Microgrid Design for Rural Island in PEA Area

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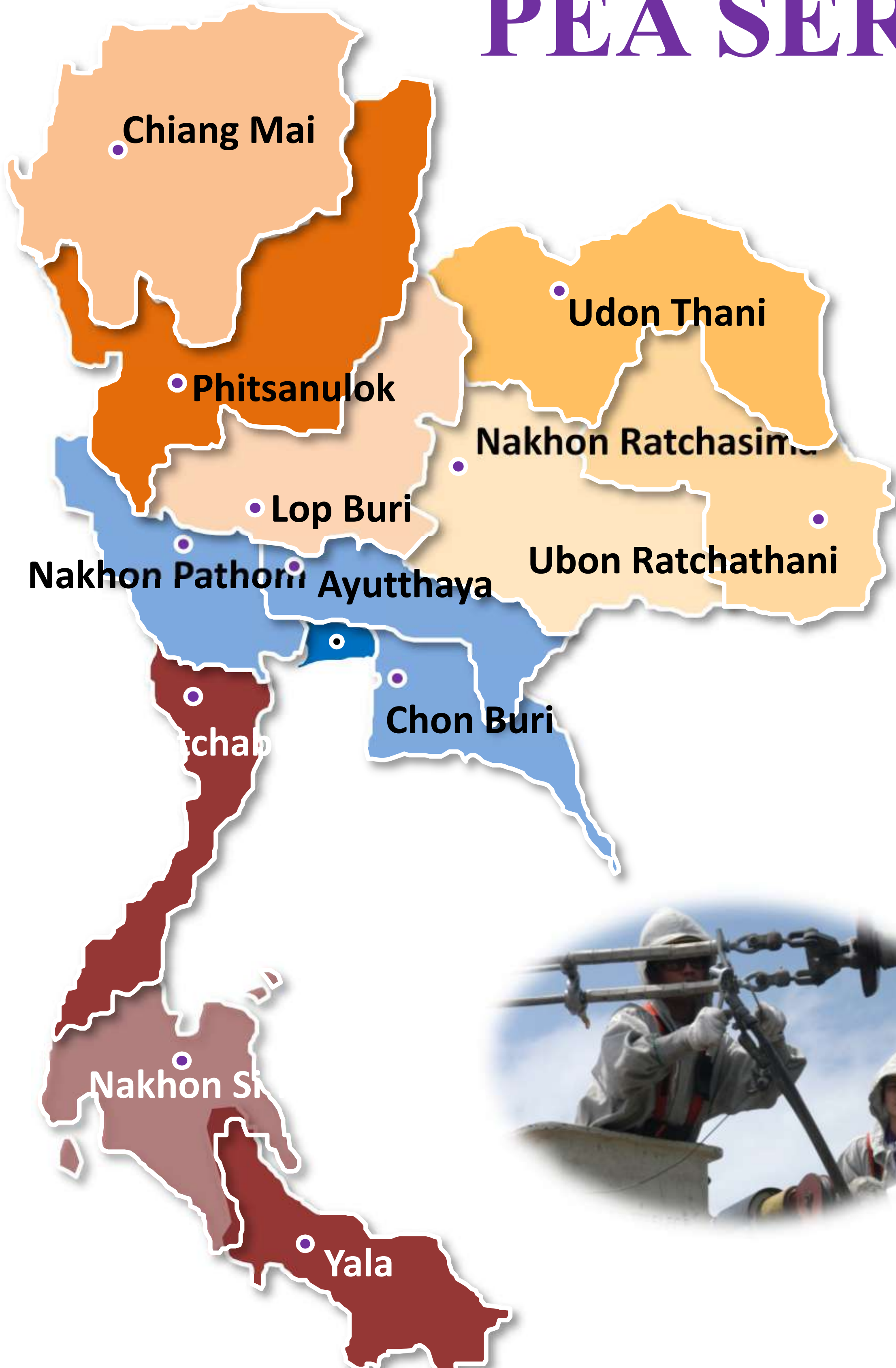
PEA SERVICE AREAS



PROVINCE : 74 Provinces

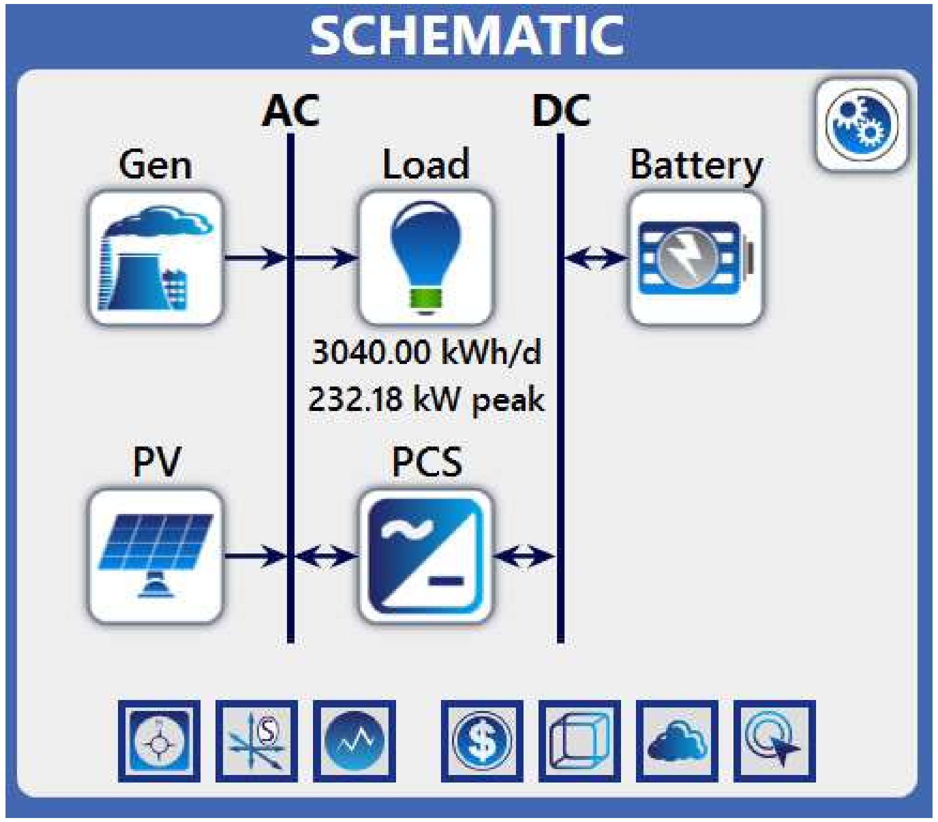
Electrified Villages : 80,062 Villages (99.99%)

Total Customers : 18.67 Million Customer

Peak Load : 20,439 MW

Topics

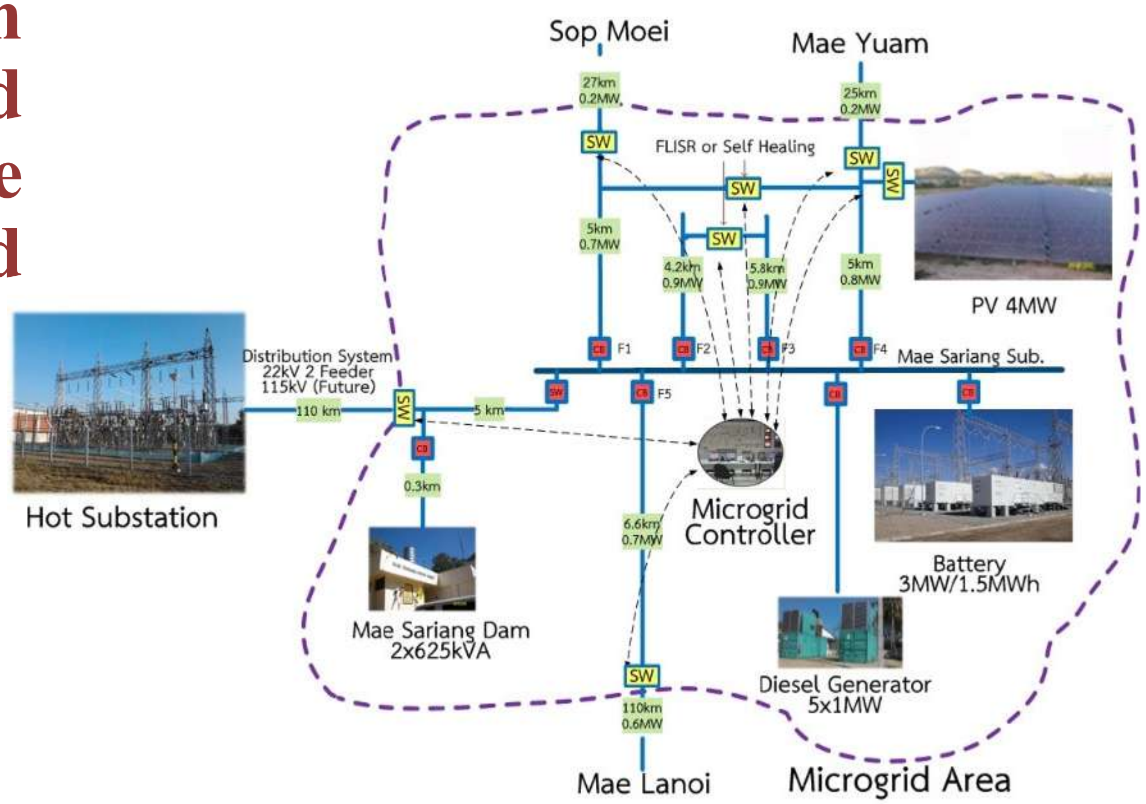
1. Introduction
2. Parameters modelling in HOMER Pro
3. Assumptions to study
4. Objective functions to study
5. Simulation results



Introduction: Microgrid definition

IEEE: a group of interconnected loads and Distributed Energy Resources (DER) with clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid. It can connect and disconnect from the grid to enable operation in both grid-connected or island modes.

