Energy Exchange[SM]

Be Efficient And Resilient

U.S. Department of Energy

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Incorporating On-Site Generation Design Using a Comprehensive Energy Strategy

Techno-Economic Energy Modeling of Distributed Energy Technologies

Presentation Overview

- PV + storage considerations
- Comprehensive analysis using REopt
- REopt Lite web tool

PV + Storage Considerations

Solar PV and Battery Storage Overview

- Federal agencies have long history of implementing grid-connected solar PV projects for cost savings
  - Value stream is well understood: Electricity is generated when the sun is shining, and lowers utility electricity purchases
- Opportunities for grid-connected battery storage are emerging, and more complicated
  - Value stream is more complicated: there are multiple ways to provide savings, but they depend on how the battery is operated
- When configured to do so, PV + storage can provide back-up power in the event on an outage
  - This requires additional equipment at added cost

Technicians install one of the 3,632 solar modules on NREL's parking garage. The garage can produce up to 1.15 megawatts. *NREL 21487*

NREL and Raytheon perform system level testing on the Miramar ZnBr Flow Battery. *NREL 32582*

Quiz tip: A typical solar PV system requires modification to provide backup generation during an extend outage

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Microgrid-Ready PV

- If there are future microgrid plans at a site, consider microgrid ready PV
- Microgrid ready PV: the practice of including low- or no-cost measures when installing a PV system that will facilitate the integration of that PV system into a microgrid at a later point
- Microgrid ready PV includes:
  - Inverters capable of operating in both grid-interactive and microgrid modes
  - Inverters capable of responding to commands from a microgrid controller
  - Reserved space near the PV system for microgrid and equipment expansions
- Check out FEMP's factsheet on Microgrid-Ready Solar PV – Planning for Resiliency: https://www.nrel.gov/docs/fy18osti/70122.pdf

Range of PV + Storage Use Cases

	Off Grid PV + Storage	Grid Connected PV + Storage	Grid Connected PV + Storage with Microgrid	PV + Storage for Large-Scale Power Generation
Purpose	Providing continuous power in lieu of utility	Lowering cost of utility purchases	Lowering cost of utility purchases Providing power during grid outage	Large-scale generation for off-site sale
Why/Where it works	• Remote sites with high fuel costs • Low grid reliability	• High demand charges • Time of use (TOU) rates • Ancillary service markets	• High demand charges • TOU rates • Ancillary service markets • Resilience requirements	• Deregulated market • Interested offtaker • large land-availability
Primary Power Supply	Distributed energy resources (DERs) (typically including generators)	Grid + DERs	Grid + DERs	Grid only
Back-up	None	None	DERs	Typically none, but could be possible

Quiz tip: Solar PV plus batteries can be cost-competitive when compared to back-up diesel generators, but it depends on the location and application

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RE + Storage Value Streams by Use Case

Value Stream	Description	Off Grid	Grid Connected	Large Scale
Fuel Offset	Offset fuel cost in off-grid remote locations	X		
Demand charge reduction	Use stored energy to reduce demand charges on utility bills		X	
Energy Arbitrage	Energy time-of-use shift (from on-peak to off-peak hours or selling during high cost and charging during low cost)		X	X
Demand response	Utility programs that pay customers to lower demand during system peaks		X	
Frequency regulation and capacity markets	Stabilize frequency on moment-to-moment basis or supply spinning, non-spinning reserves		X	X
Voltage support	Insert or absorb reactive power to maintain voltage ranges on distribution or transmission system			X
Transmission & Distribution Upgrade Deferral	Deferring the need for transmission or distribution system upgrades, e.g. via system peak shaving			X
Resiliency / Back-up power	Using battery to sustain a critical load during grid outages		X	

Quiz tip: During normal grid connected operations, battery storage has the potential to provide demand charge reduction and time-of-use energy arbitrage, and enable participation in demand response programs

