Converting Geopressured-Geothermal Reservoirs to Renewable Energy Systems with Thermal Enhanced Oil Recovery

Introduction at the Southern Methodist University Geothermal Laboratory Conference:
Geothermal Energy Utilization Associated with Oil & Gas Development

Dallas, Texas 17-18 June 2008

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GEM technology converts GPGT reservoirs to renewable energy systems (solar ponds) while enabling cost effective TEOR of collocated oil

- **Half the fuel per bbl steam** (v. gas-fired steam generators)
- **$3.50-$5.50 savings per bbl steam** (@ $10/Mcf gas)
- **Establish renewable energy systems** (goal: *revenue neutral*)
- **Half the carbon footprint** (*~zero with renewable system offset*)

Building a bridge to a sustainable tomorrow while meeting the energy demands of today

Outline

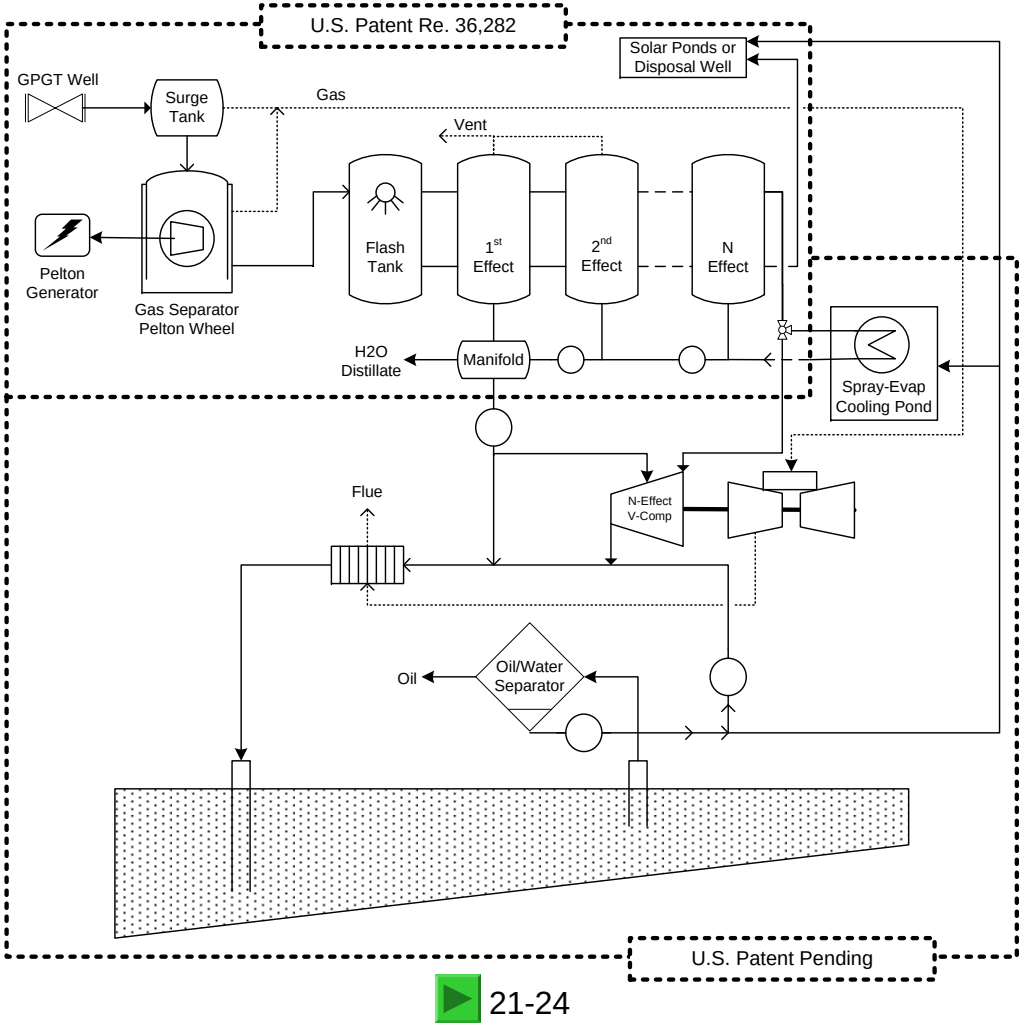
GEM Technology

- What is it?
- What are the benefits?
- What is the status of its implementation?

System Overview

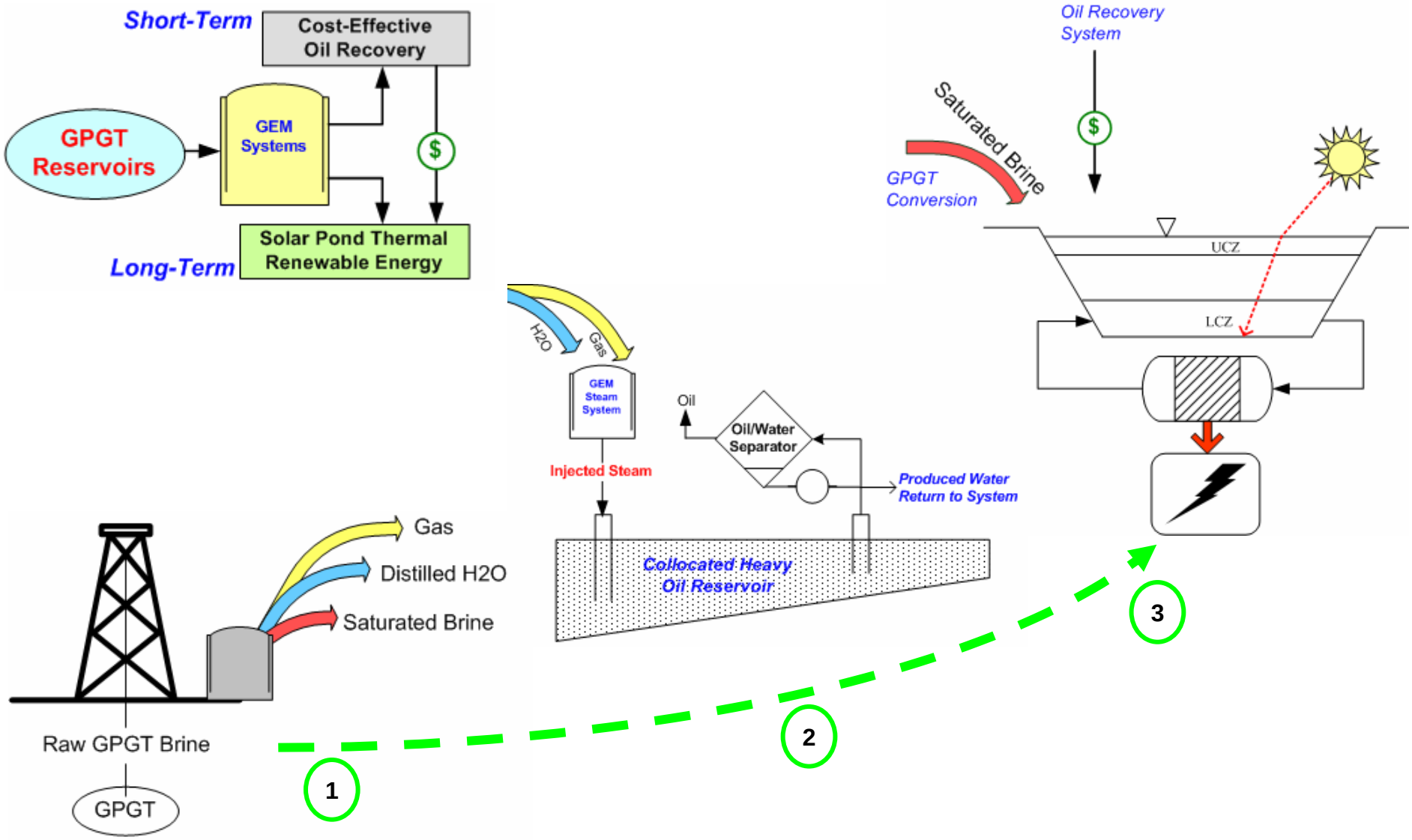
Recover Geopressured-Geothermal (GPGT) brines and use for thermal enhanced oil recovery (TEOR), with optional renewable energy system