IEC: a group of interconnected loads and distributed energy resources with defined electrical boundaries that acts as a single controllable entity and is able to operate in both grid-connected and island mode.



Introduction: Why Microgrid?

- PEA target for electrification is 100% of villages and households.
- Currently 99.99% of villages, 99.72% of households.
- Rural islands, PEA supply electricity by using diesel generators.
- Cost of diesel generators is more than 3 times.
- Unelectrified islands, PEA plan to use solar PV + diesel generators and/or submarine cable.
- The microgrid design will supply the load in the island by using solar PV as the main generation source together with a Battery Energy Storage System (BESS) to collect the surplus power form the PV and supply power to the load during hours of no sunshine.

Introduction: Main component: BESS

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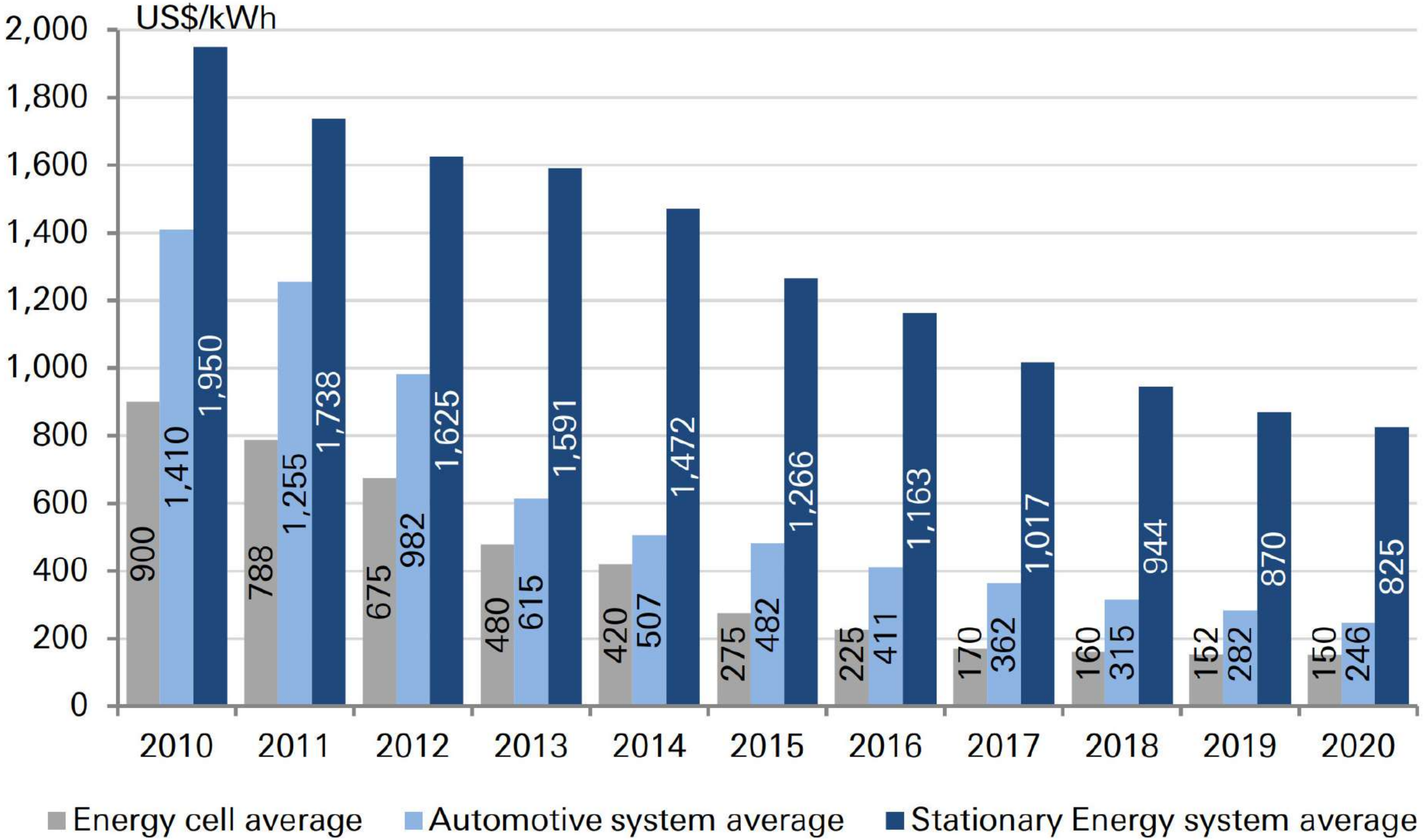


Battery Classification

Sodium Battery (Hot)

High Energy Type

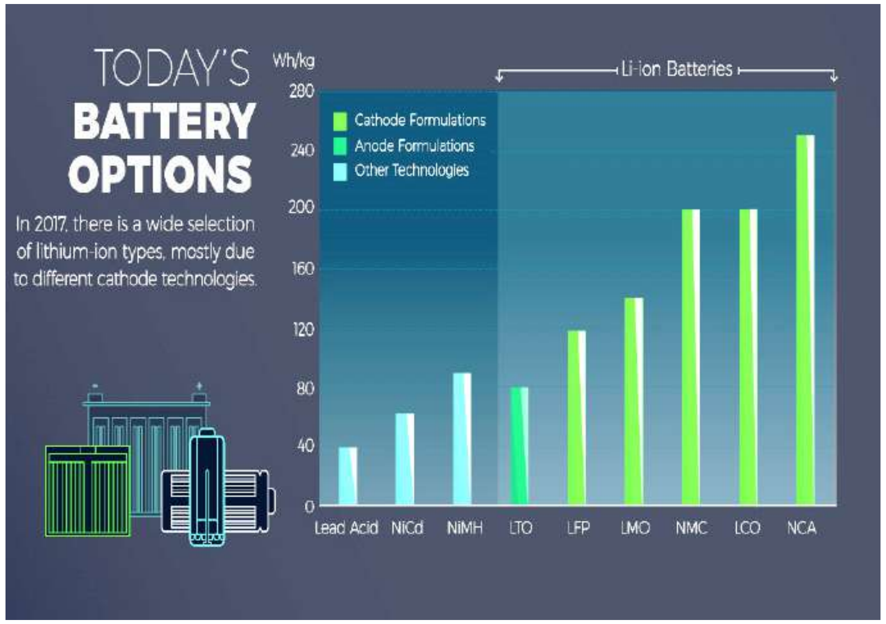
- Sodium Sulfur Battery (NaS)
- Sodium Nickel Chloride (NaNiCl)

	Cycle (Life-time)	Efficiency (AC-AC)
Na Battery	√√	√√
Lithium Battery	√√ (√)	√√√
Flow Battery	√√√√	√

Lithium Battery

High Power Type and also High Energy

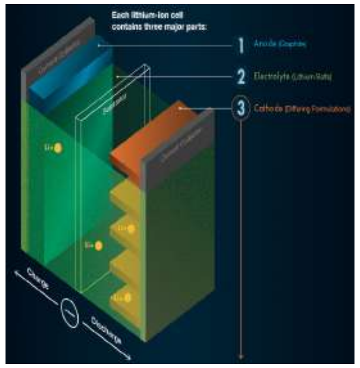
- Nickel Manganese Cobalt (NMC), LiFePO4 (LFP), Li-Ion Nanophosphate, Lithium Titanium Oxide



