SOLAR ENERGY TECHNOLOGIES OFFICE
U.S. Department Of Energy

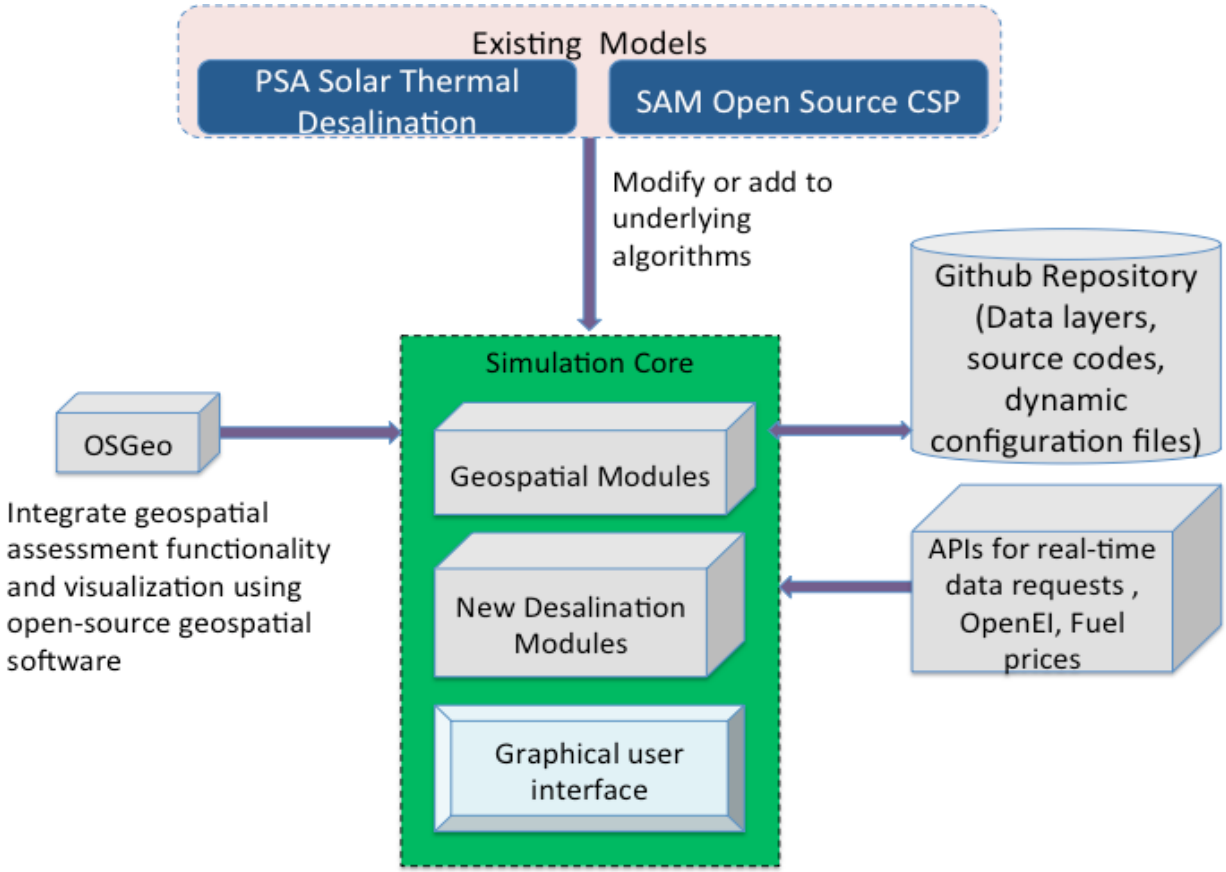
GIS-Based Graphical User Interface Tools for Analyzing Solar Thermal Desalination Systems & High-Potential Implementation Regions

Principal Investigator: Vasilis Fthenakis, Columbia University
Team Members:
Greg Yetman, co-PI, Adam Atia, Zhuoran Zhang, Vikas Vicraman, John Squires, **Columbia University**
Diego-César Alarcón-Padilla, Patricia Palenzuela, Guillermo Zaragoza, **Plataforma Solar de Almeria**
Yuri Gorokhovich, Lehman College, **City University of New York**

Advisory Board:
Hassan Arafat, **Masdar Institute;** Leon Awerbuch, **International Desalination Association;** Raed Bkayrat, **Clean Energy Business Council**; Paul Choules, **Texas Desalination Association;** Peter MacLaggan, **Poseidon Water;** Bernie Mack, **Veolia**; Aaron Mandell, **Water FX;** Yuliana Porras-Mendoza, **Bureau of Reclamation**.

Columbia University
Award # DE-EE00008441

GIS-based graphical user interface tool for analyzing solar thermal desalination systems and high-potential implementation regions

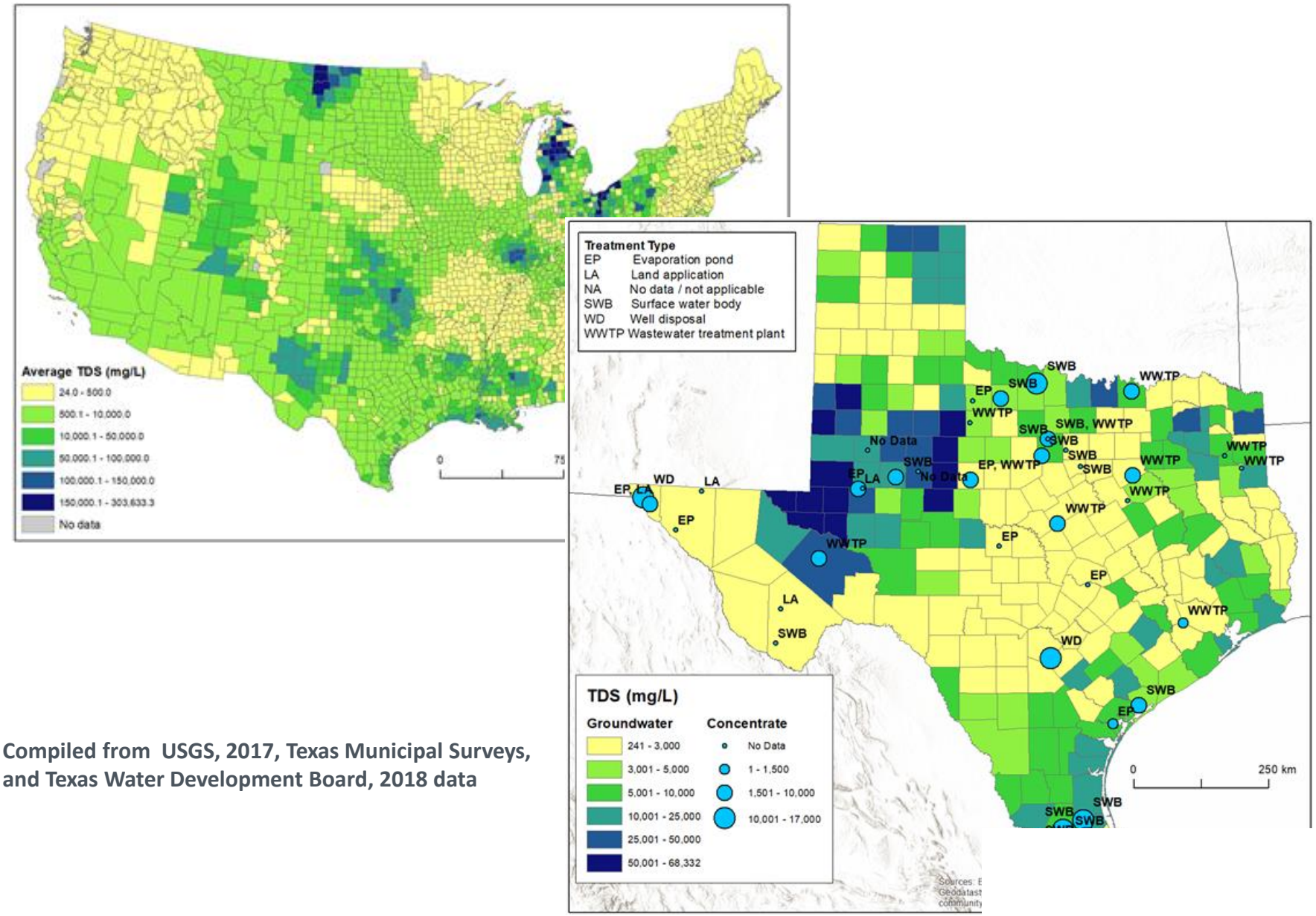


- **Developed in Python using Open Source software libraries of GIS functions**
- **It will be expandable, using a Modular Architecture**

