Microgrid Design and Operation Name ___Saif Elsaady___________________________

Project 1, due 4/9

Project 1 objective: Build a microgrid to satisfy power needs for critical services in an island. The island is Oahu, Hawaii.

Problems for all students (80 points)

Task 1: Identify a critical facility (load) on Oahu. This is your choice. Recall some examples such as airports, hospitals, water treatment, military bases, police, fire, etc. Provide the name of the facility, latitude and longitude coordinates, use 4-6 sentences to describe the functions of the facility, and use 2-3 sentences to indicate how you believe the loads will change during the year, month, and day. **(10 pts)**

Name: University of Hawaiʻi at Mānoa

Latitude & Longitude Coordinates: 21.299824° N, 157.814823° W

Functions of the Facility: The University of Hawaiʻi at Mānoa is a premier institution for higher education and research in the Pacific, situated at 21.299824° N, 157.814823° W, in Honolulu. As the main campus of the University of Hawaiʻi system, it serves a diverse student body with a wide array of undergraduate, graduate, and professional programs. The university is a beacon of innovation and intellectual growth, with strong emphasis in areas like tropical agriculture, volcanic geology, oceanography, and Asian and Pacific studies, reflecting its unique geographical location. It not only provides educational services but also functions as a critical research hub, contributing to scientific advancement and economic development in Hawaii and beyond. Moreover, the campus supports the community through cultural enrichment and public service initiatives, making it an integral part of Oahu's societal fabric.

Load Changes: The energy load at the University of Hawaiʻi at Mānoa is likely to exhibit fluctuations throughout the year, with peaks during academic semesters when students and faculty are present and a reduction during breaks and the summer session. Monthly energy usage might be higher at the start and end of semesters due to the commencement and conclusion of academic activities. Daily load patterns are expected to peak during daytime hours when classes, administrative operations, and research activities are in full swing, with a noticeable dip during the night when these activities lessen.

Task 2: Create a DESIGN project in Xendee and build your base case analysis. **(30 pts)**

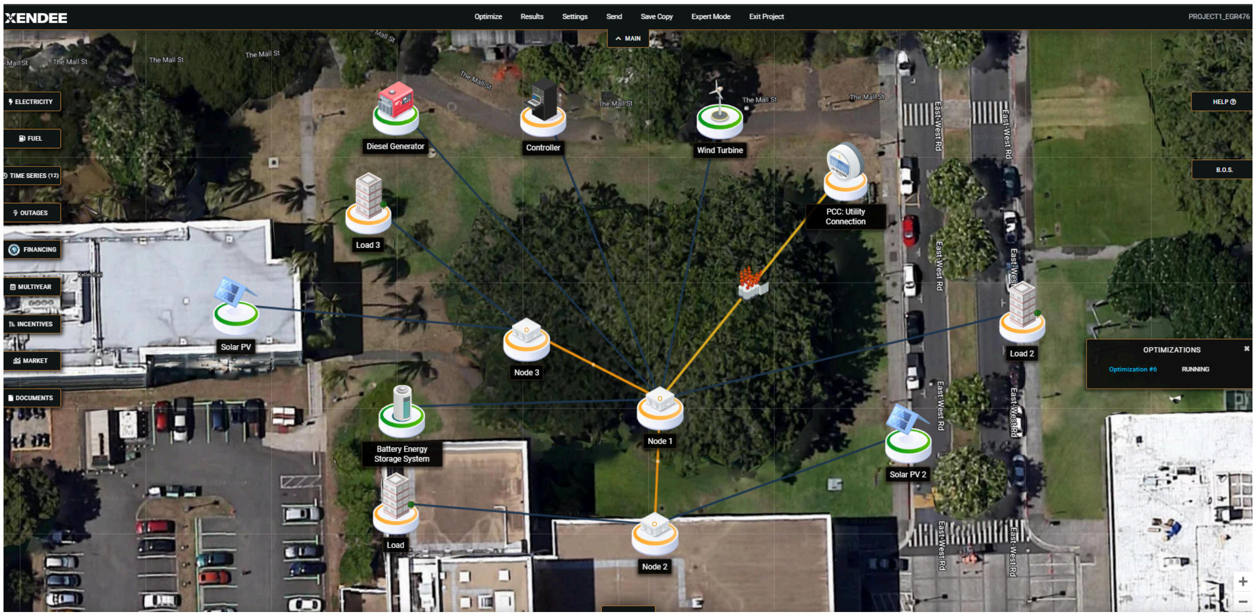
Utilize the below to create your project:

- Be sure to pick the correct latitude and longitude coordinates to begin.
- Include solar PV, battery energy storage, wind, and diesel generators in your analyses.
- For asset costs, use the average cost information from Lazard as you've done in previous models.
- For load, pick the load profile that is representative of the critical service you selected.

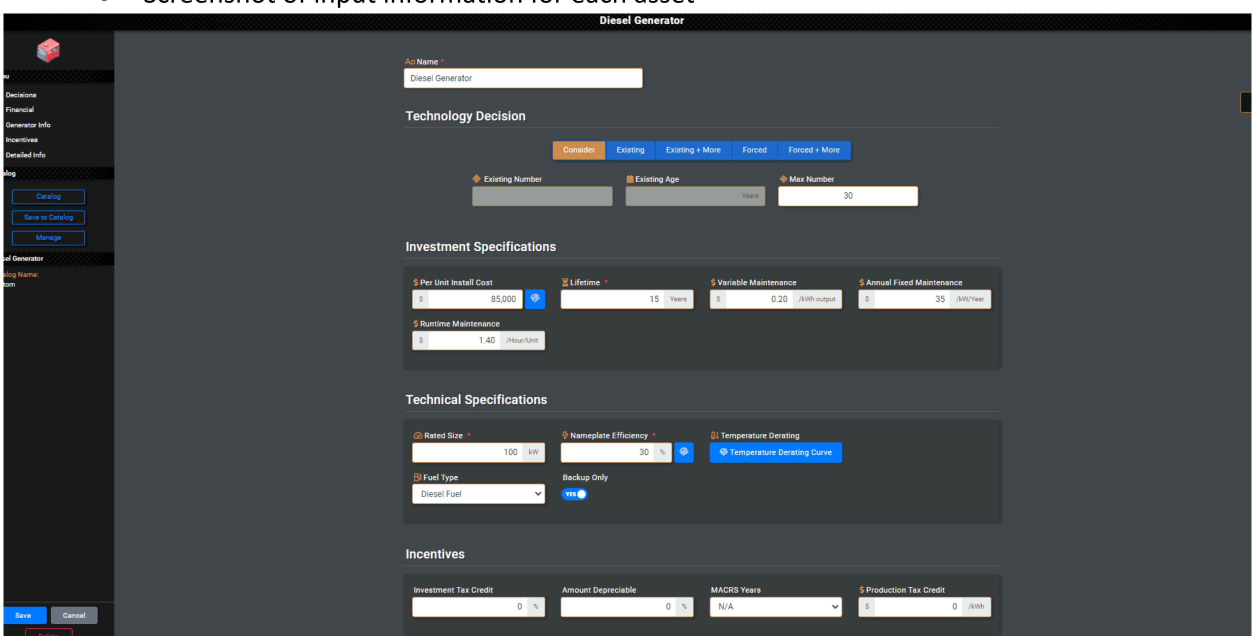
- For electricity costs, identify the appropriate [rate structure from Hawaiian Electric]() and input those costs.
- For fuel, use the [West Coast On-Highway price]() for diesel.

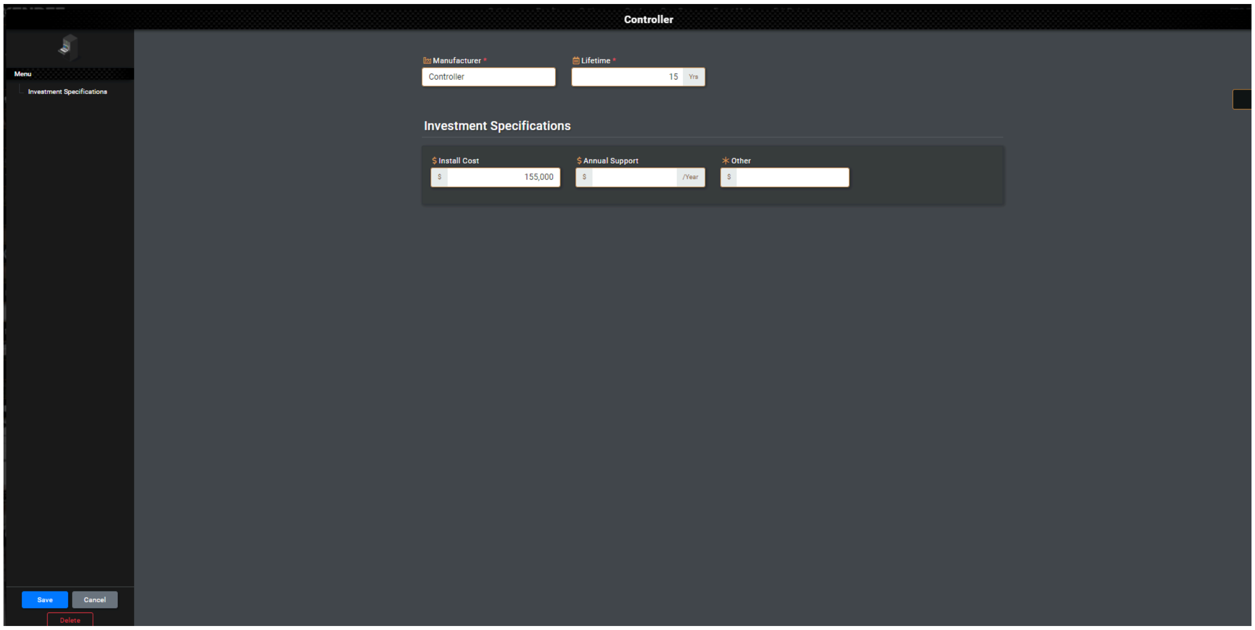
Provide the following:

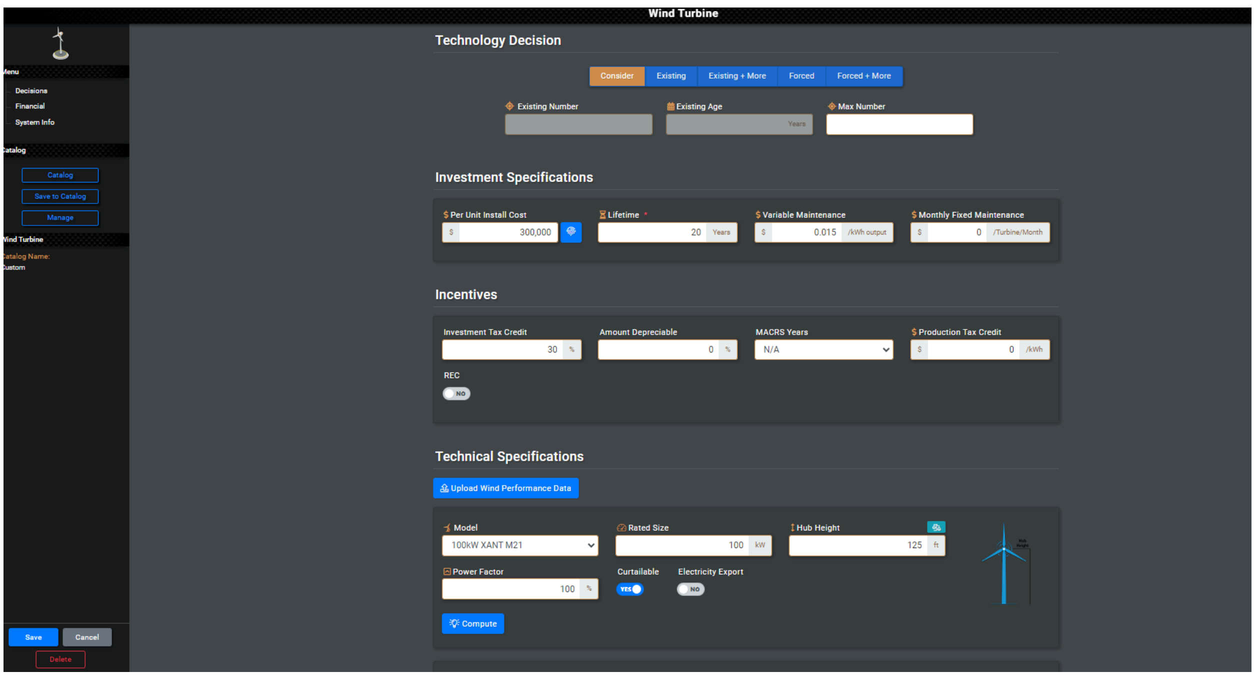
- Screenshot of the GIS layout

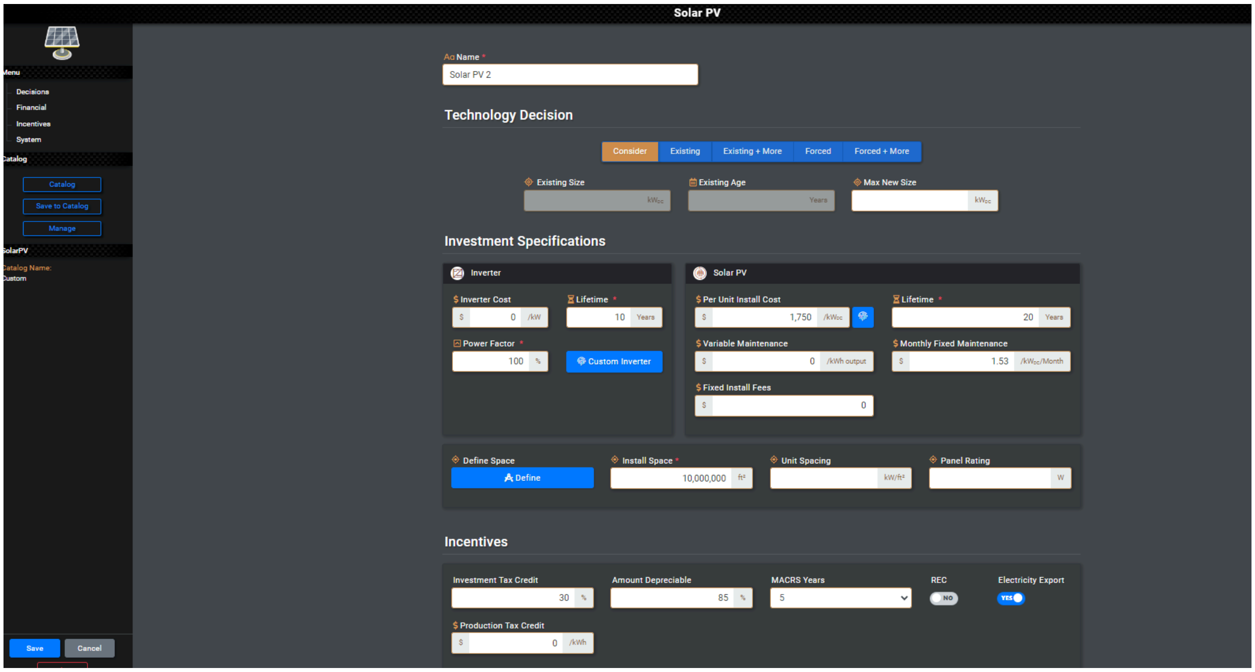


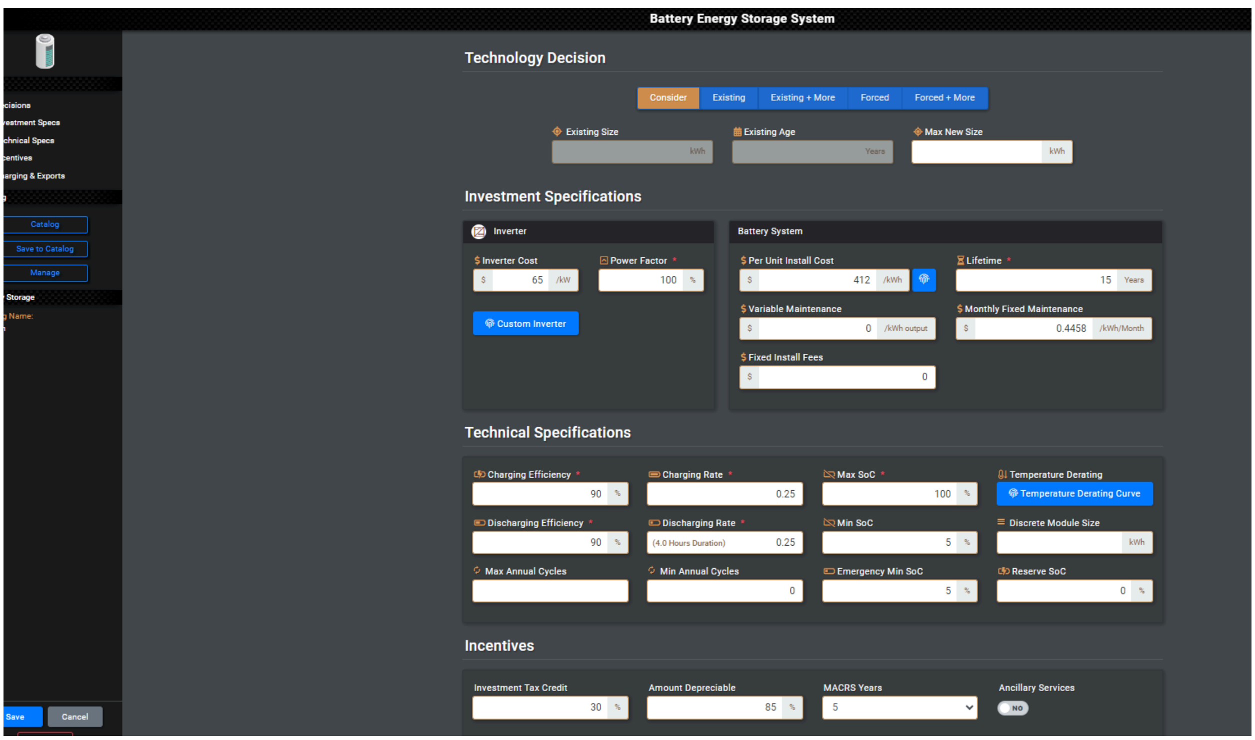
- Screenshot of input information for each asset

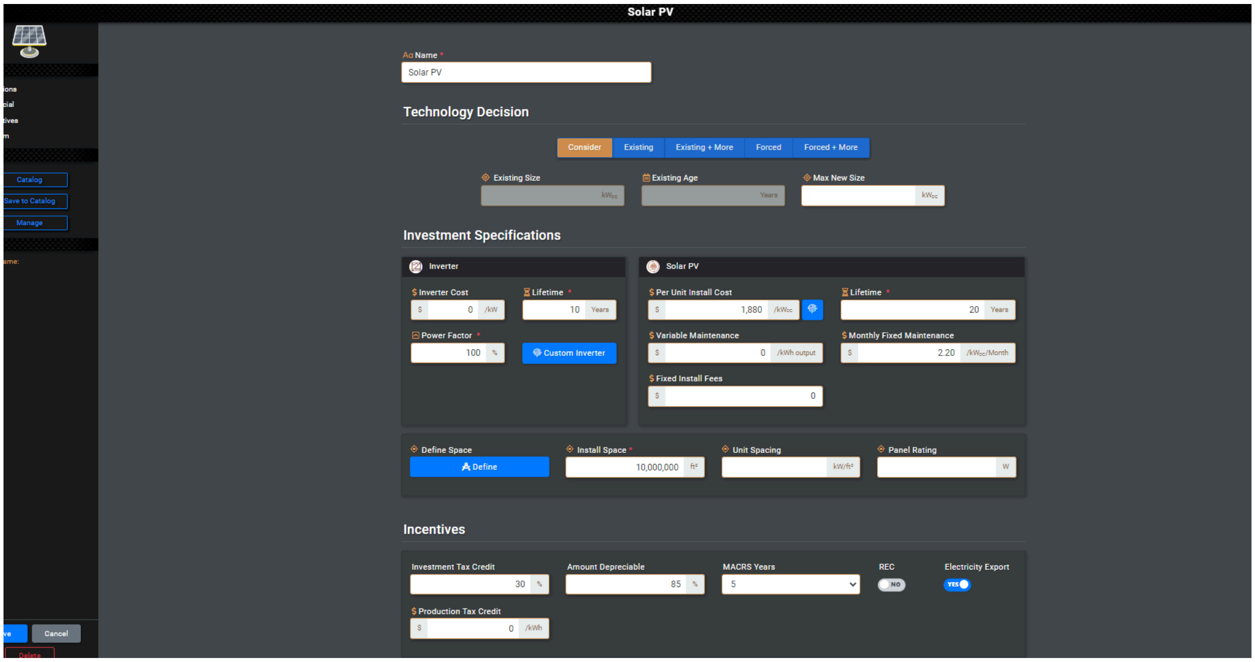



Controller
Menu
Investment Specifications
Manufacturer *
Controller
Lifetime *
15 Yrs
Investment Specifications
Install Cost
$ 155,000
Annual Support
$ /Year
Other
$
Save
Cancel
Delete

