Enhanced Oil Recovery System For Use With A Geopressured-Geothermal Conversion System:

Concept Introduction at the Society of Petroleum Engineers/ American Inst. of Chemical Engineers Joint Workshop:

Practical Strategies for Managing CO2 Emissions —Today Not Tomorrow
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GEM TEOR – Key Points

- Half the fuel per CWE bbl steam (v. gas-fired steam generators)
- \$3-\$5 savings per CWE bbl steam (@ \$8/Mcf gas)
- Establish renewable energy system as optional co-product
- Half the carbon footprint (*~zero with renewable system offset*)

Outline

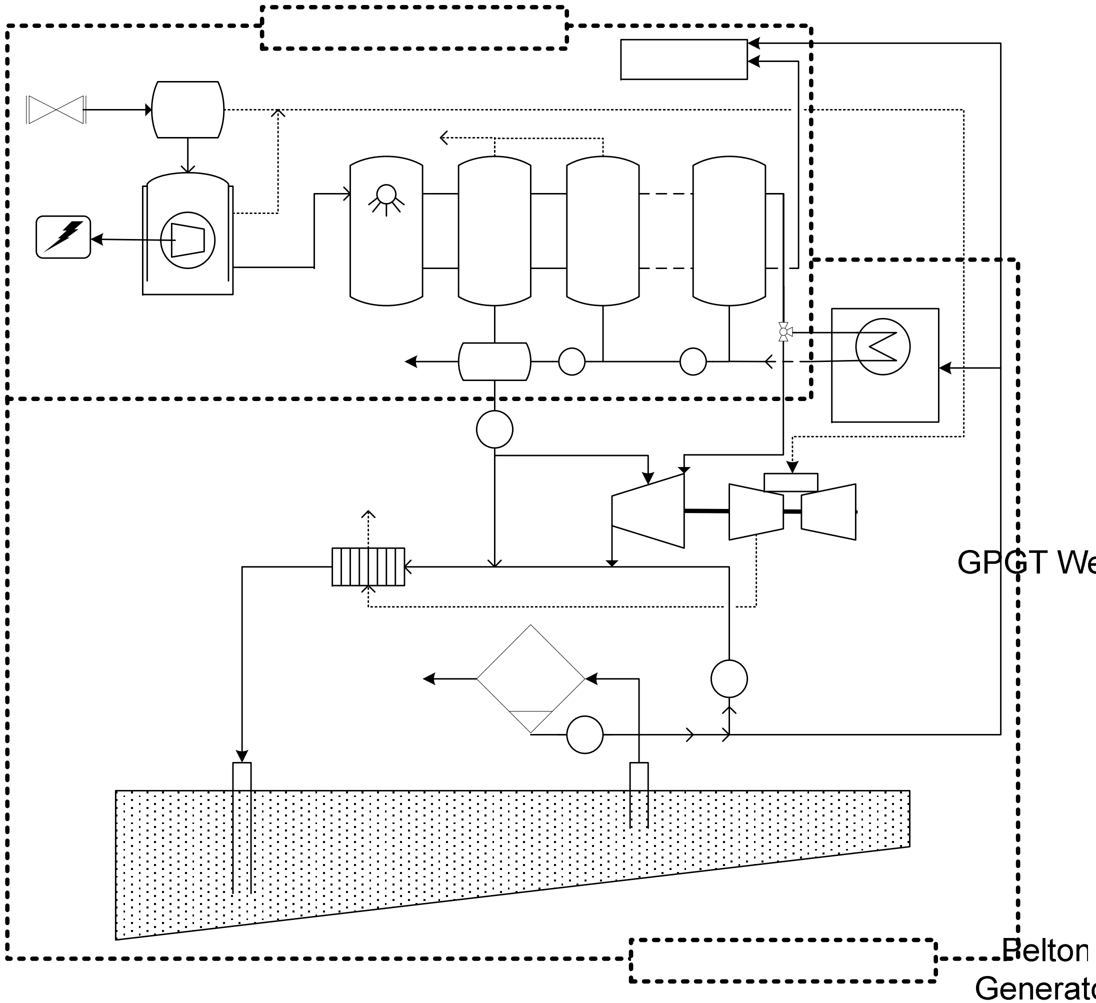
GEM TEOR

- ➡ What is it?
- What are the cost savings?
- What is the status of its implementation?

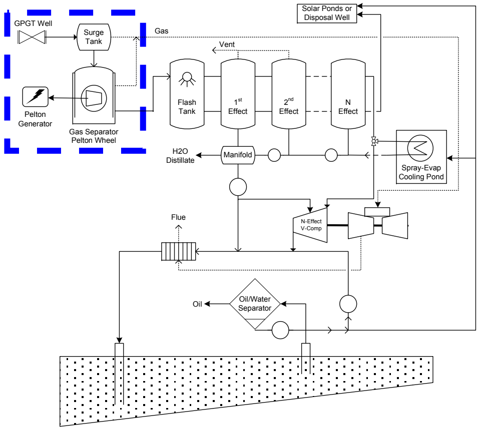
System Overview

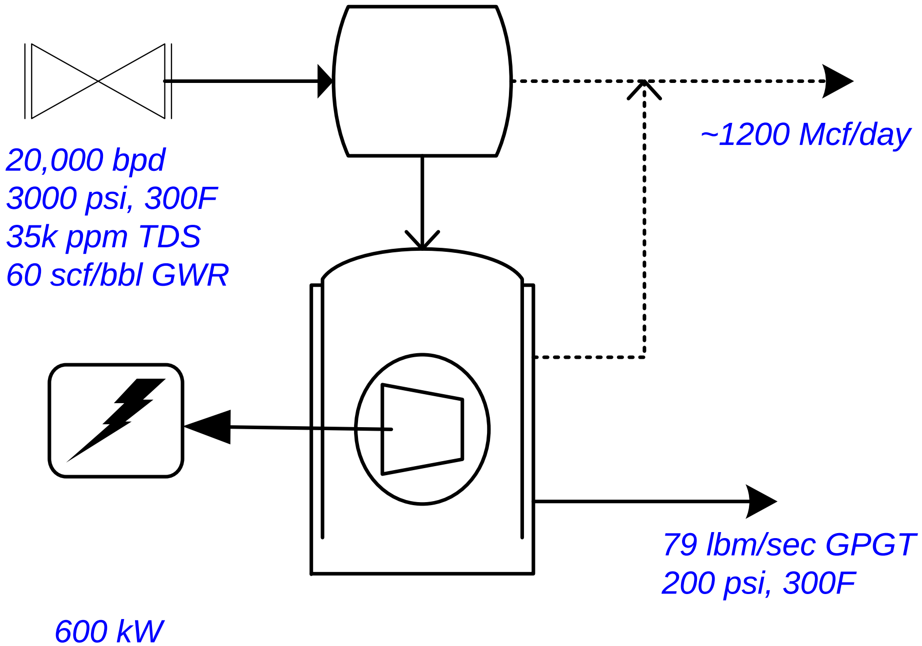
Recover Geopressured-Geothermal (GPGT) brines and use for thermal enhanced oil recovery (TEOR), with optional renewable energy system.

- **GPGT Conversion Segment** 25
  - Recover GPGT raw brine, separate gas
  - Produce H2O, electricity, saturated brine
  - Produce TEOR steam
    - half gas per CWE bbl steam
    - $3-$5 savings per CWE bbl steam
    - half carbon footprint (*or less*)
    - zero-discharge produced water
- **Optional Solar Energy Segment**
  - Use saturated brine to build solar ponds
  - Use solar ponds for renewable power
- **Other Key Attributes**
  - Patented/patent-pending technology
  - California, Texas deployment
  - 60+ GPGT basin regions worldwide
  - Flexible, modularly extensible configurations