PSA: Plataforma Solar de Almeria
SAM: NREL System Advisory Model

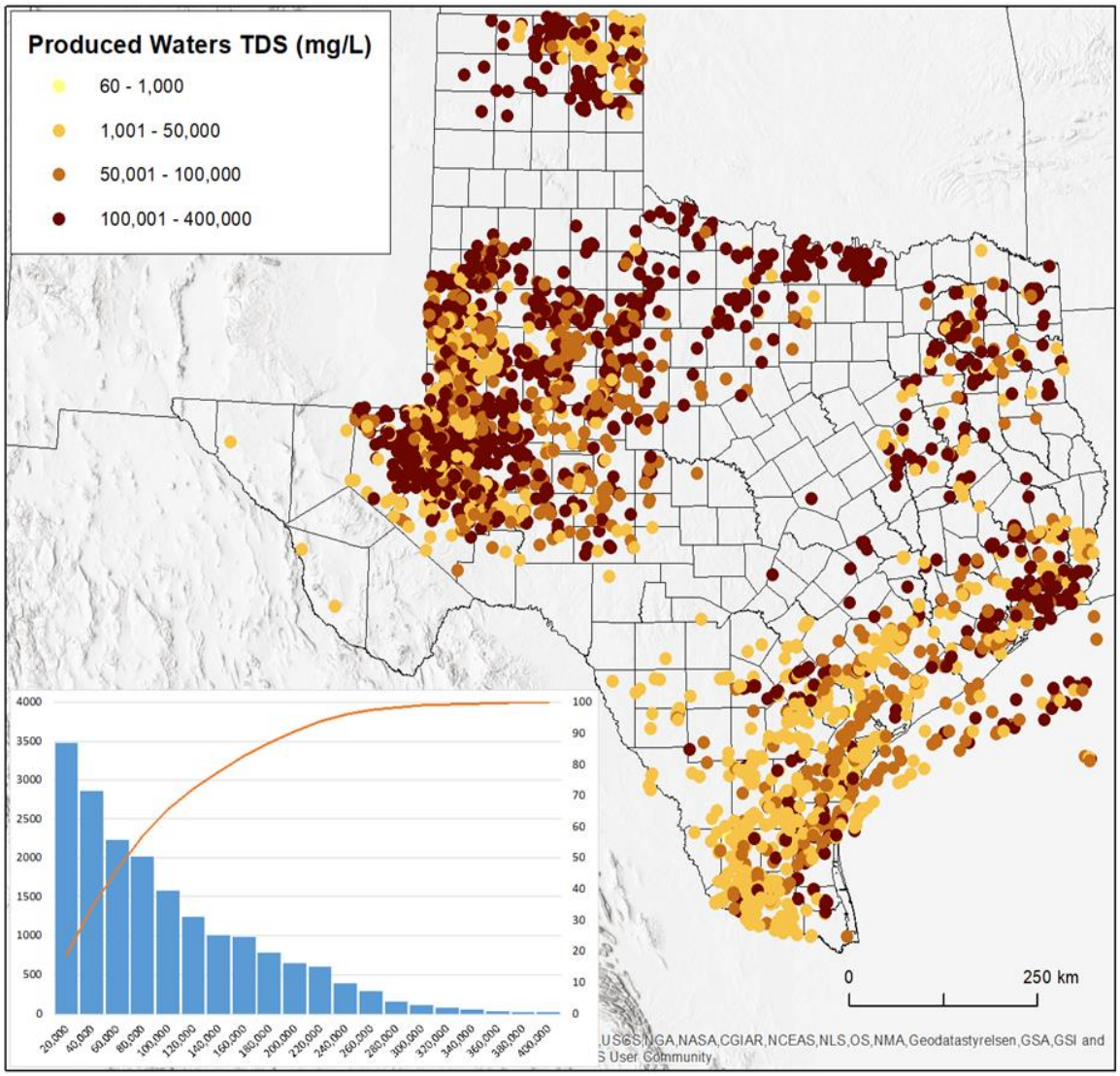
Development of Alternative Water Database
Brackish Water

Total Dissolvable Solids (TDS) Concentration (mg/L)



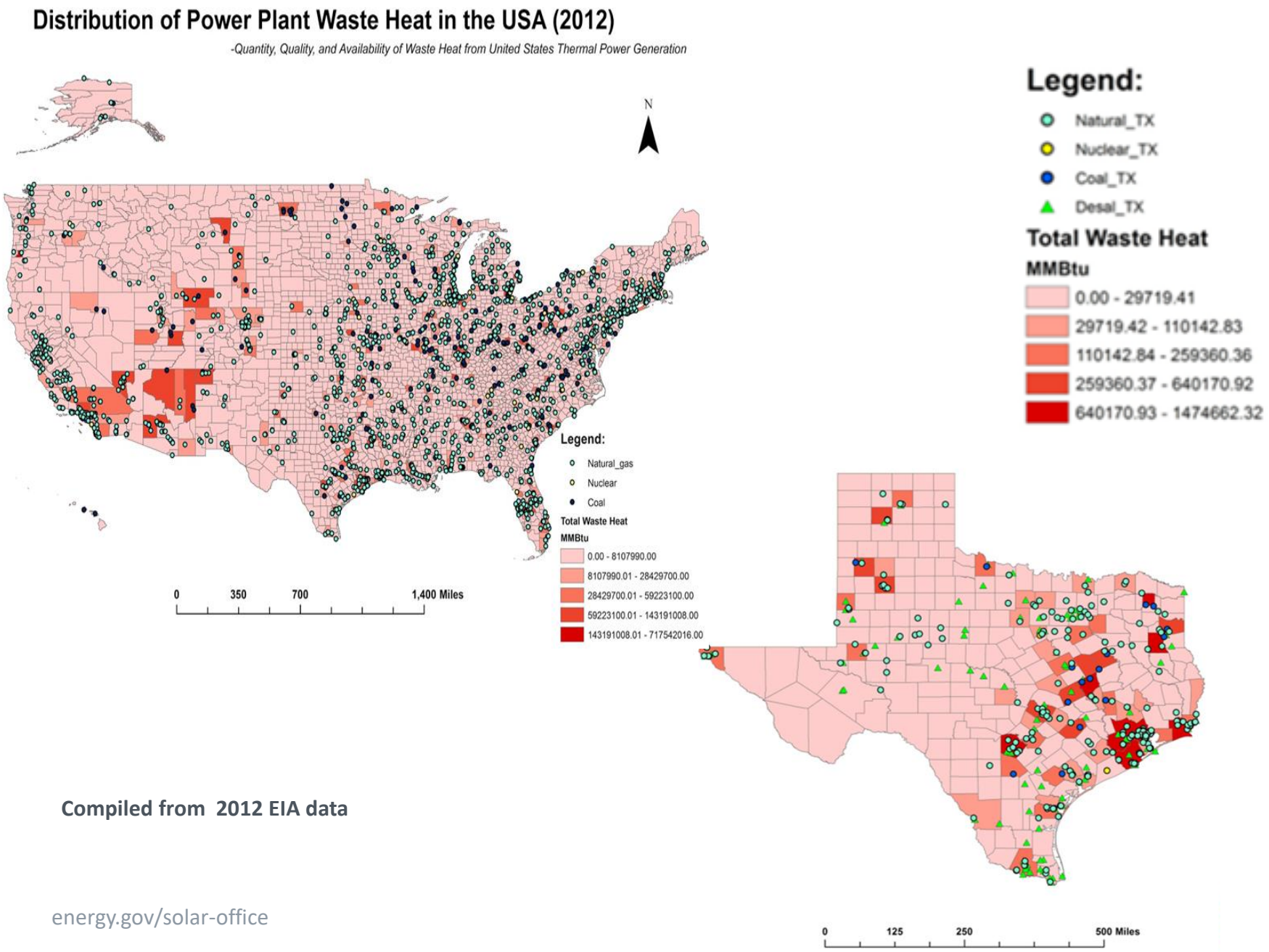
Compiled from USGS, 2017, Texas Municipal Surveys, and Texas Water Development Board, 2018 data

