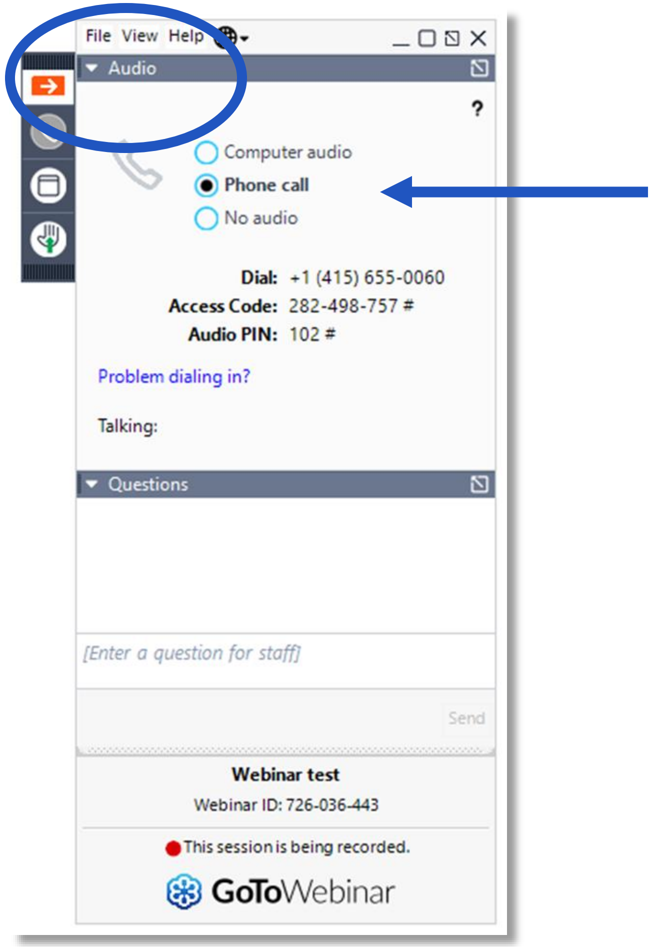
Welcome to the webinar.
We will begin at the top of the hour.

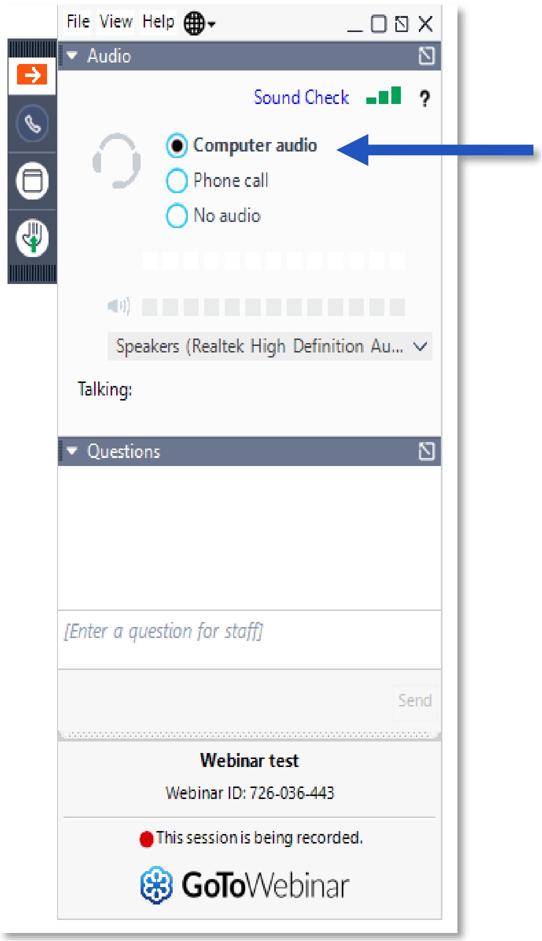
Maximize the Revenue of Utility-Scale Energy Storage — Standalone or Hybrid

Introducing new HOMER® Front modeling software | 2022

Empowering Trust®

Can’t hear the audio?





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2. Click on the phone bubble.
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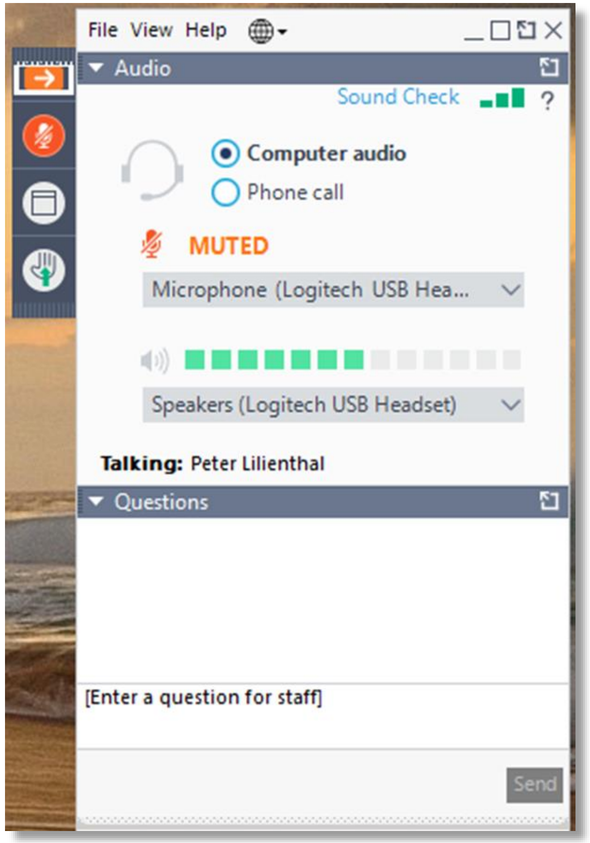
Your questions are welcome



Meet your presenters

David Mintzer

Director, Energy Storage Advisory

UL Renewables

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Steffi Klawiter

Product manager, Hybrids

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Kyle Stauffer

Senior project engineer

UL Renewables

Agenda

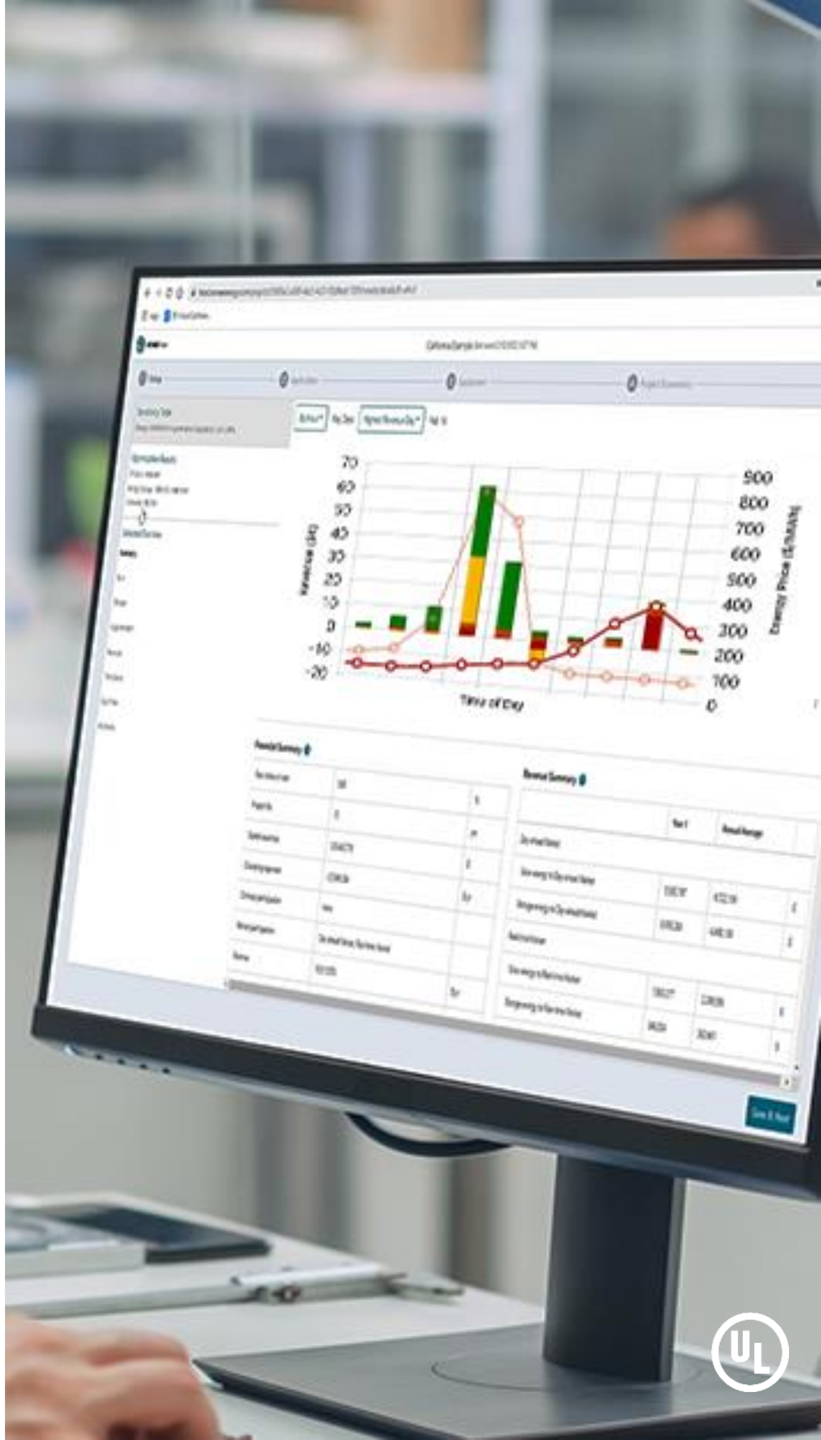
The role of energy storage in the clean energy transition
Christina Duong

Challenges with system complexity
David Mintzer

Challenges with system complexity: Markets
Christina Duong

Challenges with system complexity: Storage
Steffi Klawiter

View of HOMER® Front through case studies
Steffi Klawiter



UL: A history of trust

1894 Founded

1980 Certification of the first **solar collector**

1992 **HOMER Software** developed by Dr. Peter Lilienthal at NREL

2008 UL opens largest **photovoltaic** testing and certification facility

2009 HOMER Software commercialized by **HOMER Energy**

2012 UL acquires **renewable advisory** firm DEWI

2014 **HOMER Pro** released

UL publishes **UL 9540,*** first safety Standard to address energy storage

2016 UL acquires AWS Truepower with expertise in **solar advisory services**

2017 Harmonization of UL 1703** PV module safety Standard completed with the publication of **UL 61730-1** and **UL 61730-2†**