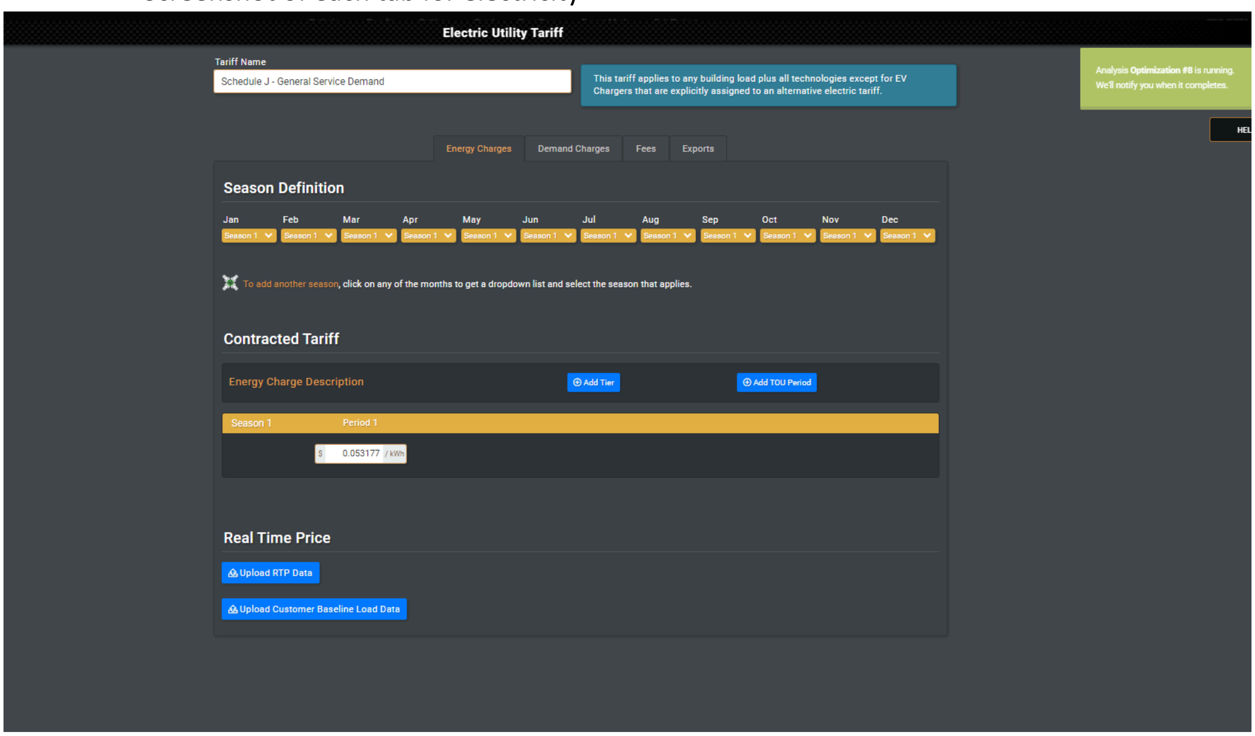

Wind Turbine
Menu
Decisions
Financial
System Info
Catalog
Catalog
Save to Catalog
Manage
Wind Turbine
Catalog Name:
Custom
Technology Decision
Consider
Existing
Existing + More
Forced
Forced + More
Existing Number
Existing Age
Years
Max Number
Investment Specifications
Per Unit Install Cost
$ 300,000
Lifetime *
20 Years
Variable Maintenance
$ 0.015 /kWh output
Monthly Fixed Maintenance
$ 0 /Turbine/Month
Incentives
Investment Tax Credit
30 %
Amount Depreciable
0 %
MACRS Years
N/A
Production Tax Credit
$ 0 /kWh
REC
NO
Technical Specifications
Upload Wind Performance Data
Model
100kW XANT M21
Rated Size
100 kW
Hub Height
125 ft
Power Factor
100 %
Curtailable
YES
Electricity Export
NO
Compute
Save
Cancel
Delete

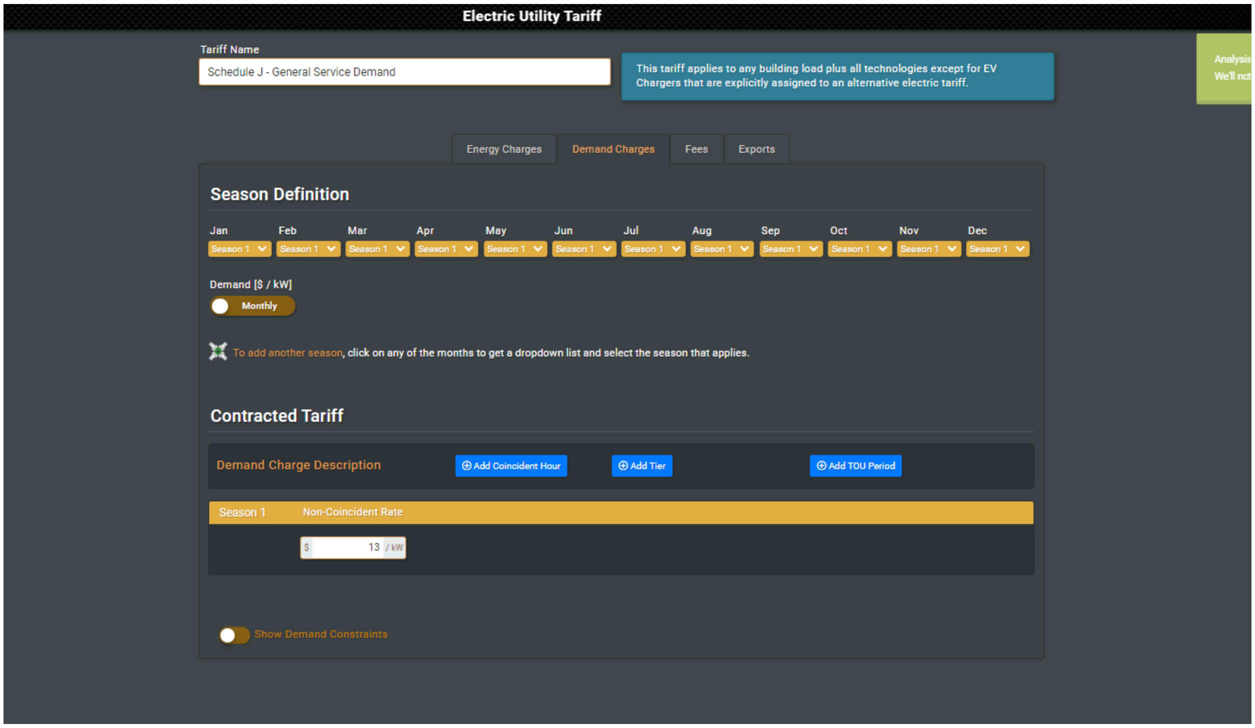

Solar PV
Menu
Decisions
Financial
Incentives
System
Catalog
Catalog
Save to Catalog
Manage
SolarPV
Catalog Name:
Custom
Save
Cancel
Name
Solar PV 2
Technology Decision
Consider
Existing
Existing + More
Forced
Forced + More
Existing Size
Existing Age
Max New Size
Investment Specifications
Inverter
Inverter Cost
Lifetime
Power Factor
Custom Inverter
Solar PV
Per Unit Install Cost
1,750
Lifetime
20
Variable Maintenance
Monthly Fixed Maintenance
1.53
Fixed Install Fees
Define Space
Define
Install Space
10,000,000
Unit Spacing
Panel Rating
Incentives
Investment Tax Credit
30
Amount Depreciable
85
MACRS Years
5
REC
Electricity Export
Production Tax Credit