Development of Alternative Water Database Produced Oil &Gas Water



Compiled from USGS Produced Water data, 2018

Development of Heat Source Database
Power Plant Waste Heat

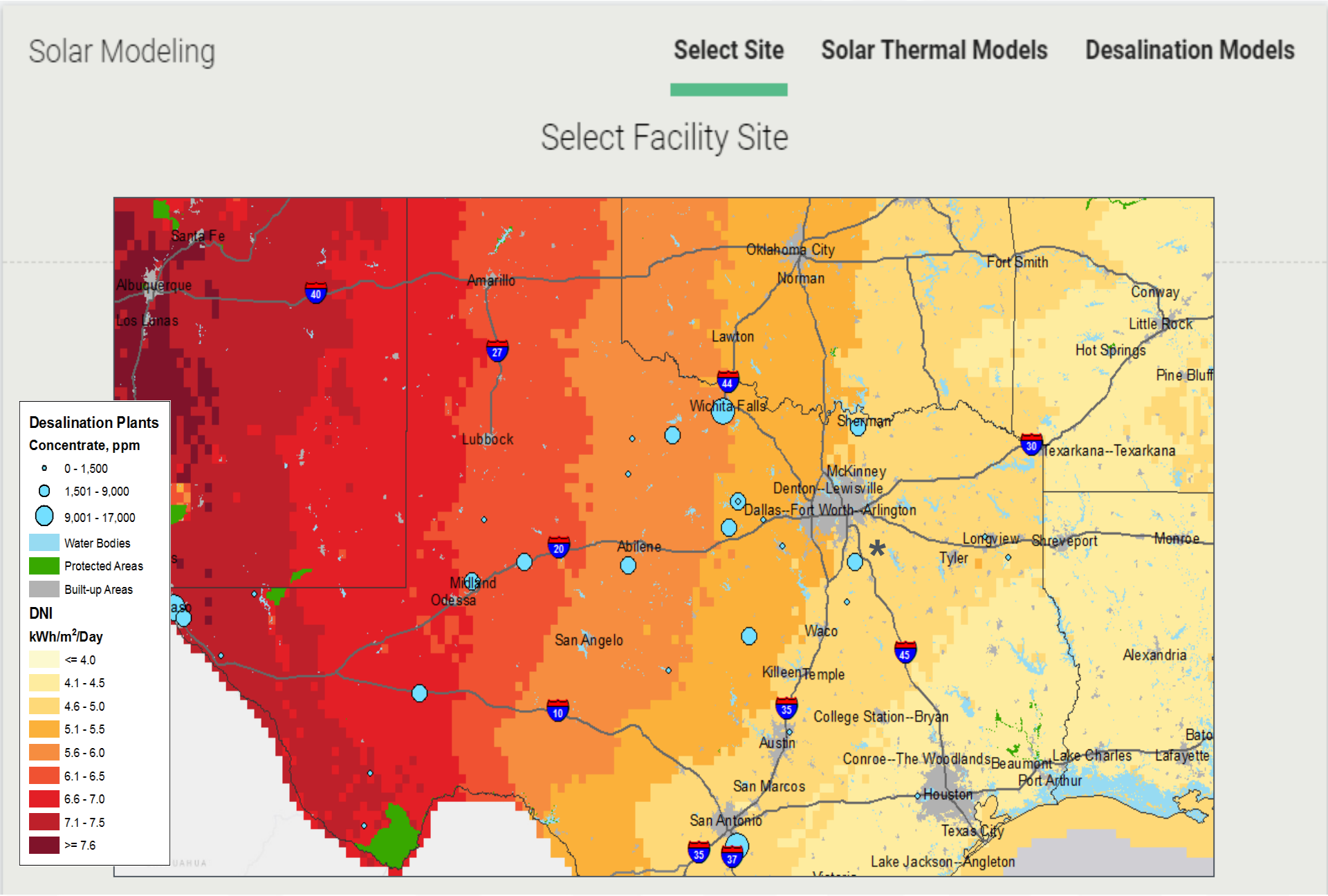


Compiled from 2012 EIA data

Software Operation Modes

- **Quick Analysis:** Preliminary identification of high desalination potential regions, based on seasonal averages of solar and water resources. Input desalination techno-economic parameters and display regions according to LCOW. Web Interface.
- **Location Driven:** Select location or region within a map. Data will be drawn from databases into solar thermal and desalination models. Output will display LCOE, LCOH, GOR, Water Production, Brine Concentration & Management Options, LCOW.
- **Design Driven**: Detailed modeling of desalination systems and hybrids. Comparisons based on NPV, LCOE, LCOH, GOR, LCOW.

Location Driven Analysis: GIS Database Application mock-up



GIS Database Application mock-up

Closest waste heat source

Plant	Ennis Power Company LLC	
Type	Natural Gas	
Net generation	-	
Exhaust residual heat	123,378,242	Mj
Condenser residual heat	4,758,993,221	Mj
Total residual heat	4,882,371,464	Mj
Distance	25	km

Closest brackish water source

Well	NURE-OR13418	
Total Dissolved Solids	2,215	ppm
Depth	121	feet
Production	-	
Distance	22	km

Closest desalination plant

Owner	City of Bardwell	
Plant year	1980	
Water source	groundwater	
Pretreatment	cartridge filter	
Posttreatment	blending; disinfection	
Use	drinking water	
Distance	30	km

Regulatory Information

State information

Federal information

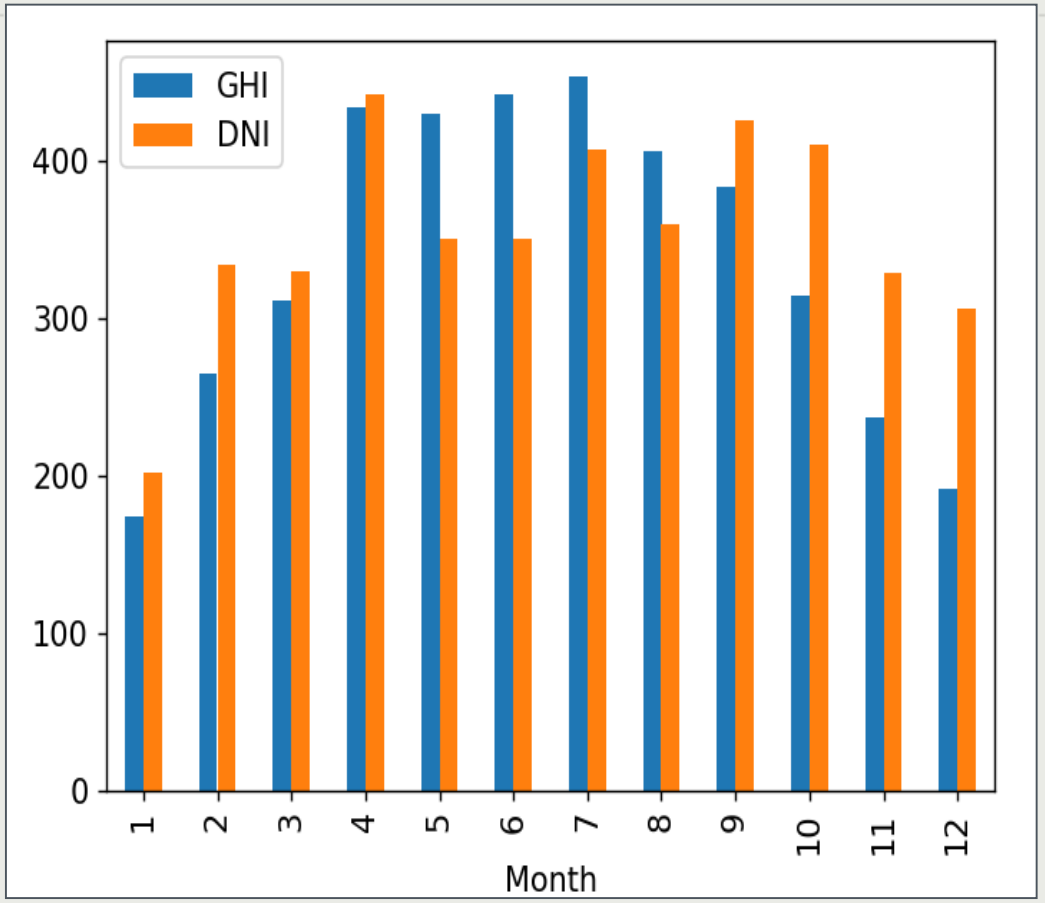
Sensitive areas

Protected area	None within 100km

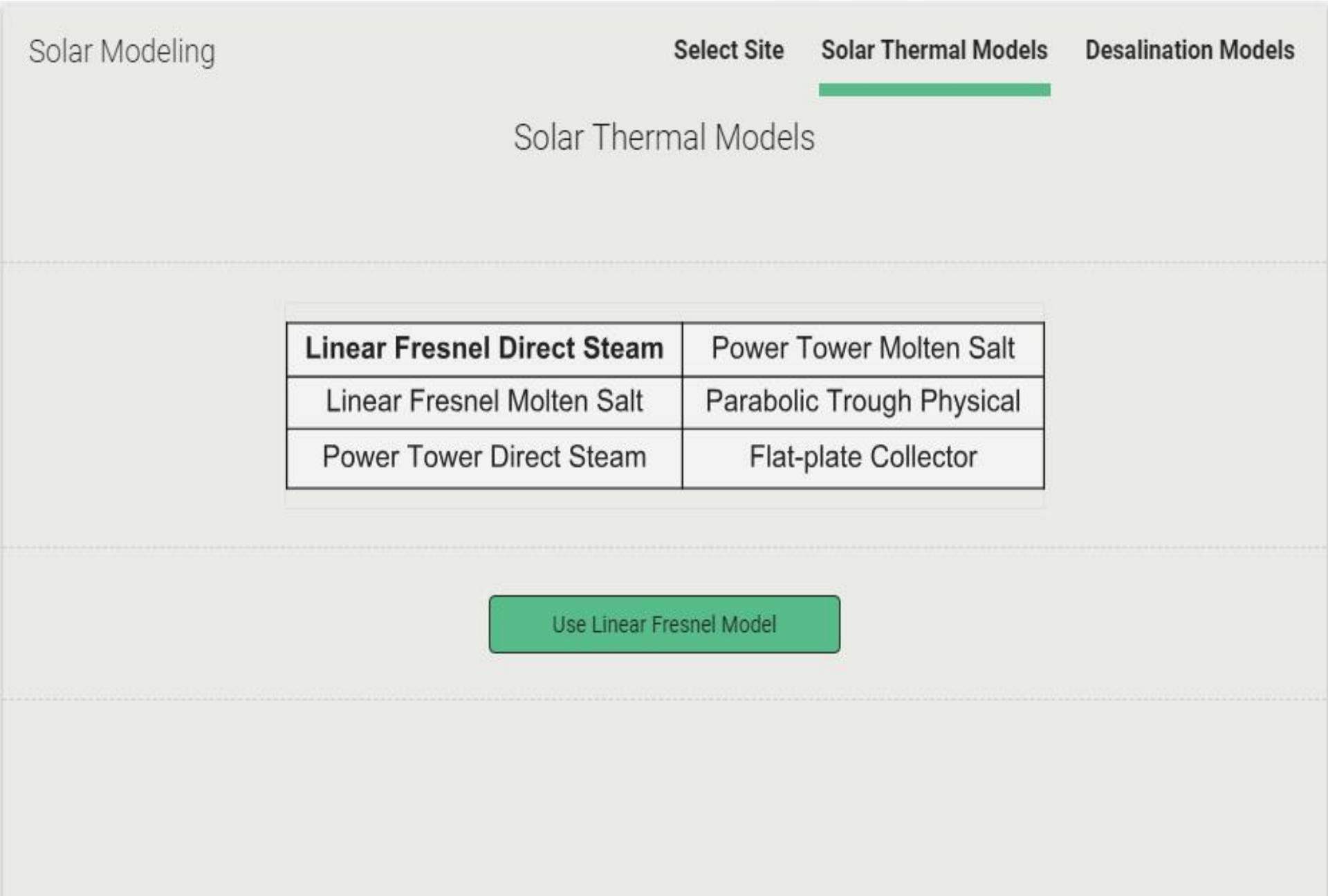
Select Site | Solar Thermal Models | Desalination Models