Drivers for On-Site Project Economics

Resource

Technology Costs & Incentives

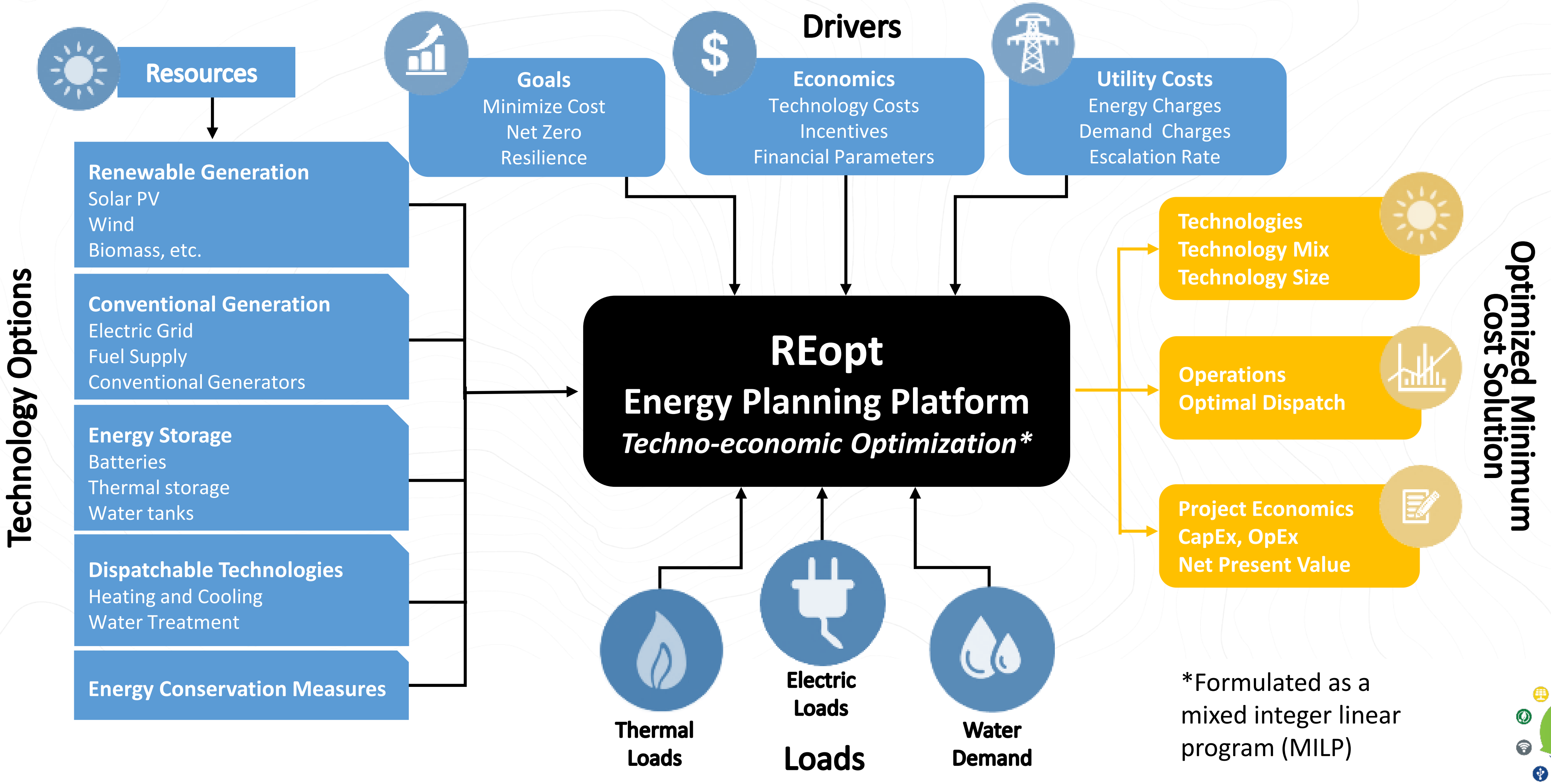
Utility Cost & Consumption

Financial Parameters

Space Available

Comprehensive Analysis Using REopt

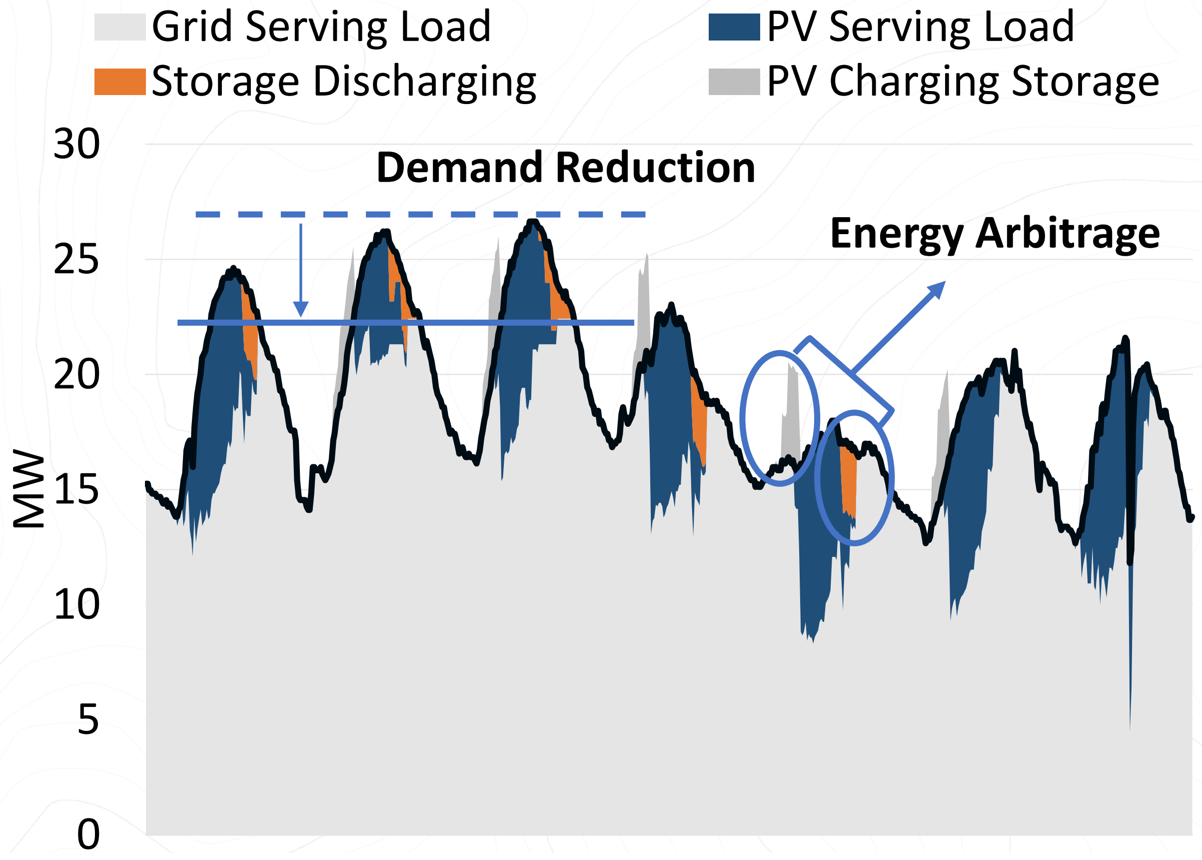
REopt Inputs and Outputs



*Formulated as a mixed integer linear program (MILP)

