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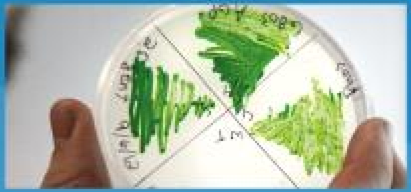



Low-Temperature Projects of the Department of Energy's Geothermal Technologies Program: Evaluation and Lessons Learned

Geothermal Resources Council 40th Annual Meeting
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NREL is a national laboratory of the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, operated by the Alliance for Sustainable Energy, LLC.

DOE Low Temperature Demonstration Projects

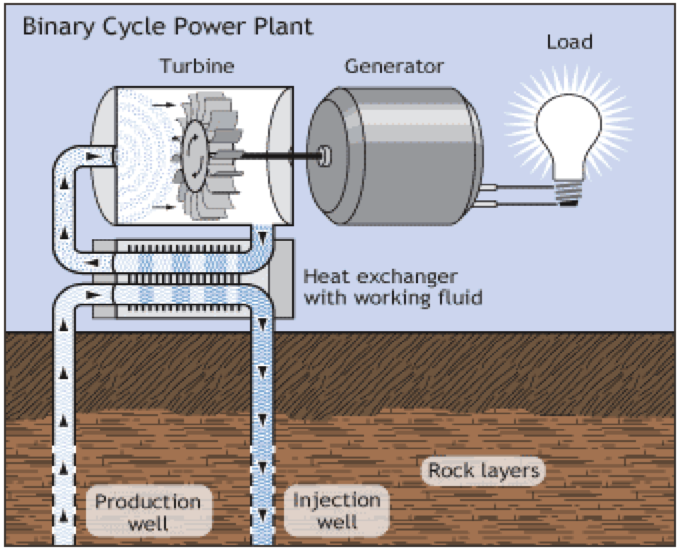
- American Recovery and Investment Act (2009) launched a series of demonstrations
  - 18 Projects for production of electricity from low temperature (< 150 ° C) geothermal
  - 12 projects determined to be uneconomic in feasibility stage
  - 6 projects progressed to development stage
  - 4 projects operational today
- What are some of the lessons learned?

How we classify systems

- Common System Requirements
  - Low temperature geothermal resource is used
  - Electricity is produced
- Taxonomy
  - Binary cycle
  - Bottoming cycle
  - Hybrid systems
  - Geothermal coproduction
  - Combined heat and power

Binary Cycle

- Plants designed solely for electricity production using low temperature resources