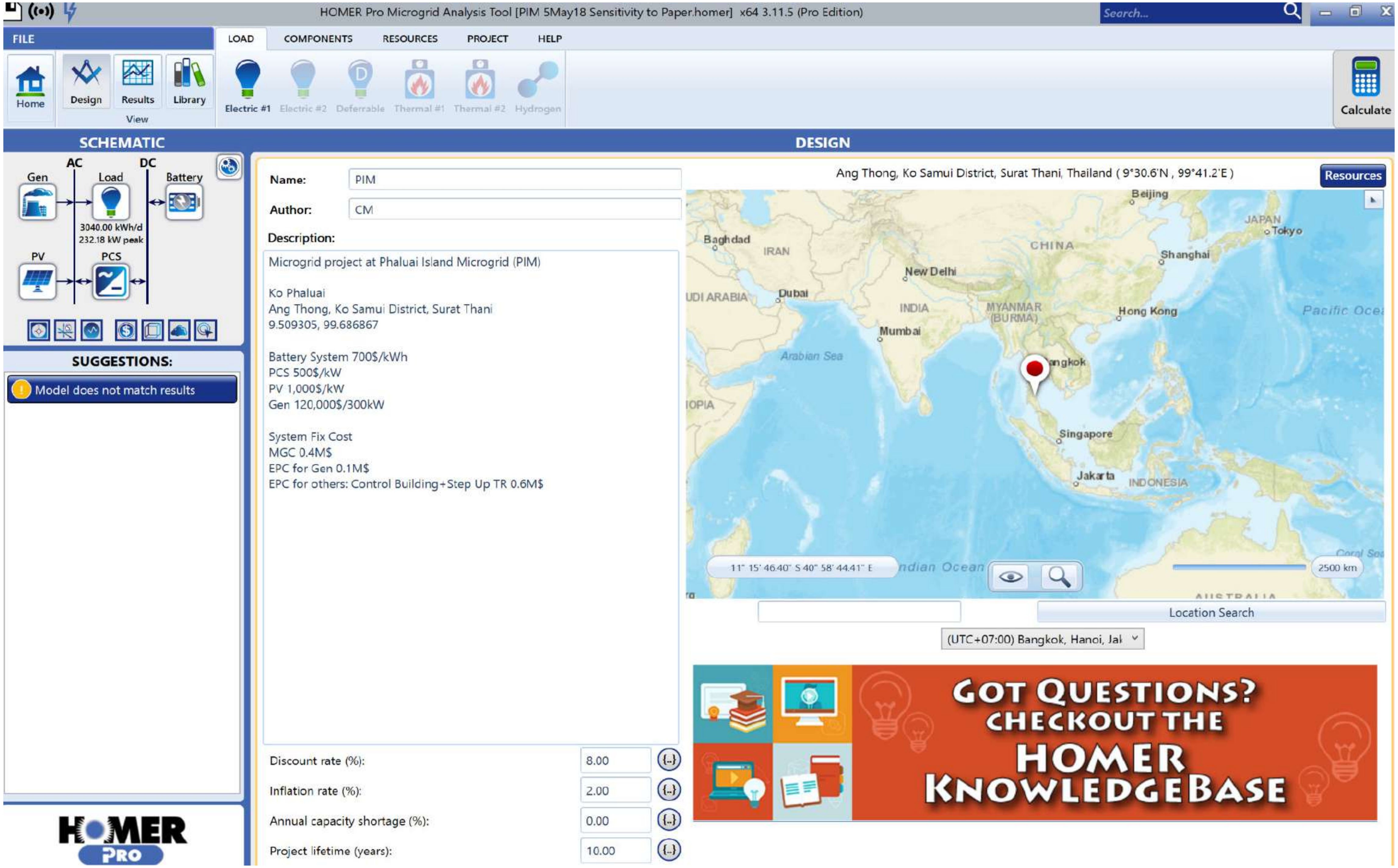
Flow Battery

High Power Type or High Energy

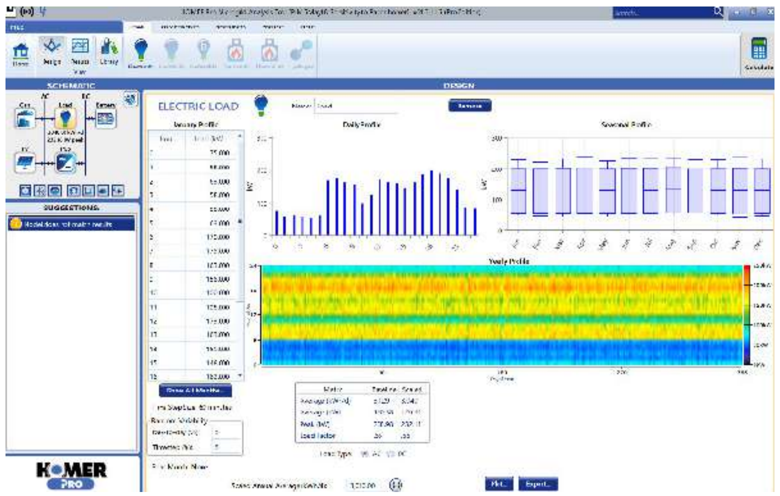
- Vanadium Redox Battery (VRB)
- Zinc-Bromine Battery (ZnBr)



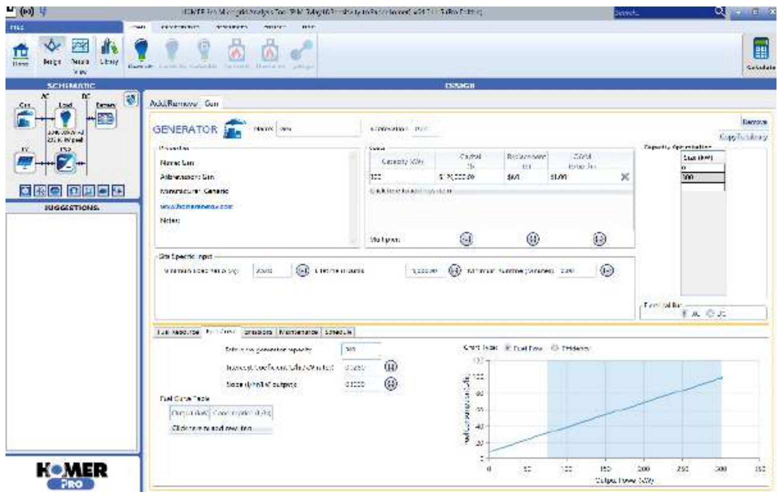
Introduction: Study case area



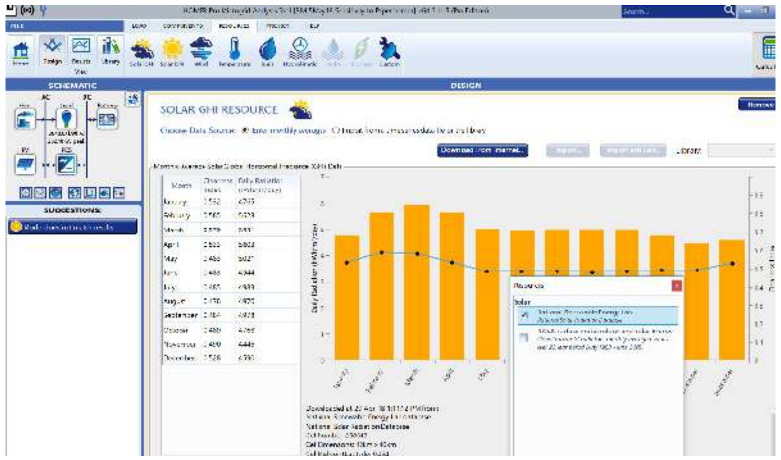
Parameters modelling in HOMER Pro



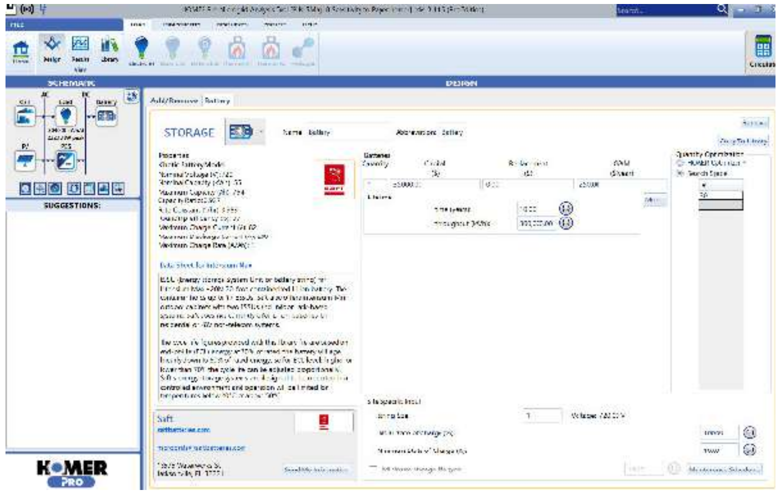
Daily load modelling



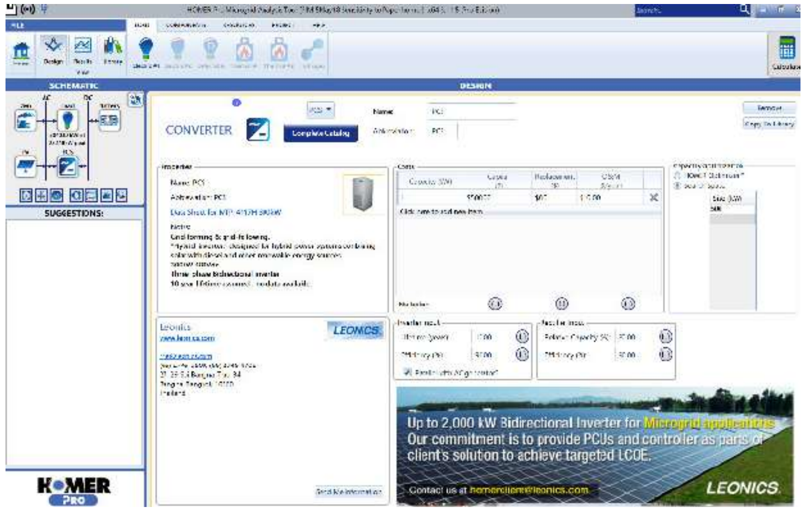
Generator modelling



PV modelling



Battery modelling



PCS modelling

ASSUMPTIONS TO STUDY

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- BESS operated at 5–95% SOC
- Project lifetime is 10 years
- BESS 5,500 cycles: 1.5 cycles/day
- System fix capital cost
  - microgrid controller $400,000
  - EPC for generator $100,000
  - EPC for others $600,000
  - The warranty 10 years, so the O&M cost defined at low cost
- BESS price at 2018 is 944 $/kWh
- BESS 1,200 $/kWh (escalation)
- Approximately shared to
  - battery system 700 $/kWh
  - PCS 500 $/kW

Detail	Assumption	Objective function
Discount rate (%)	8.0	
Inflation rate (%)	2.0	
[a]Annual capacity shortage (%)	0.0	
Project lifetime and waranty period (years)	10	
PV degration (%/year)	1.0	
System fix capital cost ($)	1,100,000	
PV cost ($/MW)	1,000,000	
PV O&M cost ($/year)	5,000	
Battery system cost ($/MWh)	700,000	
Battery O&M cost ($/MWh/year)	5,000	
PCS cost ($/500kW)	250,000	
PCS O&M cost ($/500kW/year)	5,000	
Generator cost ($/300kW)	120,000	
Generator O&M cost ($/op.hr)	1.0	
Fuel Price ($/L)	1.0	
Fuel curve slope (L/hr/kW output)	0.3	
Load scale average (%/year)	4.0	

