Webinars

Digital Twins for Geothermal Operations – decision modeling

Malcolm Ross, Ph.D
Black Swan Detector,
Ex-UT GEO, BEG, Rice Univ., Dsider, & Rothwell Group
He/Him/His; Syracuse, NY

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WE NEED AN ECONOMIC AND SUSTAINABLE PATH TO DECARBONIZATION

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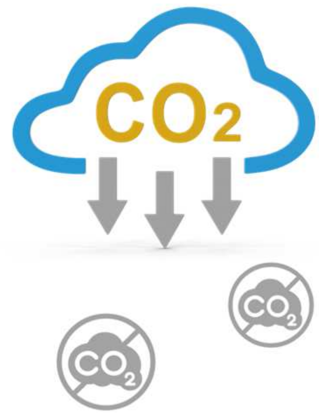
LOW CARBON ENERGY

NEXT GENERATION FUELS

NEW ENERGY SUPPLY CHAIN



SUSTAINABILITY

ESG

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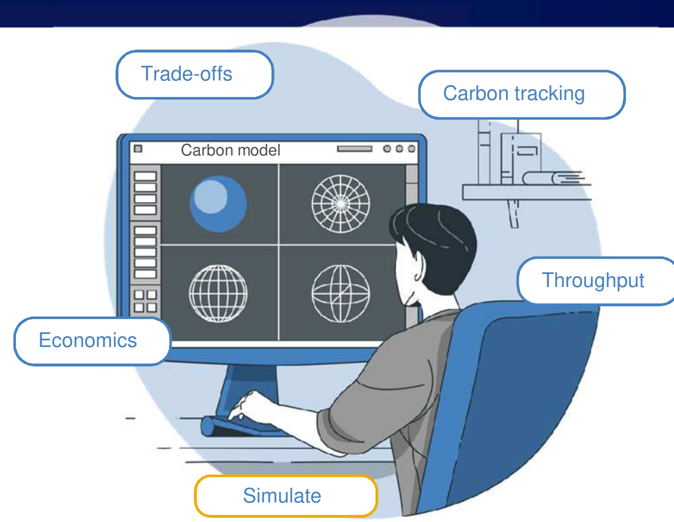
CURRENT PROCESS TO MANAGE THESE PATHWAYS ARE SILOED AND MANUAL

Webinars

COMPANIES REQUIRE INTRICATE MODELING, COMPUTATIONS AND DATA CAPTURE

AND

COLLABORATE WITH STAKEHOLDERS ACROSS THE VALUE CHAIN



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DIGITAL TWINS CREATE A CONNECTED AND STRUCTURED APPROACH TO ADDRESS ENERGY TRANSITION

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- THEY FACILITATE THE DYNAMIC SIMULATION OF ENERGY TRANSITION SYSTEMS BY CONNECTING ITS SUPPLY CHAIN AND ASSOCIATED PROCESSES
- CREATING AN ENVIROMENT THAT CAN HELP COMPANIES UNDERSTAND PRODUCTION, ECONOMICS AND CARBON REDUCTION IN REAL TIME

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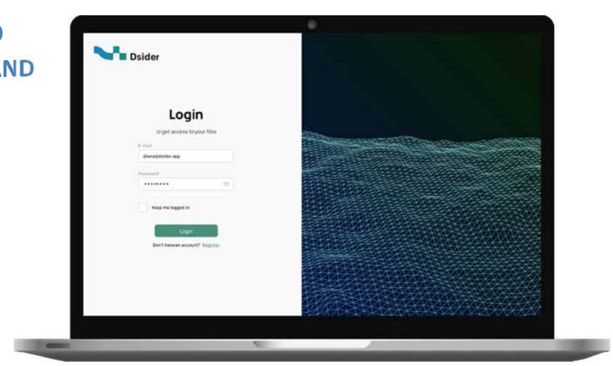
A DECISION INTELLIGENCE PLATFORM TO UNDERSTAND YOUR ENERGY TRANSITION AND DECABONIZATION PATHWAYS

THROUGH

TRANSPARENCY, INSIGHTS AND COLLABORATION



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DELIVERING DIGITAL TWINS FOR AGGREGATION AND EMISSION REDUCTION ALONG WITH GEOTHERMAL, HYDROGEN, AND CCUS - ALL IN ONE PLATFORM

DIGITAL TWINS CAN HELP THE ADOPTION OF GEOTHERMAL ENERGY

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RISK PROFILE MISMATCH

Geothermal competes with solar & wind, but its risk/economic profile looks much more like an oil & gas project and thus hard to compare/rank/evaluate.

CAPITAL INTENSIVE

Up to 50% of the CAPEX of any project geothermal project is drilling. Anything that reduces that flows to the bottom line.

EXPERTISE GAP

Geothermal projects can greatly benefit from the (very) latest technology and capabilities from the oil & gas domain

DIVERSE TECHNOLOGY

A range of technologies are available to be applied to geothermal projects – some of them brand-new (not field tested), some from adjacent fields.

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SYSTEMS MODEL LINKS THE GEOTHERMAL SUPPLY CHAIN AND THE ASSOCIATED REVENUE MODELS THROUGH A DIGITAL TWIN APPROACH

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SIMULATE VALUE CHAIN

- Map End To End Geothermal System
- Capture Assumption, Processes And Workflows
- Template Current And Future Scenarios
- Create A Geothermal Digital Twin

GEOTHERMAL MODELS

Interface To Geothermal Models from NREL

- GeoPHIRES
- GeTEM

BUILD ECONOMICS

- Based On Rules, Levers And Constraints
- Costs And Price Assumptions
- Create Kpi's, Trade Offs And Recommendations

MAKE INFORMED DECISIONS

- Create What-if And Sensitivity Analysis
- Maximize Value While Minimizing Investment
- Interface To Real Time Subsurface Data To Simulate Operational Decisions – Future Functionality