Surprise Valley Integrated Hydrothermal Facility, photo Lynn Culp

University of North Dakota – Continental Resources

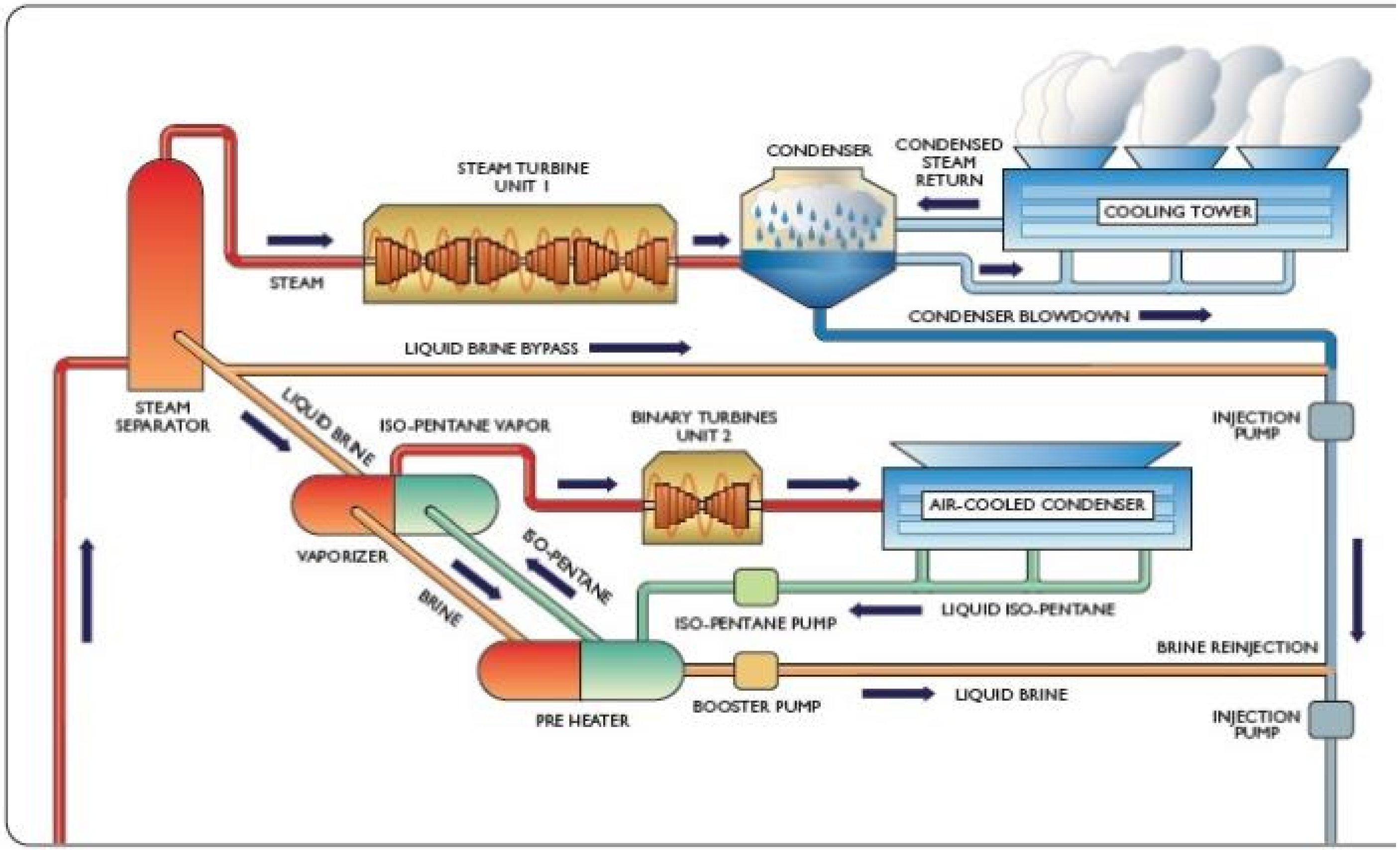
- Geothermal brine supplied from two open-hole horizontal wells
- Water used in secondary oil recovery
- 98 °C brine
- 51 kg/s flow rate
- Project included DOE grant
- Two 125 kW organic Rankine engines
- Project is located at Cedar Hills Field, which is a water flood EOR operation in Rhame, ND.
- Power production commenced April 2016

Power Generation Units

Access Energy XLT 125 kW Integrated Power Module

Low Temp Bottoming Cycles

Binary bottoming units installed on operating flash-steam power plants



http://www.pacificorp.com/content/dam/pacificorp/doc/Energy_Sources/EnergyGeneration_FactSheets/RMP_GFS_Blundell.pdf

Dixie Valley and Beowawe are two DOE funded projects that demonstrate this approach
See paper "DOE-GTO Low Temperature Project Case Study" presented at the Geothermal Resources Council 2015 Annual Meeting

