



Idaho National Laboratory

Overview of Contributors to the Cost of Geothermal Power Production

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Development of Geothermal Power

Consists of successive phases including:

- Exploration
- Confirmation
- Site Development
 - Well Field Construction
 - Plant Construction
- Operation: power generation

Risk is highest in the early phases. Cost is highest during the well field development and plant construction

Exploration and Confirmation

Activities:

- Exploratory work to target resource; drill exploration wells; drill confirmation wells; flow test

Factors influencing cost:

- New vs expansion of existing field
- Drilling (lithology, depth, temperature, etc.)
- Location (remoteness, topography, etc.)
- Size of resource
- Time delay to start of power generation

Well Field Development

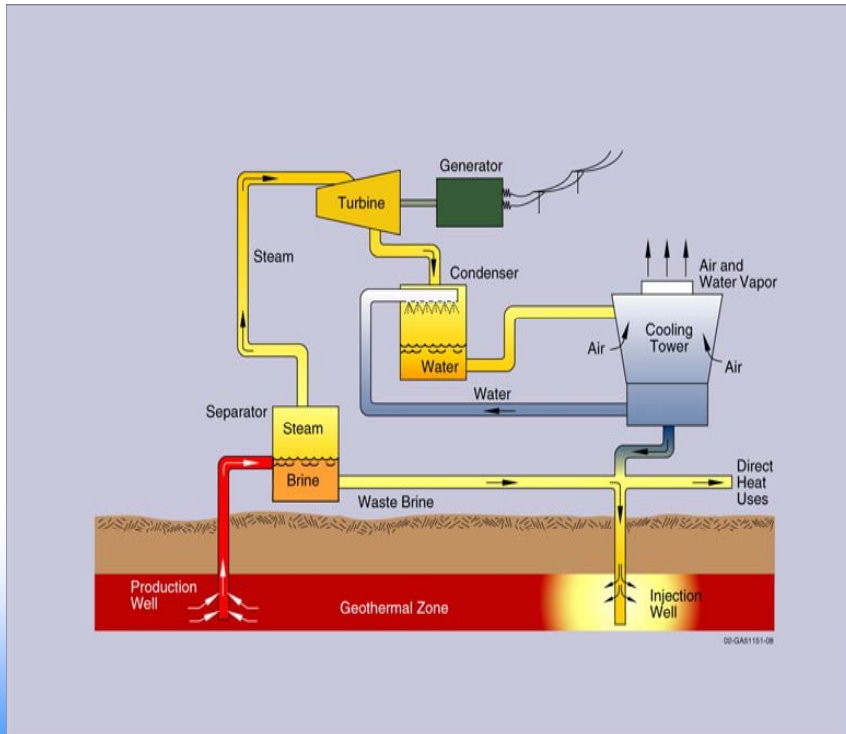
Factors influencing cost:

- **Drilling**
 - lithology
 - depth
 - temperature
 - rig availability
 - Location
- **Number of wells**
 - Project size
 - Success rate
 - Injection required?
 - Well productivity
 - Plant performance