Select Facility Site

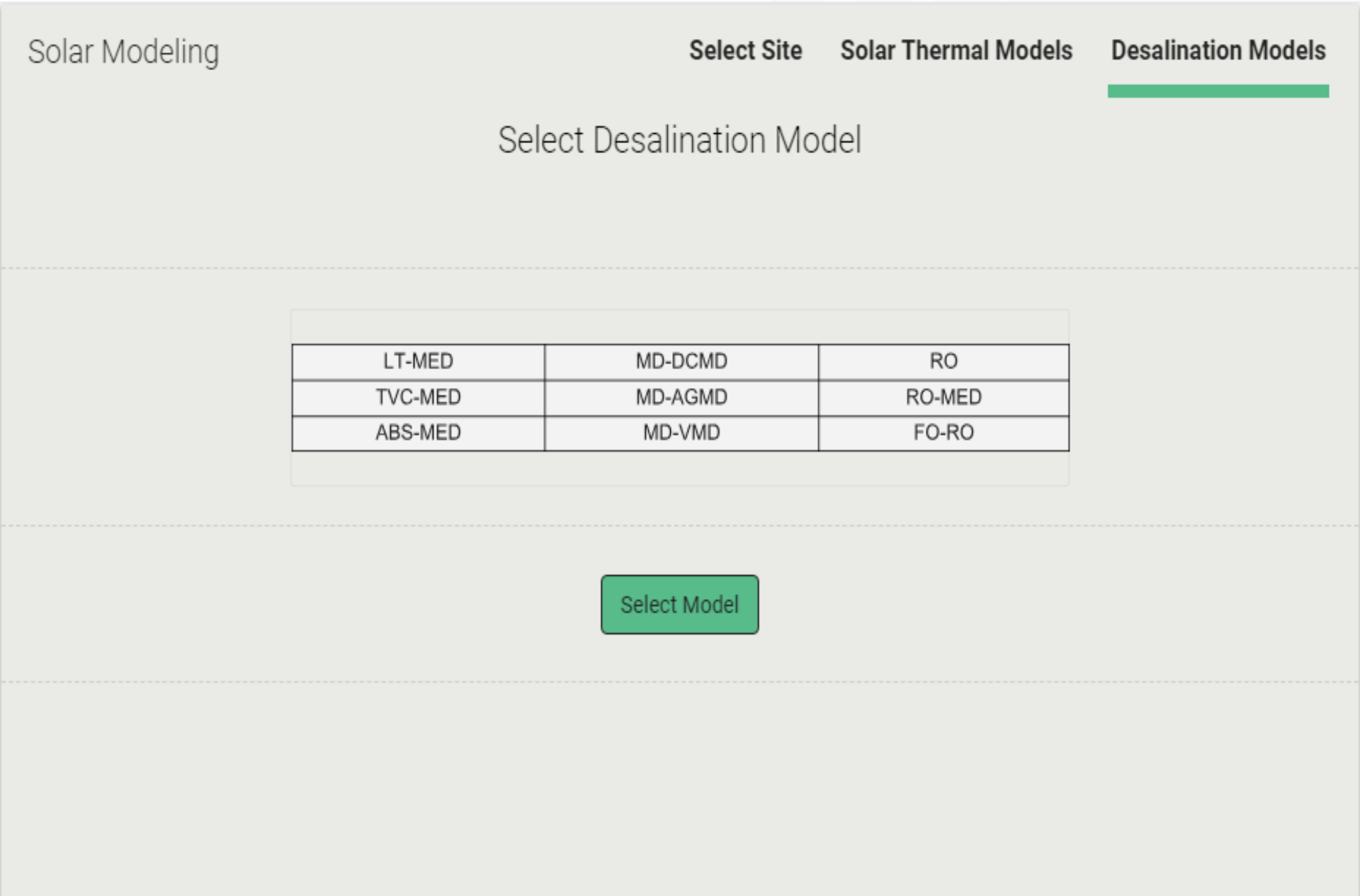
Site Details



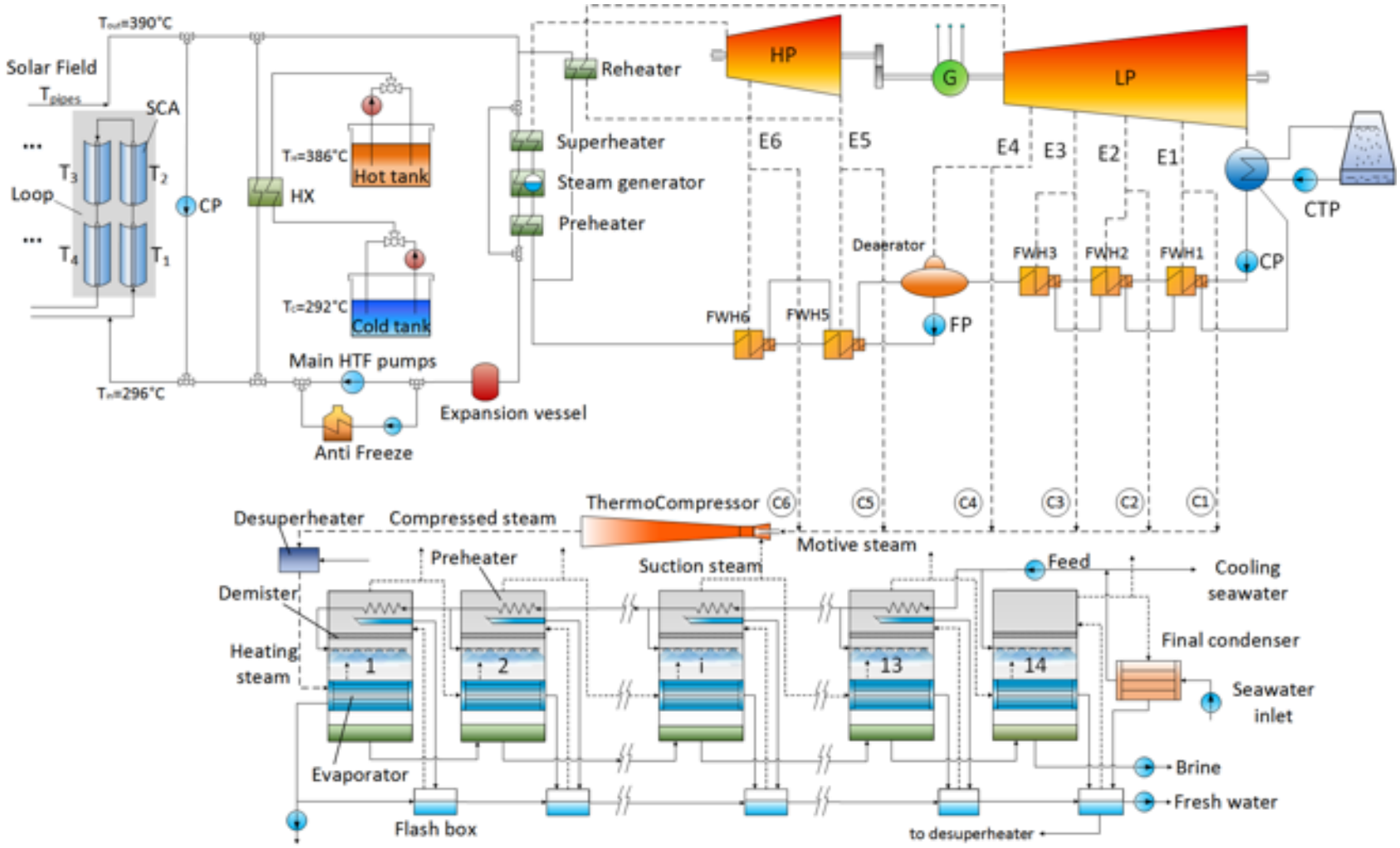
GIS Database Application mock-up



GIS Database Application mock-up

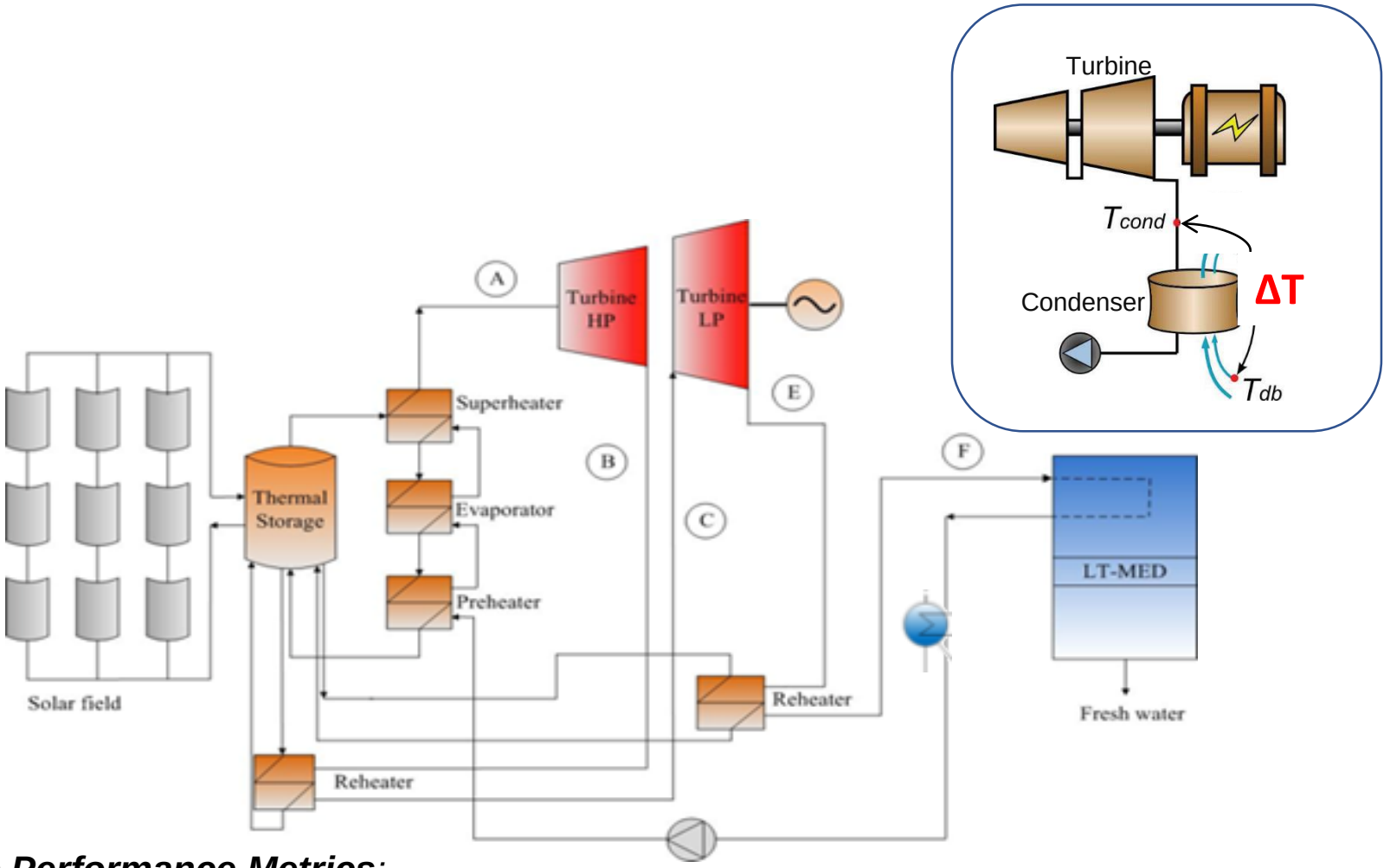


Coupling CSP and Solar Thermal Desalination: TVC-MED integrated with CSP



