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 (<300°F)
- 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

Identified reservoirs
Temperature use for direct use applications
Geothermal Energy Uses

Typical uses of geothermal energy at different temperatures

- **700°F (371°C)**: Flare & Dry Steam Geothermal Power Plants, Hydrogen Production & Minerals Recovery
- **400°F (204°C)**: Flash & Dry Steam Geothermal Power Plants, Hydrogen Production
- **350°F (177°C)**: Binary Geothermal Power Plants, Hydrogen Production
- **300°F (149°C)**: Cement & Aggregate Drying, Onion & Garlic Drying
- **250°F (121°C)**: Binary Geothermal Power Plants, Hydrogen Production
- **200°F (93°C)**: Fruit & Vegetable Drying, Soft Drink Carbonation, Mushroom Culture
- **150°F (66°C)**: Food Processing, Mushroom Culture
- **100°F (38°C)**: Snow Melting & Deicing, Geothermal Heat Pumps
- **70°F (21°C)**: Biodiesel Processing, Aquaculture
- **60°F (16°C)**: Bathing, Soil Heating & Cooling
- **50°F (10°C)**: Geothermal Heat Pumps
- **40°F (4°C)**: Geothermal Heat Pumps

*Geothermal electricity can be used to produce renewable hydrogen.
**Cold 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
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.
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$_2$S – and solder
  - Non-metallic $< 200^\circ$F
Piping (2)

Material

- **Carbon steel** >200°F
  - Expansion loops or bellows
- **FRP or PVC** <200°F – Fiberglass reinforced plastic and polyvinylchloride
- **PEX** (200°F @ 80 psi) cross-lined polyethylene
  - 2.5 x cost of PVC – only small sizes available
- **Fiberglass** < 300°F – expensive 3.5x PVC
- **AC** – Asbestos cement
  - Environmental limitation
  - Longest = Deildartunga – Akranes, Iceland at 38 miles
Concrete Block
Gravel
Concrete
Compacted Gravel
Polyurethane or Rock Wool Insulation
Aluminium or Galvanized Steel Protective Cover
Steel Pipe
Roller and Pad
Aluminium or Galvanized Steel Protective Cover
Concrete Block
Compacted Gravel
Gravel
Earth
Polyethylene Cover
Polyethylene Foam
Steel Pipe
Earth
Gravel Layer
Sand Layer around Pipe
Drainage Trench
Grass Cover
Asbestos Cement or Plastic Pipe
Scoria (Volcanic Gravel)
Drain Pipe
Concrete Duct
Polyurethane or Rock Wool Insulation
Steel Pipe
Soil Fill
Gravel Fill
Polyethylene Cover
Polyethylene Foam
Grass Cover
Soil
Drainage Trench
1.5
1
0.75
1
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
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° to 260°F water – supplied at 175°F
- Adequate to –15°F
- 830 MWt
- 62 wells
- Large storage tanks for peaking
- Oil fired booster station
District Heating – Examples (2)

Midland, South Dakota

• Population 250 - 3,300 ft deep well drilled 1969
• 152°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)
1. Well house
2. School
3. Catholic church
4. Car wash
5. Water Plant
6. Legion Hall
7. Library
8. Fire Hall
9. Tin-Buck-2 (bar & restaurant)
10. Country Place (store & campground)

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)
Tomato drying - Greece

138°F
30 lbs/hr
4 tons/yr
The diagram illustrates the relationship between temperature (°C) and percent of possible growth for three different plants: CUCUMBER, LETTUCE, and TOMATO. The x-axis represents temperature in °C, while the y-axis represents percent of possible growth. The curves show how each plant's growth changes with temperature. CUCUMBER has a higher optimal temperature range compared to LETTUCE and TOMATO. LETTUCE has a lower optimal temperature range, while TOMATO falls in between, indicating different temperature tolerances for each plant.
Greenhouse heating systems
Greece
Aquaculture – Example

Wairakei, New Zealand – freshwater prawns

• 19 ponds – 0.5 to 0.9 acre – 3 to 4 ft. deep
• 75°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
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, 1886.
Natural thermal energy was used to extract boric acid from nearby pools. Later, the geothermal steam was used to produce electricity.
Onion and garlic drying - Nevada
Rice drying - Macedonia

Wet rice

Heating air

Cooling air

Cooling zone

Drying zone

Dried rice

10°F  167°F
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°C are being used
  – Makes efficient use of the resources
  – Improves economics

• See GHC Quarterly Bulletin 26/2 (June 05)
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
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

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