Selection of Conversion System

Flash Steam

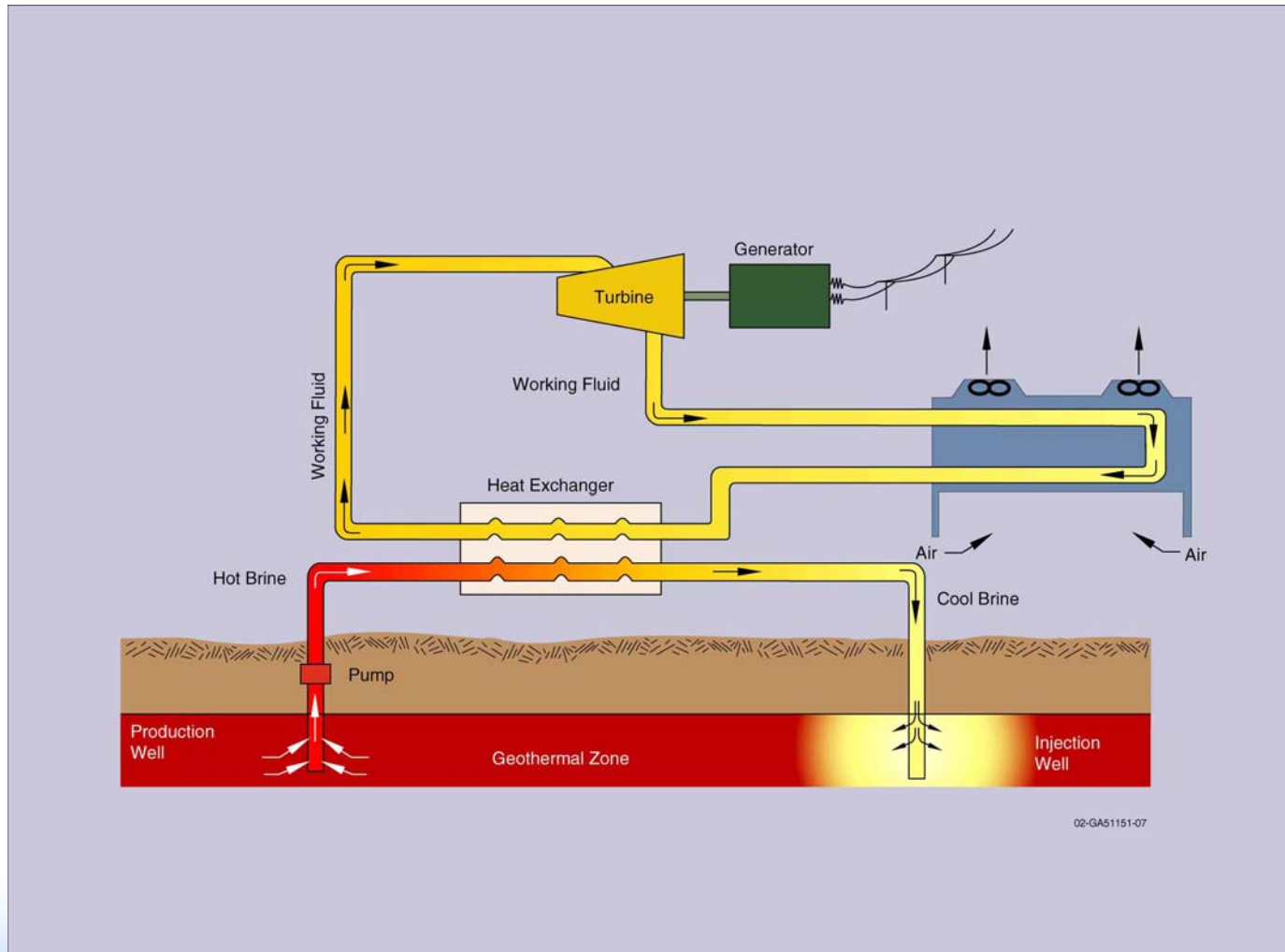
- Higher temperature resources (>~175C)
- Plants tend to be larger (10- 60 MW)
- Capital costs ~\$1,000/kW (larger, higher temperature plants)



