Europeans**
  - **American Indians (Mexico and USA regions)**

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 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 Bolot


the amazing BLUE LAGOON in ICELAND
a pool with power

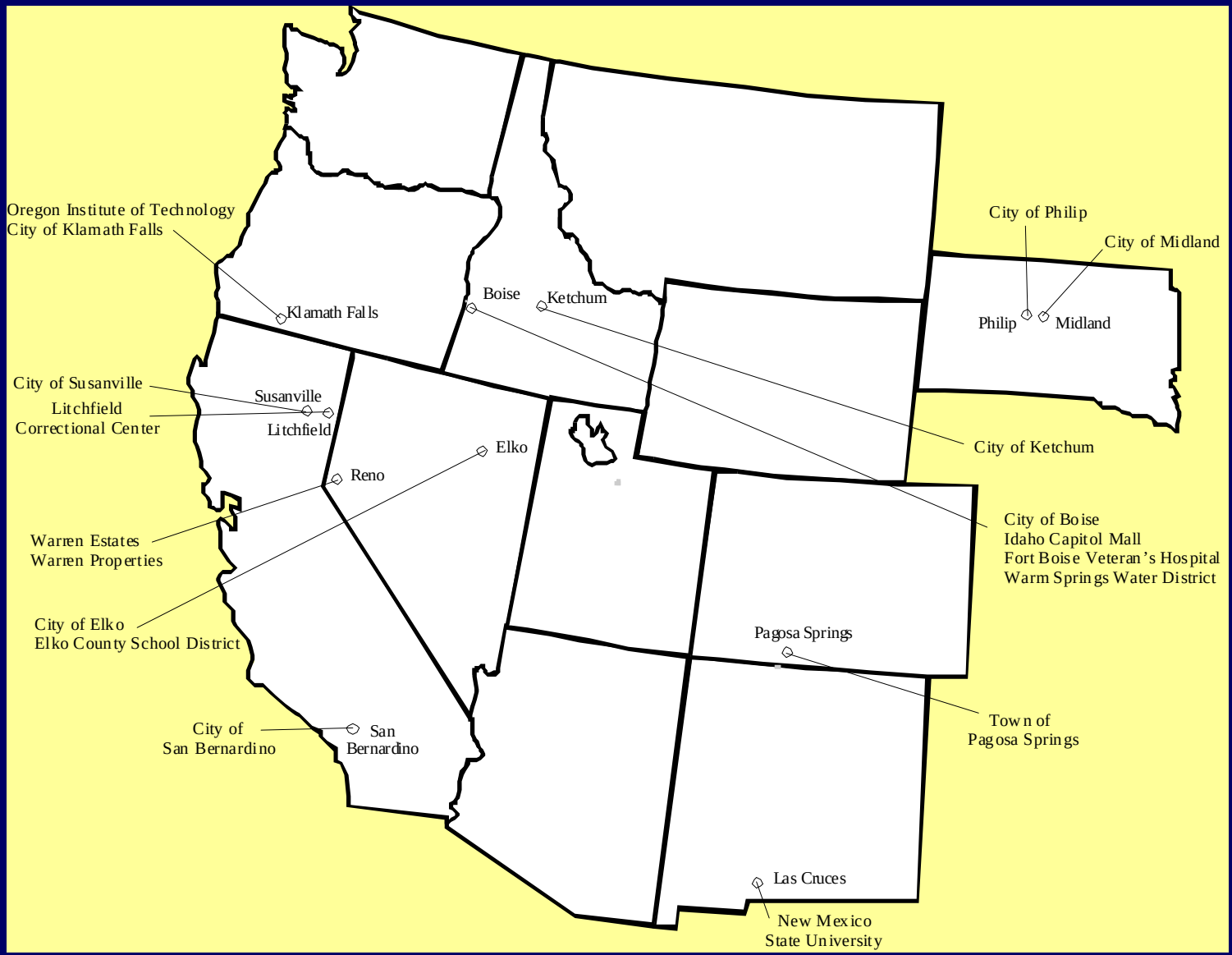
Glenwood Springs, CO – largest in the U.S.

Space Conditioning (1)

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

Space Conditioning (2)

- District heating in 18 locations in the US
- Piping system
  - Single pipe – once through system – disposal
    - Environmental problems
  - Two pipe – recirculation – residual heat conserved
    - 20 to 30% more expensive