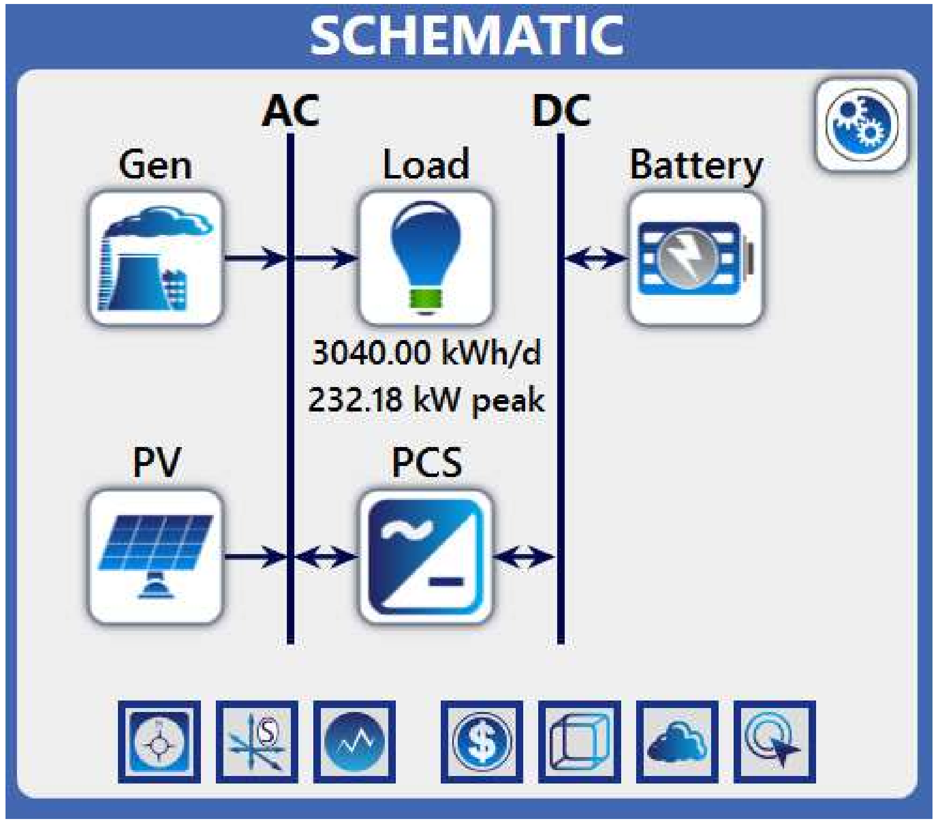
OBJECTIVE FUNCTIONS TO STUDY

- Minimize the cost of energy (COE), average cost for 10 years per kWh of useful electrical energy produced by the system. Beside minimizing the COE, it should be less than 0.5 $/kWh to be competitive with the diesel generator.
- Diesel generator operation for the first year, less than 2,000 hours.
- The renewable energy fraction, average fraction for 10 years of the energy delivered to the load that originated from renewable power sources, should be more than 75%.

COE ($/kWh)		< 0.50
Diesel generator operation of first year (hrs)		~ 2,000
Renewable energy fraction (%)		> 75

SIMULATION RESULTS

- Daily energy usage for this island is about 3,100kWh while the peak load is about 200kW
- Plant factor of PV (NREL) in this area is about 17.0% (or about 4.08 hours/day), calculated minimum sizing of PV is about 750kW (3,100/4.08)
- Candidate sizing of the Solar PV: 750kW, 1,000kW, and 1,250kW
- Candidate sizing of battery 1,000kWh, 1,250kWh, 1,500kWh, and 1,750kWh
- 300kW diesel generator that covered for peak load will be used



SIMULATION RESULTS:

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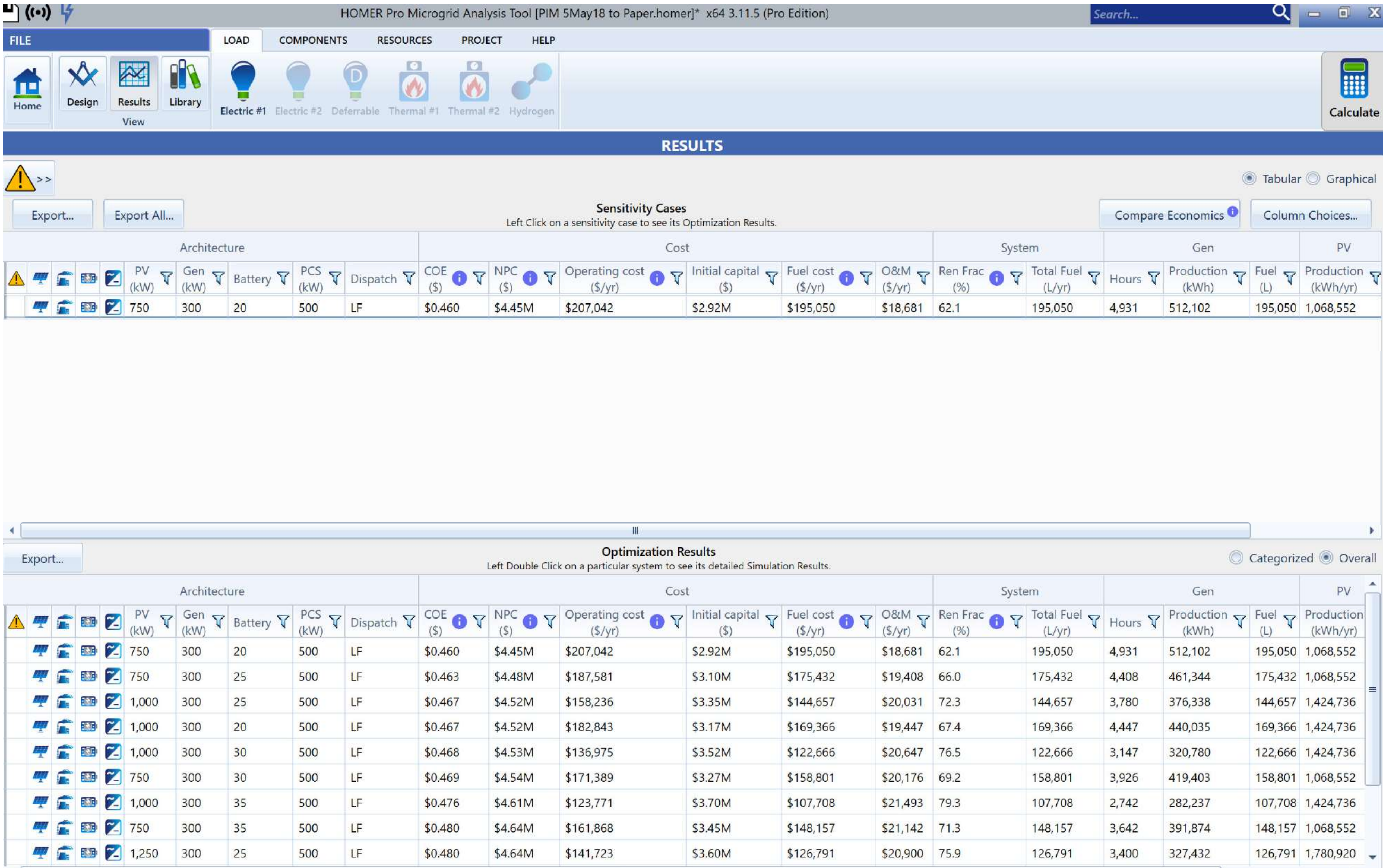

Sensitivity Cases

Architecture					Cost						System		Gen			PV
PV (kW)	Gen (kW)	Battery	PCS (kW)	Dispatch	COE ($)	NPC ($)	Operating cost ($/yr)	Initial capital ($)	Fuel cost ($/yr)	O&M ($/yr)	Ren Frac (%)	Total Fuel (L/yr)	Hours	Production (kWh)	Fuel (L)	Production (kWh/yr)
750	300	20	500	LF	$0.460	$4.45M	$207,042	$2.92M	$195,050	$18,681	62.1	195,050	4,931	512,102	195,050	1,068,552

Optimization Results

Architecture					Cost						System		Gen			PV
PV (kW)	Gen (kW)	Battery	PCS (kW)	Dispatch	COE ($)	NPC ($)	Operating cost ($/yr)	Initial capital ($)	Fuel cost ($/yr)	O&M ($/yr)	Ren Frac (%)	Total Fuel (L/yr)	Hours	Production (kWh)	Fuel (L)	Production (kWh/yr)
750	300	20	500	LF	$0.460	$4.45M	$207,042	$2.92M	$195,050	$18,681	62.1	195,050	4,931	512,102	195,050	1,068,552
750	300	25	500	LF	$0.463	$4.48M	$187,581	$3.10M	$175,432	$19,408	66.0	175,432	4,408	461,344	175,432	1,068,552
1,000	300	25	500	LF	$0.467	$4.52M	$158,236	$3.35M	$144,657	$20,031	72.3	144,657	3,780	376,338	144,657	1,424,736
1,000	300	20	500	LF	$0.467	$4.52M	$182,843	$3.17M	$169,366	$19,447	67.4	169,366	4,447	440,035	169,366	1,424,736
1,000	300	30	500	LF	$0.468	$4.53M	$136,975	$3.52M	$122,666	$20,647	76.5	122,666	3,147	320,780	122,666	1,424,736
750	300	30	500	LF	$0.469	$4.54M	$171,389	$3.27M	$158,801	$20,176	69.2	158,801	3,926	419,403	158,801	1,068,552
1,000	300	35	500	LF	$0.476	$4.61M	$123,771	$3.70M	$107,708	$21,493	79.3	107,708	2,742	282,237	107,708	1,424,736
750	300	35	500	LF	$0.480	$4.64M	$161,868	$3.45M	$148,157	$21,142	71.3	148,157	3,642	391,874	148,157	1,068,552
1,250	300	25	500	LF	$0.480	$4.64M	$141,723	$3.60M	$126,791	$20,900	75.9	126,791	3,400	327,432	126,791	1,780,920