2018 **HOMER Grid** released

2019 UL acquires **HOMER Energy**

UL 7103,ǂ the new Standard for building integrated photovoltaics, is published

2020 UL is an IE/ Owner's Engineer on 11 GW (70 projects) wind and 3.5 GW (34 projects) solar

2022 **HOMER Front** released

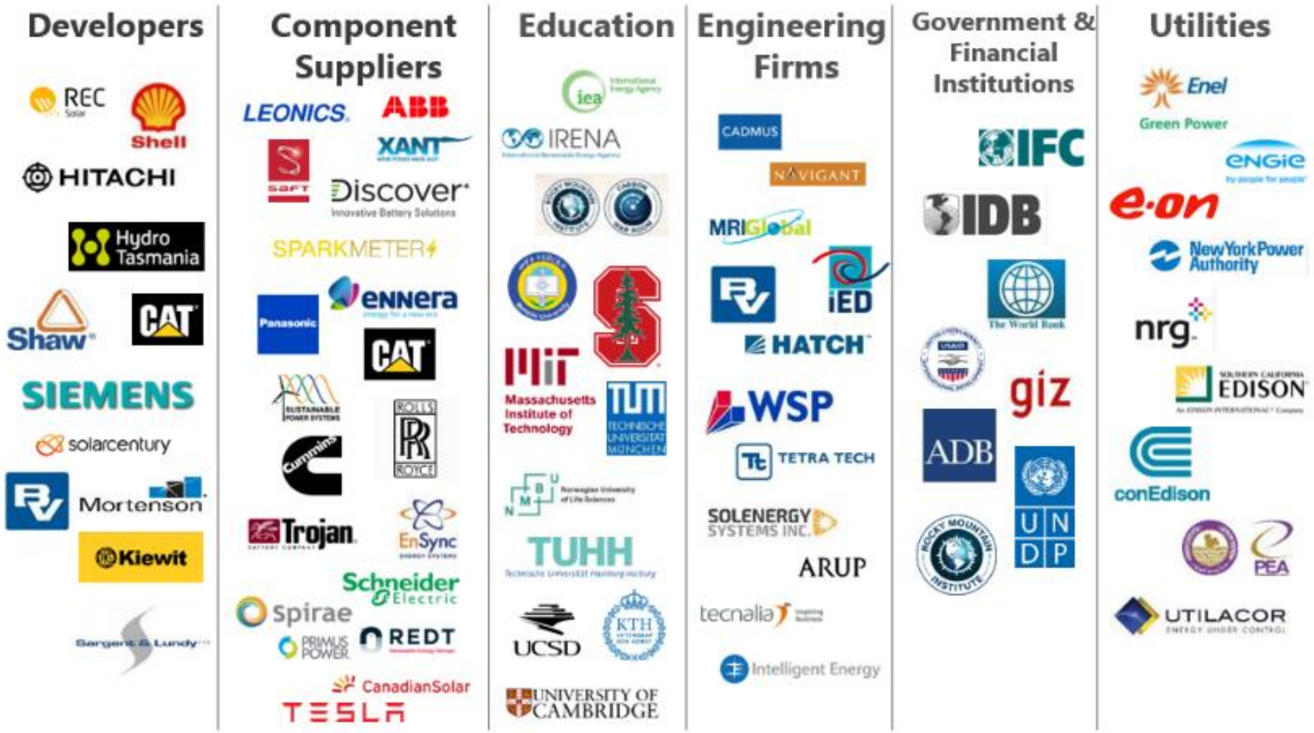
*UL 9540, the Standard for Energy Storage Systems and Equipment
**UL 1703, the Standard for Flat-Plate Photovoltaic Modules and Panels
†UL 61730-1 and -2, the Standards for Photovoltaic (PV) Module Safety Qualification – Requirements for Construction and Testing
ǂUL 7103, the Outline of Investigation for Building-Integrated Photovoltaic Roof Coverings

Advanced solar and storage advisory services

Feasibility	Development	Preconstruction and financing	Construction	Operations, repowering and refinancing
Conceptual designs and feasibility studies	Energy and storage modeling	Independent engineering	Construction monitoring	Operational reviews

Trusted global excellence in hybrid analysis

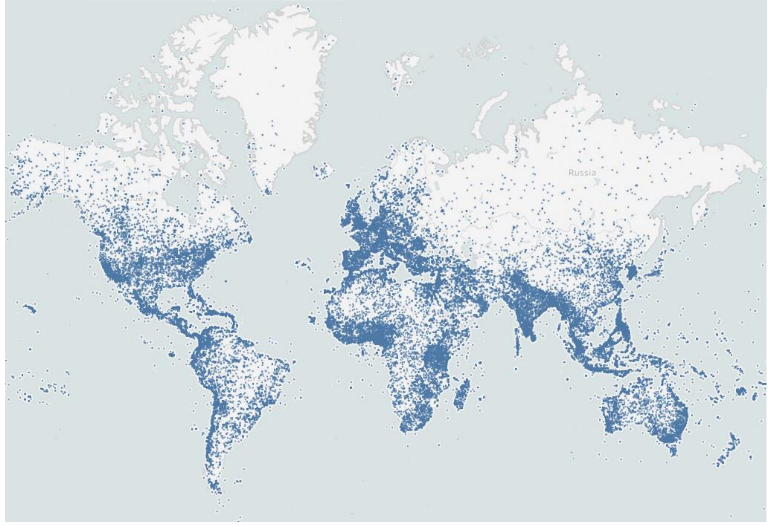
HOMER modeling sets the industry standard in more than 190 countries.



Projects worldwide

250,000 downloads, **90,000** projects modeled

3 million model runs, **193+** countries



HOMER
Hybrid optimization of multiple energy resources

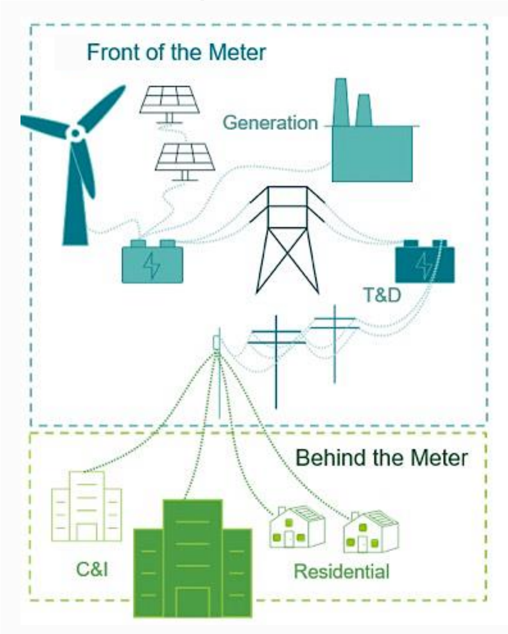
FRONT-OF-THE-METER

UTILITY-SCALE STORAGE

HOMER Front

Evaluate financial returns of energy storage, with or without solar and wind

- Maximize revenue and internal rate of return (IRR)
- Assess project feasibility
- Model storage dispatch, degradation and augmentation
- Validate revenue estimates of market participation and power purchase agreements (PPAs)



BEHIND-THE-METER

GRID-TIED DISTRIBUTED GENERATION

HOMER Grid

Reduce energy costs for grid-tied systems that serve a local load

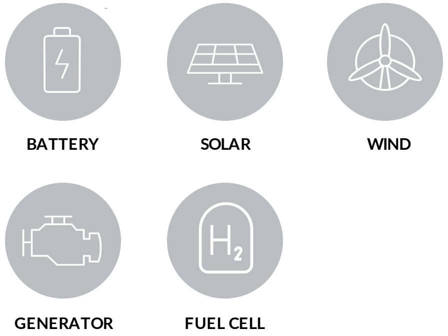
- Reduce demand charges
- Increase resilience
- Optimize electric vehicle charging
- Model combined heat and power
- Optimize against electric tariff structure
- Understand carbon and emission reductions

STANDALONE MICROGRIDS

HOMER Pro

Find the best energy mix and least-cost solution for powering off-grid systems for islands, mines, telecom towers, outposts

- Reduce energy costs, increase reliability and add renewables to your off-grid system
- Simulate and optimize any combination of energy resources
- Perform advanced sensitivity analysis



HOMER Front

Front-of-the-meter — storage, wind and solar

Utility-scale generation

Model utility-scale energy storage systems — stand-alone or combined with wind and solar.

Battery management

Dispatch based on hourly and sub-hourly price forecasts to model energy-shifting arbitrage and capacity market participation

Multiple revenue streams

Validate revenue projections of PPAs, whole energy participation (day-ahead and real-time) and capacity market participation.

System sizing

System sizing and optimization for PPAs, requests for proposal (RFPs) and information assurance (IA) compliance

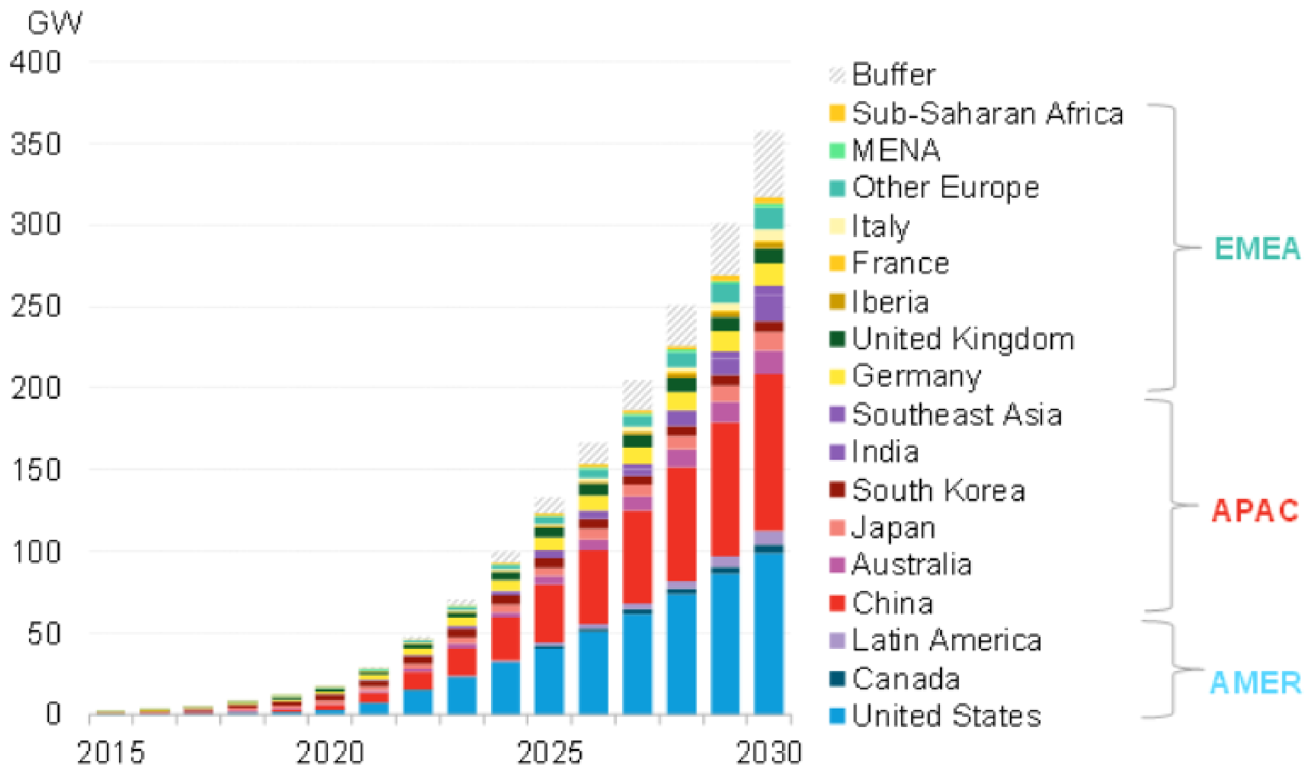
Augmentation strategies

Advanced storage module to model degradation and augmentation strategies in use cases, including cycling, depth of discharge, throughput and time horizon

