Water intensity of electricity from geothermal resources

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The presentation summarizes results of the model “Analysis of lifecycle water requirements of energy and transportation fuels: electricity from geothermal resources – Version 1.0”.

The model and its description are available at http://pubs.its.ucdavis.edu/publication_detail.php?id=1425
OBJECTIVE (1/2): What are the water requirements of electricity from geothermal resources?

- **Freshwater**
  - Power plant cooling

- **Degraded water**
  - Injection to maintain pressure of hydrothermal resources
  - Injection for heat mining of EGS resources

- **Geothermal fluid**
  - Withdrawal for power generation
  - Steam condensate used for power plant (flash) cooling
OBJECTIVE (1/2): How do water requirements depend upon resource type and power plant technologies?

- **Resource type**
  - Hydrothermal – Wet steam and hot water
  - Enhanced geothermal systems (EGS)

- **Energy conversion technology**
  - Organic Rankine Cycle (ORC) or Binary
  - Flash (Single flash only)

- **Cooling technology**
  - Dry cooling / Air cooled condensers
  - Wet re-circulating (with or without ZLD)
  - Hybrid
FUNCTIONAL UNIT: Water intensity expressed for both for electricity as well as transportation end user

- **Geothermal field** → **Power generation unit** → **Transmission & Distribution** → **End user**

**Electricity End User**
1. **Unit**: Liters / kWh
2. Compare with electricity from other sources – renewable and fossil fuels

**Transportation End User**
1. **Unit**: Liters / Vehicle kilometer traveled (VKT)
2. Compare with other transportation fuels like gasoline, ethanol, etc.
3. Compare with electricity from other sources – renewable and fossil fuels
4. **Additional factors considered**: (i) Vehicle efficiency (ii) Battery charger efficiency and battery efficiency
RESULTS: Impact of resource enthalpy on intensity of water requirements (1/2): Energy conversion using ORC

Assumptions (1) ORC with IHE (recuperated cycle) (2) Wet Re-circulating cooling system
RESULTS: Impact of resource enthalpy on intensity of water requirements (2/2): Energy conversion using Flash

Assumptions (1) Single flash (2) Wet Re-circulating cooling system
RESULTS: Impact of energy conversion technology on water requirements (EGS resources and ORC plants)

Assumptions (I) Inlet fluid temperature is 150°C
RESULTS: Impact of cooling technology on water requirements (EGS resources and ORC plants)

Assumptions (1) ORC with IHE (2) Inlet fluid temperature is 150°C

**Hybrid 2**: Hybrid cooling system with target condenser pressure of 8.47 KPa. Annual water consumption is 13% of that of a wet cooling system.

**Hybrid 4**: Hybrid cooling system with target condenser pressure of 27.09 KPa. Annual water consumption is less than 0.1% of that of a wet cooling system.
RESULTS: ORC Cycle versus Flash

Water requirements for two different conversion systems

Assumptions (1) Wet Re-circulating system (2) EGS resource
RESULTS: Comparison with other power plants (water consumption intensity)

1. Wet re-circulating cooling towers assumed for all power plants
2. Requirements of geothermal fluid not shown.
3. Source: DOE 2006
5. Includes H2O for coal mining & beneficiation of 0.113 L/kWh and H2O for Uranium mining and enrichment of 3.02 L/kWh (King & Webber 2008)
Comparison with other power plants (water withdrawal intensity)

1. Wet re-circulating cooling towers assumed for all power plants
2. Requirements of geothermal fluid not shown.
3. Source: DOE 2006. Withdrawal numbers calculated based on 8 cycles of concentration and 0.075L/kWh of mirror washing requirements (DOE 2006)
5. Includes H20 for coal mining & beneficiation of 0.113 L/kWh and H20 for Uranium mining and enrichment of 3.02 L/kWh (King & Webber 2008)
**IMPLICATION:** What is the impact on state-wide water demand if geothermal electricity displaces thermoelectricity generated within that state? (1/2)

How much (WR-cooled) thermoelectricity is displaced?

**Assumptions:**
1. Wet re-circulating cooling system for both thermoelectricity and EGS electricity
2. Resource base estimates from MIT study (Tester et al 2006),
3. Recoverable fraction of thermal energy from reservoir: 2%
4. Drilling depth: 5 km
5. Fraction of available power that is economically viable: 5%
6. ORC+IHE for resource temperature less than equal to 200°C; and Flash for greater than 200°C
IMPLICATION: What is the impact on state-wide water demand if geothermal electricity displaces thermoelectricity generated within that state? (2/2)

How much additional water is required by the state’s thermoelectricity sector?

- Arizona: % increase in withdrawal of degraded & fresh H2O: 40%
- California: % increase in withdrawal of fresh H2O: 20%
- New Mexico: % increase in overall non-irrigation fresh H2O withdrawal requirements: 8.8%
- Nevada: % increase in overall non-irrigation fresh H2O withdrawal requirements: 9.6%
- California: % increase in withdrawal of degraded & fresh H2O: 3.0%
- Nevada: % increase in withdrawal of degraded & fresh H2O: 230%
Questions?
Additional slides –

Framework used for analysis of different resource and power plant types
Resource type: Hydrothermal
Power Plant type: ORC plant

Figure 2.1: Water required for cooling

- Cooling tower – Wet re-circulating and Hybrid
  - Evaporation (F)
  - Blow down (F)
  - Make-up water (F)

- Dry cooling system – Water augmented (sprayed)
  - Make-up water (F)

Figure 2.2: Water required for heat mining of geothermal resource

- ORC Power Plant
  - Fluid Injection (G)
  - Fluid Extraction (G)

- Geothermal Resource

Legend
- Withdrawal
- Consumptive use
- Degradative use
- (F) : Freshwater water
- (D) : Degraded water
- (G) : Geothermal fluid
Resource type: EGS
Power Plant type: ORC plant

Figure 3.1: Water required for cooling

Evaporation (F)

Cooling tower – Wet recirculating and Hybrid

Blow down (F)

Make-up water (F)

Figure 3.2: Water required for heat mining of geothermal resource

ORC Power Plant

Fluid Extraction (G)

Geothermal Resource

Fluid Losses (D)

Fluid injection (G)

Degraded water injection (D)

Legend
- Withdrawal
- Consumptive use
- Degradative use
(F) : Freshwater water
(D) : Degraded water
(G) : Geothermal fluid
**Resource type:** Hydrothermal
**Power Plant type:** Flash

**Figure 4.1:** Water required for cooling

- Evaporation (G)(F)
- Cooling tower – Wet recirculating
- Blow down (G)
- Make-up – Steam Condensate (G)
- Make-up (Summer) – Freshwater (F)

**Figure 4.2:** Water required for heat mining of geothermal resource

- Flash Power Plant
- Geothermal Resource
- Fluid Extraction (G)
- Fluid injection (G)
- Degraded water Injection (D)

**Legend**
- Withdrawal
- Consumptive use
- Degradative use
- (F) : Freshwater water
- (D) : Degraded water
- (G) : Geothermal fluid
Resource type: EGS
Power Plant type: Flash

Figure 5.1: Water required for cooling

- Evaporation (G)(F)
- Make-up – Steam Condensate (G)
- Make-up (Summer) – Freshwater (F)
- Cooling tower – Wet recirculating
- Blow down (G)

Figure 5.2: Water required for heat mining of geothermal resource

Legend
- Withdrawal
- Consumptive use
- Degradative use
(F) : Freshwater water
(D) : Degraded water
(G) : Geothermal fluid