Subsystems: GPGT Well & Turbine



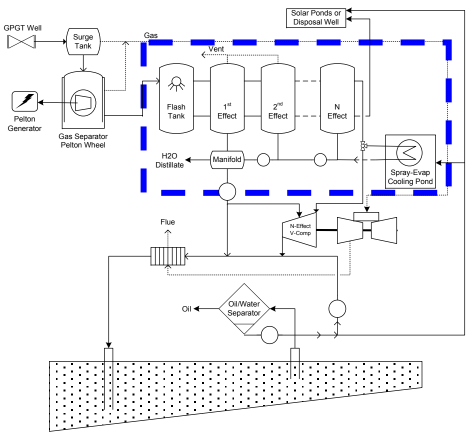


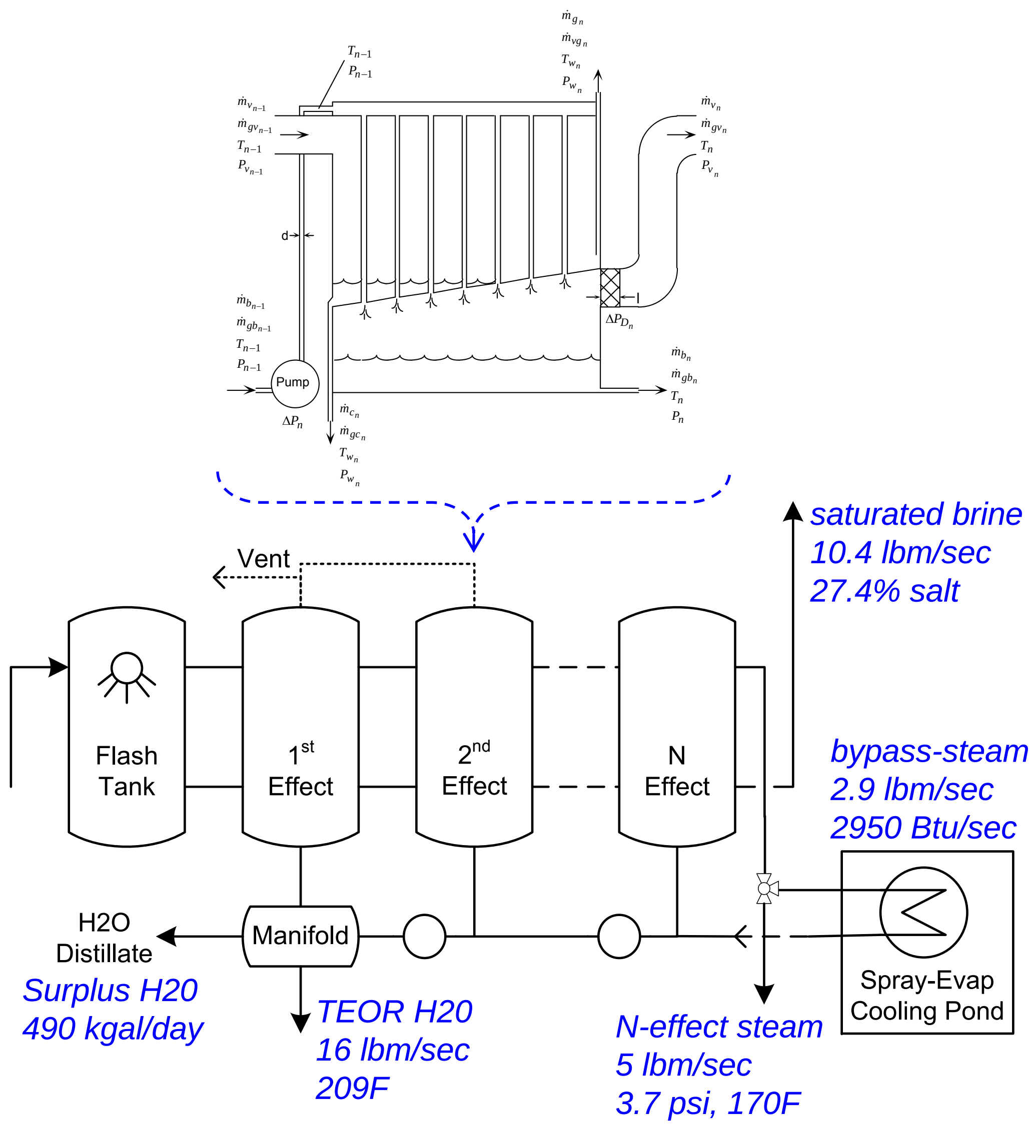
FUNCTION

- Flow GPGT brine via well bore
- Recover hydraulic energy via Pelton-Wheel turbine-generator
- Separate gas for on-site use
- Vend surplus electricity to grid

Baseline performance values noted.

Subsystems: Multi-Effect Distillation



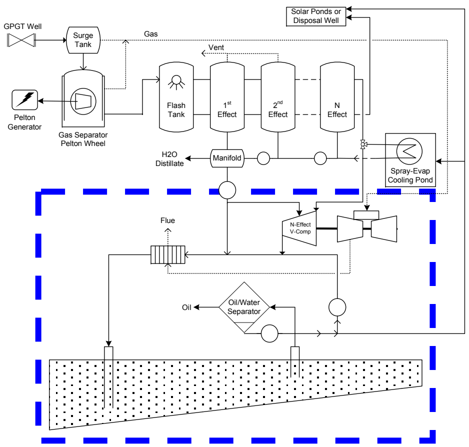


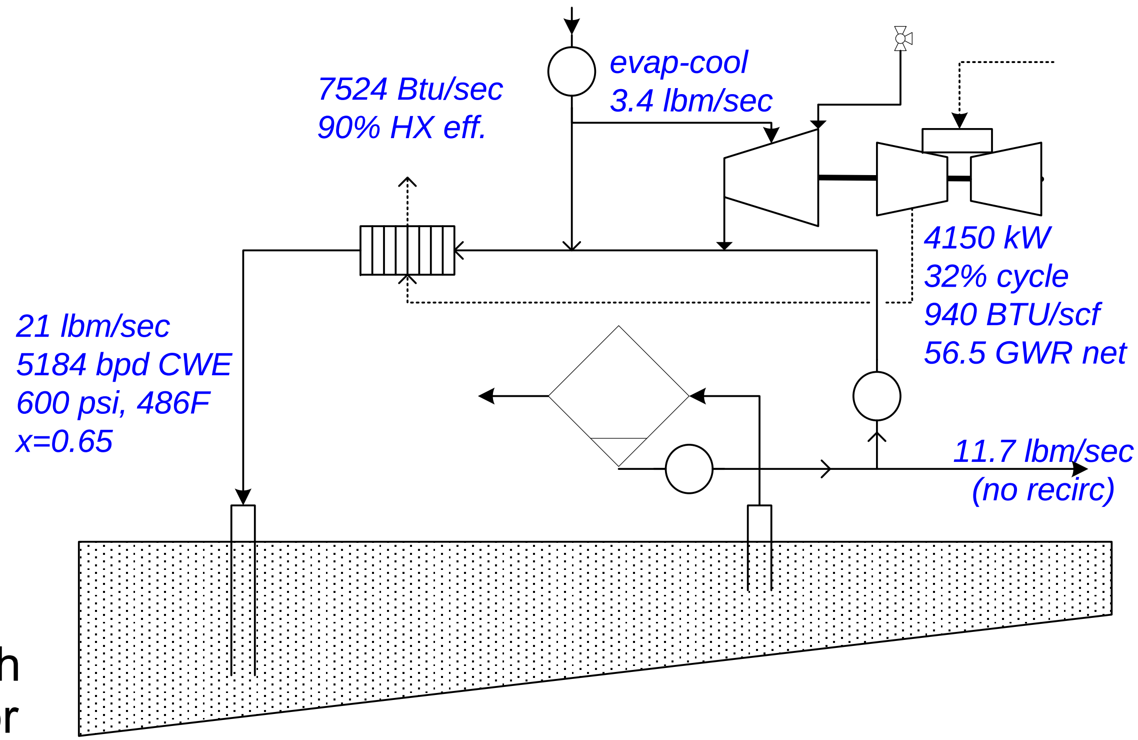
FUNCTION

1. Concentrate GPGT brine
2. Produce steam / H20 for TEOR
3. Vend distilled H20 surplus
4. Provide heat for evaporating TEOR produced water bottoms

Design Point: 600 psi, x=0.65

Subsystems: TEOR Fluid Conditioning



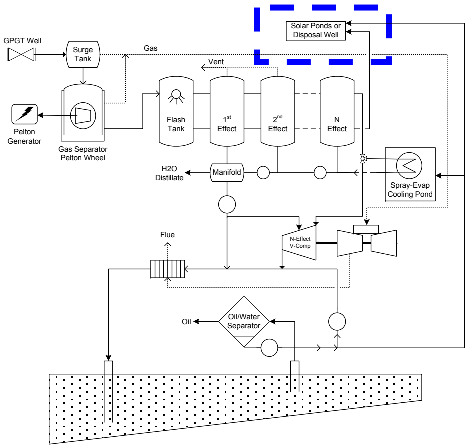


FUNCTION

1. Compress N-effect steam with gas-turbine/vapor-compressor
2. Augment steam via evaporative-cooled vapor compression
3. Recover gas-turb exhaust heat
4. Option: recirc produced waters

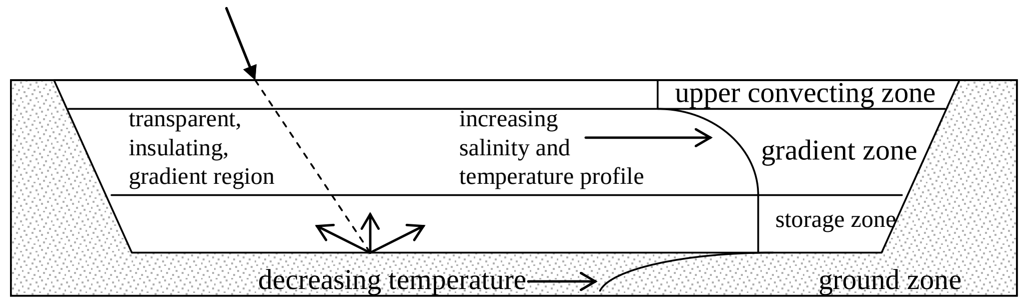
Other design points (pressure, quality) yield different TEOR steam mass rates. (see backup slides)

