METHODS FOR DISTRIBUTION GRID PLANNING

Miguel Heleno, Berkeley Lab

Utah – Grid Modernization WG
September 7, 2022

IN THIS PRESENTATION

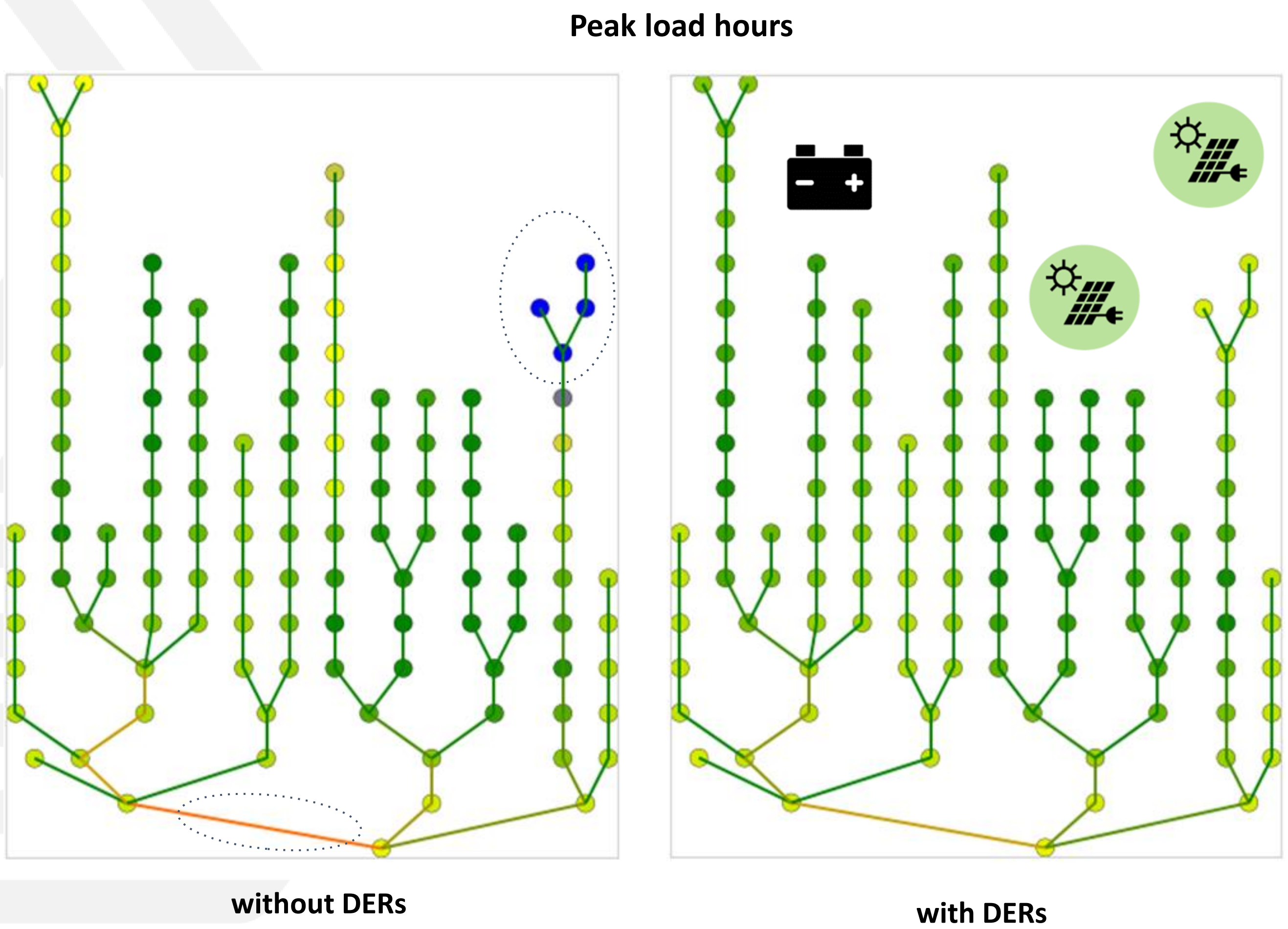
- **Current Methodologies for DER Planning**:
  - DER Impacts on the Distribution Grid
  - Regulatory approaches to value DERs in the distribution planning stage
  - Quantification of DER benefits
  - Limitations of the current methodologies
  - Capturing DER value in operations

- **Challenges:**
  - The dynamic relationship between DER incentives and grid impacts
  - Value of DERs in Reliability and Resilience contexts

DER IMPACTS ON DISTRIBUTION GRID

- In typical distribution feeders, DERs can reduce netload, which fundamentally benefits the distribution grid in 3 ways:
  - Peak capacity reduction
  - Voltage support
  - losses reduction

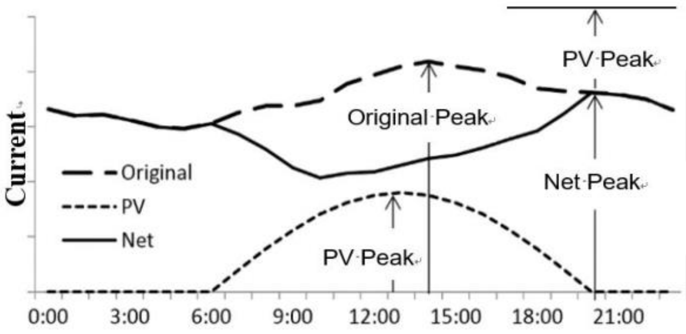
- These benefits translate into a value to the utilities and, ultimately, to the ratepayers:
  - Investment deferral
  - Operational / energy costs reduction