Steamboat ~14 MW



Binary Conversion System

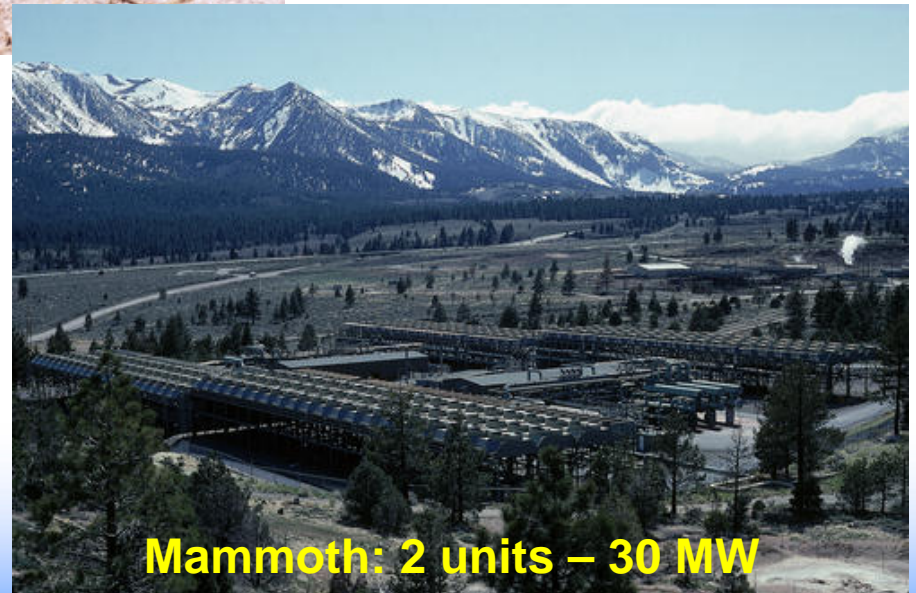


Binary Power Plants

Wineagle: 2 units - ~0.7 MW



Heber: 12 units - 33 MW



Mammoth: 2 units - 30 MW

Binary Plant Cost and Performance Factors

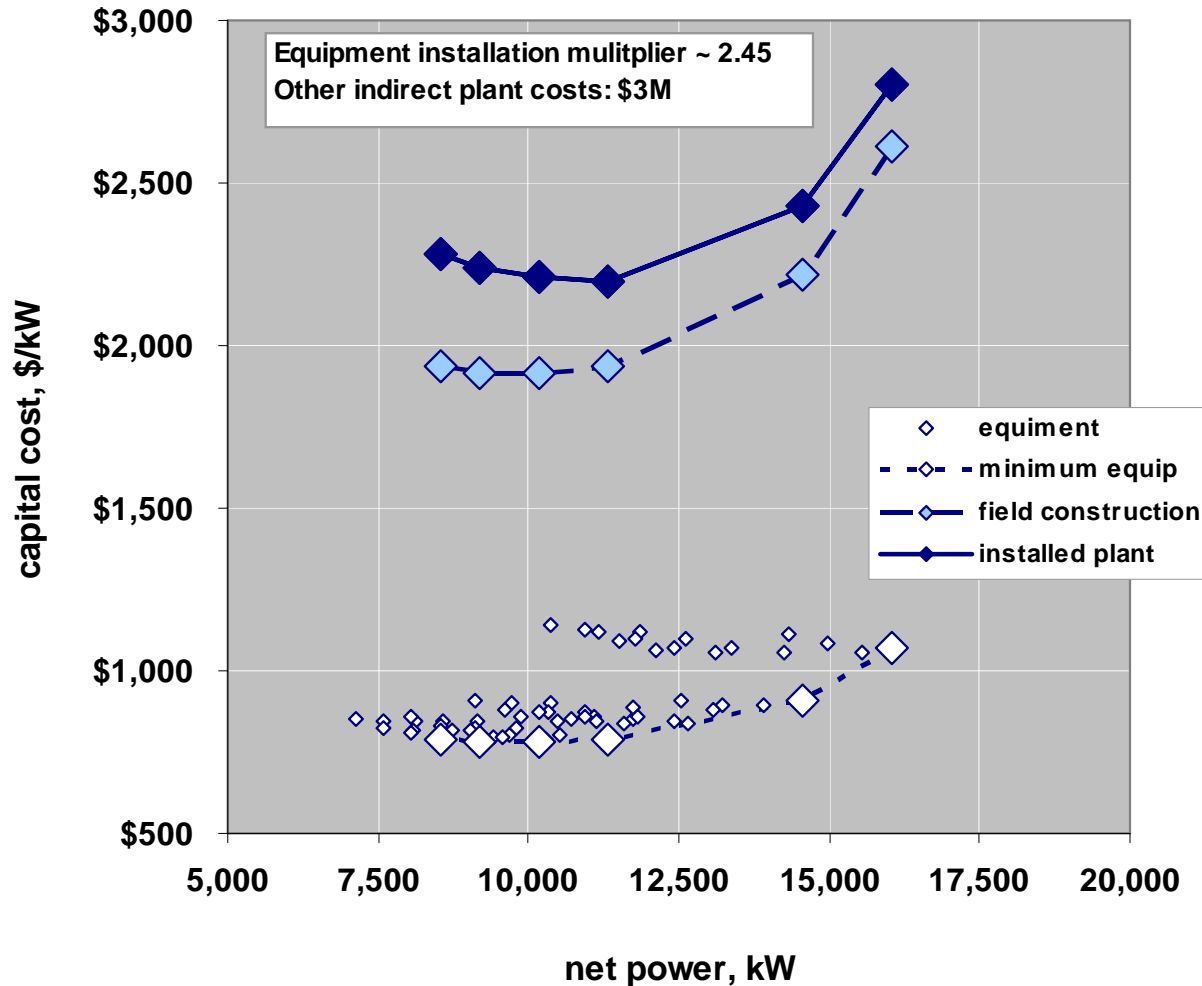
- **Resource temperature**
 - generally used $< 175\text{C}$
 - cost (\$/kW) tend to increase with decreasing temperature
 - efficiencies decrease
 - required heat exchanger areas and/or flow rates increase
 - performance decreases with decreasing temperature
- **Size**
 - range: ~500 kW up to ~15 MW
 - cost (\$/kW) tend to decrease with increase size

