CASCADED USES OF GEOTHERMAL ENERGY

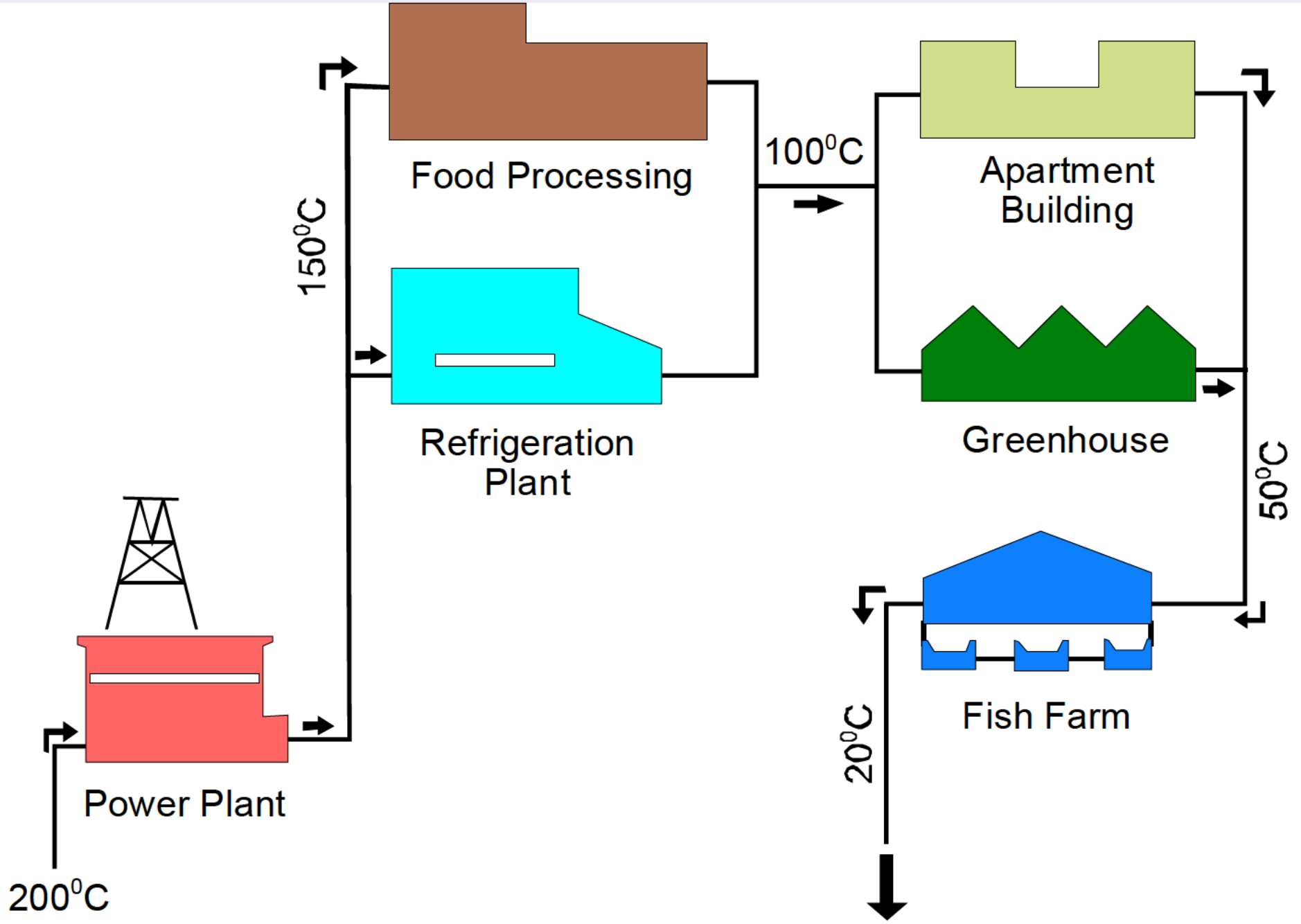
Paul Brophy
EGS, Inc. & GRC President
John W. Lund
Emeritus Geo-Heat Center
Tonya "Toni" Boyd
Emeritus Geo-Heat Center