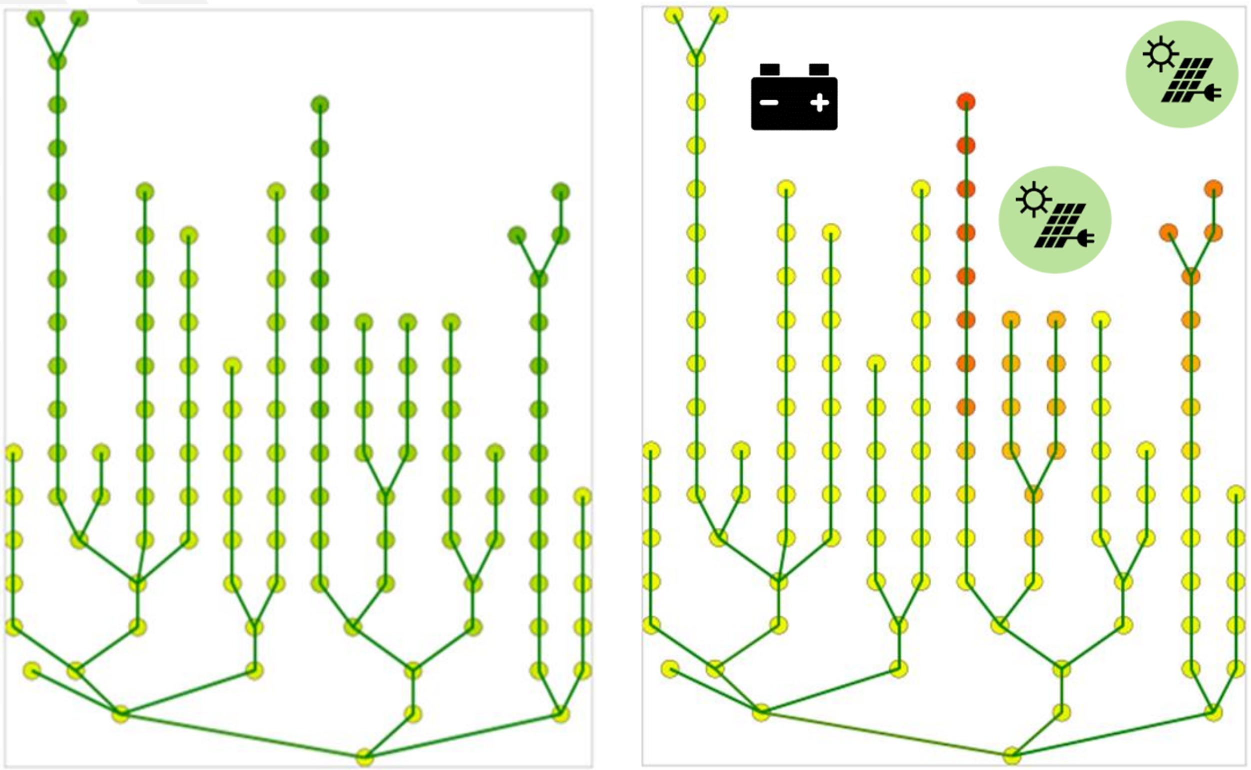
DER Impacts on Distribution Grid

- However, too much netload reduction can also be a problem to the operation of the distribution grid:
  - voltage stability
  - reverse power flows

- The benefits are associated with the temporal "alignment" between DERs output and feeder load.



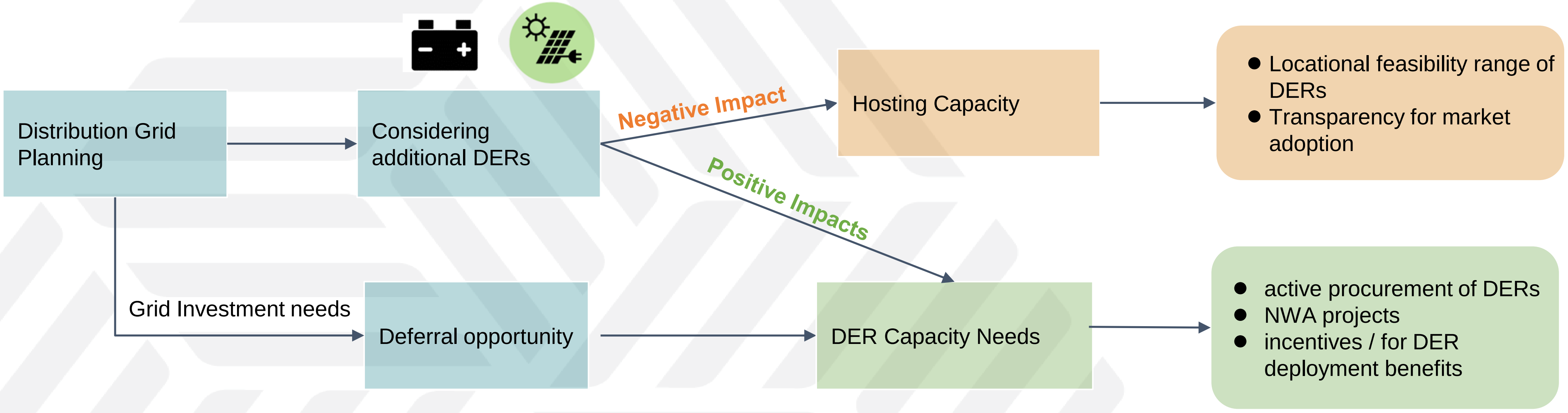
Valley load hours



without DERs

with DERs

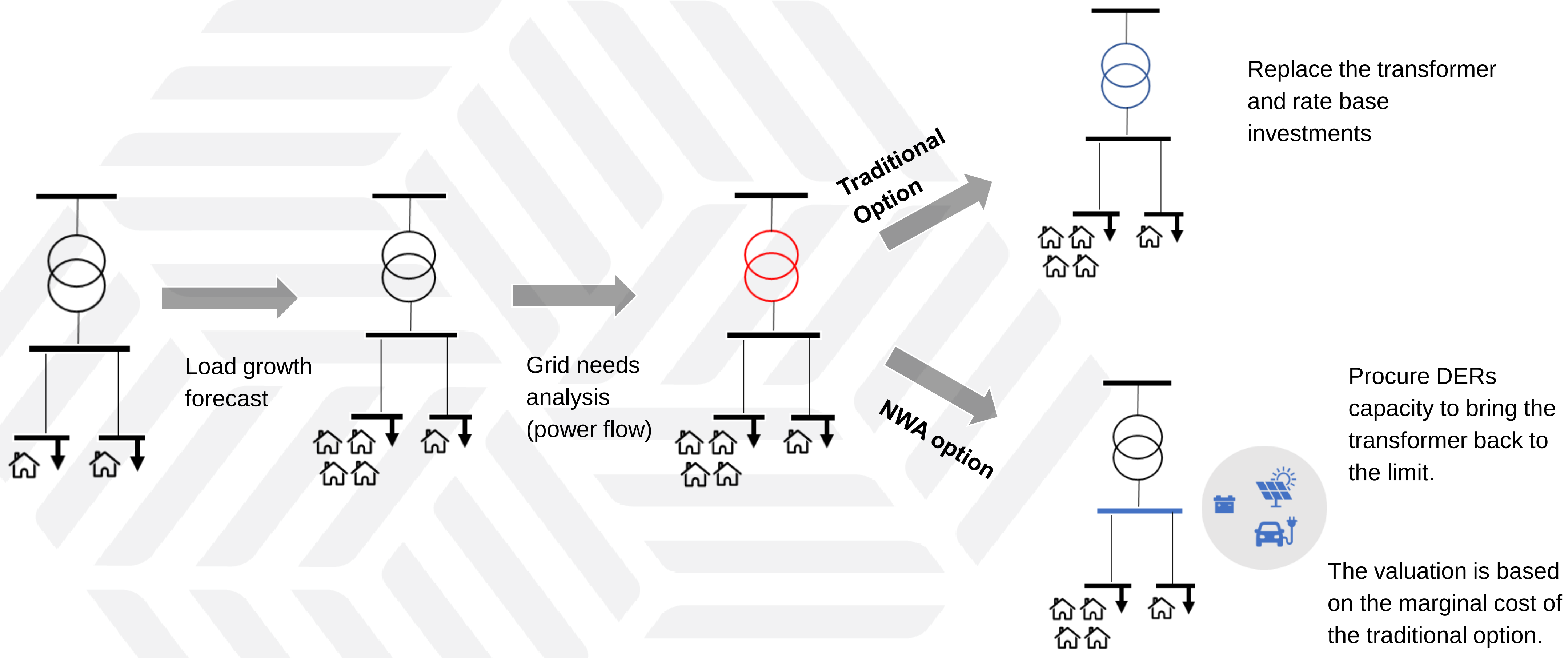
REGULATORY APPROACHES TO VALUE GRID IMPACTS OF DERS



- **Negative Impacts:** Utilities are typically not required to quantify them.
- Instead, these impacts are embedded into the hosting capacity analysis, which returns the feasible penetration of DERs in each location.

- **Positive Impacts:** Utilities are required to identify investment deferral opportunities that can be addressed by DER capacity.
- The value of the investment deferred informs the procurement of DER capacity.