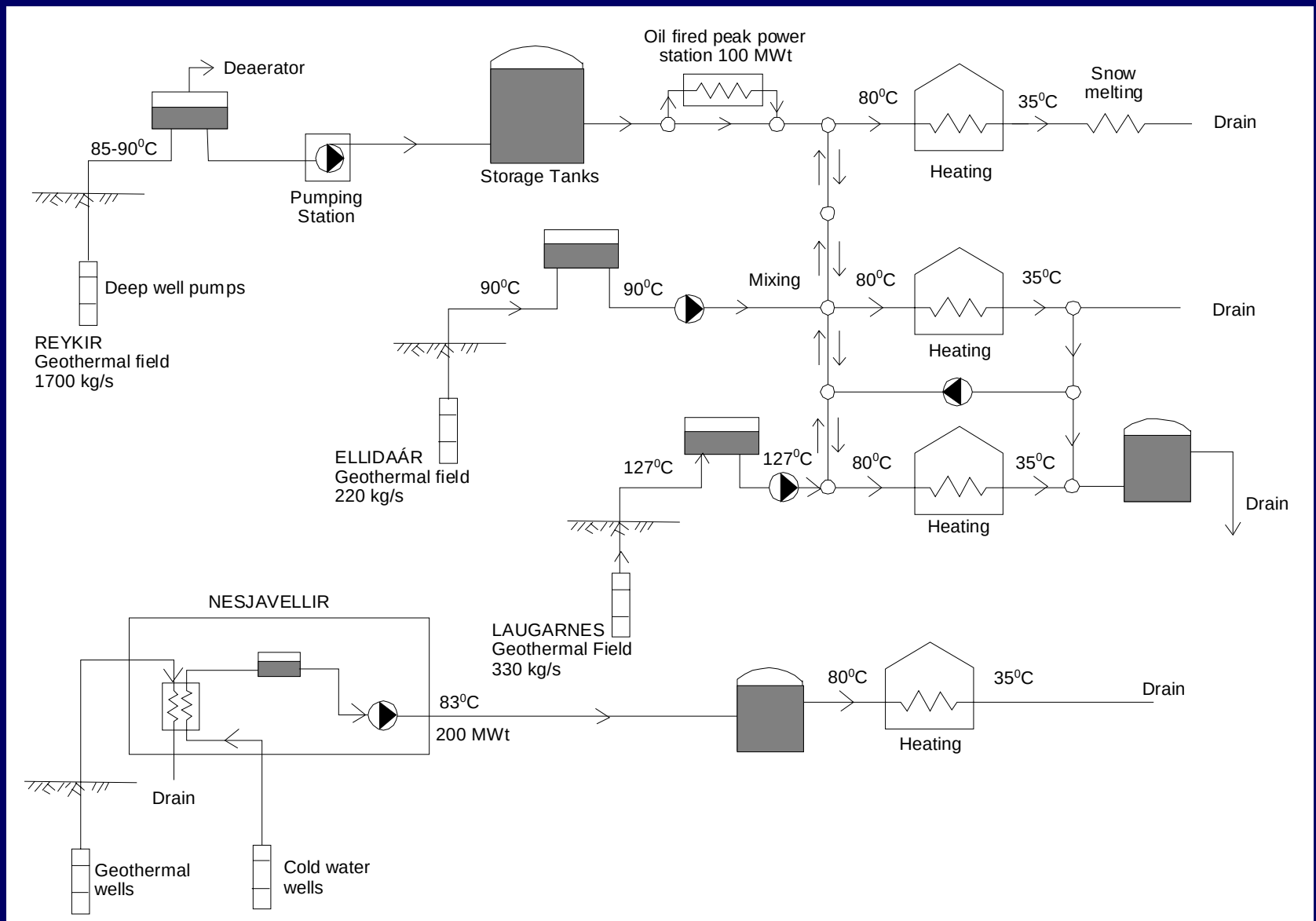


Geothermal District Heating in the U.S.

District Heating – Examples (1)

Reykjavik, Iceland

- Started 1930
- 190,000 people (99.9% of city)
- 190^{o} to 260^{o}F water – supplied at 175^{o}F
- Adequate to –15^{o}F
- 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

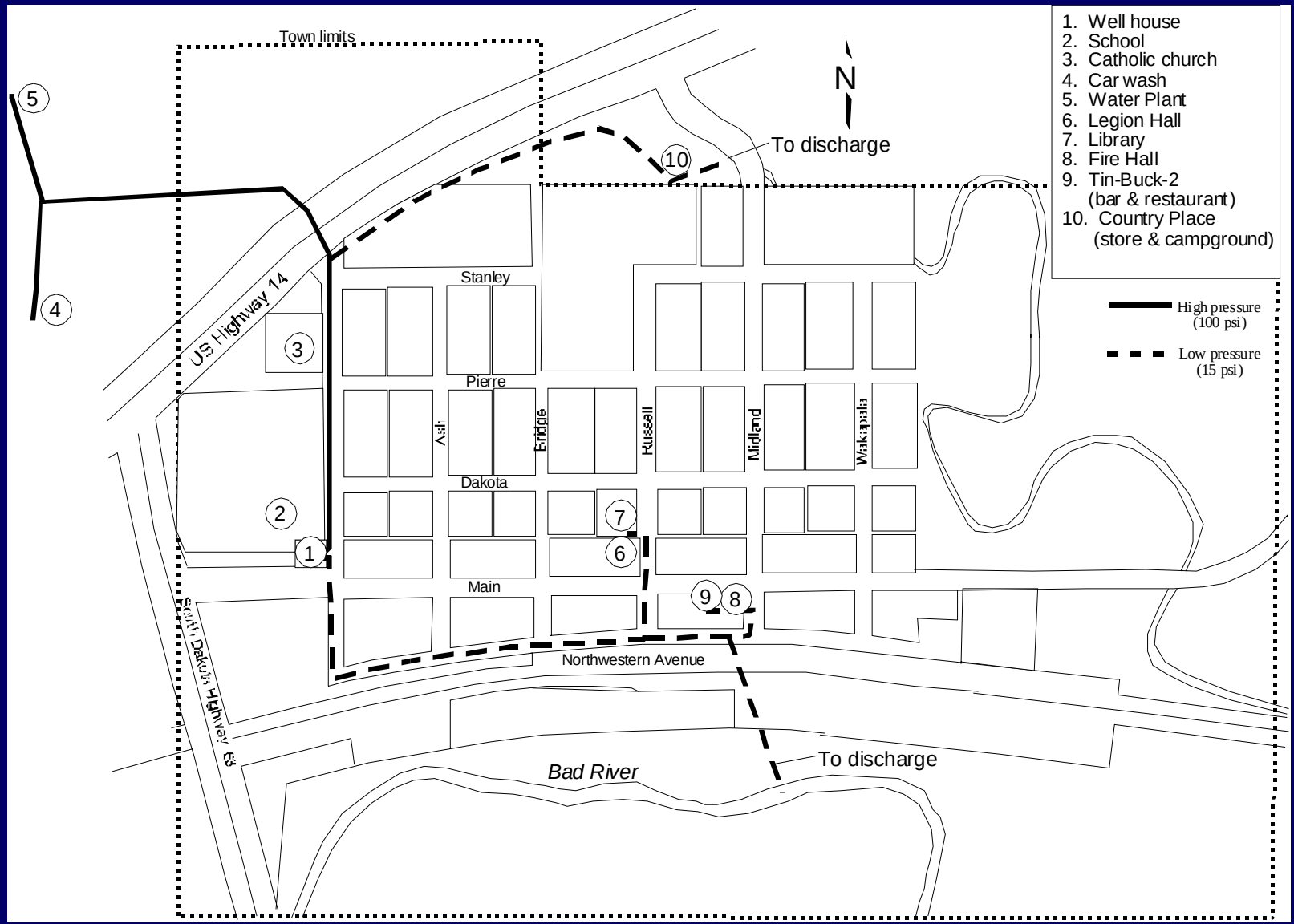

today


1930s

District Heating – Examples (2)