- **GPGT Conversion Segment** 19-20
  - Recover GPGT raw brine, separate gas
  - Produce H2O, electricity, saturated brine
  - Produce TEOR steam
    - half gas per bbl steam
    - $3.50-$5.50 savings per bbl steam
    - half carbon footprint (*or much 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



21-24

Overall GEM Conversion Process



Outline

GEM Technology

What is it?

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What is the status of its implementation?

Cheap Steam for TEOR

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

Note: CWE = Cold Water Equivalent	GEM TEOR	OTSG
20yr CAPEX 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 lb CO2 combustion gas per Mcf)	73	129
Costs $/CWE bbl steam (x=0.8)		
Gas costs (GEM @ opportunity cost)	$2.06 ($7.57/Mcf)	$4.76 ($10/Mcf)
Water treatment costs	$0	$0.10—$0.25
Offset for utilities sale ($3030/4419)	-$0.69	$0
Produced water disposal costs	$0	$0—$1.50
Projeceted Carbon Tax ($40/ton)	*$0.66*	*$1.17*
Total costs/bbl steam (*w/ carbon tax*)	$2.03	$6.03—$7.68
Total costs/bbl steam (*w/o carbon tax*)	$1.37	$4.86—$6.51
GEM TEOR cost savings per CWE bbl steam	$4.00—$5.65 (*w/ carbon tax*) $3.49—$5.14 (*w/o carbon tax*)	

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

Goal: "*Revenue Neutral*" Solar Ponds

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.					

[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.

Managing the CO2 and renewable energy tax credits, the solar ponds can be established as a "*cost free*" co-product of the TEOR operation

→ *$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 carbon offset credit ($40/ton)
- Balance: $2M—$5M SP costs
- Remainder SP costs from TEOR renewable energy tax credits – effectively "***cost free***" solar ponds

Zero-to-Negative Carbon Footprint

Carbon Avoidance – GEM TEOR

The GEM TEOR method reduces the fuel gas by half which also reduces by half the CO2 release for TEOR operations.

Carbon Offset – Solar Ponds

A 2MWe solar pond, producing *perpetual* solar-thermal electric power, will offset the CO2 release during the GEM TEOR phase.

CO2 Sequestration – GPGT Reservoirs

The post-TEOR GPGT brine reservoirs will provide for geo-sequestration of CO2, using industry methods currently in development.

The GEM TEOR method will result in a net-negative carbon footprint

TEOR Produced Water Management

TEOR Steamflood Return Water

Conventional TEOR steamflood practice results in 3-10 bbl of “produced water” for every bbl recovered oil. Management of these produced waters is becoming an increasing problem to the operators, e.g., regulations restricting disposal using percolation-evap ponds. The GEM TEOR method provides various options for dealing with the produced water, e.g., reclamation for potable/irrigation, reduce and use for solar ponds, and recirculate to the GPGT reservoir for thermal regeneration.

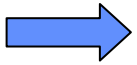
The GEM TEOR method results in zero-discharge of produced water

Outline

GEM Technology

What is it?

What are the benefits?

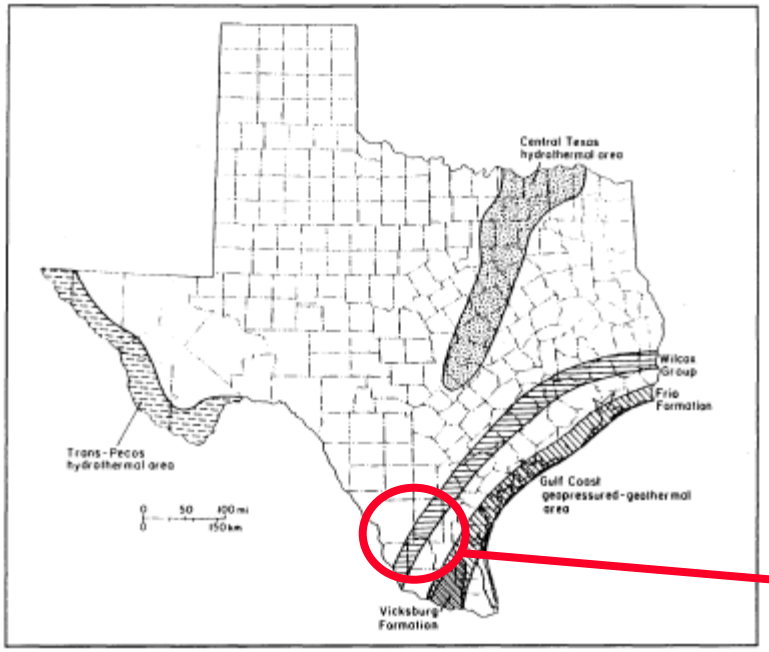


What is the status of its implementation?

GEM Technology 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
  - Further assess the CA GPGT characteristics (TX assessment by DOE tests)
  - Proof-test the GEM TEOR systems performance
  - Proof-test the instantiation and performance 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(s)
  - Preliminary vendor and stakeholder coordination, feasibility studies complete