Locational Value of DERs: Distribution Planning Example



Locational Value of DERs: Quantifying Benefits

Avoided Distribution Infrastructure

$$\text{Benefit}_{Y} = \sum_{V}\sum_{C} \frac{\Delta\text{PeakLoad}_{Y,r}}{1 - \text{Loss\%}_{Y,b\to r}} * \text{DistCoincidentFactor}_{C,V,Y} * \text{DeratingFactor}_{Y} * \text{MarginalDistCost}_{C,V,Y,b}$$

C = Constraint on an element

V = Voltage level (e.g., primary, and secondary)

Y = Year

b = Bulk System

r = Retail Delivery or Connection Point

ConEdison Benefit Cost Analysis Handbook

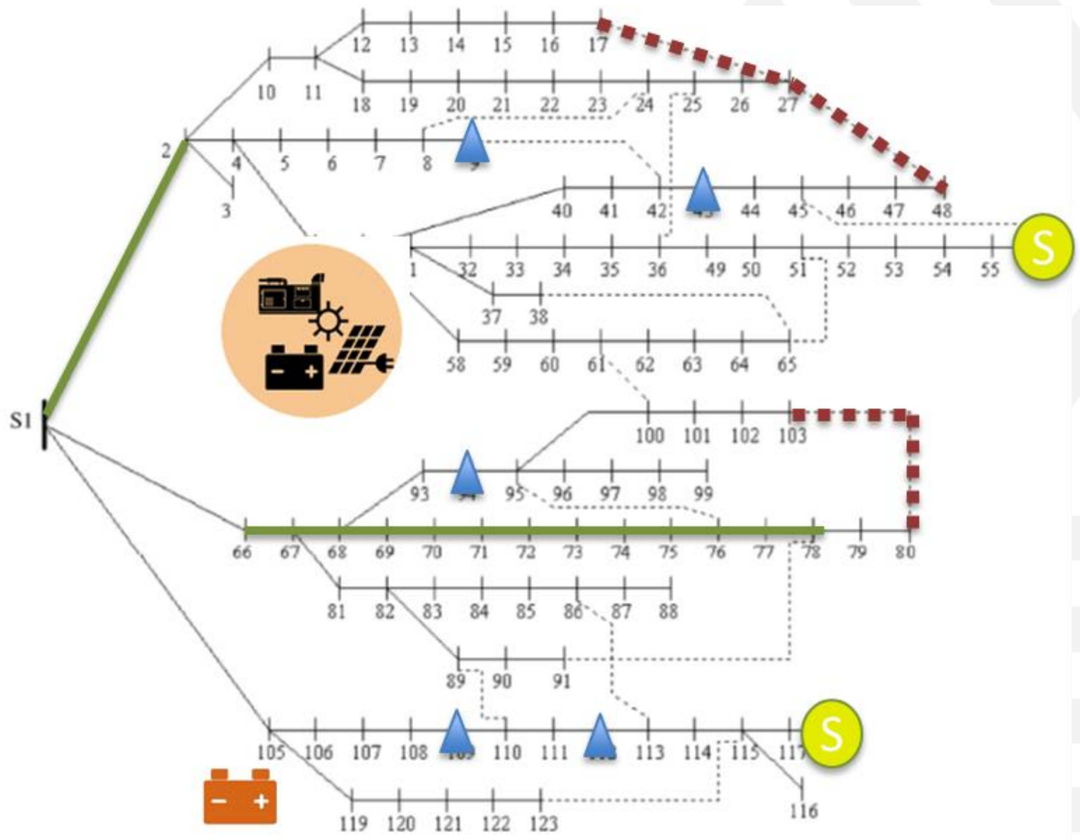
Infrastructure Investment Deferral

$$\textit{Present Worth Deferral Value} = \sum_{t=1}^{n} \frac{K_t}{(1+r)^t}\left[1 - \left(\frac{1+i}{1+r}\right)^{\Delta t}\right]$$

n = finite planning horizon in years,
t = base year,
K_t = deferrable portion of distribution investment in year t,
i = inflation rate net of technological progress,
r = a utility's cost of capital (discount rate), and
Δt = deferral time

$$\$/kW\ \textit{Marginal Cost} = \frac{\textit{Present Worth Deferral Value}}{\textit{Deferral kW}}$$

Limitations of Existing Approaches



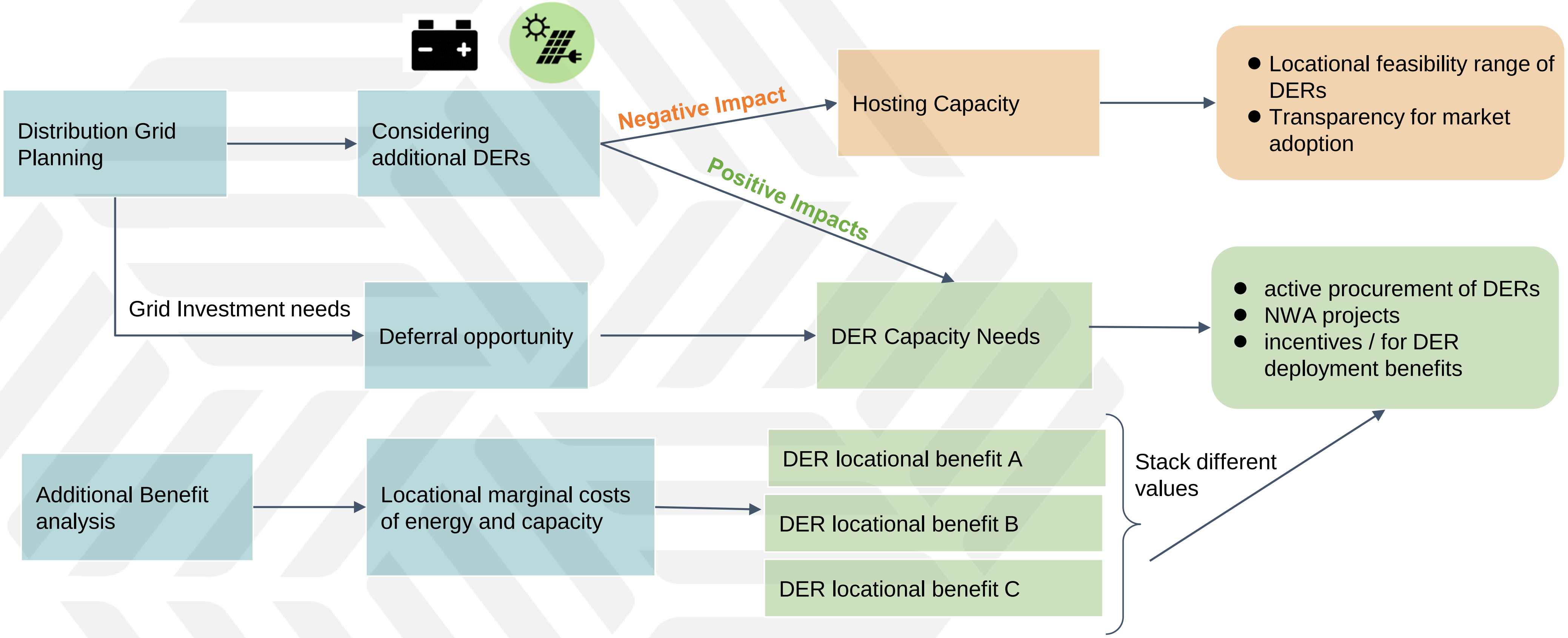
- Existing methodologies try to establish a 1:1 relationship between the investment and the benefit created.
- The reality is more complex: 1 DER investments can provide multiple benefits;
- Instead of just a power flow, utilities could be incentivized to run a least cost optimization problem with all NWA as investment options.