INTRODUCTION

- Cascading is not a new concept
- Combining heat and/or power provides
  - Increased net efficiency
  - Improved economics
- Thermodynamics of geothermal plants
  - Lower than conventional plants
  - Due to lower working fluid temperatures
    - (550^{o}C vs <200^{o}C – 1,200 vs <390°F)

INTRODUCTION 2

- 1 MWe geothermal plant with resource of 150^{o}C (300°F) = 10% net efficiency
- Thus, need 10 MWt of energy as input or parasitic loads to produce 1 MWe output.
- However, “waste” heat can be recovered for beneficial use = i.e. for direct-use
- Resulting in efficiency of the operation improved dramatically


Food Processing
100°C
Apartment Building
150°C
Refrigeration Plant
Greenhouse
50°C
Power Plant
Fish Farm
20°C
200°C

EXAMPLE 1

- Consider: Power plant and dehydration plant
- Assumptions
  - 150°C resource (300°F)
  - 2.0 MWe net binary power plant
  - US$0.07 per kWh power sales price
  - 10-month dehydration operation
  - 13,600 tonnes annual production (2 lines)
  - US$2.20/kg (US$1.00/lb) dried product wholesale price

EXAMPLE 1A

- High temperature geothermal resource **(150ºC – 300°F)** cascaded with flow of **76 L/s (1,200 gpm)**
- Provide energy for **2 MWe** power plant with three employees generating US$1 million/yr = simple net payback of **6 years**
- Adding a two-line onion dehydration plant producing **13,600 tonnes** of dried product/yr with 0.83 load factor with 75 employees = combined net payback of **2 years**

EXAMPLE 1B

- **Power plant and dehydration plant**

	Power plant	Dehydration plant
Capital Expenditure	$5 mill.	$15 mill.
Gross Revenue	$1.1 mill.	$18 mill.
Net Revenue	$0.9 mill.	$10 mill.
Resource required	76 L/s (1,200 gpm cascaded)	76 L/s
Employees	3	75

Payback (6 years for power plant vs 2 years for combined ops)

*source: D. Mendive, Geothermal Development Assoc., Reno, NV

EXAMPLE 2

- Low temperature geothermal resource **(100°C -** 212°F**)** cascaded with a flow of 44 L/s (700 gpm).
- Provides energy for a **250 kWe** binary power plant with one employee generating around **US$140,000/yr** = simple net payback of **6 years**
- Adding a greenhouse operation of **24 ha** (60 acres) with 0.25 load factor = simple net payback of **3 years** and employing **144 workers**

EXAMPLE 2A

- **Power plant and greenhouse**

	Power plant	Greenhouse operation
Capital Expenditure	$0.63 mill.	$30 mill.
Gross Revenue	$0.14 mill.	$10 mill.
Net Revenue	$0.11 mill.	$ 9 mill.
Resource required	44 L/s (700 gpm cascaded)	44 L/s
Employees	3	144

Payback (6 years for power plant vs 3 years for combined ops)