Midland, South Dakota

- Population 250 - 3,300 ft deep well drilled 1969
- 152^{o}F – 180 gpm – artesian – high & low pressure
- Heats: school, Legion Hall, library, fire hall, and bar/restaurant
- Also used to water cattle, car wash, wash farm equipment and heat swimming pool
- Water is then treated and used for domestic consumption (high pressure line)



Midland, South Dakota – Geothermal District Heating

Suwa, Japan – district “bathing” system

Agribusiness Applications (1)

- Greenhouse heating (flowers, vegetables, tree seedlings)
  - 5 to 35% savings in 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, alfalfa drying (pellets)
- Klamath Falls, OR
  - Tree seedlings, tropical fish

Tianjin Chicken and Duck Factory, China

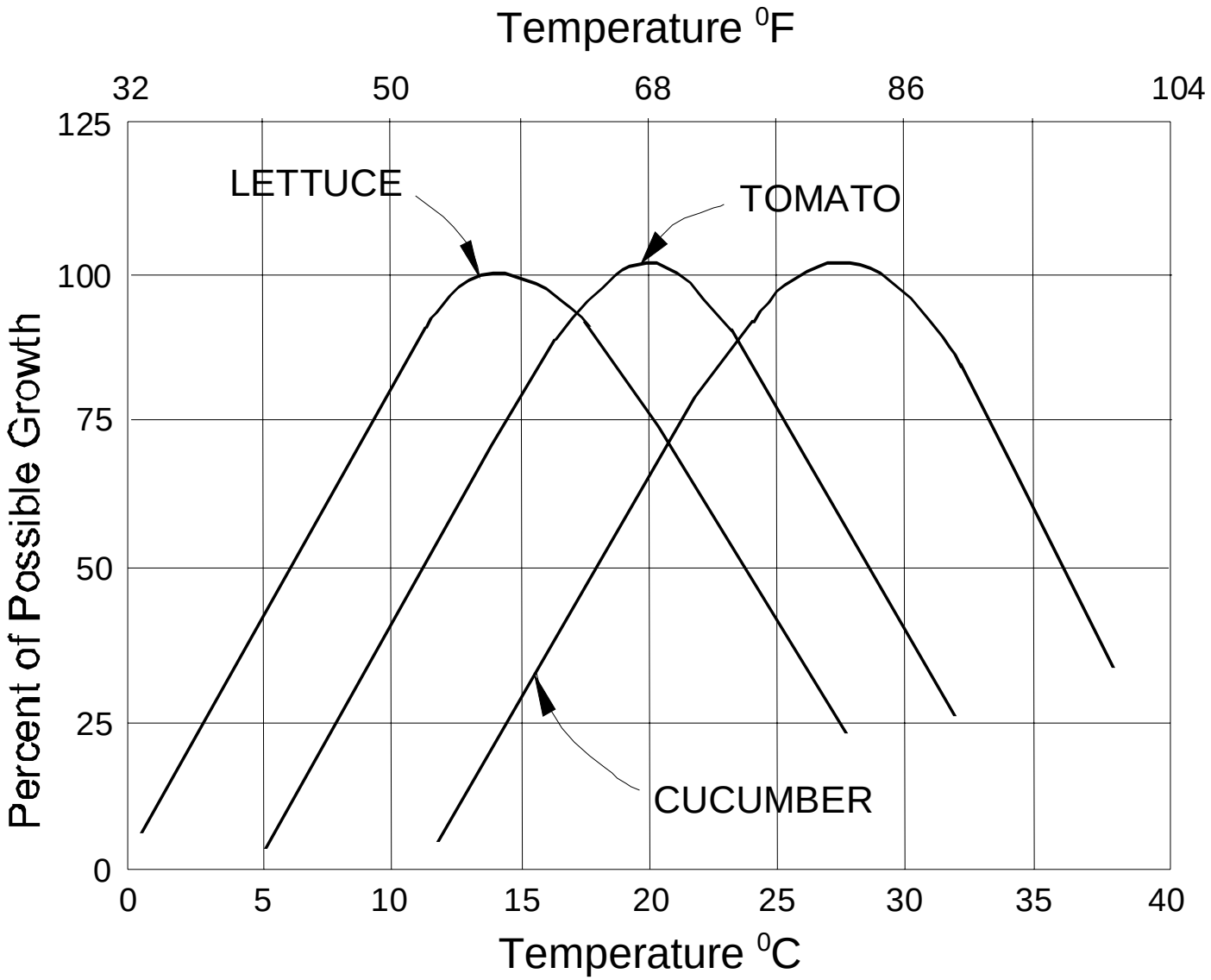
(Peking Ducks)