PV + Storage for Demand Reduction & Energy Arbitrage

- REopt considers trade-off between capital costs and optimal cost savings under complex utility tariff
- Results show 12.4MW PV + 2.4 MW:3.7 MWh storage can provide $19.3 million net present value (NPV)
- Battery is only economical when paired with PV at this site due to wide peaks

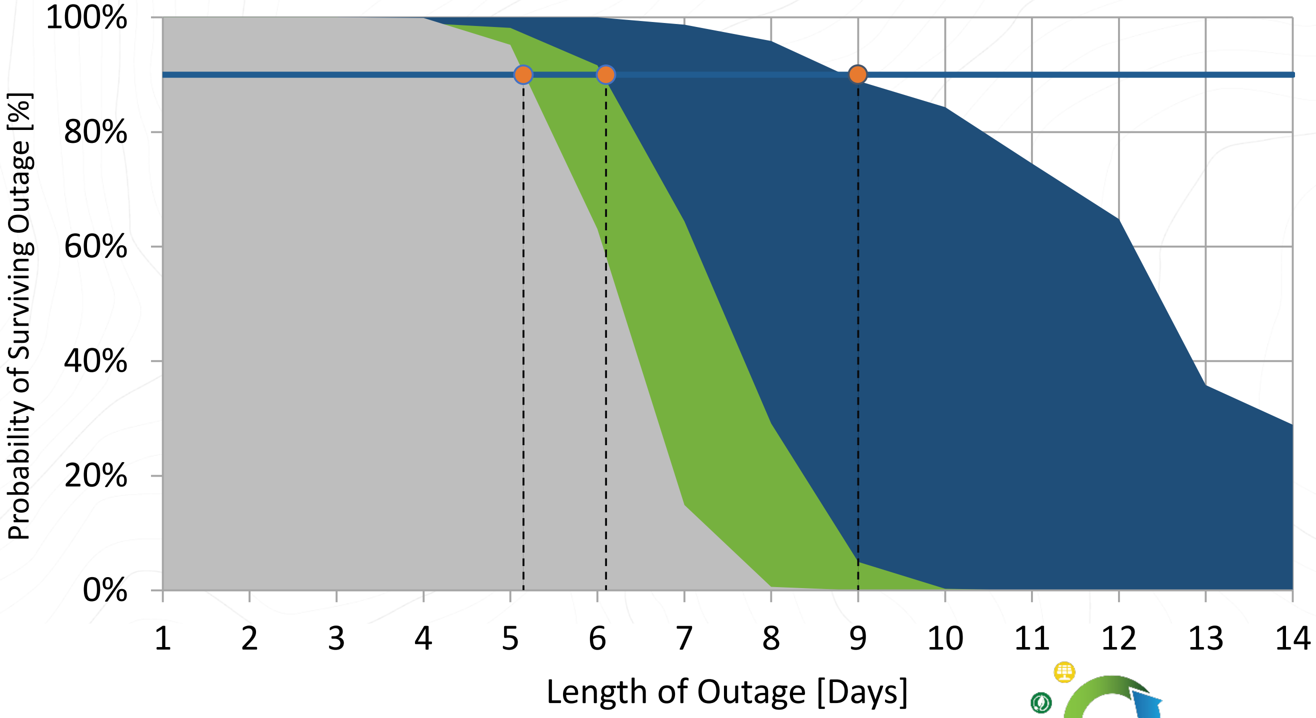


Surviving Outage vs. Cost Savings

- REopt evaluates grid outages and durations to compared number of hours the site could survive with a diesel generator and fixed fuel supply vs. generator augmented with PV and battery

- Found that lowest cost solution could lower lifecycle cost of electricity and provide 1 extra day of outage survivability

	Generator	Solar PV	Storage	Lifecycle Cost	Outage
1. Base case	2.5 MW	-	-	$20 MM	5 days
2. Lowest cost solution	2.5 MW	625 kW	175 kWh	$18.5 MM	6 days
3. Proposed system	2.5 MW	2 MW	500 kWh	$19.9 MM	9 days



Market Revenues for Back-Up Generators

- **Description:** Back-up generators are not typically utilized for economic dispatch, what value can they provide
- **Technologies:** Natural gas and diesel generators
- **Impact:** The overall cost of back-up generation can be lowered, but opportunities vary across US

Table 10. Revenue Opportunities Modeled.

Revenue Opportunity	ERCOT/TX	PJM/NJ	Florida
Tariff Switching to Interruptible Rate			Yes
Peak Shaving	Yes	Yes	Yes
Energy Self-generation	Yes	Yes	Yes
Coincident Peak Reduction	Yes	Yes	
Wholesale Real-time Pricing	Yes	Yes	
Spinning Reserve Market		Yes	
Emergency Standby Program	Yes	Yes	

Table 12. Total Unit Costs and Revenues in Present Value.