Binary Plant Cost and Performance Factors

- **Heat rejection**
 - ~90% Of heat added is rejected
 - evaporative vs sensible heat rejection
- **Chemistry**
 - material of construction
 - scale
- **Working fluid**
- **Heat exchanger pinch point**

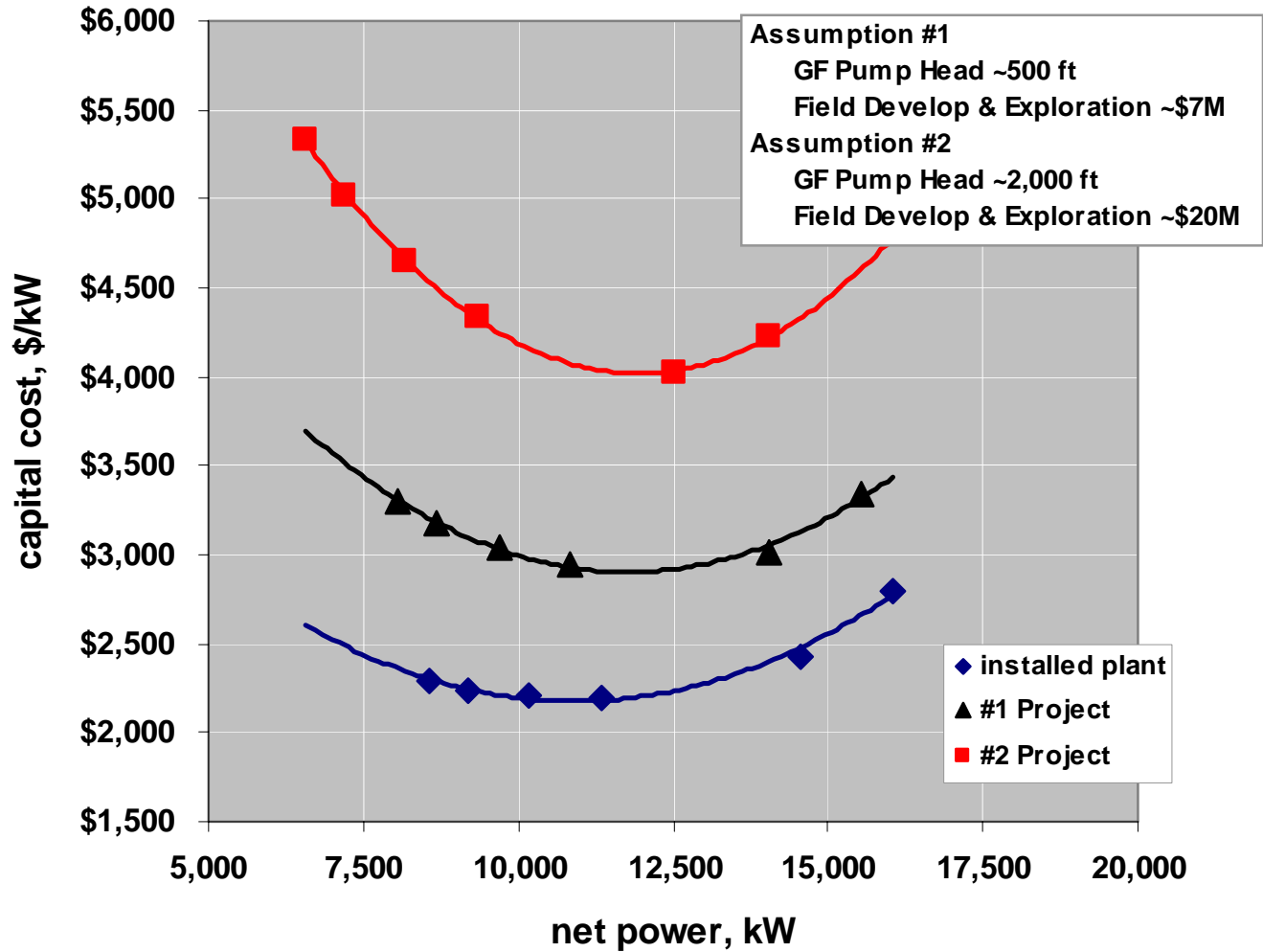
Capital Costs for Air-Cooled Binary Plant