Ortega-Delgado, Palenzuela, Alarcon-Padilla, *Desalination* 394, 2016

Coupling CSP and Solar Thermal Desalination: LT-MED using CSP waste heat



Basic Performance Metrics:

- *Gain Output Ratio(GOR)*
- *Recovery Ratio*
- *Specific Energy Consumption*
- *LCOW*

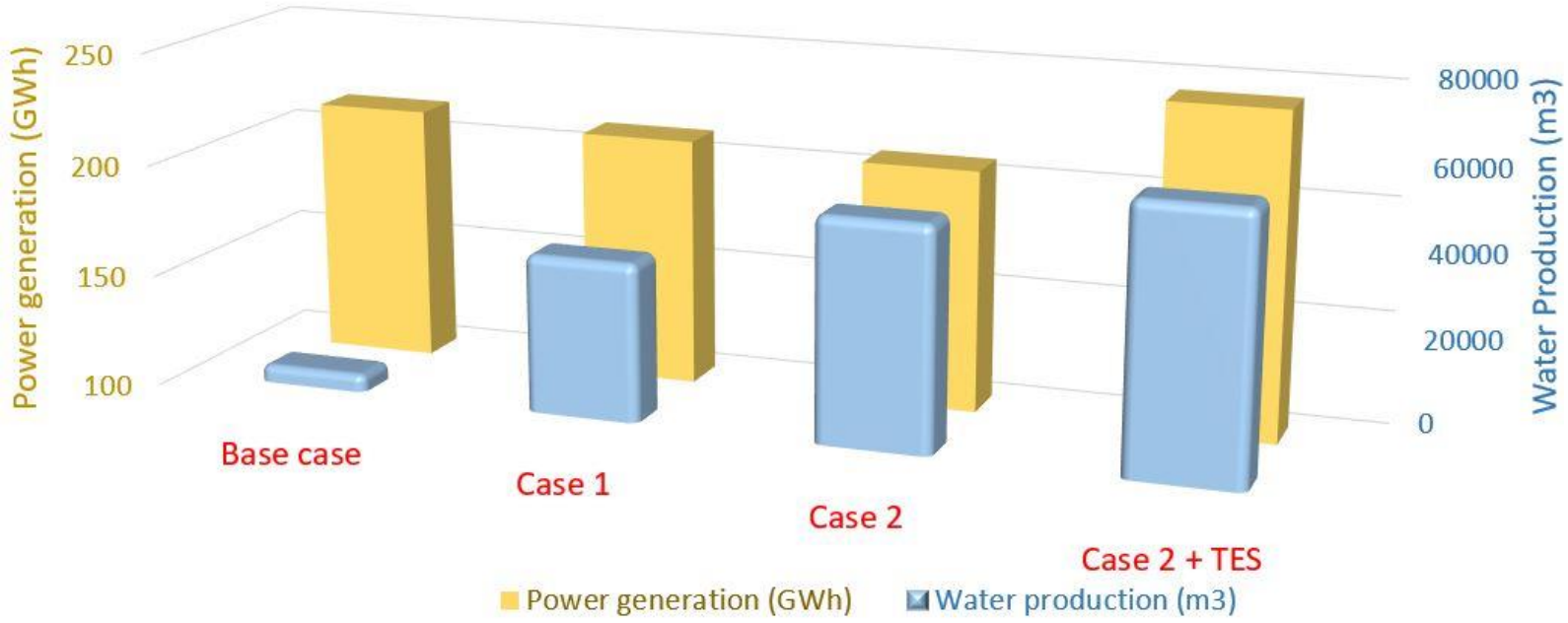
Palenzuela, Alarcon-Padilla, Zaragoza, *Desalination* 366, 2015

