The Value of Lost Load

Concepts, methods, and applications

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ENERGY TECHNOLOGIES AREA
BERKELEY LAB

Background on Berkeley Lab

Berkeley Lab By the Numbers

16
Nobel Prizes

16
National Medals of Science

82
National Academy of Sciences members

3,663
Full-time employees

1,781
Scientists and engineers

503
Lab postdoctoral scholars

$1.02 billion
Annual budget

14,000
Researchers worldwide using our facilities

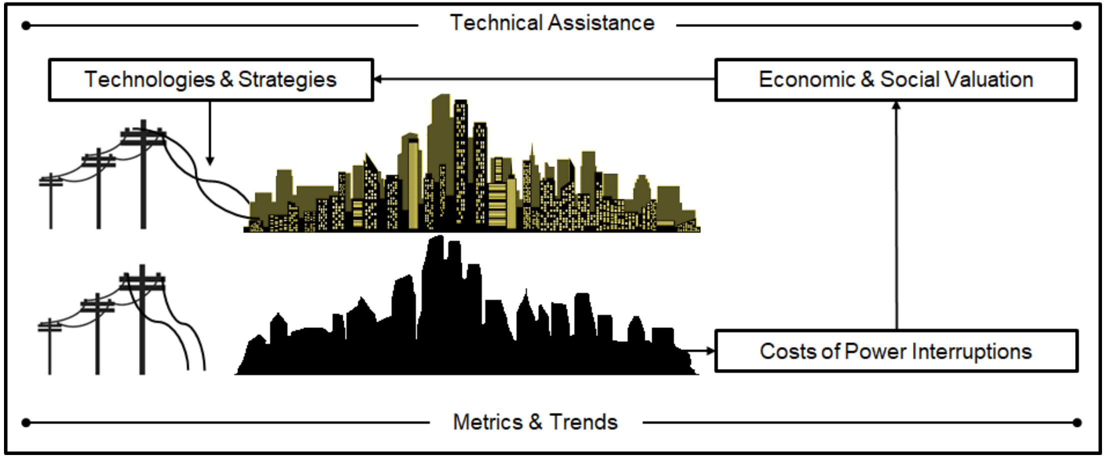
5,300
California researchers using our facilities

Three approaches to research:

- User facilities
- Large-team science with external partners
- Core research programs

Table of contents

- Defining Value of Lost Load (VoLL)
- Methods to calculate the VoLL
- Conceptual and actual applications of VoLL in the power sector
- Open discussion



VOLL: Definition, methods and concepts

What is the VoLL?

Value of service reliability or VoS is defined as a:

"reliability evaluation that explicitly incorporates into the planning process customer choices regarding reliability 'worth' and service costs" (Burns and Gross 1990)

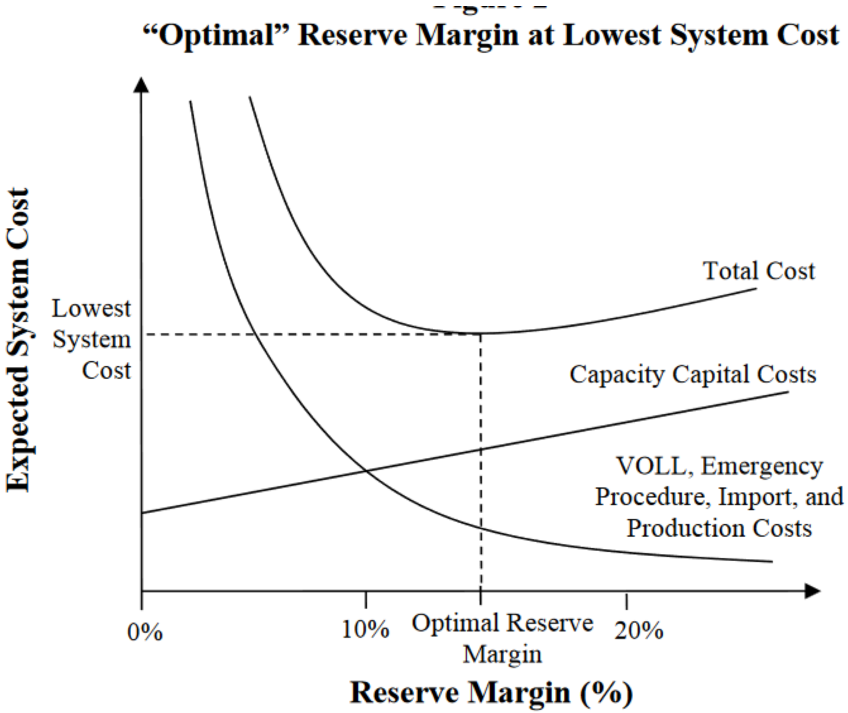
Ideally, the **additional costs of any resource employed to improve reliability should equal the benefits associated with reducing outages** by