Subsystems: Solar Ponds

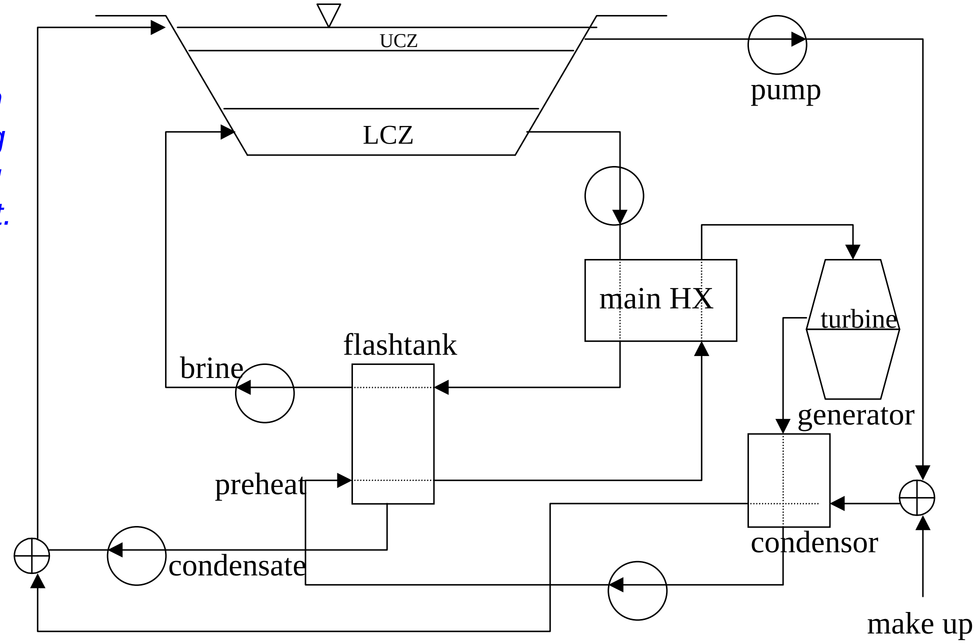


0.4m UCZ
1.4M NCZ
1.8m LCZ

Temp. LCZ:
65-105℃



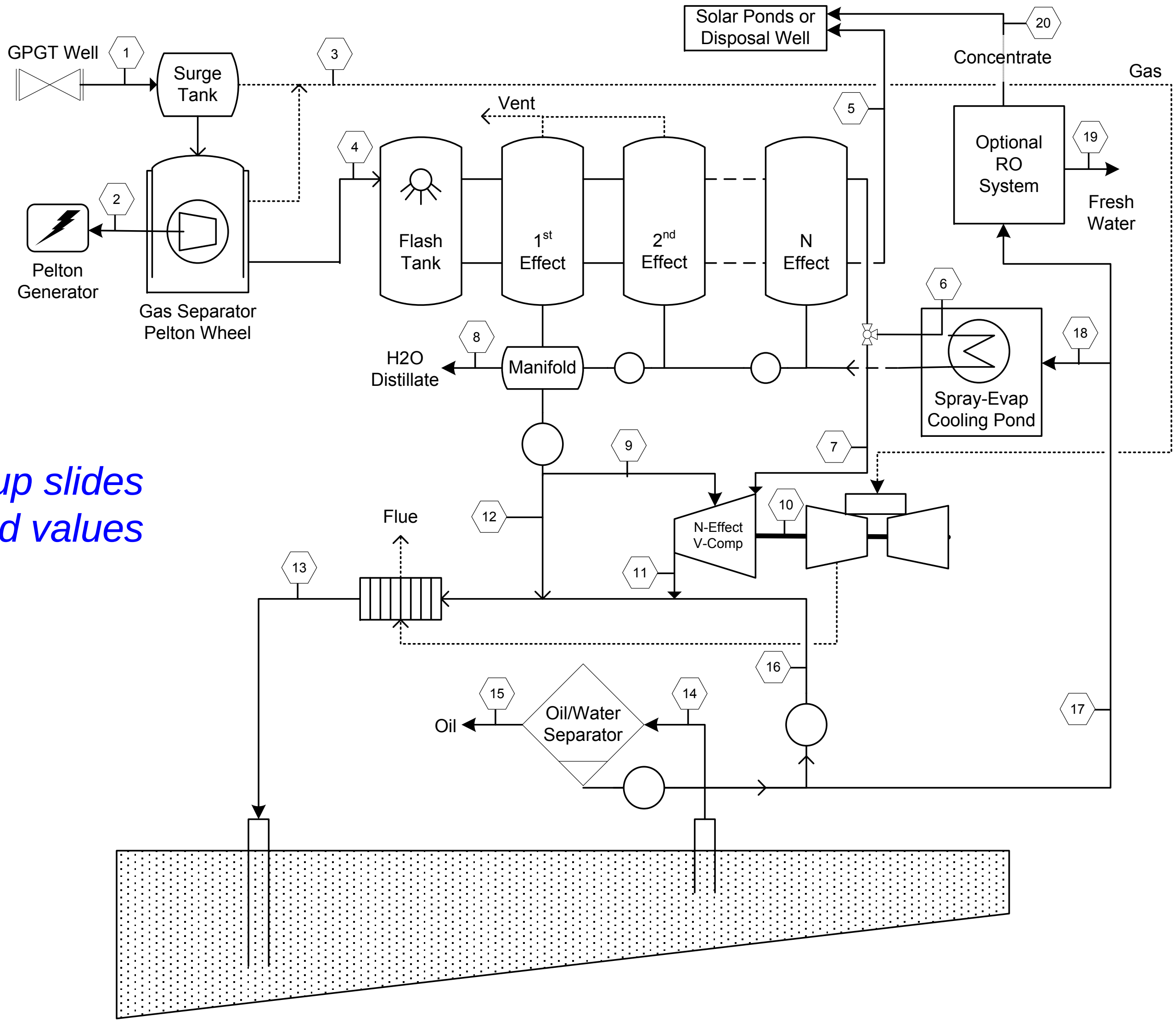
Bakersfield
3.7-5.3 W/sm
4.5 W/sm avg
1.8 MWe avg
~2.0 MWe opt.



FUNCTION

1. Establish renewable energy infrastructure as co-product
2. Revenue-neutral "market" for saturated salt brine by-product
3. Each baseline GPGT system establishes ~100 ac. solar pond
4. 100 ac. SP yields ~2 MWe continuous solar thermal electric

Overall System



See backup slides for indexed values

Outline

GEM TEOR

What is it?

→ What are the cost savings?

What is the status of its implementation?

Baseline Production & Capital Costs

Design Point (x=0.8, P=800 psi)

Daily Production

Product	Daily Production	Unit Value	Daily Gross Returns
TEOR Steam (x=0.80, P=800 psia)	4419 CWE bpd	NA	NA
Surplus H2O Distillate	520 kgal/day	$5.00/kgal	$2600
Surplus Electric	7200 kWhr/day	$0.06/kWhr	$430
		Total	$3030

Capital Costs (*Pilot*)

Component	Cost
GPGT well 10,000 ft, 5.5 inch production tubing	$3,000,000
Disposal well (for piloting; not required for solar ponding) 10,000 ft, 3.5 inch tubing (offset, lower GPGT zone)	$2,000,000
Pelton Turbine/Generator first-unit cost, including all NRE	$1,000,000
Multi-Effect Distillation Unit	$5,000,000
TEOR Fluid Cond. Equip. (gas-turbine, vapor compressor)	$7,000,000
Misc. Site Equip. & Const. (SEP, control trailer, etc.)	$1,000,000
Total	$19,000,000

Capital costs based on vendor quotes.
Water/Elec prices market estimates.

Baseline Cost Comparison
Design Point (x=0.8, P=800 psi)

Baseline comparison w/ Once-Through Steam Generator (OTSG) Design Pt. (x=0.8, P=800 psi)

	GEM TEOR	OTSG
20yr Capital Expenditure per CWE bspd	$4458	$1316-$3086
Mcf gas per CWE bbl steam (x=0.8)	0.272	0.476
Ton/day CO2 for 4419 CWE bspd (~121 lbm CO2 combustion gas per GPGT Mcf)	73	129
Effective costs $/CWE bbl steam (x=0.8)		
Gas costs (GEM gas @ opportunity costs)	$1.52 ($5.57/Mcf)	$3.81 ($8/Mcf)
Water treatment costs (industry souces)	$0	$0.10—$0.25
Offset for water/electricity sale ($3030/4419)	-$0.69	$0
Produced water disposal costs (site dependent)	$0	$0—$1.50
Carbon Tax ($40/ton)	*$0.66*	*$1.17*
Total Costs per CWE bbl steam (*w/ carbon tax*)	$1.49	$5.08—$6.73
Total Costs per CWE bbl steam (*w/o carbon tax*)	$0.83	$3.91—$5.56
GEM TEOR cost savings per CWE bbl steam	$3.59—$5.24 (*w/ carbon tax*) $3.08—$4.73 (*w/o carbon tax*)	

Does not include GEM TEOR optimization or solar energy tax breaks and additional carbon offsets.

▶ 34

Notional "*Revenue Neutral*" Solar Pond Costs

Ref →	Lu, 2002 [54] (1)		Doron, 1990 [55] (2)			May, 1983 [104] (3)
Area (Ac)	51.94	469.91	61.83	247.3	494.6	20 (3x)
$ SP_{cap}	2,374,159	15,876,715	5,045,000	10,370,000	17,470,000	4,075,000
$/$Ac_{SPcap}$	45,710	33,787	81,595	41,933	35,321	203,750 (67,917)
$ Pwr_e Eq.	N/A	N/A	1,250,000	5,000,000	10,000,000	2,480,000 (827,000)
$/$kW_e$			1,000	1,000	1,000	1,240
Total $			6,295,000	15,370,000	27,470,000	6,555,000
Total $/Ac			101,811	62,151	55,540	327,750 (109,267)
Notes	(1) Primary objective thermal energy to drive flash distillation processes; electricity generated to run pumps solely; SP build costs (1992 $) considered applicable (2) Primary objective electricity generation; actual 1980 $, Beith Ha'Arava, Israel (3) Construction costs considered 3x higher as they include an 18 acre maintenance pond, plus evaporation and cooling ponds (correlative estimate given in parenthesis, i.e. 3x 20 = 60 acre effective pond build area); reference uses SOLPOND (see App.B; MITSOL used instead of SOLPOND as source code was unavailable) and apparently assumes 3x better performance than what would be expected (from MITSOL), ergo the parenthetical $$Pwr_e$ value is also decremented 3x for comparison purposes here.					

With proper CO2 tax management and renewable tax credits, the solar ponds can be established "*cost free*"

→ *$40,000/acre construction*

\+

→ *$20,000/acre ORC pwr equip*

→ *$60,000/acre SP costs (~$50k/acre salt cost offset)*

- $60k/ac x 100 ac = $6M
- conveyance: $1M—$4M

  (Kern County – Mojave Desert)
- Total 2MW SP costs $7M—$10M
- 2MW SP offset TEOR carbon
- $5M TEOR carbon offset credit
- Balance: $2M—$5M SP costs
- For 4M bbl oil production per GPGT well, a $0.50—$1.25/bbl-oil renewable energy tax credit would install the SP "***cost free***"

[54] Lu, Huanmin, Walton, John C., and Hein, Herbert; **Thermal Desalination Using MEMS and Salinity-Gradient Solar Pond Technology**, UTEP, DOI Desalination R&D Program Report No.80, August 2002.

[55] Doron, B., Ormat Turbines Ltd Israel; **Solar Pond Activity – Status and Prospects**, 2nd International Conference on Solar Ponds, Rome, 25-31 March 1990.

[104] May, E.K., Leboeuf, C.M., Waddington, D.; Conceptual Design of a 20-Acre Salt Gradient Solar Pond System for Electric Power Production at Truscott, Texas; SERI/TR-253-1868, July, 1983.

Outline

GEM TEOR

What is it?

What are the cost savings?