MANAGING OPEN AND CLOSE LOOP GEOTHERMAL OPERATIONS FROM PREBUILD TO RUN AND MAINTAIN

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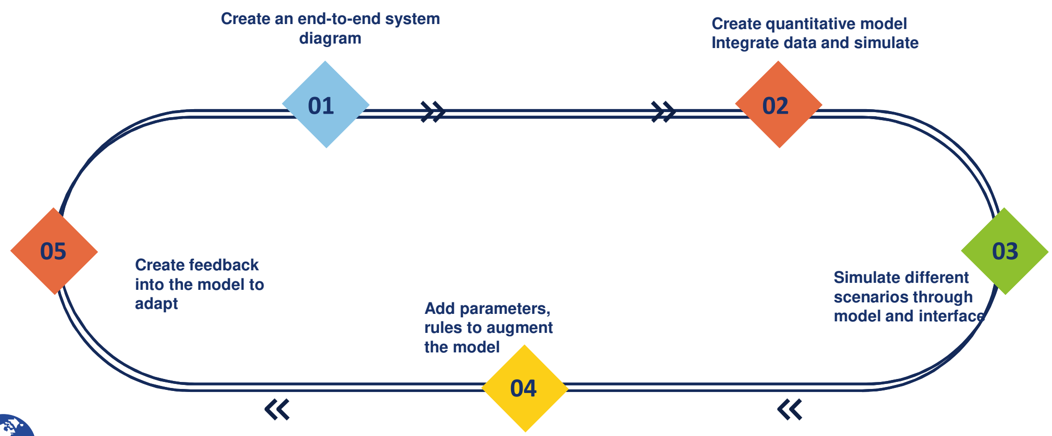
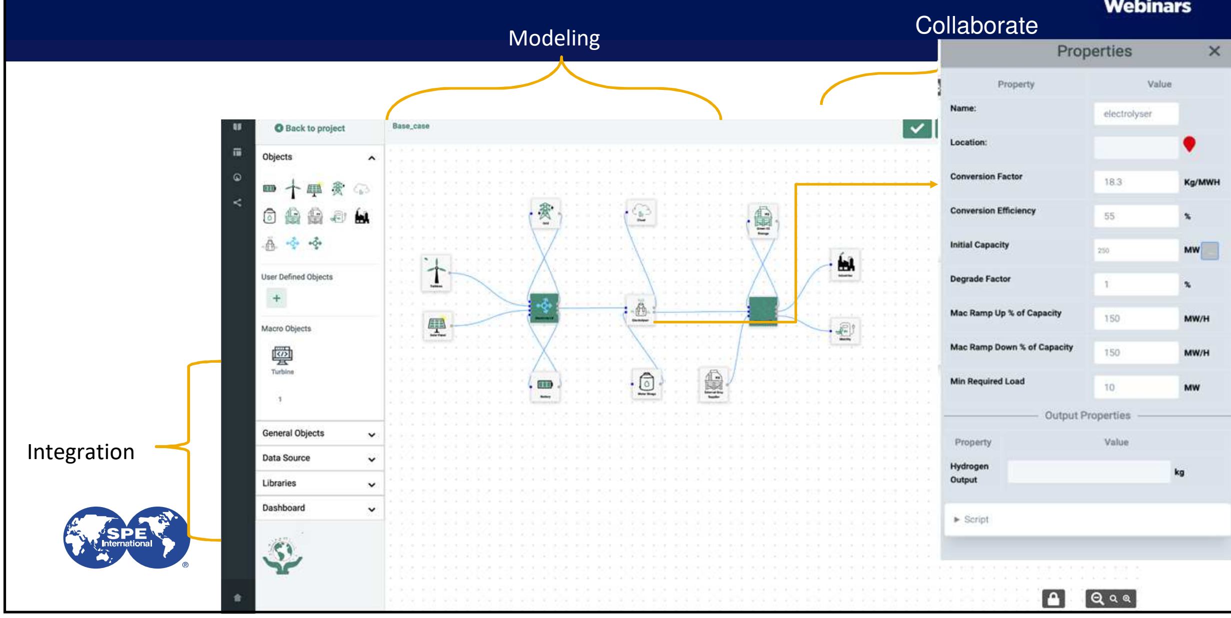
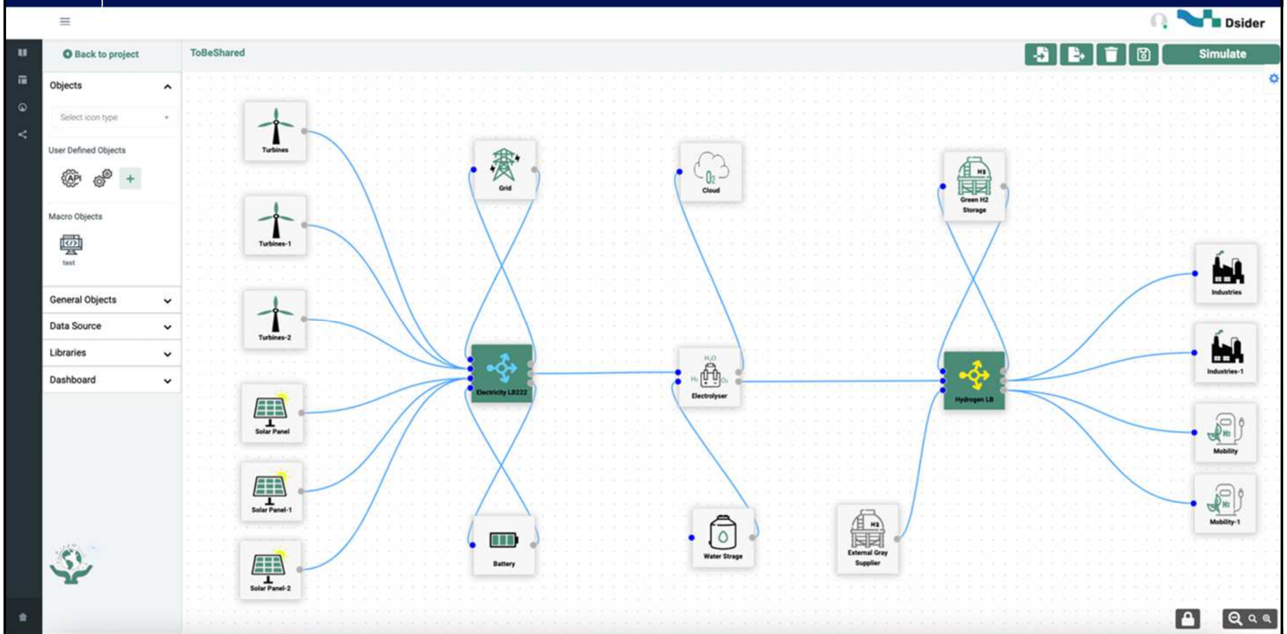
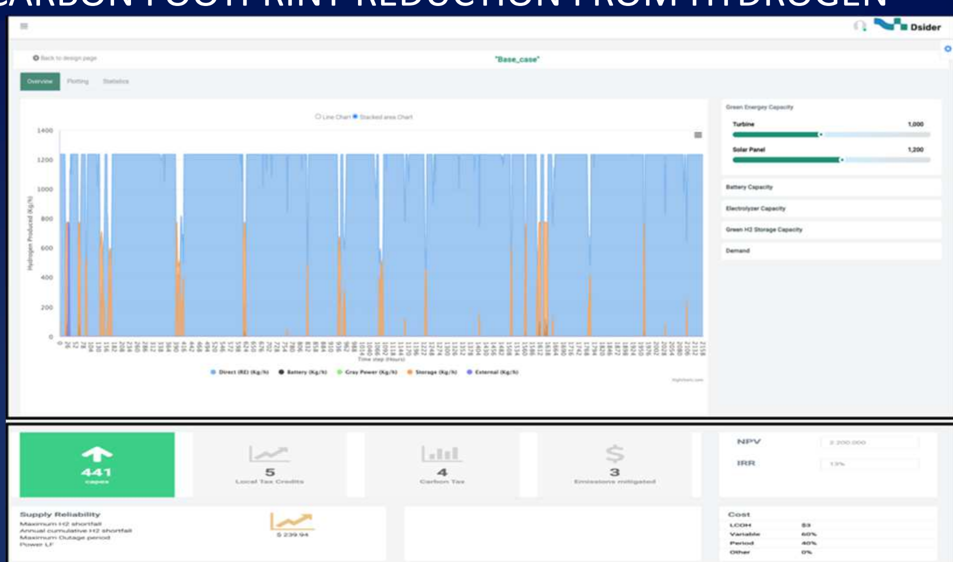
WORKFLOWS ENABLING THE DIGITAL TWIN







SIMULATE TO UNDERSTAND PRODUCTION, ECONOMICS, AND CARBON FOOTPRINT REDUCTION FROM HYDROGEN

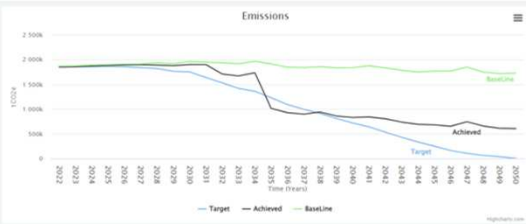


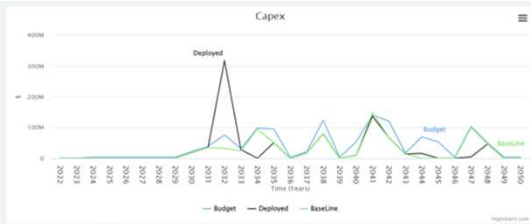
TRACKING AND MANAGING CARBON REDUCTION

Dsider

Back to design page

"Carbon_Mitigation_Scenario-0"





	Specific Period			Cumulative		
2034	tCO2 Reduced	% Target	% Base	tCO2 Reduced	% Target	% Base
Scope 1	-705,783	102.00%	142.99%	-18,224,627	102.00%	186.00%
Scope 2	-690,682	154.00%	469.76%	-4,129,616	113.00%	236.00%
Scope 3	-57,884	112.00%	177.00%	1,752,472	103.00%	184.00%
Total	-1,454,349	127.66%	88.22%	-20,601,771	103.00%	96.00%

POTENTIAL USERS

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- REGULAT
OR

Will this project comply with rules?
If this project running safely?

- GEOTHERMAL
INVESTOR

How long to break even?
What is my NPV/IRR/VIR/LCOE?
What are the trade-offs?

- OPERATING COMPANIES

Are there any warning signs of problems?
Are there optimization opportunities?
What are the current load/demand/pricing?

- LEGISLATORS/
STAKEHOLDERS

How many jobs does this project create?
Is there any induced seismicity happening?
How much CO2 is being sequestered/avoided?

- ENGINEERS/DESIGNE
RS

What is the best design overall?
How well are the operations living up to the design?

- STARTU
PS

How does my design stack up against others?
Optimization opportunities?

