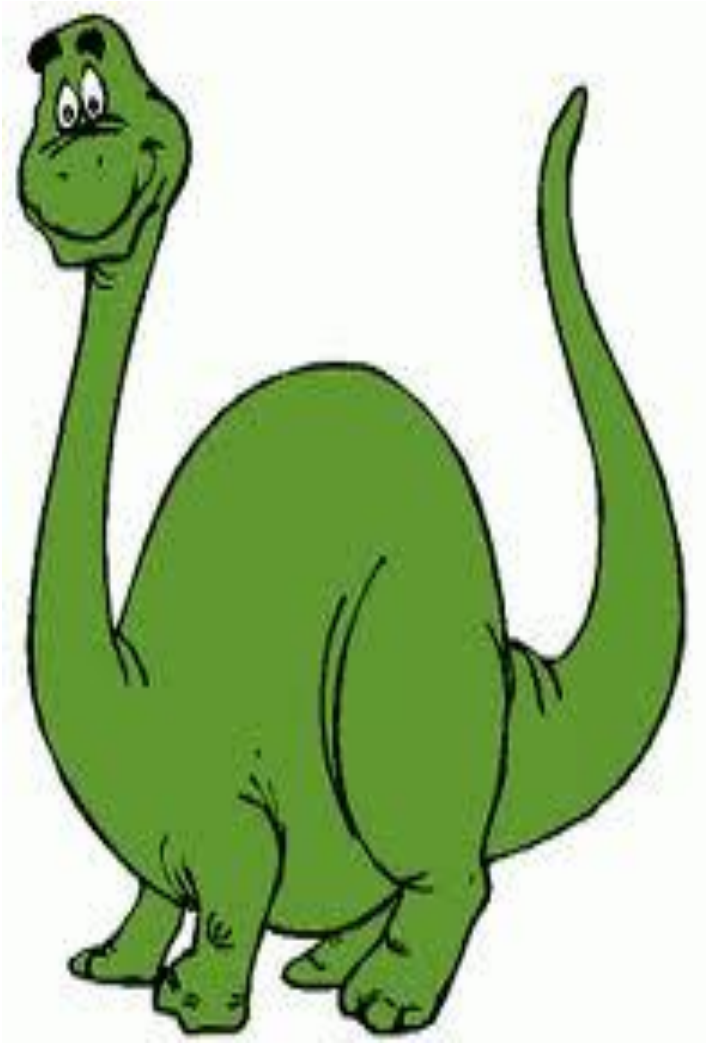
SMU Conference: Geothermal Energy Utilization Associated with Oil and Gas Development, June 13-15, 2011

"Dinosaur and Ant Are Friends – O&G and Geothermal Can Join Forces"



POWER ENGINEERS

Intro to this presentation!

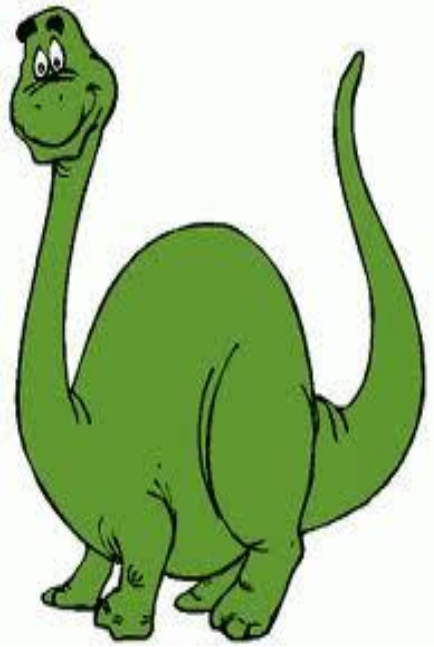
- There's a strong family resemblance between O&G projects and geothermal projects! What could it mean? Profit or efficiency opportunities?
- Areas of congruence (and cultural comfort) between O&G and geothermal.
- Areas where geothermal people (ants) can possibly contribute to O&G (dinosaurs) by supporting co-production opportunities.
- ➢ Wise words about making the most of a low-energy resource in the real world.

O&G and geothermal are friends?

Well, yes. Sure, O&G is a huge industry, and geothermal is small by comparison. But our two industries function in the same world of geological risk, and we have a similar accountability for what happens at the wellhead.

We stole it fair and square!

Much of the key technology of geothermal resource identification and production were borrowed from our oil and gas cousins. We in the geothermal world have been very generous to ourselves in cheerfully borrowing the hard-won experience of our long-chain-hydrocarbon brethren in the oil business. So part of this presentation is a belated thanks to the O&G industry for making it practical to generate electrical power from a challenging resource found deep in the earth.



Thanks, big guy!

O&G and Geo: practical similarities!