SUDURNES REGIONAL HEATING

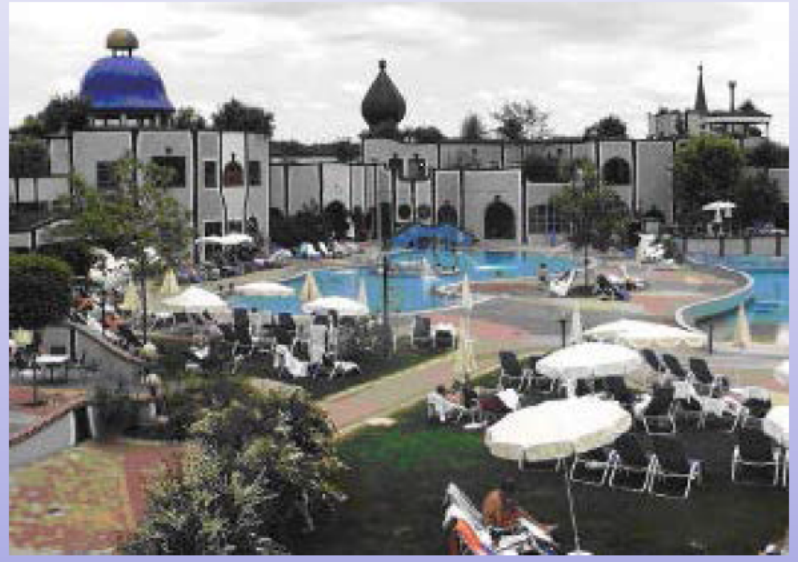
- Combined heat and power plant using 242^{o}C (468^{o}F) geothermal resource from 12 production wells
- Serving 20,000 person on Reykjanes Peninsula, Iceland with heat and power
- Plus 25,000 others with electricity
- 46.4 MWe providing 370 GWh/yr
- 200 MWt providing 2,700 TJ/yr (2,500 GBtu/yr)
- Blue Lagoon visited by 200,000 tourist/yr

<u>Svartsengi, Iceland</u>
combined heat and power plant - 242ºC (468°F)
200 MWt heat and 46 MWe electricity (8.4 MWe binary)

BAD BLUMAU, AUSTRIA

- Well water at 110^{o}C (230^{o}F)
- 250 kW binary (ORMAT) cycle plant
- 180 kW net
- 85^{o}C (185^{o}F) “waste” water fed to district heating system for Rogner Bad Blumau Hotel and Spa – including heating of a 2,500 m^{2} (27,000 sq.ft.) swimming pool
- 3.5 MWt heating + 1.5 MWt pool = 5.1 MWt total capacity
- 40,000 tourists annually with 340 jobs

BAD BLUMAU, AUSTRIA



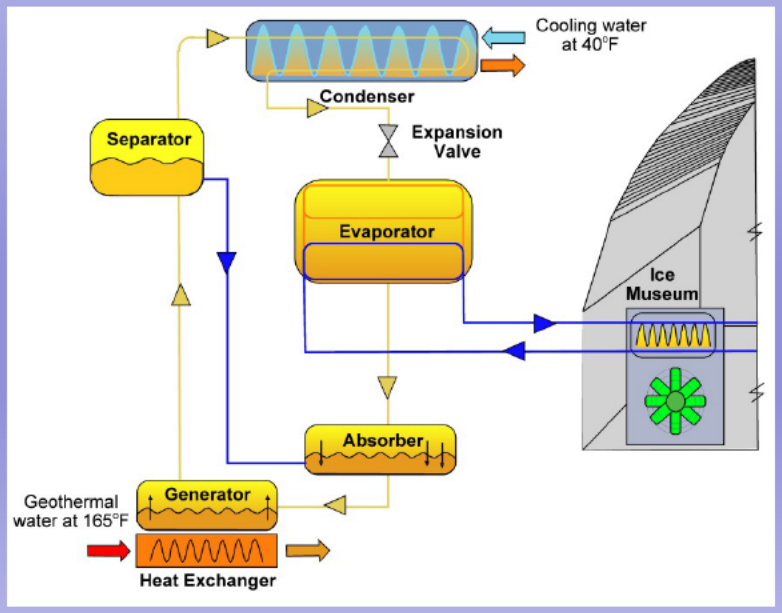
SPACE HEATING AT CHENA

- Geothermal heats approximately 10,700 m^2 (115,000 ft^2) of floor space
- 7 greenhouses: volume 5,000 m^3 (175,200 ft^3)
- Indoor and outdoor pools – 630 m^2 (6,800 ft^2)
- Using geothermal for the resort saves $535,000/yr in heating costs
- Heating with geothermal alone has a simple payback of 4 years compared to diesel.
- Geothermal offsets about 511 m^3 (135,000 gals) of diesel/yr.