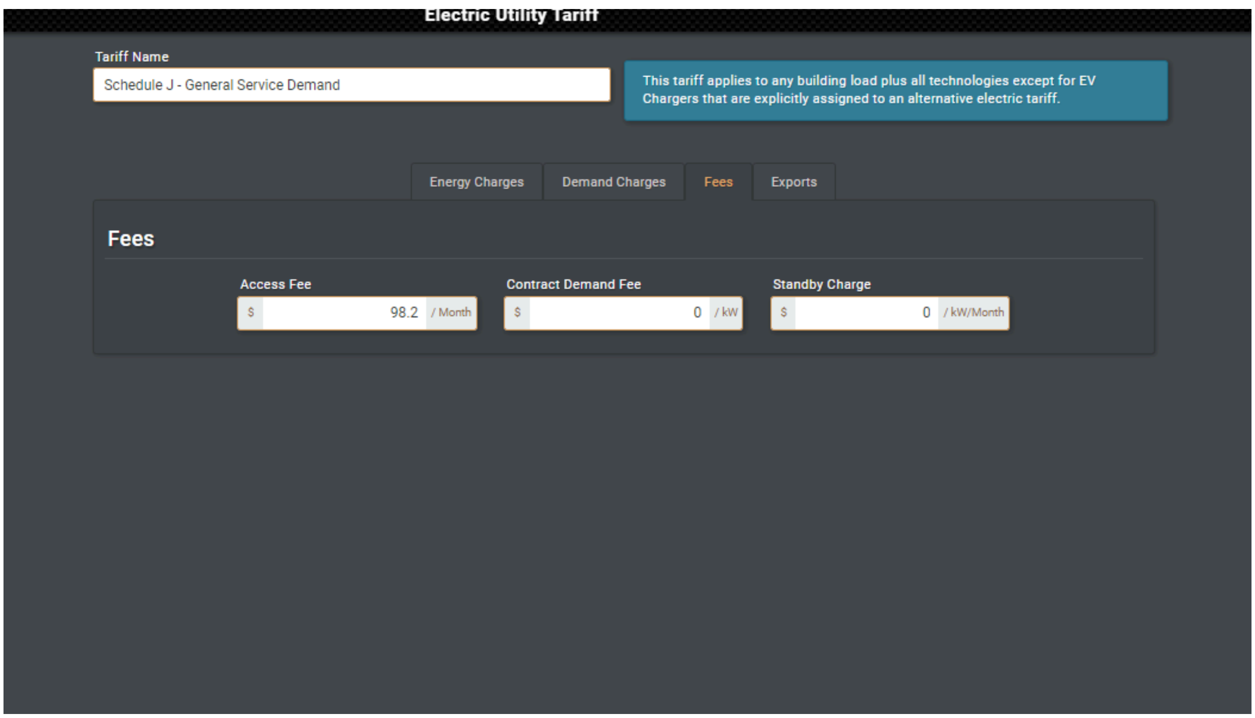

Battery Energy Storage System
Catalog
Save to Catalog
Manage
Save
Cancel
Technology Decision
Consider
Existing
Existing + More
Forced
Forced + More
Existing Size
Existing Age
Max New Size
Investment Specifications
Inverter
Inverter Cost
65
Power Factor
100
Custom Inverter
Battery System
Per Unit Install Cost
412
Lifetime
15
Variable Maintenance
Monthly Fixed Maintenance
0.4458
Fixed Install Fees
Technical Specifications
Charging Efficiency
90
Charging Rate
0.25
Max SoC
100
Temperature Derating
Temperature Derating Curve
Discharging Efficiency
90
Discharging Rate
(4.0 Hours Duration)
0.25
Min SoC
5
Discrete Module Size
Max Annual Cycles
Min Annual Cycles
Emergency Min SoC
5
Reserve SoC
Incentives
Investment Tax Credit
30
Amount Depreciable
85
MACRS Years
5
Ancillary Services

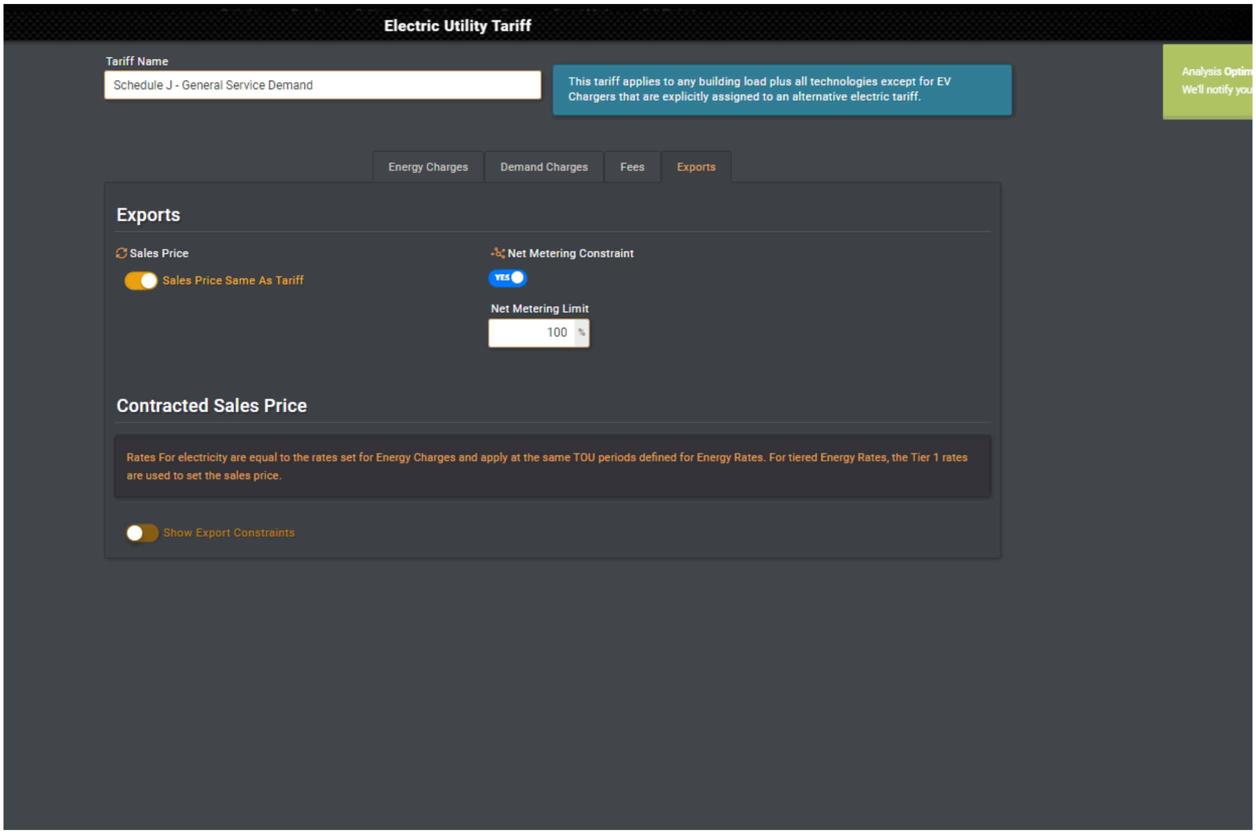


- Screenshot of each tab for electricity



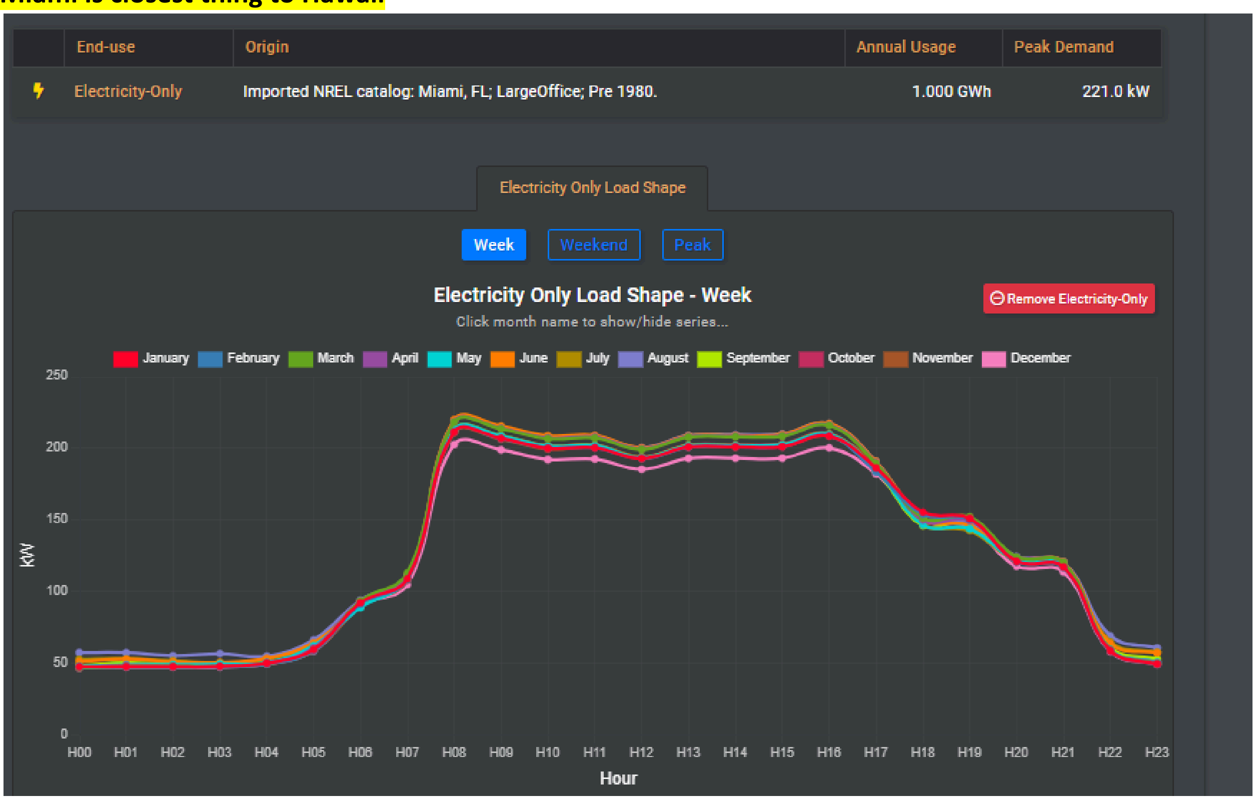

Electric Utility Tariff
Tariff Name
Schedule J - General Service Demand
This tariff applies to any building load plus all technologies except for EV Chargers that are explicitly assigned to an alternative electric tariff.
Energy Charges
Demand Charges
Fees
Exports
Season Definition
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Season 1
Demand [$ / kW]
Monthly
To add another season, click on any of the months to get a dropdown list and select the season that applies.
Contracted Tariff
Demand Charge Description
Add Coincident Hour
Add Tier
Add TOU Period
Season 1
Non-Coincident Rate
$ 13 / kW
Show Demand Constraints


Electric Utility Tariff
Tariff Name
Schedule J - General Service Demand
This tariff applies to any building load plus all technologies except for EV Chargers that are explicitly assigned to an alternative electric tariff.
Energy Charges
Demand Charges
Fees
Exports
Fees
Access Fee
$ 98.2 / Month
Contract Demand Fee
$ 0 / kW
Standby Charge
$ 0 / kW/Month