"explicitly incorporating customer outage cost information" or value of lost load (VoLL)

Value-based reliability planning is the concept that reliable electric service and strategies to improve reliability have value to society (or utility customers) and these values can be measured using a number of different techniques, including proxy methods, market-based methods, after-the-fact-measurement, and survey-based methods (Burns and Gross 1990).

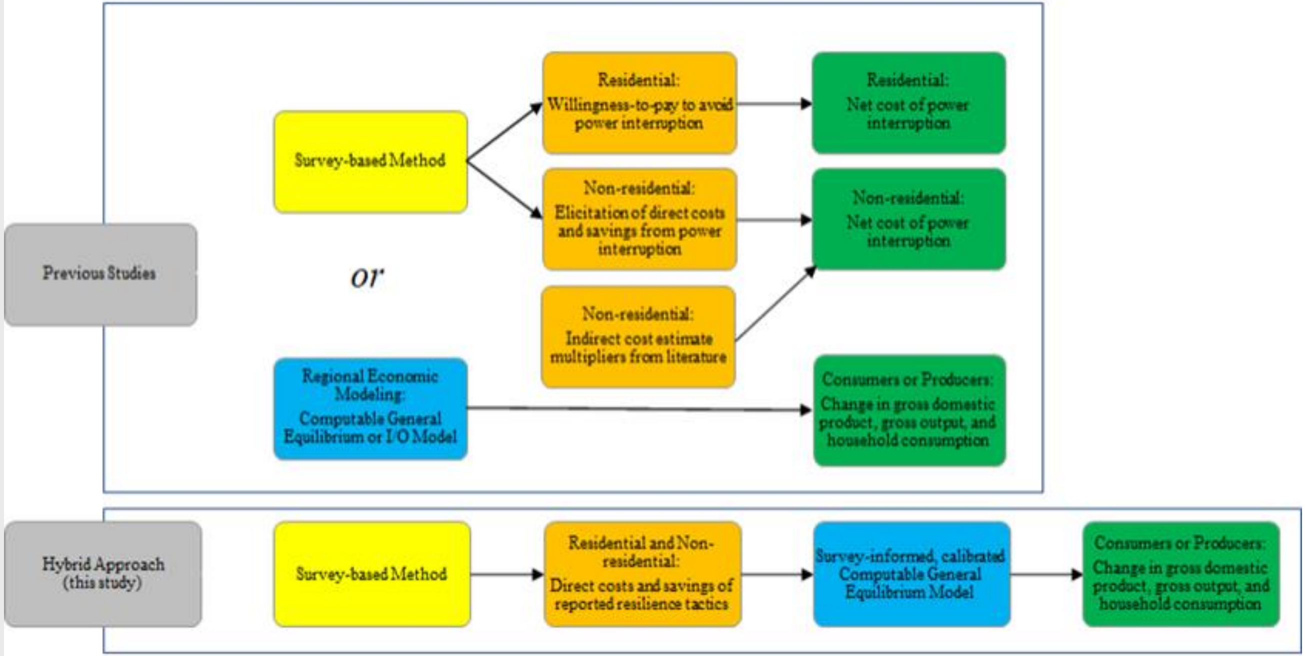
Economics of VOLL

- Larger reserves reduce the system costs of lost load
- However, larger reserves also increase the capital costs for supply and transmission
- A theoretical optimal point is when the total cost is minimized
- **How to produce that VOLL curve?**



Pfeifenberger and Spees, 2013

Methods to measure VoLL



- There are a few ways of measuring VoLL:

  (1) survey-based methods ("stated preference")

  (2) regional economic modeling

  (3) hybrid valuation (survey-informed economic modeling)

  (4) revealed preference (not shown)

  (5) ex-post impacts analysis (not shown)

Examples of VoLL assessment

- Berkeley Lab is pioneering new R&D into the costs of both short duration and localized as well as long duration, widespread power interruptions

