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Geothermal Energy Storage (Geo-TES) Using Traditional Oil Reservoirs

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Abstract

Developing power grid stabilizing, zero emissions power production projects is a critical component to meeting California's year 2045 greenhouse gas emissions reduction targets and clean power requirements. Established oilfields in the San Joaquin Valley, coupled with favorable solar irradiance characteristics, offer a transformational opportunity for the oil and gas industry that could meet the state's long-duration storage needs through the use of synthetic geothermal methods, integrating Geothermal Energy Storage (GeoTES) practices. Premier Resources Management (PRM) is planning a demonstration project which demonstrates that this innovative process, appropriately expanded, can meet the electric power production needs for the people of California. Application of unguided process application can result in uneconomic investment practices, however.

Methods, Procedure, Process

Subsurface geologic formations have been characterized through aquifer exemption applications with the California Geologic Energy Management Division (CalGEM). The process of demonstrating GeoTES potential will continue at PRM's existing leases and include simulation validation for solar irradiance on location, concentrated solar power (CSP) as a mechanism to heat produced brackish water, and reservoir heating. This demonstration project will validate the conversion of traditional oilfields by deploying and combining proven technologies in an innovative process. Datasets will be compiled between Premier Resource Management, a private entity, and national laboratories to support technoeconomic viability.
Second-Level Heading.

Methods, Procedure, Process

Power production is a complex and highly regulated activity, requiring insights into State regulatory practices and politics, local and regional power demands, and skill in designing a process which will align to these often-conflicting demands. This design and analysis process is a complex integration activity, which, if not performed with all due care, will result in unacceptable project economics. When properly applied, profitable developments can be designed which will result in power grid stabilization with zero emissions while reusing extant oil reservoirs for the purpose.

California Regulated Power Grid Conditions

The power generation and distribution system, i.e., the power grid, for the State of California is marginally stable and is being further transformed to a less stable configuration.

These changes risk further grid destabilization if several factors are not addressed:

- State goals for renewable energy supplies will exceed the ability of the power generation process, subverting the use of standard base load powerplants, including nuclear power plants.
- Overwhelming application of photovoltaic (PV) power plants for the supply of renewable power will interfere with standard network stabilization practices. Further, State commitment to the use of batteries for power storage is vulnerable to supply shock; when the ability to produce the quantity of batteries is grossly exceeded by electricity storage demands (Von Kaenel, 2022).
- State goals to redistribute wealth through fixed rates, as proposed to the California Public Utility Commission (CPUC), subvert the production/distribution processes to the detriment of the rate payers in favor of the utilities, in violation of Public Utility Code (Nikolewski, 2023).
- Misstatement of the cost of renewable energy misleads the public. For instance, the term "levelized cost of storage" (LCOS) grossly misrepresents the true cost of power when it is being used, placing those costs on the backs of the rate payers, so as to justify the reasonableness of conversion to renewable energy supplies (e.g., LCOS of battery storage is ~$0.05/kW-hr while actual use-based power dissipated is more in the range of $0.20/kW-hr) (Lazard, 2020).
- State phase out of the fossil oil production industry in California forces conversion to electric power despite the economic cost. This will increase electric power demands in the State by an estimated 100% by 2045 while greatly increasing the State's sale price of utility power, already one of the highest costs in the nation (Pressler, 2023).

Solar renewable powerplants are fundamentally unavailable during the nighttime and seasonal weather events. Solving this problem requires cost-effective storage of clean energy which may be dispatched when other renewable power supplies are insufficient (Strategen, 2020). Several technologies attempt to address power supply intermittency through the use of various storage methods: electric batteries, pumped water storage hydropower, expanding compressed air power production, falling mass power generation, etc. In each of these concepts, the cost of the storage system becomes uneconomic or fails to meet multi-day demand events.

Moreover, an oversupply of photovoltaic power during high-irradiance daytime periods have caused spot-power pricing to become negative, making the future supply of additional power a necessity to be produced during periods of low or zero irradiance (i.e., during cloudy and non-daylight periods) if commercially economic power production is a goal of investment capital for renewable power production.

California Power Generation

Figure 1 demonstrates the relative contribution that renewable energy contributes to the State's daily power supply. As noted, there are periods of the day where renewable power generation currently exceeds power demands, which negatively impacts methods typically used to create a stable power grid and thereby requiring renewably-generated power be pushed out of the State for use elsewhere.