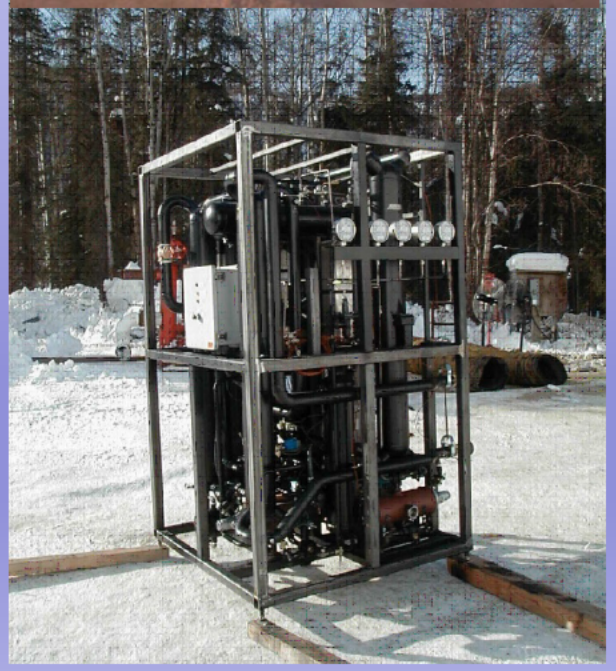
GEOTHERMAL POWER AT CHENA

- 1998 – First geothermal well drilled
  - Provided Heat for the resort
- 2006 – Second well drilled and two 200kW power plants were installed
  - Both units were online by 2007
- 2014 – Screw Expander power plant installed
- Producing 1.3 million kWh/yr
- $400,000/yr savings
- Saves 400 m^3 (105,000 gal) of diesel/yr
- Lowest temperature geothermal use for power generation in the world
- 74°C (165°F) resource and 5°C (41°F) cooling water

Chena Hot Springs Resort – Ice Museum



5.4 l/s @ 74°C geothermal
5.0 l/s @ 4°C river water.
Supplied at -20°C @ 3.5 l/s to museum