SIMULATION RESULTS: 1st year

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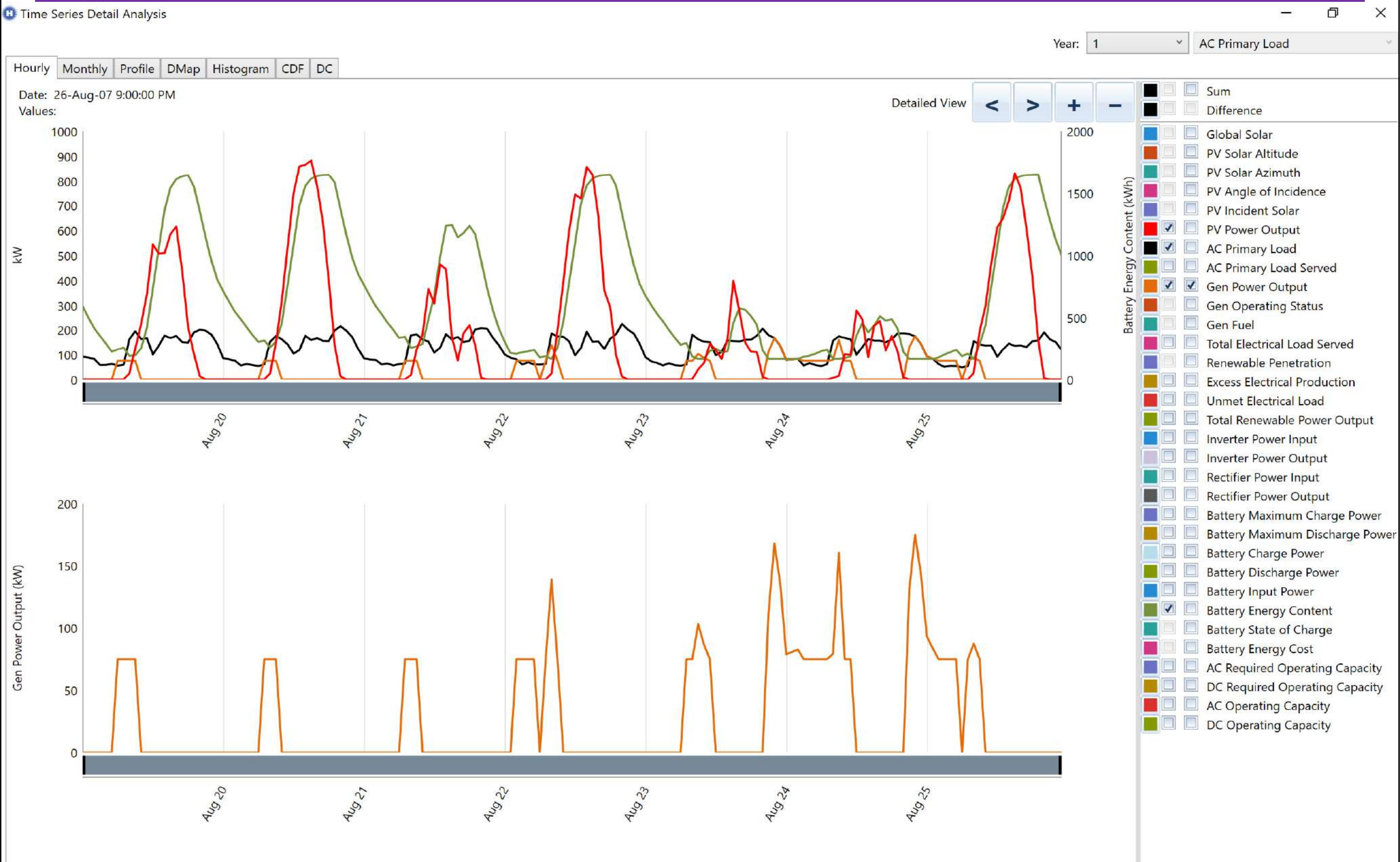
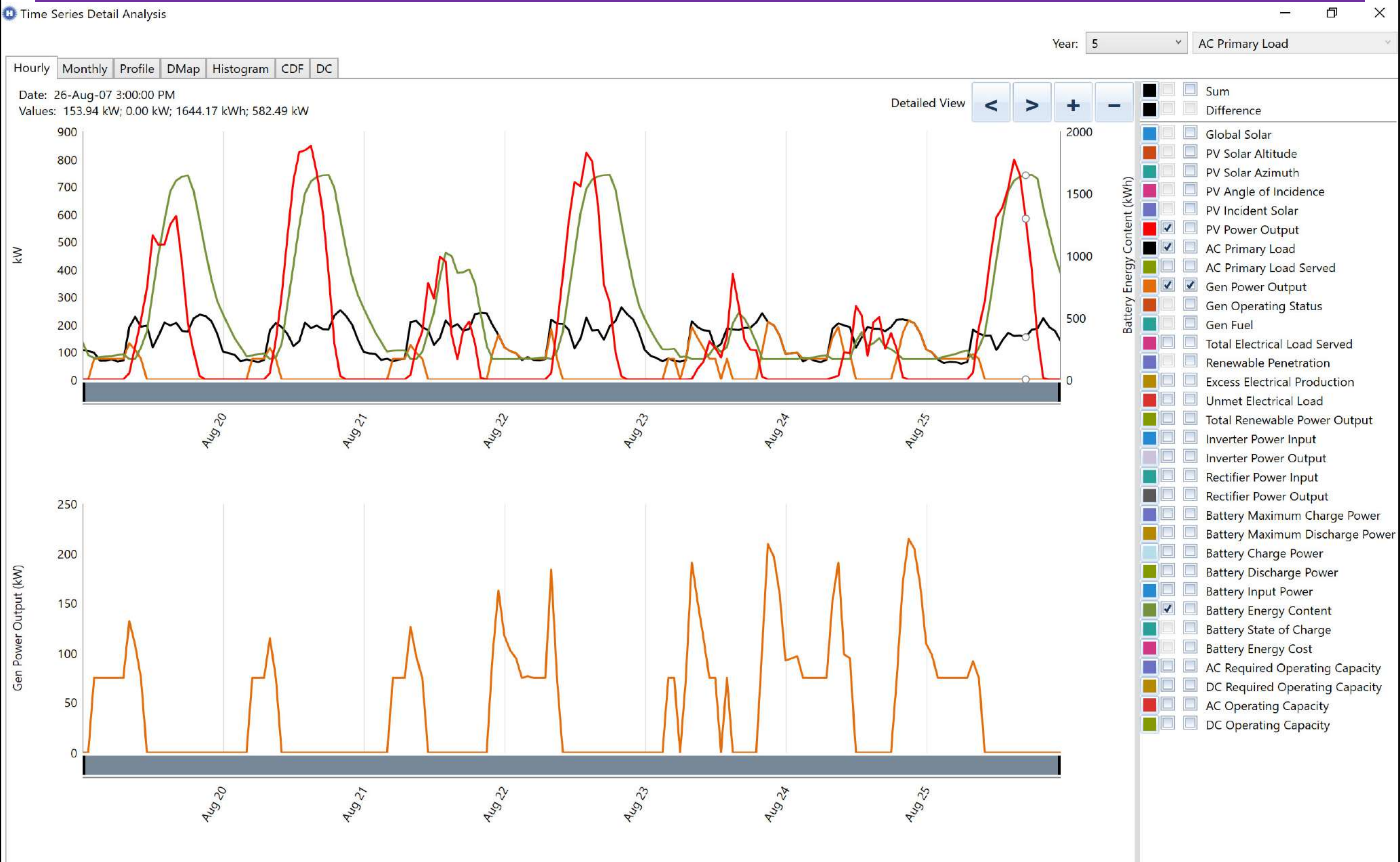
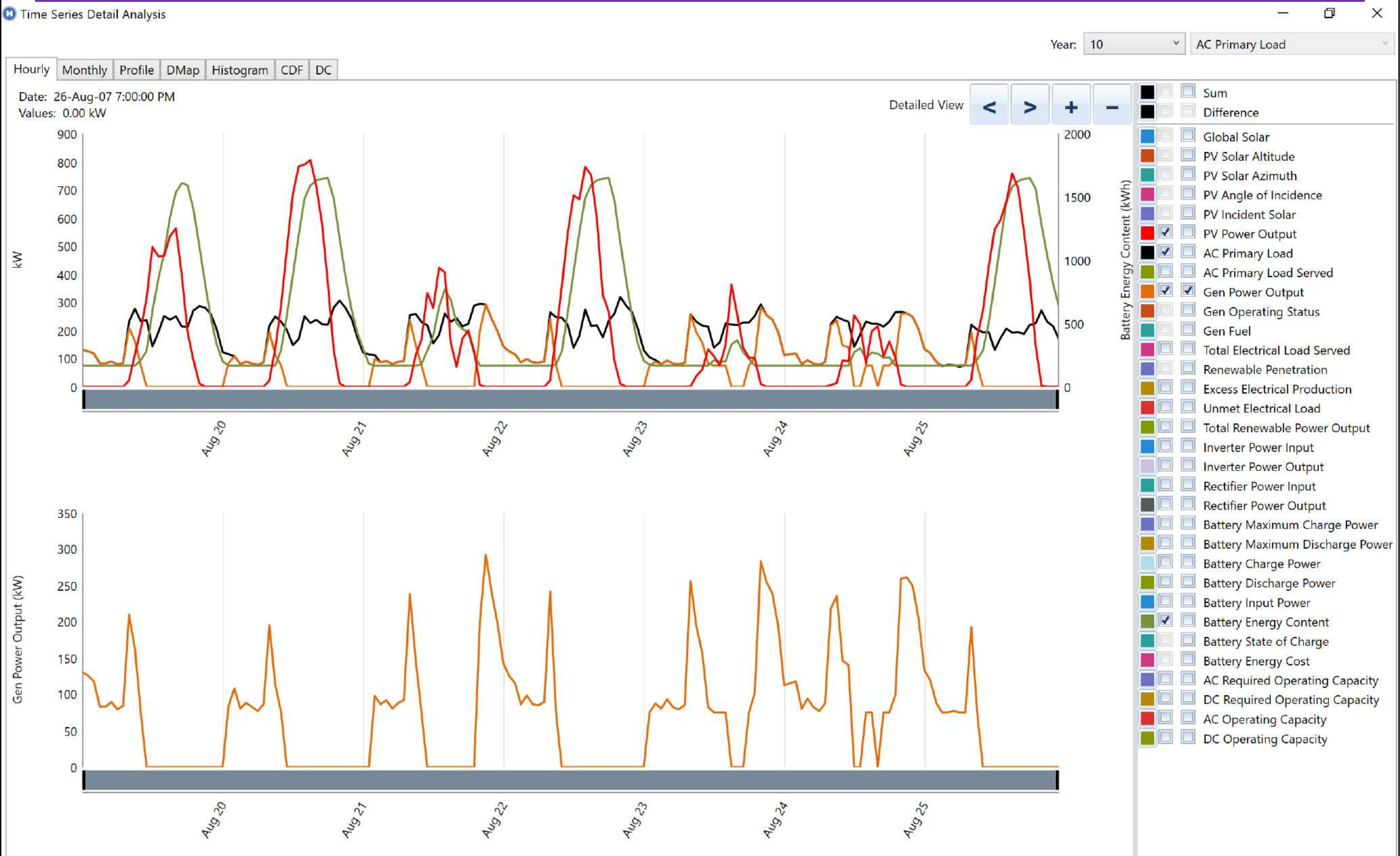


