

The Impact of Falling Storage Prices on Least Cost Hybrid System Design

Dr. Peter Lilienthal
CEO, HOMER Energy

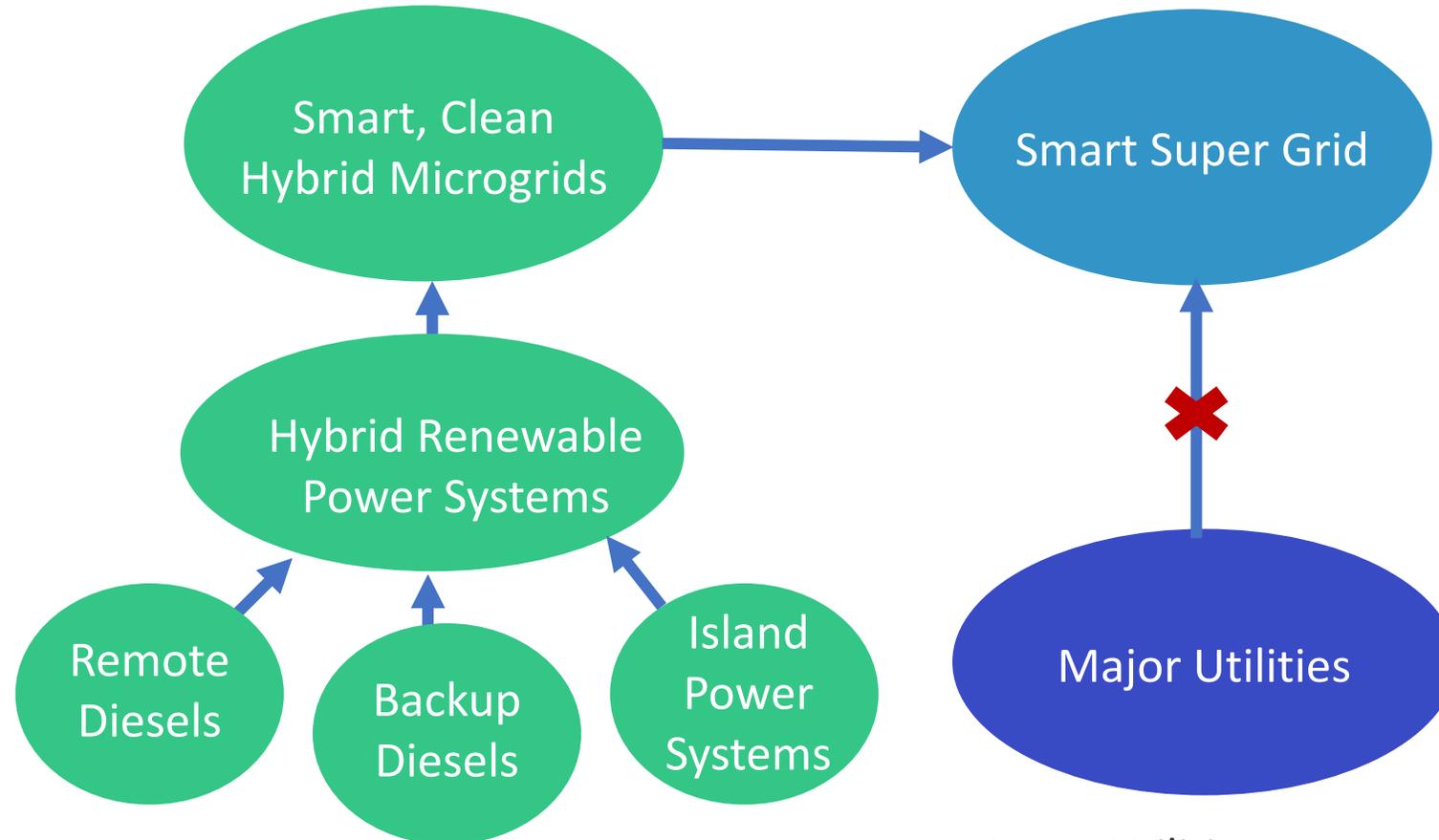
International Hybrid Power Systems Workshop
Crete, May 22, 2019