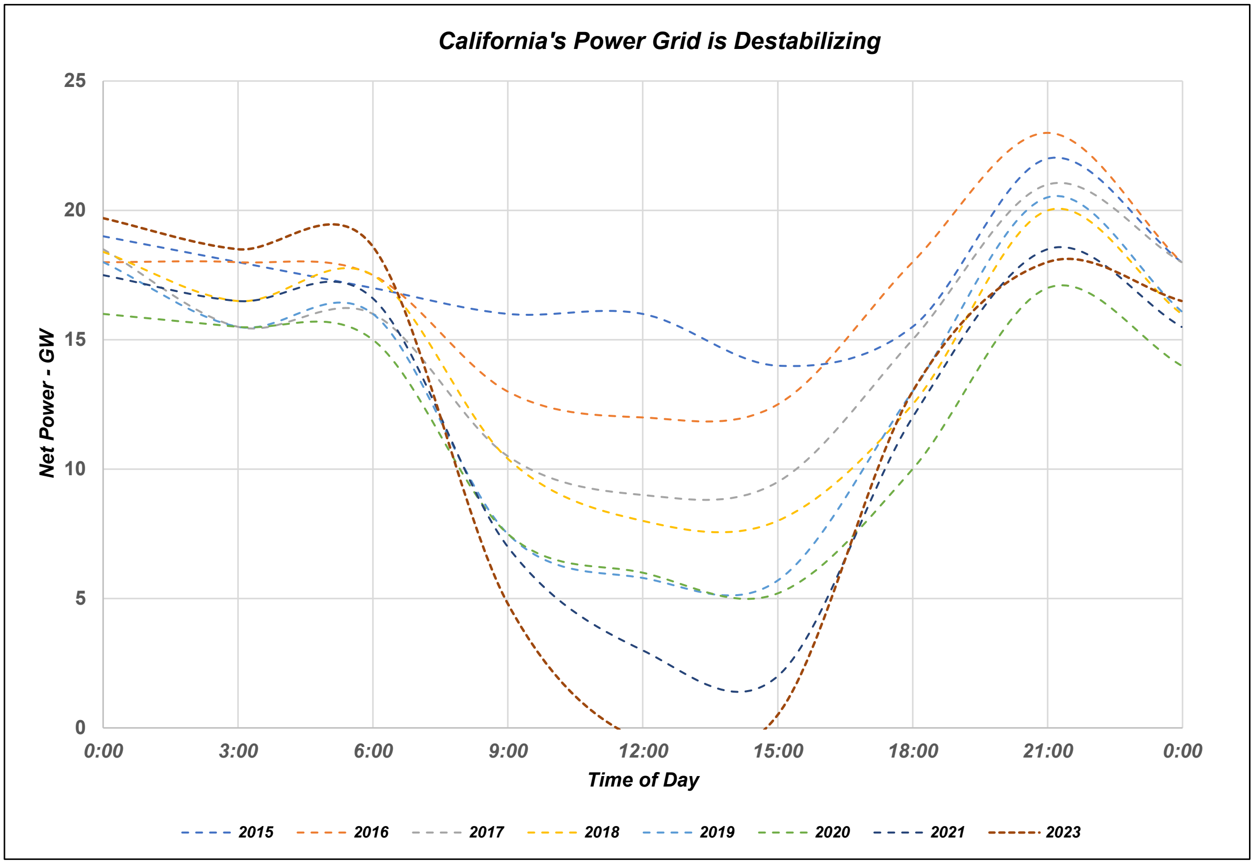

Fig. 1—California Independent System Operator (CAISO) "Duck Curve" net power requirements. Large change causes system instability.

California Power Pricing

Figure 2 shows California Independent System Operator (CAISO, 2023) energy sales price data (by the minute) for calendar year 2022. The data show that from ~0700 to ~1700 hours average energy prices are ~$3/MW-hr. This chart also shows the impact of excess power generation, whereby there is a statistical likelihood that power prices will be negative during this period. And, to further confirm the situation, CAISO has curtailed ~2 million MW-hr of energy production capacity in 2022 (CAISO, 2022). Any project which attempts to produce power in the State of California must reflect these pricing conditions for profitable investment. The PRM project will be so configured, as shown below, in Figure 3.

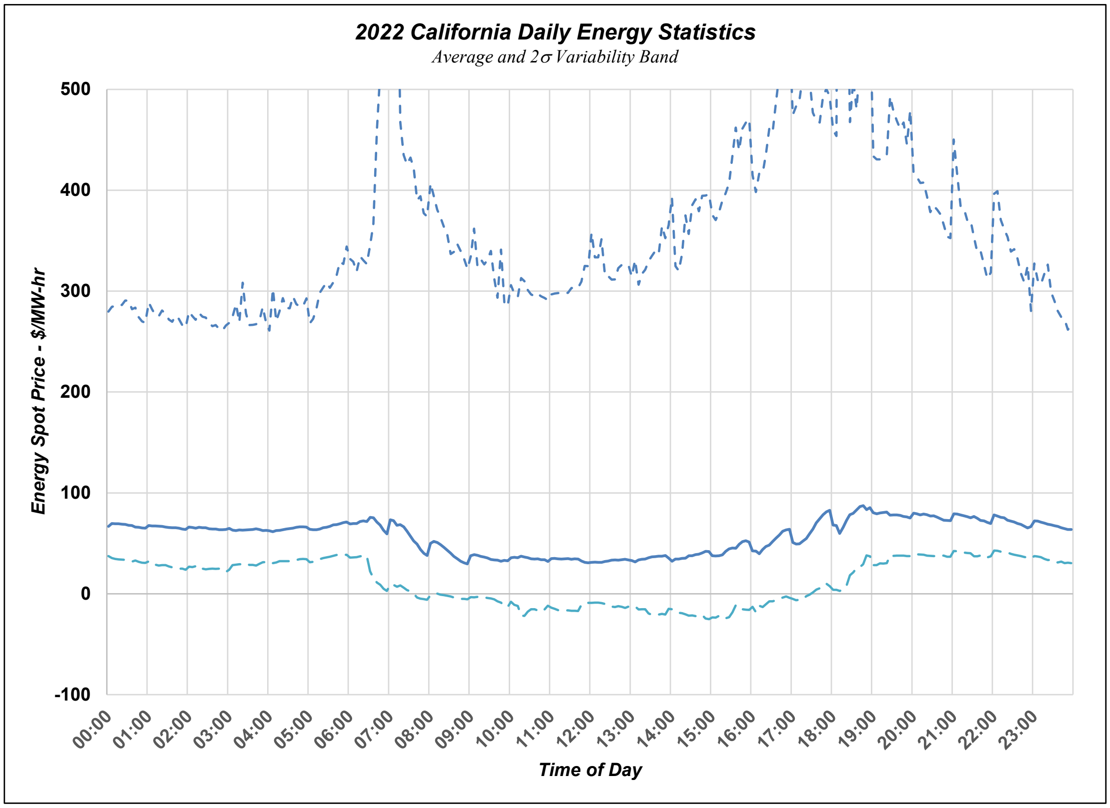

Fig. 2—California daily pricing statistics for CAISO, 2022.

Geothermal Systems for Clean Power

California has a stated goal of adding a gigawatt of geothermal power by 2025 (Richter, 2021). There are several geothermal energy system processes, both natural and synthetic, which are considered for production of low-emission power production, and which might be of consideration to meet the State's needs.

Natural Geothermal: Power is produced by recovering heated steam from hot rocks. In natural geothermal systems, the heated rocks, when found to possess the right characteristics, are extensively distributed in a geothermal region. These reservoir characteristics include:

- Rocks are heated by wide-area near-magma heat sources.
- Stresses on the hot rocks have been high, causing them to naturally fracture.
- Fractures are permeated by an ample water supply.