- Betting on production of stuff nobody can see
- Reliance on crusty, highly knowledgeable old-timers who are usually not presentable to bankers
- Funny smells
- Weird stuff building up in the pipes
- Chemical-process-intensive content of technology

- Risk and depletion issues for production and financing
- Similar community concerns re: environmental impacts

Specific Areas of Congruence

Obvious Resource Congruencies

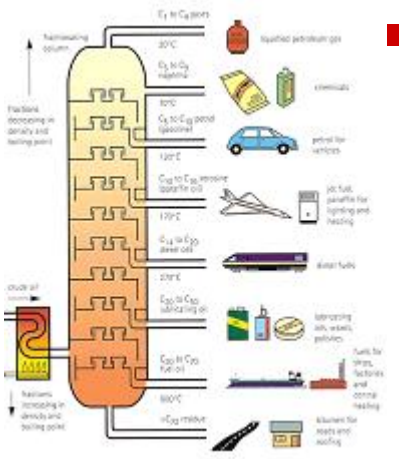
- Risk: both industries bet on resources nobody can see
- Exploration techniques
- Drilling and well completion techniques
- Resource management strategies: long-term drilling program, planning for depletion, scaling/corrosion control, well-field management

Congruency in export strength

- U.S. production and well service technologies are world-leading industries.
- U.S. geothermal technology suppliers and engineers are in a strong export position as well.

- The U.S. Department of Commerce, through TDA and Ex-Im Bank, support alternative technology exports.
- It's tempting to think about leveraging the U.S. competitive position to achieve co-production capacity development worldwide.

Congruency: Multiple cash streams



- O&G is used to breaking down its production into various resource streams. Similarly, geothermal can deliver:
  - Electricity
  - Process and district heat
  - Bottom-end minerals recovery (zinc, lithium, sulfur)
  - Wastewater disposal (in injection wells)
  - CO_2 injection/sequestration (in injection wells)
  - Sites for cost-effective co-location of other renewables such as wind

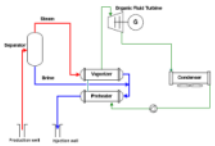
A Quick Look at Technical Aspects of Co-Production

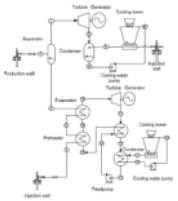
Co-Production: familiar stuff

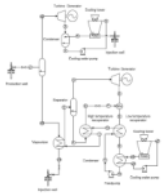
- Mechanical interconnection, separation, brine handling systems = no-brainer
- Cooling system selection = thought-provoking, climate- and water-dependent
- Cycle selection (flash, binary) = sometimes thought-provoking, most likely flash
- T-G and B.O.P. design = sometimes thought-provoking
- Electrical interconnection systems = sometimes thought-provoking

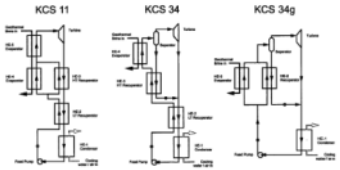
Dizzying Array of Cycle Choices

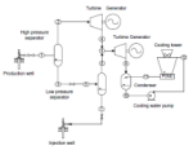
- Customization is often worth it
- Bigger is better, unless it isn't
- Consider O&M

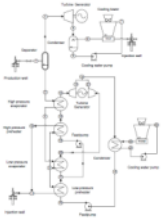


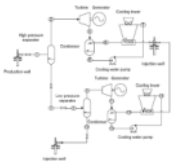




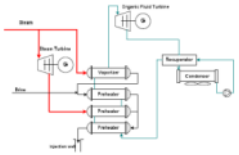


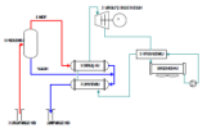






- Combine standardization with flexibility
- No such thing as waste





(Mlcak, 2002)
(Swandaru and Palsson, 2010)
(Kaplan, 2007)

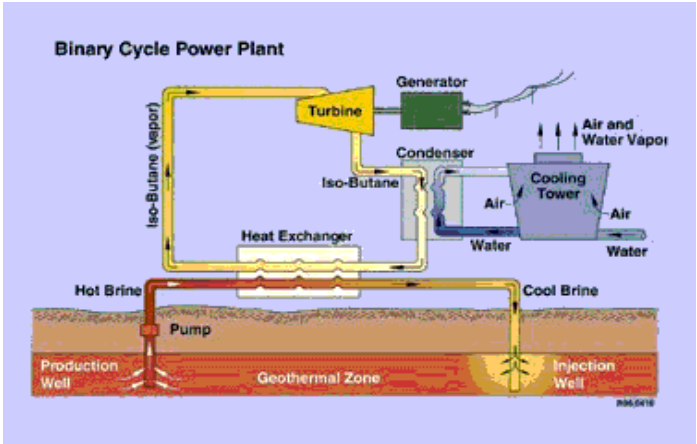
The dynamic binary marketplace

- Package wrap or equipment supply
- Big or small
- High or low temperature

- Binary solutions applicable to geothermal, co-production, industrial heat recovery, etc.