Example TX Pilot Project Locations



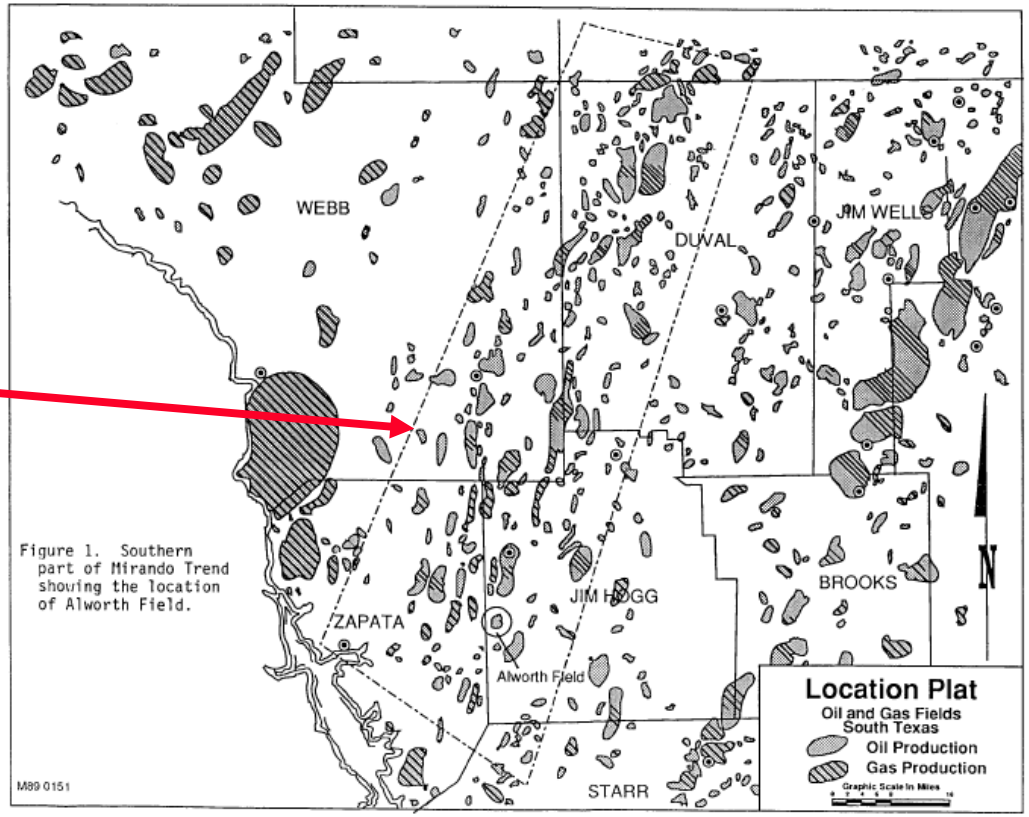
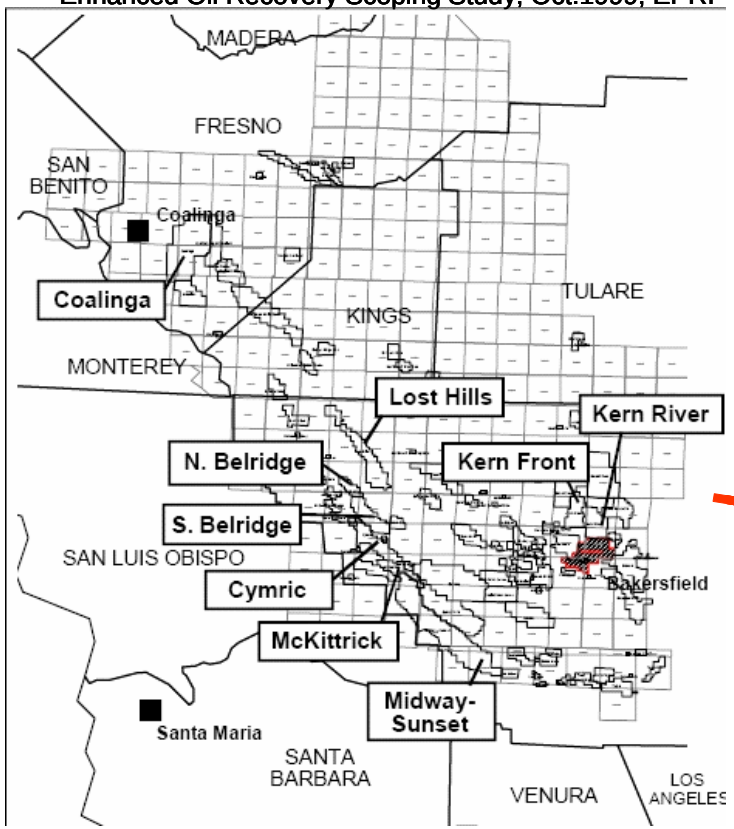


Figure 1. Southern part of Mirando Trend showing the location of Alworth Field.

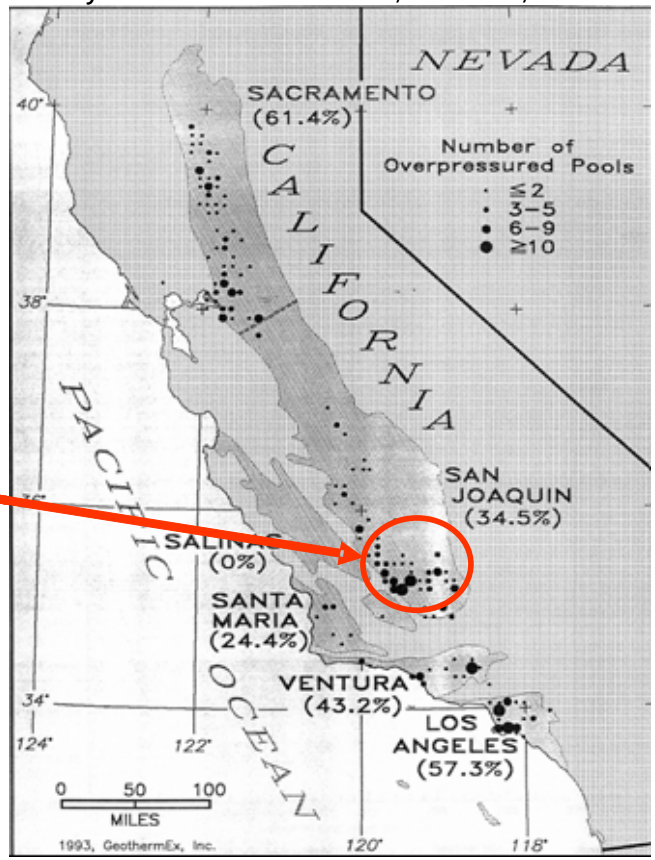
Ref.: Thermal Enhanced Oil Recovery Using GPGT Brine, Idaho National Engineering Laboratory, Dec. 1989

Example CA Pilot Project Locations

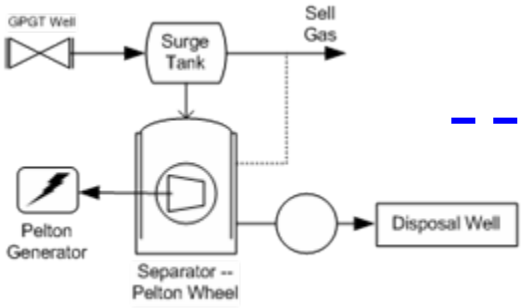
Enhanced Oil Recovery Scoping Study, Oct.1999, EPRI



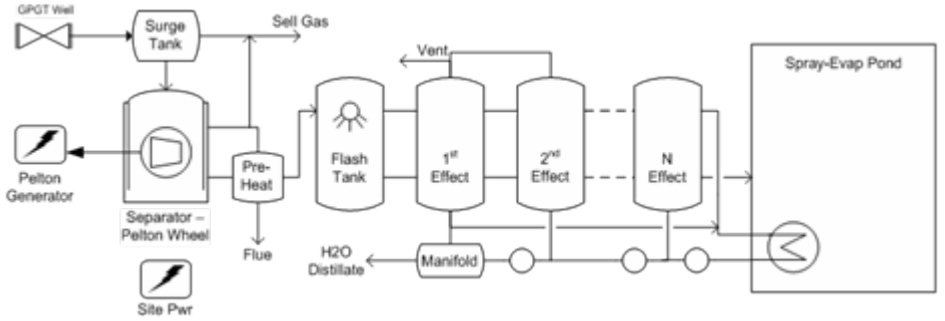
Survey of Potential GPGT in CA, Mar.1993, GeothermEx