ICE CALCULATOR

Customer costs of short duration, localized interruptions

POWER OUTAGE ECONOMICS TOOL

Economic impacts of long duration, widespread interruptions

Two examples of VOLL applications for decision-making

Example of VoLL use: utility undergrounding decision

- Berkeley Lab research into factors that impact long-term reliability of the U.S. power system led to research on the **value of undergrounding power lines**
- Increase in % share of transmission and distribution lines that are **underground has a statistically significant correlation with improved reliability/resilience** ([Larsen et al. 2020](#))

Energy Policy

Distribution-level electricity reliability: Temporal trends using statistical analysis

Joseph H. Eto, Kristina H. LaCommare, Peter Larsen, Annika Todd, Emily Fisher

Energy

Recent trends in power system reliability and implications for evaluating future investments in resiliency

Peter H. Larsen, Kristina H. LaCommare, Joseph H. Eto, James L. Sweeney

Example of VOLL use: customer backup power

- **Residential rooftop and storage systems (PVESS) can mitigate long duration interruptions** by providing backup power during power outages. This can reduce the economic and social impacts of power outages—a key resilience benefit.

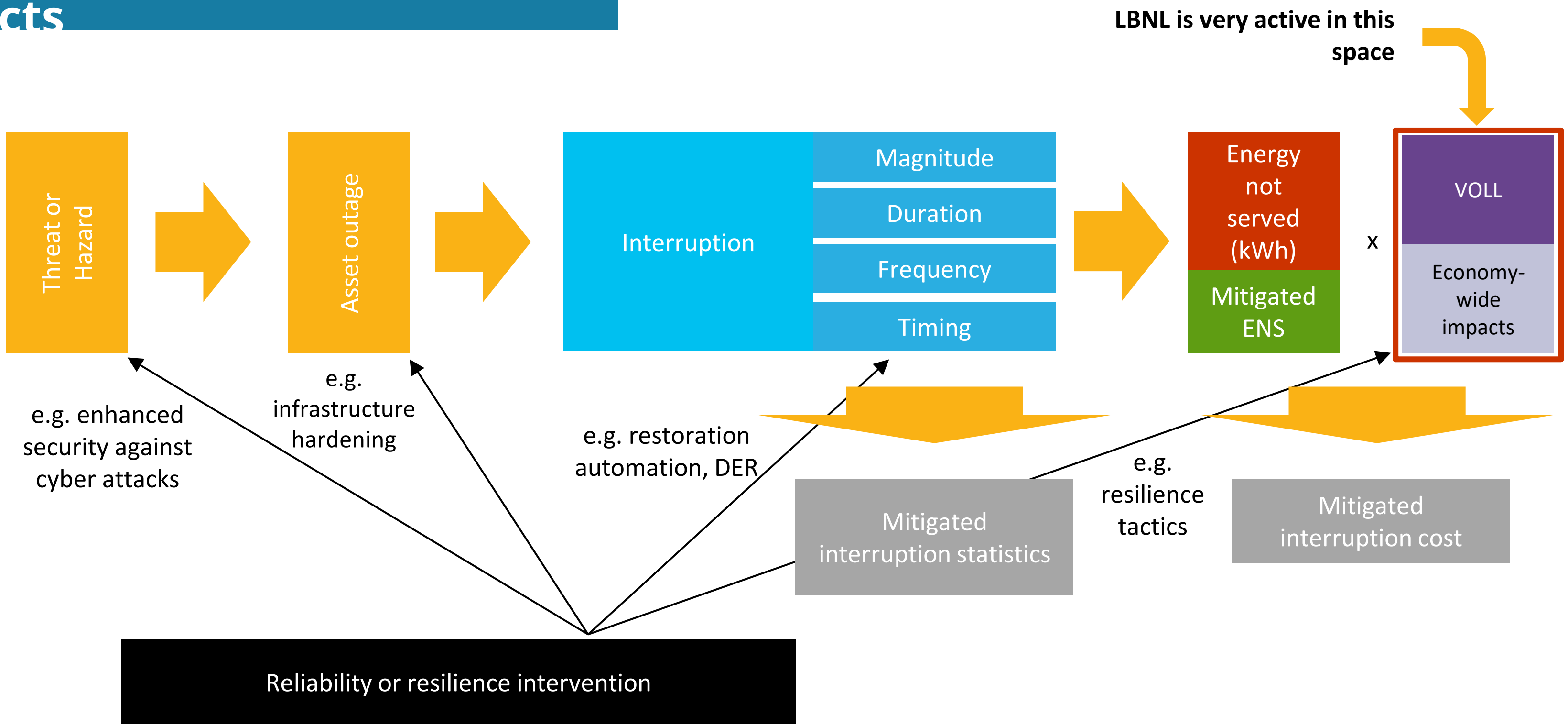
- The benefit-cost ratio (BCRs) of PVESS varies by region, depending on the cost of PVESS, the value of lost load (VOLL), and the likelihood of long duration interruptions.