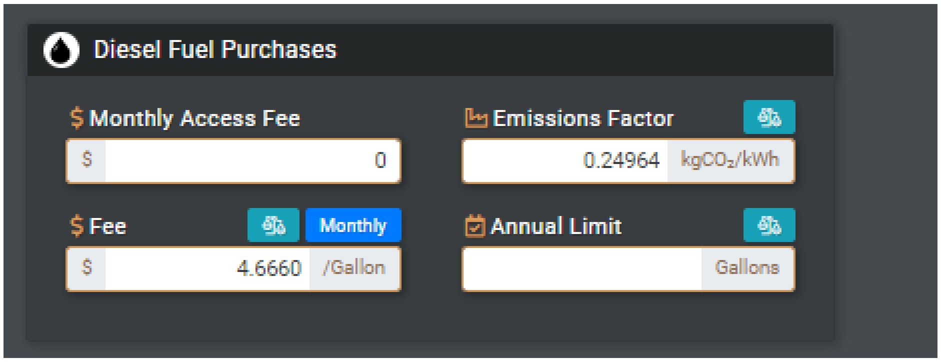


- Screenshot of the load profile

Miami is closest thing to Hawaii



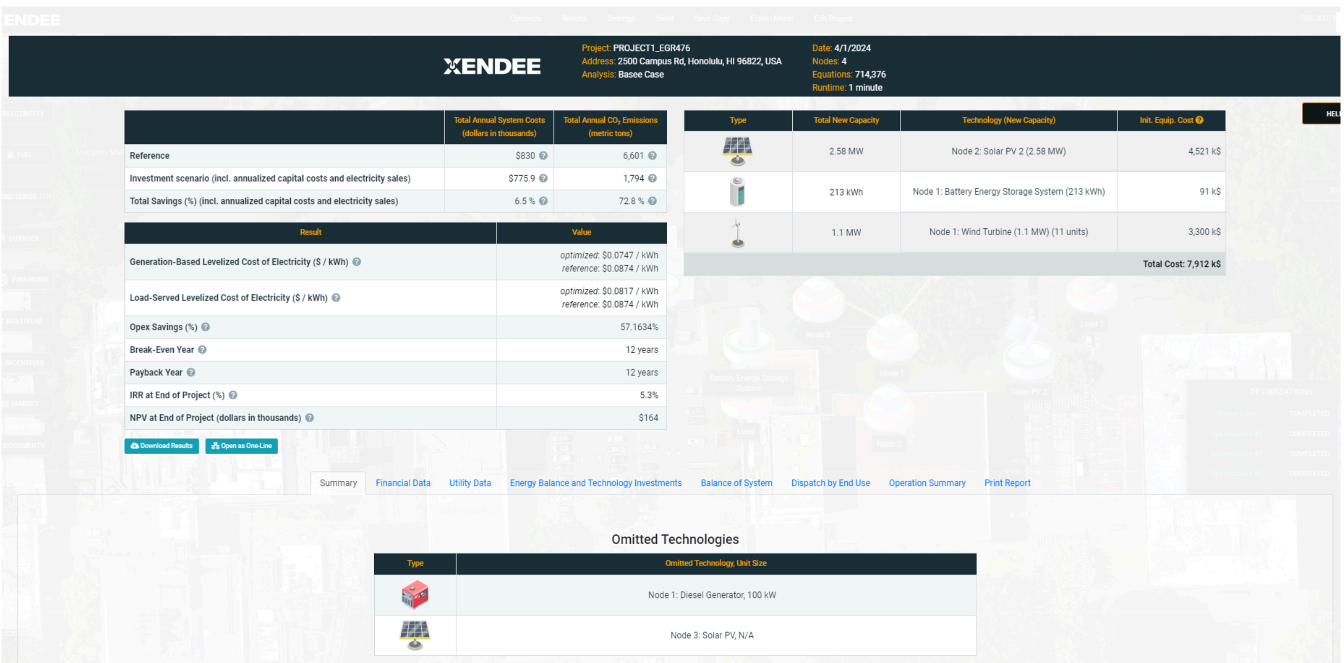
- Screenshot of diesel fuel price entry



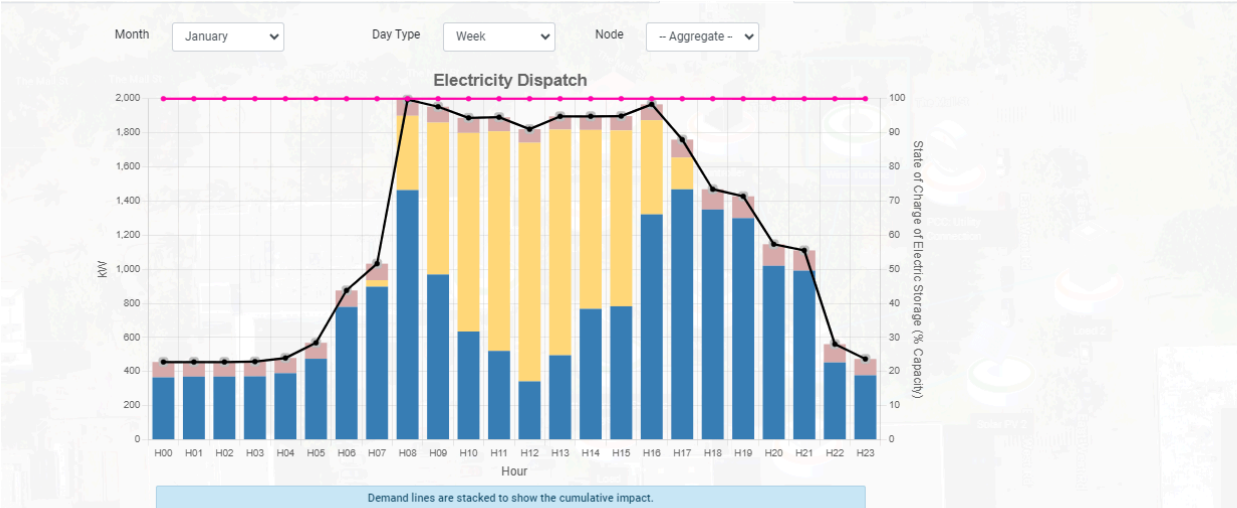
Task 3: Run an optimization termed "Base case". **(10 pts)**

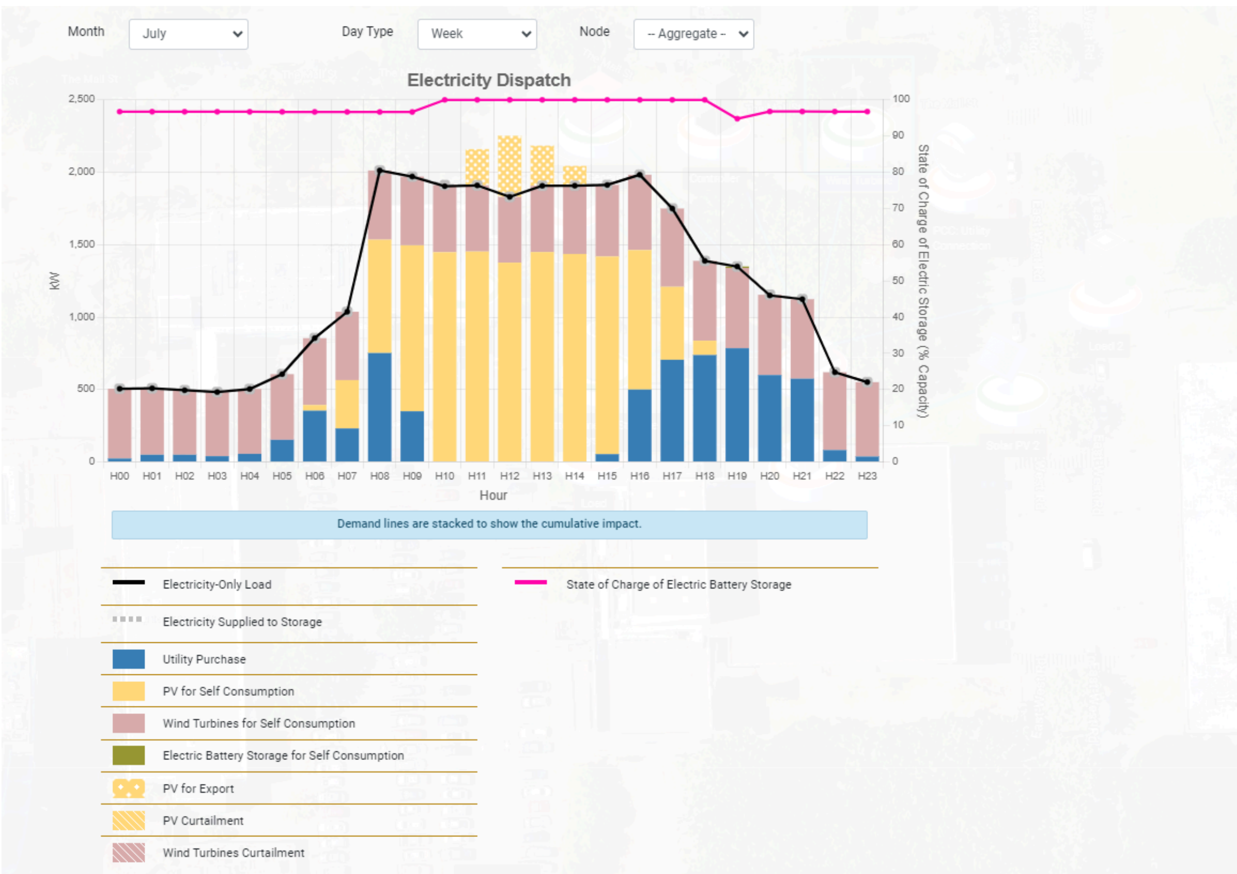
Provide the following:

- Screenshot of the techno-economic results



- Screenshot of dispatch for January weekday and for July weekday





- Short paragraph with 3-5 sentences discussing why assets were selected by Xendee (or not selected) and include description of the dispatch profile to defend your statements (e.g., battery used for peak shaving).