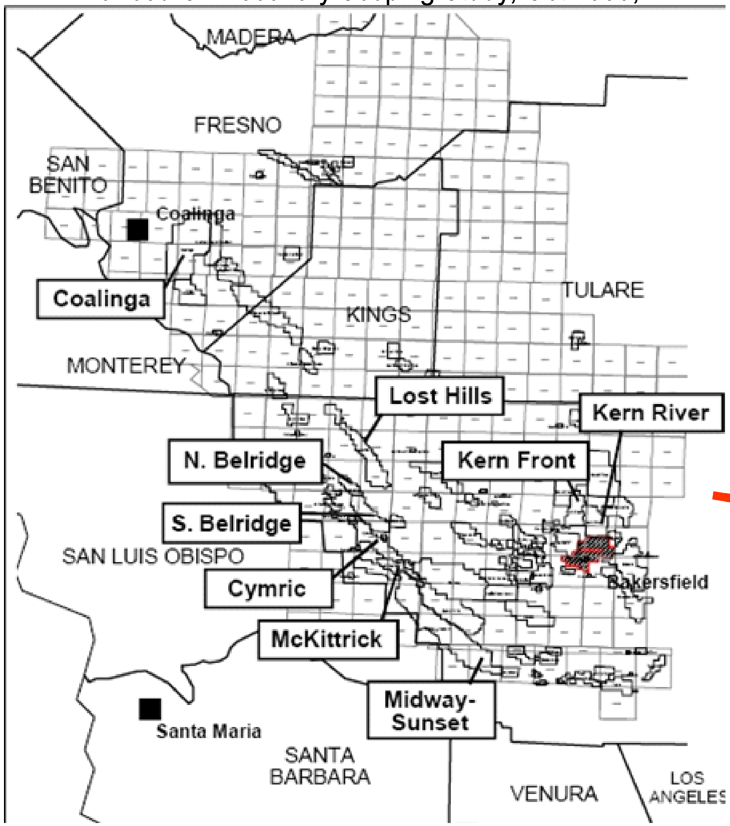
➡ What is the status of its implementation?

GEM TEOR is Pilot Project Ready

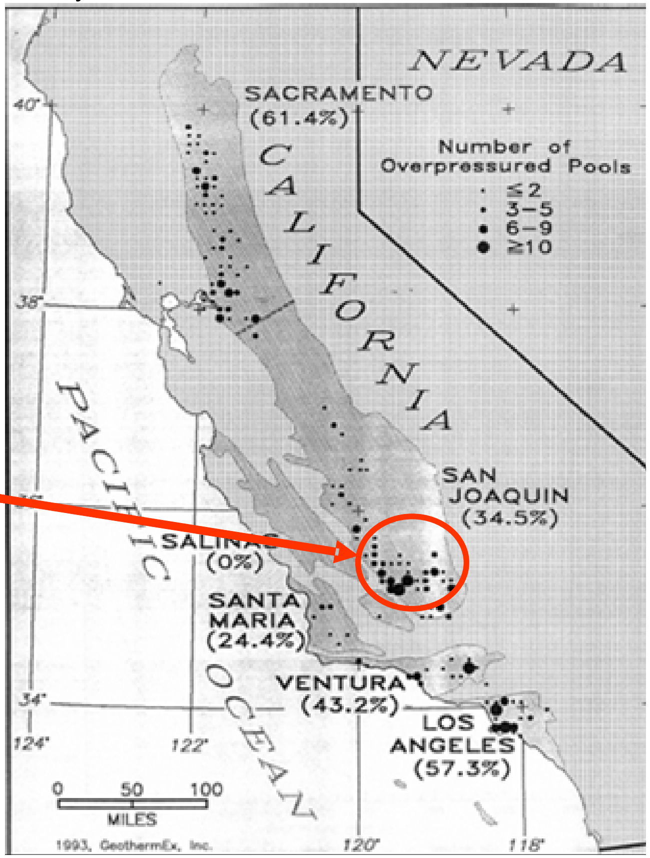
- **Establish a Pilot Project to profitably demonstrate GEM TEOR**
  - Patented technology to protect stakeholder interests
  - Profitable pilot, revenue sharing amongst stakeholders
  - Assess the California GPGT energy capacity / characteristics
  - Proof the GEM TEOR systems performance
  - Optionally proof the instantiation of co-product solar ponds
- **Candidate Pilot Project Partners:**
  - Heavy-oil lease operators
  - Renewable-energy infrastructure developer / purveyor
  - Other industry partners (equipment suppliers)
  - State and Federal agencies (e.g., for cost share, data support)
- **Role of Good Earth Mechanics, LLC**
  - Holds GEM TEOR intellectual property
  - Association of subject matter experts to promote/optimize GEM GPGT designs
  - Provide subject matter expertise to help develop/support/manage the pilot
  - Preliminary vendor and stakeholder coordination, feasibility studies complete

Pilot Project Candidate Locations

Enhanced Oil Recovery Scoping Study, Oct.1999, EPRI

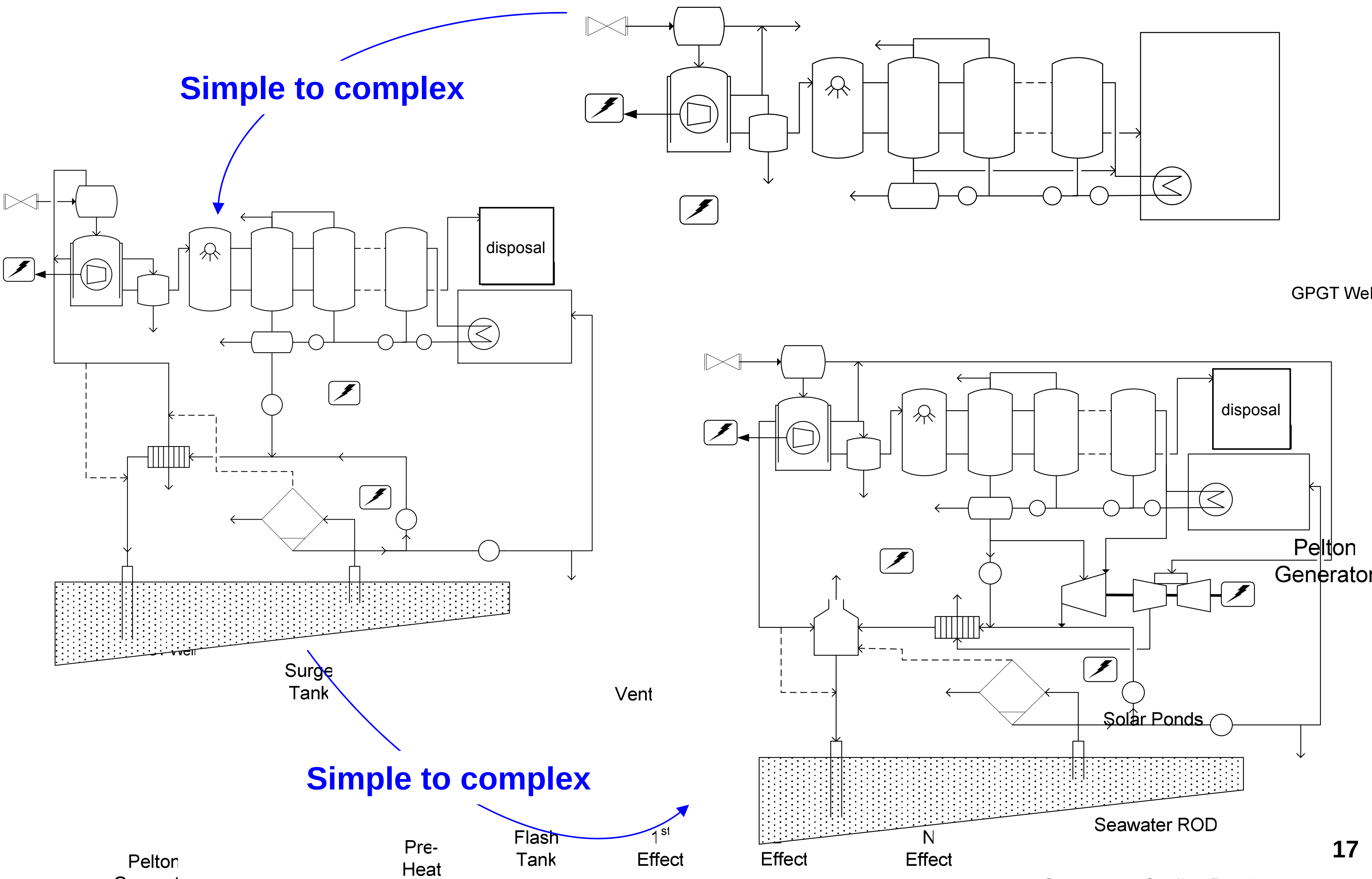


Survey of Potential GPGT in CA, Mar.1993, GeothermEx



South Texas GPGT fairways will also provide candidate locations for a Texas Pilot Project

Example Pilot Configuration Build-Up



Pilot Project General Risk Assessment

Component	Risk Characteristics	Risk Mitigation	Risk Rank
GPGT Wells	CA GPGT resource untested, well design, CACO3 scaling	TX GPGT flow-test experience by DOE, CEC evaluated CA GPGT, Govt cost-share for GPGT proofing	**Medium (Low in TX)**
Environmental	GPGT reservoir subsidence, tectonic activity, SP impacts	Carbon offsets motivation, early impact studies, Gulf Coast GPGT testing showed no adverse impacts	**Low-Med**
Pelton Turbine	High pressure seals, adjust for decreasing head, environment	Material selection, non-critical component (i.e., replace with purchased electricity if needed)	**Low**
MED	Modified off-the-shelf design, titanium, scaling, control	Early coordination with vendors, material selection, scale inhibiter	**Low**
TEOR FCS	Modified vapor compressor, evap-cooled –compression	Iterative design improvement planned	**Low**
Solar Pond	Permitting, gradient maintenance, algae plumes	Solar pond practitioner and maintenance expertise, fail-safe design, renewable energy motivation	**Low**

Pilot project is generally low-to-medium-risk, using off-the-shelf systems.