Integration of NREL-SAM Parabolic Trough CSP and PSA LT-MED desalination models

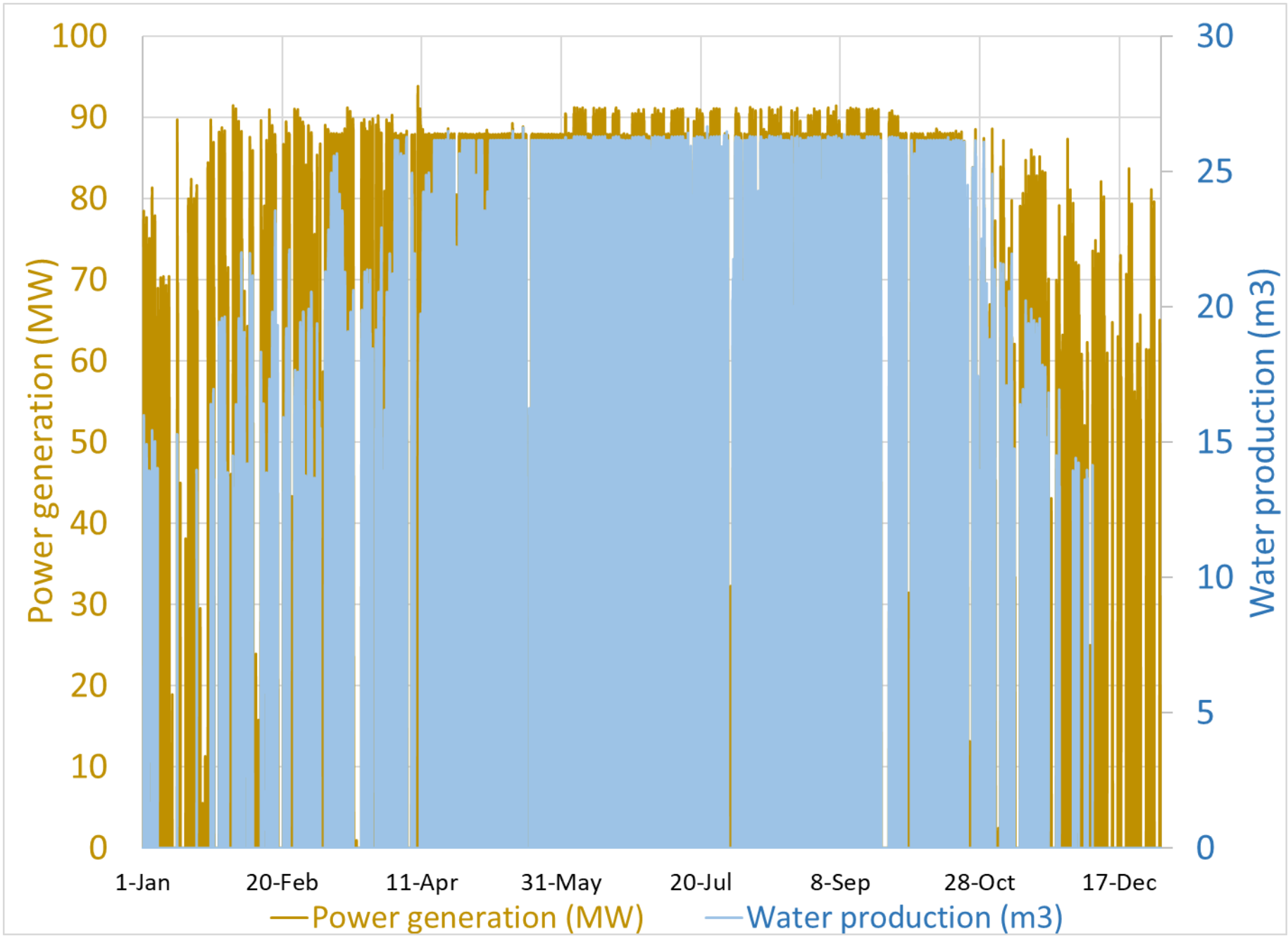
	Base case	Case 1	Case 2	Case 2 +6hr-TES
ΔT (°C) Turbine exhaust to ambient	16	30	40	40
Annual Power Generation (GWh)	214	210	207	243
Annual Water production (m^3)	4205	37614	52860	62304

CSP Design Power Capacity: 88 MW

Location: Phoenix, AZ Annual GHI: 2,110 kWh/m2 Annual DHI: 2,520 kWh/m2



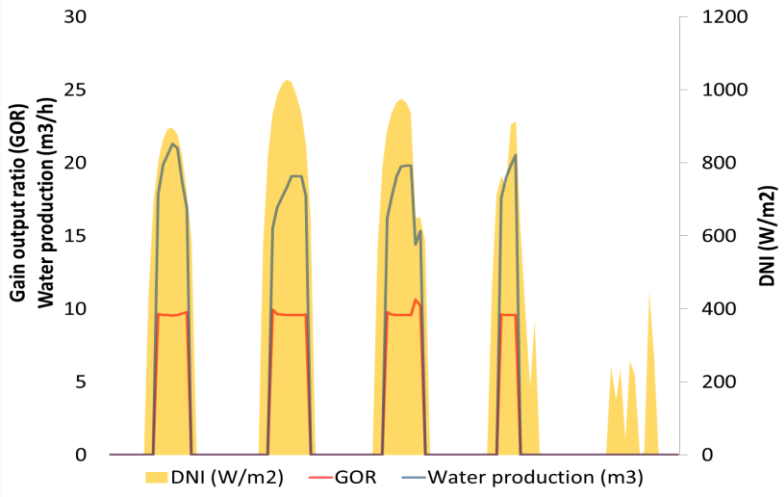
Energy and water production
Parabolic Trough-MED model (Phoenix, AZ)



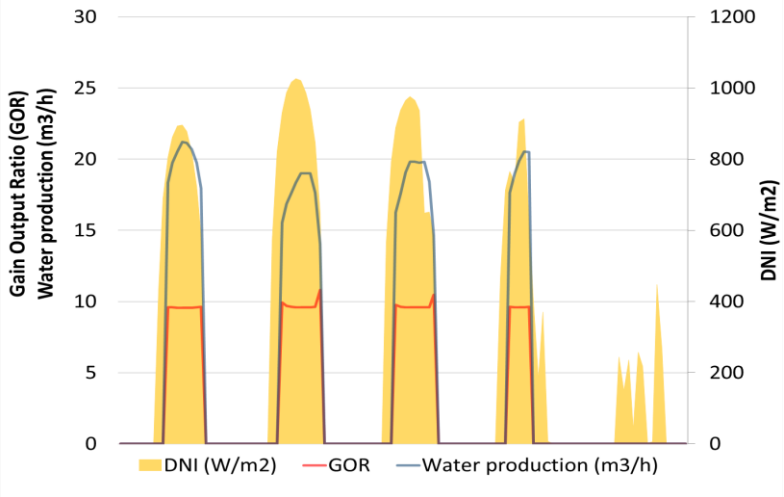
Energy and water production

Parabolic Trough - LT-MED model (Phoenix, AZ)

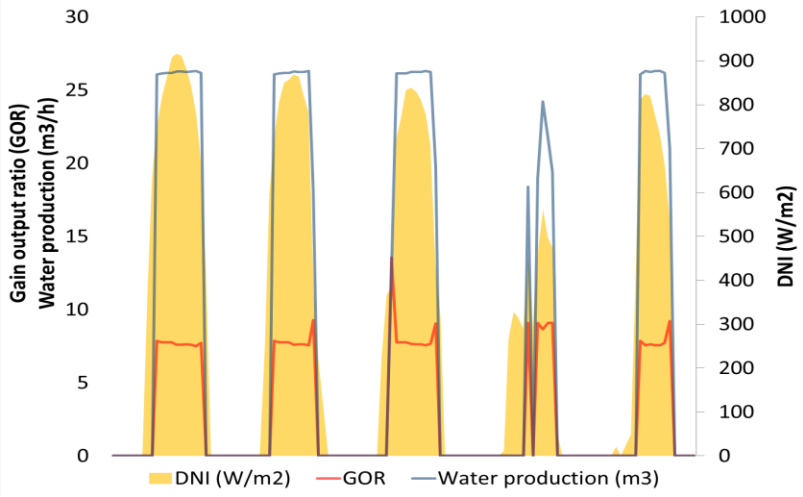
March 14th -18th



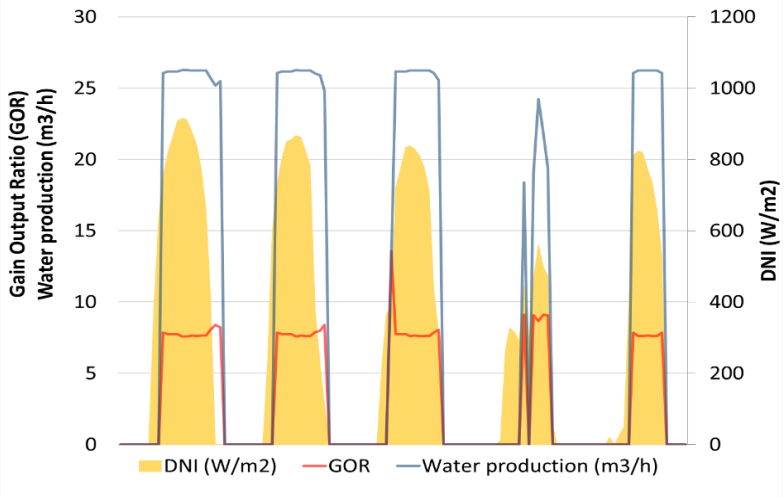
March 14th – 18th With TES



August 6th to 10th



August 6th -10th With TES



Questions & Answers

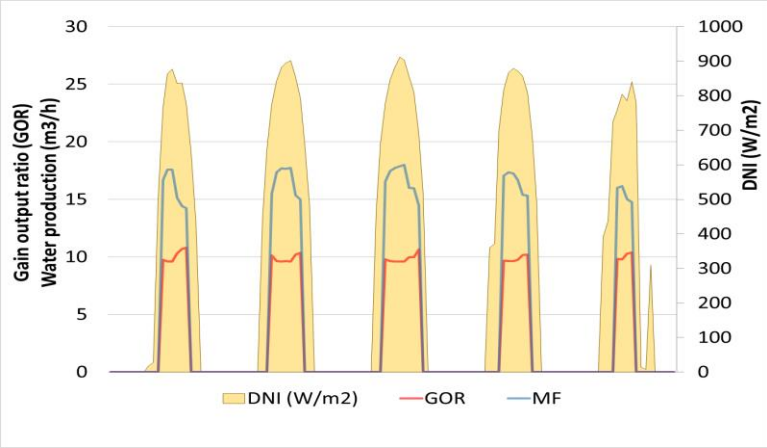
Suggestions?