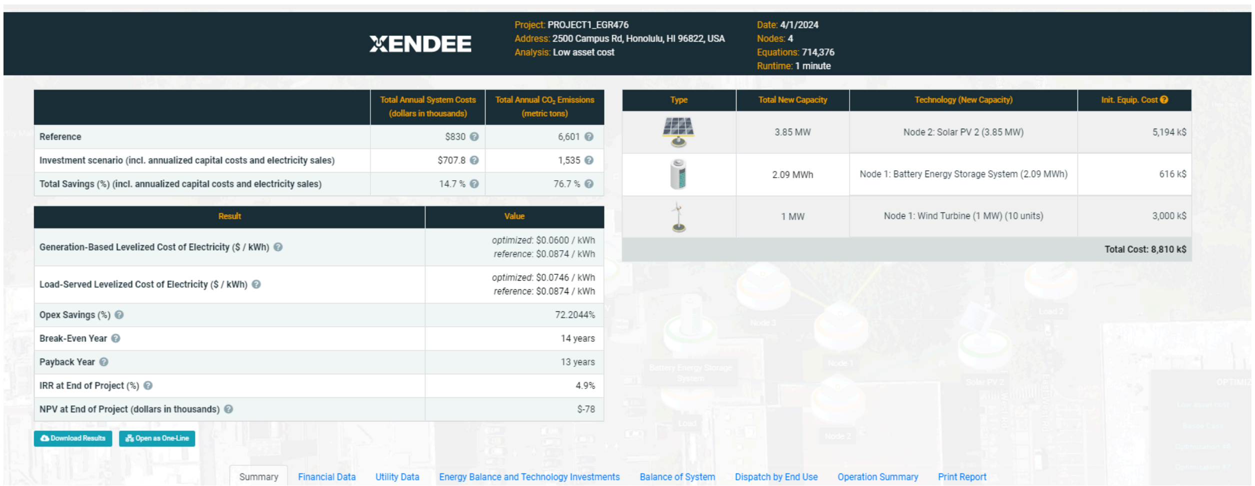
The selection of assets by Xendee for the University of Hawaiʻi at Mānoa's microgrid project includes solar PV, wind turbines, and a battery energy storage system, reflecting an integrated approach to harness renewable energy sources and enhance grid resilience. The deployment of solar PV is strategically aligned with Hawaii's ample sunlight, contributing significantly to the daytime energy supply and minimizing reliance on grid electricity, as indicated by the dispatch profiles which show solar PV meeting a substantial portion of the load during daylight. Wind turbines have been

included to provide additional power generation, particularly useful during periods when solar energy may be insufficient, thereby ensuring a more constant energy flow throughout the day. The battery energy storage system plays a critical role in peak shaving, evidenced by its utilization pattern of charging during peak solar generation and discharging during times of high demand or reduced renewable generation. This setup not only curtails demand charges but also bolsters the microgrid's capability to provide consistent energy amidst the variability of renewable sources.

Task 4: Update the asset cost inputs to include the low-end of the ranges provided by Lazard. Run a least-cost optimization termed "Low asset cost". **(10 pts)**

Provide the following:

- Screenshot of the techno-economic results



XENDEE

Project: PROJECT1_EGR476
Address: 2500 Campus Rd, Honolulu, HI 96822, USA
Analysis: Low asset cost

Date: 4/1/2024
Nodes: 4
Equations: 714,376
Runtime: 1 minute

	Total Annual System Costs (dollars in thousands)	Total Annual CO_2 Emissions (metric tons)
Reference	$830	6,601
Investment scenario (incl. annualized capital costs and electricity sales)	$707.8	1,535
Total Savings (%) (incl. annualized capital costs and electricity sales)	14.7 %	76.7 %

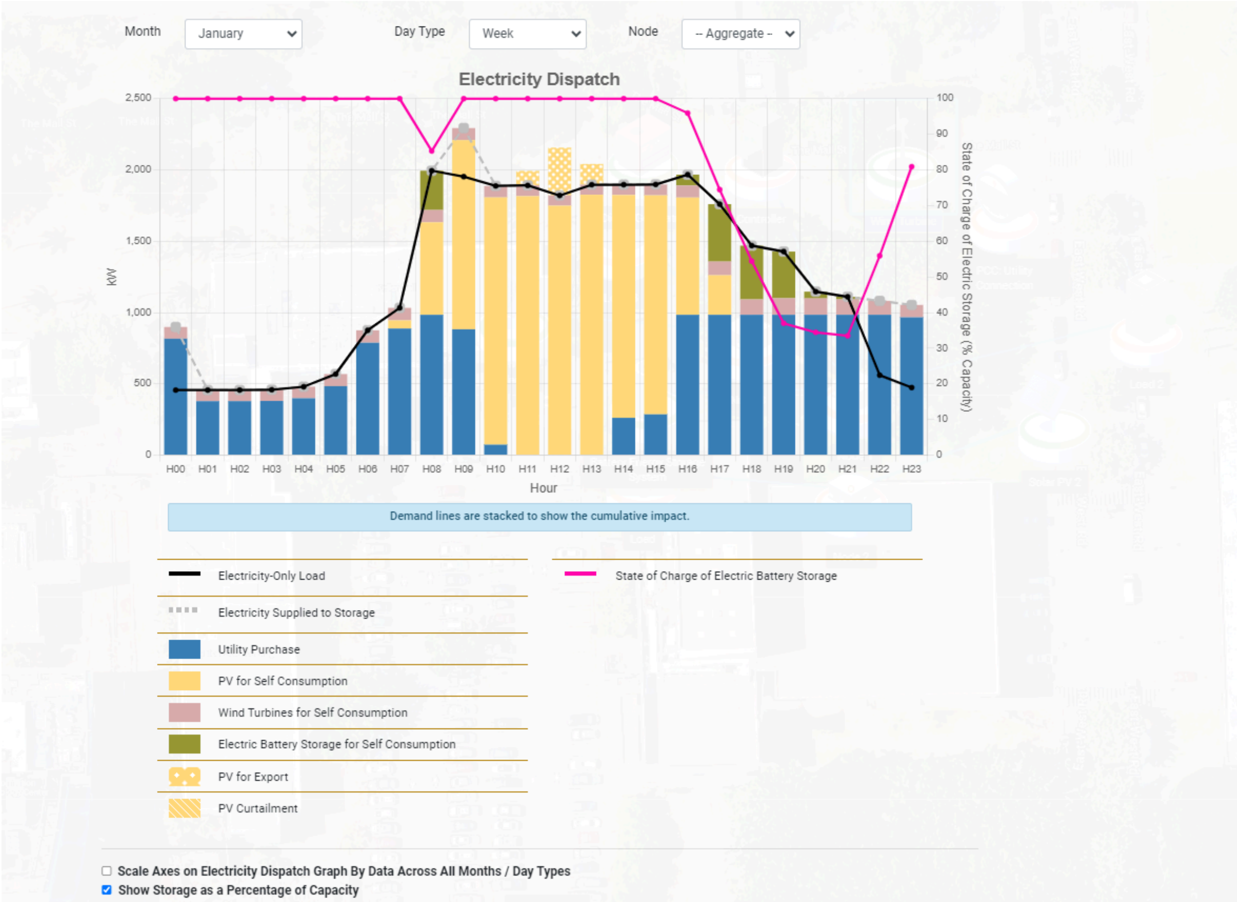
Result	Value
Generation-Based Levelized Cost of Electricity ($ / kWh)	*optimized*: $0.0600 / kWh *reference*: $0.0874 / kWh
Load-Served Levelized Cost of Electricity ($ / kWh)	*optimized*: $0.0746 / kWh *reference*: $0.0874 / kWh
Opex Savings (%)	72.2044%
Break-Even Year	14 years
Payback Year	13 years
IRR at End of Project (%)	4.9%
NPV at End of Project (dollars in thousands)	$-78

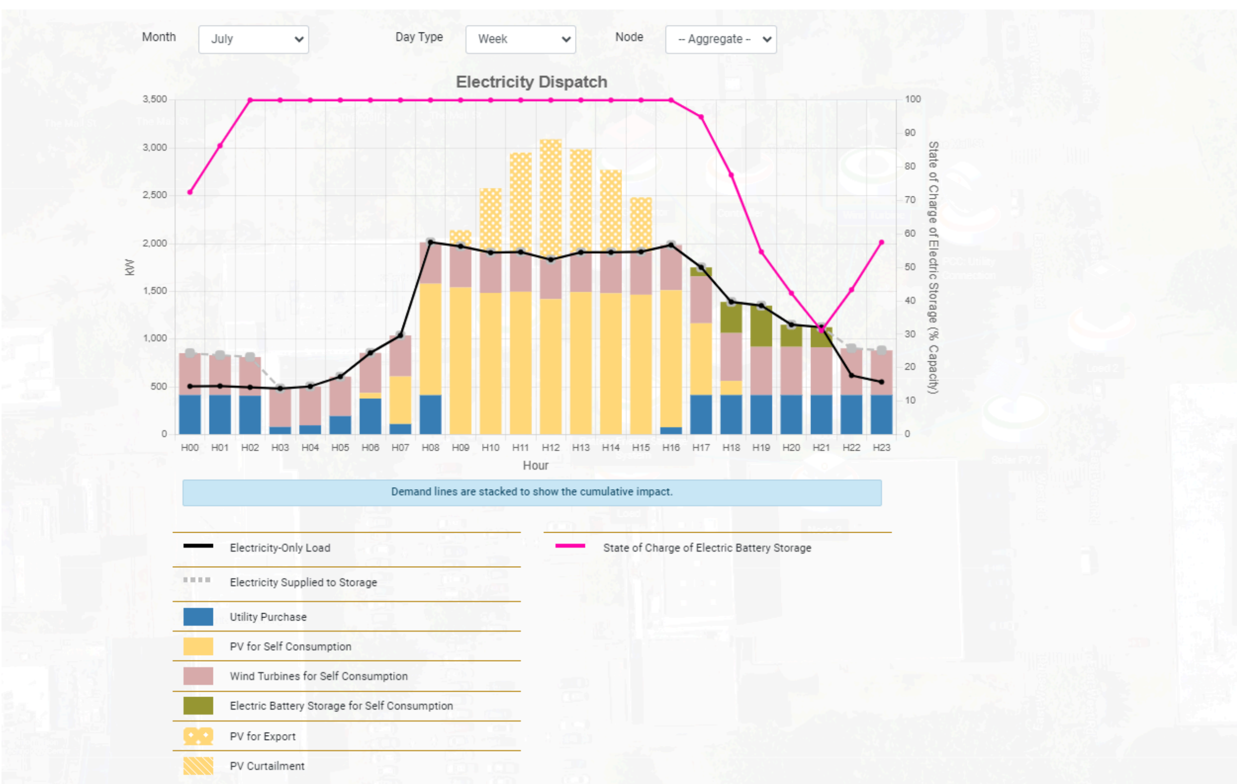
Download Results | Open as One-Line

Type	Total New Capacity	Technology (New Capacity)	Init. Equip. Cost
	3.85 MW	Node 2: Solar PV 2 (3.85 MW)	5,194 k$
	2.09 MWh	Node 1: Battery Energy Storage System (2.09 MWh)	616 k$
	1 MW	Node 1: Wind Turbine (1 MW) (10 units)	3,000 k$
			Total Cost: 8,810 k$