GF: 150C, 5,000 gpm



Air-Cooled Binary Project Costs

GF: 150C & 5,000 gpm



Operating Costs

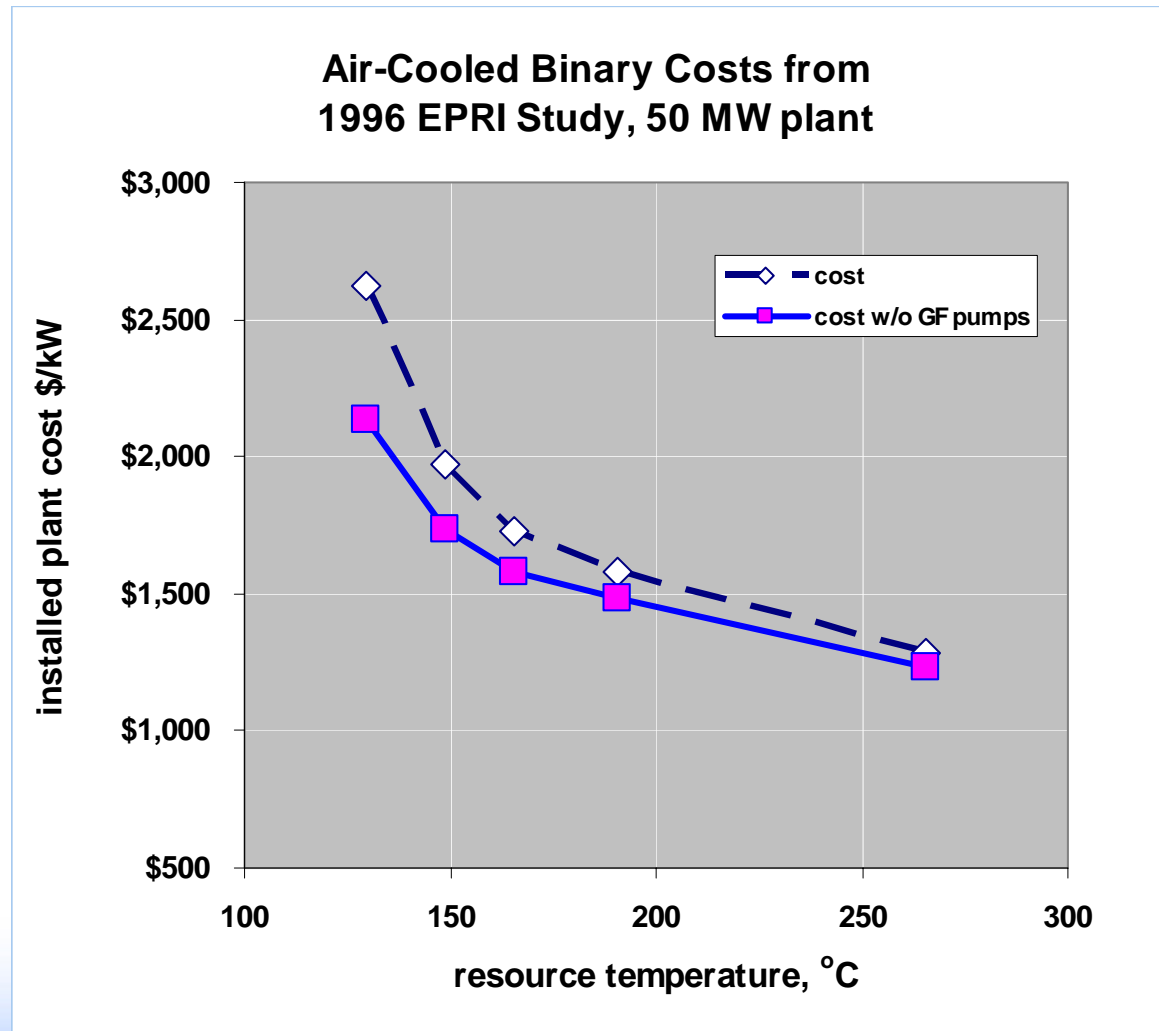
- **Labor**
 - more significant for smaller plants
 - automated vs manned operation
- **Chemicals**
 - corrosion & scale inhibitors
 - working fluid makeup
- **Availability 95%+**
- **Replacement wells & well work-over**
- **Submersible pump repair/replacement**
- **Royalties**

