

12<sup>th</sup> Meeting of the Oregon Geothermal Working Group

April 11, 2011

U.S. DEPARTMENT OF  
**ENERGY** | Energy Efficiency &  
Renewable Energy



## City of Klamath Falls, Oregon

Feasibility Study of a Geothermal Power Plant to Generate  
Electricity Using Existing Geothermal Water Resources  
Co-Funded by the Energy Trust of Oregon

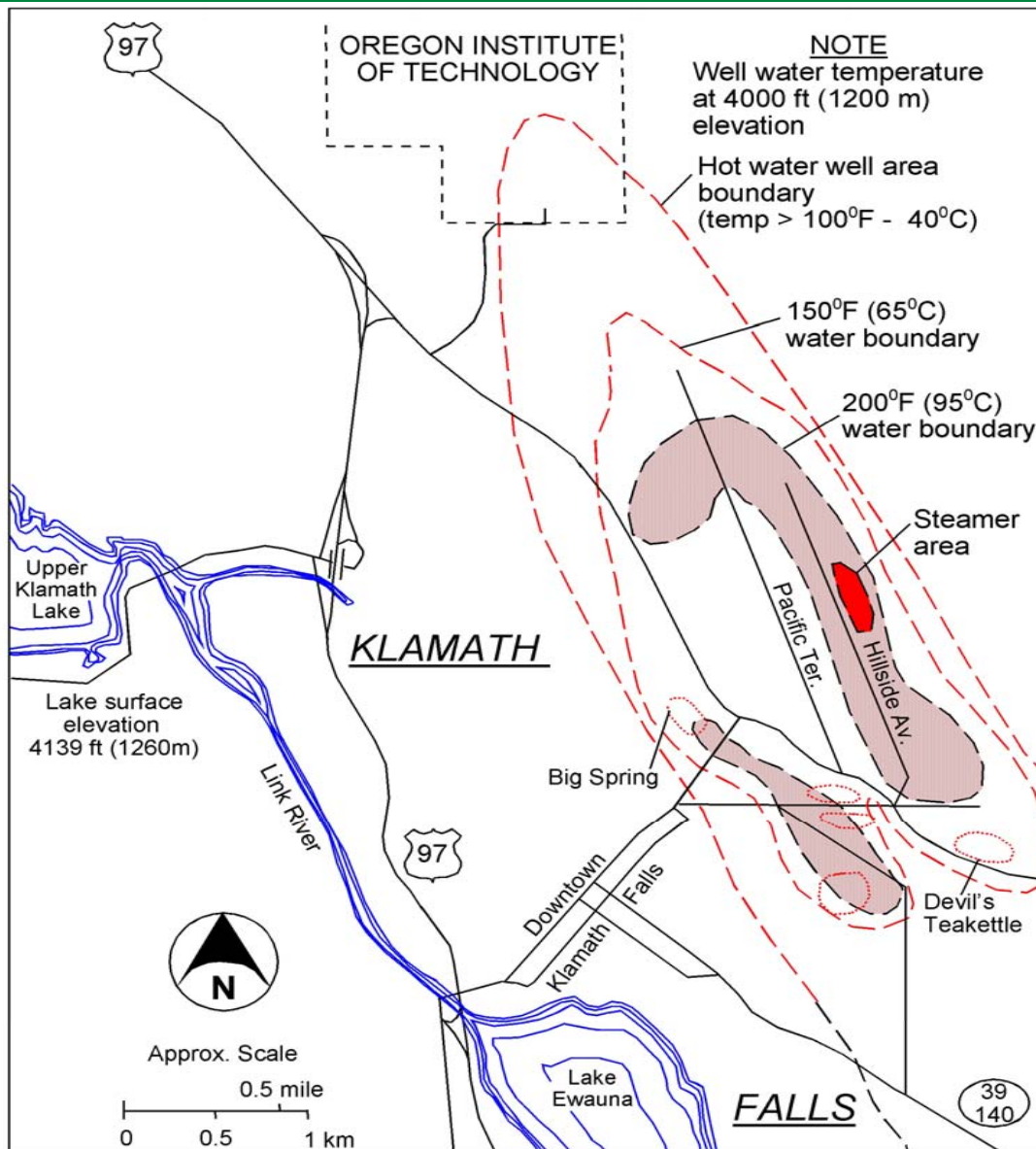
April 11, 2011

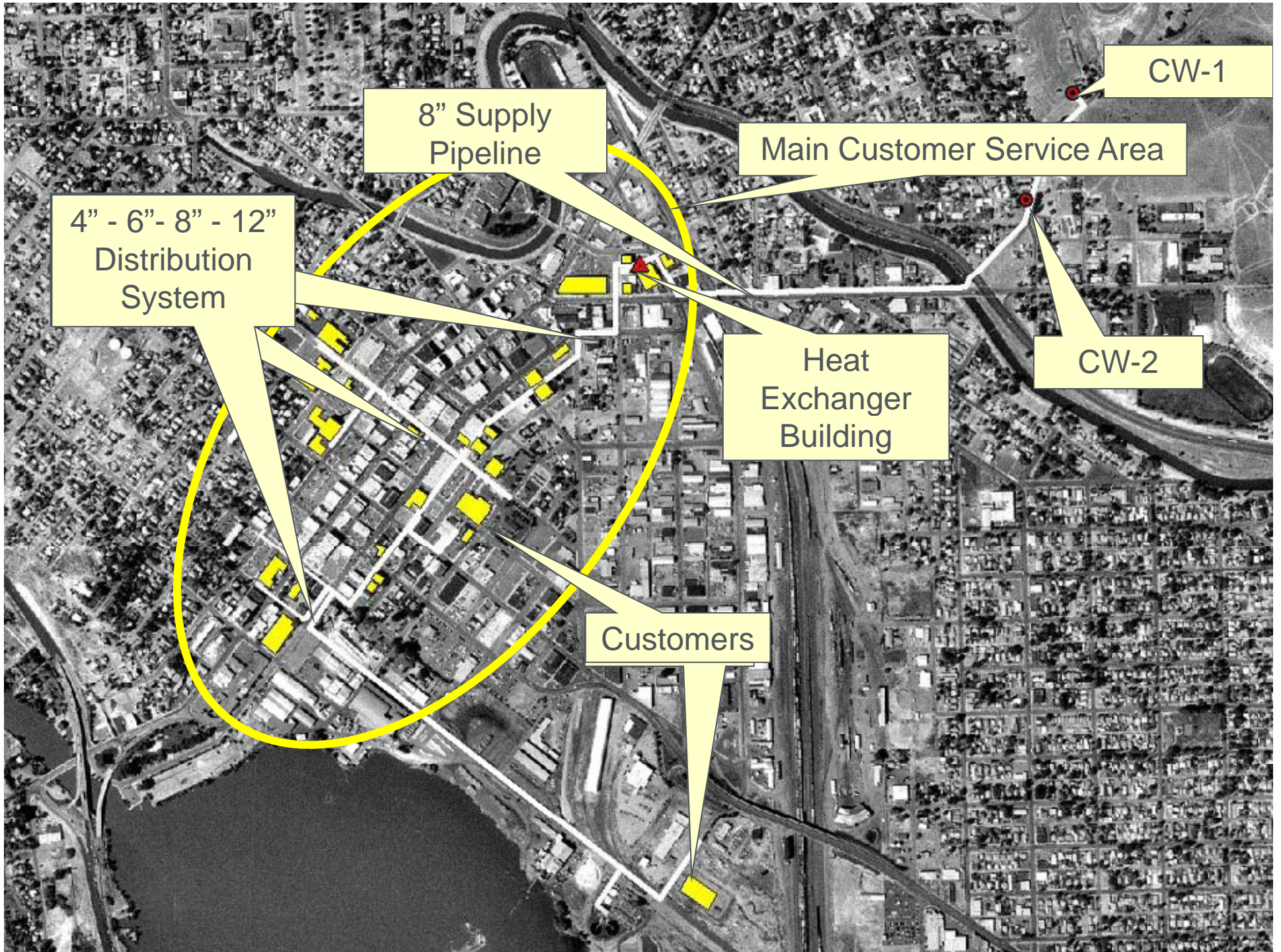
**Brian Brown,**  
**Brian Brown Engineering LLC**  
**Steve Anderson,**  
**Evergreen Energy**