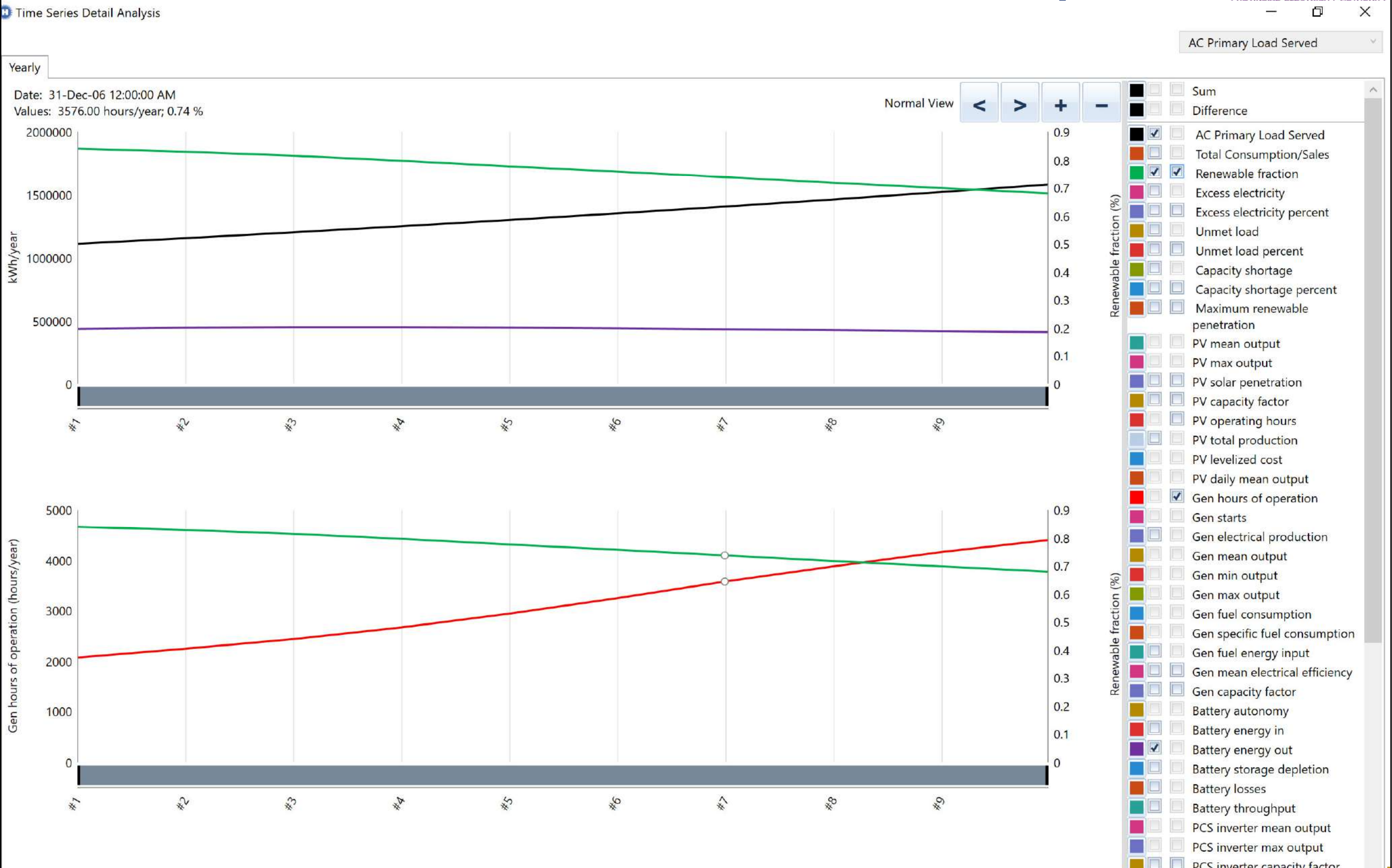
SIMULATION RESULTS: 5th year



SIMULATION RESULTS: 10th year



SIMULATION RESULTS: 1st to 10th year



SIMULATION RESULTS:

COE ($/kWh)		< 0.50
Diesel generator operation of first year (hrs)		~ 2,000
Renewable energy fraction (%)		> 75

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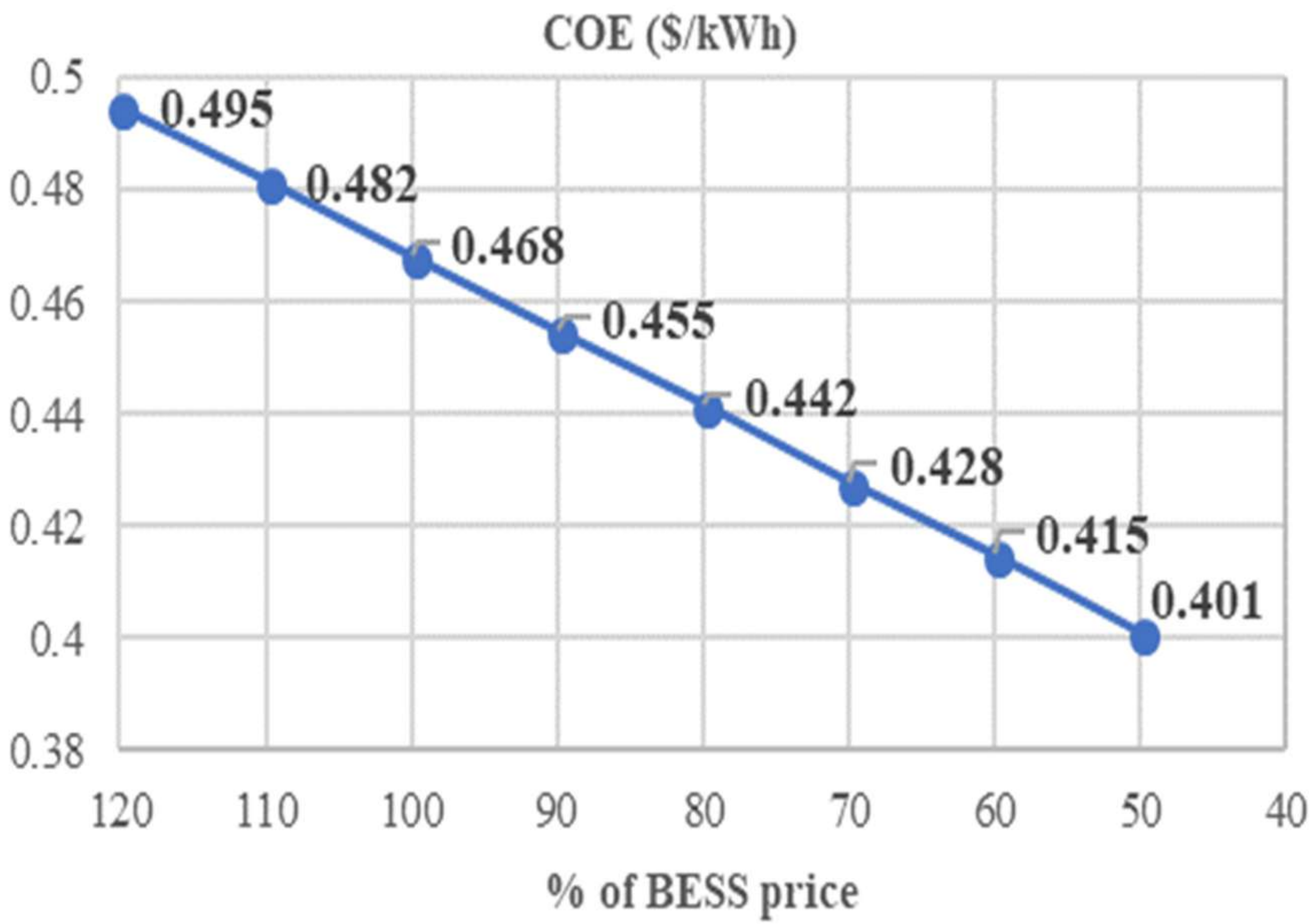
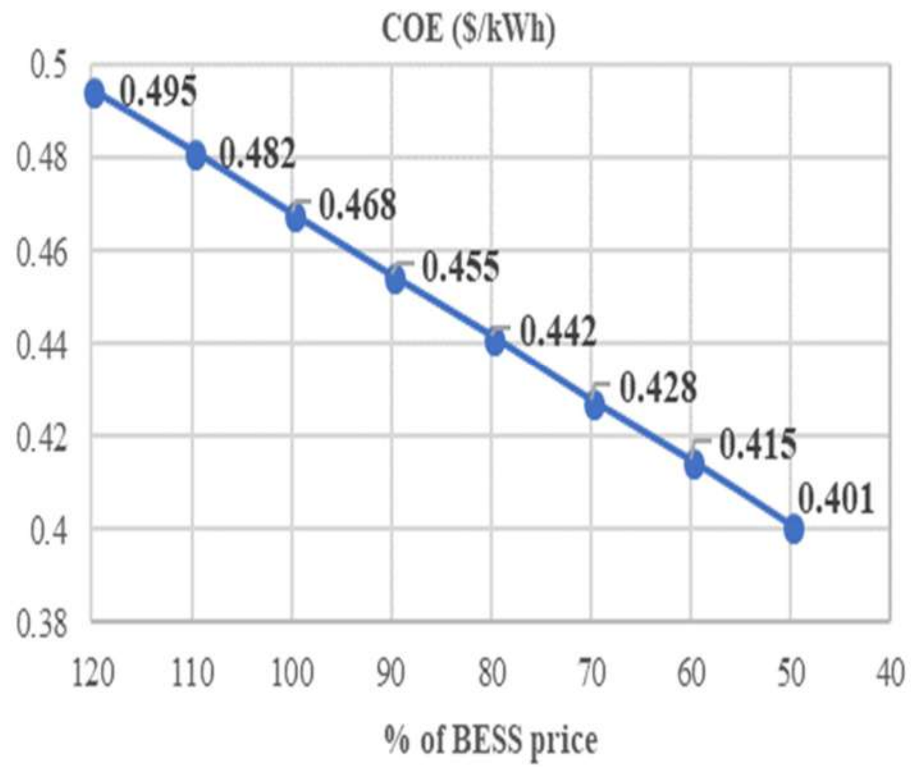
PV (kW)	Battery (kWh)	COE ($/kWh)	Renewable energy fraction (%)	Gen 1st yr (hrs)	Gen avg of 10yrs (hrs)
750	1,000	0.460	62.09	3,906	4,931
1,000	1,000	0.467	67.44	3,420	4,447
750	1,250	0.463	65.99	3,134	4,408
1,000	1,250	0.467	72.31	2,506	3,781
1,250	1,000	0.502	70.58	3,129	4,149
1,000	1,500	0.468	76.51	2,059	3,147
750	1,500	0.469	69.22	2,671	3,926
1,250	1,250	0.480	75.95	2,158	3,400
1,250	1,500	0.480	80.49	1,764	2,708
1,000	1,750	0.476	79.33	1,911	2,743
750	1,750	0.480	71.30	2,485	3,642
1,250	1,750	0.488	83.39	1,642	2,283