Generator Type	Diesel			Natural Gas		
Region	TX	FL	NJ	TX	FL	NJ
CAPEX + Non-fuel O&M ($/kW)	-$1,205			-$1,405		
Total Revenues/Savings ($kW)	$968	$1,380	$3,064	$1,091	$1,380	$3,153
Fuel Cost for Revenue Generation (Grid Services) ($/kW)	-$187	$0	-$341	-$199	$0	-$272
NPV of Backup Power per Unit ($/kW)	-$425	$175	$1,518	-$513	$25	$1,476

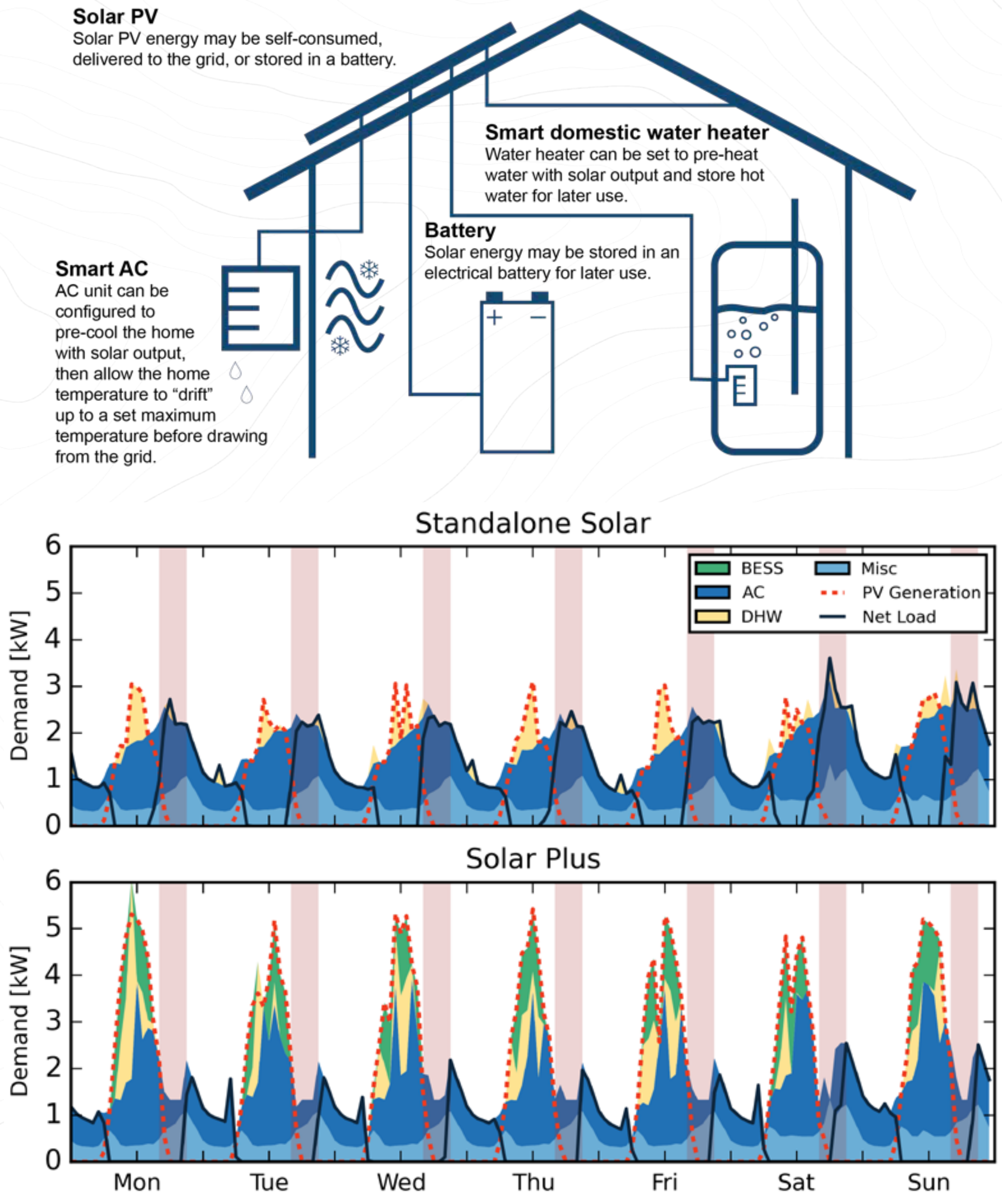
https://www.nrel.gov/docs/fy19osti/72509.pdf

Aligning Generation & Load with Storage & Demand Response

- **Description:** Evaluating controllable load (smart A/C and water heater) and storage options to improve customer economics of solar under post-net metering utility tariffs

- **Technologies:** Solar, storage, buildings

- **Impact:** Flexible loads increase the value of solar by aligning generation to load to maximize value