The Future of Power is Distributed & Hybrid



- Technology improvements
 - Solar, storage, communications, controls
 - Erase advantage of centralized plants
- Storage is the real game-changer
- Hybrid microgrids are flexible & robust

Power Industry Evolution



Smaller Systems

- Liquid fuels from oil
- High renewable penetrations

Large Utilities

- Security challenges
- Regulatory challenges



Microgrid Markets

- Grid-Connected (behind the meter)

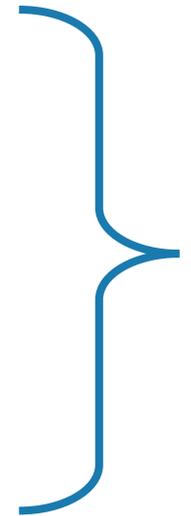
- Reliability & resilience
- Utility cost management



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- Off-Grid

- Energy Access
 - No existing infrastructure
- Island & isolated utilities
 - Existing diesel-based power system

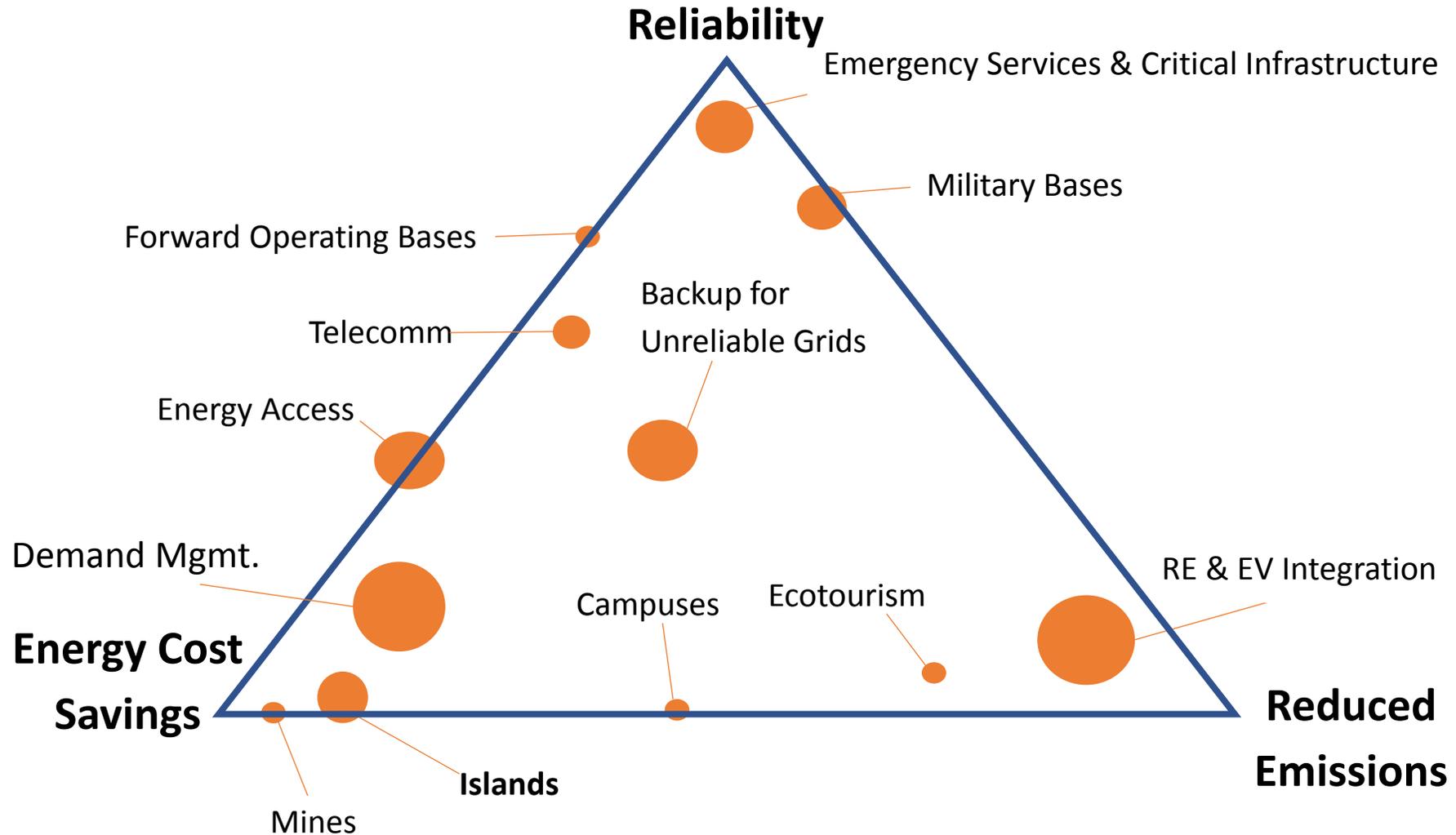


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Microgrid Value Propositions