## Klamath Falls Geothermal Power Feasibility Study / Project Objectives

- Demonstrate technical and financial feasibility of the use of an existing low-temperature geothermal resource for combined heat and power using:
  - Two existing production wells 216° & 226°F
  - 800 gallons per minute capacity per well
  - Existing injection well
- Maintain and enhance existing geothermal district heating operation
  - Currently serves 350,000 square feet of buildings, 160,000 square feet of greenhouses, and 135,000 square feet, sidewalk snowmelt systems.
- Renewable power generation with modular equipment
  - Goal is 280-640 kW gross / 200 kW+ net
- Positive cash flow
- Technology transfer

# Klamath Falls Known Geothermal Resource Area





CW-1

8" Supply Pipeline

Main Customer Service Area

4" - 6" - 8" - 12" Distribution System

Heat Exchanger Building

CW-2

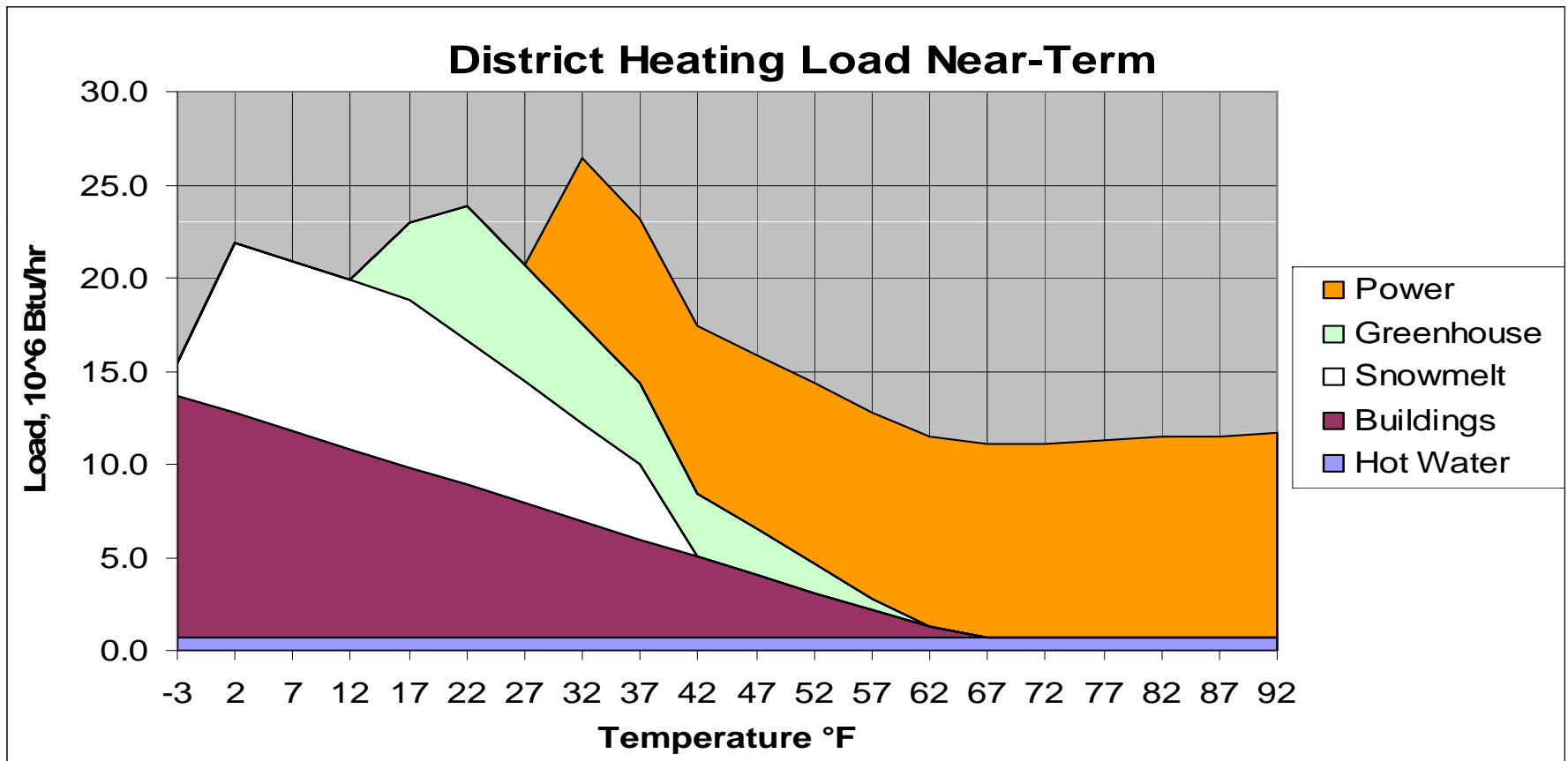
Customers

# District Heating System Photos





# District Heating Load Profile, 2015



- Phase 1A: Feasibility Study and Preliminary Design
  - 2010-2011 time frame
  - Go/No-go decision to proceed
- Phase 1B: Detailed Construction Design
- Phase 2: Procurement, Installation, and Startup
- Phase 3: Operations and Reporting