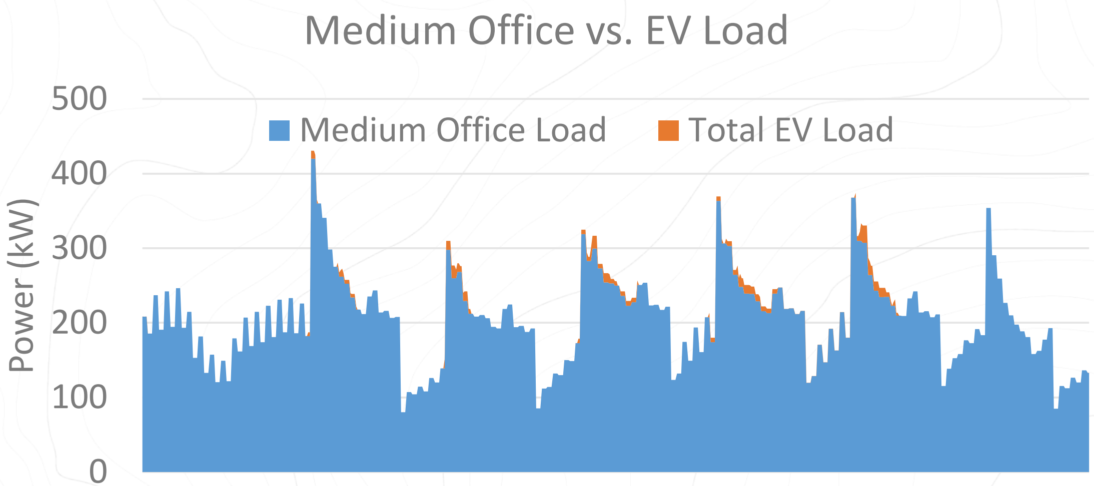
Eric O'Shaughnessy, Dylan Cutler, Kristen Ardani, Robert Margolis (2018). "Solar Plus: Optimization of Distributed Solar PV through Battery Storage and Dispatchable Load in Residential Buildings." *Applied Energy,* March 2018, vol. 213, pp 11-21. https://doi.org/10.1016/j.apenergy.2017.12.118

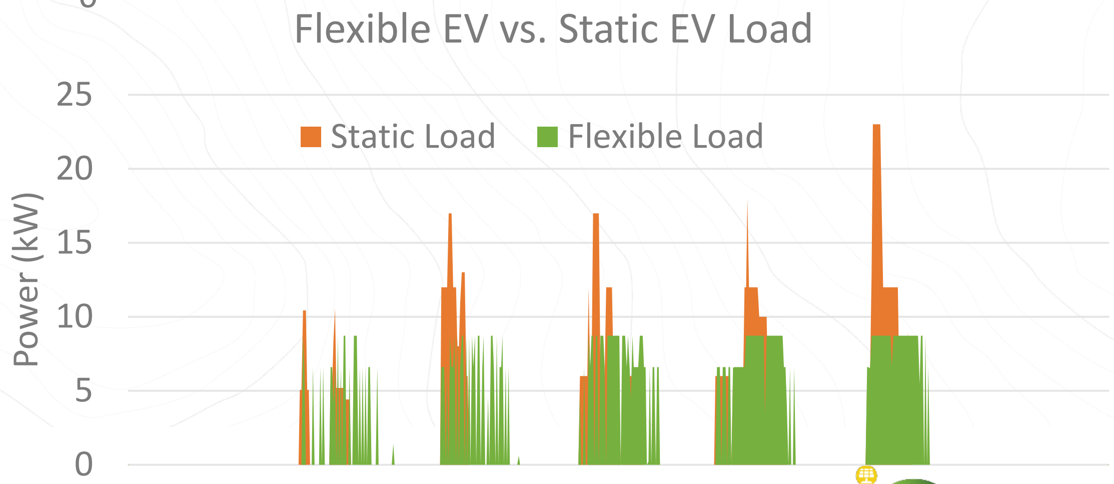
Evaluating Impacts of EV Load in Conjunction with Building Load

- **Description:** How can the impacts of electric vehicles (EV) charging stations loads be mitigated?

- **Technologies:** EV charging stations, solar PV, stationary storage

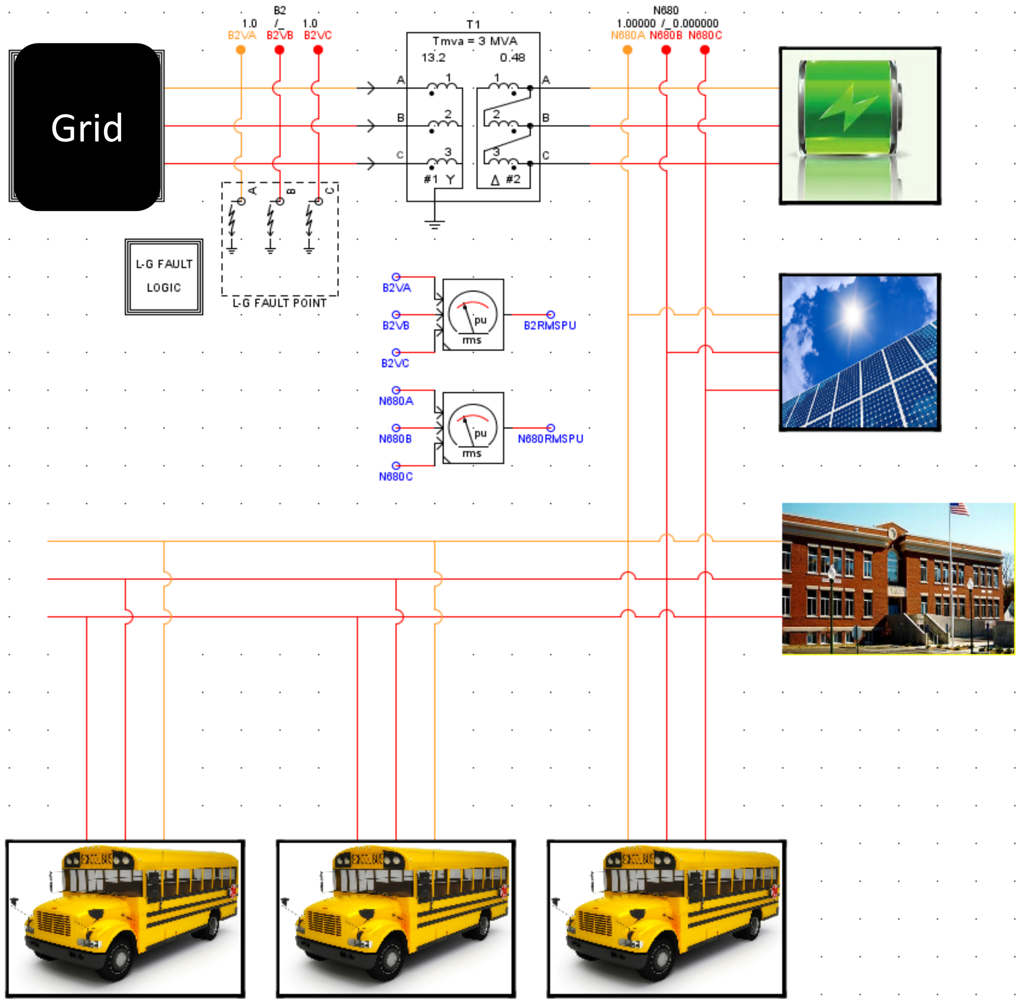
- **Impact:** The cost of EV loads can be mitigated through co-location with building load, PV and stationary storage deployment, and optimizing EV charging times