Role of energy storage in the clean energy transition

Christina Duong

Global cumulative energy storage installations, 2015-2030



Source: BloombergNEF. Note: MENA = Middle East & North Africa. Buffer represents markets and use-cases that we are unable to forecast due to lack of visibility.

Energy storage state targets as of July 2021

Total: 10,500 MW and 1,000 MWh

By the end of 2025

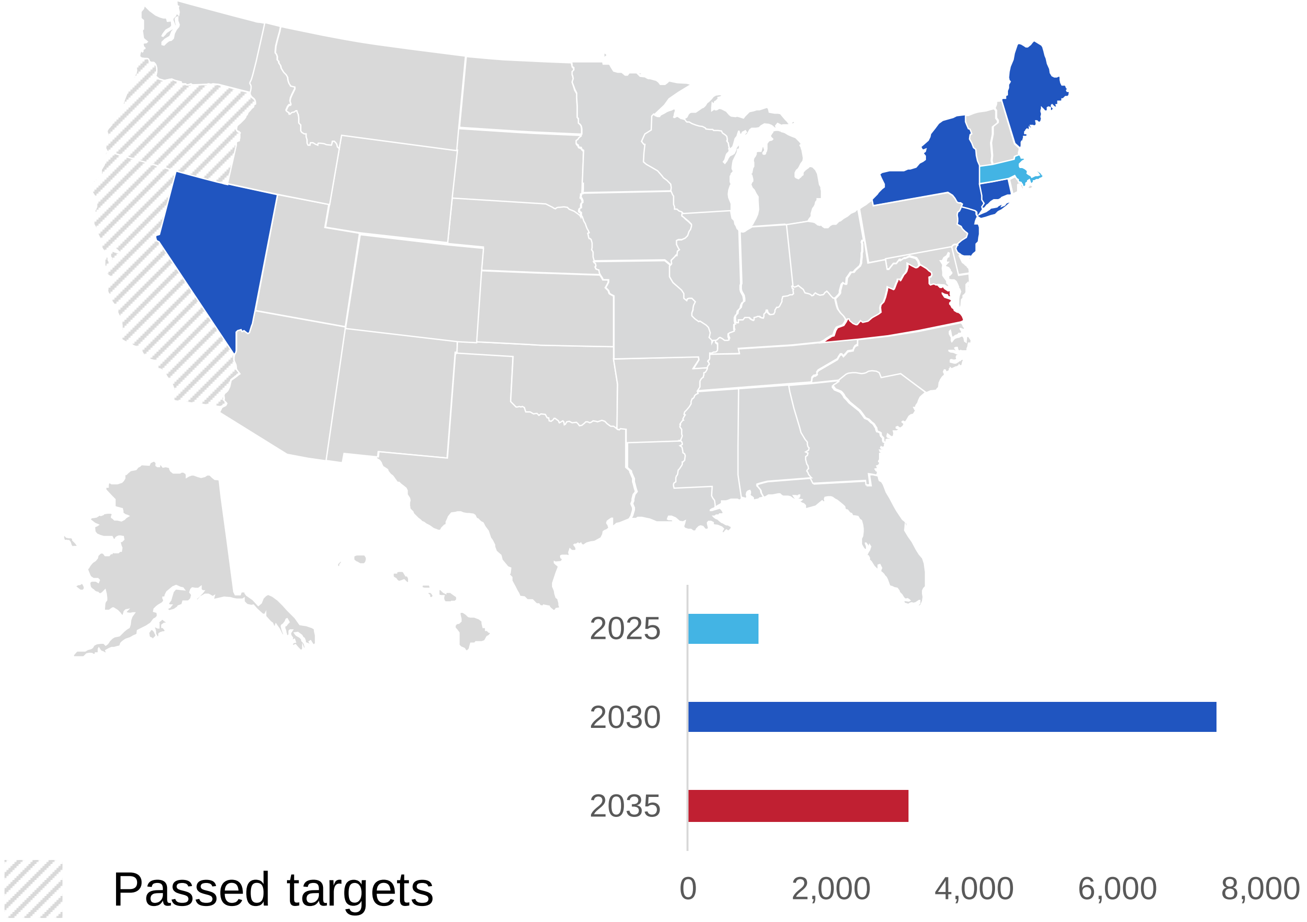
Massachusetts:	1,000 MWh

By the end of 2030

New York*:	3,000 MW
New Jersey:	2,000 MW
Nevada:	1,000 MW
Connecticut:	1,000 MW
Maine:	400 MW

By the end of 2035

Virginia:	3,100 MW

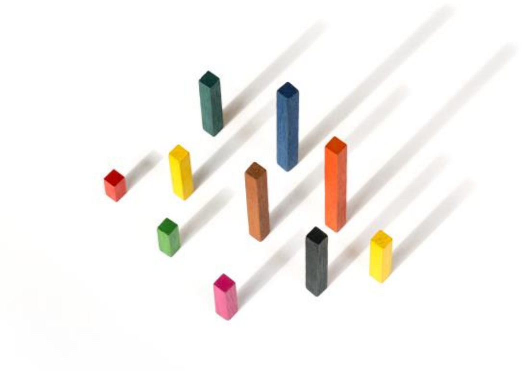


*February 2022: New York Gov. Kathy Hochul announced plans to double the state's energy storage deployment target to at least 6 GW by 2030.

Challenges with system complexity

David Mintzer

Energy storage considerations



- **Energy storage is not monolithic:** Choosing to include energy storage and deciding on the platform type requires careful consideration of the grid network, both physical and where the ecosystem is concerned.
- **Dispatch services:** Energy vs. power, high-power/high-frequency applications such as frequency regulation, long-duration energy, resiliency — system could be stand-alone or hybrid with solar and wind
- **Off-take arrangements:** PPAs with time-shifting, wholesale energy, ancillary services, tolling arrangements, capacity agreement, transaction swap
- **Terms:** Contract duration, warranties, performance guarantees, energy capacity augmentation plan — Are these consistent with the technology? Where are the risks?
- **Architecture/technology:** AC/DC-coupled, LFP, NMC, flow, other
- **Other:** Bankability; insurability; policy consistency; safety; certification, e.g., to UL 9540A, the Standard for Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems; Investment Tax Credit (ITC); interconnection

Techno-economic analysis is essential for success

- **Integration**

  Integrates factors and enables comparing and screening the viability of multiple systems and configurations

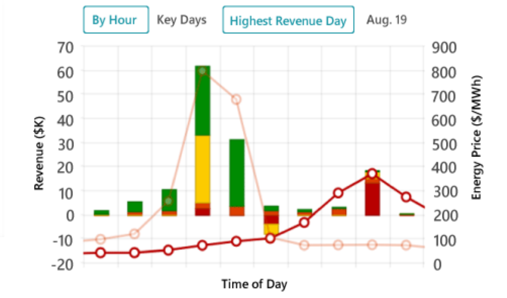
- **Value**

  Helps developers understand the value of including storage and de-risk project internal rate of return

- **Sensitivity, project life and pipeline**

  Enables the design of a feasible system that addresses realistic performance constraints over the project lifetime; includes battery behavior and the viability impact of design choices, such as augmentation strategies

HOMER Front

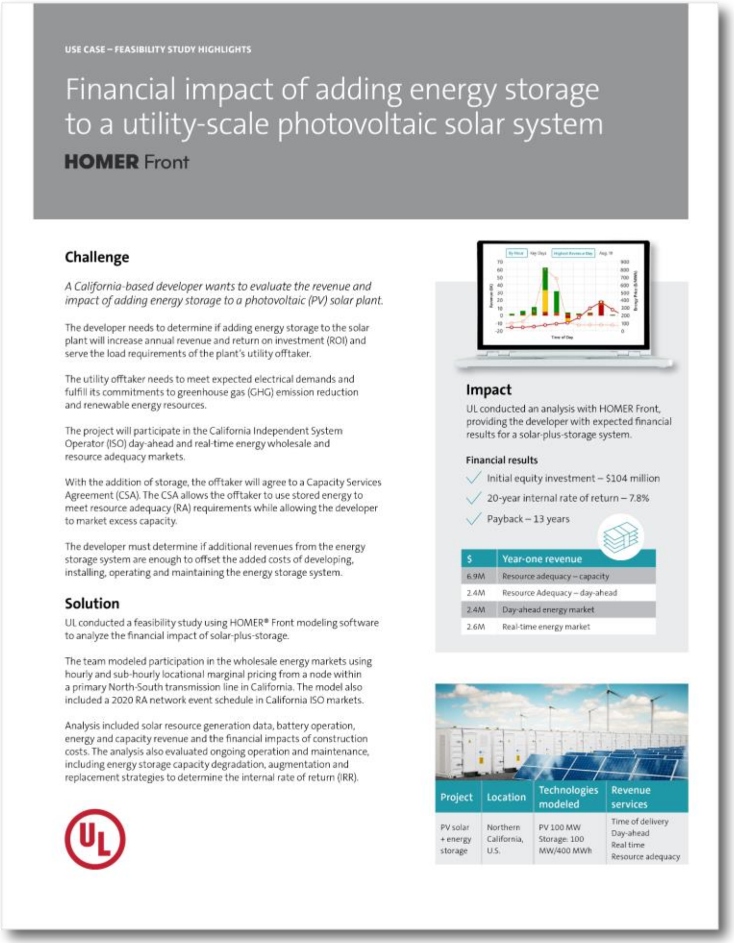


Proposed solar and storage system inputs	
Location	Northern California
Interconnection limit	100 MW
PV size	100 MW
ESS size	100 MW/400 MWh
ESS capacity degradation	2.0%/year, 100% DoD, 1 cycle/day
Battery characterization	Advanced storage model, lithium iron phosphate (LFP)
Power conversion electronics	DC-coupled
Solar resource model	Full-diligence energy production report (EPR)
System CAPEX	$194.6M, turnkey – Includes generation equipment, balance of plant, development fees, interconnection, extended warranty, financing
Location marginal price	NP-15, 2020
Resource adequacy	Back-casted settlement, four-hour duration
Revenue streams	Energy wholesale, including day-ahead energy, real-time energy, resource adequacy (capacity) markets
Financial parameters	Discount rate: 8% State tax rate: 8.25% Federal tax rate: 21% ITC: 26% Other – MACRS, bonus depreciation
CAPEX assumptions	PV: $0.80/W$_{DC}$ Storage: $290/kWh$_{DC}$
OPEX assumptions	PV – $6.64/kW$_{DC}$/year Storage – $22.08/kWh$_{DC}$/year