Minimize Ann. Investment Costs

St
nodal balance constraints
power flow constraints
substations constraints

For Peak conditions

CAPTURING ADDITIONAL OPERATIONAL BENEFITS



► Utilities can be required to capture additional values (beyond investment deferral), such as reduction of bulk power system capacity and energy uses.

LIMITATIONS OF EXISTING APPROACHES

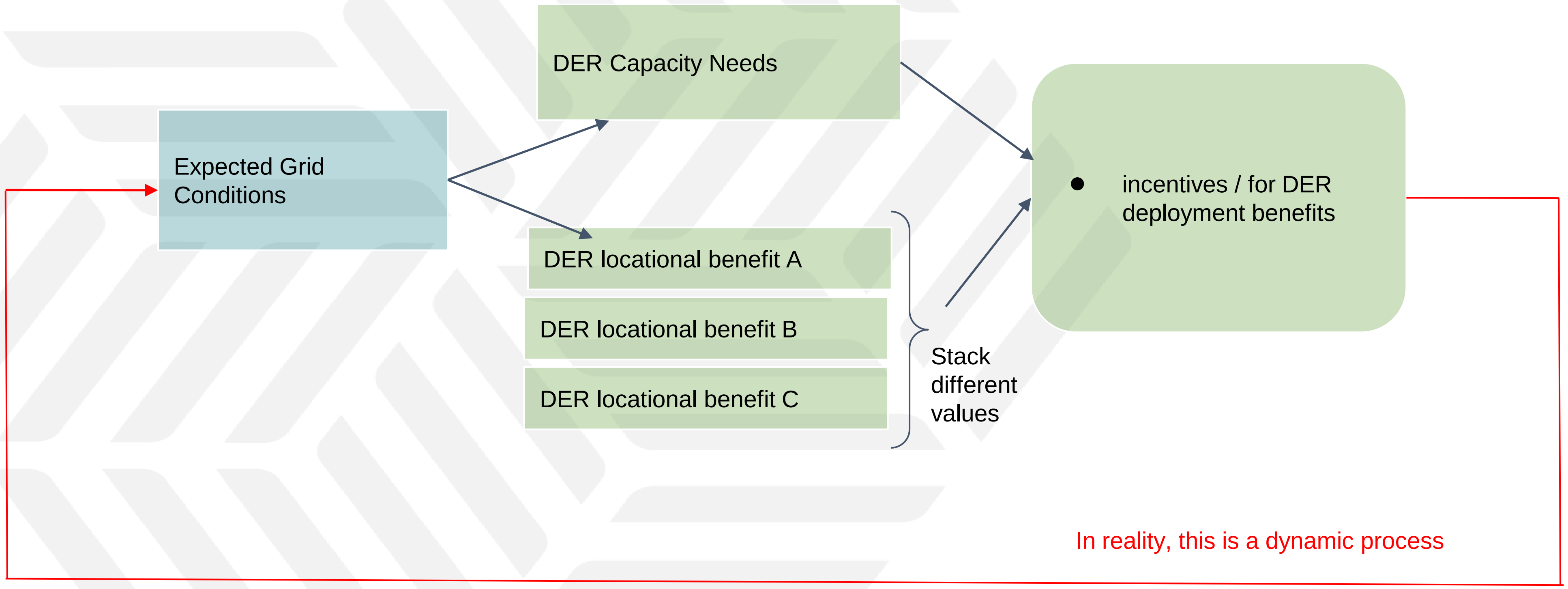
Value Name	Description	Eligible DERs
Energy Value (LBMP)	LBMP is the day-ahead wholesale energy price as determined by NYISO. It changes hourly and is different according to geographic zone.	All technologies: PV, storage, CHP, digesters, wind, hydro, and fuel cells.
Capacity Value (ICAP)	ICAP is the value of how well a project reduces New York State's energy usage during the most energy-intensive days of the year. Developers can choose from three payout alternatives and most ICAP rates change monthly.*	All technologies receive ICAP. Dispatchable technologies (stand-alone storage, CHP, digesters, and fuel cells) will receive Alternative 3.
Environmental Value (E)	E is the value of how much environmental benefit a clean kilowatt-hour brings to the grid and society. The E value is locked in for 25 years.**	PV, wind, hydro, and storage charged exclusively from PV or wind energy. Stand-alone storage is not eligible at this time.
Demand Reduction Value (DRV)	DRV is determined by how much a project reduces the utility's future needs to make grid upgrades. DRV is locked in for 10 years.**	All technologies.
Locational System Relief Value (LSRV)	LSRV is available in utility-designated locations where DERs can provide additional benefits to the grid. Each location has a limited number of MW of LSRV capacity available. The LSRV is locked in for 10 years.**	All technologies. Project must be on a utility-specified substation.
Community Credit (CC)	CC is available on a limited basis to encourage the development of Community Distributed Generation (CDG) projects. CC is the successor to the Market Transition Credit (MTC) and is similar in structure. The CC is locked in for 25 years.** PV projects in utility territories that have fully expended their CC may be eligible for the Community Adder – an upfront incentive administered by NY-Sun.	Available for CDG projects including PV and digesters. Wind, hydro, and fuel cells receive CC at a derated value. Not available for stand-alone storage or CHP.

NYSERDA Value Stack Eligibility

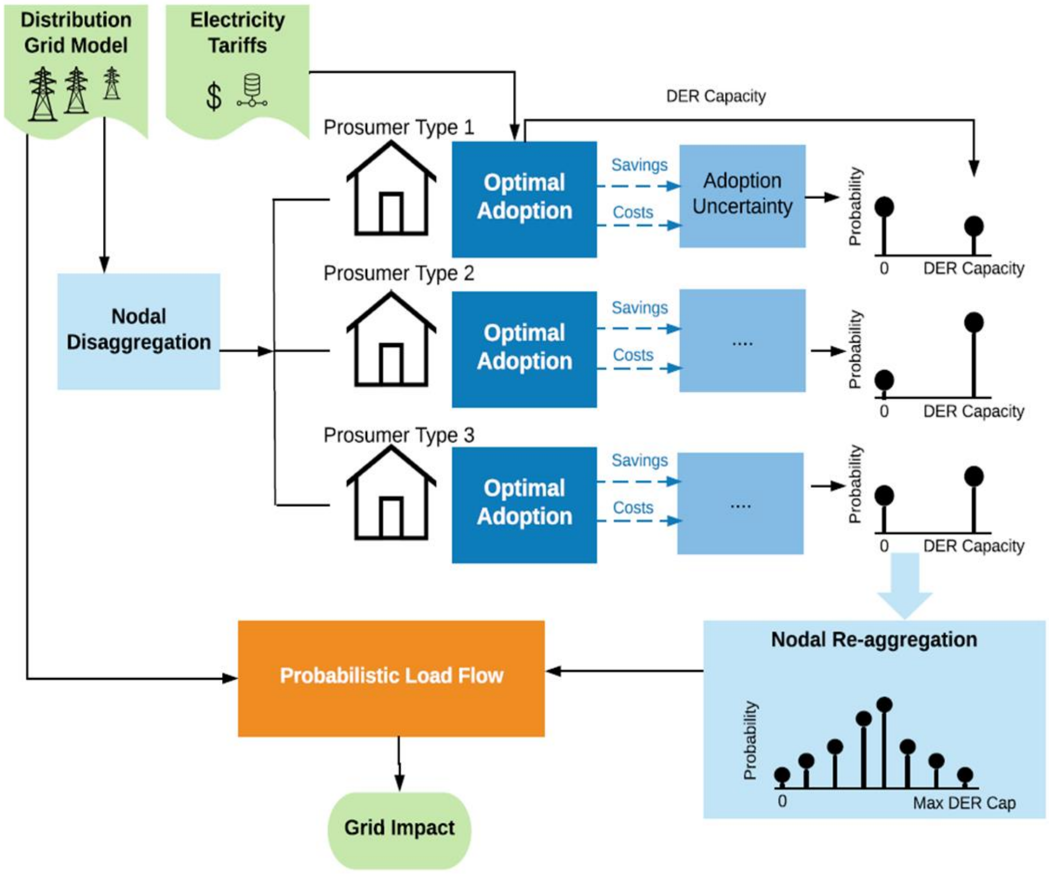
- Multiple DER value (including locational ones) can be integrated into different incentives and compensation mechanisms.
- This provides more realistic incentives (including temporal) that can capture the operational value of DERs.