Summary | Financial Data | Utility Data | Energy Balance and Technology Investments | Balance of System | Dispatch by End Use | Operation Summary | Print Report

- Screenshot of dispatch for January weekday and for July weekday


Month
January
Day Type
Week
Node
-- Aggregate --
Electricity Dispatch
kW
State of Charge of Electric Storage (% Capacity)
Hour
H00 H01 H02 H03 H04 H05 H06 H07 H08 H09 H10 H11 H12 H13 H14 H15 H16 H17 H18 H19 H20 H21 H22 H23
0 500 1,000 1,500 2,000 2,500
0 10 20 30 40 50 60 70 80 90 100
Demand lines are stacked to show the cumulative impact.
Electricity-Only Load
State of Charge of Electric Battery Storage
Electricity Supplied to Storage
Utility Purchase
PV for Self Consumption
Wind Turbines for Self Consumption
Electric Battery Storage for Self Consumption
PV for Export
PV Curtailment
Scale Axes on Electricity Dispatch Graph By Data Across All Months / Day Types
Show Storage as a Percentage of Capacity


Month
July
Day Type
Week
Node
-- Aggregate --
Electricity Dispatch
kW
State of Charge of Electric Storage (% Capacity)
Hour
H00 H01 H02 H03 H04 H05 H06 H07 H08 H09 H10 H11 H12 H13 H14 H15 H16 H17 H18 H19 H20 H21 H22 H23
0 500 1,000 1,500 2,000 2,500 3,000 3,500
0 10 20 30 40 50 60 70 80 90 100
Demand lines are stacked to show the cumulative impact.
Electricity-Only Load
State of Charge of Electric Battery Storage
Electricity Supplied to Storage
Utility Purchase
PV for Self Consumption
Wind Turbines for Self Consumption
Electric Battery Storage for Self Consumption
PV for Export
PV Curtailment

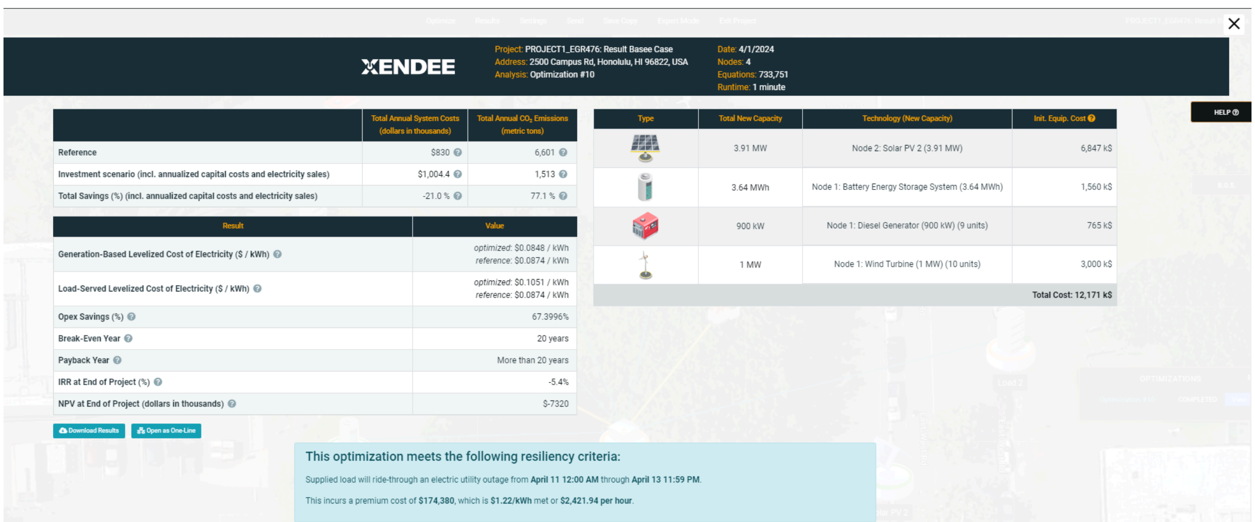
- Short paragraph with 3-5 sentences discussing why assets were selected by Xendee (or not selected) and include description of the dispatch profile to defend your statements (e.g., battery used for peak shaving).

After updating the asset cost inputs to reflect the lower end of Lazard's cost range and running a "Low asset cost" optimization, Xendee selected a diverse mix of solar PV, battery storage, and wind turbines for the University of Hawaiʻi at Mānoa's microgrid. The larger capacity of solar PV, amounting to 3.85 MW, highlights an effort to maximize the use of Hawaii's abundant solar resources for cost-effective, renewable power generation. The battery storage system, at 2.09 MWh, is likely chosen not only for its potential in peak shaving—where stored energy is used during times of high electricity prices or demand—but also for enhancing the reliability of power supply when solar or wind generation is intermittent. A smaller inclusion of wind turbines at 1 MW indicates a supplementary role to the solar generation, likely catering to periods when solar resources are minimal. The dispatch profiles exhibit a significant reliance on solar PV during daylight hours, with batteries supplying power during peak periods and reducing utility purchases, thereby optimizing costs and enhancing the project's sustainability.

Task 5: Return asset costs to their nominal values from Task 3. Now run a Resiliency analysis for a 3-day outage **(20 pts)**

Provide the following:

- Screenshot of the techno-economic results



	Total Annual System Costs (dollars in thousands)	Total Annual CO_2 Emissions (metric tons)
Reference	$830	6,601
Investment scenario (incl. annualized capital costs and electricity sales)	$1,004.4	1,513
Total Savings (%) (incl. annualized capital costs and electricity sales)	-21.0 %	77.1 %

Result	Value
Generation-Based Levelized Cost of Electricity ($ / kWh)	*optimized*: $0.0848 / kWh *reference*: $0.0874 / kWh
Load-Served Levelized Cost of Electricity ($ / kWh)	*optimized*: $0.1051 / kWh *reference*: $0.0874 / kWh
Opex Savings (%)	67.3996%
Break-Even Year	20 years
Payback Year	More than 20 years
IRR at End of Project (%)	-5.4%
NPV at End of Project (dollars in thousands)	$-7320

Download Results | Open as One-Line

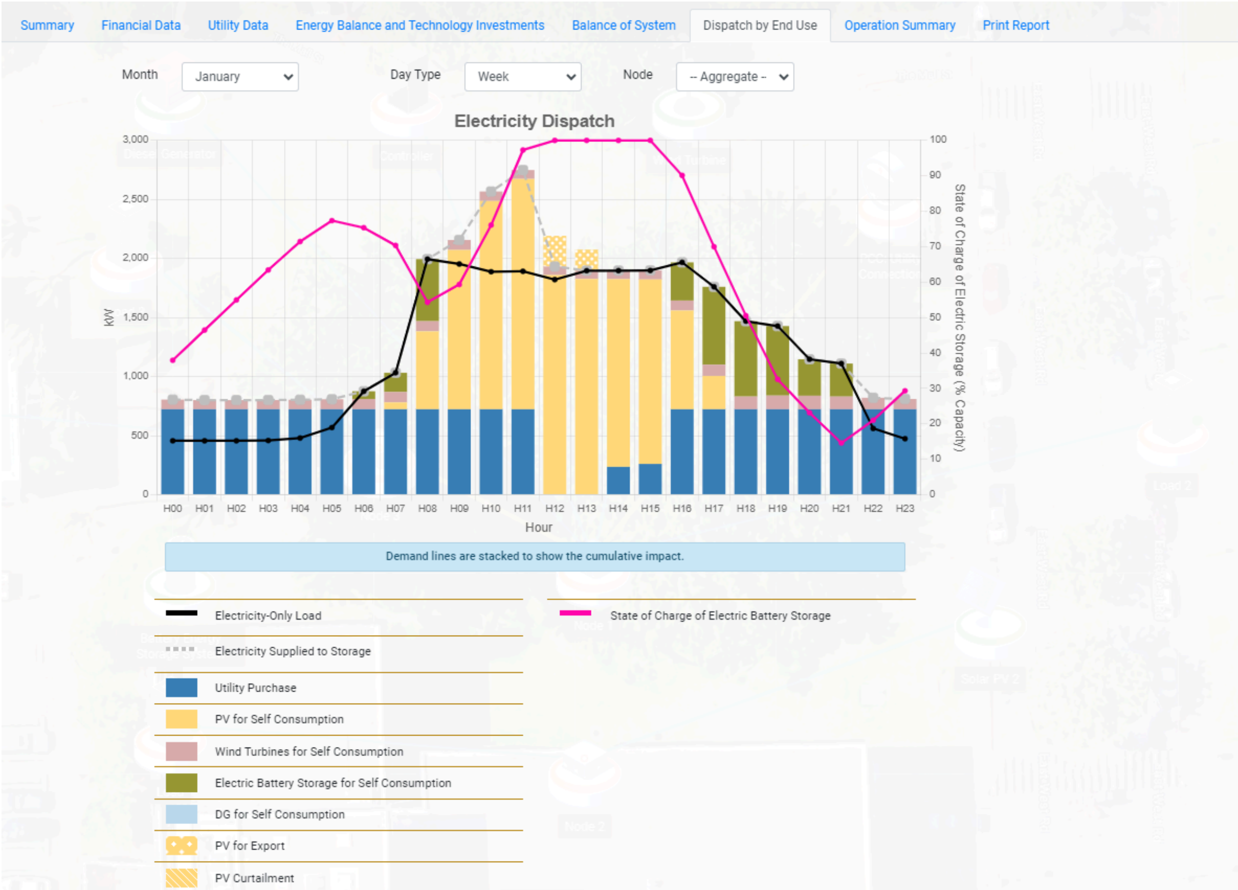
Type	Total New Capacity	Technology (New Capacity)	Init. Equip. Cost
	3.91 MW	Node 2: Solar PV 2 (3.91 MW)	6,847 k$
	3.64 MWh	Node 1: Battery Energy Storage System (3.64 MWh)	1,560 k$
	900 kW	Node 1: Diesel Generator (900 kW) (9 units)	765 k$
	1 MW	Node 1: Wind Turbine (1 MW) (10 units)	3,000 k$
			Total Cost: 12,171 k$