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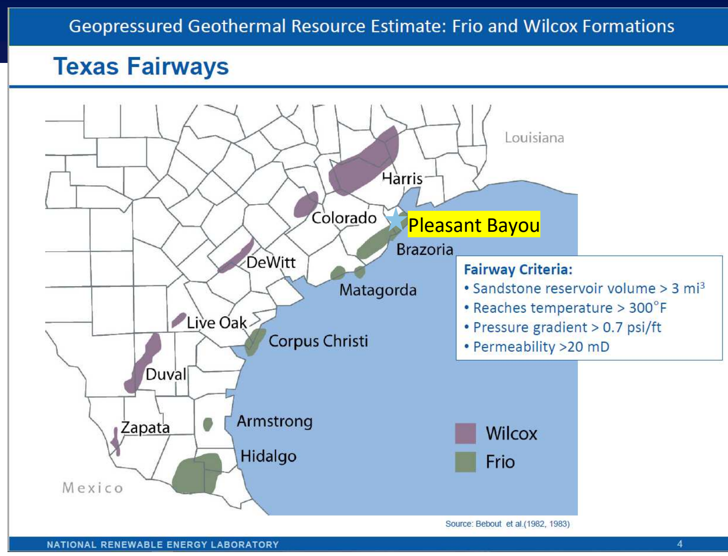
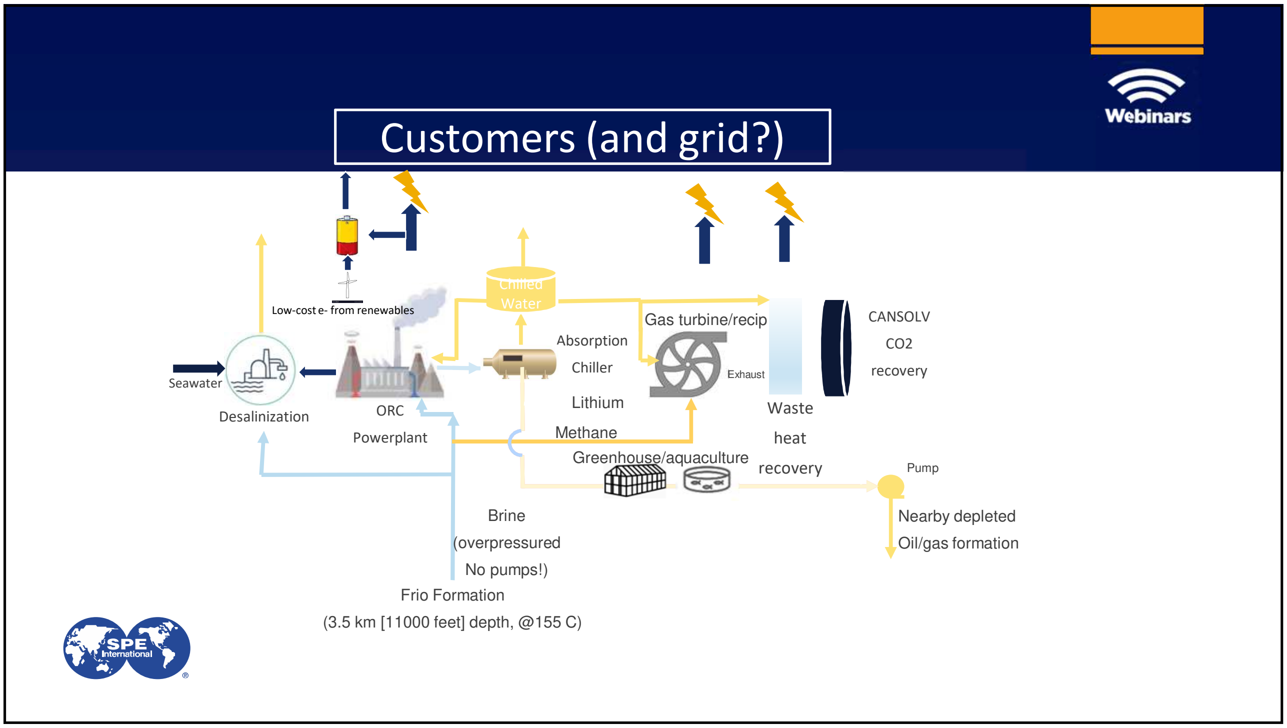


PLEASANT BAYOU AS PROOF-OF-CONCEPT

- In the early 1980s, Ben Holt Co. designed, built, and operated a demo plant at Pleasant Bayou, Texas (co-funded by the U.S. Department of Energy and the Electric Power Research Institute)
  - ~3.2 km (10500 ft) deep, 150 C (300 F), ~100 scf methane/bbl brine, ~75 kg/sec (41,000 bbl/day) flow rate, minimum 20 year lifetime: Frio
- The power plant operated successfully
  - Electricity could be generated from geopressured resources
  - high reliability, using standard materials of 1970's construction
- Using a hybrid cycle
  - Electricity generated by burning entrained gas in engines
  - heat from the gas engine exhaust supplements heat from the brine
  - improve efficiency of the binary cycle
- **Produced 1.0 MW from 10,000 BPD of geopressured, saline, methane-rich water for one year**


Webinars
Customers (and grid?)
Low-cost e- from renewables
Chilled Water
Seawater
Desalinization
ORC
Powerplant
Absorption
Chiller
Lithium
Methane
Gas turbine/recip
Exhaust
Waste
heat
recovery
CANSOLV
CO2
recovery
Greenhouse/aquaculture
Pump
Nearby depleted
Oil/gas formation
Brine
(overpressured
No pumps!)
Frio Formation
(3.5 km [11000 feet] depth, @155 C)
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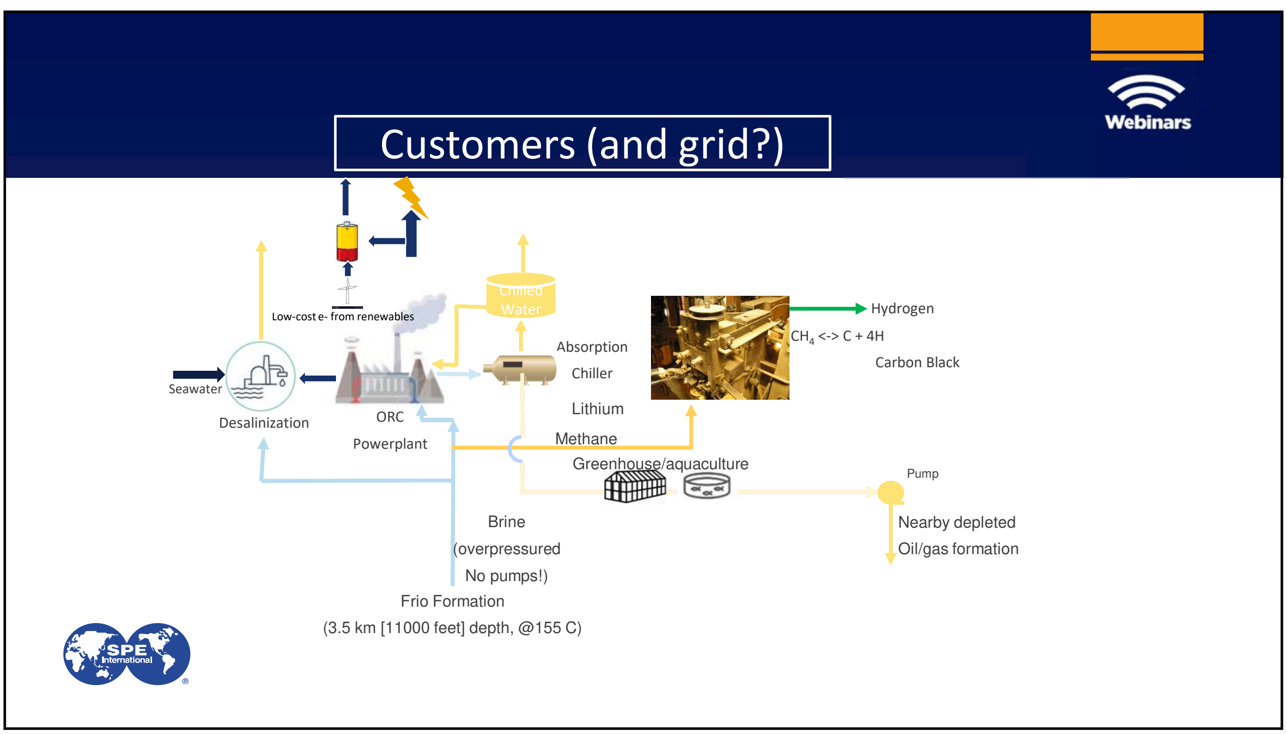
Webinars
Customers (and grid?)
Low-cost e- from renewables
Chilled Water
Seawater
Desalinization
ORC
Powerplant
Absorption
Chiller
Lithium
Methane
Hydrogen
CH_4 <-> C + 4H
Carbon Black
Greenhouse/aquaculture
Pump
Nearby depleted
Oil/gas formation
Brine
(overpressured
No pumps!)
Frio Formation
(3.5 km [11000 feet] depth, @155 C)
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Backups

Webinars

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Geoscience questions to ask & answer (1)

Webinars

- **Reservoir**

1. How much brine is down there? Enough for 20-30 years? (>3 bln US gallons in 20 years! >400 MM cubic feet)
2. What is the radius of effect? Effect of sharing the reservoir (and sink)? Fault-bound compartment size?
3. How will reservoir behave (poro-perm) long-term with extract of >10,000 bpd?
4. How will brine temperature evolve over a 20–30-year project (how much cooler or hotter)?
5. Will there be significant subsidence/seismicity?
6. How long will the geopressure last?
7. Relative benefit/cost of going to Wilcox (deeper but hotter) or completing in both?
8. Need to frack?
9. do you expect to deplete the pressure sufficiently to pass through the bubble point of the brine in the reservoir? Will this exsolution of gas provide much additional reservoir drive and/or will the exsolution of gas create mobility issues in the reservoir? (i.e. pores becoming blocked by gas bubbles)

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Geoscience questions to ask & answer (2)

Webinars

- **Sink**
1. What reservoir(s) could we inject into?
2. How much capacity does it have? Need >3 bln gallons!
3. What pressures do we have to overcome (costs electricity)?
4. How will reservoir behave with injection of mild acid? Poro-perm over time?
5. While the injection induce seismicity?
6. Will the injector well(s) need to be special steel?
7. Need to frack?

- **Geophysics**
1. Can we map heat anomalies with seismic studies? EM studies?
2. Can we map brine?
3. Can we watch heat/brine changes over time (as in 4D seismic)?
4. Could we make such investigations under the constraints of a relatively low margin business?