CHALLENGE 1: A DYNAMIC PROCESS

- ► The procurement of DERs through incentives (e.g. rates, compensation mechanisms) changes the behavior of adoption, which may lead to unexpected changes in the grid itself.
  - ► DERs make ratemaking and distribution planning interdependent.



Example of Dynamic Incentives

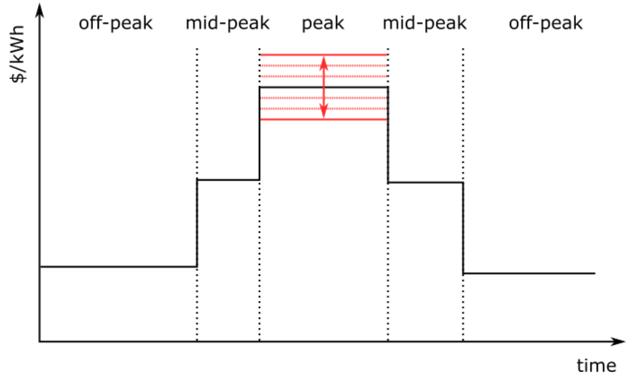


- Change solar compensation incentives for Solar + Storage adoption.
- Model how those incentives would change the adoption and operation of DERs.
- Capture the impact on the distribution grid.

2 Type of incentives

Vary solar compensation as a function of the volumetric energy tariff.

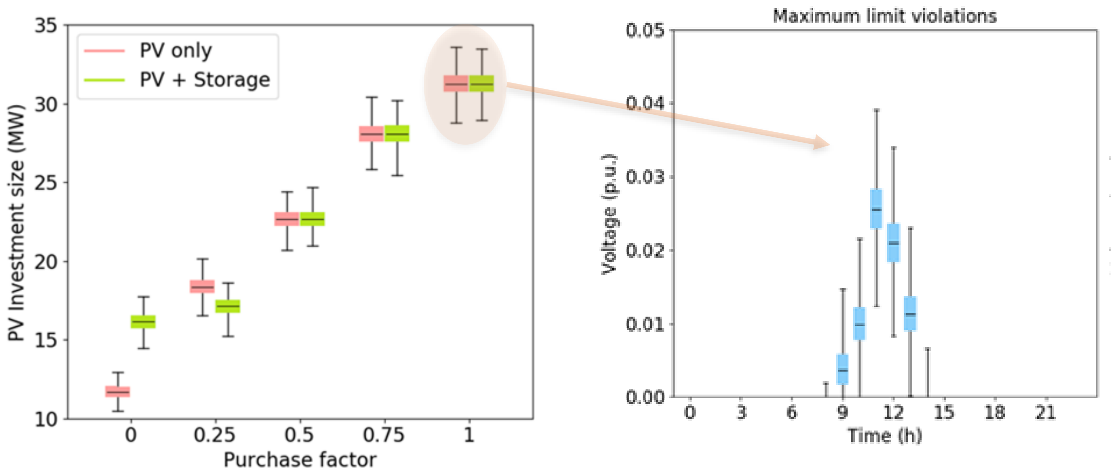
Vary energy cost during the <u>peak time</u> to control the grid peak.



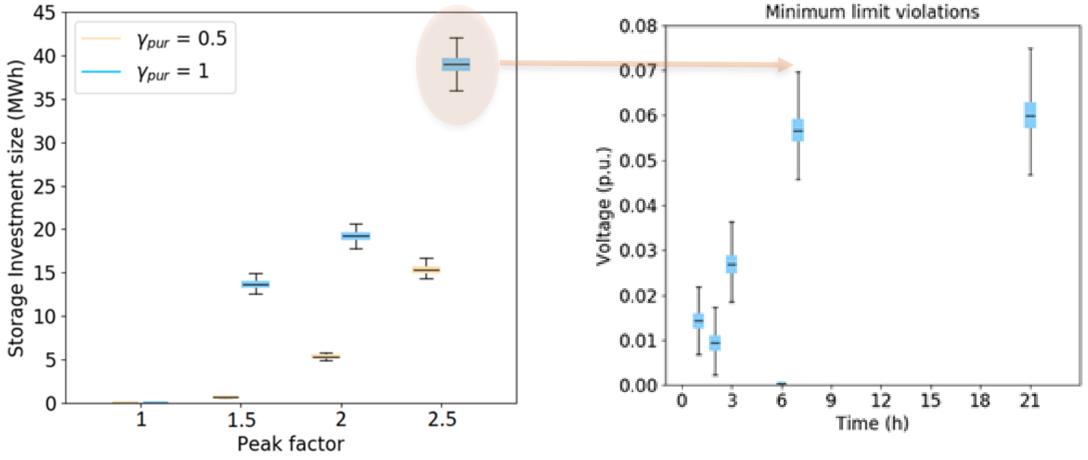
M. Heleno, D. Sehloff, A. Coelho, A. Valenzuela, “Probabilistic impact of electricity tariffs on distribution grids considering adoption of solar and storage technologies", Applied Energy, vol. 279, December 2020.

Example of Dynamic Incentives

- Increasing solar compensation leads to more adoption of behind the meter PV, which reduces the energy uses.
- However, when those incentives are too high, we see some violations of the upper voltage limits in the grid.



- Increasing the energy cost at the peak hours introduce a price differentiation that makes storage technologies attractive and reduces the peak load.
- However, when those incentives are too high, there is a risk of undervoltage violations due to aggressive energy arbitrage behaviors.