Techno-economic analysis is essential for success

- **Results**

  Helps project developers understand how to combine and compare multiple potential revenue opportunities, including:
  - Multiple energy markets
  - Capacity markets
  - Power purchase agreements
  - Off-taker obligations



USE CASE – FEASIBILITY STUDY HIGHLIGHTS

Financial impact of adding energy storage to a utility-scale photovoltaic solar system

HOMER Front

Challenge

A California-based developer wants to evaluate the revenue and impact of adding energy storage to a photovoltaic (PV) solar plant.

The developer needs to determine if adding energy storage to the solar plant will increase annual revenue and return on investment (ROI) and serve the load requirements of the plant's utility offtaker.

The utility offtaker needs to meet expected electrical demands and fulfill its commitments to greenhouse gas (GHG) emission reduction and renewable energy resources.

The project will participate in the California Independent System Operator (ISO) day-ahead and real-time energy wholesale and resource adequacy markets.

With the addition of storage, the offtaker will agree to a Capacity Services Agreement (CSA). The CSA allows the offtaker to use stored energy to meet resource adequacy (RA) requirements while allowing the developer to market excess capacity.

The developer must determine if additional revenues from the energy storage system are enough to offset the added costs of developing, installing, operating and maintaining the energy storage system.

Solution

UL conducted a feasibility study using HOMER® Front modeling software to analyze the financial impact of solar-plus-storage.

The team modeled participation in the wholesale energy markets using hourly and sub-hourly locational marginal pricing from a node within a primary North-South transmission line in California. The model also included a 2020 RA network event schedule in California ISO markets.

Analysis included solar resource generation data, battery operation, energy and capacity revenue and the financial impacts of construction costs. The analysis also evaluated ongoing operation and maintenance, including energy storage capacity degradation, augmentation and replacement strategies to determine the internal rate of return (IRR).

Impact

UL conducted an analysis with HOMER Front, providing the developer with expected financial results for a solar-plus-storage system.

Financial results

- Initial equity investment – $104 million
- 20-year internal rate of return – 7.8%
- Payback – 13 years

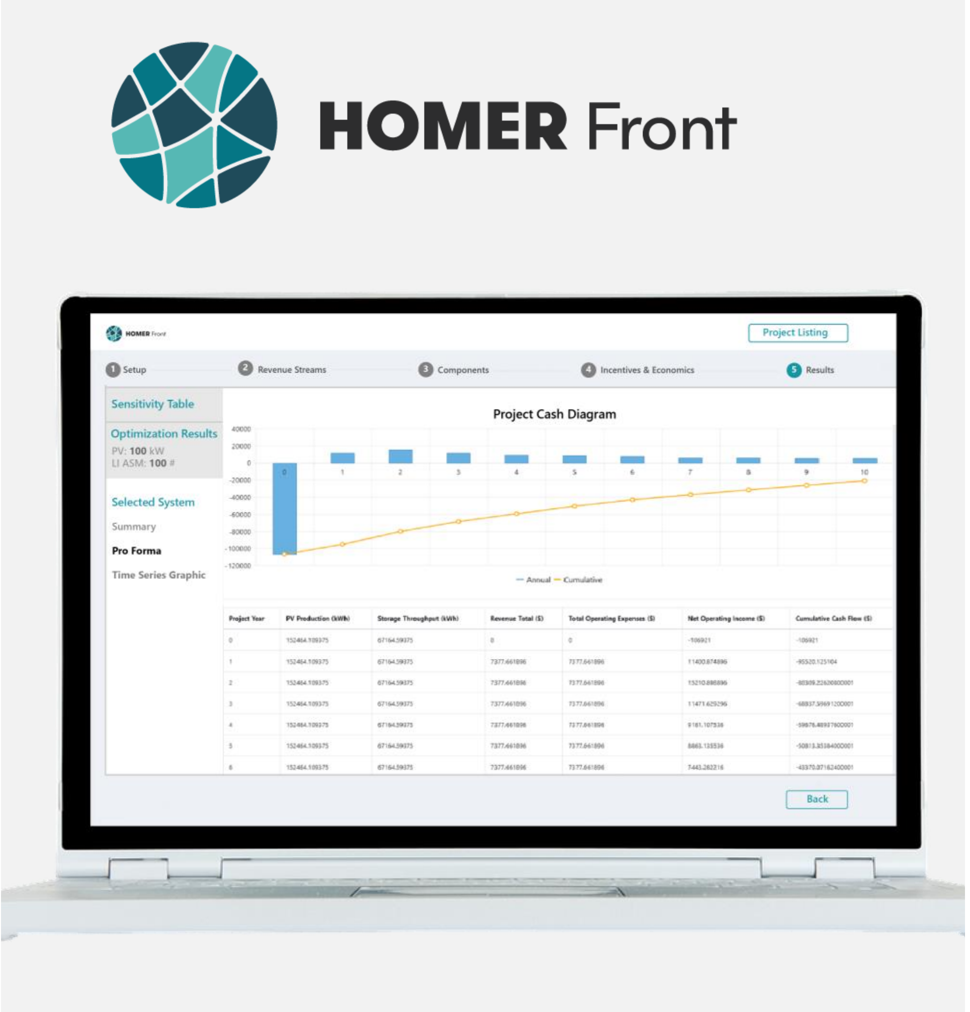
$	Year-one revenue
6.9M	Resource adequacy – capacity
2.4M	Resource Adequacy – day-ahead
2.4M	Day-ahead energy market
2.6M	Real-time energy market

Project	Location	Technologies modeled	Revenue services
PV solar + energy storage	Northern California, U.S.	PV 100 MW Storage: 100 MW/400 MWh	Time of delivery Day-ahead Real time Resource adequacy

Challenges with system complexity: Markets

Christina Duong

Multiple revenue streams



HOMER Front helps project developers understand how to combine and compare multiple potential revenue sources, including multiple energy markets, capacity markets, power purchase agreements and off-taker obligations.

Energy markets — energy arbitrage

- Day-ahead market
- Fifteen-minute market
- Real-time market

Capacity market — resource adequacy

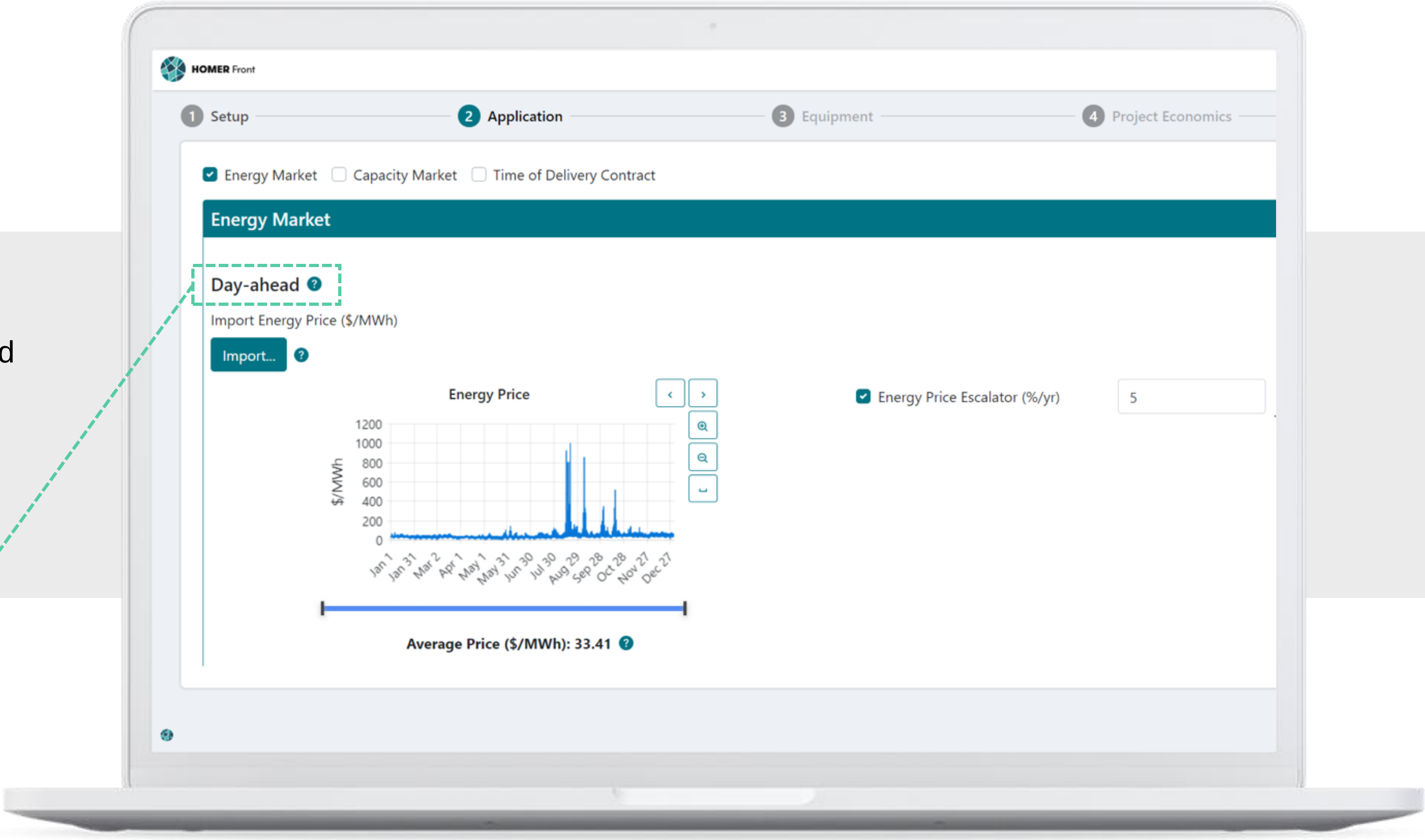
Contract — delivery obligations

Model setup — energy markets

HOMER Front

Energy market inputs

- Wholesale energy: day-ahead and real-time, hourly and sub-hourly
- Locational marginal pricing (price strips)