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Geoscience questions to ask & answer (3)

Webinars

- **Brine (Geochemistry)**
1. How will brine evolve – after methane extraction, after temperature drop, after CO_2 injection? Precip/Scaling? Corrosion?
2. How much CO_2 per unit volume can we inject?
3. Microbial effects? Biofouling?

- **CO_2 sequestration**
1. Will there be seal integrity problems due to numerous well penetrations? Growth faults in area?

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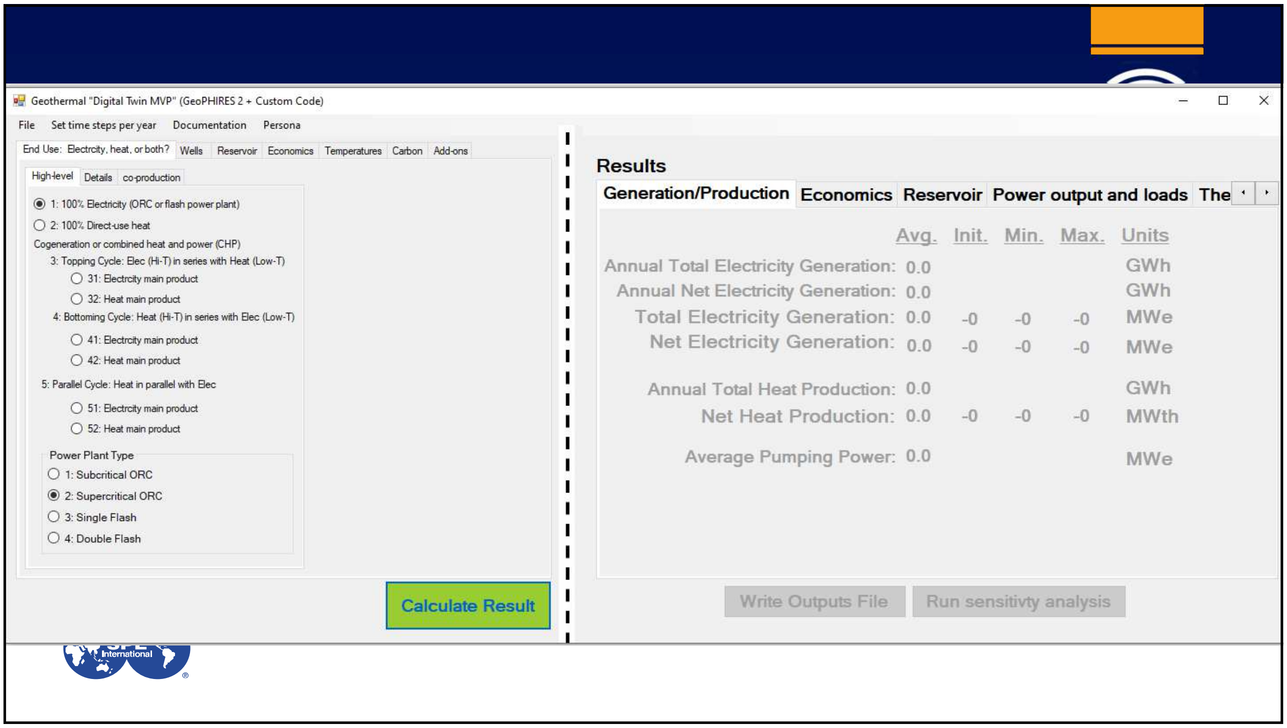
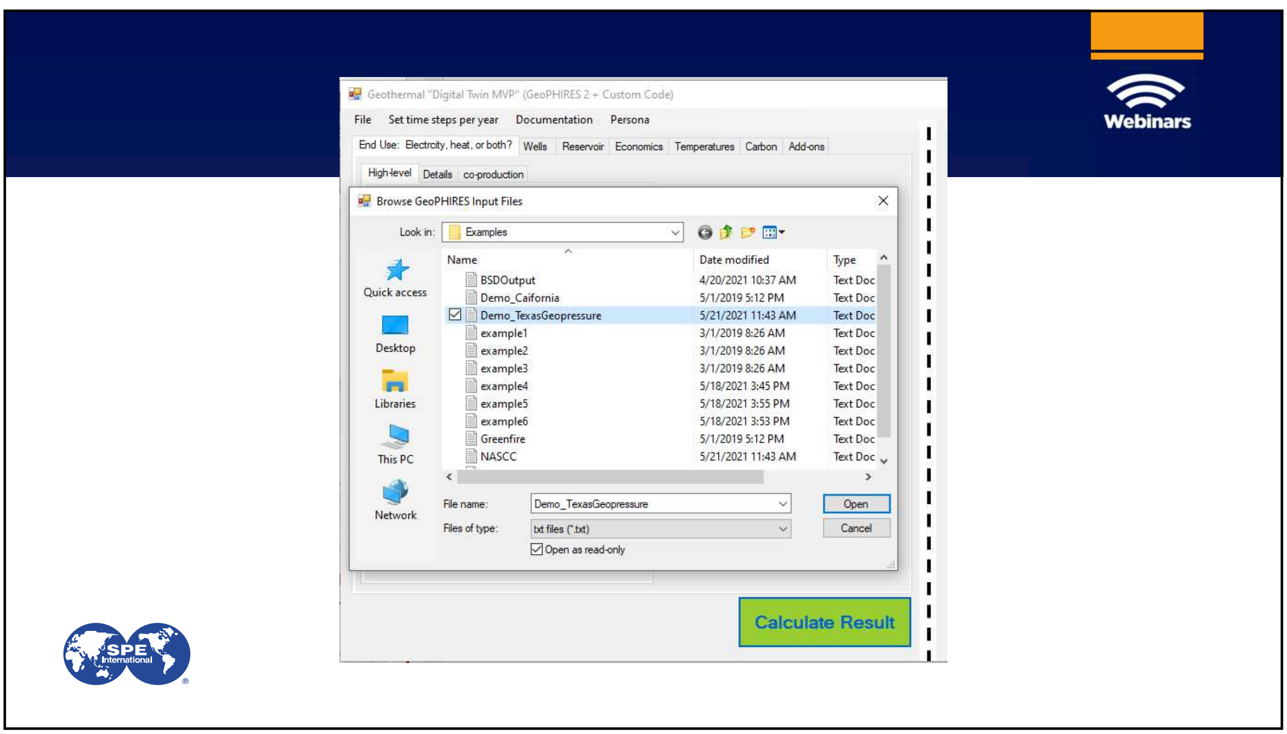

Geothermal "Digital Twin MVP" (GeoPHIRES 2 + Custom Code)
File
Set time steps per year
Documentation
Persona
End Use: Electricity, heat, or both?
Wells
Reservoir
Economics
Temperatures
Carbon
Add-ons
High-level
Details
co-production
1: 100% Electricity (ORC or flash power plant)
2: 100% Direct-use heat
Cogeneration or combined heat and power (CHP)
3: Topping Cycle: Elec (Hi-T) in series with Heat (Low-T)
31: Electricity main product
32: Heat main product
4: Bottoming Cycle: Heat (Hi-T) in series with Elec (Low-T)
41: Electricity main product
42: Heat main product
5: Parallel Cycle: Heat in parallel with Elec
51: Electricity main product
52: Heat main product
Power Plant Type
1: Subcritical ORC
2: Supercritical ORC
3: Single Flash
4: Double Flash
Calculate Result
Results
Generation/Production
Economics
Reservoir
Power output and loads
The
Avg.
Init.
Min.
Max.
Units
Annual Total Electricity Generation: 0.0 GWh
Annual Net Electricity Generation: 0.0 GWh
Total Electricity Generation: 0.0 -0 -0 -0 MWe
Net Electricity Generation: 0.0 -0 -0 -0 MWe
Annual Total Heat Production: 0.0 GWh
Net Heat Production: 0.0 -0 -0 -0 MWth
Average Pumping Power: 0.0 MWe
Write Outputs File
Run sensitivty analysis