Annual O&M costs: 1-1/2 to 2-1/2 cents/kW-h

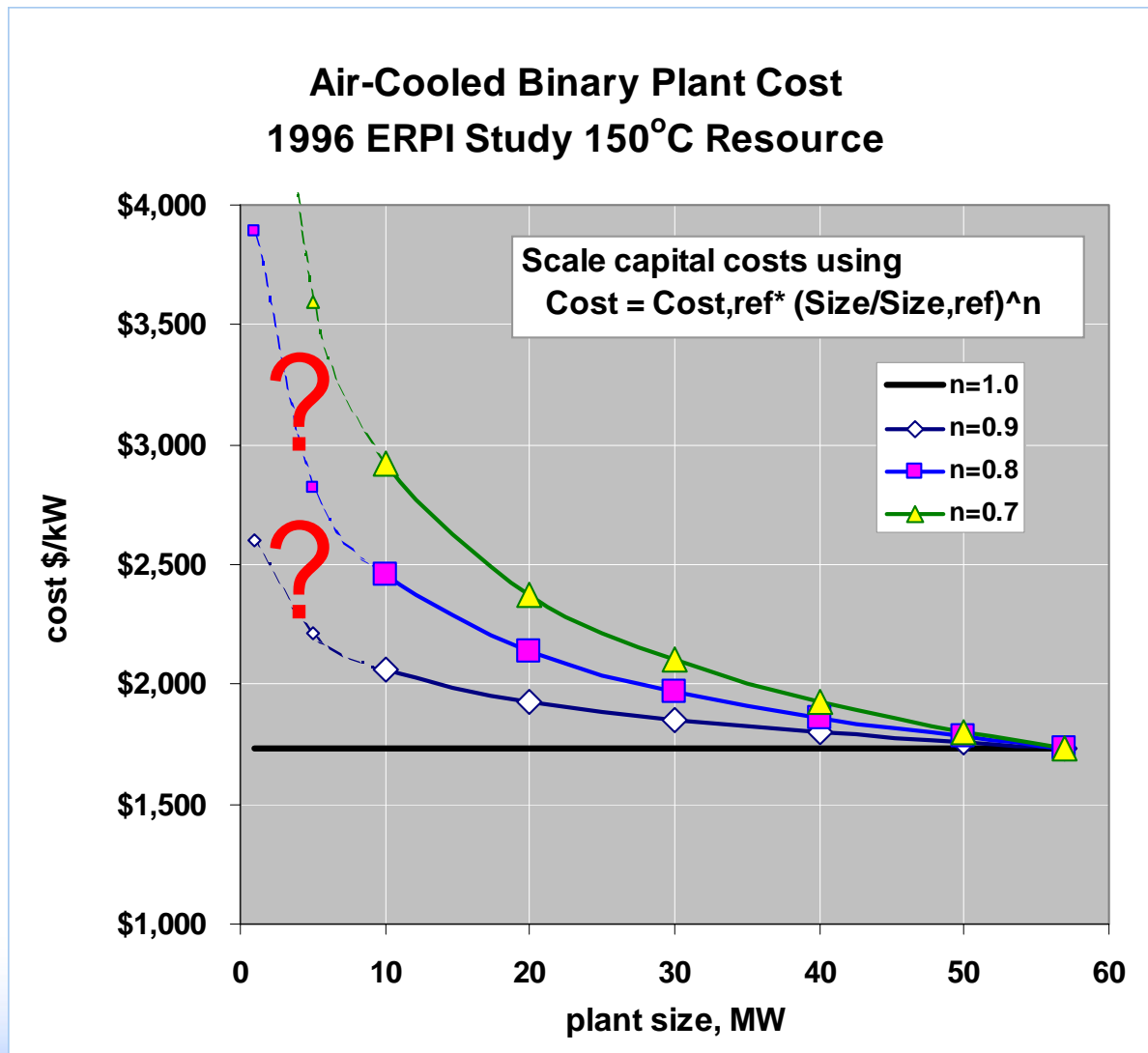
Acknowledgment

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Effect of Temperature on Plant Cost