Recent GPGT-Energy Legislation

Potential GPGT-well pilot program cost-share, risk-reduction

Advanced Geothermal Energy Research and Development Act of 2007

Section 7. Geothermal Energy Production from Oil and Gas Fields and Recovery and Production of Geopressured Gas Resources

Establishes a demonstration program to prove the feasibility of co-producing geothermal power from hot water "co-produced" from oil and gas fields. This section also directs the Secretary of Energy to hold a design competition to produce preliminary designs for state-of-the-art approaches to recovering the energy contained in geopressured resources *– which contain heat, pressure, and dissolved methane – in and near the Gulf of Mexico.*

Energy Independence and Security Act of 2007

Subtitle B, Geothermal Energy

DOE is directed to establish a program of R&D, demonstration, and commercial application for geothermal energy production from oil and gas fields and from geopressured resources*. Section 616 directs DOE to implement a grant program for at least three demonstration projects that use geothermal techniques to extract energy from marginal, unproductive, and productive oil and gas fields. Also, DOE is directed to establish a* grant program for the recovery of energy from geopressured resources*.*

GEM TEOR Summary

- **GEM TEOR design concept is ready for piloting in CA, TX**
  - Half the fuel per CWE bbl steam (v. gas-fired steam generators)
  - $3-$5 savings per CWE bbl steam (@ $8/Mcf gas)
  - Establish renewable energy system as optional co-product
  - Half the carbon footprint (*~zero with renewable system offset*)
- **Seeking pilot partners / sponsors / Govt. cost share**
  - Revenue sharing amongst stakeholders, arrangement TBD
  - Patent-protected technology
  - Utilize GEM engineering support, studies, and vendor coordination
- **For more information contact:**

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Backup Material

Good Earth Mechanics (GEM) TEOR: System Synopsis

Enhanced Oil Recovery System For Use With A Geopressured-Geothermal Conversion System

The Geopressured-Geothermal (GPGT) conversion system recovers raw GPGT brine through a wellbore, separates the natural gas, and concentrates the brine in a multi-effect evaporator.

The separated gas and distillate H20 from the evaporator are used in a unique process to provide cost-effective steamflood of collocated (shallower) heavy oil. The patent-pending Thermal Enhanced Oil Recovery (TEOR) process uses half the fuel per CWE bbl steam compared to conventional steam generators, reducing the carbon footprint while mitigating logistical problems of steam feed water treatment and TEOR produced water disposal.

An optional co-product of the system is the establishment of large-scale solar ponding, from the concentrated brine discharge. The solar ponds can be equipped and used as a renewable energy resource, e.g., producing solar-thermal electricity.

A baseline system is projected to provide 4400 bpd steam (CWE) at 800 psi, x=0.80 quality, for a five-year GPGT flow-life. The co-product solar pond will produce 2 MW_e annual average.

The system is proposed for deployment in California and/or Texas, where the two largest U.S. GPGT basins exist. The California GPGT capacity is estimated at 1000+ baseline systems, and the Texas GPGT capacity is conservatively twice that of California.

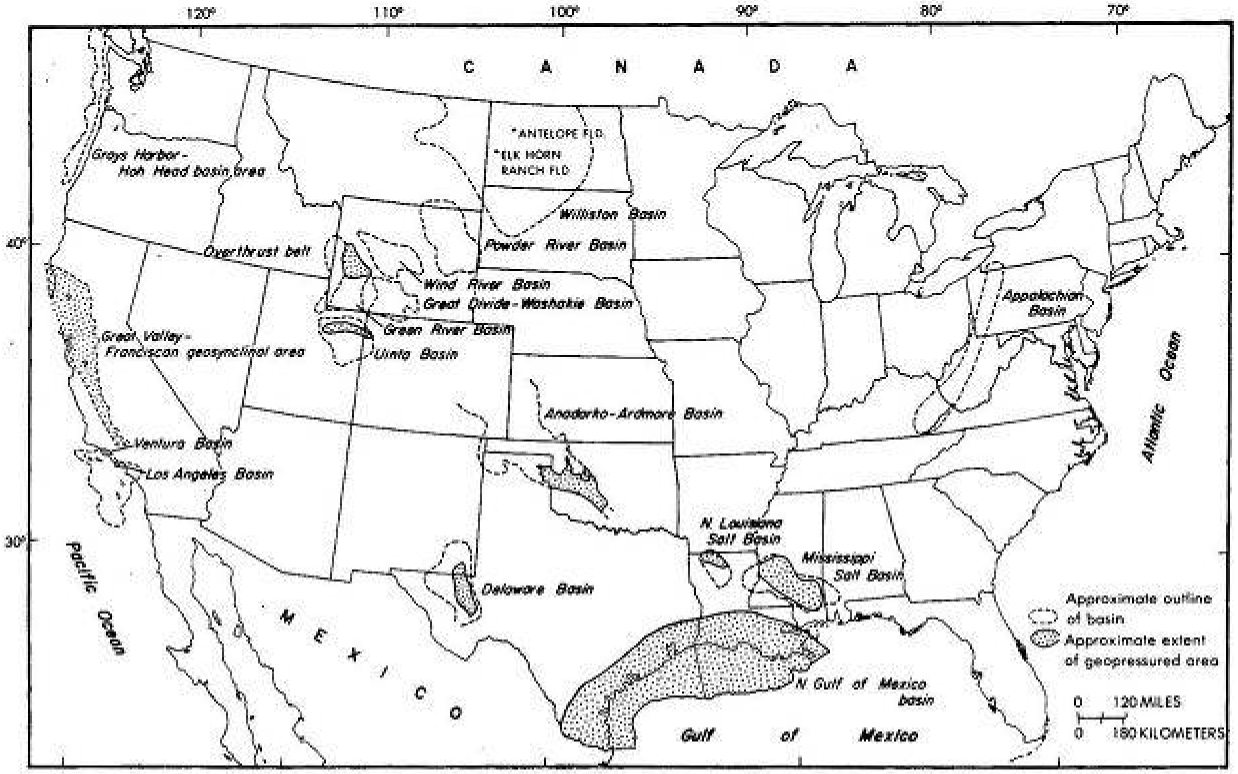
The GPGT Resource

Geopressured-Geothermal energy (GPGT) is an immense energy resource that remains relatively untapped throughout the world

- **High pressure, high temperature, gas cut, brine reservoirs**
  - wellhead pressure: 1000–4000 psi
  - brine temperature: 250–400°F
  - GPGT brines contain 20–100 scf/bbl natural gas
  - normally found at depths greater than 10,000 feet
  - can be produced at high flow rates: 20,000–40,000 bbl/day
  - GPGT brines contain 15,000–200,000 ppm dissolved solids, typically 85% NaCl
  - outstanding flow longevity (Dept. of Energy flow tests, Gulf Coast region)
- **The recoverable GPGT energies are**
  - thermal (heat exchange with brine)
  - mechanical (flowing pressure at wellhead)
  - chemical (natural gas)
- **U.S. GPGT regions are strategically collocated**
  - California/Gulf Coast GPGT collocation with water crisis regions
  - GPGT collocation with medium-to-heavy U.S. oil reserves

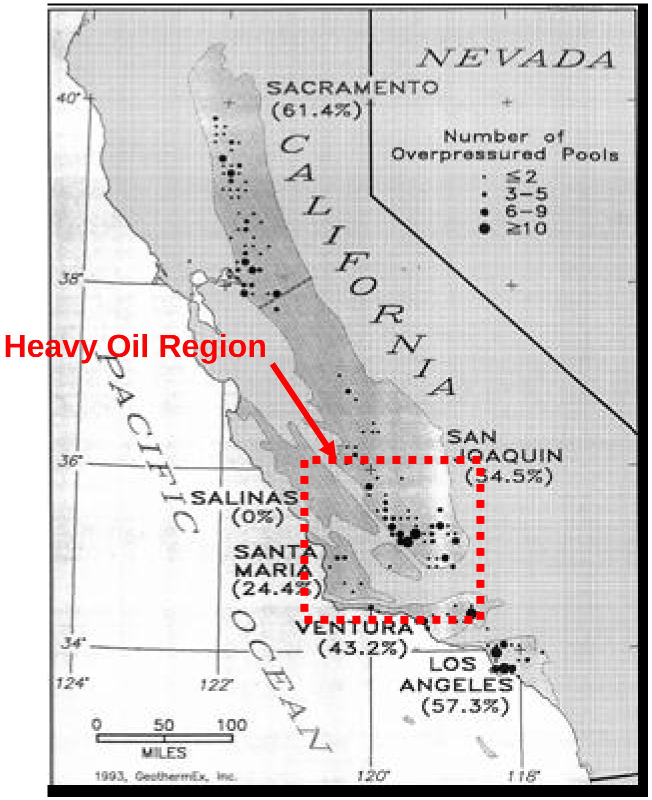
Not to be confused with “*hot-rock*” geothermal energy