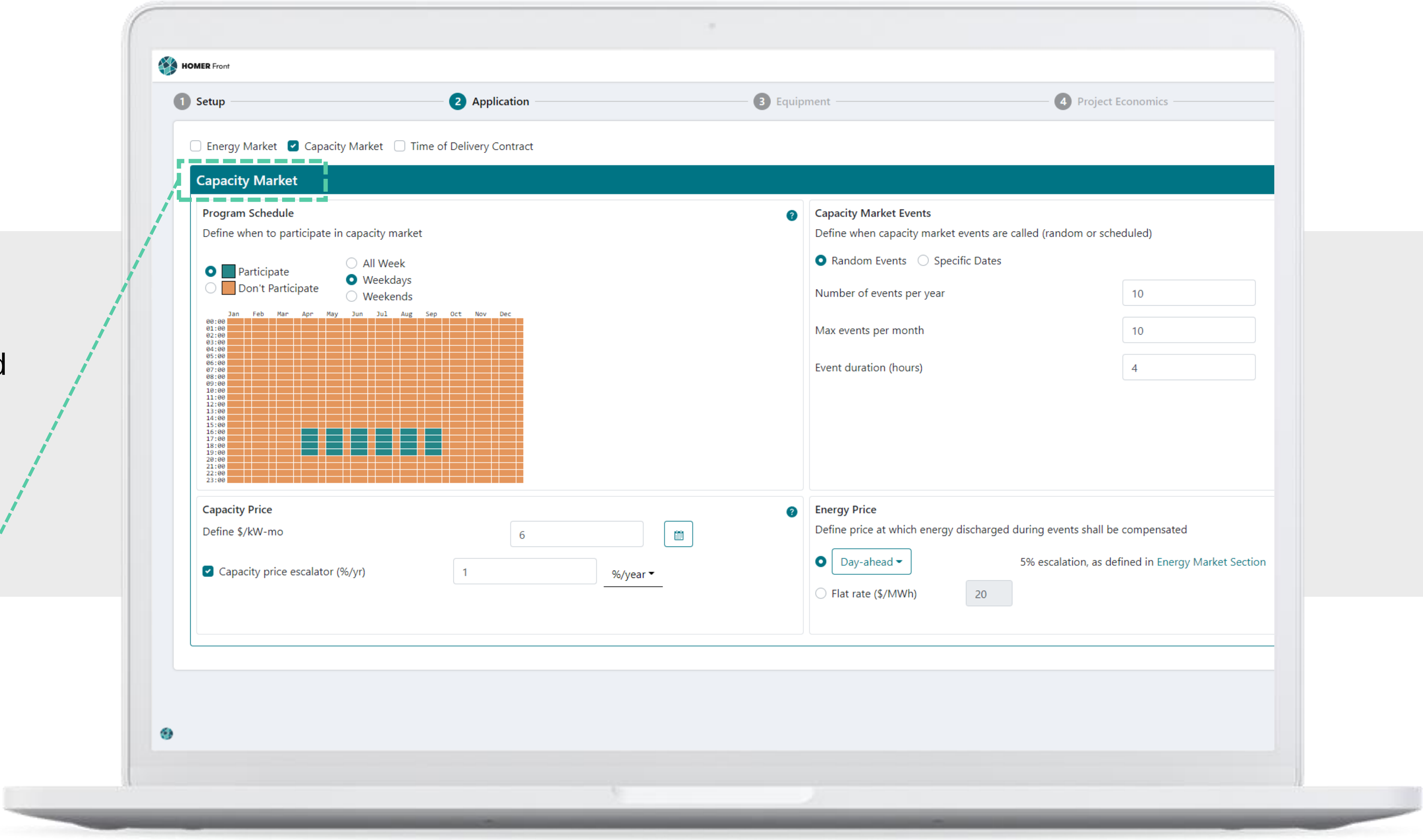


Software screen captures throughout are owned by UL

Model setup — capacity market and other revenue streams

HOMER Front

Supports renumeration for reserved capacity and additional revenue opportunity for dispatched energy



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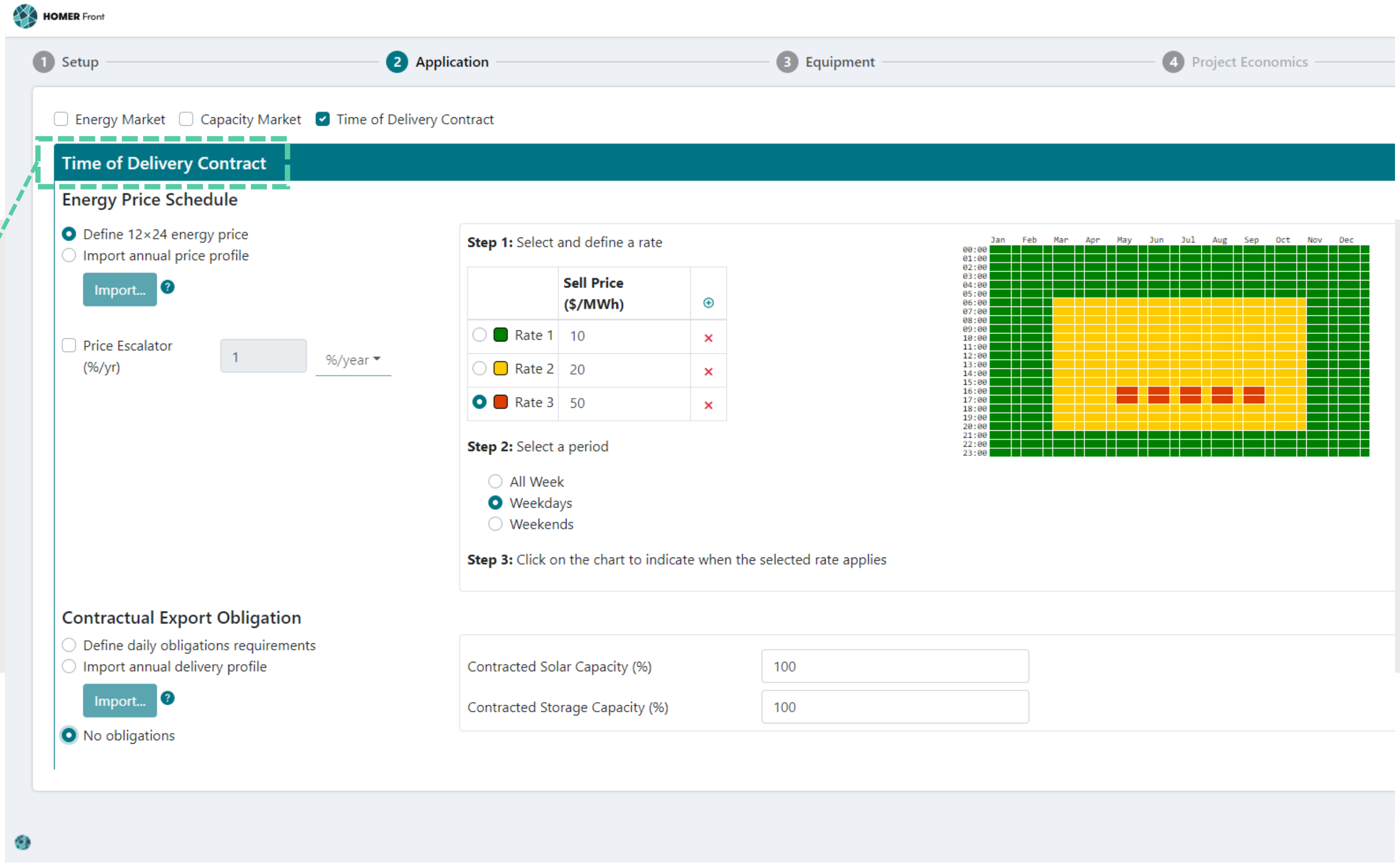
Model setup — power purchase agreements, time of delivery

HOMER Front

Contracted solar and storage capacity may be compensated at a structured rate



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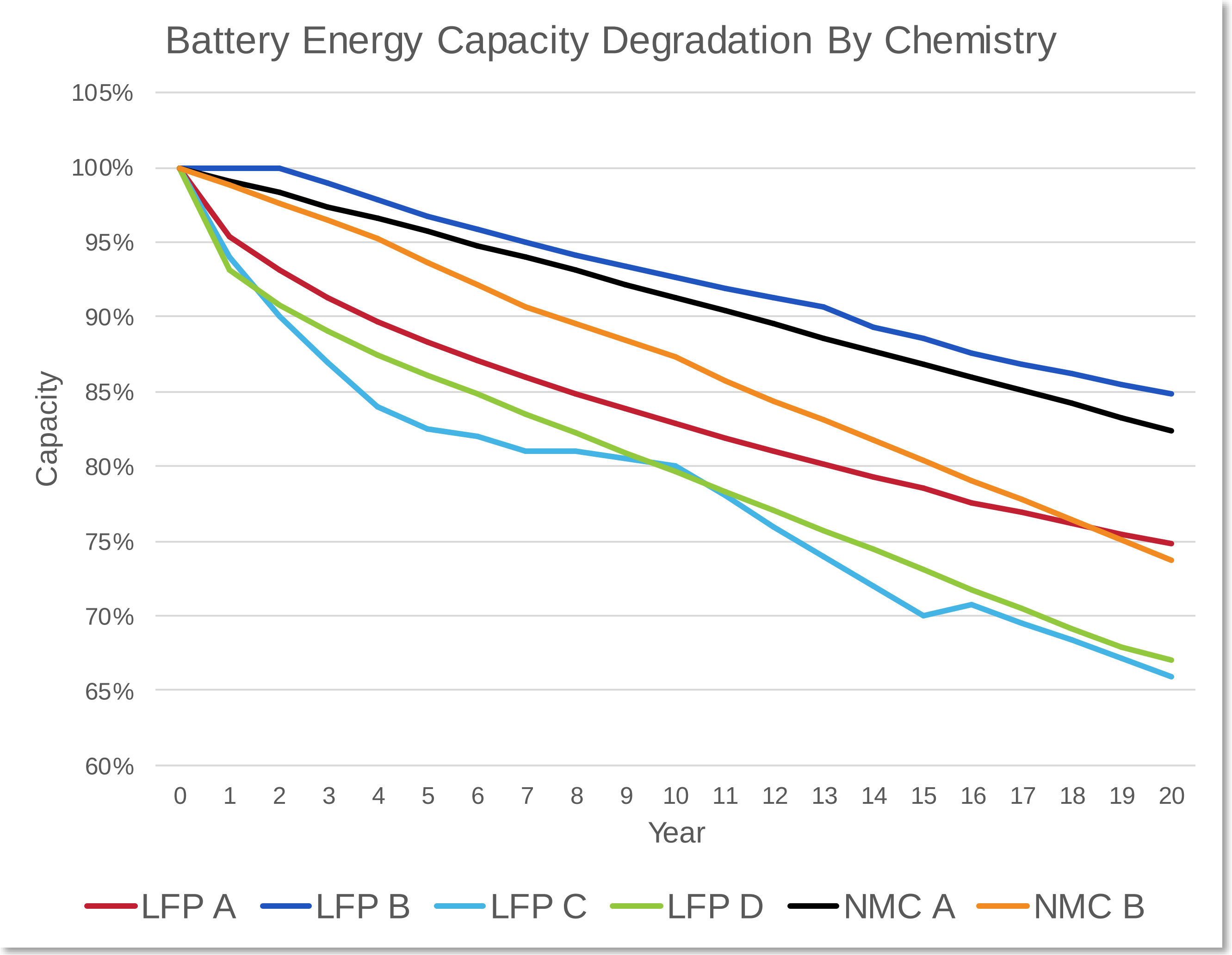
Challenges with system complexity: Storage