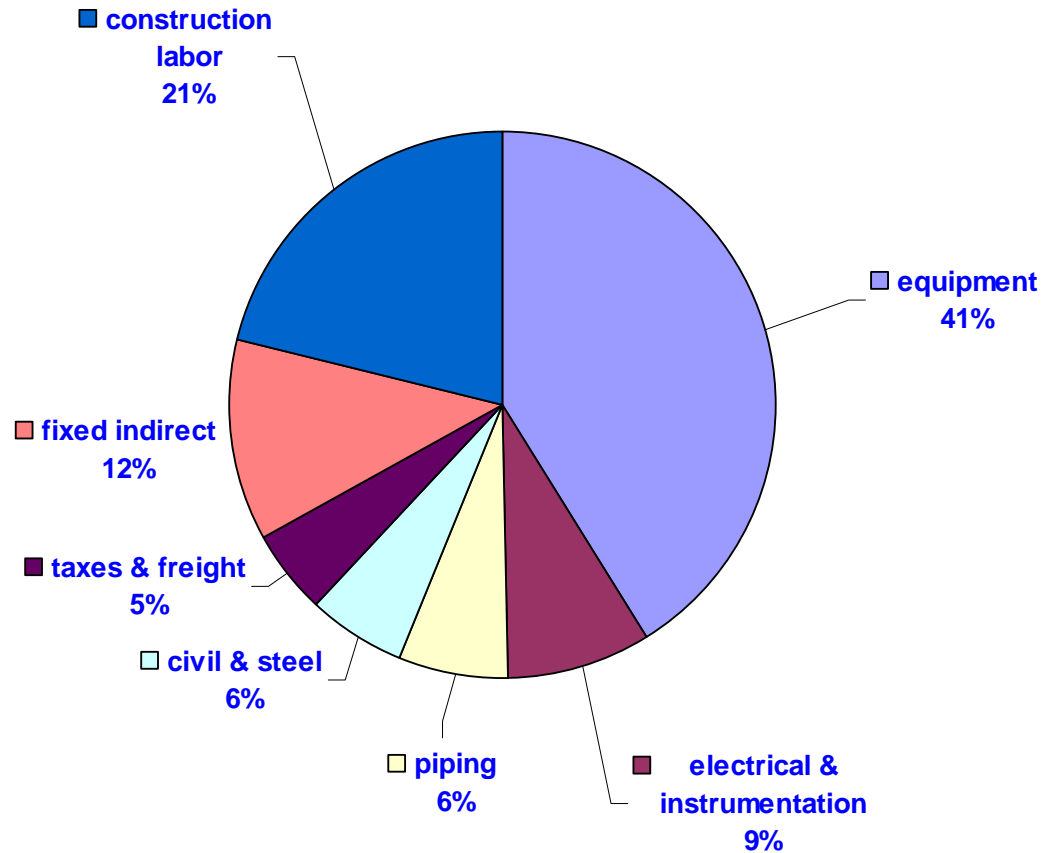
Effect of Size on Plant Cost



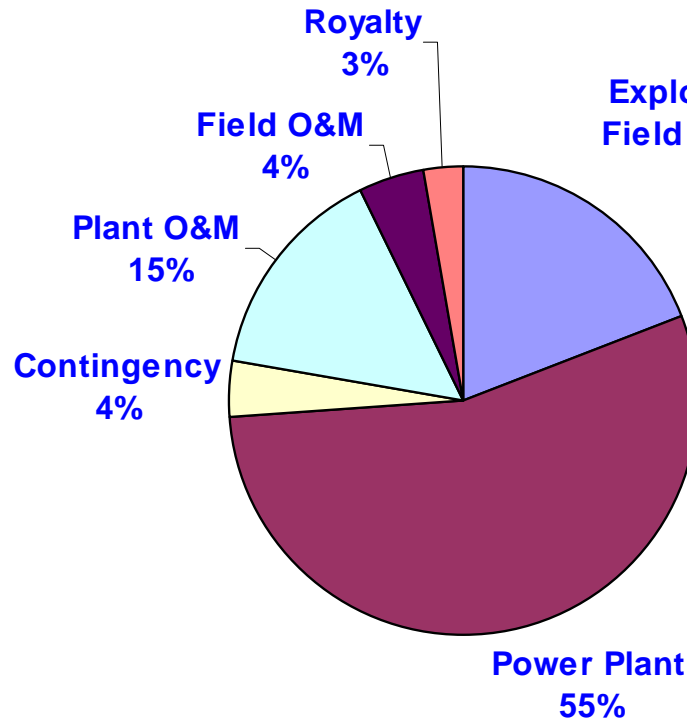
Summary

- **Exploration and Well Field Development costs**
 - Drilling costs
 - Well productivity
- **Conversion System costs**
 - Resource temperature
 - Type of conversion system
 - Performance and cost tradeoff
 - Plant size
- **Operating & Maintenance cost**
 - Labor
 - Conversion system
 - Self-flowing vs pumped wells

Air-Cooled Binary Power Plant Capital Cost Distribution



Cost of Power Estimate Air Cooled Binary 150C, LCOE ~\$0.085 per kW-h



- Estimate made with GETEM (Geothermal Electricity Technology Evaluation Model) - DOE Analysis Tool

- Estimate does not reflect the costs for current commercial power generation. The scenario depicted by the estimate provides a basis for DOE to assess the impact of technology improvements.