SIMULATION RESULTS: sensitivity analysis



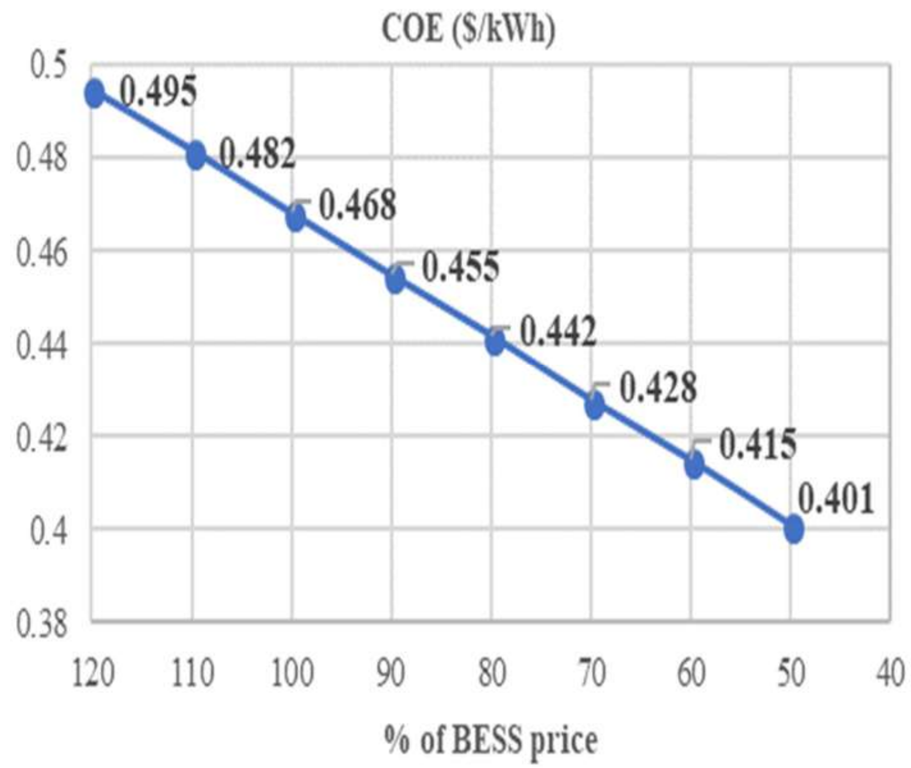
SIMULATION RESULTS: diesel generator only

- The system fixed capital cost would be $100,000 instead of $1,100,000
- The sizing of generator would be 400kW for 10 years lifetime
- The COE would be 0.458 $/kWh
- It means that for this case if the BESS price is about 90% of 2018 price, the proposed microgrid system could be competitive compared with the diesel generator only system.



SIMULATION RESULTS: 100% RE

- Annual capacity shortage must be 5% instead of 0%. [The total capacity shortage divided by the total electric load]
- Some load must be unsupplied at some period
- The system fix capital cost would be $1,000,000 instead of $1,100,000
- The PV sizing would be 3,000kW, BESS 500kW/2,250kWh
- The COE 0.541 $/kWh that cannot competitive with the diesel generator only
- However, if 0% of annual capacity, PV 6,000kW, BESS 500kW/3,250kWh COE 0.930 $/kWh



Proposed microgrid design results

Conclusion

- 1,000kW of PV as the main generation source together with a BESS 500kW/1,500kWh to collect the surplus power form the solar PV and supply power to the load during hours of no sunshine
- 300kW diesel generator will be considered to supply the power at some specific hours per year
- The COE for this case is 0.468 $/kWh
- Additional BESS and PV will be considered for the 7th year to meet the 75% or more of renewable energy fraction.
- The appropriate electricity tariff for microgrid systems that can be proposed to the government if this new business model would be implemented in the Kingdom of Thailand in near future that comply with this assumption is about 0.468 $/kWh plus some percent of benefit.
- Again, if the price of BESS is going down, the proposed methodology could be applied.

PEA Microgrid Project

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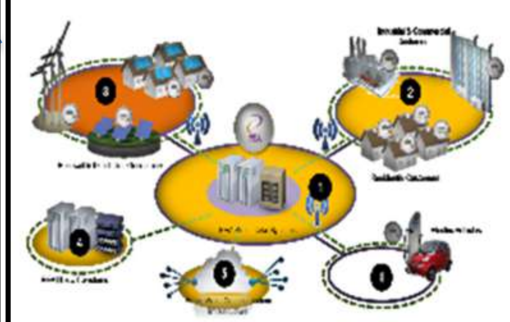
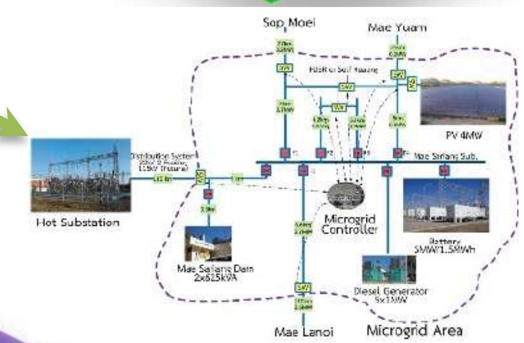
STAGE 1: Pilot

Establish the foundation for customer-centric smart grid

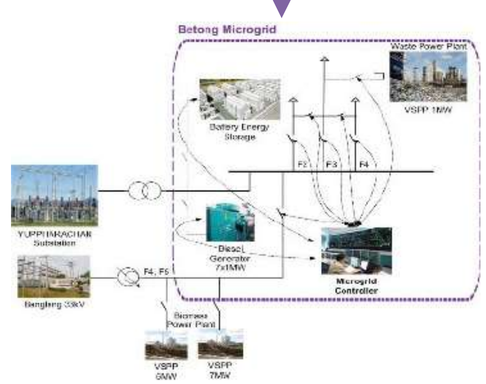


Khun Pae, Chiang Mai (R&D)

Mae Sariang, Mae Hongson



Betong, Yala



Microgrid at Khun Pae (R&D Project)