Steffi Klawiter

Energy capacity decreases

Storage health depends on:

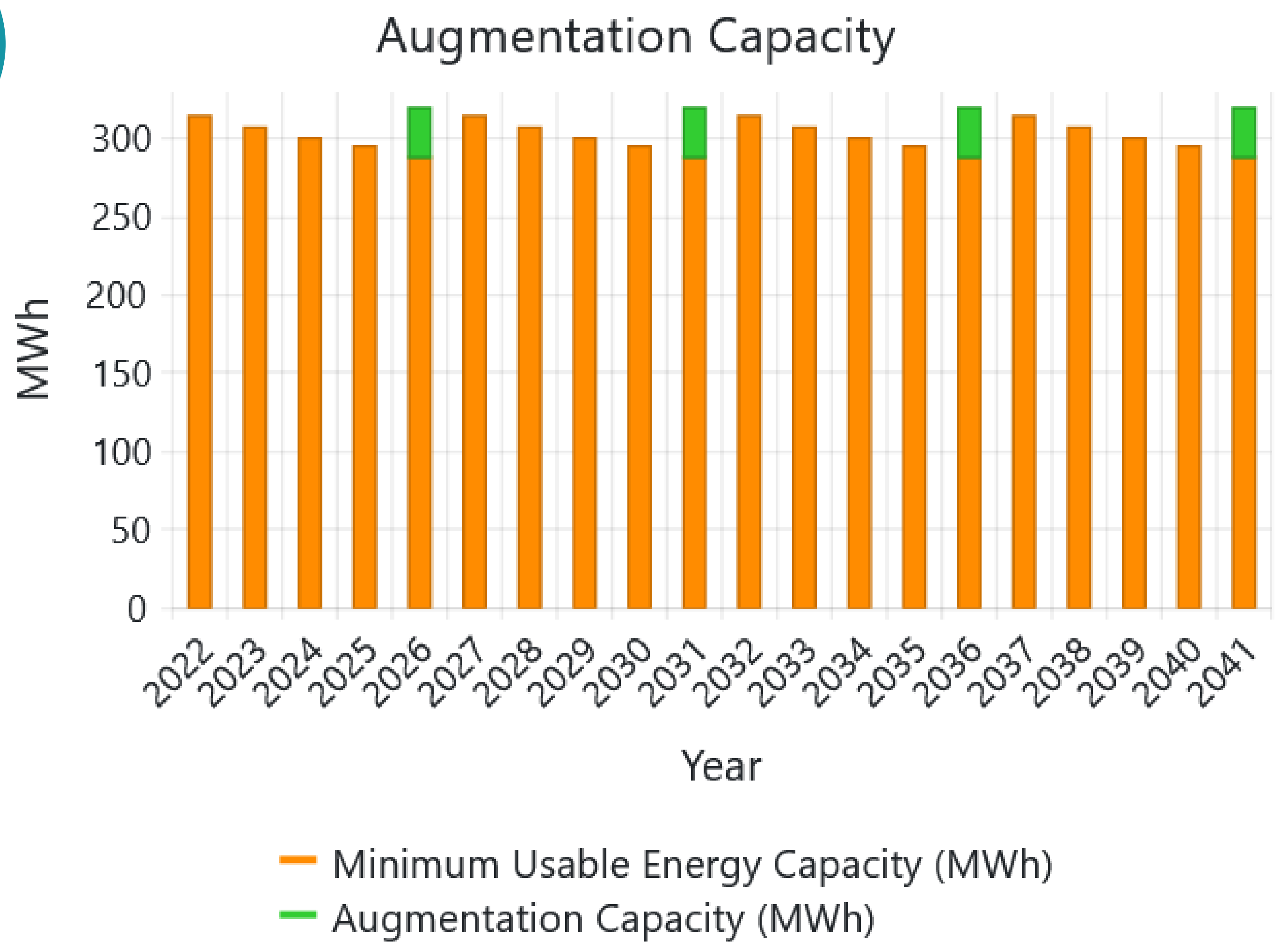
- Cycling
- Thermal
- Calendar



Mitigating capacity loss in batteries

Every successful project needs an energy capacity degradation plan.