Key Research Questions

- What is the regional distribution of the ability of residential PVESS to mitigate resilience events (long duration interruptions lasting longer than 1 day)?
- Assuming regionally-differentiated PVESS costs and VOLL, what is the benefit-cost of storage investments on existing PV systems?
- How does this benefit-cost change considering Inflation Reduction Act (IRA) support?

Source: Baik et al. (2023)

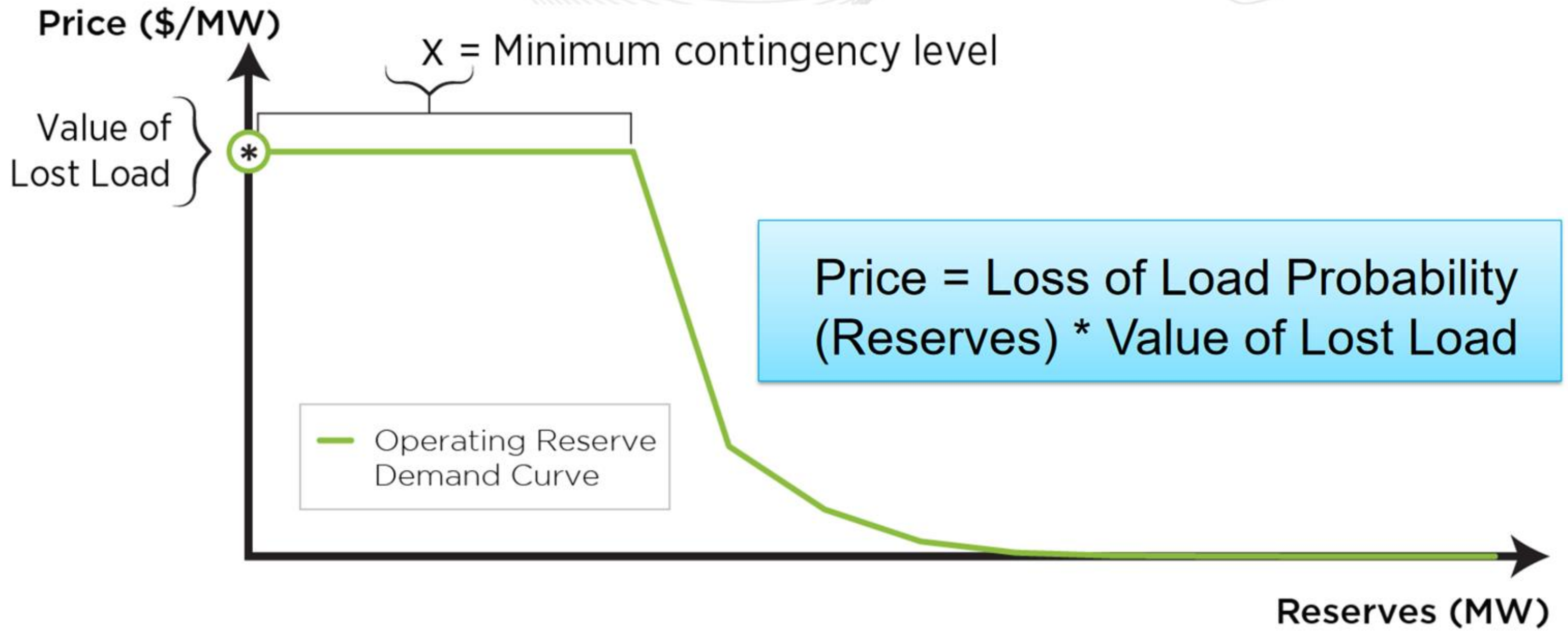
A framework to quantify reliability and resilience impacts