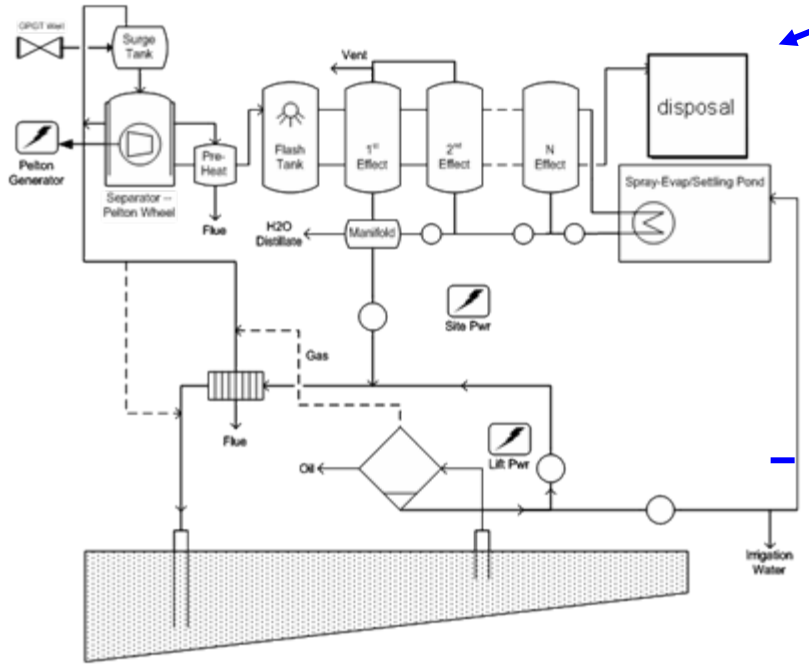


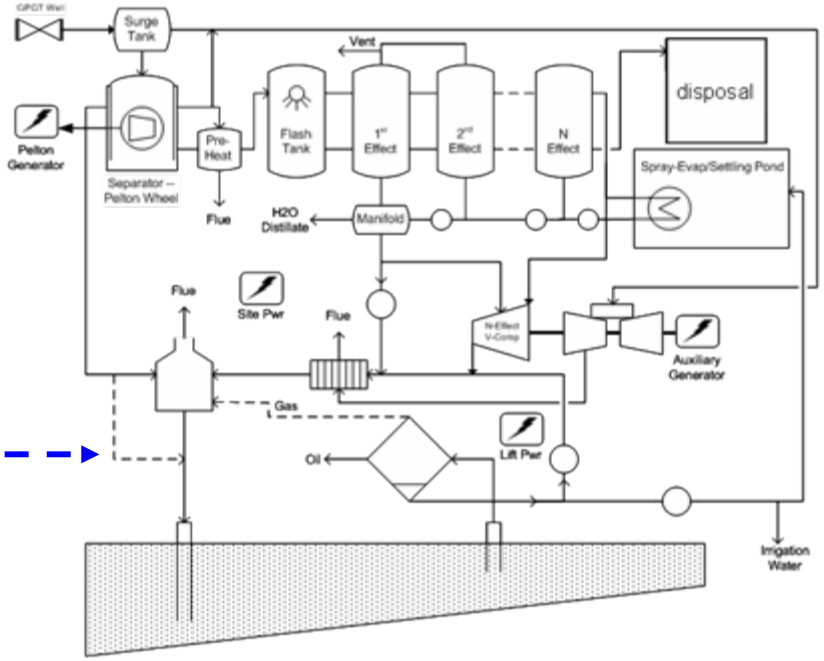
Flexible Pilot Configuration Build-Up



Simple to complex







Pertinent Legislation

➢ H.R. 6: Energy Independence and Security Act of 2007

- Signed into law 19 Dec. 2007
- Funding allocation pending departmental execution (e.g., DOE)
- GEM opportunity could help the departmental motivation
- GEM technology touches (***at least***) five sections of H.R.6

  - **SEC. 602**. THERMAL ENERGY STORAGE RESEARCH AND DEVELOPMENT PROGRAM 26
  - **Sec. 616 (d)** GEOPRESSURED GAS RESOURCE RECOVERY AND PRODUCTION 27
  - **SEC. 618.** CENTER FOR GEOTHERMAL TECHNOLOGY TRANSFER 28
  - **SEC. 711.** CARBON DIOXIDE SEQUESTRATION CAPACITY ASSESSMENT 29
  - **SEC. 917.** UNITED STATES-ISRAEL ENERGY COOPERATION 30

GEM Technology Summary

- **GEM TEOR design concept is ready for piloting in CA, TX**
  - Half the fuel per bbl steam (v. gas-fired steam generators)
  - $3.50-$5.50 savings per bbl steam (@ $10/Mcf gas)
  - Establish renewable energy systems (goal: *revenue neutral*)
  - 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:**

George Nitschke / Judith Oppenheim
Good Earth Mechanics, LLC
www.goodearthmechanics.com

Questions/Comments?