Absorption chiller 33 kW

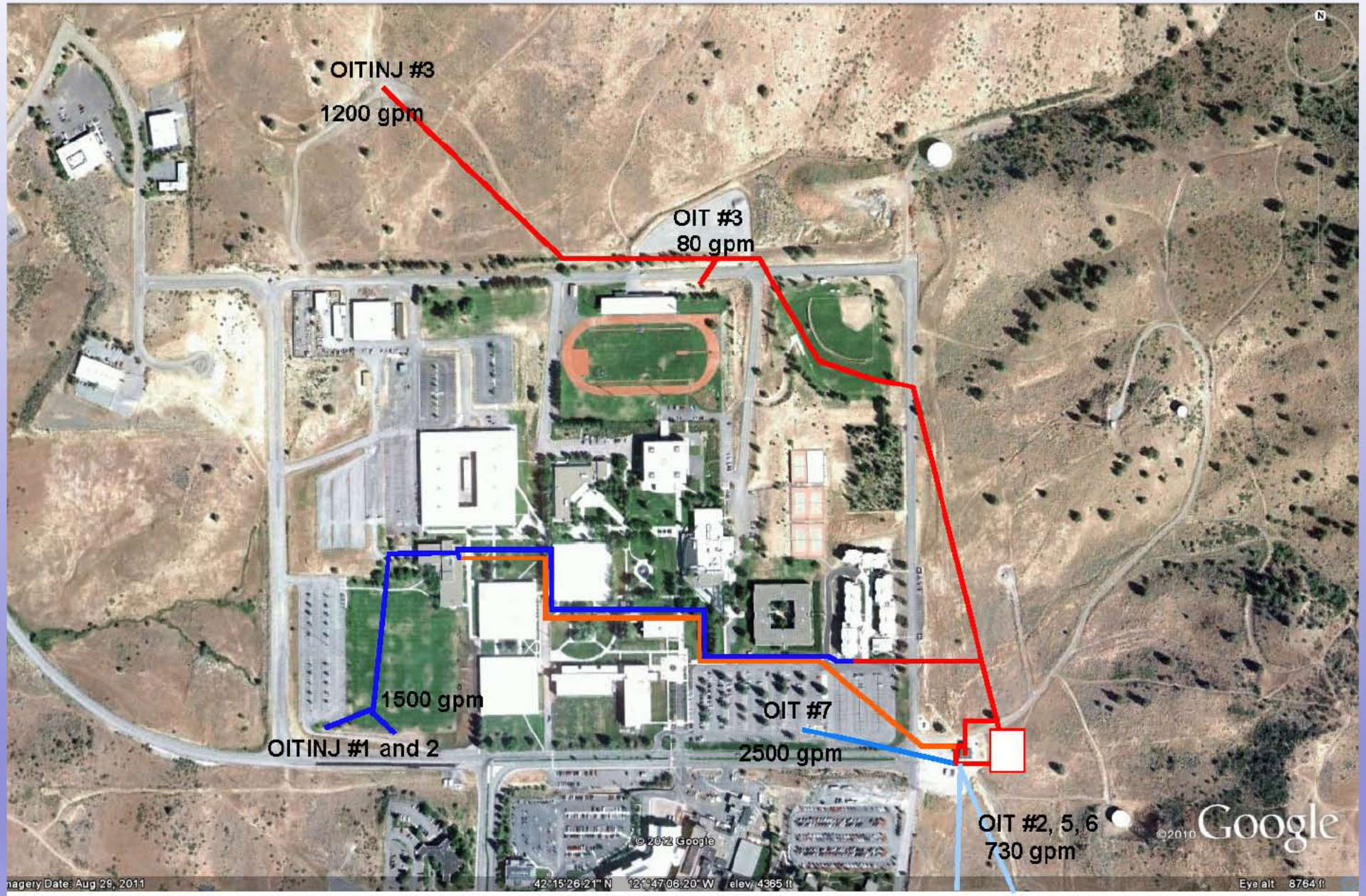
Oregon Institute of Technology

91°C (196°F) water

4 wells: 400 – 1,600 m (1,200 – 5,300 ft)

6 MWt – 14 GWh/yr

Saving $1mil/yr in heating cost


OITINJ #3
1200 gpm
OIT #3
80 gpm
1500 gpm
OITINJ #1 and 2
OIT #7
2500 gpm
OIT #2, 5, 6
730 gpm
©2010 Google
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#7 Supply line
BPP Effluent line
Heating Supply Line
Heating Return Line
OIT 5 and 6 Supply line