California has several locales which possess these characteristics. It is unfortunate that the amount of heat withdrawn from these reservoirs has, over time, exceeded their ability to support the desired power generation investments. Like any depleting resource, natural geothermal power is governed by diffusion limits as classically described in reservoir engineering texts. It is estimated by U.S. Department of Energy (DOE) reports that the United States has up to 60GW of natural geothermal power capacity, while current geothermal power production is about one twelfth this value (DOE, 2023) (EERE, 2023).

There remain many challenges to natural geothermal power production, including the environmental impact caused by emissions of:

- Arsenic
- Mercury
- Hydrogen Sulfide
- Radioactive Materials
- Fine Siliceous Particulate Matter
- Carbon Dioxide
- Extreme Noise

(Brown, 2011; FANC, 2019; Forrest, 2013; Gawell & Kagel, 2005; UOCS, 2013)

These emissions have not been effectively managed for older power producing geothermal plants. Modern plants present fewer emissions through the use of hydrocarbon-based low-temperature-boiling-point working fluids for Rankine-cycle power generation. Nonetheless, the environmental impact of naturally occurring geothermally-heated power plants remains a serious impediment to their further, and widespread application.

Enhanced Geothermal Systems (EGS): A second geothermal concept has come of interest, where drilling into and fracturing hot dry rock is seen as a means of tapping into the natural bounty of magma-heated earth crust. The work presented by various researchers implies that EGS can provide near-unlimited heat and power supply for the world. Many such assessments do not truly reflect the limitations already demonstrated by naturally occurring geothermal heat sources; that being the exhaustibility of the heat source, due to the thermal diffusion limitations of the rock. Roughly 40 years ago, the DOE demonstration at Mount Kilauea, Hawaii revealed that transient conduction limitations quickly exhaust an apparently unlimited heat source (Morita, et al. 1992) (Kinslow, et al. 2012). Steam flood heat transfer measurements further demonstrate these limits (Winderasta, 2018)

Synthetic Geothermal: Geologic Thermal Energy Storage (GeoTES) offers the use of the collection of solar heat and its introduction into porous, permeable rock, for the purposes of that heat's reuse. This geothermal concept has been studied by at least two research groups, and has been presented both in patent form (Meksvanh, et al. 2009) and in technical presentation form (Sharan, et al. 2020, technical review of this prior work is left to the reader).

In summary, the amount of energy which may be stored is immense. By example, the daily amount of electrical energy used in the USA is roughly 40,000 GW-hr (EIA, 2023). To compare this stored energy to that which may be stored using batteries currently in service, said batteries can store mere seconds of the country's power needs. The amount of energy which is storable through introduction of heated fluids into a porous, permeable reservoir of small size (1 square mile by 300 feet), is proximate to this USA daily energy usage. Within the realm of California reservoirs which can be used to store heat, there exists thousands of square miles and thousands of vertical feet which could be used to store many times the USA daily energy usage or be used to support power demands when renewable power plants cannot operate. Unlike fractured, hot dry rock, the rate of heat transfer, both in storage and in recovery, has no practical limit.

Since there must be the presence of a permeable, porous, bounded reservoir which can be used for this new purpose, synthetic geothermal, and its potential for unlimited power generation, offers a transformational opportunity for the legacy petroleum business and its depleted oilfields.

Synthetic Geothermal Demonstration in California

Premier Resources Management (PRM) currently possesses development rights to a defined porous, permeable reservoir located on the western edge of the southern San Joaquin Valley of California, as shown in Figure 3.