Webinars
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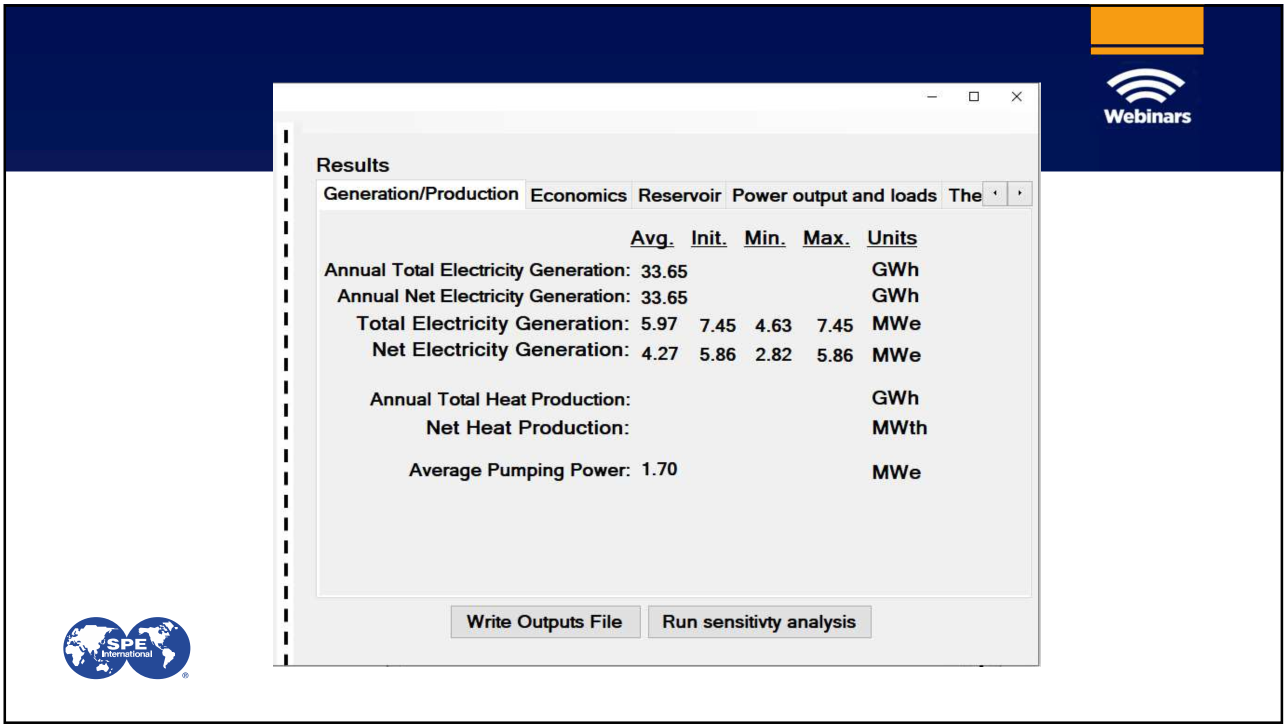
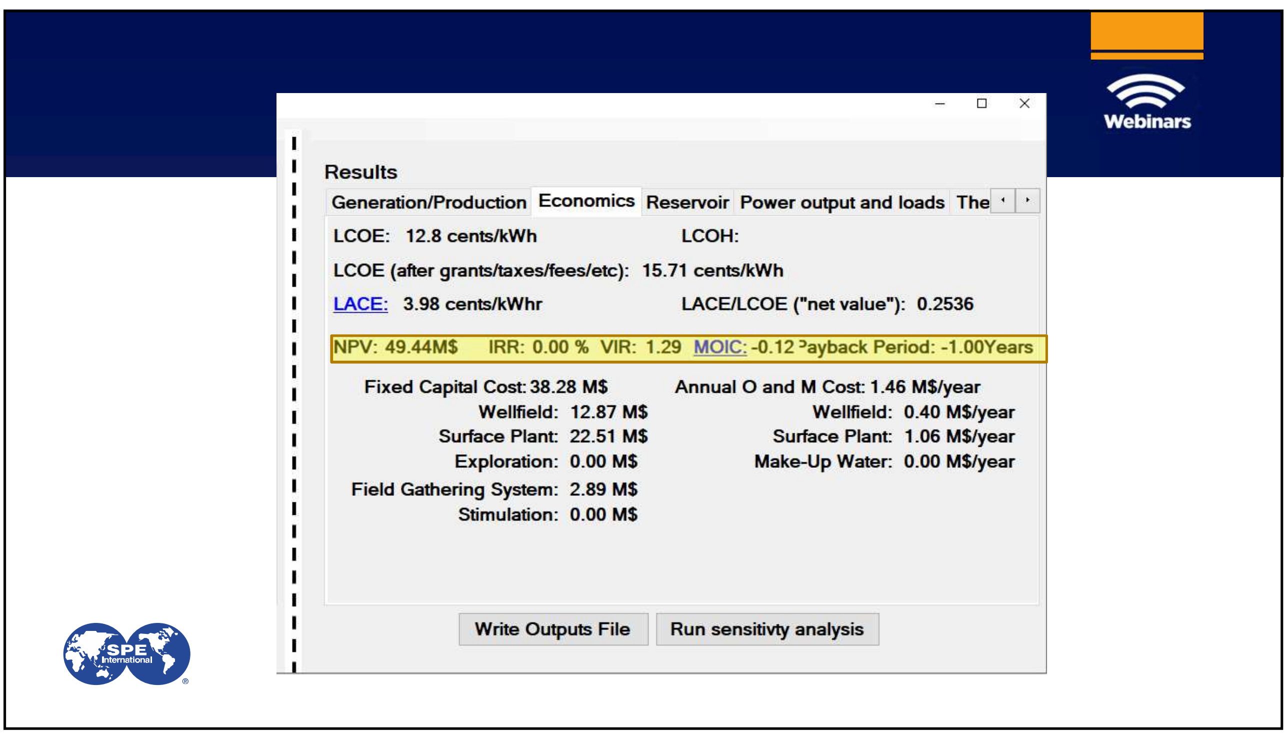
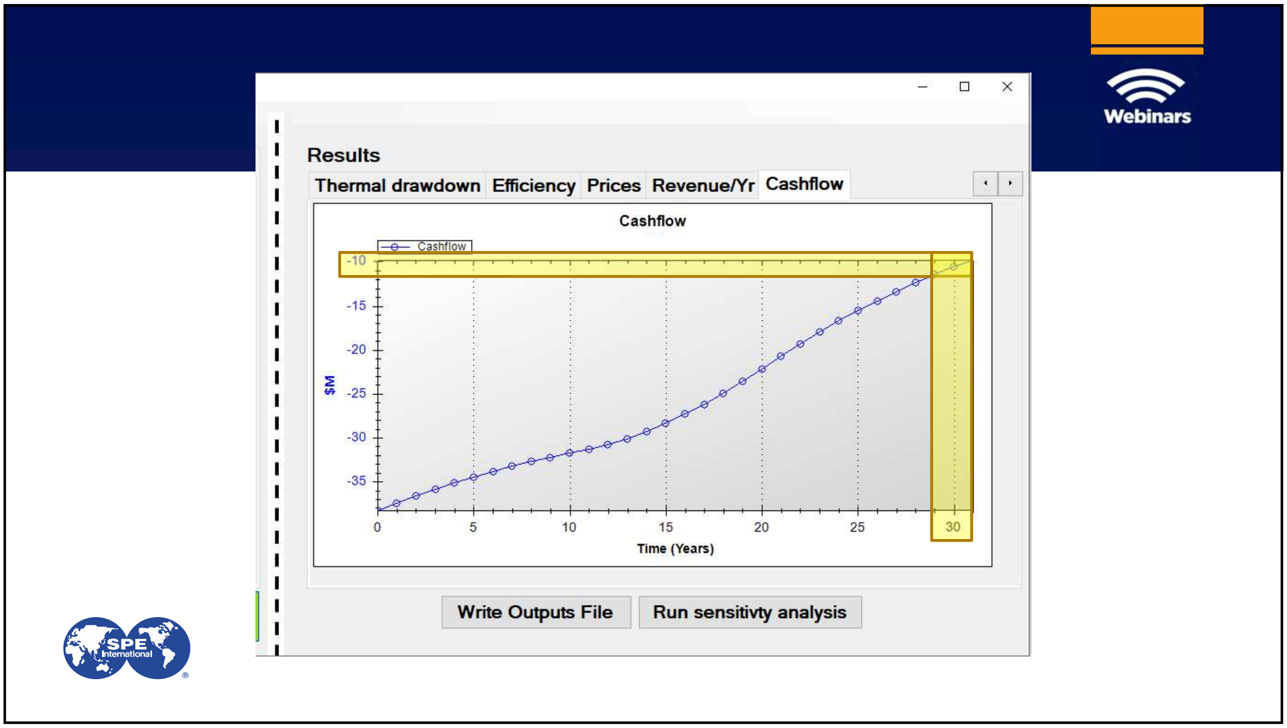
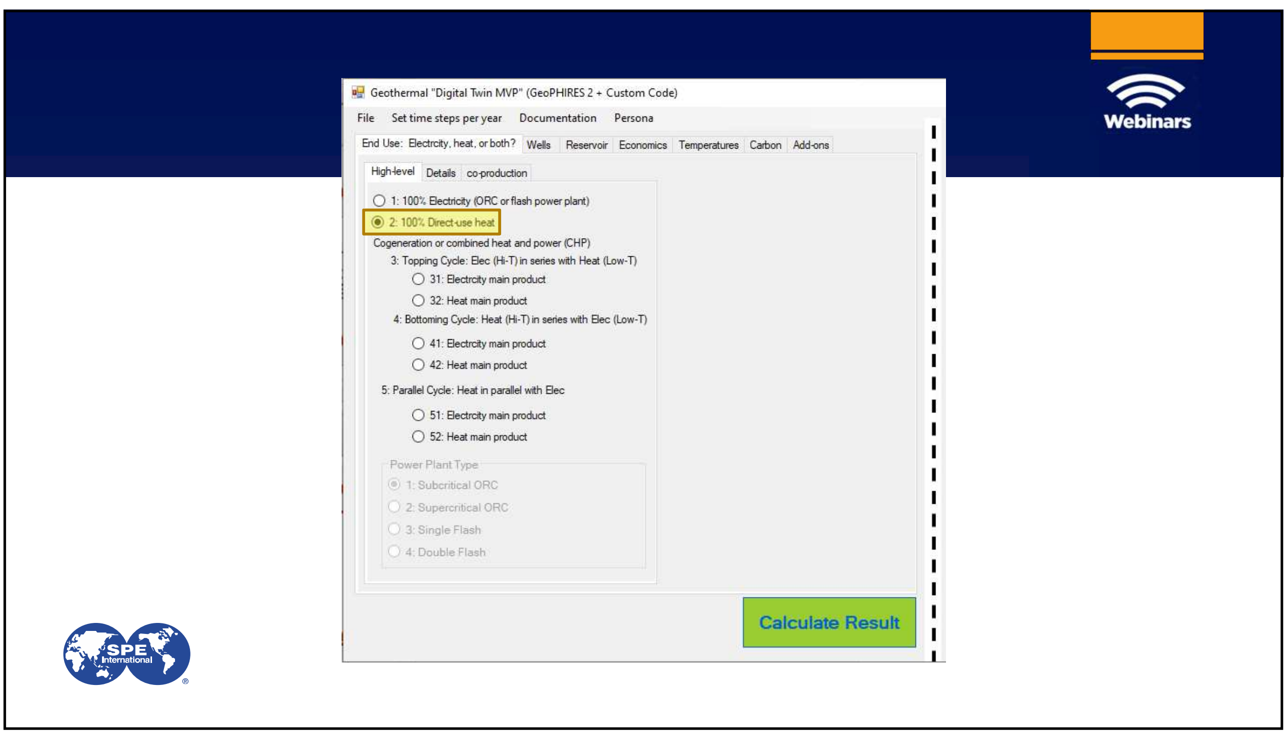
co-production
Browse GeoPHIRES Input Files
Look in:
Examples
Quick access
Desktop
Libraries
This PC
Network
Name
Date modified
Type
BSDOutput 4/20/2021 10:37 AM Text Doc
Demo_Caifornia 5/1/2019 5:12 PM Text Doc
Demo_TexasGeopressure 5/21/2021 11:43 AM Text Doc
example1 3/1/2019 8:26 AM Text Doc
example2 3/1/2019 8:26 AM Text Doc
example3 3/1/2019 8:26 AM Text Doc
example4 5/18/2021 3:45 PM Text Doc
example5 5/18/2021 3:55 PM Text Doc
example6 5/18/2021 3:53 PM Text Doc
Greenfire 5/1/2019 5:12 PM Text Doc
NASCC 5/21/2021 11:43 AM Text Doc
File name:
Demo_TexasGeopressure
Files of type:
txt files (*.txt)
Open as read-only
Open
Cancel
Calculate Result