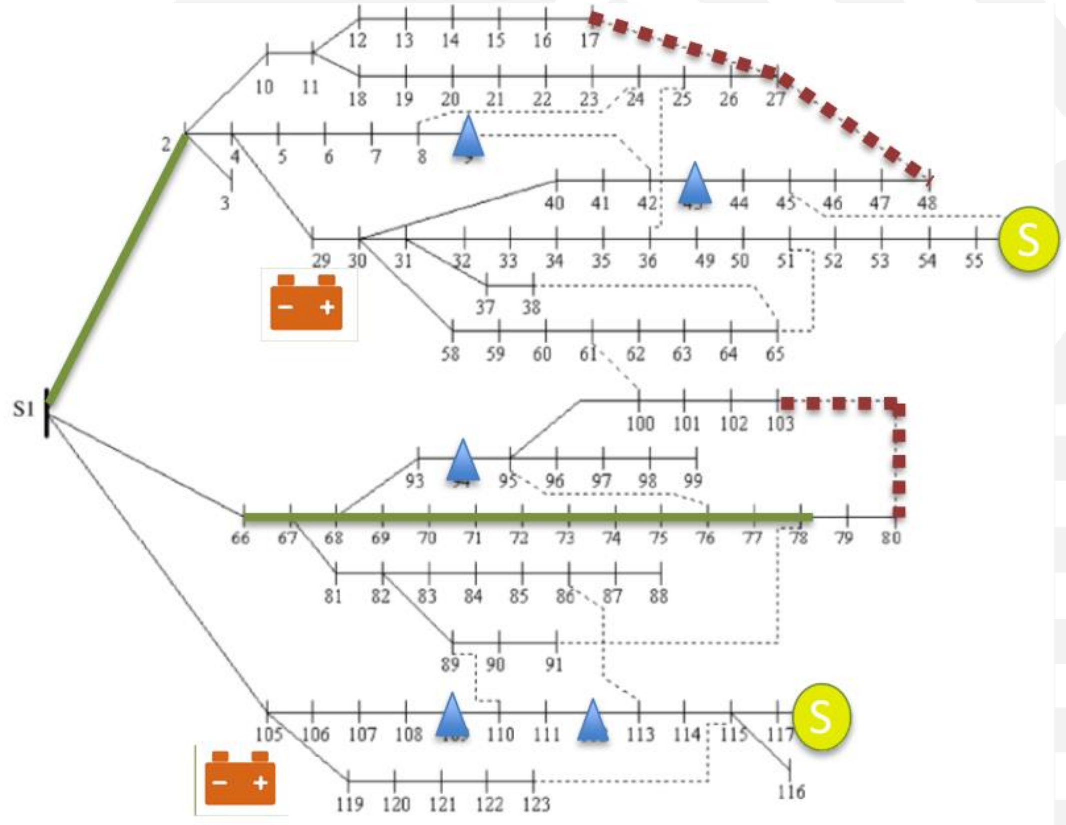
M. Heleno, D. Sehloff, A. Coelho, A. Valenzuela, "Probabilistic impact of electricity tariffs on distribution grids considering adoption of solar and storage technologies", Applied Energy, vol. 279, December 2020.

CHALLENGE 2: VALUING DERs IN RELIABILITY AND RESILIENCE CONTEXTS

GRID MODERNIZATION LABORATORY CONSORTIUM
U.S. Department of Energy

- How to make sure utilities have the necessary resources on the ground to respond to routine failures and mitigate the HILP events?
- How can utilities make risk informed decisions when planning for investments with DERs?
- What are the trade-offs between optimizing for Economic, Reliability and Resilience targets?

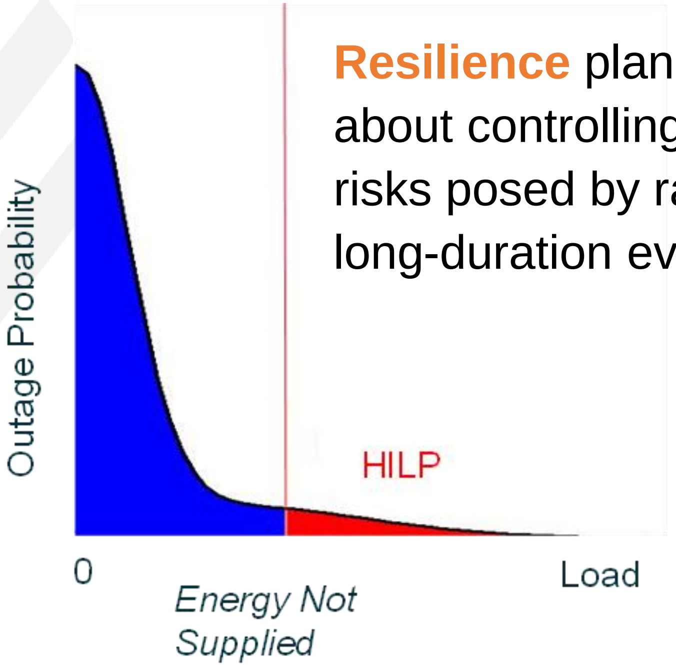
RELIABILITY VS RESILIENCE PLANNING



Reliability planning is about mitigating outages caused by routine events.

- Expected value of interruptions.

Resilience planning is about controlling the risks posed by rare, long-duration events.



Can we Capture Risk-Aversion in Distribution Planning?

cost $\begin{cases} \text{Investment costs} \\ \text{Operation costs} \\ \text{Outage costs} \end{cases}$

St
nodal balance constraints
power flow constraints
substations constraints

time coupling constraints
for battery operation

DG model and technical limits

For each hour "t" of a typical day "d"

Reliability
Expected value of the outages
(Routine events)

Resilience
Conditional value at Risk of outages
(HILP events)

$$\text{Minimize}(1-\lambda)\underline{E}[cost] + \lambda \underline{CVaR}[cost]$$

Level of Risk Aversion considered in the **reliability vs resilience** planning exercise

EXAMPLE: TEST FEEDER

Test Feeder

13.5 kV

54 Nodes – 50 Lines

7 MW Peak

Scenarios

1263 scenarios of **routine** failures (1 every 2.5 years)

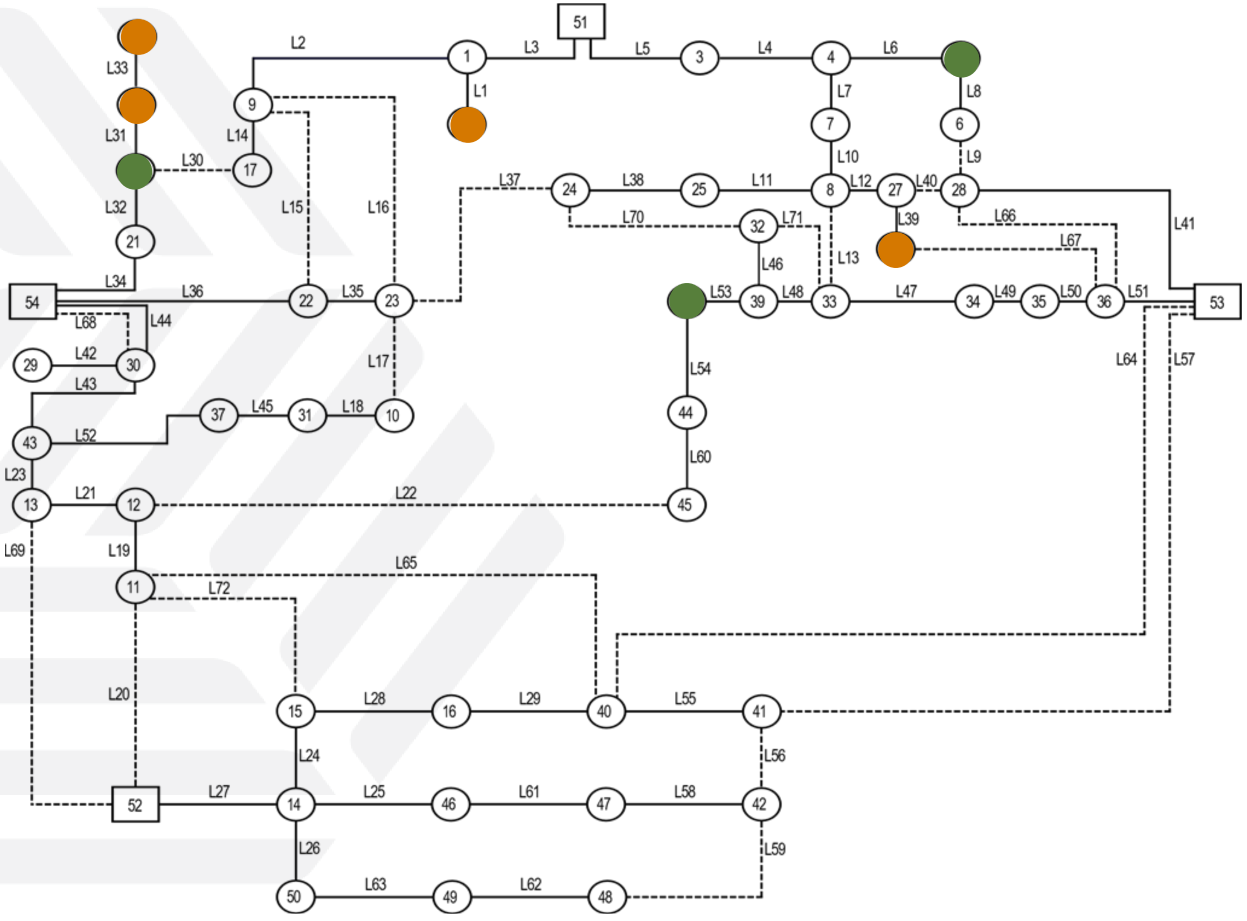
100 scenarios of **HILP events** (1 every 70 years)