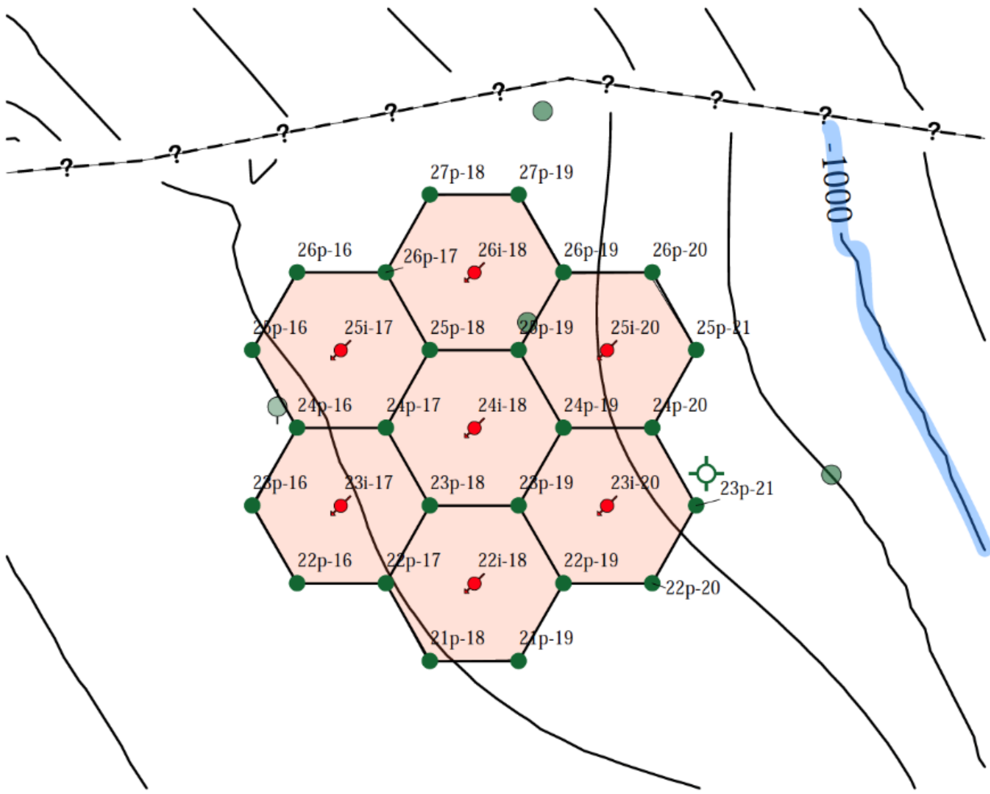

Fig. 3—Planned Seven-Spot Project

PRM plans to construct a synthetic geothermal power plant using CSP parabolic troughs to harvest the sun's renewable energy for charging a subsurface reservoir with thermal energy (Solar Spaces, 2018), thereby providing power when the CAISO price demands that power, allowing the project to generate a economically-positive cash flows. This project would be configured to provide 10MW of electric power produced for about five hours, nightly. In so doing, the heat stored in the reservoir will remain routinely available for such generation purposes. However, the project configuration will also allow the plant to provide continuous power for up to 40+ days, should seasonal conditions dictate the need for this form of "base load" power. In such an operation, the energy stored in the reservoir will be exhausted at the end of the draw period and will require months of energy recharge to allow renewed efficient power production. The plan for this project will be to operate with zero regulated substance emission.

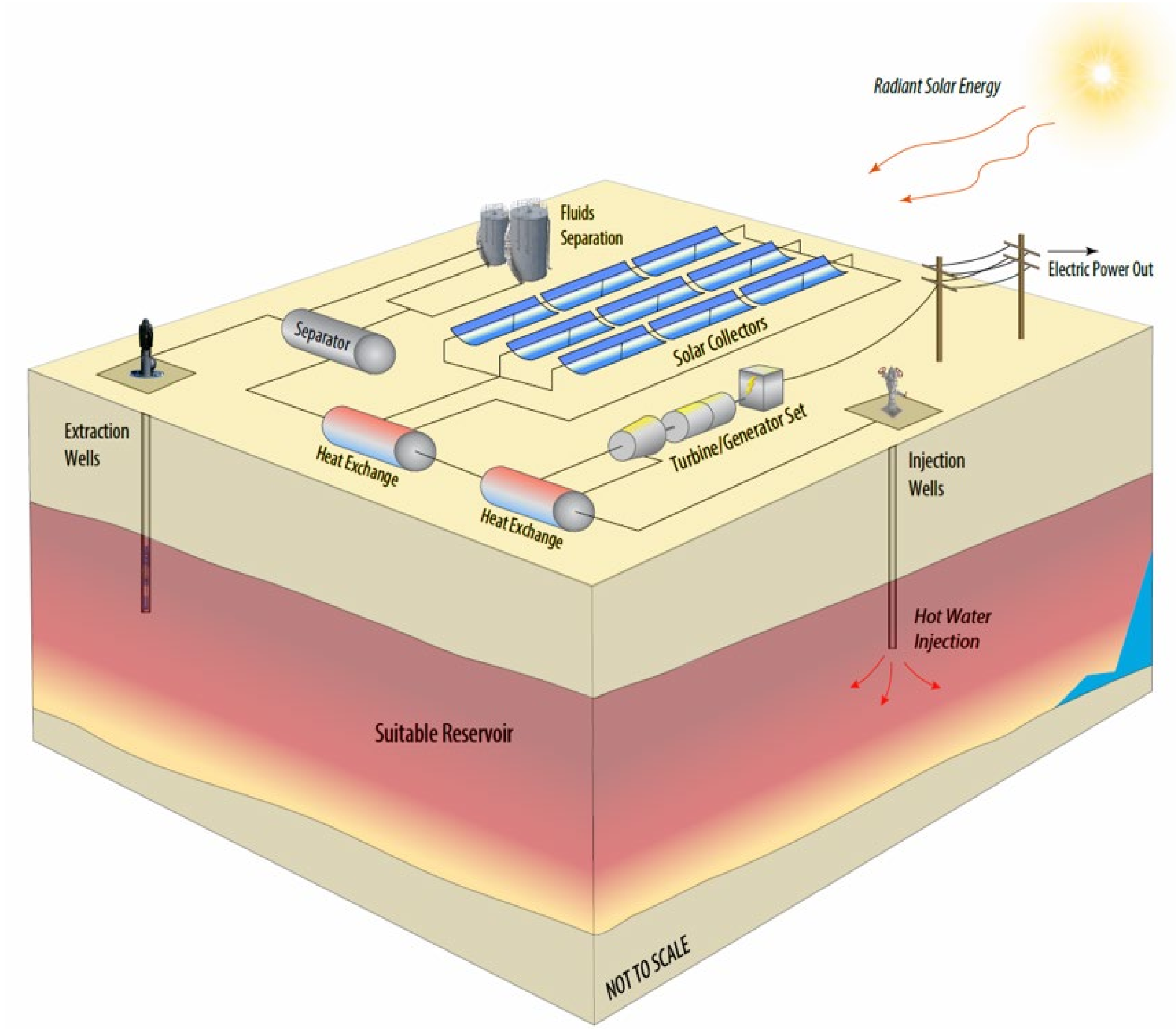

Fig. 4—Artist Rendition of PRM Project Process

Solar Variation

An economic project must be configured to recover solar heat when it is available, as shown by the 20-year solar irradiance data, Figure 5. This chart (NREL 2023) clearly demonstrates that solar irradiance is highly variable. Design of any heat absorbing process is complex, requiring sophisticated process management equipment and practices for the purpose.