Industry applications of VOLL

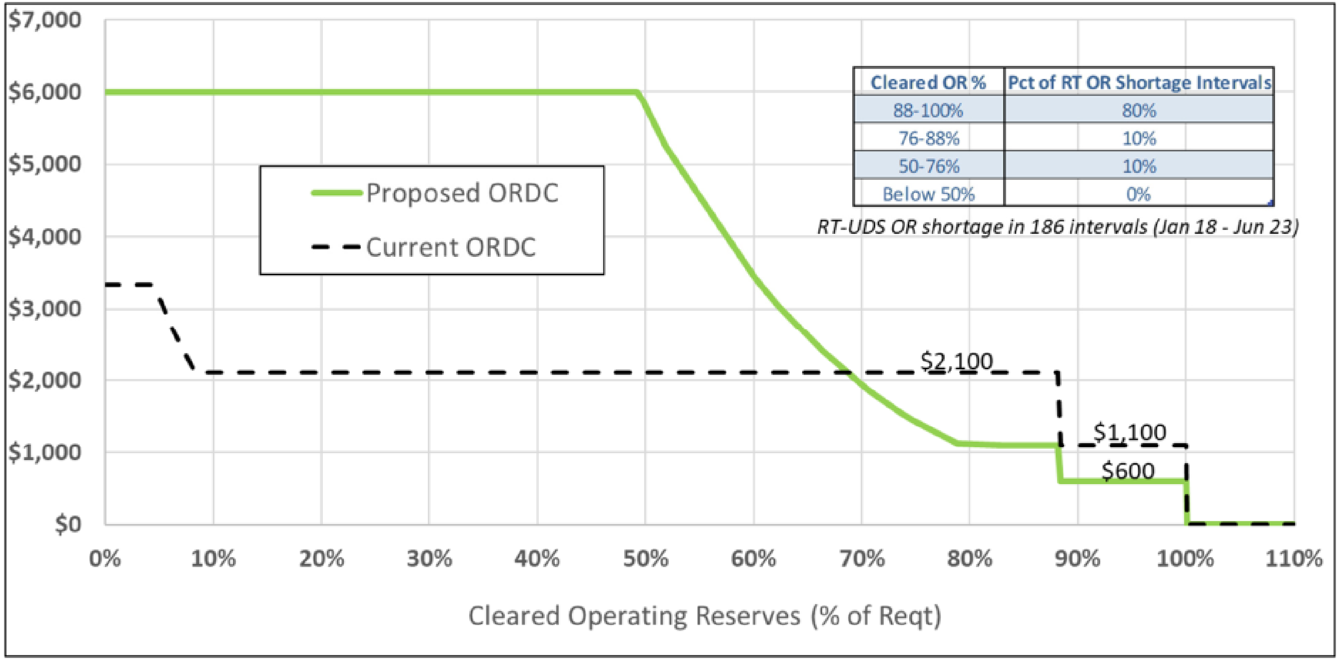
Op Reserve Demand Curve

Example of a traditional administratively set OR demand curve (this one from ERCOT)