GEM
Good Earth Mechanics

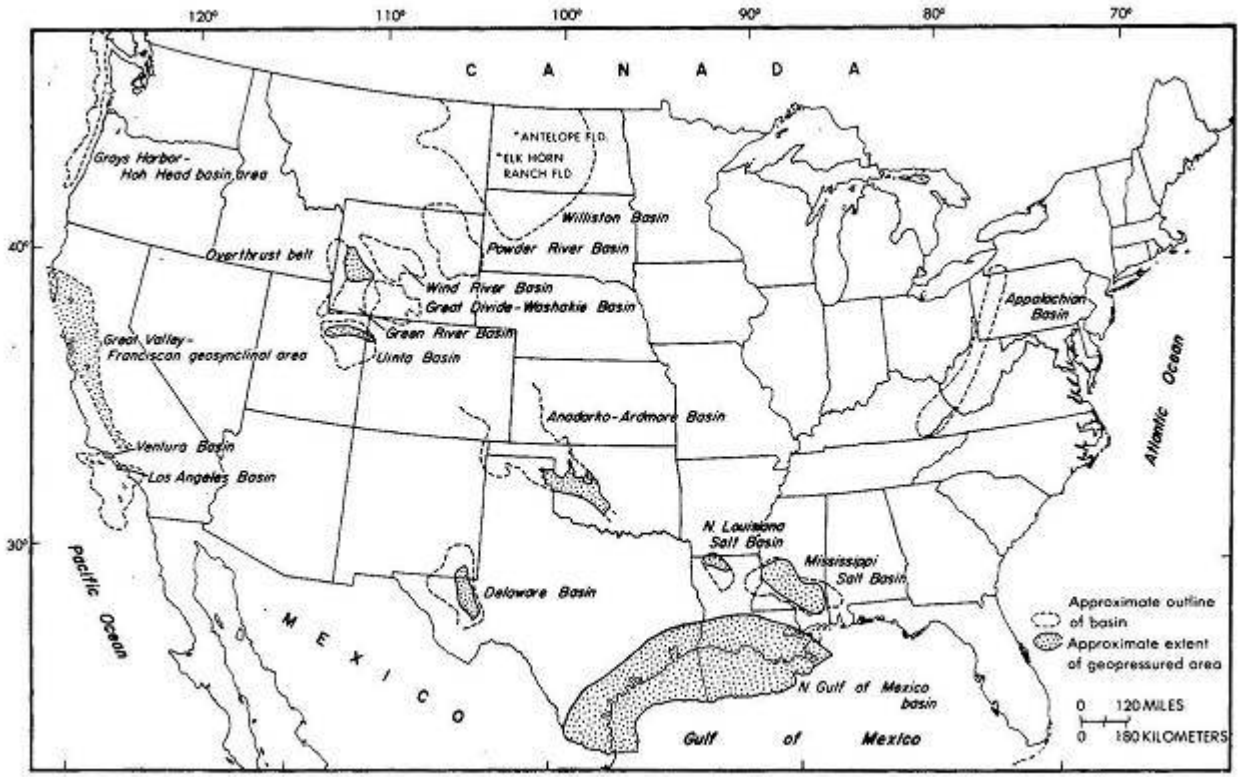
The GPGT Resource

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

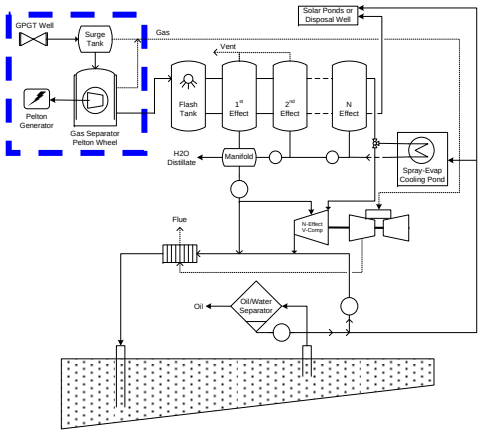
The GPGT Resource

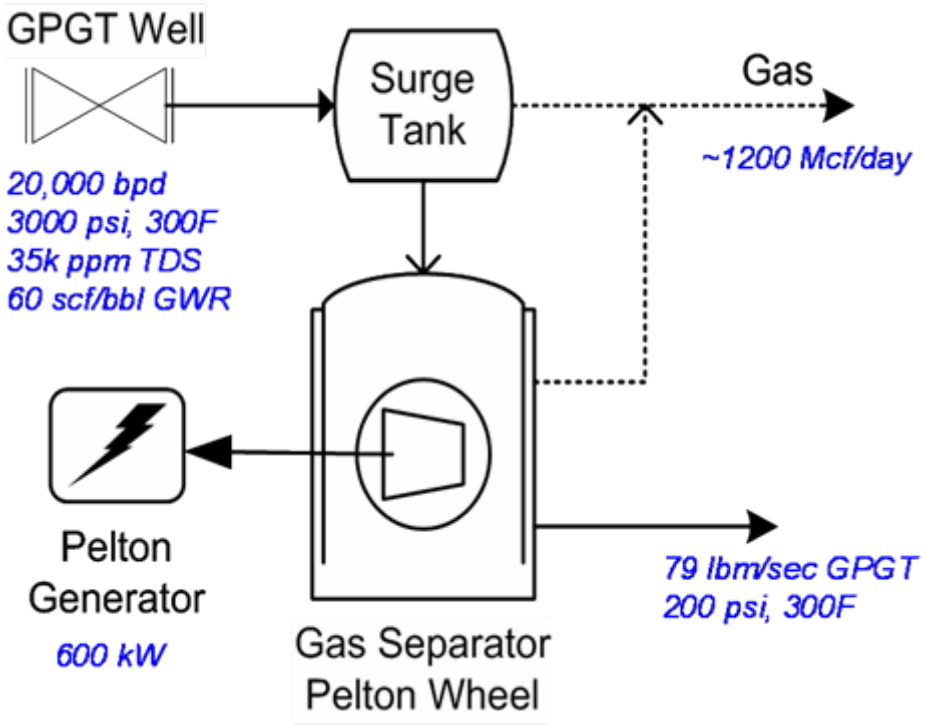


U.S. GPGT Regions

4

Subsystems: GPGT Well & Turbine



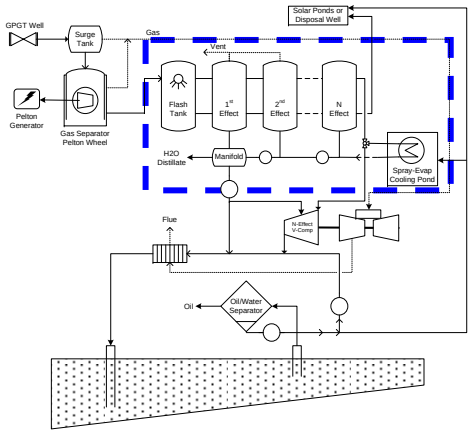


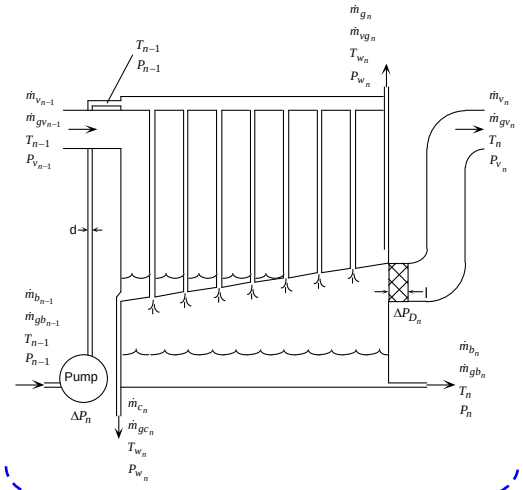
FUNCTION

- 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

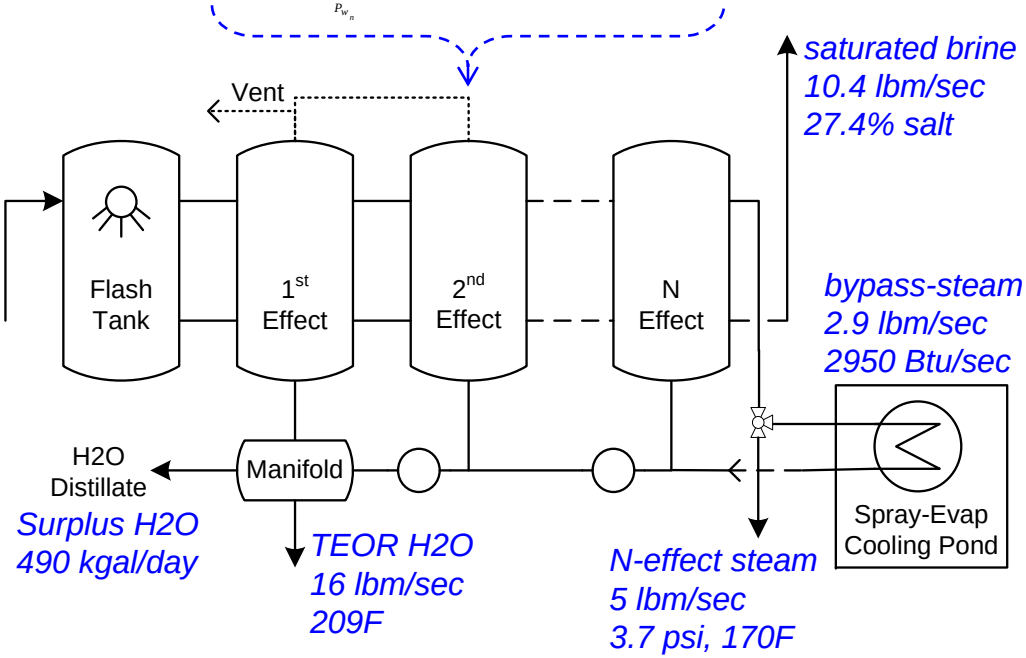