- Phase 1A: Feasibility Study and Preliminary Design
  - Review district heating system loads and surplus capacity available for power generation
  - Evaluate available modular or field-erected Organic Rankine Cycle power generation equipment for:
    - Power production
    - Construction cost
    - Operation and maintenance costs
    - Compatibility with district heating system operation
  - Evaluate heat rejection options
    - Open cooling tower
    - Hybrid/dry condenser to reduce water consumption
  - Schematic-level design of power plant and installation

- Phase 1A: Feasibility Study and Preliminary Design
  - Evaluate electrical interconnection study with utility
  - Determine power purchase rates from utility
  - Prepare applications for funding from State and local sources
  - Reviewed Permit Requirements
    - Oregon Water Resources: Modify water rights for increased production
    - Oregon DEQ: Injection permit modification for power production
    - FERC Qualifying Facility self certification
  - Prepare technical analysis and performance projections
  - Prepare economic projections
  - Prepare feasibility study report
- Decision by the City, ODOE (BETC) and USDOE

- Minimum Requirements for an Organic Rankine Cycle Module at Klamath Falls:
  - Capable of operation with 210°F geothermal resource at 600 to 1400 GPM available flow.
  - Generator module size of 250 kW to 640 kW.
  - Allow seasonally adjusted 170°F to 190°F district heating system supply temperature.
  - Available for installation in the United States

- Preferred Requirements :
  - 800 GPM or less design flow to allow operation with only one of the two geothermal production pumps.
  - Ability to utilize 160°F return water / waste geothermal heat in the power cycle.
  - Minimize water supply and disposal cost for heat rejection; possible option for dry or hybrid cooling.
  - Oil-free, gearbox-free turbine or expander for reduced gearbox maintenance cost.
  - Refrigerant selection that allows design pressures less than 200 psig for greater safety.
  - Multiple working units in similar service.
  - Minimize noise and other impacts

- Pratt & Whitney PureCycle 280
  - 280 kW gross rating
  - Modular Design, little customization flexibility
  - Essentially fixed capacity / No part load capability
  - Oil-lubricated, gear drive turbine-generator
  - Reliable, Proven design



- Other Commercially Available Modules
  - None were determined to be economically and/or technically viable
- Custom Power Plant
  - 320 kW or 640 kW with one or two turbines
  - Custom design to match needs of district heating system
  - Utilizes waste geothermal heat for ~25% of heat input results in a significant efficiency improvement
  - Controllable capacity / no threshold drop-off
  - Oil-free, direct drive magnetic bearing turbine-generator results in dramatic reduction in operations and maintenance costs
  - Completed design concept only

- P&W PureCycle 280
  - Total Capital Requirement: About \$1.6 million
    - USDOE \$816,000
    - Oregon BETC: \$261,000
    - Energy Trust of Oregon: \$115,000
    - City Requirement: \$367,000
  - Annual net MWh: 1,700
  - First Year power revenue: \$100,000
  - Operations, Maintenance & administrative: \$60,000
  - City water and sewer: \$24,000
  - First year net income: \$16,000

# Financial Projection Overview- Custom Designed Module

- Preliminary Design indicated an approximate capital cost of: \$1.9 million for a 267 net kW unit; \$2.6 million for a 483 net kW unit
- The larger unit with a higher net efficiency yielded a slightly better investment return
- The additional capital cost was unattractive to the City.

- A combined heat and power generation facility would be technically and financially viable at the Klamath Falls location, but would not yield high returns
- The cost of city water supply and disposal impacts the earnings potential significantly
- The alternative of dry cooling or hybrid cooling systems has a high capital cost
- Higher power purchase prices would improve the potential for success
- The City has tentatively decided not to proceed at this time
- The team will complete the USDOE Report & participate in the USDOE Peer Review in Washington DC in June