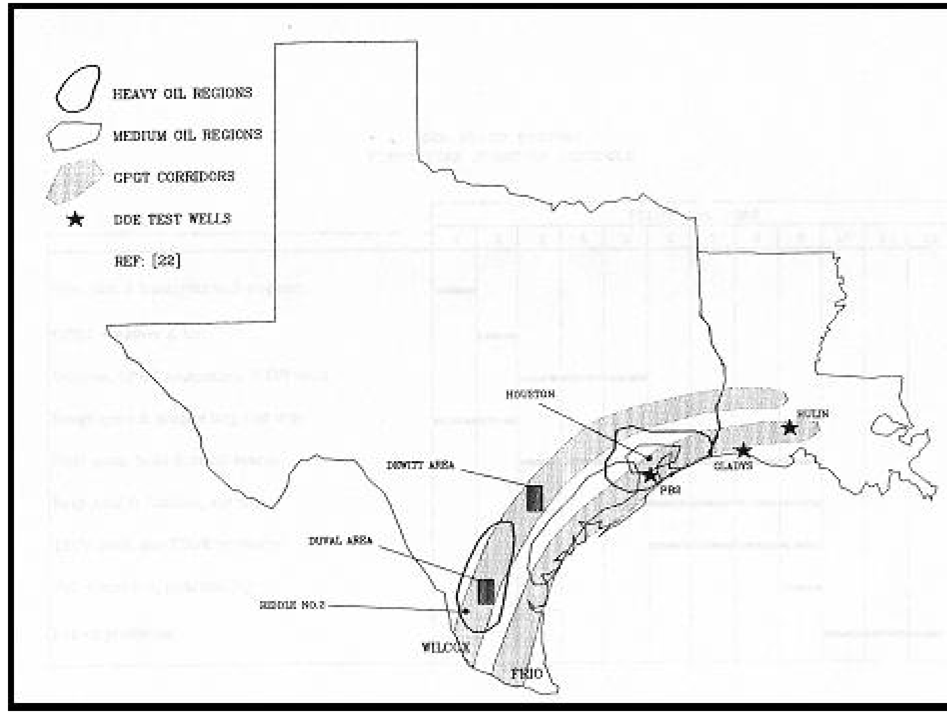
The GPGT Resource



U.S. GPGT Regions

The GPGT Resource

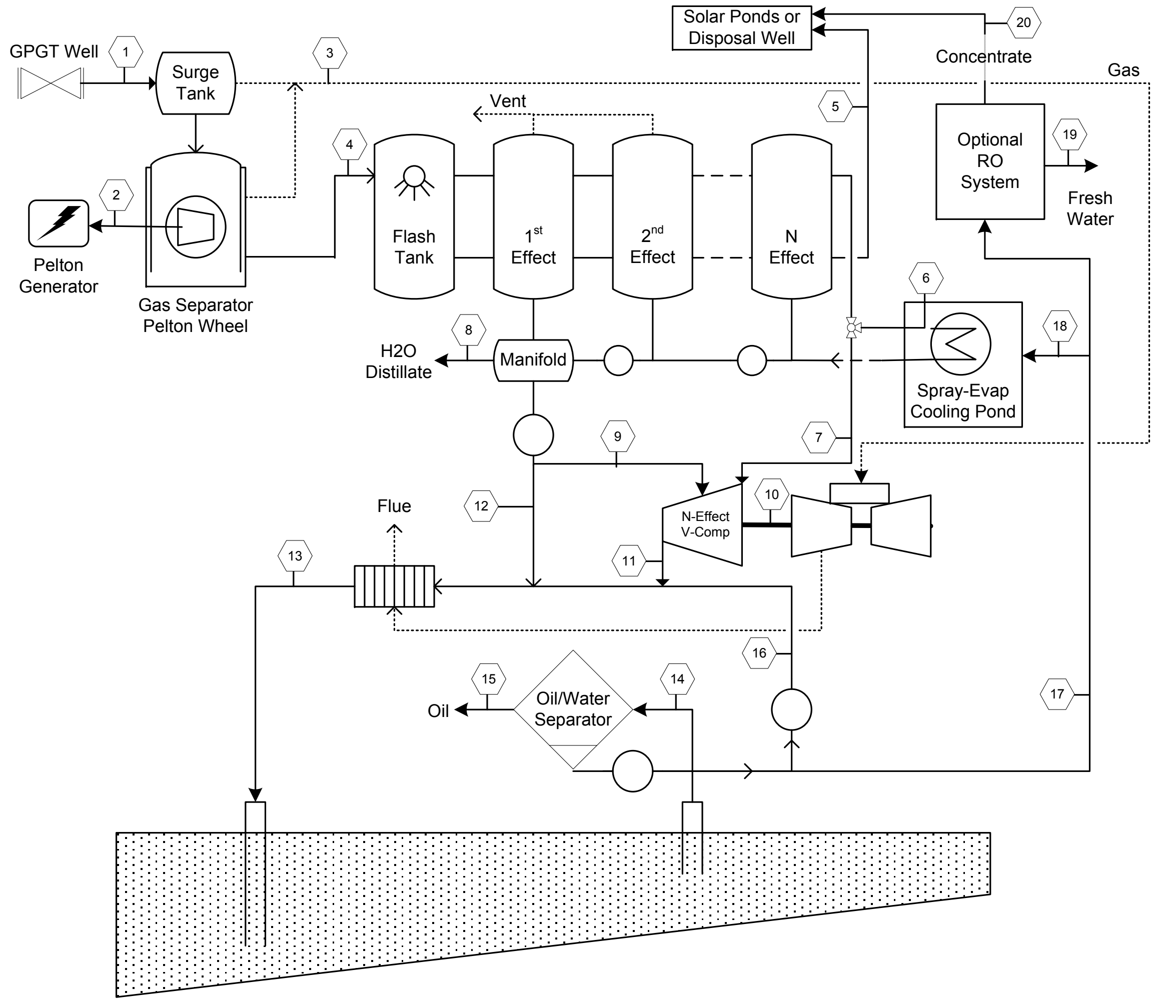




U.S. GPGT and Heavy Oil Collocational Aspects

4

GEM TEOR Evaluation No. 1R: Case 5

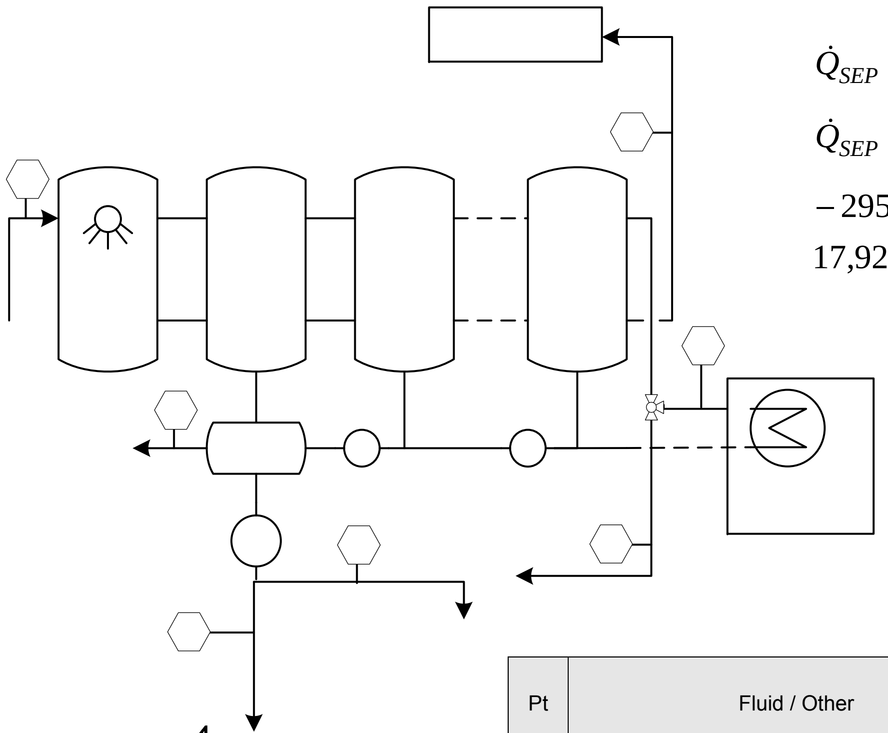


GEM TEOR Evaluation No. 1R: Case 5

(x=0.65, P=600 psi)

Pt	Fluid / Other	Mass Rate (lbm/s)	Pressure (psia)	Temperature (F)	Remarks
1	20,000 bpd GPGT brine, 3.5% salt	79.65	3000	300	Case 5: 35k ppm, 300F, 60 scf/bbl GWR
2	Power produced by Pelton Turbine	NA	NA	NA	600 kW (η: 87.2% Pelton, 95% generator)
3	Gas, from Surge Tank & Separator	0.86	200	300	0.12 lbm/s H2O; dry gas 81% mol CH4 0.46 lbm/s
4	de-gassed GPGT brine to flash tank	78.79	200	300	Tflash = 250F, Pflash = 28.9 psia
5	saturated brine output from MED	10.41	4.44	170	27.4% mass salt (83% NaCl, 13% CaCl, 2% KCl)
6	MED steam bypassed to condenser	2.90	3.69	170	20.3°F superheat (12.4°F boiling point rise effect N)
7	N-effect vapor for compression	4.96	3.69	170	
8	H2O distillate withdrawn for sale	47.35	28.5	209	
9	inner-stage evap-cool water	3.40	as req'd	209	inner-stage evap cool provided at pressure required
10	gas-turbine pwr for vap-compress	NA	NA	NA	4150 kW (dry gas: 940 BTU/scf, 56.5 GWR net)
11	compressor TEOR steam	8.36	600	495	superheat ratio Dsh = 0.05
12	makeup H20 for target TEOR x	12.63	600	209	turbine exhaust heat recovered = 7524 BTU/s
13	x=0.65 quality TEOR steam	21.00	600	486	5184 CWE bpd TEOR steam
14	oil and TEOR return water	NA	NA	100 (est.)	recovered oil plus TEOR water less hole losses
15	recovered oil	2300 bpd	NA	NA	SOR = 2.25 bbl oil per CWE bbl steam
16	recirculated TEOR fluid	0	NA	NA	no-recirculation for this evaluation
17	recovered TEOR water for line out	11.68	surface	100 (est.)	estimate 2300 bpd H2O (hole losses = bbl oil rec)
18	evap-cool water for zero-out SEP	2.90	30	100	0.1 acre zero-discharge spray-evap pond
19	RO potable water	1300 bpd	NA	NA	assuming 60% recovery
20	RO concentrate	867 bpd	NA	NA	density f{TEOR water TDS}, estimate as water
The above projections apply to **No Recirculation**. The following projections apply for **Full Recirculation** (only differences tabulated below, all other data equivalent between the two configurations)					
8	H2O distillate withdrawn for sale	56.61			
12	makeup H20 for target TEOR x	3.37			
13	x=0.65 quality TEOR steam	19.80			4888 CWE bpd TEOR steam
14	oil and TEOR return water				
15	recovered oil	2170 bpd			SOR = 2.25 bbl oil per CWE bbl steam
16	recirculated TEOR fluid	8.11	600	100 (est.)	full recirculation (less water for zero-out SEP)
17	recovered TEOR water for line out	2.90			estimate 715 bpd H2O (hole losses = bbl oil rec)
18	evap-cool water for zero-out SEP				
19	RO potable water	0			
20	RO concentrate	0			

Mass / Energy Balance Check: MED



$$\dot{Q}_{SEP} + \dot{m}_4 h_4 = \dot{m}_5 h_5 + \dot{m}_7 h_7 + \dot{m}_8 h_8 + \dot{m}_9 h_9 + \dot{m}_{12} h_{12}$$

$$\dot{Q}_{SEP} = \dot{m}_6 \left(h_{f,3.7\,psia} - h_6\right) = 2.90(117.4 - 1135) = -2951 \frac{Btu}{s}$$