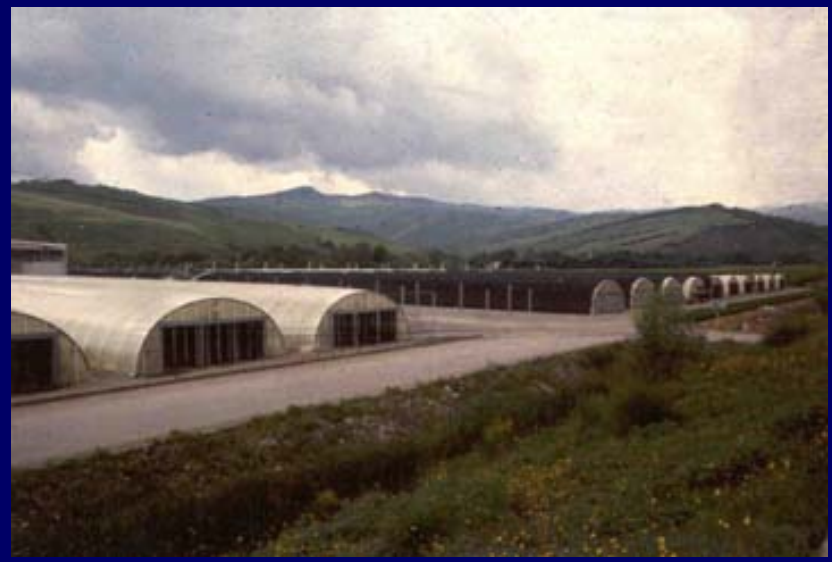
138°F

30 lbs/hr

4 tons/yr

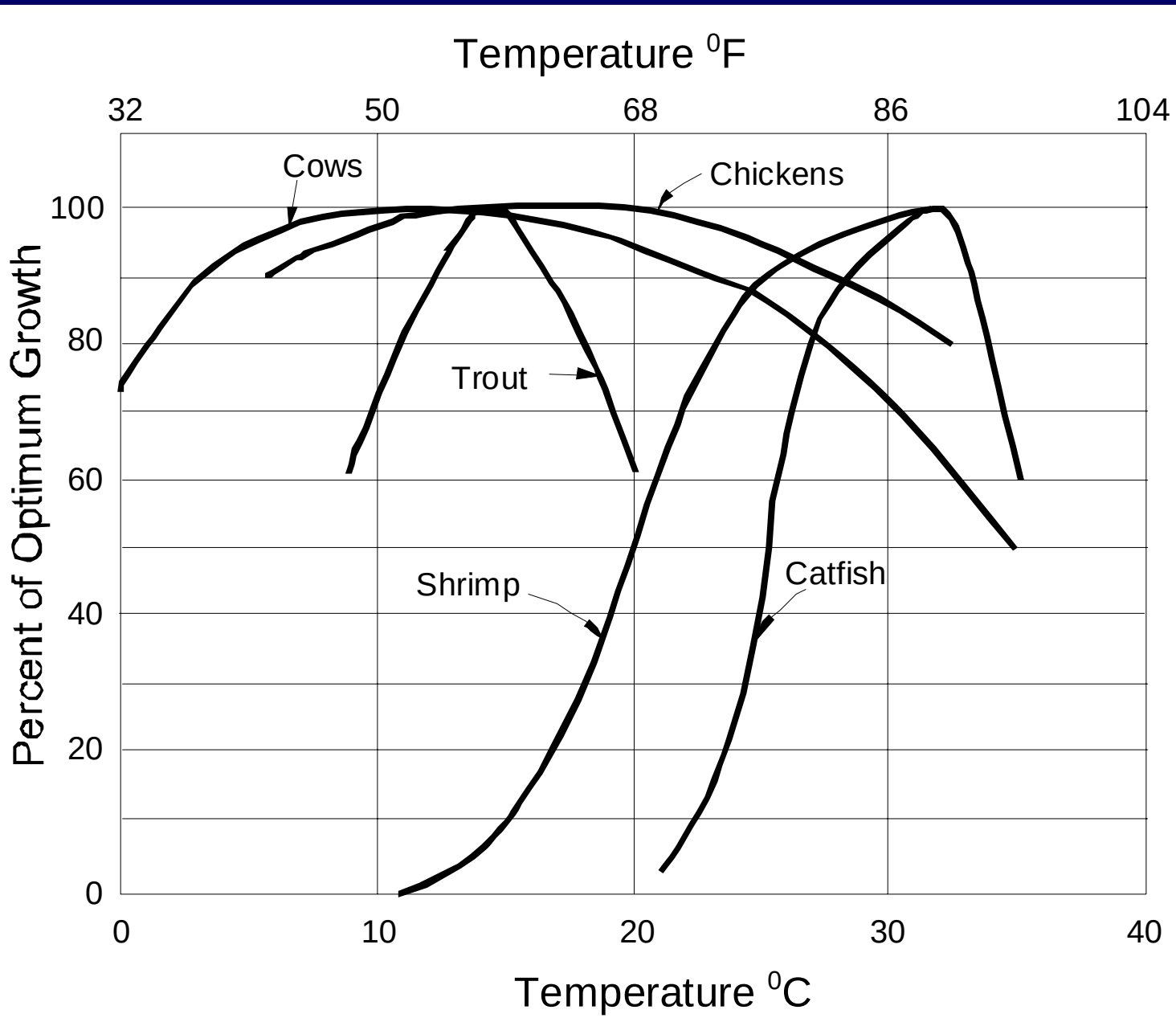
Tomato drying - Greece


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 heating systems

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

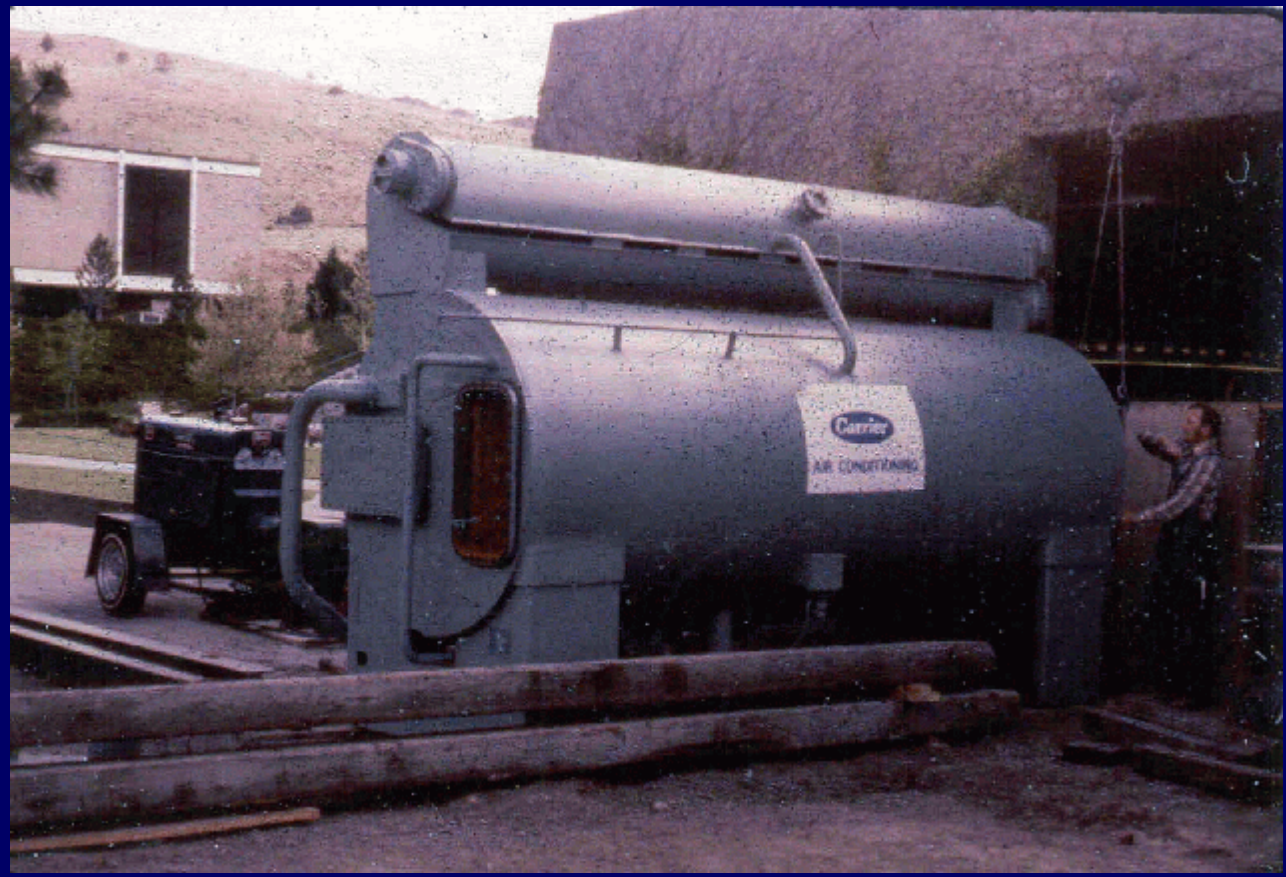
Aquaculture – Example

Wairakei, New Zealand – freshwater prawns

- 19 ponds – 0.5 to 0.9 acre – 3 to 4 ft. deep
- 75^{o}F – effluent from power plant
- Produces 30 tons/yr
- Harvested after 9 months at 14 to 18 tails/lb
- Sold for US$17/lb wholesale and US$27/lb retail
- 90% sold to restaurant on the property
- 25,000 tourists/yr
- Future expansion to 100 acres and will produce 400 tons/yr – income of US$ 6.7 mill.

Refrigeration

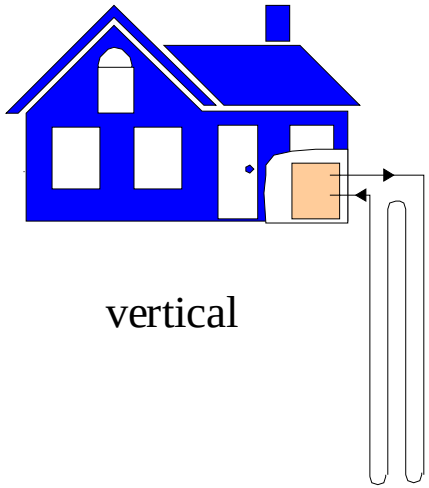
- **Lithium bromide system (most common – uses water as the refrigerant)**