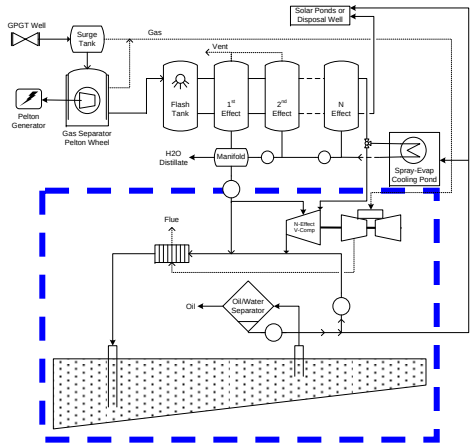
FUNCTION

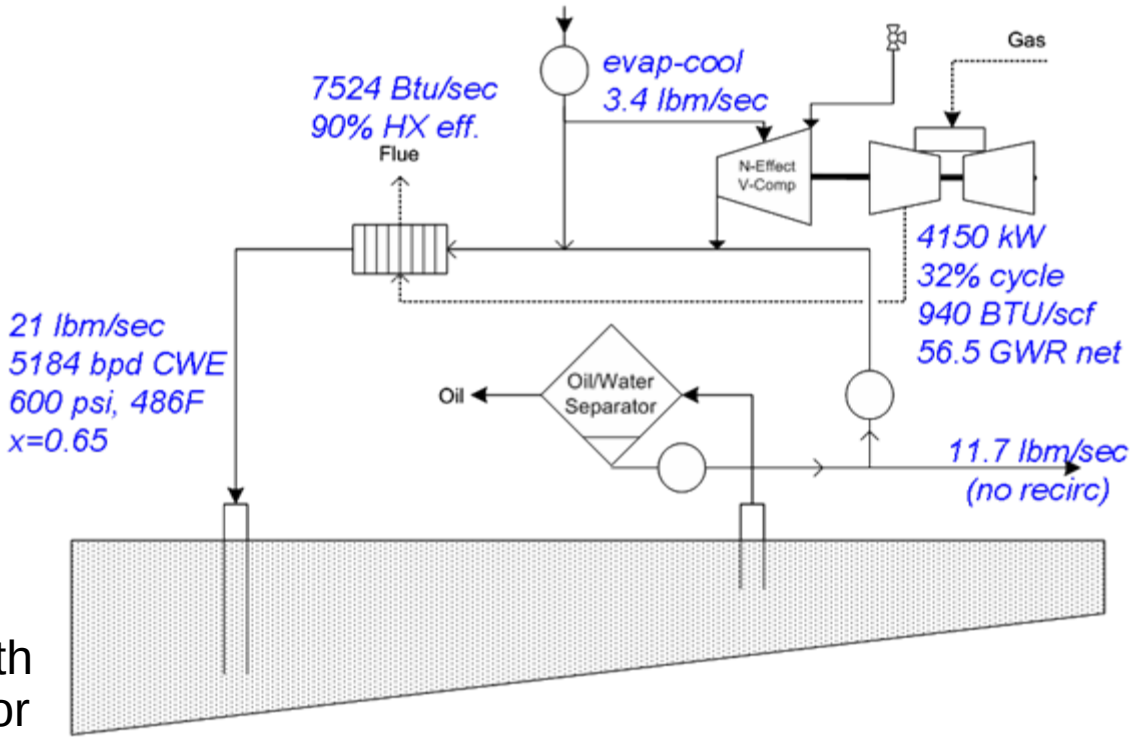
1. Concentrate GPGT brine
2. Produce steam / H2O for TEOR
3. Vend distilled H2O surplus
4. Provide heat for evaporating TEOR produced water bottoms

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

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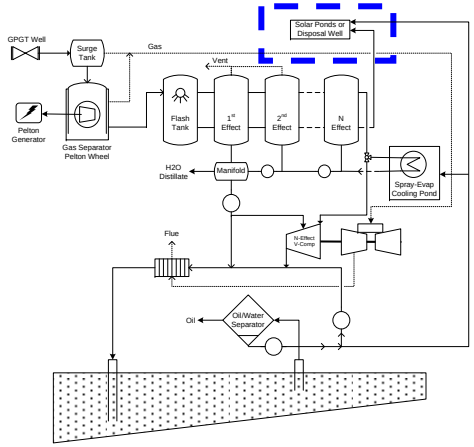
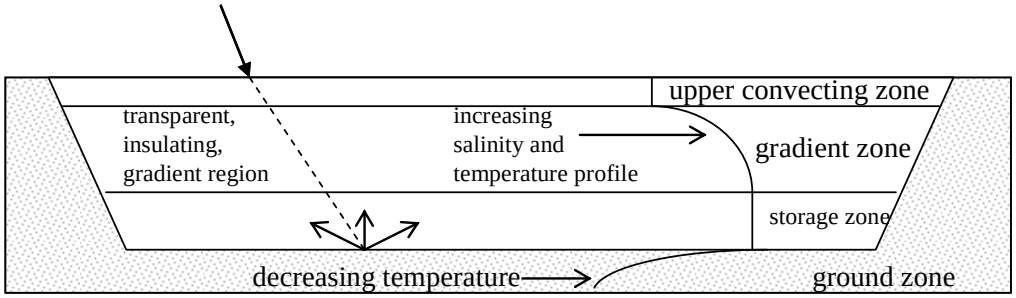
Subsystems: Solar Ponds