Binary Working Fluids

- Hot – Heavy, Low – Light
- Hydrocarbons, Refrigerants, Mixed
- *Can turbine/condenser operate?*
- *Are materials compatible?*
- *Is permitting easier?*
- *Are heat exchangers costly?*
- *Is piping costly?*
- *Is the working fluid costly?*
- *Are equations of state adequate?*



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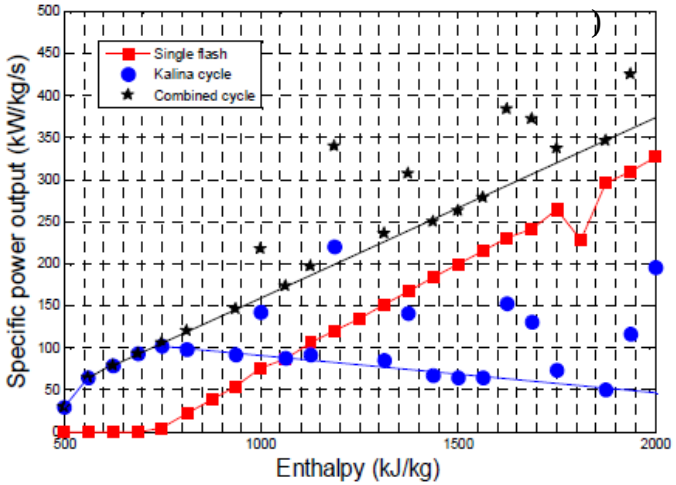


(Swandaru and Palsson, 2010)

Heat rejection: very important

Selection of the optimal cooling system is crucial to getting the most out of the unit, since a co-production turbine-generator machine needs to take efficient advantage of a fairly narrow temperature difference between the resource and the environment.

Geothermal plant engineers pay an obsessive amount of attention to cooling system design.

Where to connect!

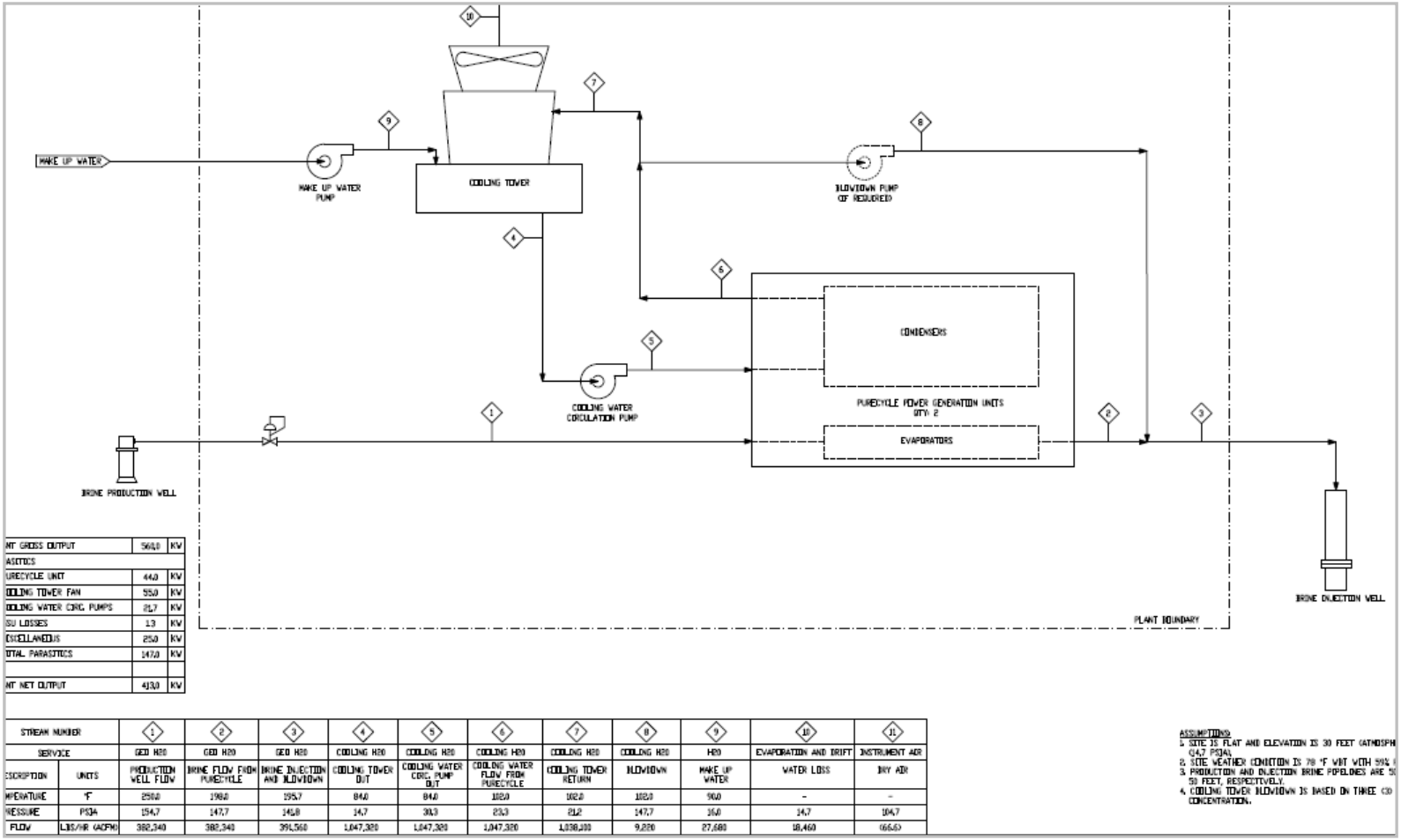
- A wellfield with a number of small turbine-generator co-production wellhead units over a wide area, is similar to the typical wind farm system.
- Do we get a PPA and sell to the grid?
- Or is it easier to keep it behind the meter?