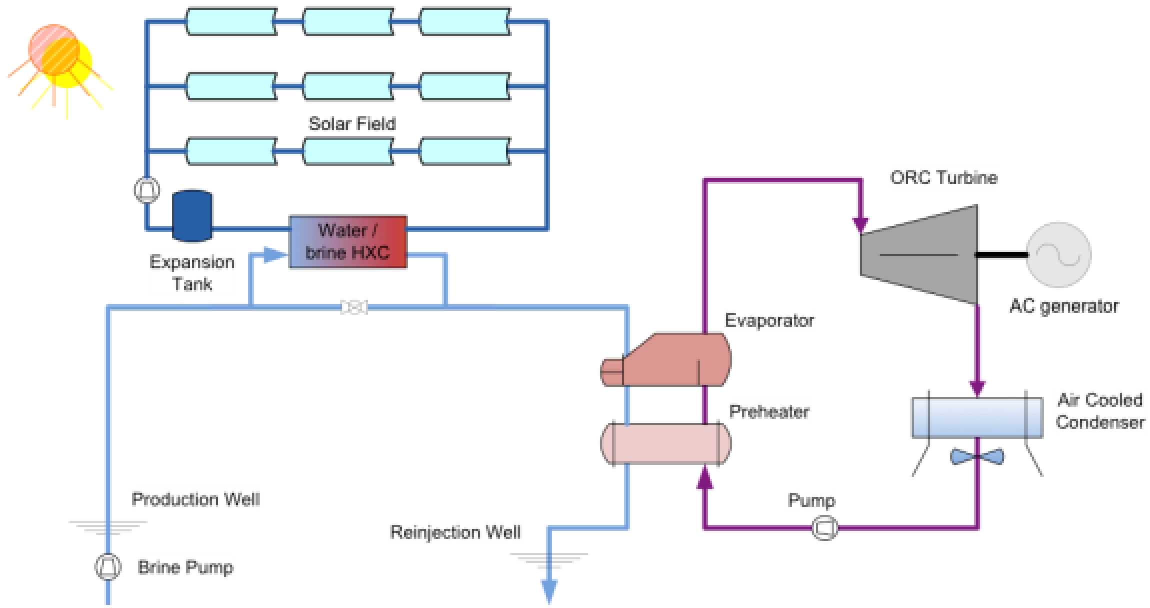
Geothermal Coproduction

- Water produced as a byproduct of oil and gas operations can have significant thermal energy
- Geothermal energy can produce electricity for field operations or sale

250 kW geothermal coproduction demonstration system at Rocky Mountain Oilfield Testing Center

Hybrid Systems

- Energy from a non-geothermal source integrated in power system
- Integration of thermal energy allows broader optimization of power cycle



Example of a hybrid geothermal / concentrating solar power plant

Hybrid Systems Potential Benefits

- Reduced reservoir development risk
- Offset output losses during high ambient temperatures
- Reduced reservoir decline risk
- Increased thermal conversion efficiency

Image: Enel Green Power

Enel Green Energy’s Stillwater power plant utilizes PV and Concentrating Solar Power to augment geothermal production

Combined heat and power

Rogner Bad Blumau Resort
Austria

- 250 kW electricity generation
- 5 MWt heat used for resort room heating and spa pools

http://www.insidersguidetospas.com/reviews/rogner-bad-blumau/

Fang Geothermal Plant
Thailand

- 300 kW electricity generation
- Thermal energy used for:
  - Crop drying
  - Crop refrigeration
  - Spa

Photo by Ormat http://www.ormat.com/print/471

Surprise Valley Case Study

- Geothermal discovered while drilling irrigation well
- Geothermal resource 112 °C
- 189 liter/second flow rate (3000 gpm)
- Project included DOE ARRA grant
- 2.4 MW net power