- Cycling limits
- Oversizing
- Augmentation



HOMER Front case studies

1. Compare two storage technologies
2. Compare augmentation price forecasts

Evaluate assumptions to de-risk project

Steffi Klawiter

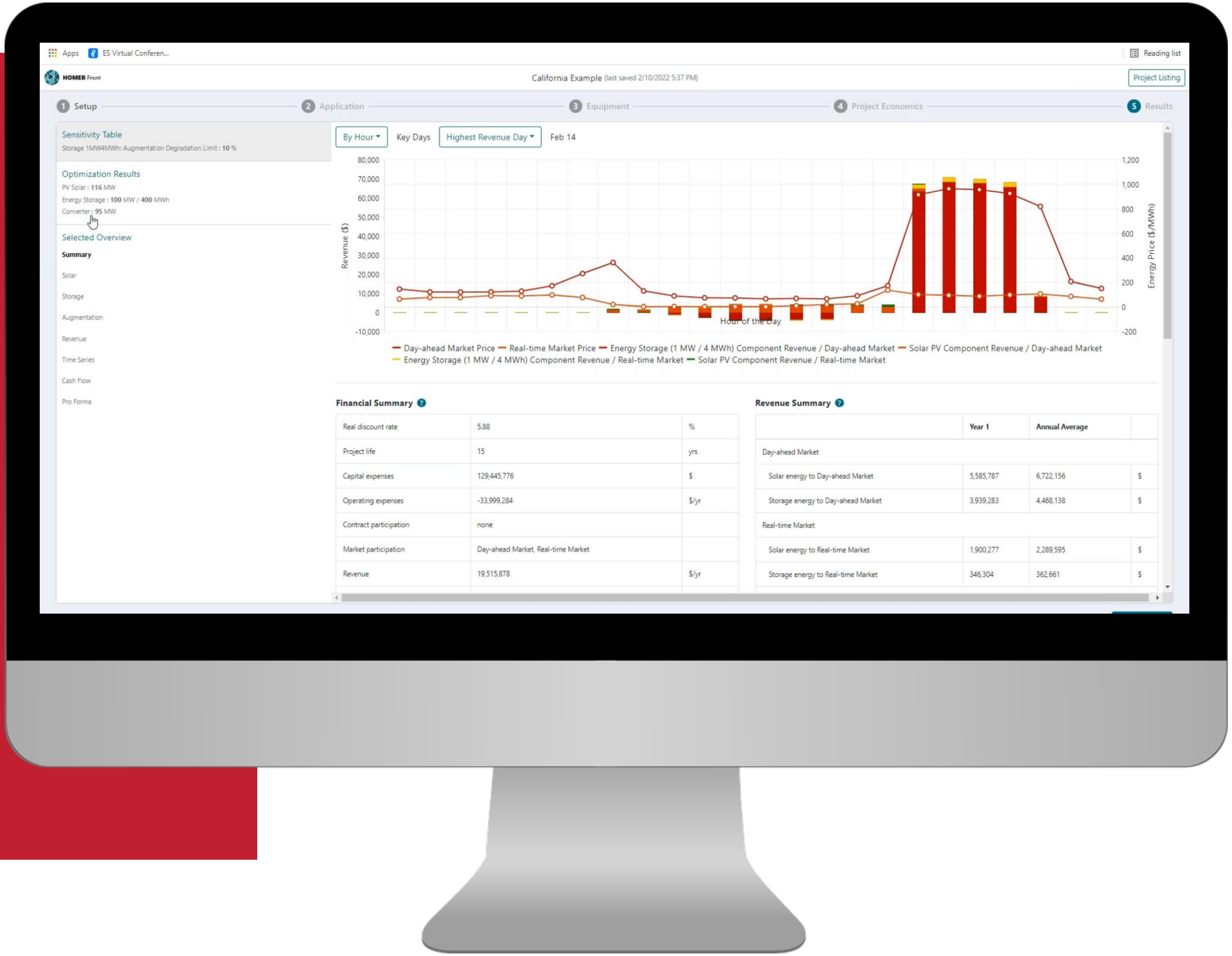
Benefits

HOMER Front

Empowering Trust®

HOMER Front

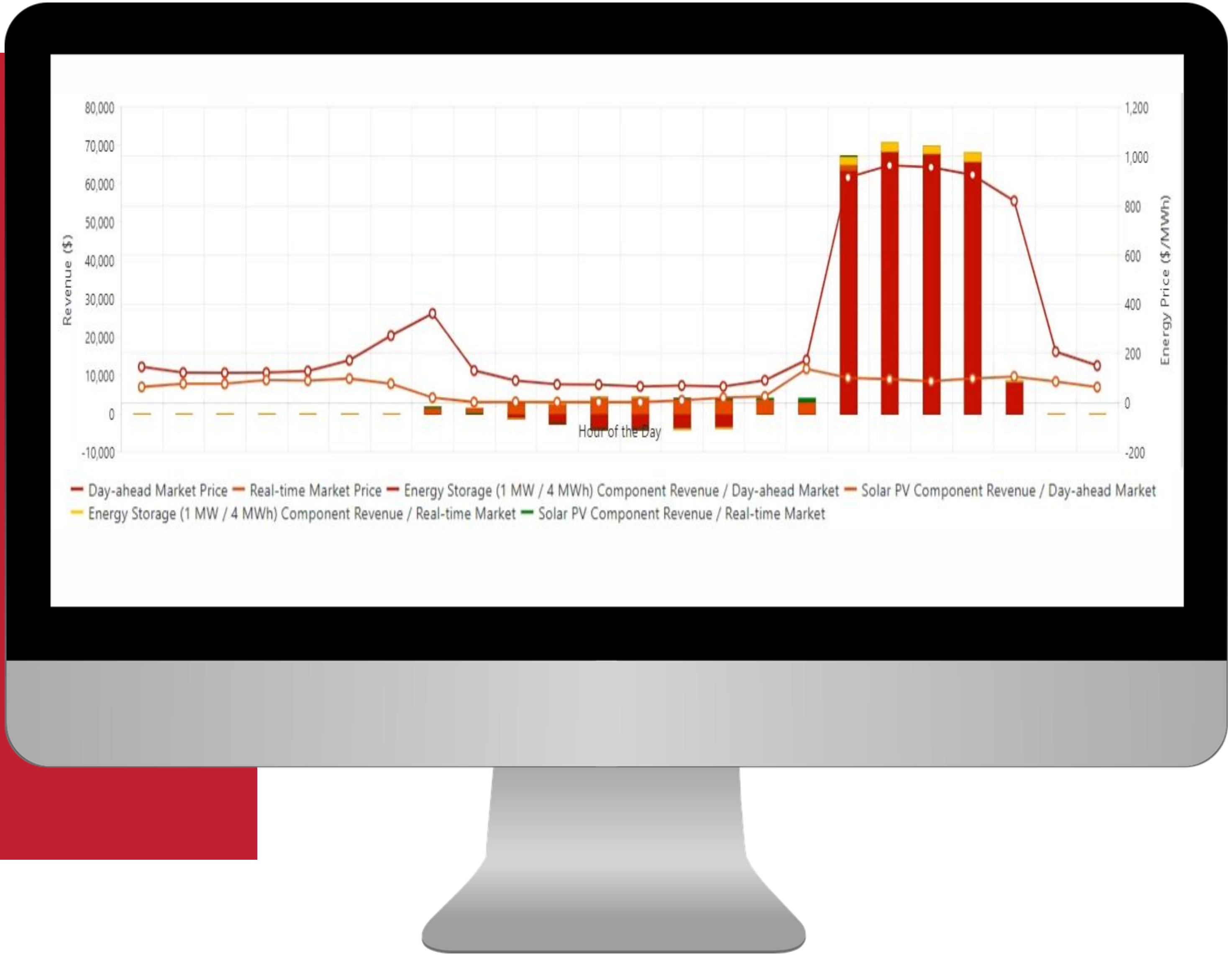
Break down the complexity in assessing system performance and economic viability



HOMER Front

Break down the complexity in assessing system performance and economic viability

Maximize value of adding storage and de-risk internal rate of return

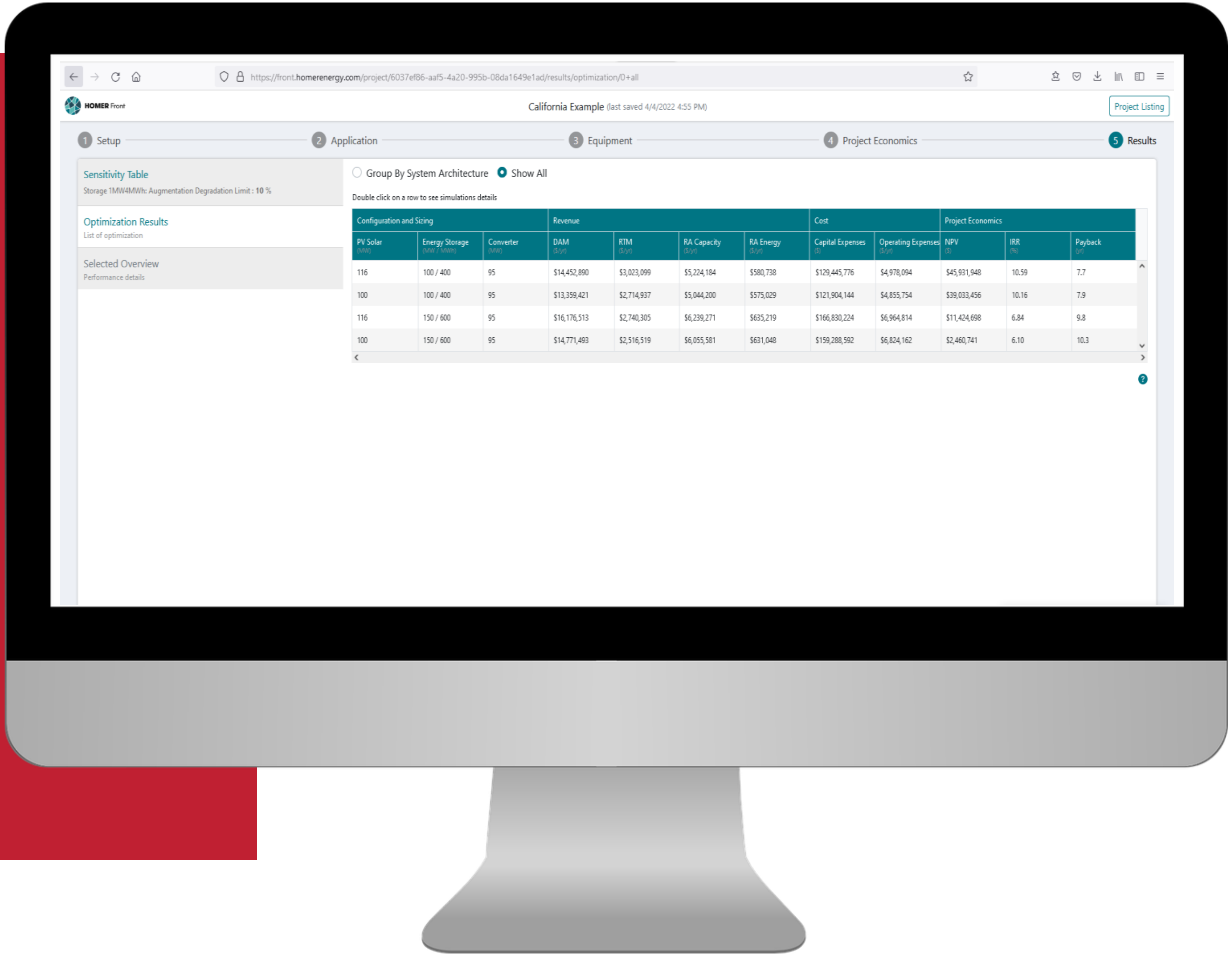


HOMER Front

Break down the complexity in assessing system performance and economic viability

Maximize value of adding storage and de-risk internal rate of return

Test multiple system sizes and configurations and integrate energy market revenue



Configuration and Sizing			Revenue				Cost		Project Economics		
PV Solar (MW)	Energy Storage (MW / MWh)	Converter (MW)	DAM ($/yr)	RTM ($/yr)	RA Capacity ($/yr)	RA Energy ($/yr)	Capital Expenses ($)	Operating Expenses ($/yr)	NPV ($)	IRR (%)	Payback (yr)
116	100 / 400	95	$14,452,890	$3,023,099	$5,224,184	$580,738	$129,445,776	$4,978,094	$45,931,948	10.59	7.7
100	100 / 400	95	$13,359,421	$2,714,937	$5,044,200	$575,029	$121,904,144	$4,855,754	$39,033,456	10.16	7.9
116	150 / 600	95	$16,176,513	$2,740,305	$6,239,271	$635,219	$166,830,224	$6,964,814	$11,424,698	6.84	9.8
100	150 / 600	95	$14,771,493	$2,516,519	$6,055,581	$631,048	$159,288,592	$6,824,162	$2,460,741	6.10	10.3

HOMER Front

Break down the complexity in assessing system performance and economic viability

Maximize value of adding storage and de-risk internal rate of return

Test multiple system sizes and configurations and integrate energy market revenue

Perform sensitivity and risk analysis — model batteries with degradation and augmentation strategies

Year	Maximum Usable Energy Capacity (MWh)	Minimum Usable Energy Capacity (MWh)	Augmentation (%)	Augmentation Capacity (MWh)	Augmentation Cost ($/MWh)	Battery Augmentation Cost ($)
2024	401	388	0%	0	$150	-$0
2025	388	375	0%	0	$137	-$0
2026	375	362	0%	0	$123	-$0
2027	401	361	10%	40	$110	$3,226,344
2028	389	376	0%	0	$103	-$0
2029	376	363	0%	0	$97	-$0