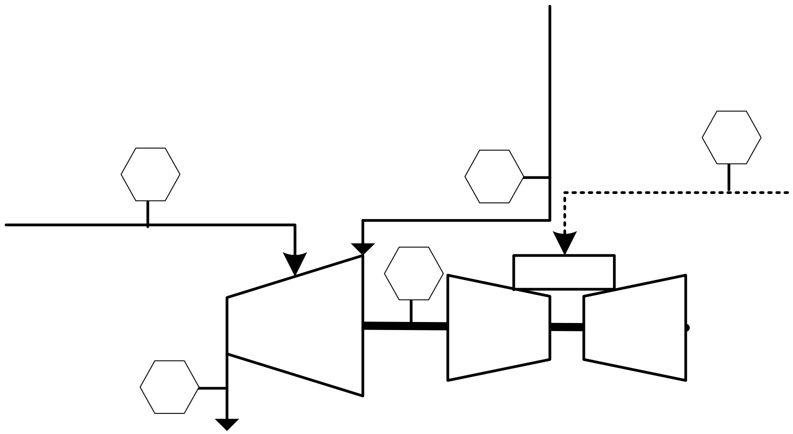
$$-2951 + (78.79)265 = (10.41)110 + (4.96)1135 + (47.35 + 3.40 + 12.63)177$$

$$17{,}928 = 17{,}993$$

Pt	Fluid / Other	Mass Rate (lbm/s)	Pressure (psia)	Temperature (F)	Enthalpy Btu/lbm
4	de-gassed GPGT brine to flash tank	78.79	200	300	265 [1]
5	saturated brine output from MED	10.41	4.44	170	110 [2]
6	MED steam bypassed to condenser	2.90	3.69	170	1135 [3]
7	N-effect vapor for compression	4.96	3.69	170	1135
8	H2O distillate withdrawn for sale	47.35	28.5	209	177
9	inner-stage evap-cool water	3.40	as req'd	209	177
12	makeup H20 for target TEOR x	12.63	600	209	177

Notes: [1] specific heat of 3.5%, 300F brine = 0.984 Btu/lbm*R
[2] specific heat of 27.4%, 170F brine = 0.797 Btu/lbm*R
[3] 20.3F superheat, condensed to sat. liquid in SEP

Mass / Energy Balance Check: TEOR FCS



$$\dot{m}_7 h_7 + \dot{m}_9 h_9 + \dot{W}_{10} = \dot{m}_{11} h_{11}$$

$$(4.96)1135 + (3.40)177 + 3934 = (8.36)1212$$

$$10{,}165 = 10{,}132$$

Pt	Fluid / Other	Mass Rate (lbm/s)	Pressure (psia)	Temperature (F)	Enthalpy Btu/lbm
3	Gas, from Surge Tank & Separator	0.86 [1]	200	300	NA
7	N-effect vapor for compression	4.96	3.69	170	1135
9	inner-stage evap-cool water	3.40	as req'd	209	177
10	gas-turbine pwr for vap-compress	NA	NA	NA	4150 kW [2]
11	compressor TEOR steam	8.36	600	495 [3]	1212 [3]

Notes: [1] 940 BTU/scf, 56.5 GWR net, 20,000 bpd GPGT flow rate = 12,294 Btu/s
[2] Brayton Cycle efficiency = 32% (3934 Btu/s = 5565 SHP = 4150 kW
[3] superheat ratio Dsh = 0.05

3

Gas

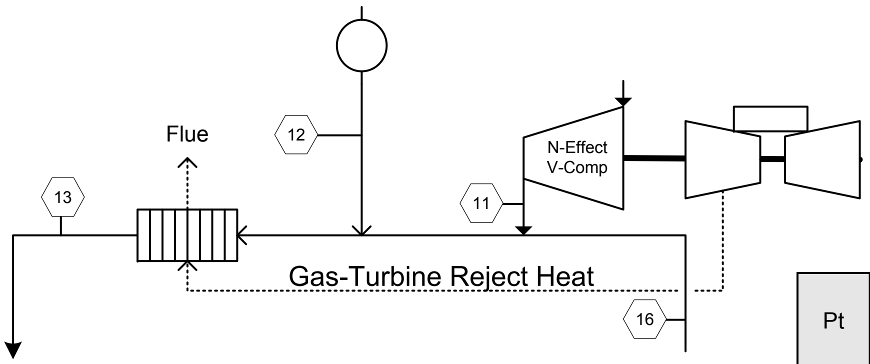
9

7

10

N-Effect
V-Comp

Mass / Energy Balance Check: Gas-Turbine Heat Recovery



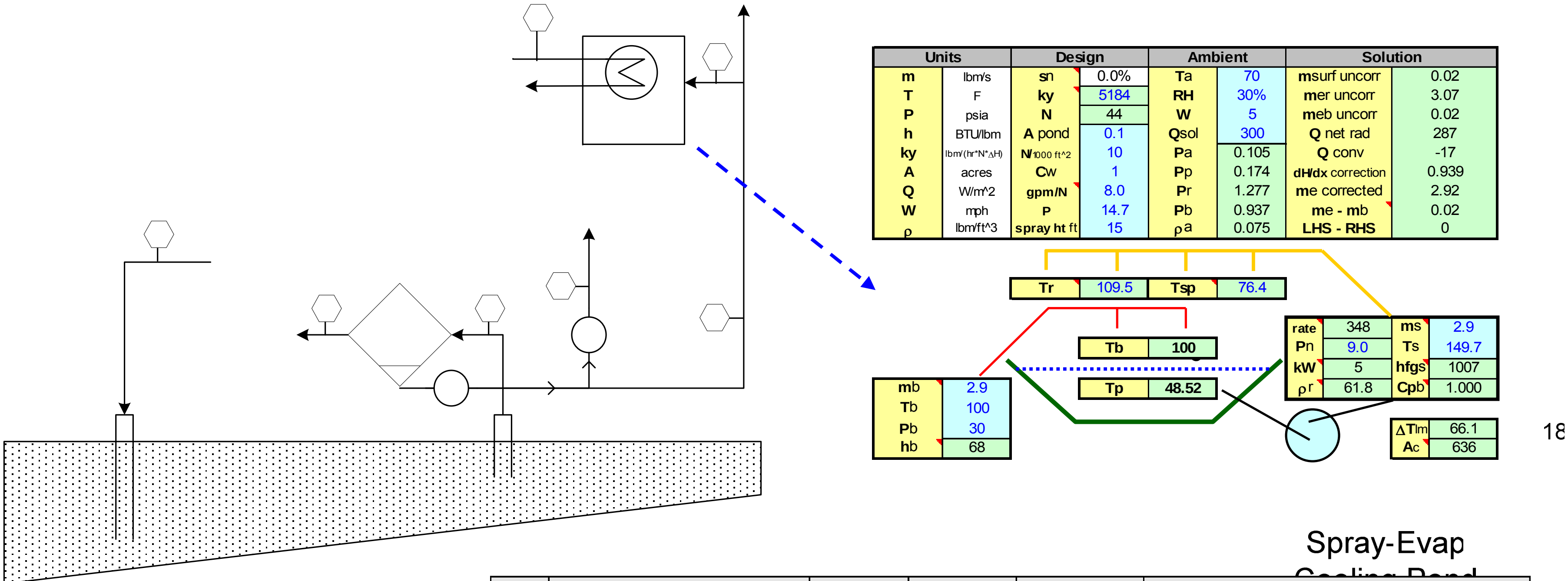
Pt	Fluid / Other	Mass Rate (lbm/s)	Pressure (psia)	Temperature (F)	Enthalpy Btu/lbm
11	compressor TEOR steam	8.36	600	495	1212
12	makeup H20 for target TEOR x	12.63	600	209	177
13	x=0.65 quality TEOR steam	21.00	600	486	947.8
16	recirculated TEOR fluid	0	NA	NA	
NA	Gas-Turbine Rej.Heat	NA	NA	NA	7524 Btu/s [1]
Notes [1] (1-0.32)12,294 = 8360 Btu/s; 0.90 thermal efficiency Recover Heat = 7524 Btu/s					

$$\dot{m}_{16}h_{16} + \dot{m}_{11}h_{11} + \dot{m}_{12}h_{12} + \dot{Q}_{HX} = \dot{m}_{13}h_{13}$$

$$0 + (8.36)1212 + (12.63)177 + 7524 = (21.0)947.8$$

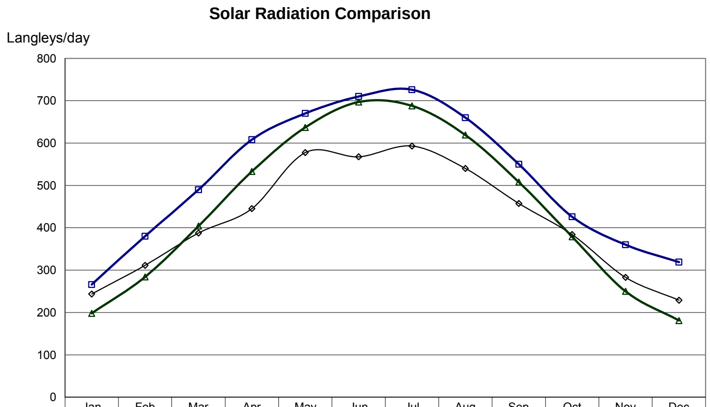
$$19{,}892 = 19{,}904$$

Mass / Energy Balance Check:
Hole, Zero-Discharge SEP

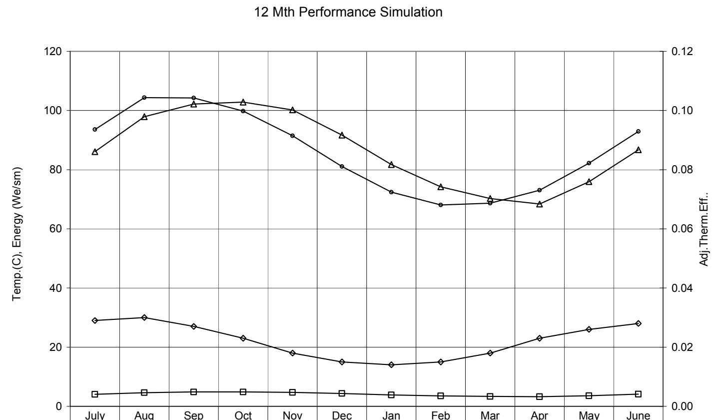


Pt	Fluid / Other	Mass Rate (lbm/s)	Pressure (psia)	Temperature (F)	Remarks
6	MED steam bypassed to condenser	2.90	3.69	170	2951 Btu/s to condense (see MED balance check)
13	x=0.65 quality TEOR steam	21.00	600	486	5184 CWE bpd TEOR steam
14	oil and TEOR return water	NA	NA	100 (est.)	recovered oil plus TEOR water less hole losses
15	recovered oil	2300 bpd	NA	NA	SOR = 2.25 bbl oil per CWE bbl steam
16	recirculated TEOR fluid	0	NA	NA	no-recirculation for this evaluation
17	recovered TEOR water for line out	11.68	surface	100 (est.)	estimate 2300 bpd H2O (hole losses = bbl oil rec)
18	evap-cool water for zero-out SEP	2.90	30	100	0.1 acre zero-discharge spray-evap pond