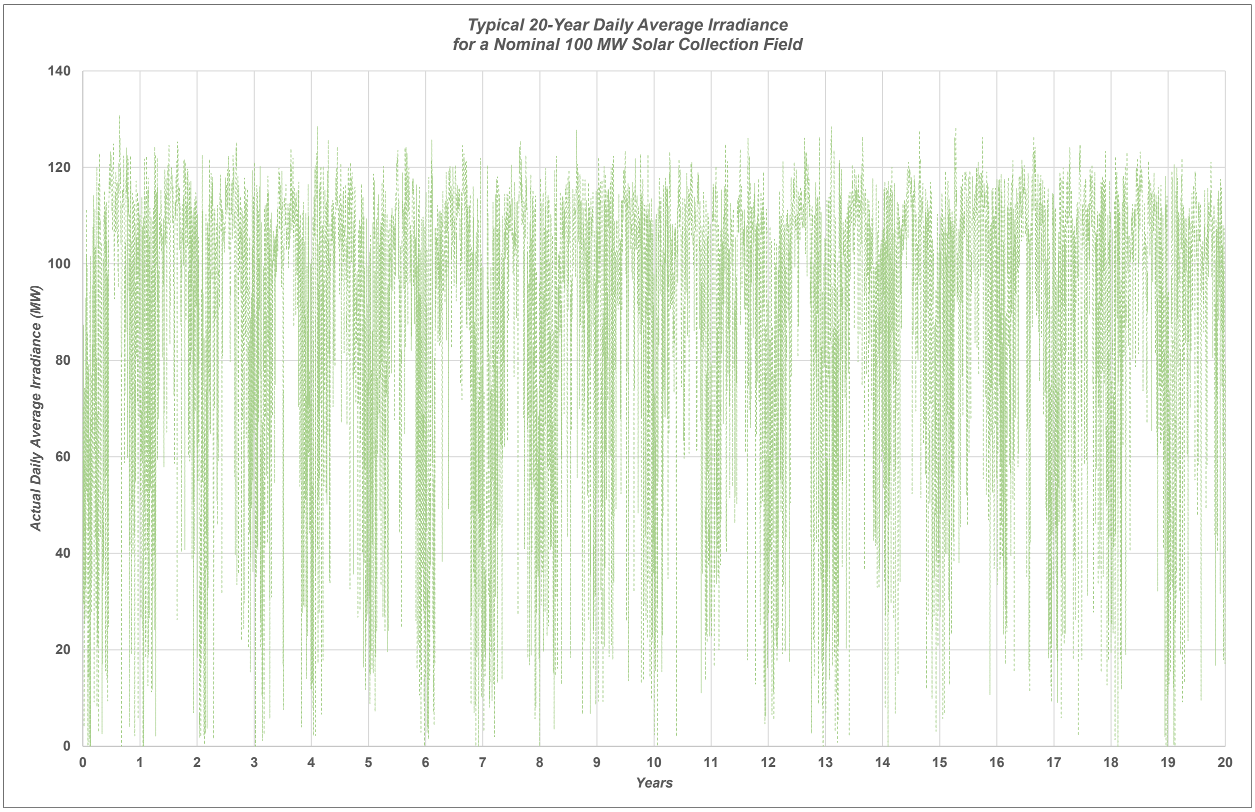

Fig. 5—Solar irradiance for the area proximal to the proposed project

Project Integration Processes

As can be seen, synthetic geothermal projects are complex, requiring clear understandings of local irradiance, reservoir description for knowledge of heat storage and fluid circulation capacity. The process must also conform to economical pricing associated with regional power demands for successful economic results. We believe this integration is achievable and have demonstrated these practices can be employed using proprietary simulation tools. PRM plans to demonstrate these competencies. However, for widescale application by others with convertible oilfields and power utilities wishing to use this solution method, the following list of industrial method studies and resultant tools will be required:

- Definition of wellbore configurations for the purposes presented herein
- Optimization of solar heat absorbing equipment for application in variant terrain service
- Reservoir definition for circulation capacity and energy storage