Storage Value Streams

- Location Agnostic
 - Frequency regulation
 - Duck Curve
- Value for Centralized Projects
 - Increase transmission loading from RE Projects
- Value for Distributed Projects
 - Reliability
 - Voltage VAR stability
 - Utility rate management
 - Demand charges
 - TOU rates
 - Sellback restrictions

Storage Modeling Challenges

- Chronology is important
 - Load Duration Curves are inadequate
- Batteries are complex
 - Capacity varies with discharge rate
 - Temperature effects
- Valuing the energy
 - Demand charges are hard to model
 - Resilience and reliability are site specific & difficult to quantify
 - Storage often is highest lifetime cost component

Storage Modeling in HOMER

- 3 algorithms

- Idealized model
- Kinetic Battery Model
 - 2 tank
- Advanced Storage Model
 - Temperature effects

- Technologies

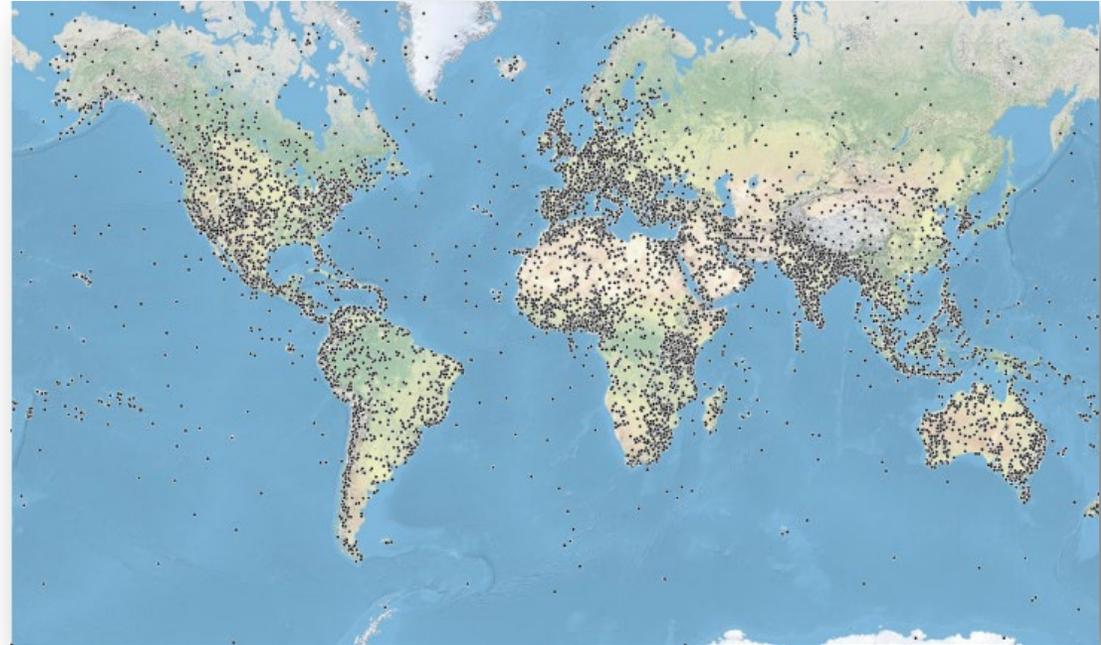
- Lithium
- Lead
- Nickel
- Flow Batteries
 - Zinc
 - Vanadium
- Flywheels
- Pumped Hydro