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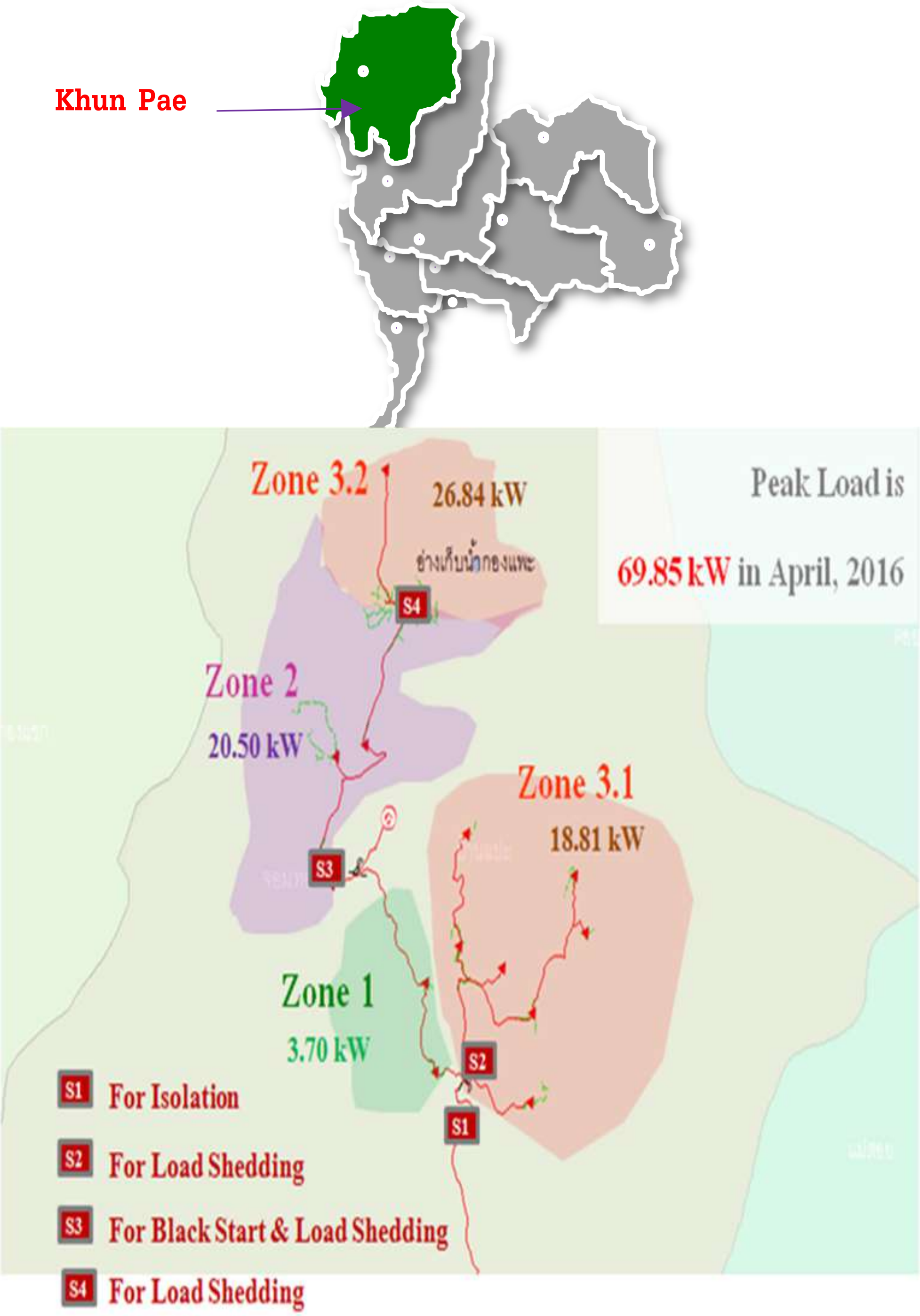

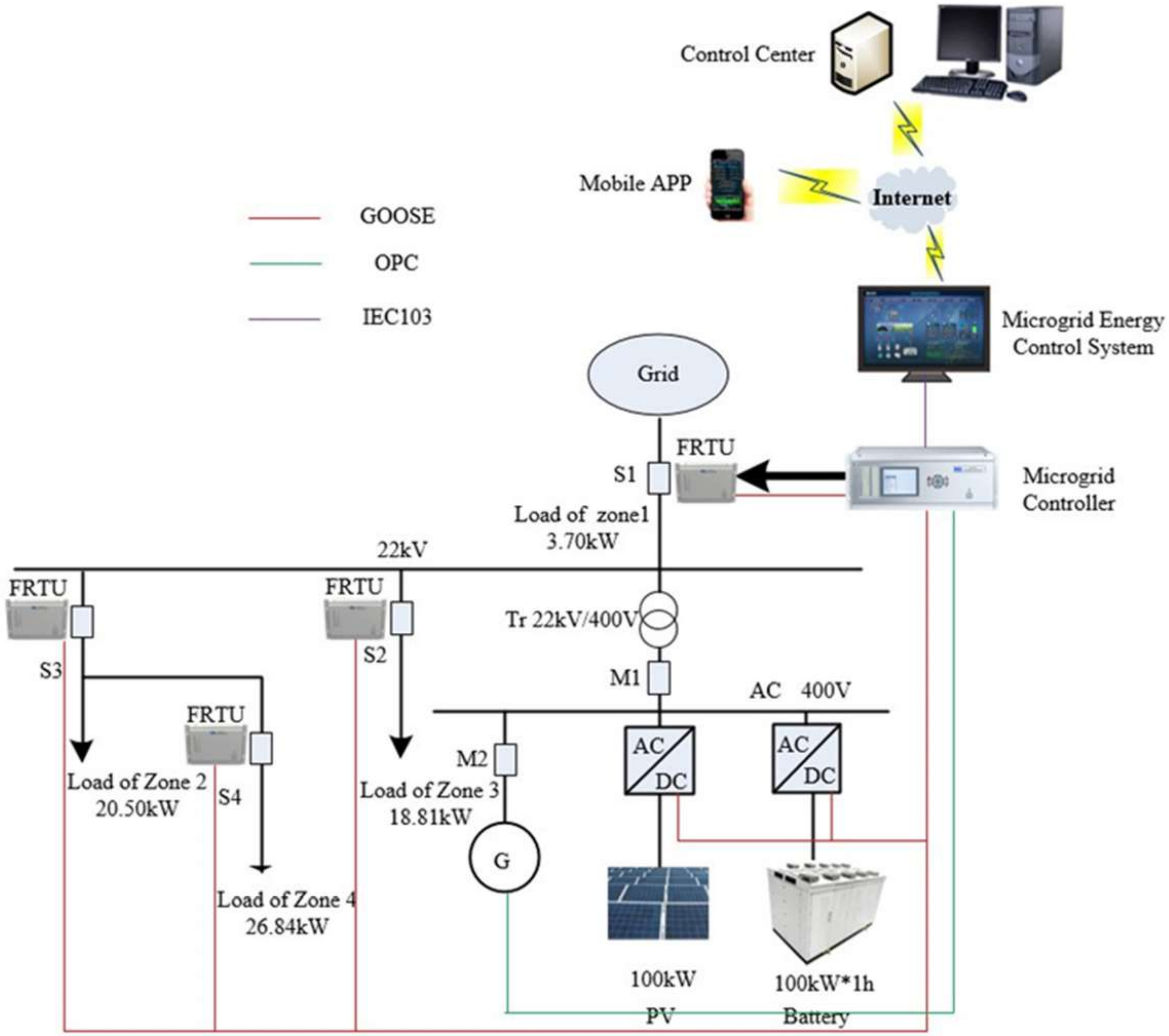

Microgrid at Khun Pae (R&D Project)

Microgrid Controller

BESS 100kW/100kWh

Microgrid Components

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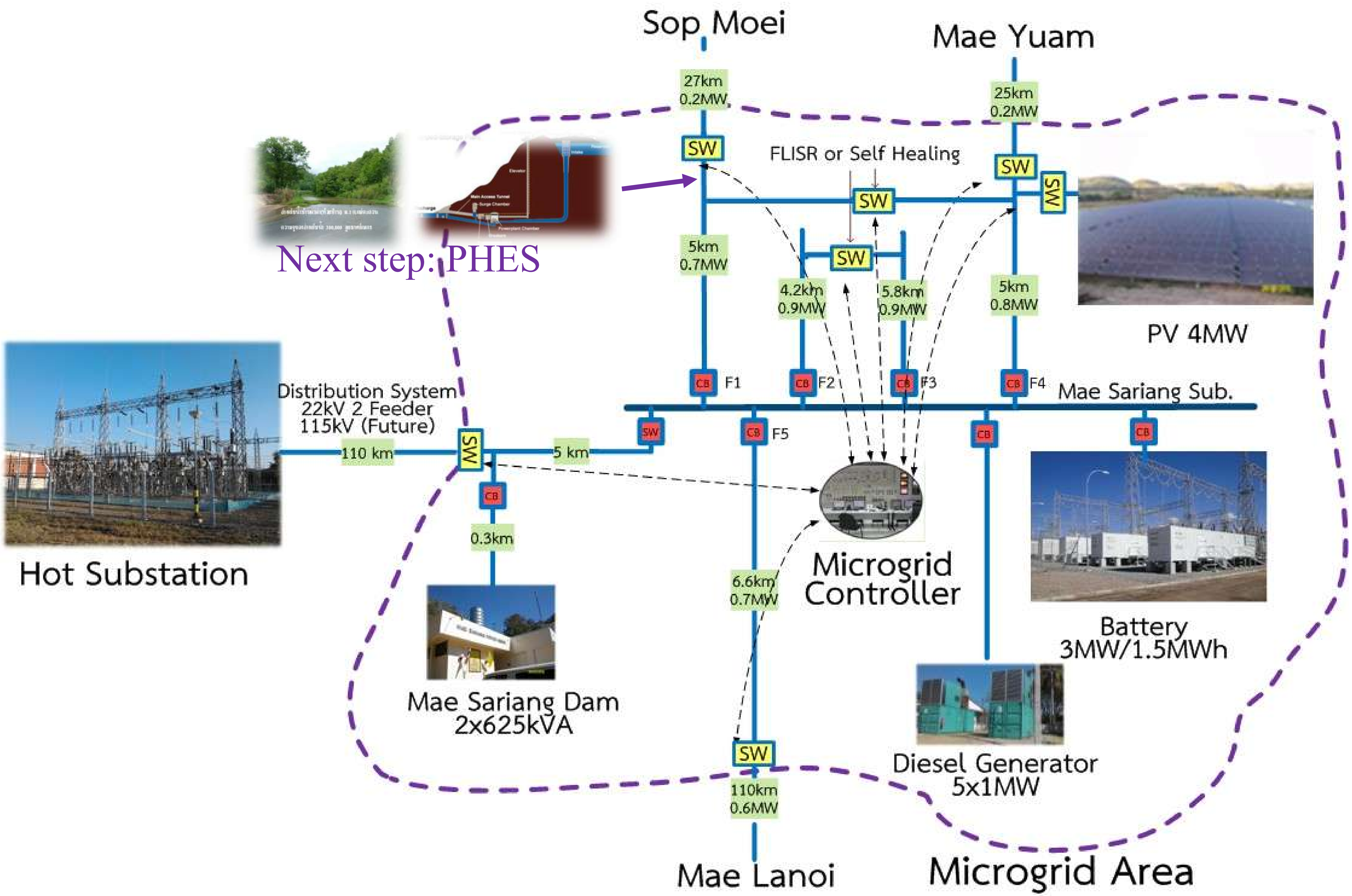

Microgrid at Betong, Yala Province

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เบตงไมโครกริด (Betong Microgrid)