Webinars
SPE International
Results
Generation/Production
Economics
Reservoir
Power output and loads
The
Avg. Init. Min. Max. Units
Annual Total Electricity Generation: 33.65 GWh
Annual Net Electricity Generation: 33.65 GWh
Total Electricity Generation: 5.97 7.45 4.63 7.45 MWe
Net Electricity Generation: 4.27 5.86 2.82 5.86 MWe
Annual Total Heat Production: GWh
Net Heat Production: MWth
Average Pumping Power: 1.70 MWe
Write Outputs File
Run sensitivty analysis


Webinars
SPE International
Results
Generation/Production
Economics
Reservoir
Power output and loads
The
LCOE: 12.8 cents/kWh
LCOH:
LCOE (after grants/taxes/fees/etc): 15.71 cents/kWh
LACE: 3.98 cents/kWhr
LACE/LCOE ("net value"): 0.2536
NPV: 49.44M$ IRR: 0.00 % VIR: 1.29 MOIC: -0.12 Payback Period: -1.00Years
Fixed Capital Cost: 38.28 M$
Wellfield: 12.87 M$
Surface Plant: 22.51 M$
Exploration: 0.00 M$
Field Gathering System: 2.89 M$
Stimulation: 0.00 M$
Annual O and M Cost: 1.46 M$/year
Wellfield: 0.40 M$/year
Surface Plant: 1.06 M$/year
Make-Up Water: 0.00 M$/year
Write Outputs File
Run sensitivty analysis


Webinars
Results
Thermal drawdown
Efficiency
Prices
Revenue/Yr
Cashflow
Cashflow
$M
Time (Years)
Write Outputs File
Run sensitivty analysis


Webinars
Geothermal "Digital Twin MVP" (GeoPHIRES 2 + Custom Code)
File
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Persona
End Use: Electricity, heat, or both?
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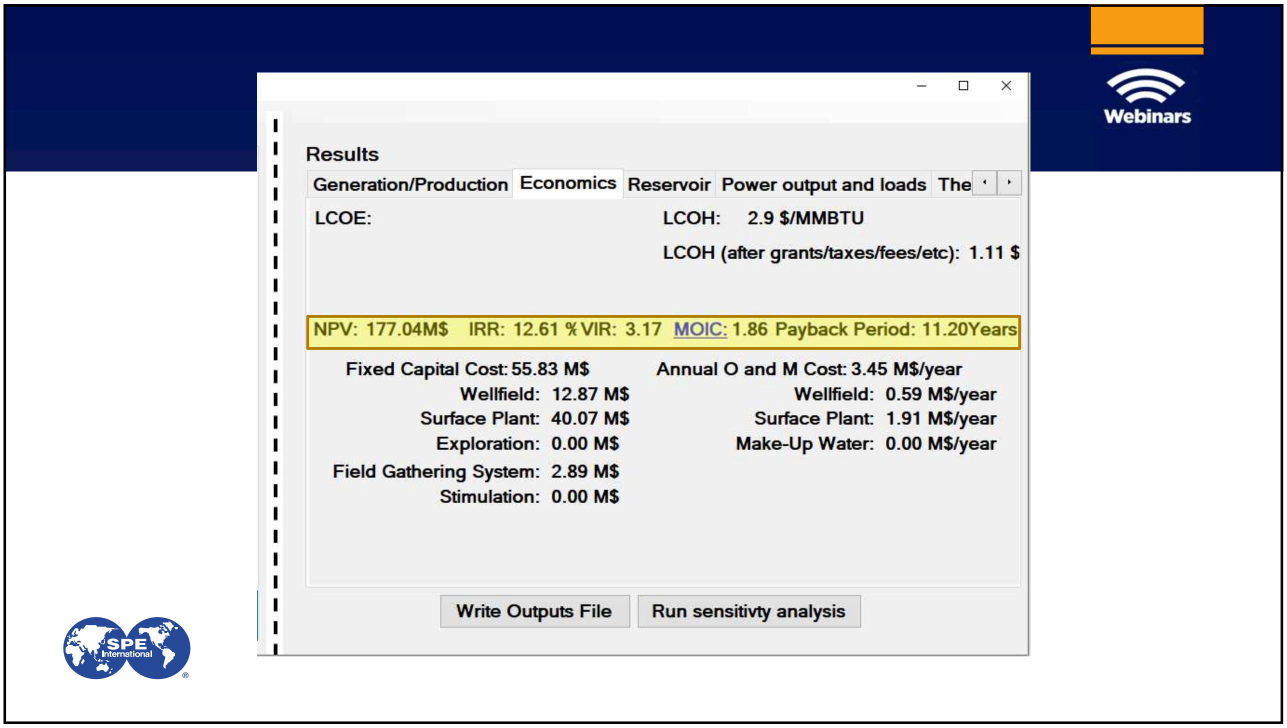
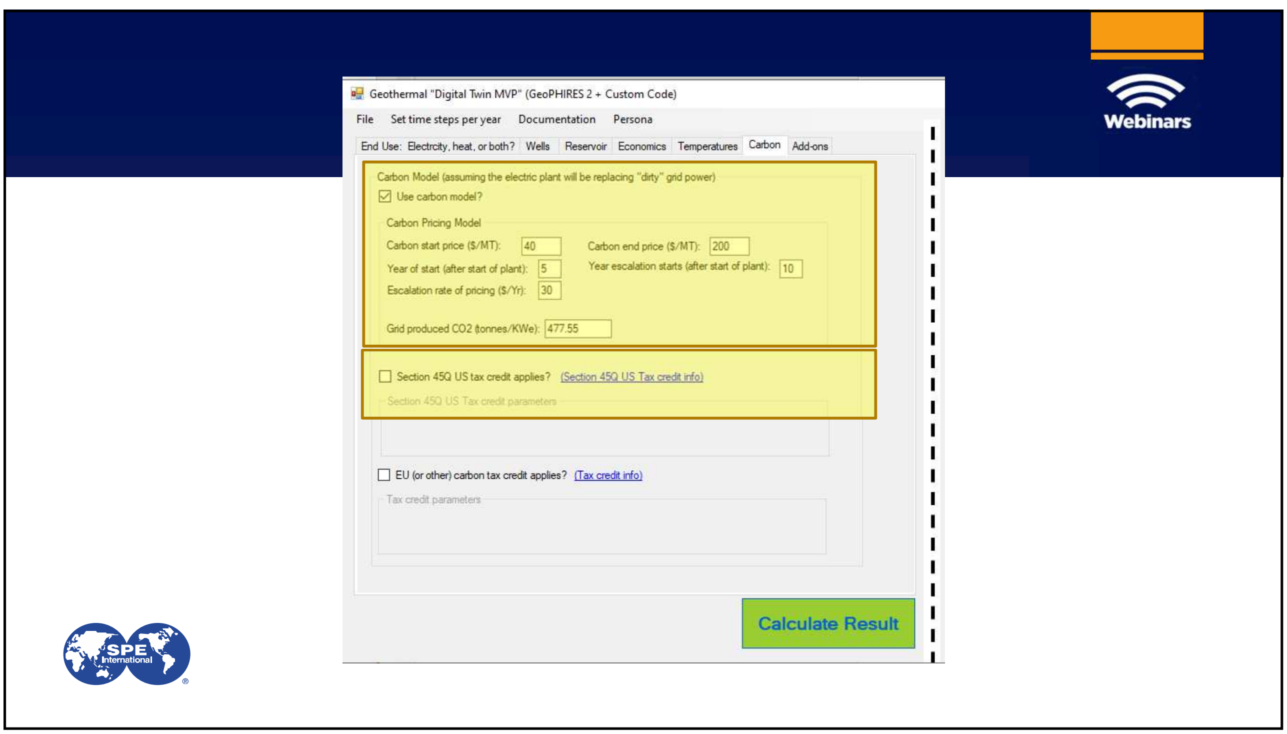