Email: VMF5@COLUMBIA.EDU

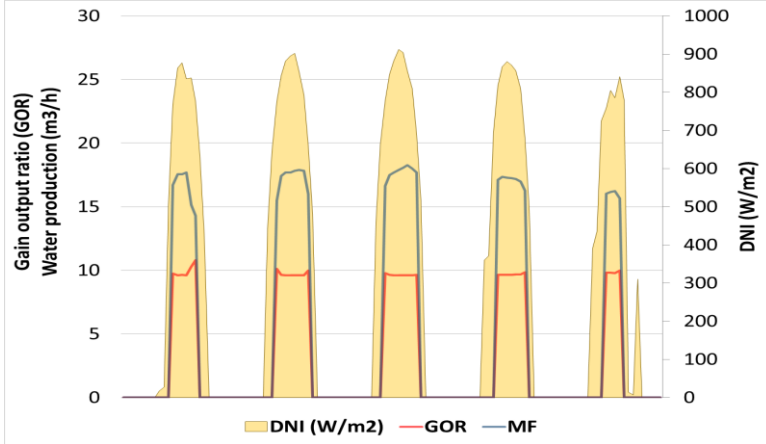
Auxiliary Slides

Energy and water production
Parabolic Trough-MED model (Almeria, Spain)

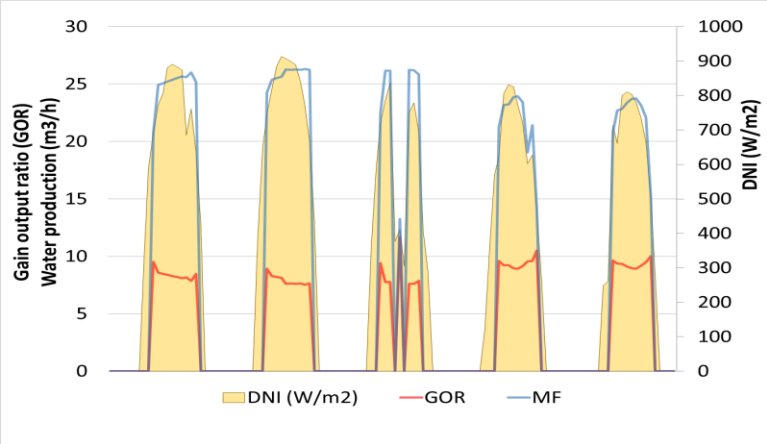
March 16th -20th



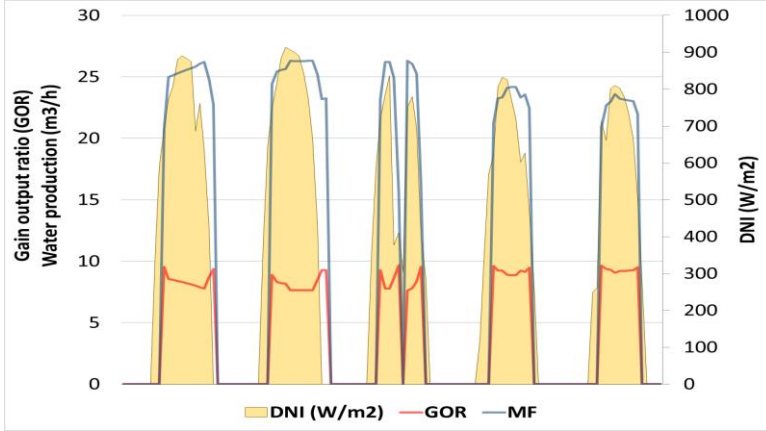
March 16th -20th With TES



August 5th -9th



August 5th -9th With TES



Integration of NREL-SAM CSP and PSA LT-MED desalination models

Parabolic Trough – LT-MED Model

	Base case	Modified case	Modified case + 6hr-TES
Solar field area (km^2)	0.56		
Initial temperature difference (°C)	16	40	40
Average steam T in winter (°C)	34.0	36.8	37.3
Average steam T in Spring/Fall (°C)	38.2	59.3	60.9
Average steam T in Summer (°C)	51.0	69.9	70.8
Annual Power Generation (GWh)	214	207	243
Power generation difference	-	-3.3%	+13.5%
Annual Water production (m^3)	4205	52860	62304

Linear Fresnel Direct Steam– LT-MED Model

Base case	Modified case
0.61	
16	40
31.4	40.5
32.1	59.7
42.7	71.7
194	188
-	-3.1%
5449	43209

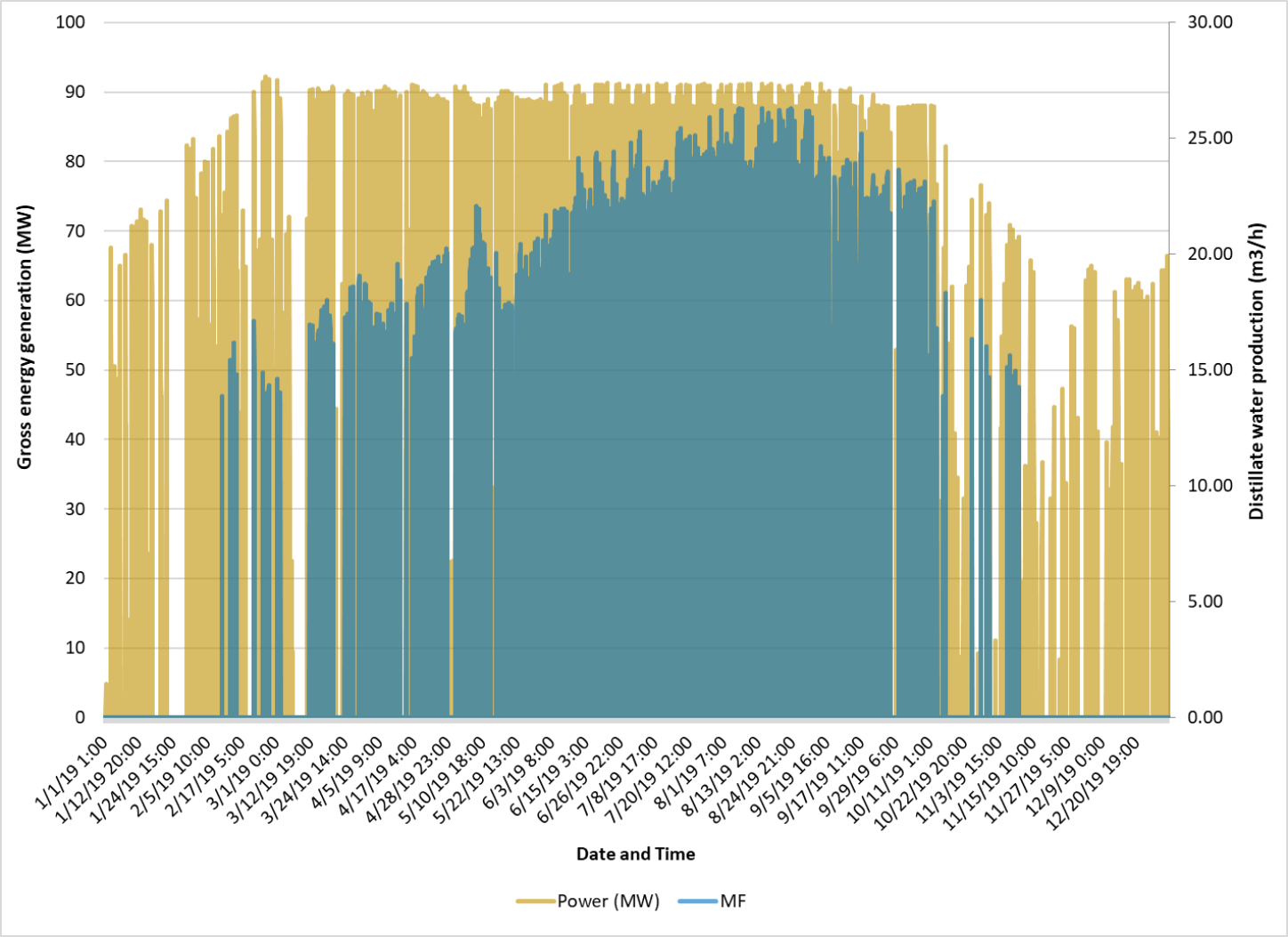
CSP Design Power Capacity: 88 MW
Location: Phoenix, AZ
Annual GHI: 2,110 kWh/m2
Annual DHI: 2,520 kWh/m2