- Integrated modeling processes for heat absorption and recovery
- Powerplant integration into power grid demand structures
- Parametric capital plant models to facilitate process framing
- Process control methods to optimize plant economic return

Summary

PRM is in the planning phases to construct a project in the San Joaquin Valley of California. The project will be configured to collect and store (in an oil reservoir) solar heat for reuse in the production of electric power. This plant will be designed to operate in conformance with power grid demands (as induced by favorable power prices). Proprietary energy modeling software estimates a heating time to efficiently generate electric power of ~18 months. Treatment of the project as a “base load” power plant would result in uneconomic investment results. Further study and tool development in the integration of reservoir and economic conditions will be a requirement to extend this project’s expected performance to other oilfields.

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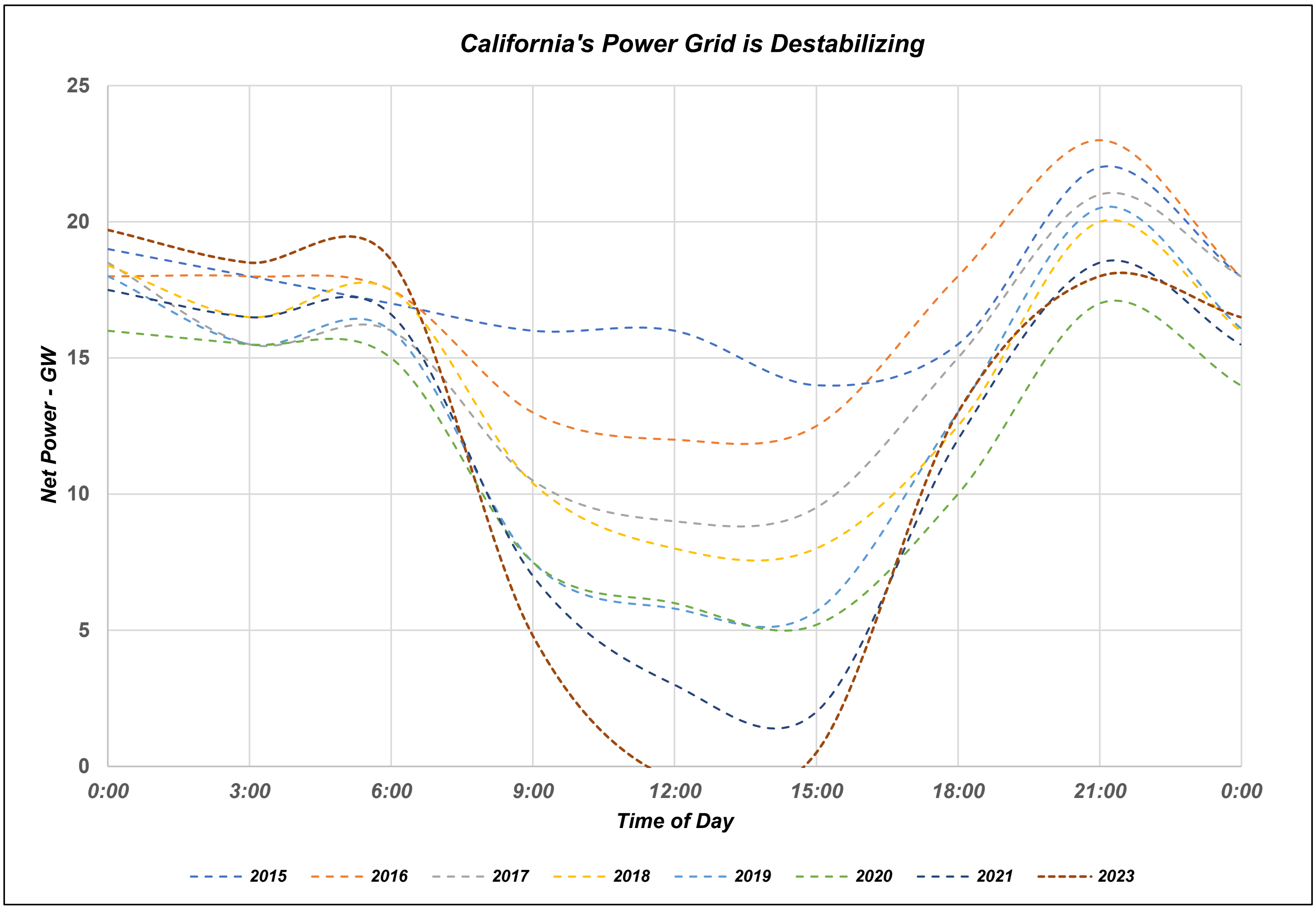