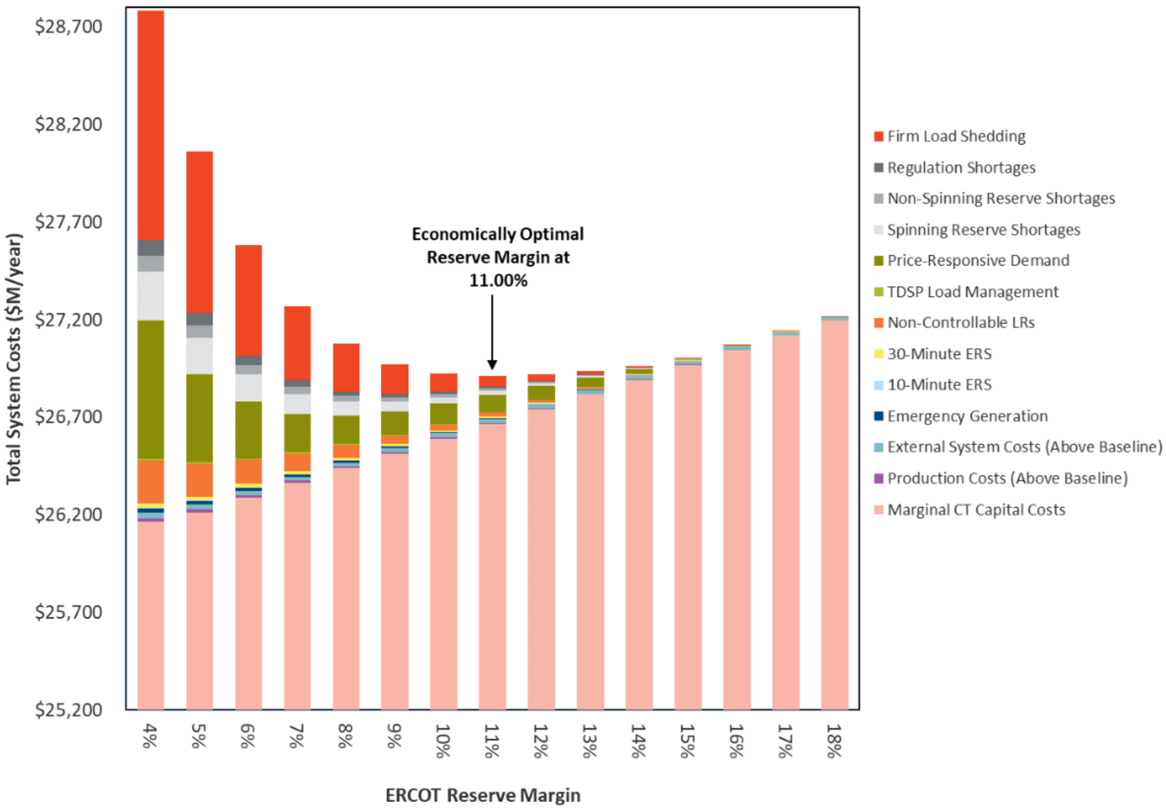
MISO's proposed curve

- In MISO's case, the VOLL establishes an overall threshold
- The upper bound of the ORDC is additive to other system wide caps for energy and reserves



Econ Optimal Reserve Margin

- Example of ERCOT's 2021 study to set the ME and EO reserve margins
- This scenario-based approach shows the relationship between the EORM and the VOLL implied in the monetized load shedding costs



Industry applications for VOLL: ISO/RTO

- MISO:
  - Energy and operating reserve market prices, LMPs and MCPs are capped using the VOLL
  - Use the VOLL as the price during EEA3 event (firm load shedding)
- ERCOT:
  - Historically, the VOLL was used to set the System Wide Offer Cap, but after 2022 this was discontinued
  - Used to set the cap value of the ORDC
  - Also used to determine the Economically Optimal Reserve Margin (EORM) by explicitly adding the cost of lost load to a system capital and production costs
- PJM:
  - Maximum price in 10 and 30-minute ORDC
- CAISO:
  - Transmission Economic Assessment Methodology (TEAM) uses VOLL to monetize the benefits of improved reliability due to transmission upgrades by estimating the consumer surplus.

Industry applications for VOLL: Distribution

- Avoided Energy Supply Costs in New England (AESC)
  - Utilities in NE use the AESC to monetize the benefits of demand side interventions
  - The VOLL is used to monetize the reliability benefits of demand side interventions that reduce the planning reserve margin
  - The 2018 study used a 26 $/kWh VOLL; the 2021 study found a 73 $/kWh as the appropriate cost.

- Public Utilities Co of New Mexico (PNM)
  - Analyze utility-owned distributed storage benefits that would reduce unserved energy for customers in specific circuits. Assumed a weighted average VOLL of 12 $/kWh.

Issues using VOLL for ORDC

Issues with VOLL: measurement

- Surveys may be asking respondents to speculate on impacts to power interruptions that they may have never experienced before
- Willingness-to-pay valuation approaches (residential surveys) may have inherent biases, but they are preferred over willingness-to-accept approaches
- Regional economic models are often not grounded in empirically-based information
- It is extremely difficult to collect detailed information using revealed preference approaches (e.g., sales of backup generators purchased across the U.S.)
- Calculating defensible estimates of VoLL is an expensive and time-consuming undertaking
- The units of VOLL deeply affect its implications ($/kWh vs $/kW vs $/hour vs $/customer)

Issues with VOLL: application in bulk power system

- VOLL applied at the bulk power system level should **reflect direct and indirect costs** of interruptions
- However, VOLL assessed through customer surveys **reflects private benefits**, not public benefits. In other words, customers are reflecting their willingness to pay to avoid a local interruption
- The consequences of bulk power system originated interruptions are **significantly larger than those of local system interruptions**, with substantial spillover effects throughout the economy.
- Estimating an appropriate VOLL to use in bulk power system analysis should use general equilibrium model methods rather than customer survey methods to capture **both direct and indirect costs**.