LOW TEMPERATURE POWER PLANT SUMMARY

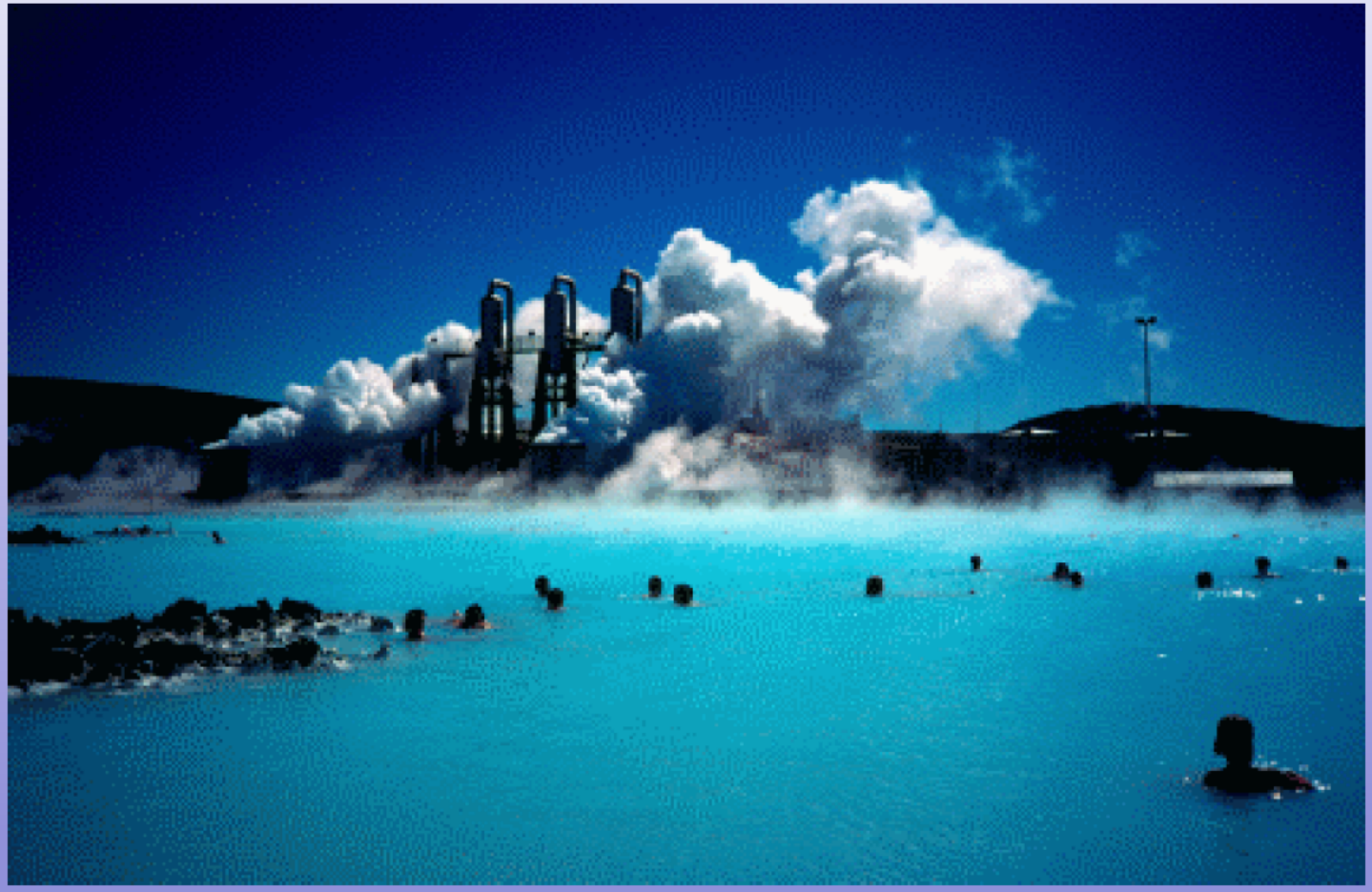
- Use existing wells at approx. 38 l/s (600 gpm)
- Take >8^{o}C (>15^{o}F) off the top (89 - 81^{o}C = 192 – 177^{o}F)
- Remainder adequate to heat campus
- Binary (organic Rankine cycle) power plant – 280 kW gross (85-140 kW net)
- Water cooling though a cooling tower (21^{o}C = 70^{o}F)
- Demonstration site and student laboratory
- New 1.75 MWe binary power plants added 2014

280 kW UTC unit – evaporator HE (bottom), condenser HE (top), turbine-generator set covered

CONCLUSIONS

- Combined heat and power plants improve:
  - Efficiency and economics of the project
- Cascading from the power plant provides energy for direct-use project
  - District heating
  - Greenhouse and fish pond heating
  - Industrial applications
  - Spa and pool heating
- High load factors are better
- Job creation additional benefit
- Need good coordination between operators

CASCADED USE AT ITS BEST



THANK YOU