  - **Supplies chilled water for space and process cooling – above the freezing point**
  - **The higher temperature, the more efficient (can use geothermal fluids below 200°F – however, >240°F better for 100% efficiency)**
- **Ammonia absorption used for refrigeration below freezing normally large capacity and require geothermal temperatures above 250°F**



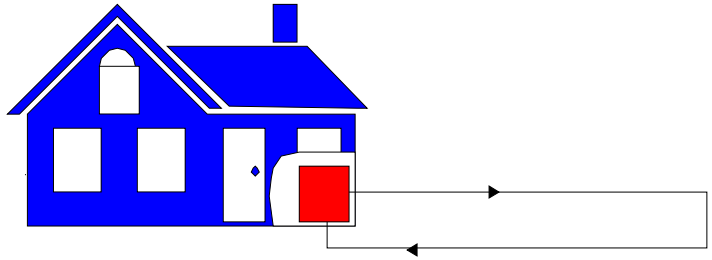
300 ton (150 ton net) chiller on OIT campus

Heat Pumps

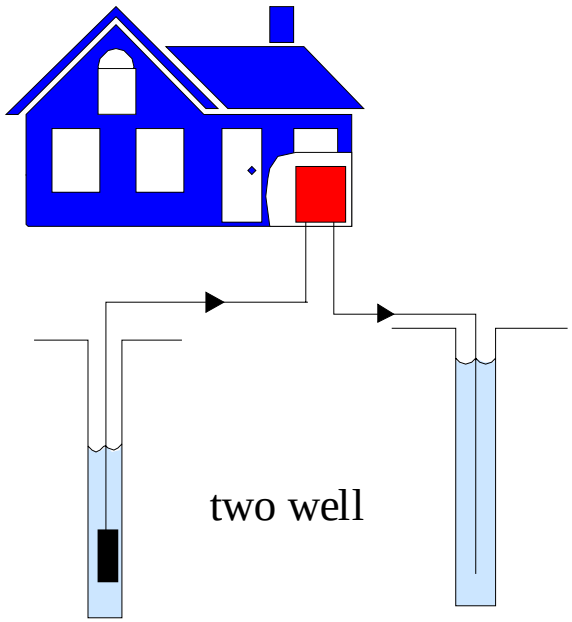
- Ground source and geothermal heat pumps (GSHP or GHP) – uses 40 to 90°F ground temperature
- Used for both heating and cooling
- 50 to 100% more efficient than air source, since uses constant temperature resource
- 33 countries – US the leader
- >600,000 units installed in the US
- Growing at a rate of 25% per year