Issues with VOLL: application in bulk power system

- Misalignment between
  - VOLL surveys that identify the cost to specific customers of interruptions of specific duration

  And

  - Load curtailment decisions whose duration and composition of customers affected vary widely depending on the operational needs, season, location of event, etc

- ORDC instruments
  - ORDC themselves oversimplify the complexity of VOLL in terms of customers, temporal resolution, and spatial resolution, into a single value
  - The use of a single $/MWh value when $/event has shown to be a more consistent estimate by customer type
  - A VOLL could be better implemented as a demand curve, potentially replacing the ORDC rather than just using it as a cap

Contact info

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Appendix

Conceptual applications of VoLL

Method/Application	Units	Examples	Comments
Least-cost, best-fit	$ divided by a non-monetary value	X dollars invested in grid to avoid Y number of fatalities X dollars invested in grid to reduce SAIDI by Y minutes	●Presumes that an investment is needed and helps prioritize options to achieve objectives ●Does not require monetization of any or all benefits of project
Cost-benefit analysis	$ divided by $	X dollars invested in grid leads to Y dollars in societal benefits	●Does not presume that an investment is needed ●Allows for an apples-to-apples comparison of options ●Can be extremely challenging to put a dollar value on some benefits

Example of VoLL use: utility undergrounding decision

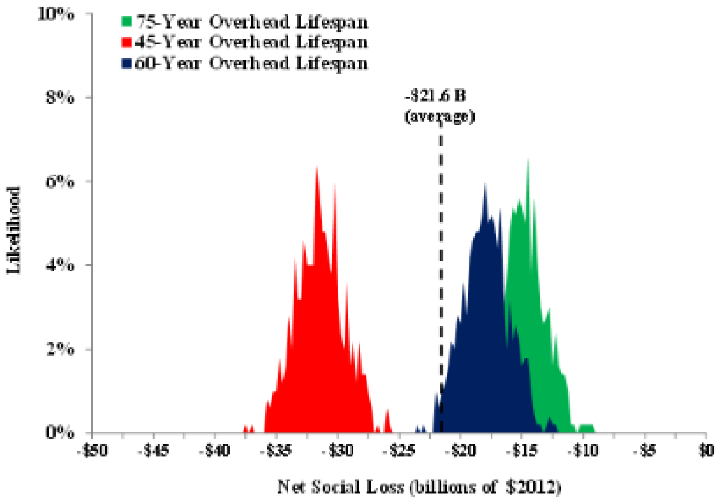
Key Stakeholders	Undergrounding Mandate	
	Selected Costs	**Selected Benefits**
IOUs	• Increased worker fatalities and accidents*	
Utility ratepayers	• Higher installation cost of underground lines***** • Additional administrative, siting, and permitting costs associated with undergrounding* • Increased ecosystem restoration/right-of-way costs**	• Lower operations and maintenance costs for undergrounding*
All residents within service area		• Avoided societal costs due to less frequent power outages*** ← **VoLL** • Avoided aesthetic costs**

* Denotes degree of impact on overall results

Example of VoLL use: utility undergrounding decision

The initial valuation indicated that **broadly mandating undergrounding when overhead T&D lines have reached the end of their useful life is not cost-effective for Texas IOUs.**

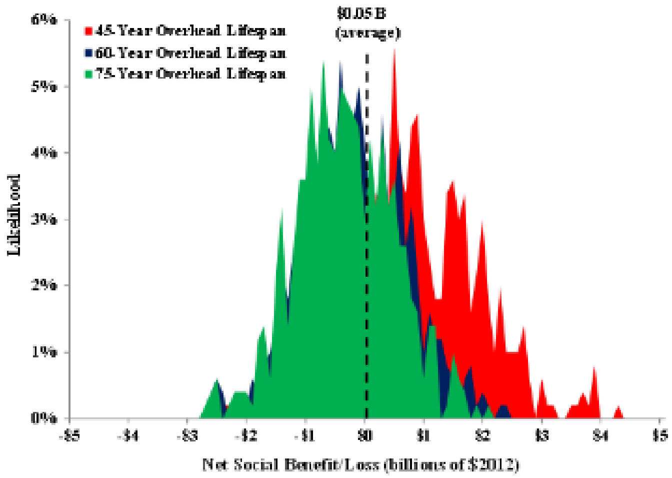
Impact Category	Undergrounding	Status Quo	Net Cost ($billions)
Environmental restoration	$2.8	$1.0	$1.8
Health & safety	$0.56	$0.31	$0.2
Lifecycle costs	$52.3	$26.1	$26.3
Total net costs (Undergrounding)			$28.3
Impact Category	**Undergrounding**	**Status Quo**	**Net Benefit ($billions)**
Interruption cost	$182.7	$188.4	$5.8
Avoided aesthetic costs	$12.1	$10.6	$1.5
Total net benefits (Undergrounding)			$7.3
Net Social Benefit (Undergrounding)			
Net social benefit (billions of $2012)			-$21.0
Benefit-cost ratio			0.3