HOMER Front

Break down the complexity in assessing system performance and economic viability

Maximize value of adding storage and de-risk internal rate of return

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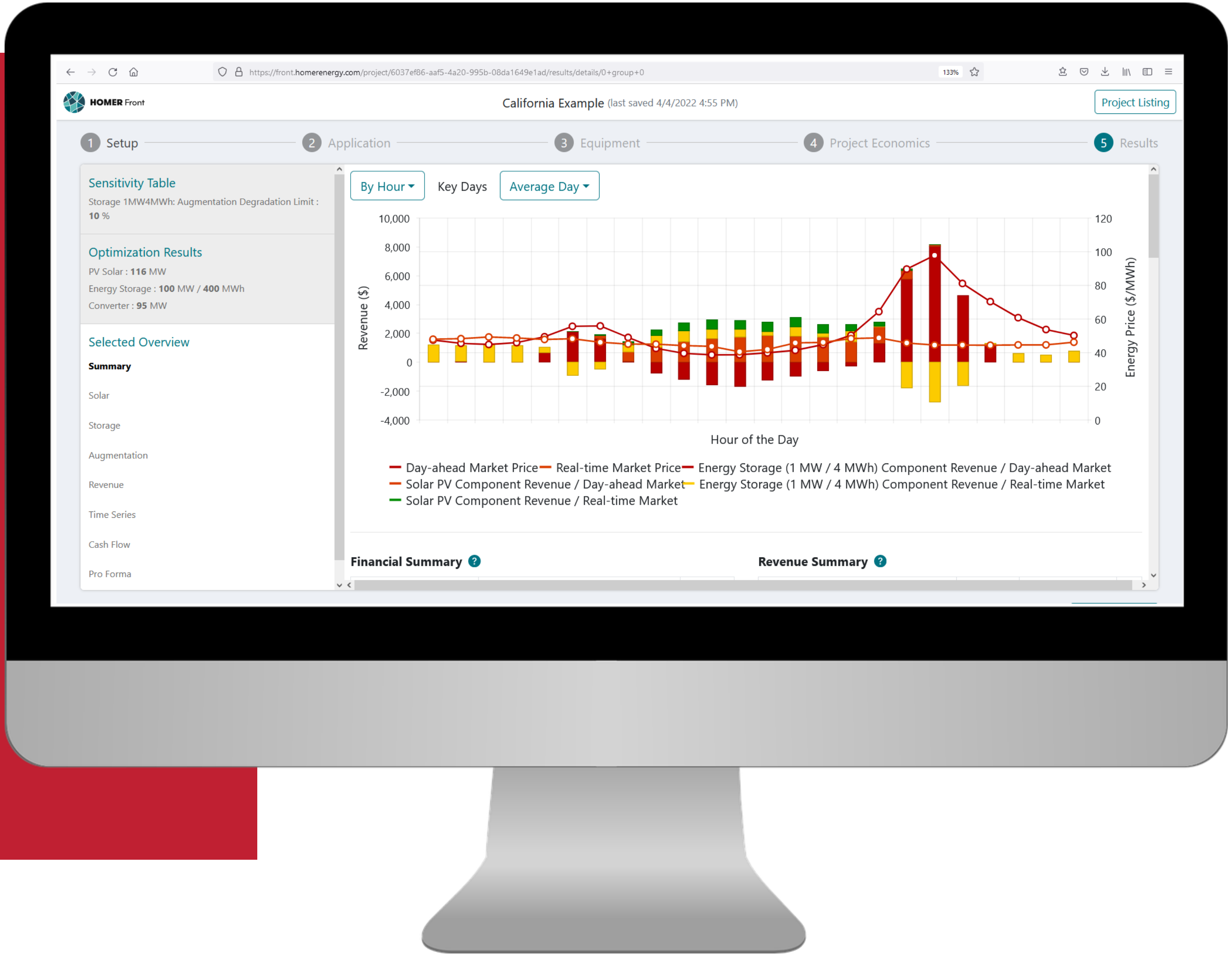
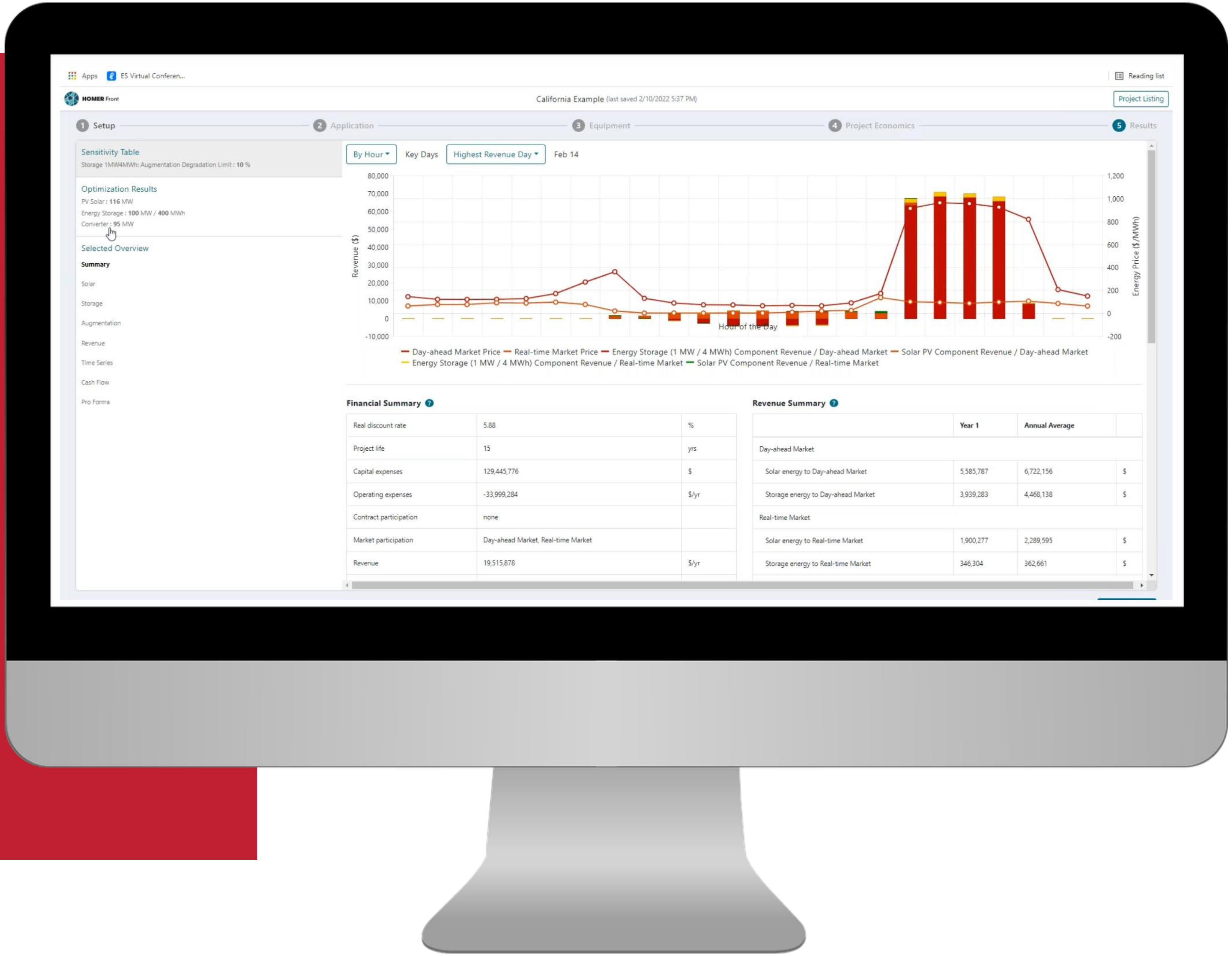
Third-party tool informs stakeholders, enabling collaboration internally and externally



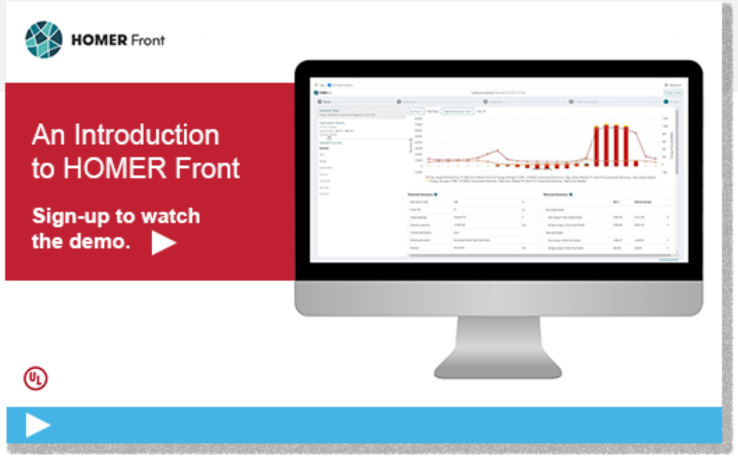
HOMER Front

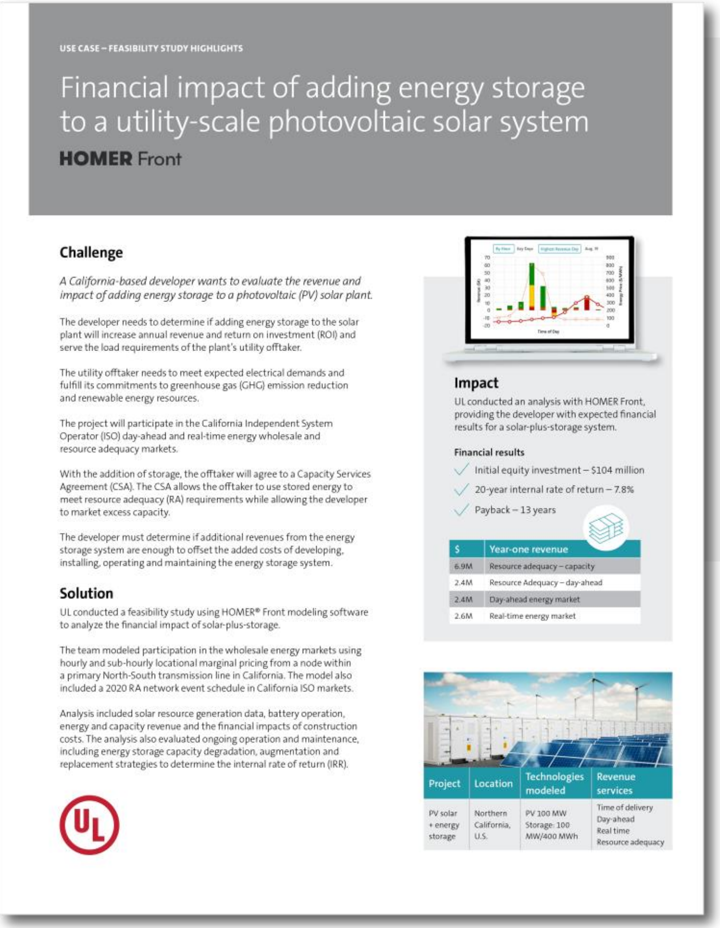
Robust tool for evaluating technical and economic viability of utility-scale systems



Learn more and get started!

- Go to https://www.homerenergy.com/products/front/
- Fill in the form.
- Get a demonstration video and example feasibility study.





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Experience the power

HOMER Pro

Remote, standalone microgrids
homerenergy.com/TryPro

HOMER Grid

Grid-connected DERs
homerenergy.com/TryGrid

HOMER Front

Utility-scale storage
with or without solar and wind
www.homerenergy.com

www.UL.com/HOMERsoftware

Questions?

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Director, Energy Storage Advisory

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Product manager, Hybrids

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Christina Duong

Energy market specialist

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Kyle Stauffer

Senior project engineer

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Upcoming events

We'd love to meet you at:

American CleanPower, San Antonio, May 16-18

Microgrid 2022, Philadelphia, June 1-2

- HOMER Technology Workshop June 2, 2:45 p.m.
- Use the code HOMERVIP for a 10% discount
- Learn more at microgridknowledge.com/microgrid-2022/

Upcoming webinars: Date to be announced

- CESA Spotlight Webinar: Enhancing the value of solar with storage
- HOMER Front: Focus on California Market

Thank you!

Empowering Trust®