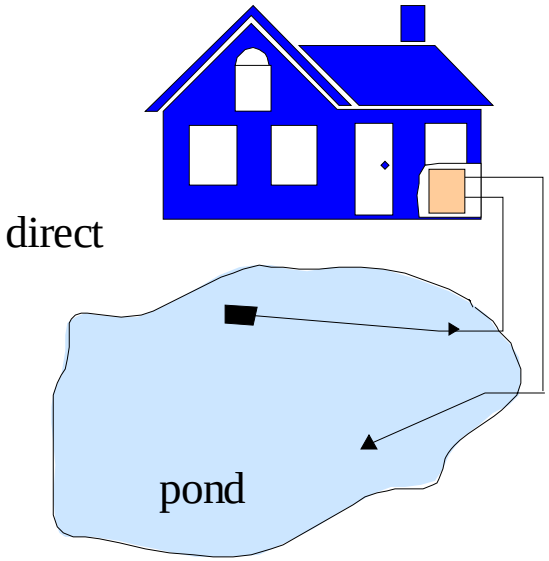
vertical



horizontal



two well



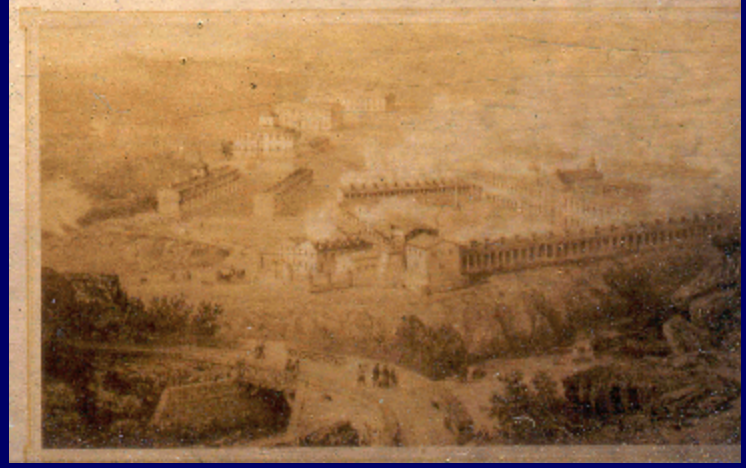
direct

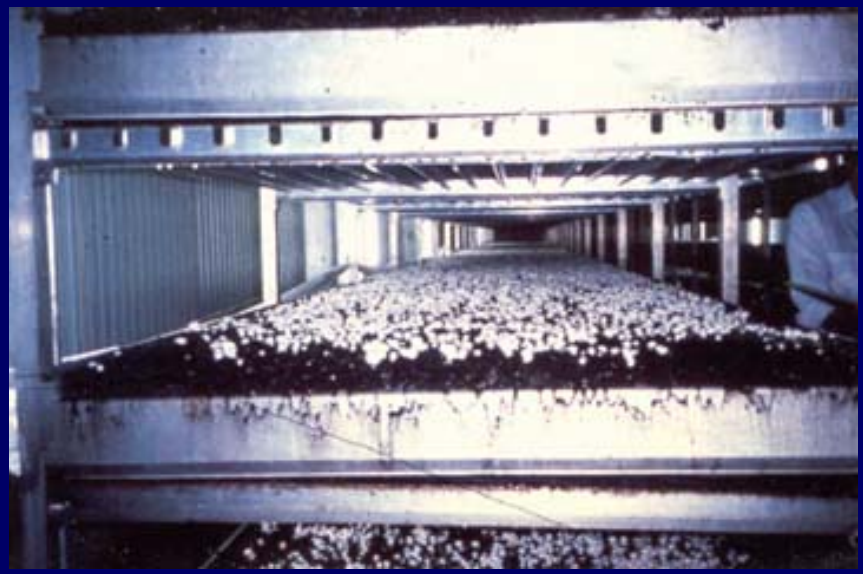
pond

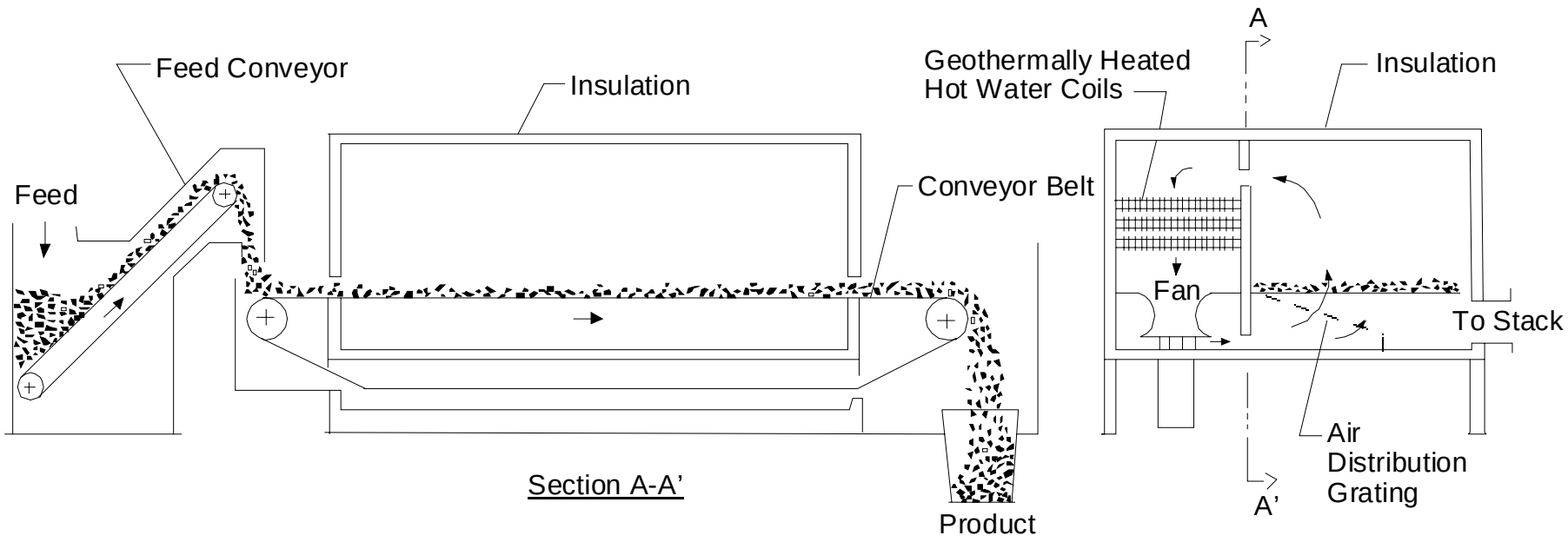
Industrial Applications

- **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**
  - **Fish drying and salt production**
- **USA: vegetable dehydration (onion) – Nevada & gold extraction (heap leaching) - Nevada**