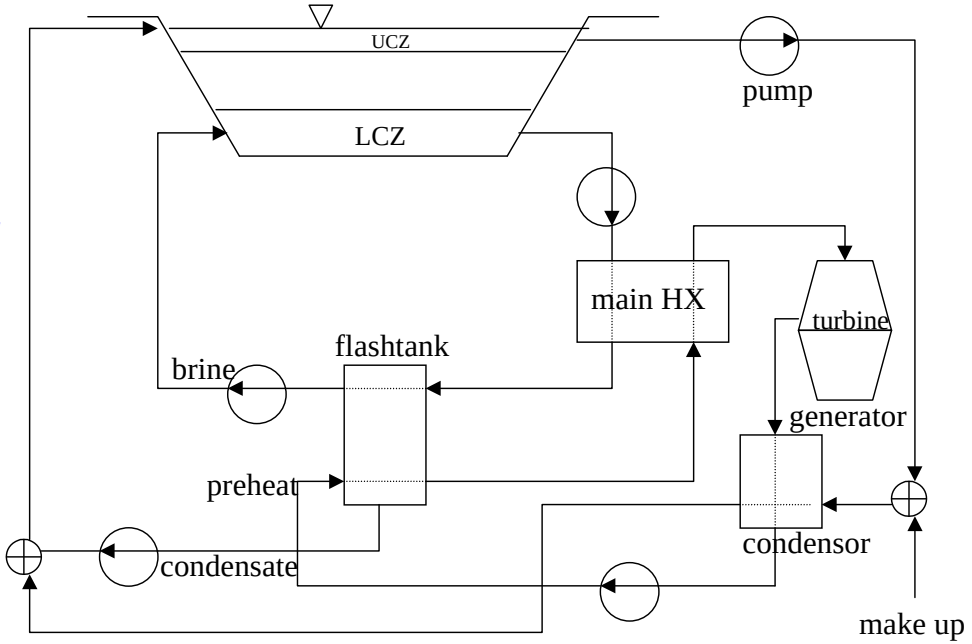


0.4m UCZ
1.4M NCZ
1.8m LCZ

Temp. LCZ:
65-105℃



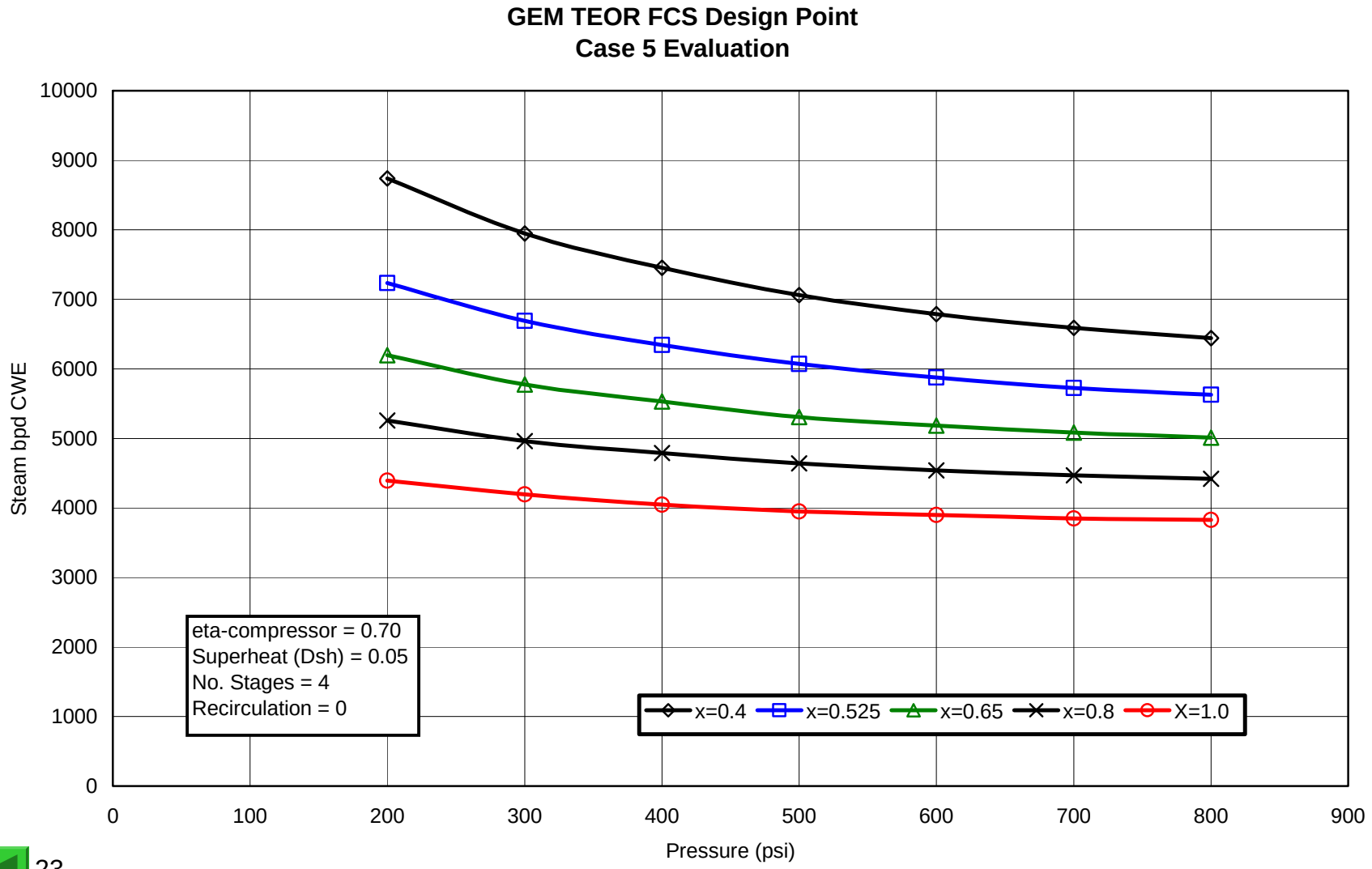
Bakersfield
3.7-5.3 W/sm
4.5 W/sm avg
1.8 MWe avg
~2.0 MWe opt.



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

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



H.R.6: Energy Independence and Security Act of 2007, Sec.602

TITLE VI—ACCELERATED RESEARCH AND DEVELOPMENT

Subtitle A—Solar Energy

Sec. 601. Short title.
Sec. 602. Thermal energy storage research and development program.
Sec. 603. Concentrating solar power commercial application studies.
Sec. 604. Solar energy curriculum development and certification grants.
Sec. 605. Daylighting systems and direct solar light pipe technology.
Sec. 606. Solar Air Conditioning Research and Development Program.
Sec. 607. Photovoltaic demonstration program.

Subtitle B—Geothermal Energy

SEC. 602. THERMAL ENERGY STORAGE RESEARCH AND DEVELOPMENT PROGRAM.

(a) ESTABLISHMENT.—The Secretary shall establish a program of research and development to provide lower cost and more viable thermal energy storage technologies to enable the shifting of electric power loads on demand and extend the operating time of concentrating solar power electric generating plants.

(b) AUTHORIZATION OF APPROPRIATIONS.—There are authorized to be appropriated to the Secretary for carrying out this section

$5,000,000 for fiscal year 2008, $7,000,000 for fiscal year 2009, $9,000,000 for fiscal year 2010, $10,000,000 for fiscal year 2011, and $12,000,000 for fiscal year 2012.

H.R.6: Energy Independence and Security Act of 2007, Sec.616

Subtitle B—Geothermal Energy

Sec. 611. Short title.
Sec. 612. Definitions.
Sec. 613. Hydrothermal research and development.
Sec. 614. General geothermal systems research and development.
Sec. 615. Enhanced geothermal systems research and development.
Sec. 616. Geothermal energy production from oil and gas fields and recovery and production of geopressured gas resources.
Sec. 617. Cost sharing and proposal evaluation.
Sec. 618. Center for geothermal technology transfer.
Sec. 619. GeoPowering America.
Sec. 620. Educational pilot program.
Sec. 621. Reports.
Sec. 622. Applicability of other laws.
Sec. 623. Authorization of appropriations.
Sec. 624. International geothermal energy development.
Sec. 625. High cost region geothermal energy grant program.