HOMER Energy

Designing Least Cost Hybrid Systems for over 25 years

- 1992 – 2008 at NREL
- 2009: HOMER Energy created with exclusive license
- >250,000 people have used HOMER
- >100,000 opted-in to our hybrid system design network
- **Global Data**
 - 3 million HOMER files
 - >70,000 projects modeled since 2014



Hybrid System Design in HOMER[®]

Project Inputs



Economics

Load Profile

Site-Specific
Renewable Resources

System Components

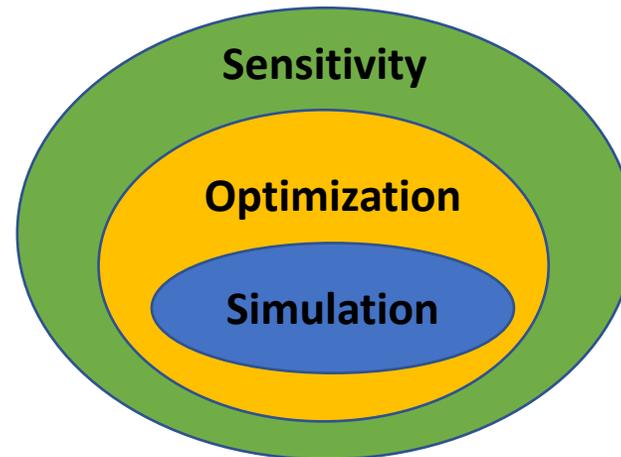
Analysis



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Results