Integration of NREL-SAM CSP and PSA LT-MED desalination models

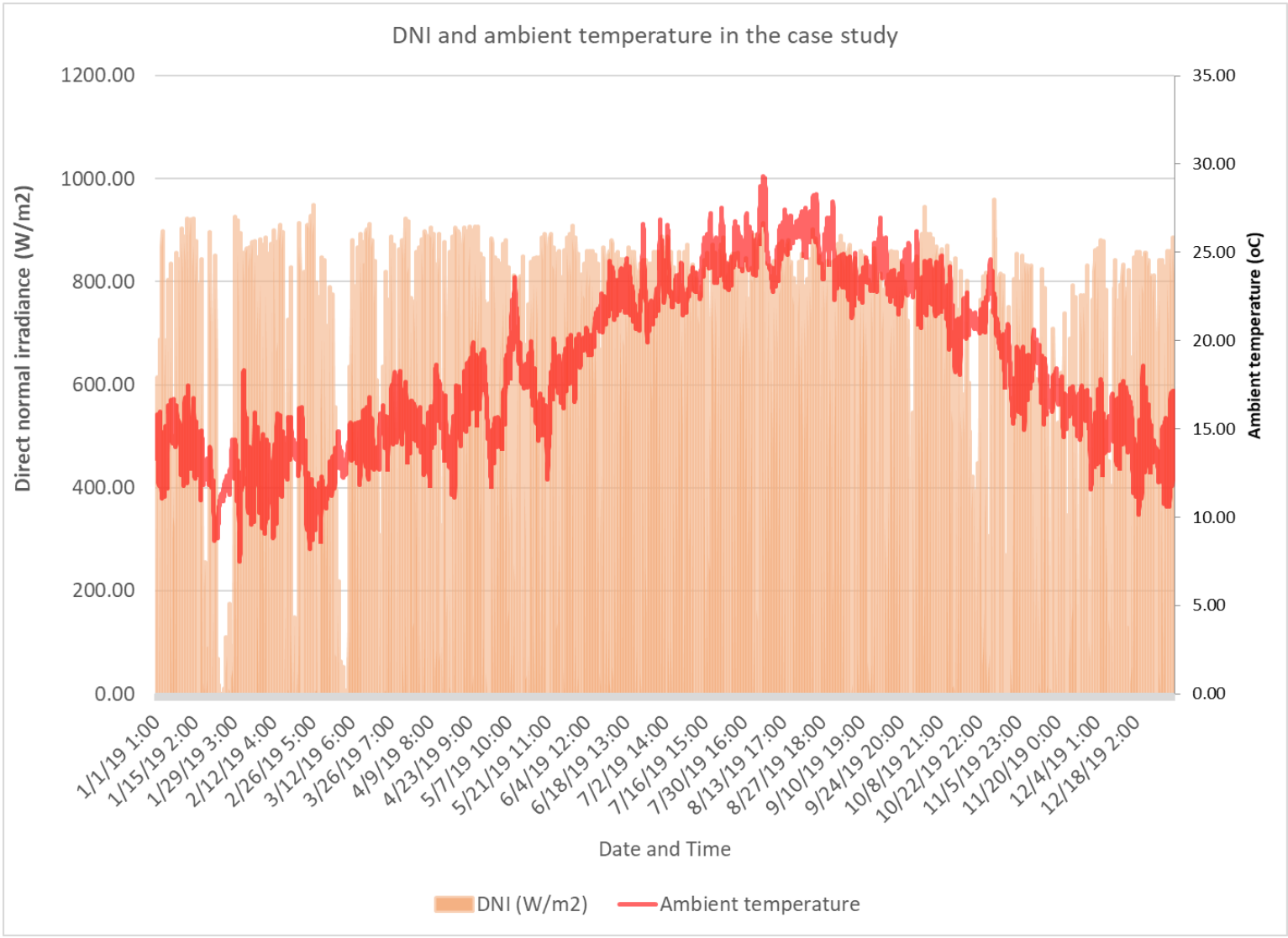
	Parabolic Trough – LT-MED Model			Linear Fresnel Direct Steam– LT-MED Model	
	Base case	Modified case	Modified case + 6hr-TES	Base case	Modified case
Solar field area (km^2)	0.56			0.61	
Initial temperature difference (^oC)	16	40	40	16	40
Average steam T in winter (^oC)	31.9	36.8	37.3	31.4	40.5
Average steam T in Spring/Fall (^oC)	32.1	59.3	60.9	32.1	59.7
Average steam T in Summer (^oC)	42.3	69.9	70.8	42.7	71.7
Annual Power Generation (GWh)	177	166	185	157	148
Power generation difference	-	-6.2%	+4.5%	-	-5.7%
Annual Water production (m^3)	0	32250	37411	0	24887

CSP Design Power Capacity: 88 MW
Location: Almeria, Spain
Annual GHI: 1, 890 kWh/m2
Annual DHI: 2,160 kWh/m2

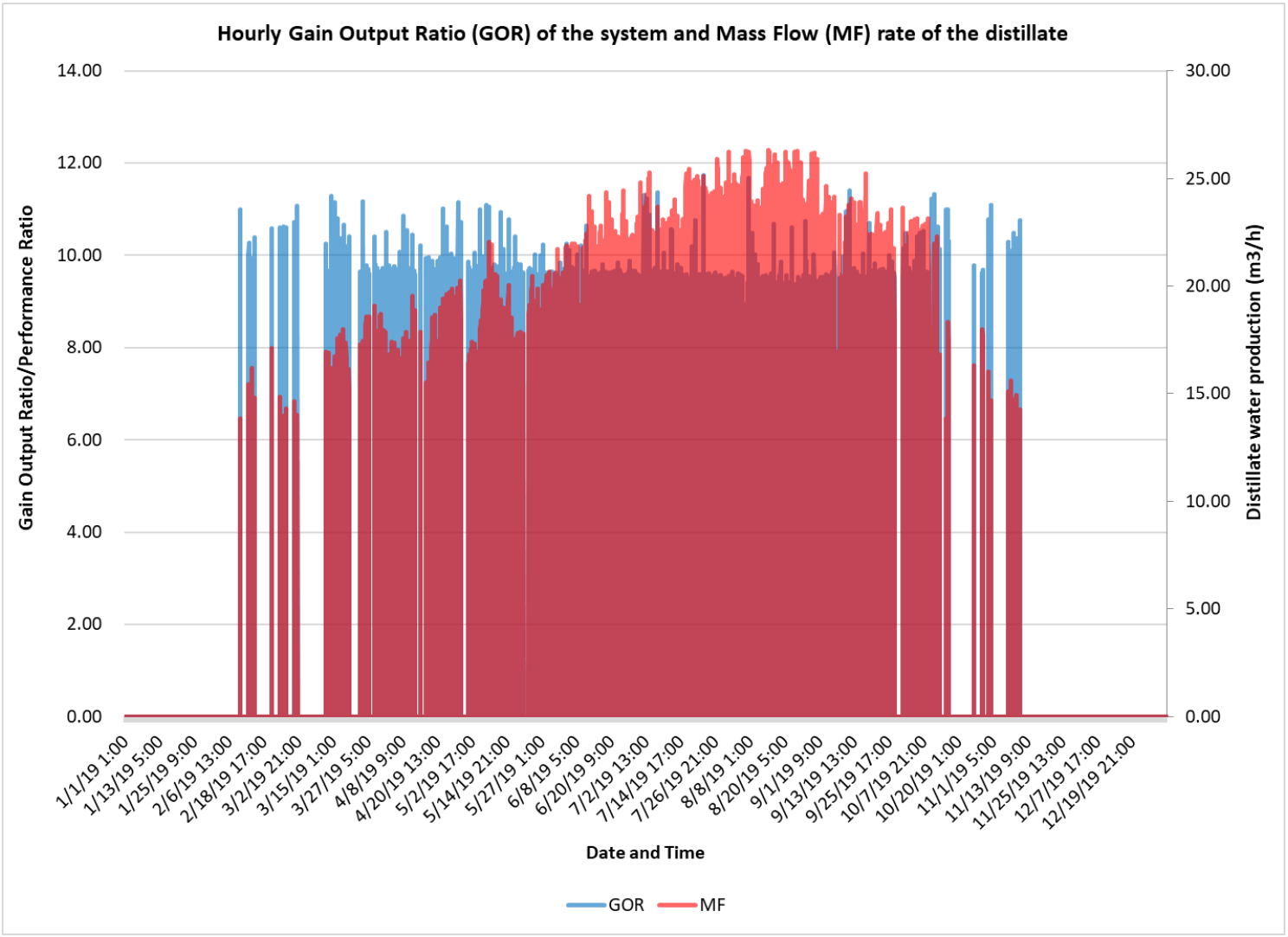
Energy and water production
Parabolic Trough-MED model (Almeria, Spain)



DNI and Ambient temperature
(Almeria, Spain)



Parabolic Trough-LT-MED model
(Almeria, Spain)



PSA Solar Desalination Research

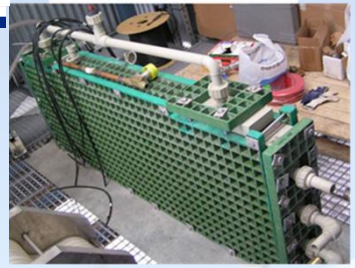
- **Large-capacity** thermal processes with special emphasis in **multi-effect distillation** (LT-MED, TVC-MED, ABS-MED)
- **Small-capacity** thermal processes with special emphasis in **membrane distillation** (MD) and **forward osmosis** (FO)
- **Co-generation** of electricity and desalinated water (CSP+D)
- **Thermal-driven separation** processes for brine concentration and industrial waste water treatment
- **Dynamic modeling, process optimization** and **advanced control strategies** in solar desalination processes.

Membrane Distillation (MD)

Aqua still

TRIMEM MEMBRANE TECHNOLOGY

Keppel Seghers



Working with all systems available in the market, Plataforma Solar de Almería (in Spain) has become a reference centre for R&D on MD technologies at pilot scale powered by solar energy

SCARAB DEVELOPMENT AB

aquaver

memsys