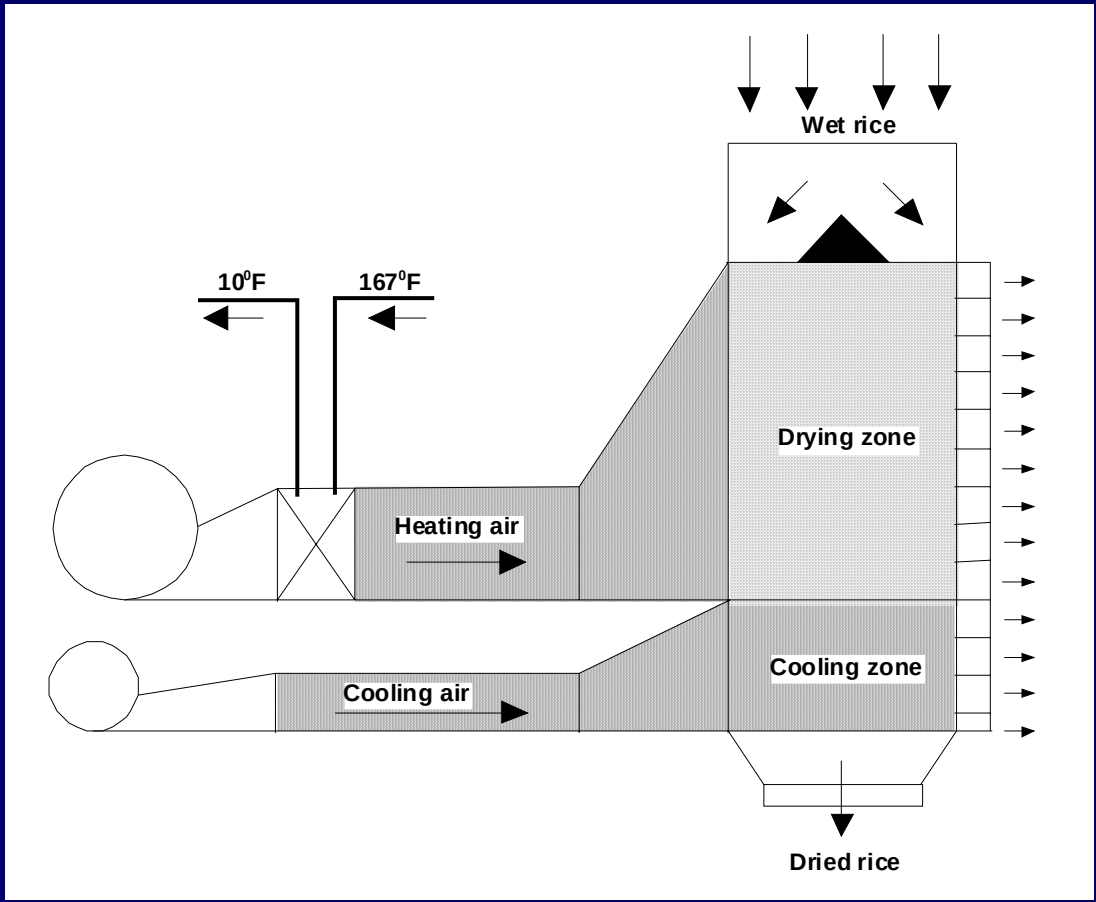
The "Factory" in Larderello, 1850. Natural thermal energy was used to extract boric acid from nearby pools. Later the geothermal steam was used to produce electricity.






Feed Conveyor
Insulation
Feed
Conveyor Belt
Section A-A'
Product
A
Geothermally Heated
Hot Water Coils
Insulation
Fan
To Stack
Air
Distribution
Grating
A'