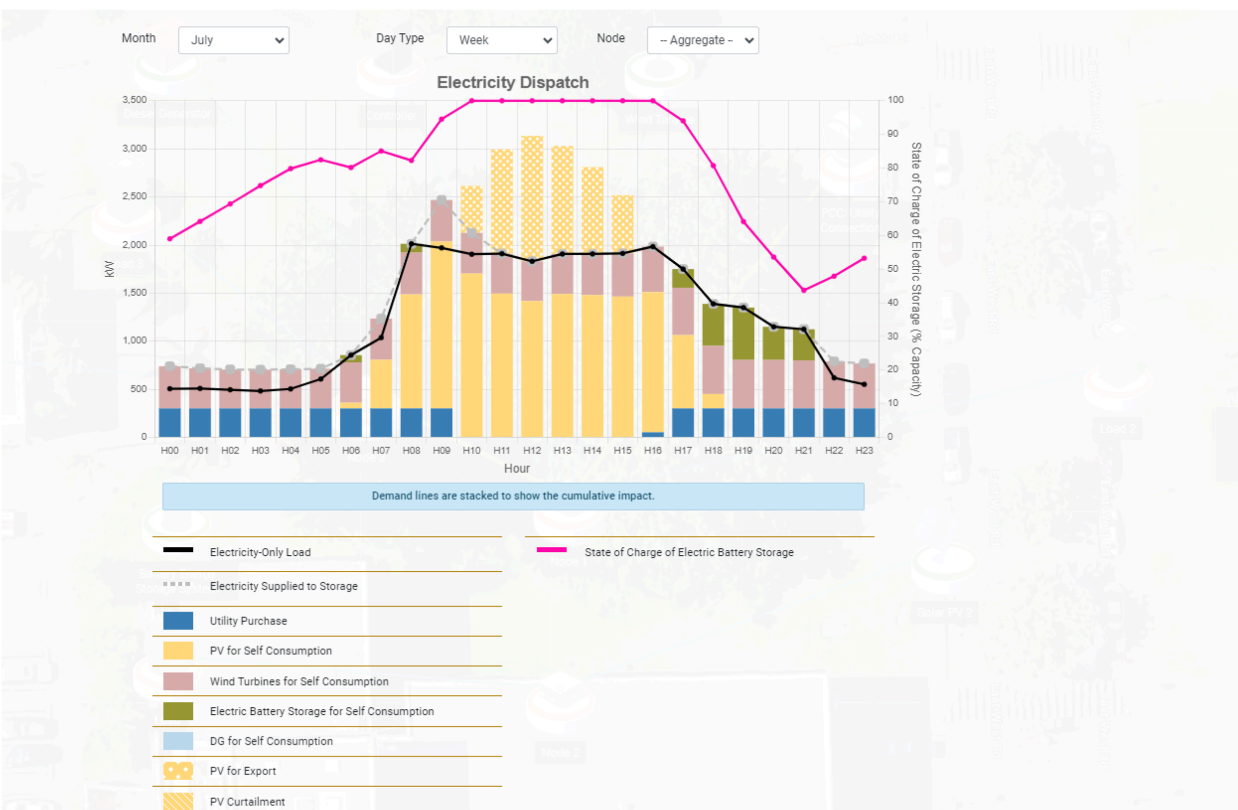
This optimization meets the following resiliency criteria:

Supplied load will ride-through an electric utility outage from **April 11 12:00 AM** through **April 13 11:59 PM**.

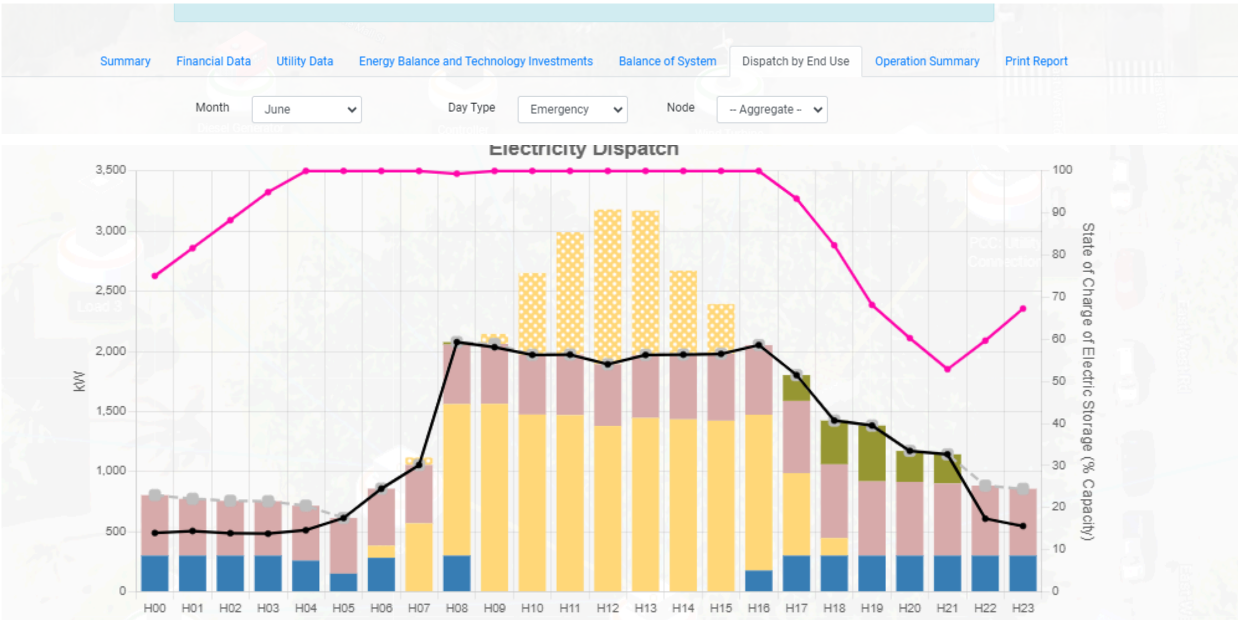
This incurs a premium cost of **$174,380**, which is **$1.22/kWh** met or **$2,421.94 per hour**.

- Screenshot of dispatch for January weekday and for July weekday


Summary
Financial Data
Utility Data
Energy Balance and Technology Investments
Balance of System
Dispatch by End Use
Operation Summary
Print Report
Month
January
Day Type
Week
Node
-- Aggregate --
Electricity Dispatch
kW
3,000
2,500
2,000
1,500
1,000
500
0
State of Charge of Electric Storage (% Capacity)
100
90
80
70
60
50
40
30
20
10
0
H00 H01 H02 H03 H04 H05 H06 H07 H08 H09 H10 H11 H12 H13 H14 H15 H16 H17 H18 H19 H20 H21 H22 H23
Hour
Demand lines are stacked to show the cumulative impact.
Electricity-Only Load
State of Charge of Electric Battery Storage
Electricity Supplied to Storage
Utility Purchase
PV for Self Consumption
Wind Turbines for Self Consumption
Electric Battery Storage for Self Consumption
DG for Self Consumption
PV for Export
PV Curtailment


Month
July
Day Type
Week
Node
-- Aggregate --
Electricity Dispatch
kW
3,500
3,000
2,500
2,000
1,500
1,000
500
0
State of Charge of Electric Storage (% Capacity)
100
90
80
70
60
50
40
30
20
10
0
H00 H01 H02 H03 H04 H05 H06 H07 H08 H09 H10 H11 H12 H13 H14 H15 H16 H17 H18 H19 H20 H21 H22 H23
Hour
Demand lines are stacked to show the cumulative impact.
Electricity-Only Load
State of Charge of Electric Battery Storage
Electricity Supplied to Storage
Utility Purchase
PV for Self Consumption
Wind Turbines for Self Consumption
Electric Battery Storage for Self Consumption
DG for Self Consumption
PV for Export
PV Curtailment

- Screenshot of dispatch for the Emergency period when the outage occurs



- Short paragraph with 4-7 sentences discussing why assets were selected by Xendee (or not selected) and include description of the dispatch profile to defend your statements (e.g., generator needed to guarantee power). *Be sure to mention if and why the assets and sizes from Task 5 are different from Task 3.*

The Xendee optimization for the University of Hawaiʻi at Mānoa's microgrid project has strategically selected assets that align with the university's energy needs and operational objectives. The inclusion of a considerable solar PV capacity and a complementary battery energy storage system underlines a commitment to clean energy and sustainability, harnessing Hawaii's abundant solar resources. The solar PV directly offsets daytime energy needs, with excess power used to charge the battery storage, which then provides energy during peak demand periods or when solar production is insufficient, effectively shaving peak loads. The presence of wind turbines and diesel generators within the asset mix demonstrates a layered approach to resilience, with the turbines contributing to the renewable energy portfolio and the diesel generators serving as a reliable backstop to guarantee power during periods when renewable sources are not available or during system contingencies. The dispatch profile indicates that solar and wind are the primary energy sources, with storage acting as a buffer and diesel generators as a last resort, ensuring continuous power supply and operational resilience for the critical facility. This carefully designed energy system aims to provide an economically feasible and environmentally sound solution for the university's energy demands.

The selection and sizing of assets in Task 5 as compared to Task 3 could be due to various factors, including the optimization goals set within Xendee, such as cost minimization or CO2 emission reduction, and the operational constraints or resiliency requirements of the University of Hawaiʻi at Mānoa. Variations in asset sizes may result from updated cost inputs or a refined understanding of the load profiles and patterns, leading to more precise sizing to avoid over- or under-provisioning. Additionally, any changes could reflect new or more accurate data on the expected performance of the technologies, such as improvements in solar PV efficiency or battery storage capacity. If there is a shift toward greater resiliency, it might explain an increased reliance on storage or backup generators to ensure stability during outages or fluctuations in renewable generation. Each iteration of the design

aims to strike a balance between technical feasibility, economic viability, and the institution's sustainability targets, which could account for shifts in the energy strategy from one task to another.