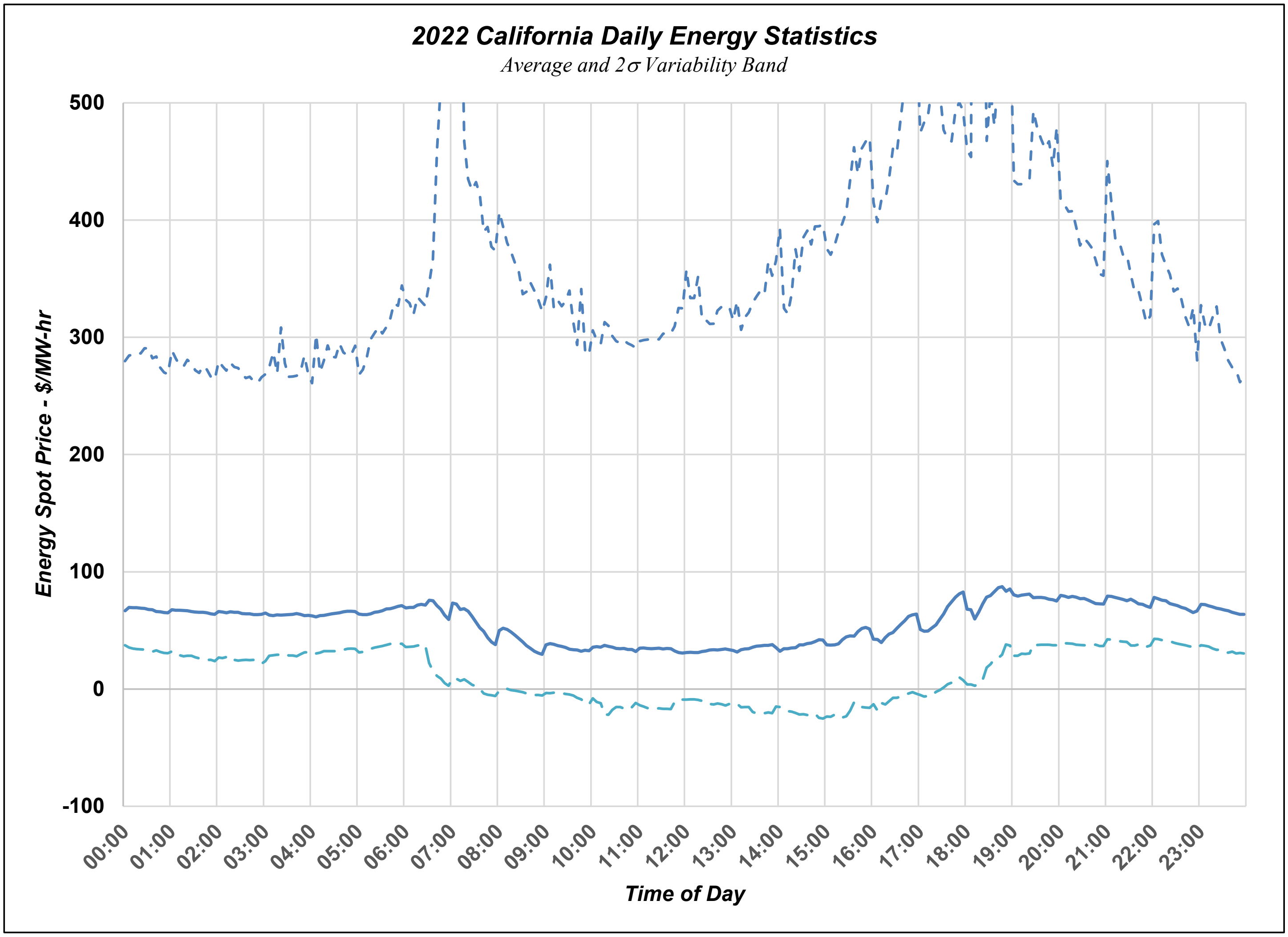

2022 California Daily Energy Statistics
Average and 2σ Variability Band
Energy Spot Price - $/MW-hr
500
400
300
200
100
0
-100
00:00
01:00
02:00
03:00
04:00
05:00
06:00
07:00
08:00
09:00
10:00
11:00
12:00
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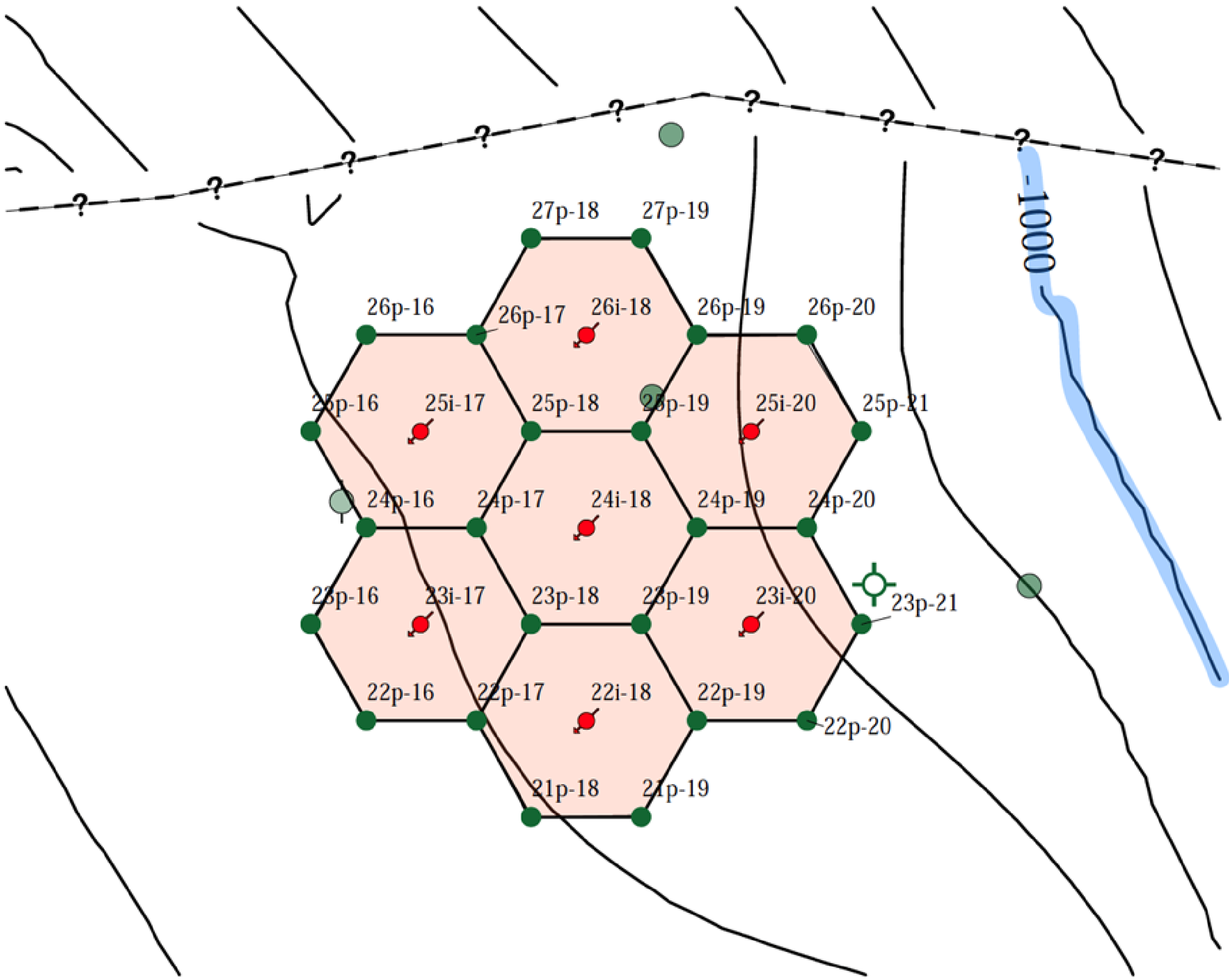