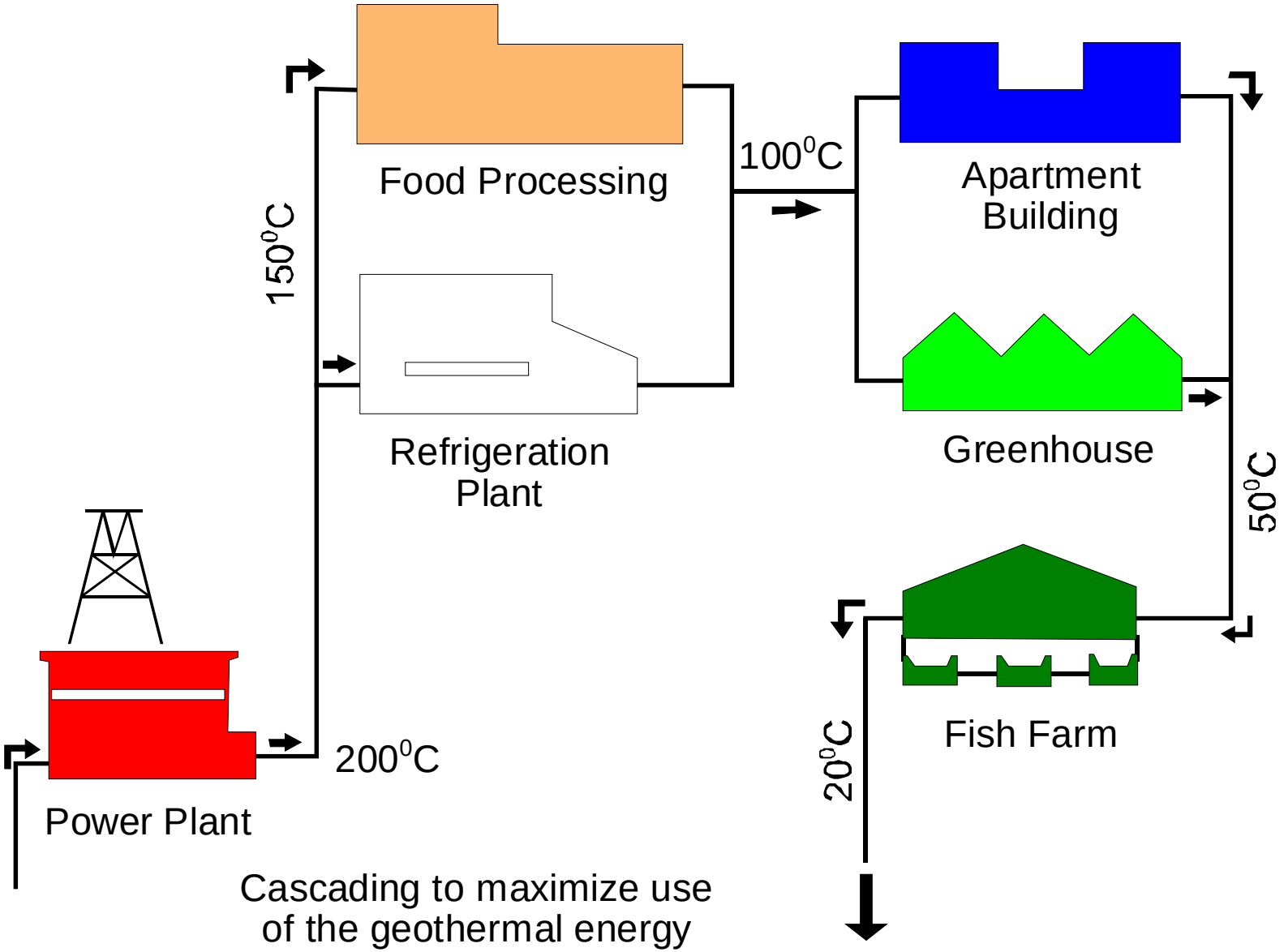
Onion and garlic drying - Nevada



Rice drying - Macedonia

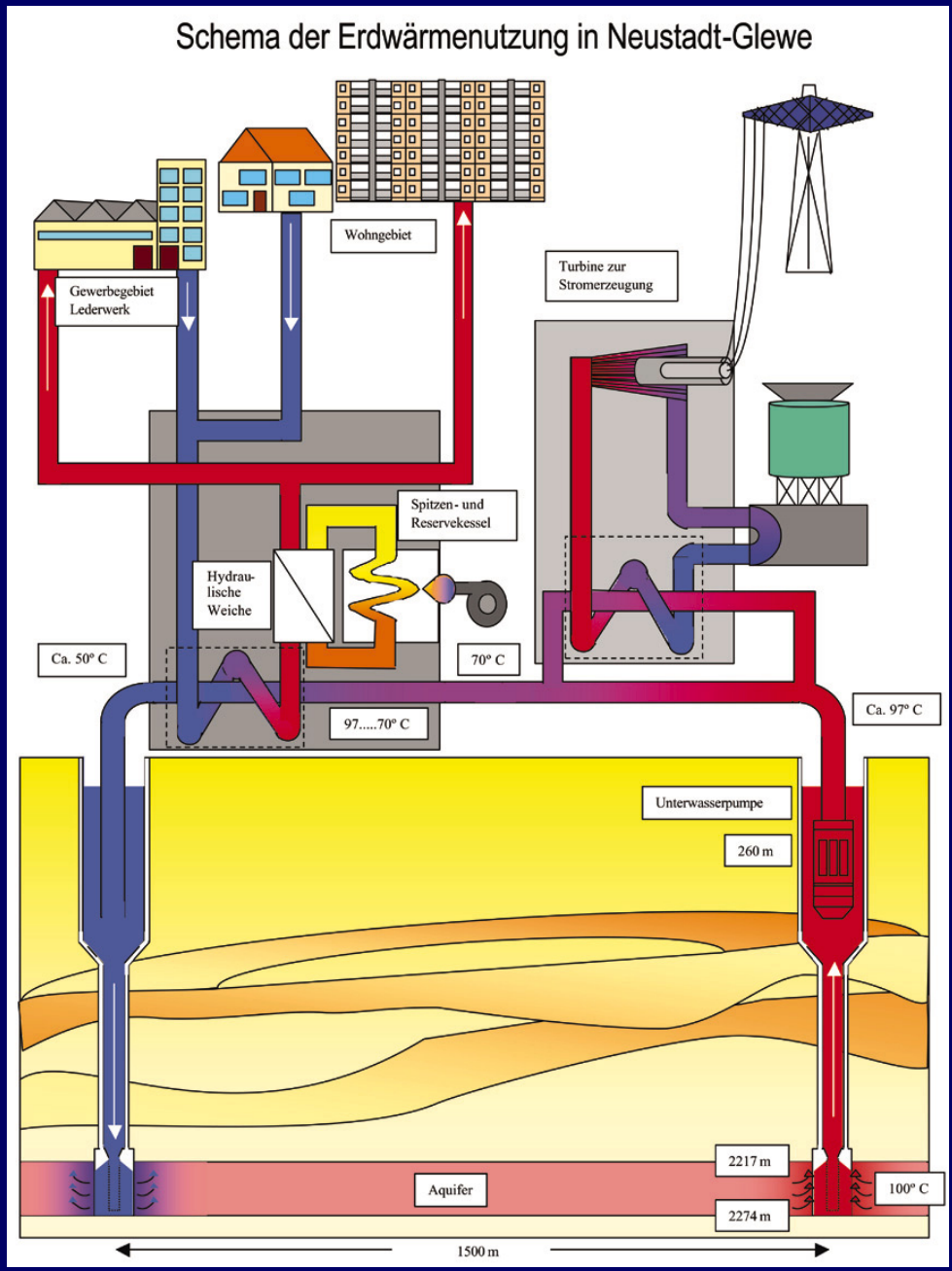
NEW TRENDS

- **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**
- **See GHC Quarterly Bulletin 26/2 (June 05)**


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

COMBINED GEOTHERMAL HEAT AND POWER PROJECT NEUSTADT GLEWE, GERMANY

- Wells drilled 1986 and 1989 – 7,500 ft
- Geothermal water at 208ºF – 2,700 gpm
- 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
260 m
2217 m
2274 m
Aquifer
100° C
1500 m

Conclusions

- **High temperature** >300 to 350°F
  flash steam electric power
  industrial applications
- **Intermediate temperature:** 230 to 300°F
  binary cycle electric power
  space cooling, some industrial
- **Low temperature:** 90 to 230°F
  greenhouses, aquaculture,
  & space heating
- **Normal ground temperature** <90°F
  pools and geothermal heat pumps

Space & Domestic Hot Water Heating

- **>140°F geothermal water best to provide 120°F tap water - used for wash water, shower water and kitchen water uses**
- **>120°F best to provide 100°F space heating using forced air, hot water radiators or radiant floor heating**
- **>100°F best for swimming pools to give 75°F pool water**

Future Developments

- **Collocated resources and use**
  - **Within 5 miles of a "community" – over 400 in the U.S.**
- **Sites with high heat and cooling load density**
  - **> 96 MWt/mile^2 (328 million Btu/hr peak load)**
- **Food and grain dehydration**
  - **Especially in tropical countries where spoilage is common – and to extend the work season**
- **Greenhouses in colder climates**
- **Aquaculture**
  - **Optimize growth – even in warm climates**
- **Ground coupled and ground water heat pumps**
  - **For both heating and cooling**
- **Combined heat and power projects - cascading**

THANK YOU