Candidate Assets

22 new lines

4 batteries nodes

4 types of DG in 3 candidate nodes



. . . . **New Lines**

Battery nodes

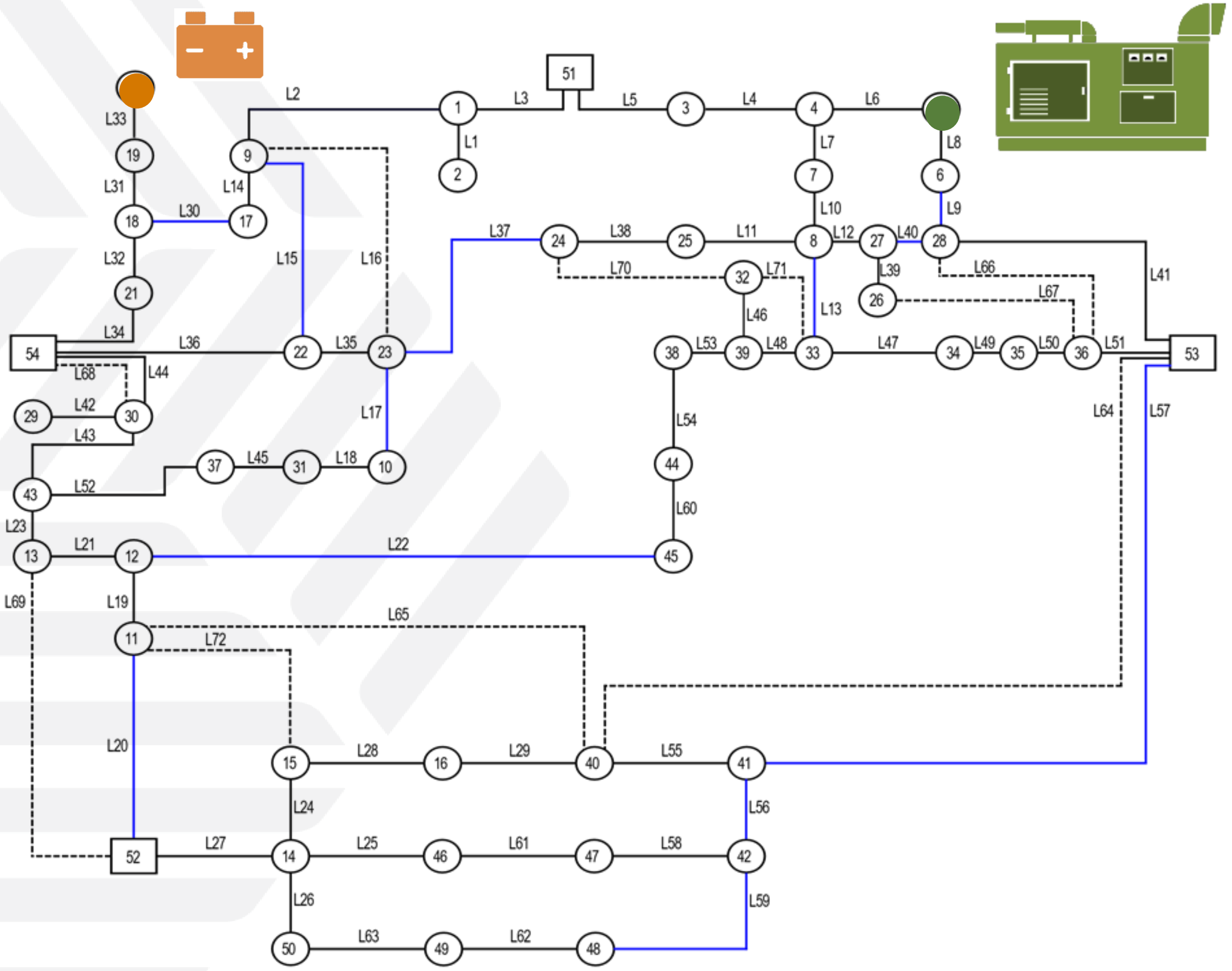
DG nodes

Planning Solution Considering Reliability Only (λ=0)