Sec. 616 (d) GEOPRESSURED GAS RESOURCE RECOVERY AND PRODUCTION.

(1) The Secretary shall implement a program to support the research, development, demonstration, and commercial application of cost-effective techniques to produce energy from geopressured resources.

(2) The Secretary shall solicit preliminary engineering designs for geopressured resources production and recovery facilities.

(3) Based upon a review of the preliminary designs, the Secretary shall award grants, which may be cost-shared, to support the detailed development and completion of engineering, architectural and technical plans needed to support construction of new designs.

(4) Based upon a review of the final design plans above, the Secretary shall award cost-shared development and construction grants for demonstration geopressured production facilities that show potential for economic recovery of the heat, kinetic energy and gas resources from geopressured resources.

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H.R.6: Energy Independence and Security Act of 2007, Sec.618

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Subtitle B—Geothermal Energy

Sec. 611. Short title.
Sec. 612. Definitions.
Sec. 613. Hydrothermal research and development.
Sec. 614. General geothermal systems research and development.
Sec. 615. Enhanced geothermal systems research and development.
Sec. 616. Geothermal energy production from oil and gas fields and recovery and production of geopressured gas resources.
Sec. 617. Cost sharing and proposal evaluation.
Sec. 618. Center for geothermal technology transfer.
Sec. 619. GeoPowering America.
Sec. 620. Educational pilot program.
Sec. 621. Reports.
Sec. 622. Applicability of other laws.
Sec. 623. Authorization of appropriations.
Sec. 624. International geothermal energy development.
Sec. 625. High cost region geothermal energy grant program.

SEC. 618. CENTER FOR GEOTHERMAL TECHNOLOGY TRANSFER.

(a) IN GENERAL.—The Secretary shall award to an institution of higher education (***or consortium thereof***) a grant to establish a Center for Geothermal Technology Transfer (referred to in this section as the ''Center'').

(b) DUTIES.—The Center shall—

(1) serve as an information clearinghouse for the geothermal industry by collecting and disseminating information on best practices in all areas relating to developing and utilizing geothermal resources;

(2) make data collected by the Center available to the public; and

(3) seek opportunities to coordinate efforts and share information with domestic and international partners engaged in research and development of geothermal systems and related technology.

(c) SELECTION CRITERIA.—In awarding the grant under subsection (a) the Secretary shall select an institution of higher education (or consortium thereof) best suited to provide national leadership on geothermal related issues and perform the duties enumerated under subsection (b).

(d) DURATION OF GRANT.—A grant made under subsection (a)—

(1) shall be for an initial period of 5 years; and (2) may be renewed for additional 5-year periods on the basis of—

(A) satisfactory performance in meeting the duties outlined in subsection (b); and

(B) any other requirements specified by the Secretary.

H.R.6: Energy Independence and Security Act of 2007, Sec.711

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TITLE VII—CARBON CAPTURE AND SEQUESTRATION

Subtitle A—Carbon Capture and Sequestration Research, Development, and Demonstration

Sec. 701. Short title.
Sec. 702. Carbon capture and sequestration research, development, and demonstration program.
Sec. 703. Carbon capture.
Sec. 704. Review of large-scale programs.
Sec. 705. Geologic sequestration training and research.
Sec. 706. Relation to Safe Drinking Water Act.
Sec. 707. Safety research.
Sec. 708. University based research and development grant program.

Subtitle B—Carbon Capture and Sequestration Assessment and Framework

Sec. 711. Carbon dioxide sequestration capacity assessment.
Sec. 712. Assessment of carbon sequestration and methane and nitrous oxide emissions from ecosystems.
Sec. 713. Carbon dioxide sequestration inventory.
Sec. 714. Framework for geological carbon sequestration on public land.

SEC. 711. CARBON DIOXIDE SEQUESTRATION CAPACITY ASSESSMENT.

(a)(2) CAPACITY.—The term ‘‘capacity’’ means the portion of a sequestration formation that can retain carbon dioxide in accordance with the requirements (including physical, geological, and economic requirements) established under the methodology developed under subsection (b).

(a)(6) SEQUESTRATION FORMATION.—The term ‘‘sequestration formation’’ means a deep saline formation, unmineable coal seam, or oil or gas reservoir that is capable of accommodating a volume of industrial carbon dioxide.

(f)(2) GEOLOGICAL VERIFICATION.—As part of the assessment under this subsection, the Secretary shall carry out a drilling program to supplement the geological data relevant to determining sequestration capacity of carbon dioxide in geological sequestration formations, including—

(A) well log data; (B) core data; and (C) fluid sample data.

(f)(3) PARTNERSHIP WITH OTHER DRILLING PROGRAMS.—As part of the drilling program under paragraph (2), the Secretary shall enter, as appropriate, into partnerships with other entities to collect and integrate data from other drilling programs relevant to the sequestration of carbon dioxide in geological formations.

(g) AUTHORIZATION OF APPROPRIATIONS.—There is authorized to be appropriated to carry out this section $30,000,000 for the period of fiscal years 2008 through 2012.

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TITLE IX—INTERNATIONAL ENERGY PROGRAMS

Sec. 901. Definitions.

Subtitle A—Assistance to Promote Clean and Efficient Energy Technologies in Foreign Countries

Sec. 911. United States assistance for developing countries.
Sec. 912. United States exports and outreach programs for India, China, and other countries.
Sec. 913. United States trade missions to encourage private sector trade and investment.
Sec. 914. Actions by Overseas Private Investment Corporation.
Sec. 915. Actions by United States Trade and Development Agency.
Sec. 916. Deployment of international clean and efficient energy technologies and investment in global energy markets.
Sec. 917. United States-Israel energy cooperation.

Subtitle B—International Clean Energy Foundation

Sec. 921. Definitions.

SEC. 917. UNITED STATES-ISRAEL ENERGY COOPERATION.

(b) GRANT PROGRAM.—

(1) ESTABLISHMENT.—In implementing the agreement entitled the ''Agreement between the Department of Energy of the United States of America and the Ministry of Energy and Infrastructure of Israel Concerning Energy Cooperation'', dated February 1, 1996, the Secretary shall establish a grant program in accordance with the requirements of sections 988 and 989 of the Energy Policy Act of 2005 (42 U.S.C. 16352, 16353) to support research, development, and commercialization of renewable energy or energy efficiency.

(2) TYPES OF ENERGY.—In carrying out paragraph (1), the Secretary may make grants to promote—

(A) solar energy; (B) biomass energy; (C) energy efficiency; (D) wind energy; (E) geothermal energy; (F) wave and tidal energy; and (G) advanced battery technology.

(3) ELIGIBLE APPLICANTS.—An applicant shall be eligible to receive a grant if the project of the applicant—

(A) addresses a requirement of improved energy efficiency or renewable energy sources, as determined by the Secretary; and

(B) is a joint venture between—

(i)(I) a for-profit business entity, academic institution, National Laboratory, or nonprofit entity in the United States; and

(II) a for-profit business entity, academic institution, or nonprofit entity in Israel; or

(ii)(I) the Federal Government; and (II) the Government of Israel.