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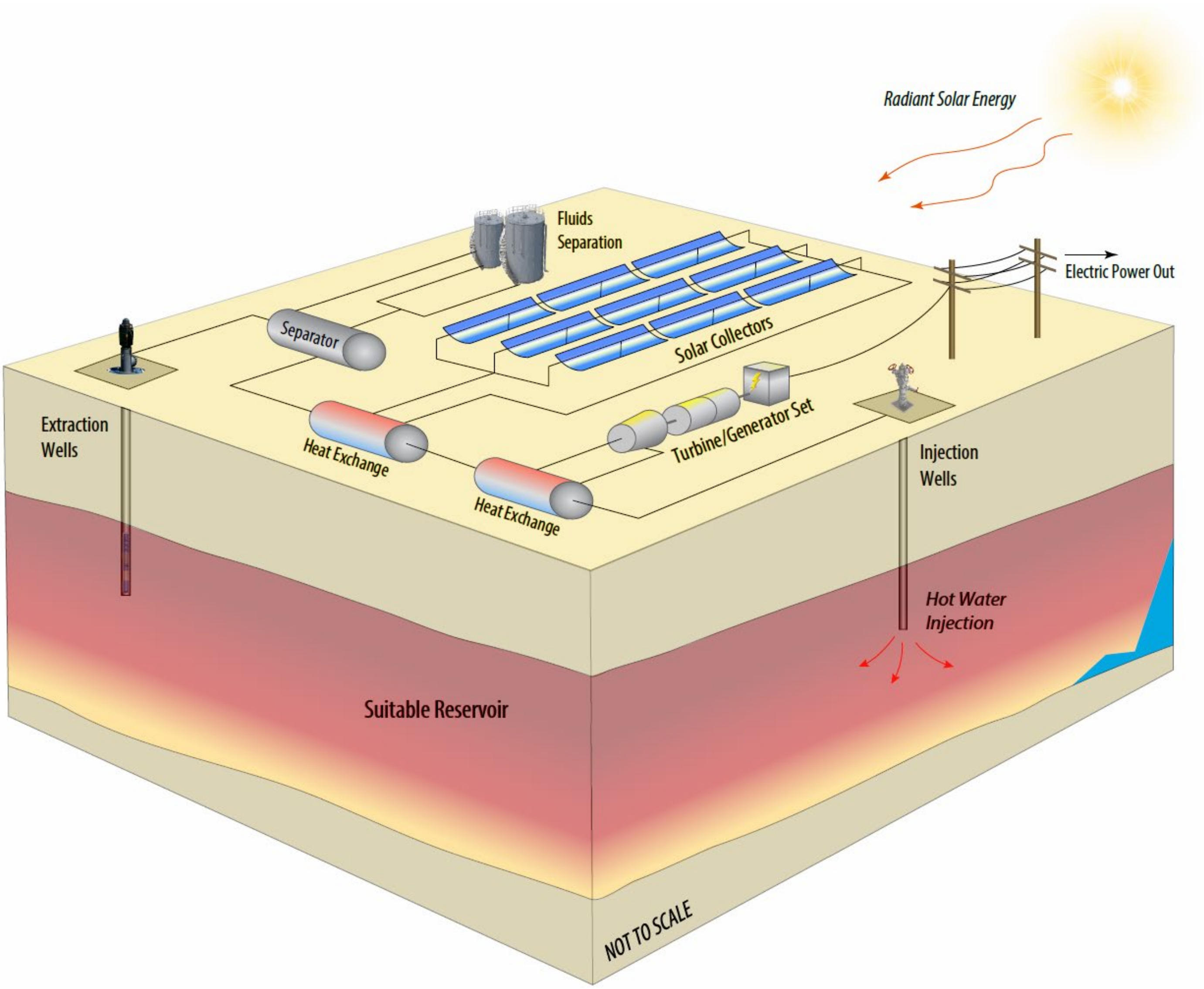
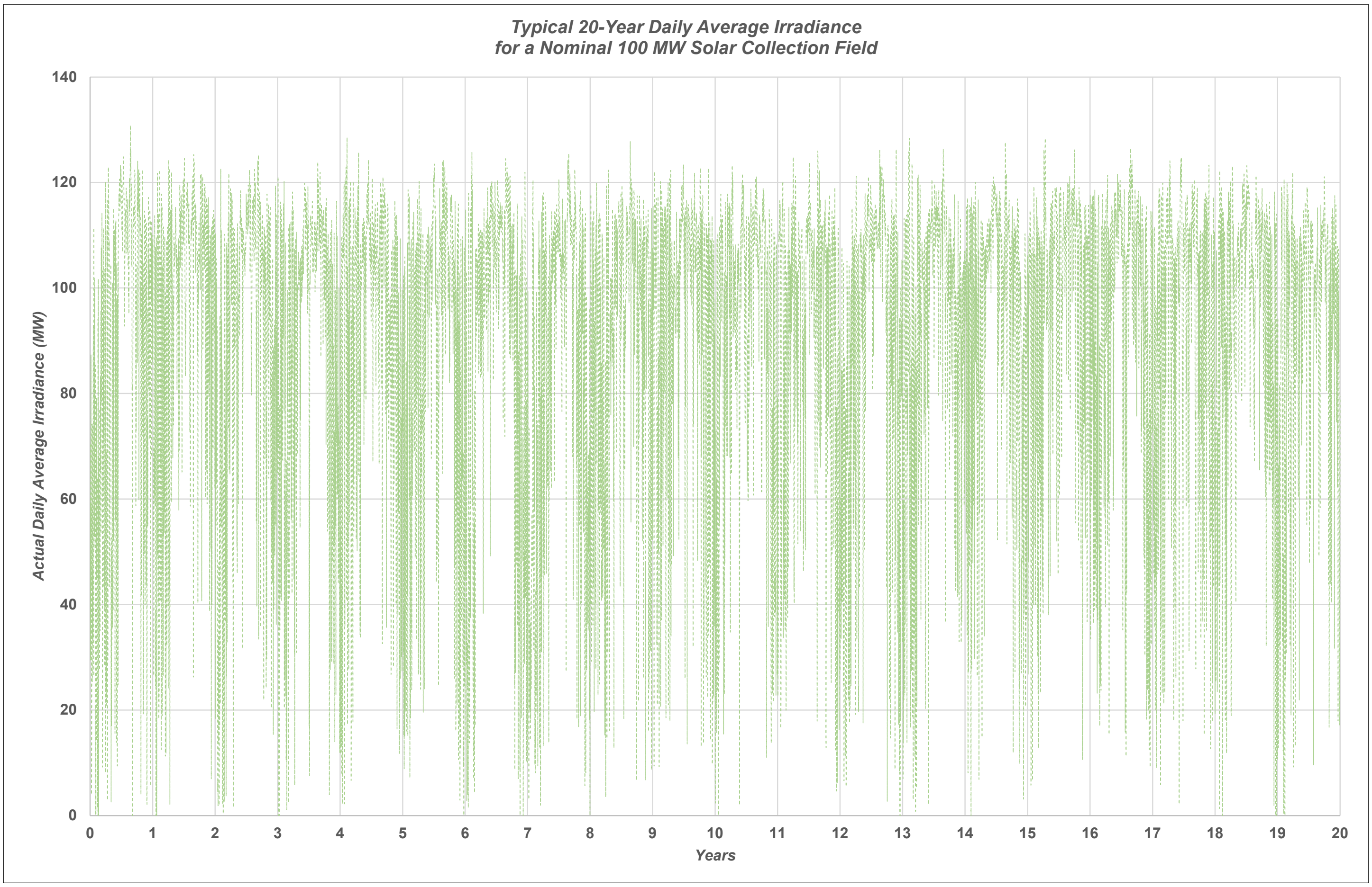

Radiant Solar Energy
Fluids
Separation
Electric Power Out
Separator
Solar Collectors
Extraction
Wells
Turbine/Generator Set
Injection
Wells
Heat Exchange
Heat Exchange
Hot Water
Injection
Suitable Reservoir
NOT TO SCALE



Typical 20-Year Daily Average Irradiance
for a Nominal 100 MW Solar Collection Field
Actual Daily Average Irradiance (MW)
0
20
40
60
80
100
120
140
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Years