New Lines: 12

Battery nodes: 1 x 280 kWh

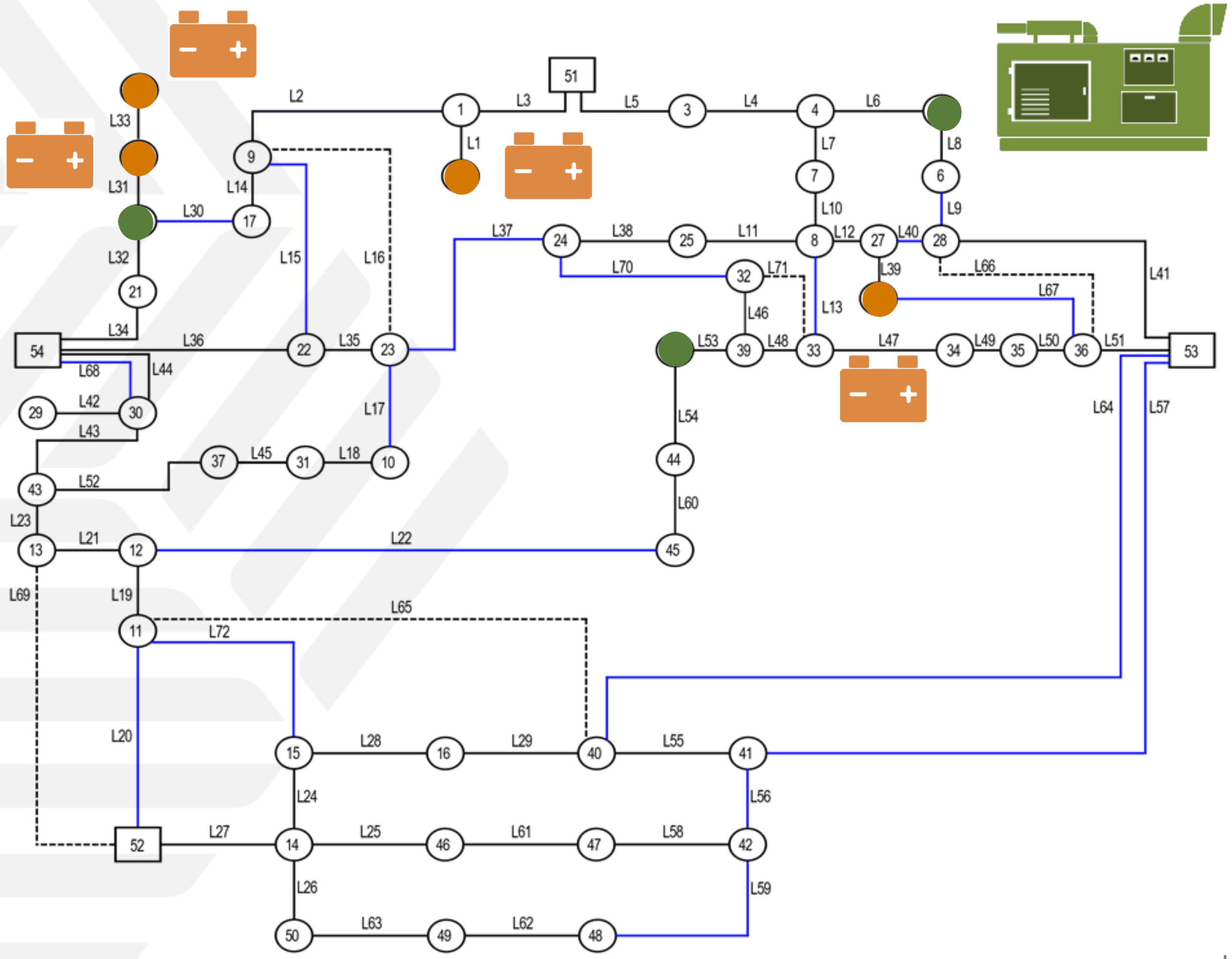
DG: 1 x 800 kW (NG)



New Lines: 17

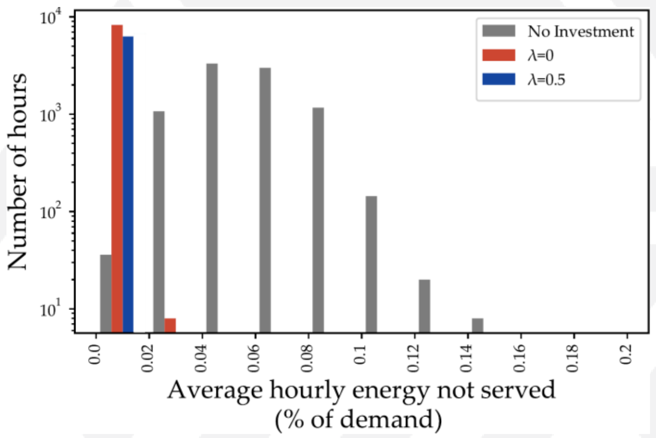
Battery nodes: 1 x 800 kWh
1 x 500 kWh
1 x 360 kWh
1 x 360 kWh

DG: 1 x 800 kW (NG)

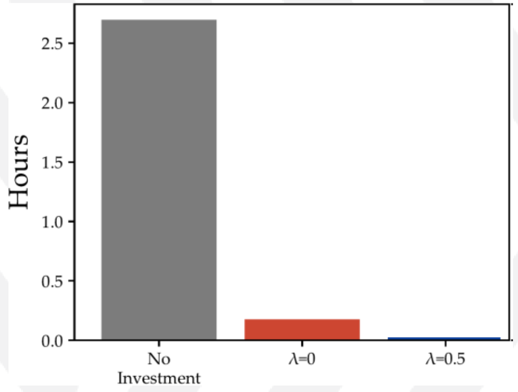


CASE STUDY RESULTS

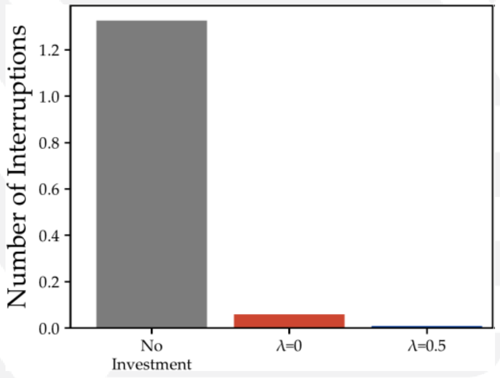
% AENS – distribution



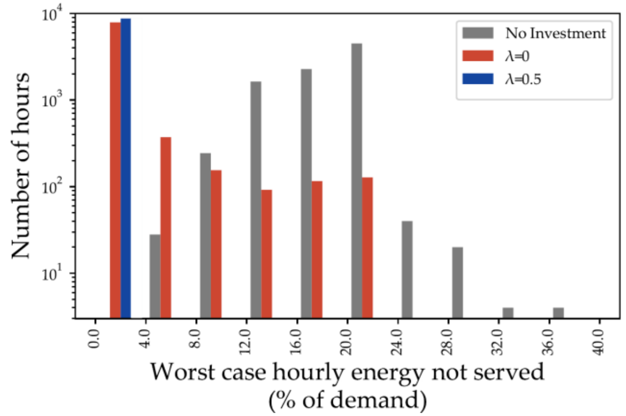
SAIDI



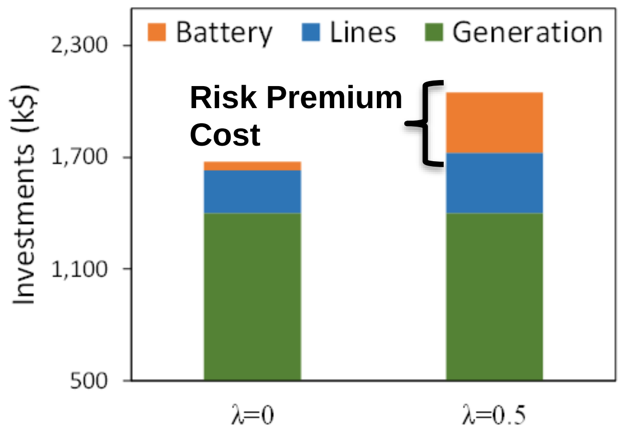
SAIFI



Worst case evaluation



Investments



KEY TAKEAWAYS

- **Valuing DERs in the Planning Stage**
  - Negative DER impacts are embedded into hosting capacity methodologies.
  - Positive impacts are valued based on direct investment deferral.
  - The main limitation of this approach is to neglect the inter-dependent nature of DER investments.

- **Valuing DER in operations**
  - Existing methodologies capture different values of DER capacity (per kWh or kW) related to energy, capacity or even environmental benefits.
  - These values can be obtained in different temporal and geographical dimensions and used to build advanced (stack-based) compensation mechanisms.

- **Challenges**
  - Due to the dynamic nature of DERs, excessive indirect incentives can create unexpected grid impacts.
  - To quantify the value of DERs in resilience applications, it is necessary to adopt new methodologies that allow transparent risk-aversion policies in distribution grid planning.