Image: Lynn Culp, Surprise Valley Electric Corporation

Surprise Valley Geothermal Plant near Paisley, Oregon

Surprise Valley Project

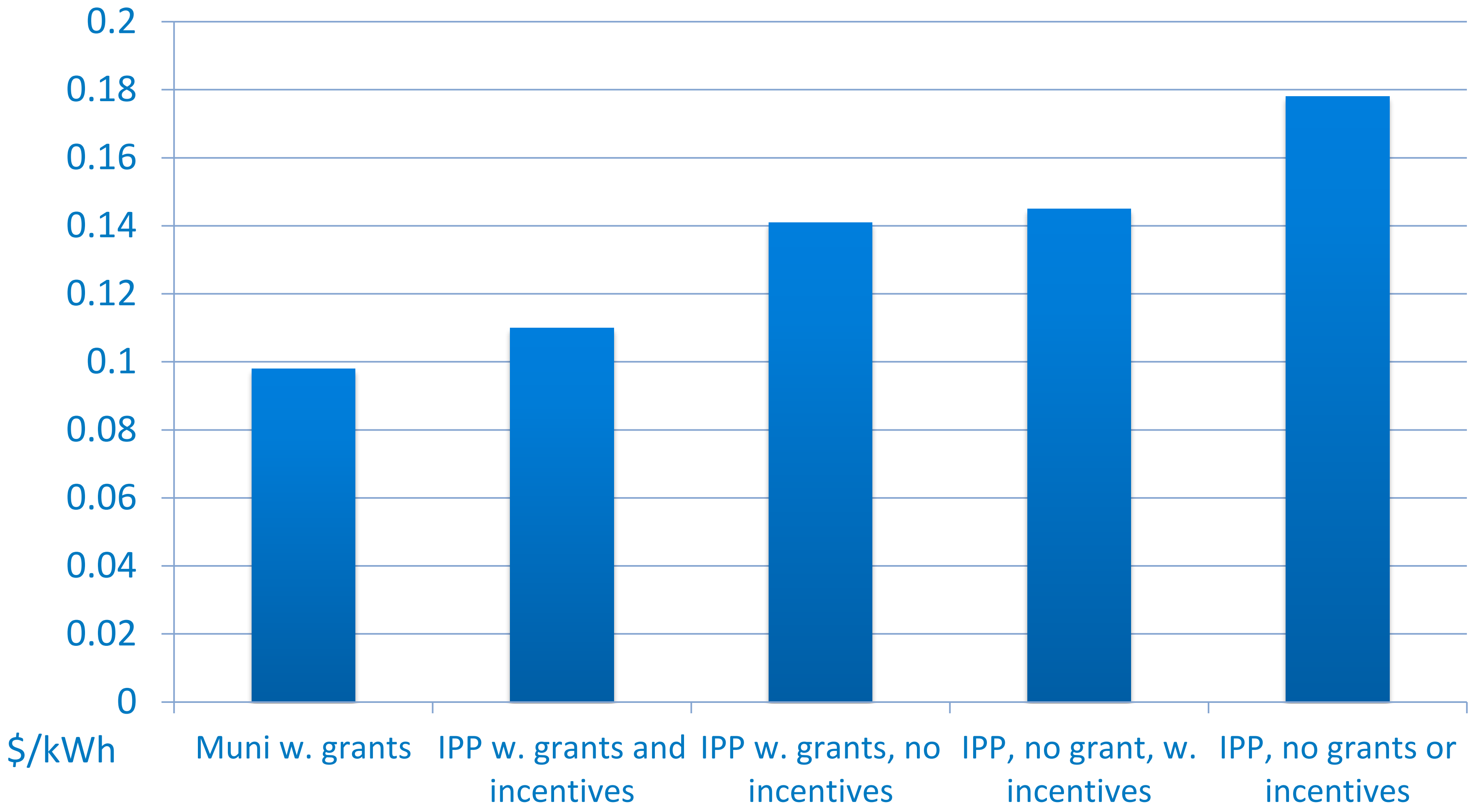
Objectives are to demonstrate:

- Production of sustainable and reliable competitively priced base-load power.
- Use of local labor resources (e.g., irrigation well drillers, local trades) to develop geothermal resources economically.
- The Cooperative Business Development Model (non-profit) can develop the small geothermal resources within its service territory.
- The advantage of fully utilizing the rural cooperative electric transmission system.
- That developing geothermal is an advantage to COOP members.
- Geothermal development improves when geothermal uses are cascaded, e.g., when both electrical and direct-heat uses are considered.
- That geothermal development can be integrated with an operating ranch to make both operations better.
- Benefit to BPA when direct customers develop their own sources of power.
- Use of the 2-meter-depth temperature survey to facilitate the location of injection wells.
- Development of distributed small resources contributes to building a sustainable region.

Status and lessons learned

- Plant is operational, benefits will accrue over many years
- Power purchase agreement is delayed, still under negotiation
- Deadlines for grants lead to rushed decision making
- Geothermal development challenging for small project developers
- Unexpected O&M expenses for small plants can have significant impacts on economics

Levelized Cost of Energy for Various Scenarios



Muni – Municipal utility IPP – Independent Power Producer

Observations and conclusions

- Technical viability of low-temperature geothermal electricity is established
- Economic feasibility is challenged by both thermodynamics and economies of scale
- Obtaining a good power purchase agreement is both essential and challenging
- Alternative design approaches such as hybrids and combined heat and power are promising