Economics

System Sizing

Performance Details

Various Reports



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HOMER Solutions Framework

Market Access

Conferences and Webinars

Microgrid News

Industry Partner Program

Network Component Library

Software Solutions

HOMER Pro

HOMER Grid

HOMER QuickStart

HOMER QuickGrid

HOMER SaaS API

HOMER Controller API

Services

Consulting

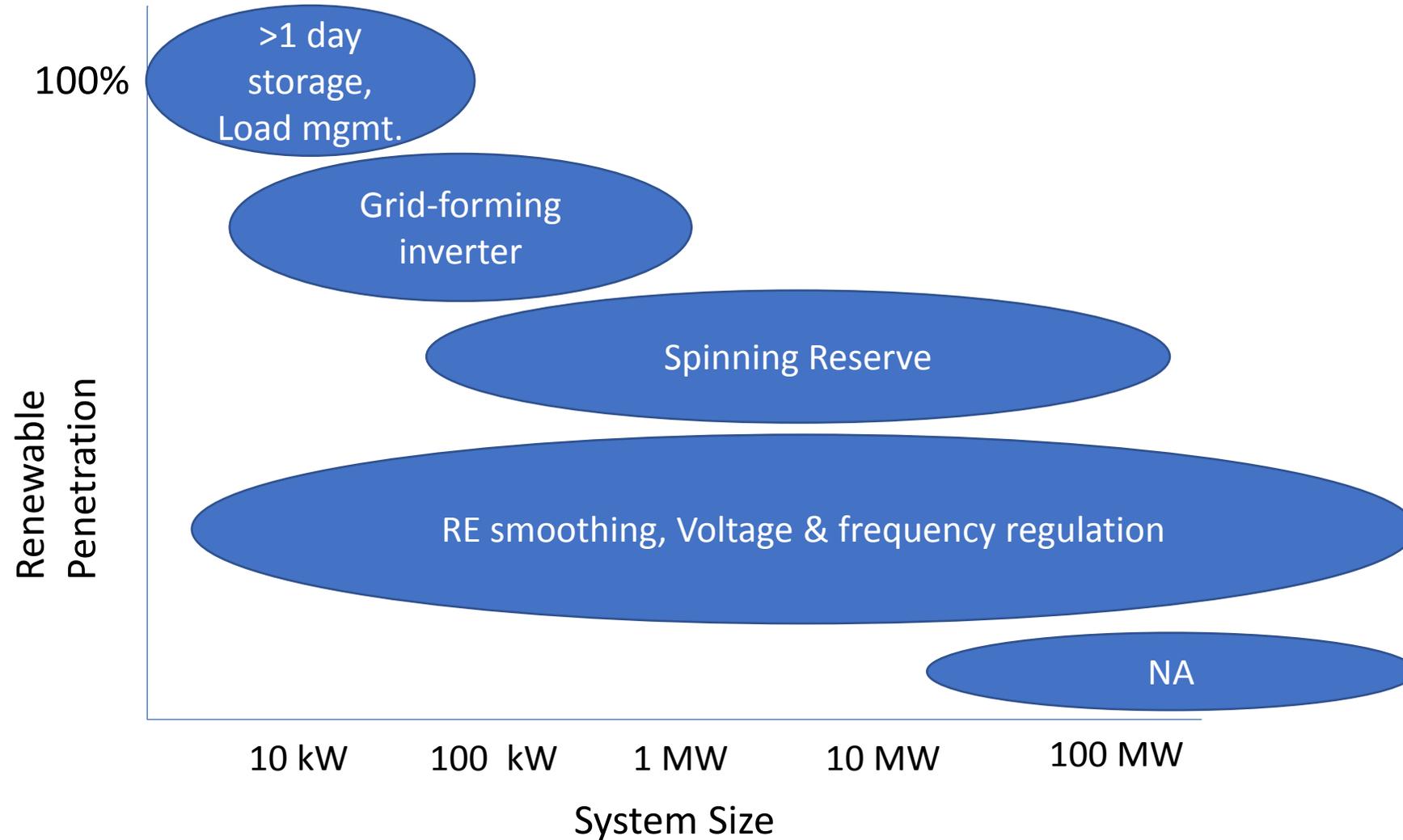
Training

Support



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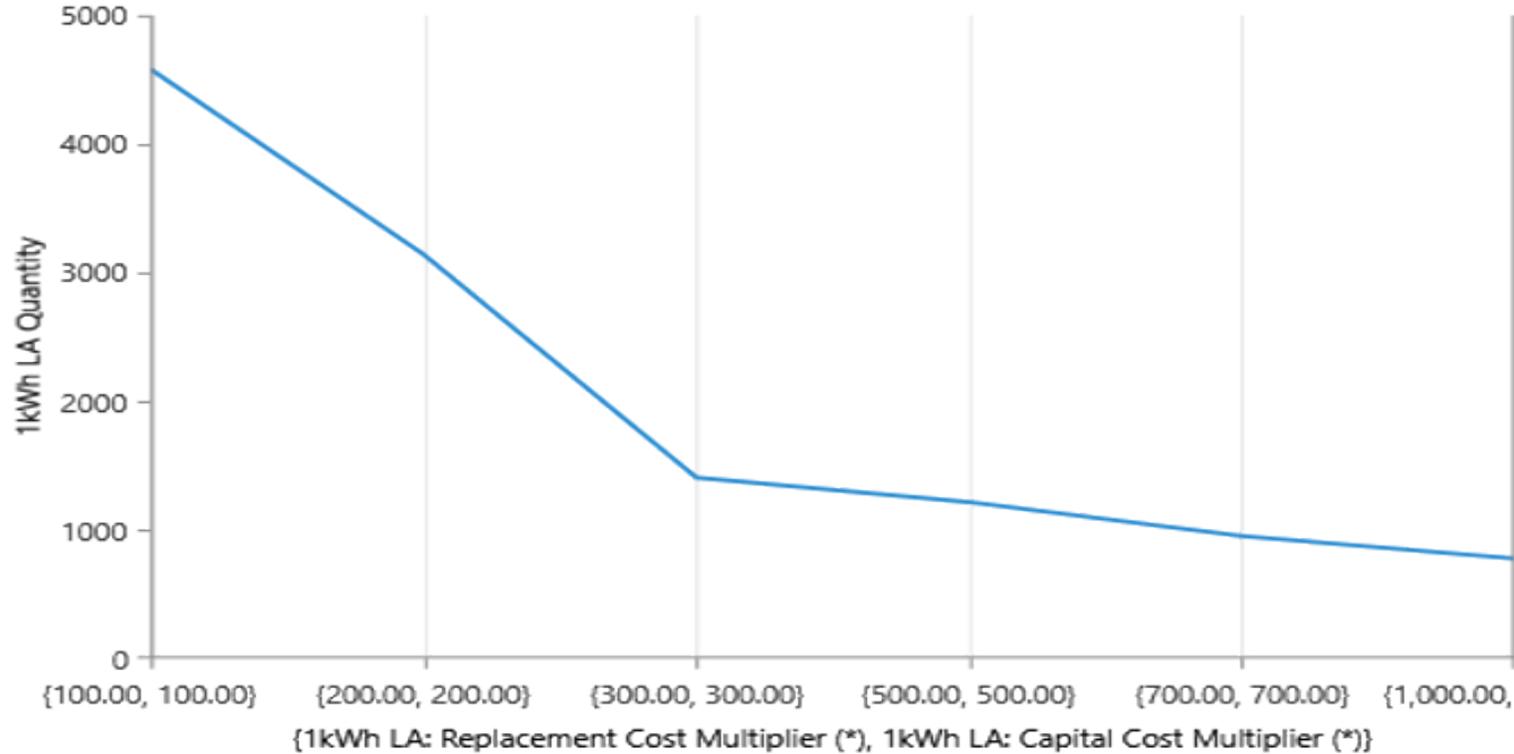
Role of Storage