Integrating Loads and Diverse DER Technologies

- **Description:** Electrification of transportation fleets provide an opportunity for optimizing multiple DER technologies.
- **Technologies:** Mobility, storage, buildings, solar, advanced system integration controls
- **Impact:** Develop and validate an integrated framework to optimize mobility with solar, buildings and storage to maximize value

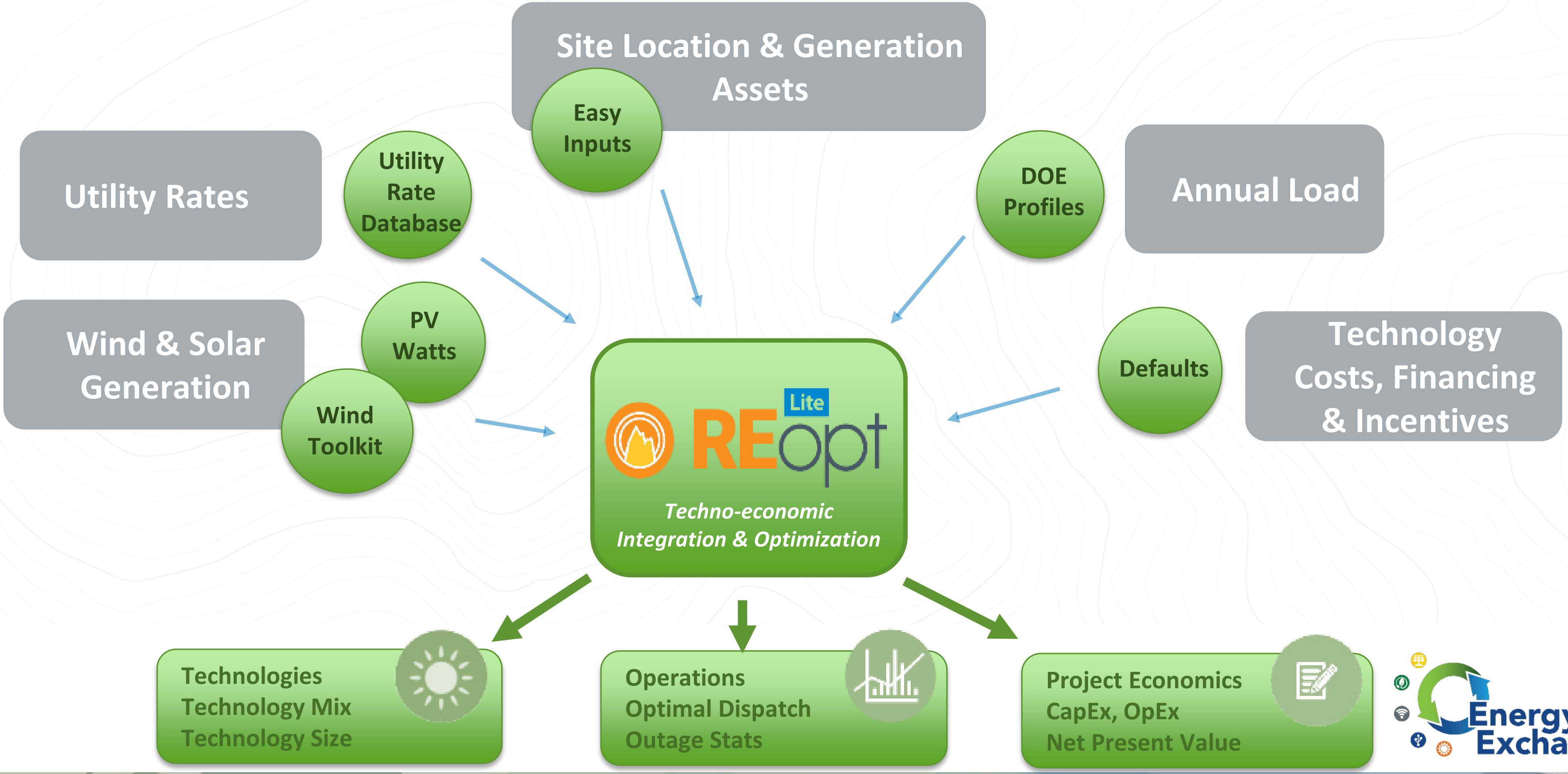


REopt Lite

Free Web Tool

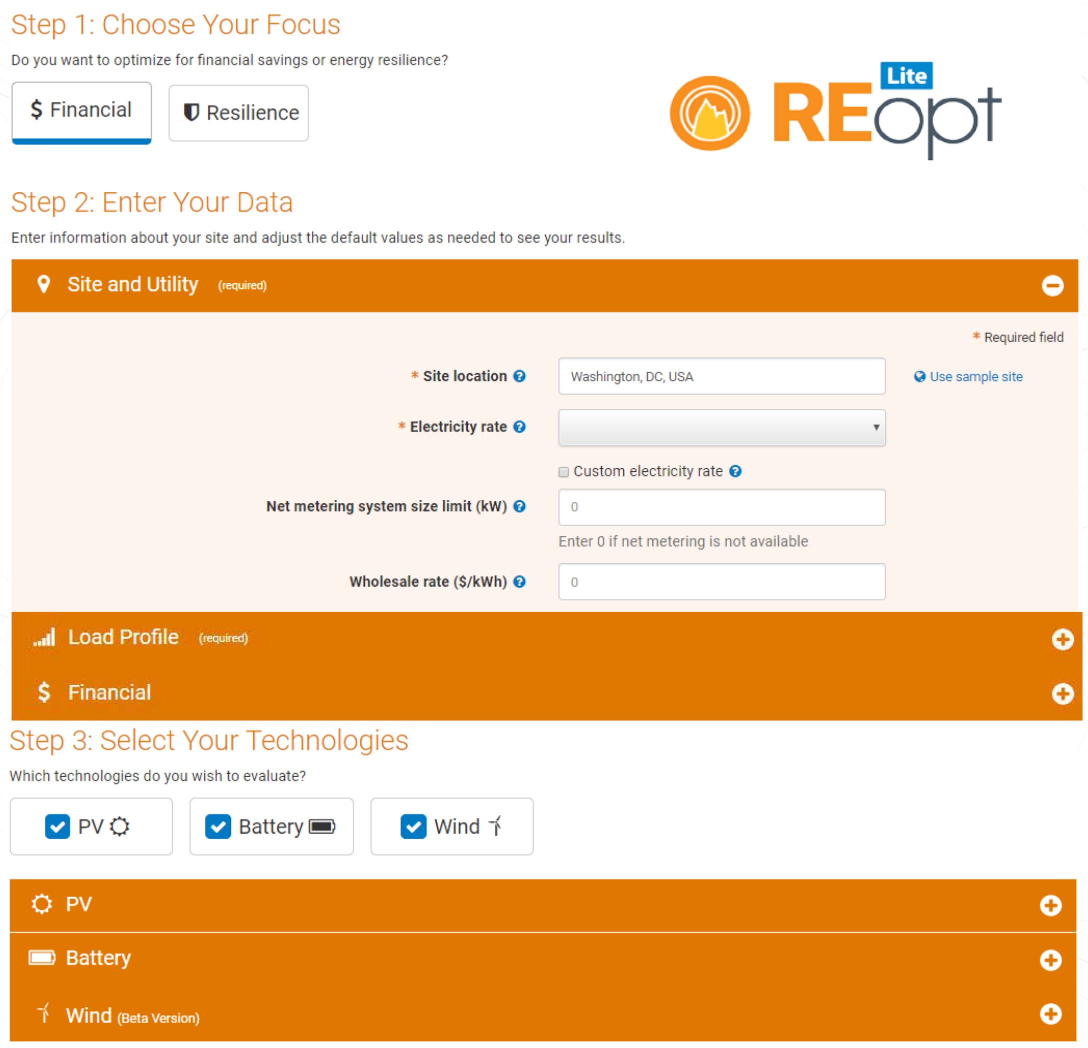
New system decisions are complex…

… REopt Lite is here to help



REopt Lite Web Tool

- **REopt Lite** is a web tool that offers a no-cost subset of NREL's more comprehensive REopt model
- **Financial mode** optimizes PV, wind, and battery system sizes and battery dispatch strategy to minimize life cycle cost of energy
- **Resilience mode** optimizes PV, wind, and storage systems along with exiting back-up generators to sustain critical load during grid outages
- To access REopt Lite: https://reopt.nrel.gov/tool



Summary Results Include System Sizes & Savings

Results for Your Site

These results from REopt Lite summarize the economic viability of PV and battery storage at your site. You can edit your inputs to see how changes to your energy strategies affect the results.

Edit Inputs

REopt Lite

Your recommended solar installation size

781 kW
PV size

Measured in kilowatts (kW) of direct current, this recommended size minimizes the life cycle cost of energy at your site.