Solar Pond Performance

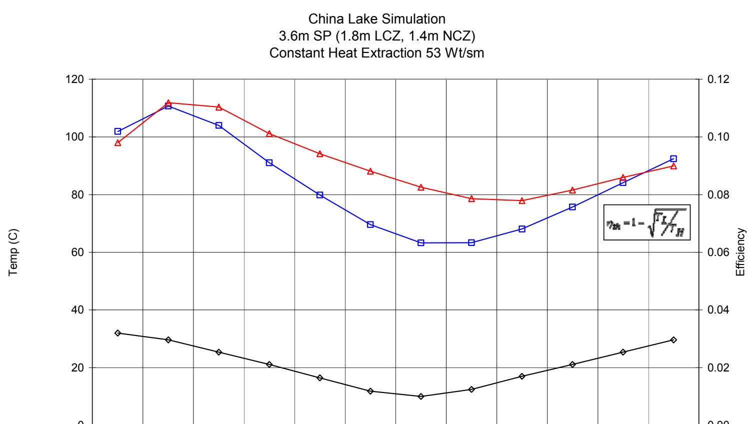


	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Corpus Christi	244	311	388	445	578	568	593	540	457	384	283	229
China Lake	266	380	490	608	670	710	726	660	550	426	360	319
Bakersfield	198	284	404	533	637	697	688	619	508	379	250	181



	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June
T-LCZ	93.59	104.38	104.24	99.78	91.44	81.09	72.39	68.04	68.65	73.07	82.2	92.92
T-AMB	29	30	27	23	18	15	14	15	18	23	26	28
Energy	4.05	4.60	4.80	4.83	4.71	4.31	3.84	3.49	3.30	3.21	3.57	4.08
ETA	0.09	0.10	0.10	0.10	0.10	0.09	0.08	0.07	0.07	0.07	0.08	0.09

Figure 7: Performance Parameters for 12 Mth Production Corpus Christi
(9.5 MW_{th} Steady Extraction Rate, i.e. 47 W/m^2)



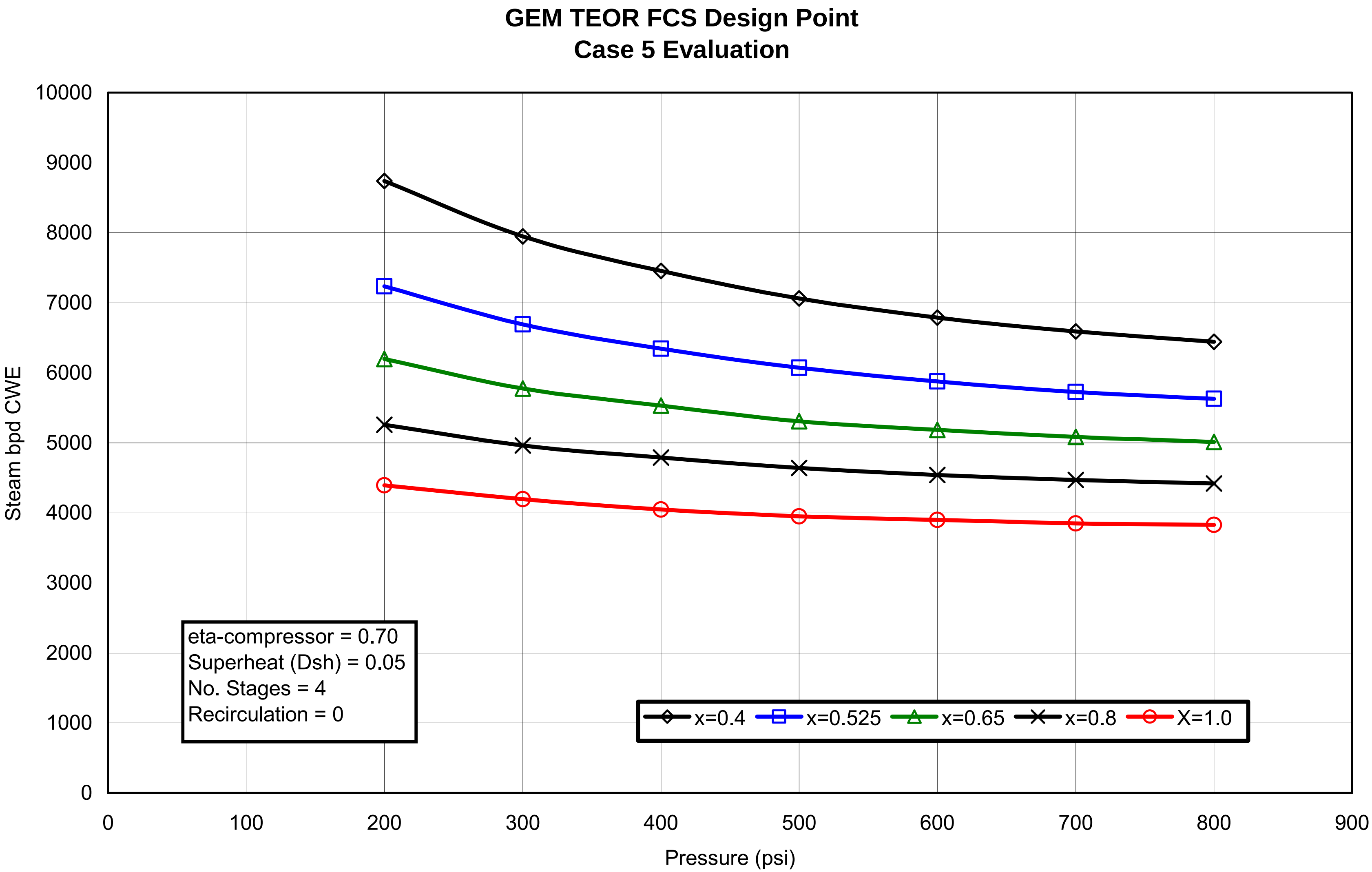
	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June
T-LCZ	101.92	110.70	104.00	91.05	79.82	69.61	63.24	63.33	68.09	75.68	84.15	92.43
T-AMB	32.00	29.63	25.37	21.11	16.48	11.85	10.00	12.50	17.00	21.11	25.37	29.63
ETA	0.098	0.112	0.110	0.101	0.094	0.088	0.083	0.079	0.078	0.082	0.086	0.090

Figure 2.2.2-8 China Lake 12 Month Simulation: Performance

Watts Elec / sq.meter

	Mojave	Kern	Corpus
July	5.19	4.62	4.05
Aug	5.93	5.27	4.60
Sep	5.85	5.33	4.80
Oct	5.36	5.10	4.83
Nov	4.99	4.85	4.71
Dec	4.67	4.49	4.31
Jan	4.37	4.11	3.84
Feb	4.17	3.83	3.49
Mar	4.13	3.71	3.30
Apr	4.32	3.77	3.21
May	4.56	4.06	3.57
June	4.77	4.42	4.08
Estimate Kern County average of Mojave & Corpus			
Average	4.86	4.46	4.07

GEM TEOR FCS Design Point (x,P)
Case 5 Evaluation



Cost Comparison: GEM TEOR v. OTSG

The **GEM TEOR CAPEX** for a 20 yr system (assuming the OTSG life is likewise 20 yr) is estimated as follows (x=0.8, P=800 psi):

4 x 5yr GPGT wells at $3M per well =	$6.7M (NPV to t=0 at i=10%)
1 Pelton-Generator set (production) =	$0.5M
MED system =	$5M
FCS gas turbine and vapor comp. =	$7M
Misc controls, SEP, trailer =	$0.5M
4 x 2MW solar ponds =	$0.0M (revenue neutral)
Total	$19.7M

Hence GEM TEOR CAPEX = $19.7M/4419 bspd = $4458 per CWE bspd.

OTSG CAPEX $1316-$3086 per CWE bpd steam from industry sources.

For **OTSG**, assuming inlet water (70F), h_{inlet} = 38.09 BTU/lbm for PEOR=800 psi at x=0.8, h_{EOR} = 1061.38 BTU/lbm, allowing thermal efficiency = 80%, 940 BTU/scf GPGT gas, 350 lbm/CWE-bbl steam, then

$$\frac{\dot{m}\left(h_{EOR} - h_{inlet}\right)}{\eta_{boiler}} = \dot{Q}$$ = 447,689 Btu/CWE-bbl steam = **0.476 Mcf gas/CWE bbl**.

GEM TEOR (Case 5) at x=0.8 and PEOR=800 psi, TEOR CWE steam = 4419 CWE bpd.
At 60 scf/bbl x 20,000 bpd GPGT = 1200 Mcf/day, or 1200/4419 = **0.272 Mcf gas/CWE bbl**.

Note: 0.272/0.476 = 0.57. With system optimization this ratio will approach 0.50 (half gas).

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G.S. Nitschke Biography

DR. NITSCHKE BIO:

Dr. George S. Nitschke completed his doctorate in renewable energy at the University of Massachusetts in October 2006. Nitschke is currently a Lead Engineer for the MITRE Corporation, providing technical support to the Dept. of Defense on airborne systems. Prior to MITRE, Nitschke worked for the Boeing Company, engineering airborne mechanical systems on both commercial and defense platforms. Nitschke received his M.S. Mech. Eng. in 1994 from the University of Washington and his B.S. Mech. Eng. in 1988 from the Wichita State University. Prior to becoming an engineer, Nitschke spent 12 years drilling exploratory oil, gas, and geothermal wells in Saudi Arabia, Venezuela, Jamaica, Peru, Brazil, Chad, Ascension Island, the Rocky Mountains and the U.S. Midwest. A licensed Professional Engineer, Nitschke holds patent(s) in Geopressured-Geothermal (GPGT) conversion systems and was a principal contributing consultant/author to the U.S. Department of Energy's GPGT consortium (circa 1990-92). Nitschke formed Good Earth Mechanics, LLC (GEM) in the fall of 2007. GEM is chartered to develop and promote the optimal conversion of the GPGT resource using technical expertise and intellectual property.