Power/Energy ratio depends on RE penetration

Least Cost Design Response to Price Decrease

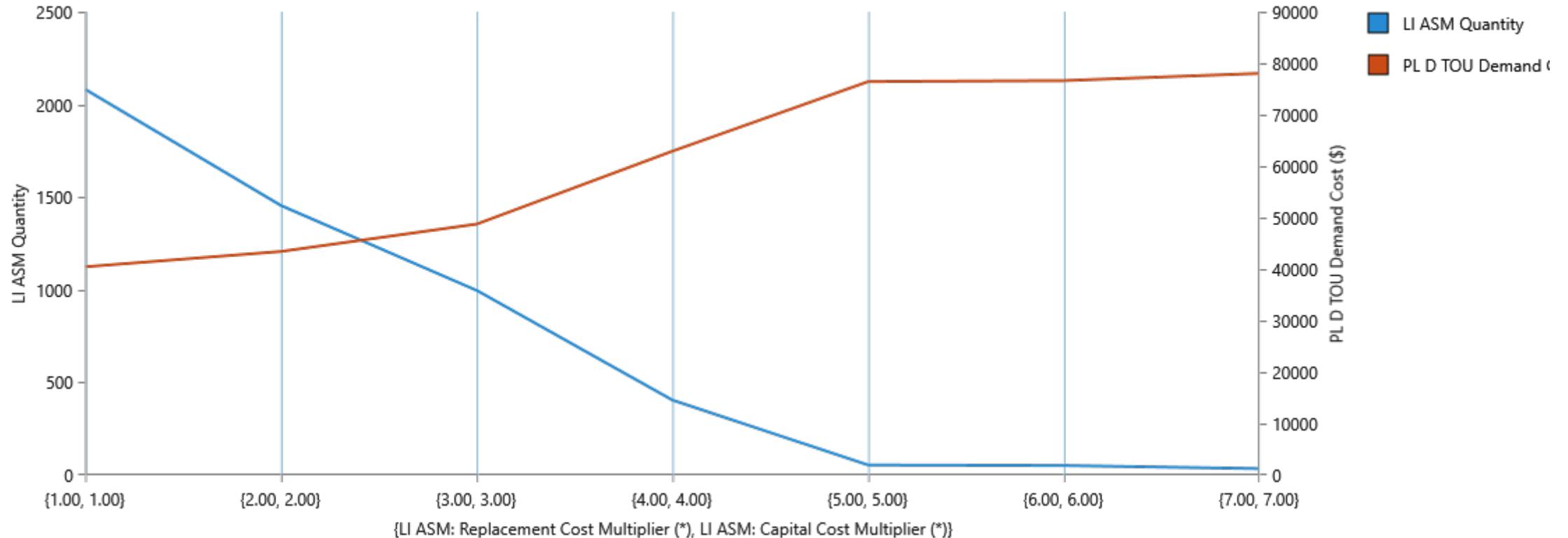
Isolated Grid



\$300 / kWh (installed) threshold for lead batteries

Least Cost Design Response to Price Decrease

Grid connected



All scenarios with 4 day outages had PV & Batteries

Conclusions

- The future is distributed & hybrid
 - RE-only systems are going away
- Batteries are breaking the cost barrier
- Modeling storage is hard
 - Chronology
 - Electrochemistry
 - Complex rate structures
 - Reliability