Your recommended battery power and capacity

131 kW
battery power

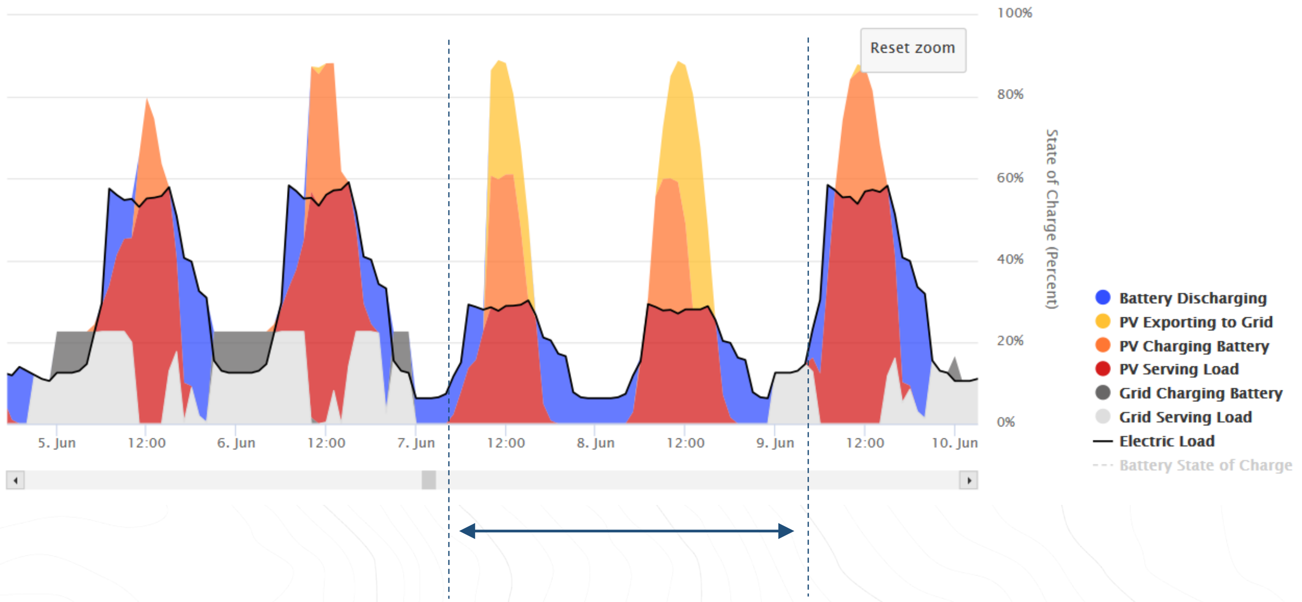
556 kWh
battery capacity

This system size minimizes the life cycle cost of energy at your site. The battery power and capacity are optimized for economic performance.

Your potential life cycle savings (20 years)

This is the net present value of the savings (or costs if negative) realized by the project based on the difference between the life cycle energy cost of doing business as usual compared to the optimal case.

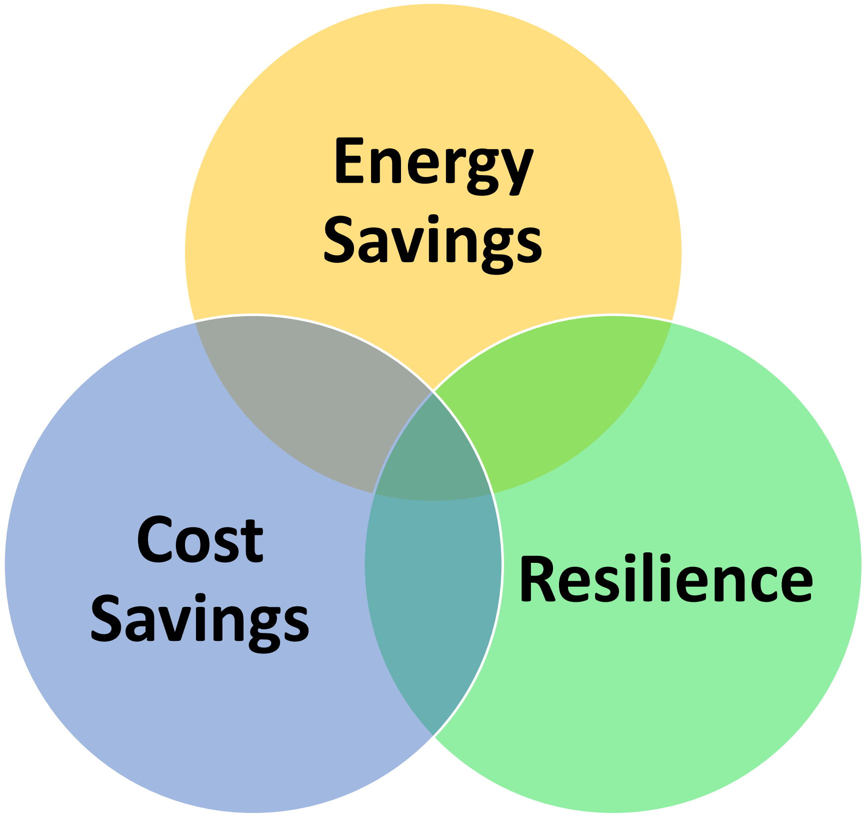
$439,275



Outage occurring June 6–7
Critical load 50% of typical load

Conclusion

- RE + storage can provide revenue streams and savings while grid connected
  - Savings may allow for the incorporation of additional microgrid components
- When integrated into a microgrid, RE + storage can increase survival time during a grid outage when fuel supplies are limited
- Techno-economic modeling can quantify economic and resilience benefits



Thank you!

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Disclaimer

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