Example of VoLL use: utility undergrounding decision

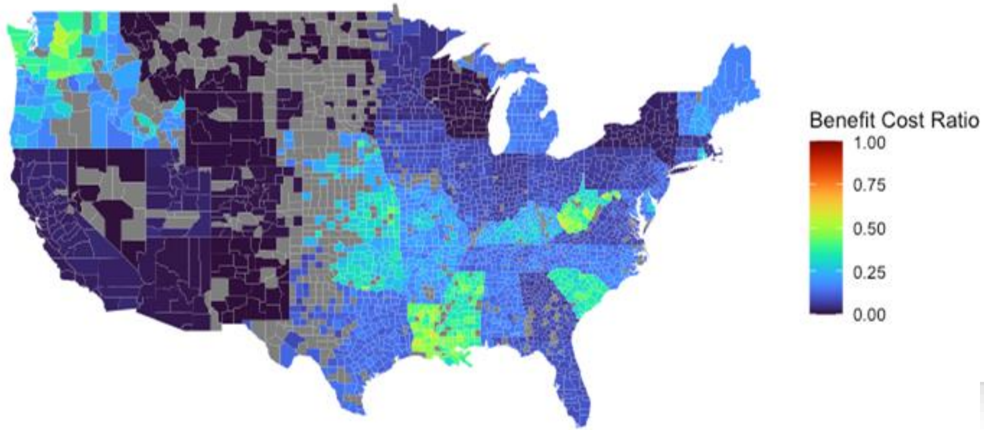
Texas policymakers should consider requiring that all T&D lines be undergrounded in places where:

- **there are a large number of customers per line mile** (e.g., greater than 40 customers per T&D line mile)
- **there is an expected vulnerability to frequent and intense storms**
- **there is the potential for economies of scale for installing underground T&D lines** (e.g., installation costs decrease each year)
- **overhead line rights-of-way are larger than underground line rights-of-way (i.e., less environmental footprint)**



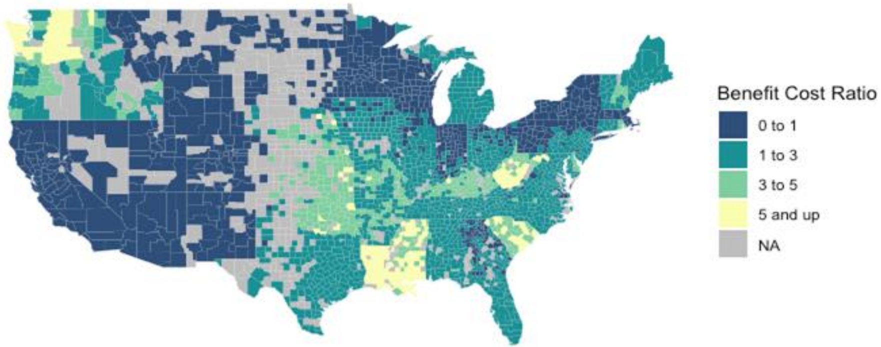
Example of VOLL use: customer backup power

- Resilience benefits from PVESS averaged 20% of total costs, ranging from 0% to 83% depending on load served, event frequency, duration, and state-level VOLL estimates
- However, **resilience was the only benefit considered in this research effort**
- **Other benefit streams are often included as part of the decision to install PVESS**



Example of VOLL use: customer backup power

- Scenario and sensitivity-based analyses communicate the range of possible outcomes given uncertainties
- Four scenarios were analyzed individually and collectively: two **storage cost** scenarios, a **high VOLL scenario**, and a **higher event frequency** scenario
- Individual scenarios achieve BCR > 1.0 in some states
- We also evaluated the **combined impact** of storage cost reduction, a high VOLL, and increased frequency of resilience events



- Customers experiencing **above-average long-duration** event frequencies and **higher VOLL** are likely to observe resilience benefits greater than the cost of installing PVESS