Webinars
Results
Generation/Production
Economics
Reservoir
Power output and loads
The
LCOE:
LCOH: 2.9 $/MMBTU
LCOH (after grants/taxes/fees/etc): 1.11 $
NPV: 177.04M$ IRR: 12.61 % VIR: 3.17 MOIC: 1.86 Payback Period: 11.20Years
Fixed Capital Cost: 55.83 M$
Wellfield: 12.87 M$
Surface Plant: 40.07 M$
Exploration: 0.00 M$
Field Gathering System: 2.89 M$
Stimulation: 0.00 M$
Annual O and M Cost: 3.45 M$/year
Wellfield: 0.59 M$/year
Surface Plant: 1.91 M$/year
Make-Up Water: 0.00 M$/year
Write Outputs File
Run sensitivty analysis
SPE International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Documentation
Persona
End Use: Electrcity, heat, or both?
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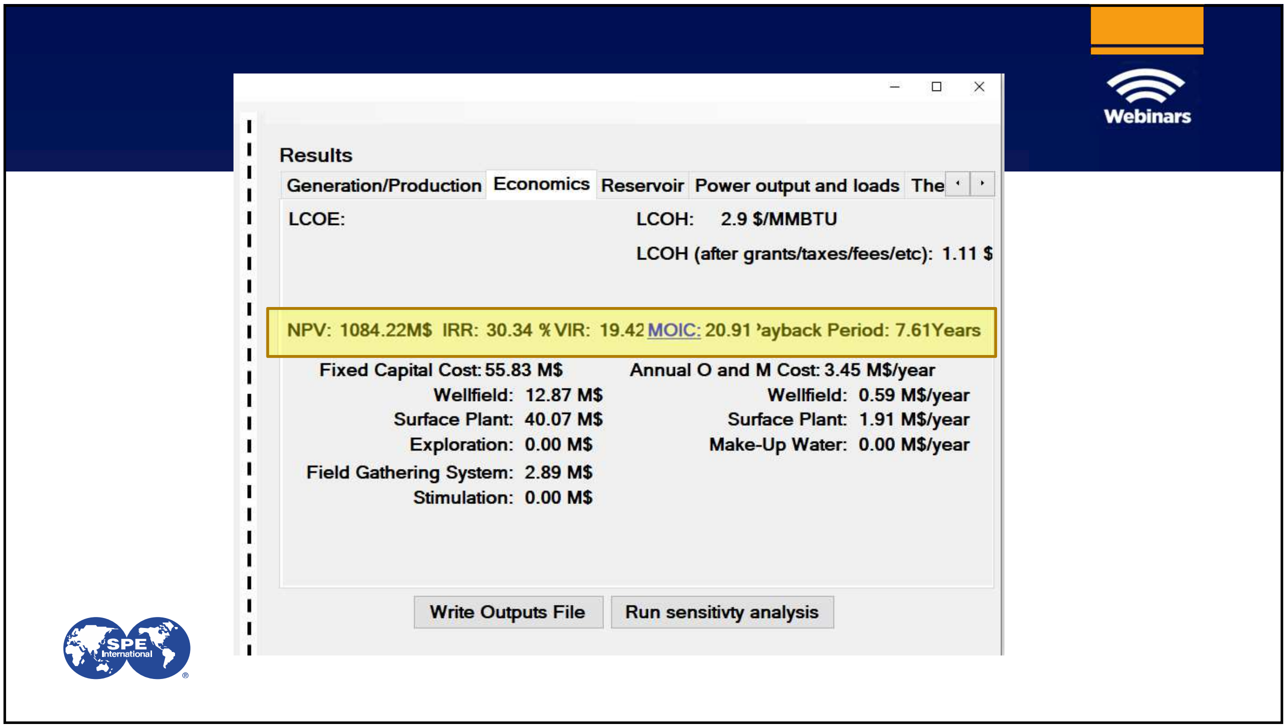
Carbon
Add-ons
Carbon Model (assuming the electric plant will be replacing "dirty" grid power)
Use carbon model?
Carbon Pricing Model
Carbon start price ($/MT): 40
Carbon end price ($/MT): 200
Year of start (after start of plant): 5
Year escalation starts (after start of plant): 10
Escalation rate of pricing ($/Yr): 30
Grid produced CO2 (tonnes/KWe): 477.55
Section 45Q US tax credit applies?
(Section 45Q US Tax credit info)
Section 45Q US Tax credit parameters
EU (or other) carbon tax credit applies?
(Tax credit info)
Tax credit parameters
Calculate Result
SPE International