Commercial Considerations

Commercial Considerations

- Get a survivable power sales agreement (PPA), if you're selling to the grid. Or use output to offset purchases.
- Get a good process flow diagram/heat balance so you know what you're getting. You can't fool Mother Nature.
- Any small unit is a potentially expensive way of making a little power. So it should be specified and designed right to be cost-effective. Payback margins for geothermal installations are typically smaller than for O&G.
- Use the tax incentives!

An example PFD/heat balance



NT GROSS OUTPUT	564.0	KV
ASSTICS		
URECYCLE UNIT	44.0	KV
OLING TOWER FAN	55.0	KV
OLING WATER CIRC. PUMPS	21.7	KV
SU LOSSES	1.3	KV
CELLANEOUS	25.0	KV
OTAL PARASITICS	147.0	KV
NT NET OUTPUT	413.0	KV

STREAM NUMBER		1	2	3	4	5	6	7	8	9	10	11
SERVICE		GEO H20	GEO H20	GEO H20	COOLING H20	COOLING H20	COOLING H20	COOLING H20	COOLING H20	H20	EVAPORATION AND DRIFT	INSTRUMENT AIR
ESCRIPTION	UNITS	PRODUCTION WELL FLOW	BRINE FLOW FROM PURECYCLE	BRINE INJECTION AND BLOWDOWN	COOLING TOWER OUT	COOLING WATER CIRC. PUMP OUT	COOLING WATER FLOW FROM PURECYCLE	COOLING TOWER RETURN	BLOWDOWN	MAKE UP WATER	WATER LOSS	DRY AIR
MPERATURE	°F	250.0	198.0	195.7	84.0	84.0	102.0	102.0	102.0	90.0	-	-
RESSURE	PSIA	154.7	147.7	145.0	14.7	30.3	23.3	21.2	147.7	16.0	14.7	104.7
FLOW	LBS/HR (ACFM)	382,340	382,340	391,560	1,047,320	1,047,320	1,047,320	1,038,100	9,220	27,680	18,460	(66.6)

ASSUMPTIONS:
1. SITE IS FLAT AND ELEVATION IS 30 FEET (ATMOSPH
   (14.7 PSIA).
2. SITE WEATHER CONDITION IS 78 °F WBT WITH 59% I
3. PRODUCTION AND INJECTION BRINE PIPELINES ARE 5
   50 FEET, RESPECTIVELY.
4. COOLING TOWER BLOWDOWN IS BASED ON THREE CO
   CONCENTRATION.

Indicative costs & project approaches

Cost

- Indicative Cost for 560 kW gross: $3,900/kW (1-2 wells)
- Indicative Cost for 2.5 MW gross: $3,000/kW (5-10 wells)

Approach

- EPC – full wrap with 15% markup or more due to small scale
- Design/Bid/Build with self or local financing

Summary!

- In many ways, O&G people are on familiar ground when it comes to geothermal co-production.
- The O&G and geothermal industries have potentially lavish export and domestic application possibilities.
- Equipment economics will improve with wider and more applications!
- Ant ♥ ♥ ♥ dinosaur! Open invitation to share forces and insights for heat recovery/co-production and geopressure opportunities!

Thank you for your attention!

Any questions?
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