Results
Generation/Production
Economics
Reservoir
Power output and loads
The
LCOE:
LCOH: 2.9 $/MMBTU
LCOH (after grants/taxes/fees/etc): 1.11 $
NPV: 1084.22M$ IRR: 30.34 % VIR: 19.42 MOIC: 20.91 'ayback Period: 7.61Years
Fixed Capital Cost: 55.83 M$
Wellfield: 12.87 M$
Surface Plant: 40.07 M$
Exploration: 0.00 M$
Field Gathering System: 2.89 M$
Stimulation: 0.00 M$
Annual O and M Cost: 3.45 M$/year
Wellfield: 0.59 M$/year
Surface Plant: 1.91 M$/year
Make-Up Water: 0.00 M$/year
Write Outputs File
Run sensitivty analysis
Webinars
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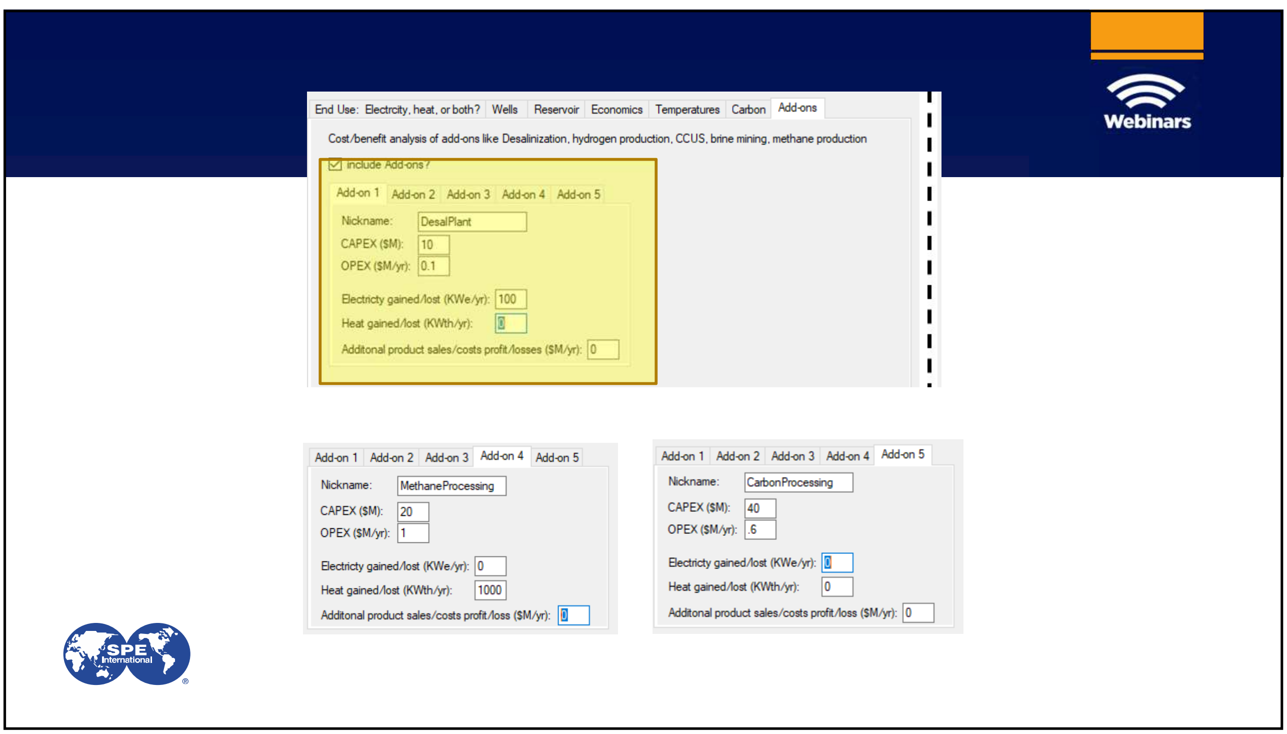
End Use: Electricty, heat, or both?
Wells
Reservoir
Economics
Temperatures
Carbon
Add-ons
Cost/benefit analysis of add-ons like Desalinization, hydrogen production, CCUS, brine mining, methane production
Include Add-ons?
Add-on 1
Add-on 2
Add-on 3
Add-on 4
Add-on 5
Nickname: DesalPlant
CAPEX ($M): 10
OPEX ($M/yr): 0.1
Electricty gained/lost (KWe/yr): 100
Heat gained/lost (KWth/yr): 0
Additonal product sales/costs profit/losses ($M/yr): 0
Nickname: MethaneProcessing
CAPEX ($M): 20
OPEX ($M/yr): 1
Electricty gained/lost (KWe/yr): 0
Heat gained/lost (KWth/yr): 1000
Additonal product sales/costs profit/loss ($M/yr): 0
Nickname: CarbonProcessing
CAPEX ($M): 40
OPEX ($M/yr): .6
Electricty gained/lost (KWe/yr): 0
Heat gained/lost (KWth/yr): 0
Additonal product sales/costs profit/loss ($M/yr): 0
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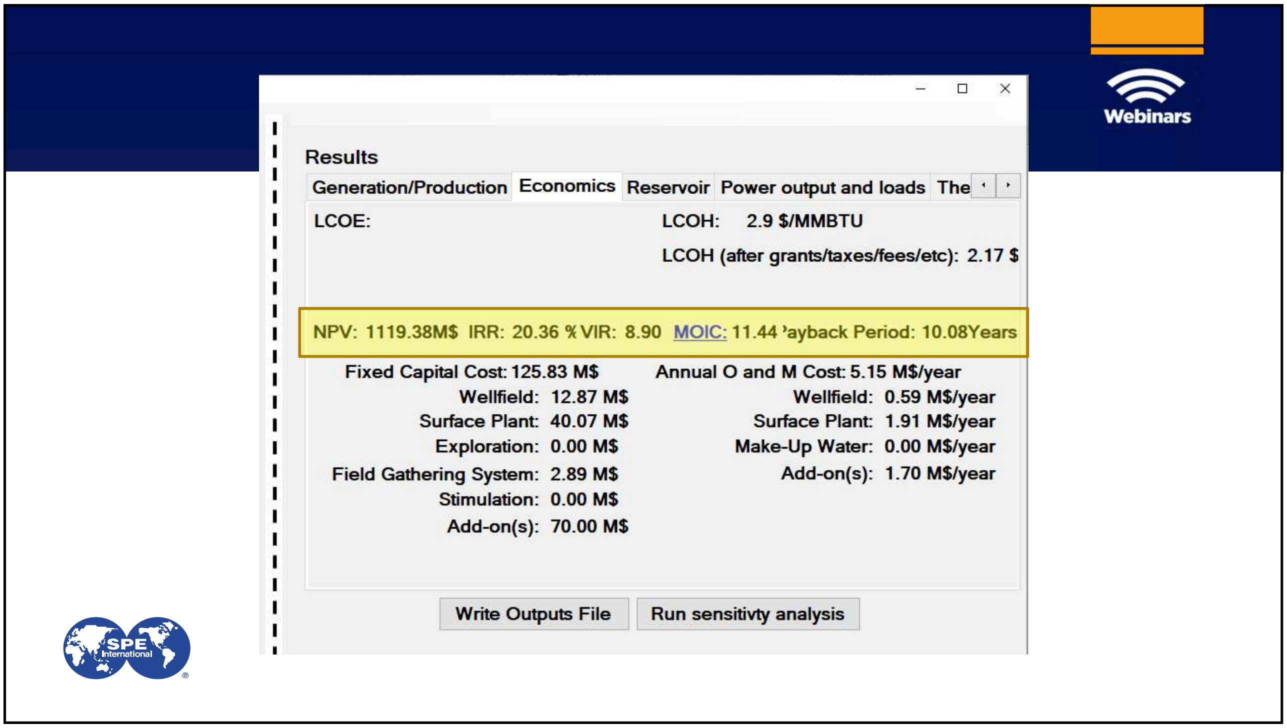
Webinars
SPE International
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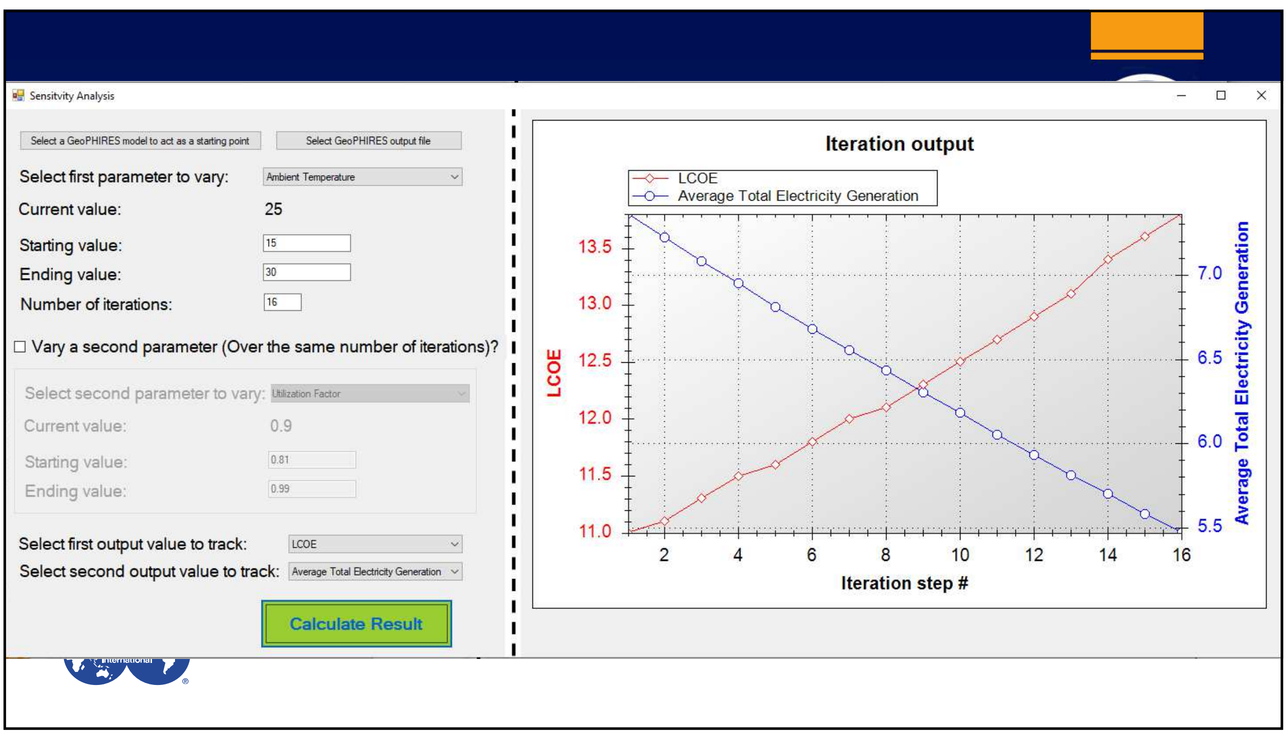
The
LCOE:
LCOH: 2.9 $/MMBTU
LCOH (after grants/taxes/fees/etc): 2.17 $
NPV: 1119.38M$ IRR: 20.36 % VIR: 8.90 MOIC: 11.44 'ayback Period: 10.08Years
Fixed Capital Cost: 125.83 M$
Wellfield: 12.87 M$
Surface Plant: 40.07 M$
Exploration: 0.00 M$
Field Gathering System: 2.89 M$
Stimulation: 0.00 M$
Add-on(s): 70.00 M$
Annual O and M Cost: 5.15 M$/year
Wellfield: 0.59 M$/year
Surface Plant: 1.91 M$/year
Make-Up Water: 0.00 M$/year
Add-on(s): 1.70 M$/year
Write Outputs File
Run sensitivty analysis


Sensitvity Analysis
Select a GeoPHIRES model to act as a starting point
Select GeoPHIRES output file
Select first parameter to vary:
Ambient Temperature
Current value:
25
Starting value:
15
Ending value:
30
Number of iterations:
16
Vary a second parameter (Over the same number of iterations)?
Select second parameter to vary:
Utilization Factor
Current value:
0.9
Starting value:
0.81
Ending value:
0.99
Select first output value to track:
LCOE
Select second output value to track:
Average Total Electricity Generation
Calculate Result
Iteration output
LCOE
Average Total Electricity Generation
LCOE
Average Total Electricity Generation
Iteration step #