Integrating the Value of Resilience into Energy Decisions

Kate Anderson, Nick Laws, Caitlin Murphy, Eliza Hotchkiss

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Value of Resilience

- How can resilience be quantified?
- How is resilience valued?
- How is resilience monetized or incentivized?
- How is the value of resilience integrated into investment and/or operational decisions?

Quantifying Resilience Through Metrics

- Many resilience metrics have been developed, primarily from the perspective of the electric utility
- Most proposed metrics are immature, and none are widely agreed upon
- There is a need for metrics that go beyond reliability metrics
- There is no one definition or metric that can be applied broadly; depends on goals, context of the event, threats, scale, and perspective
- For quantitative analysis, it is preferable to use performance-based metrics that consider:
  - Likelihood and consequence of a given event
  - Temporal evolution of an event

Proposed Metrics	Proposed (data needed)
Cumulative customer-hours of outages	customer interruption duration (hours)
Cumulative customer energy demand not served	total kVA of load interrupted
Avg (or %) customers experiencing an outage during a specified time period	total kVA of load served
Cumulative critical customer-hours of outages	critical customer interruption duration
Critical customer energy demand not served	total kVA of load interrupted for critical customers
Avg (or %) of critical loads that experience an outage	total kVA of load severed to critical customers
Time to recovery	
Cost of recovery	
Loss of utility revenue	outage cost for utility ($)
Cost of grid damages (e.g., repair or replace lines, transformers)	total cost of equipment repair
Avoided outage cost	total kVA of interrupted load avoided $ / kVA
Critical services without power	number of critical services without power total number of critical services
Critical services without power after backup fails	total number of critical services with backup power duration of backup power for critical services
Loss of assets and perishables	
Business interruption costs	avg business losses per day (other than utility)
Impact on GMP or GRP	
Key production facilities w/o power	total number of key production facilities w/o power (how is this different from total kVA interrupted for critical customers?)
Key military facilities w/o power	total number of military facilities w/o power (same comment as above)

Unserved load [kW, kWh, h, customer type]

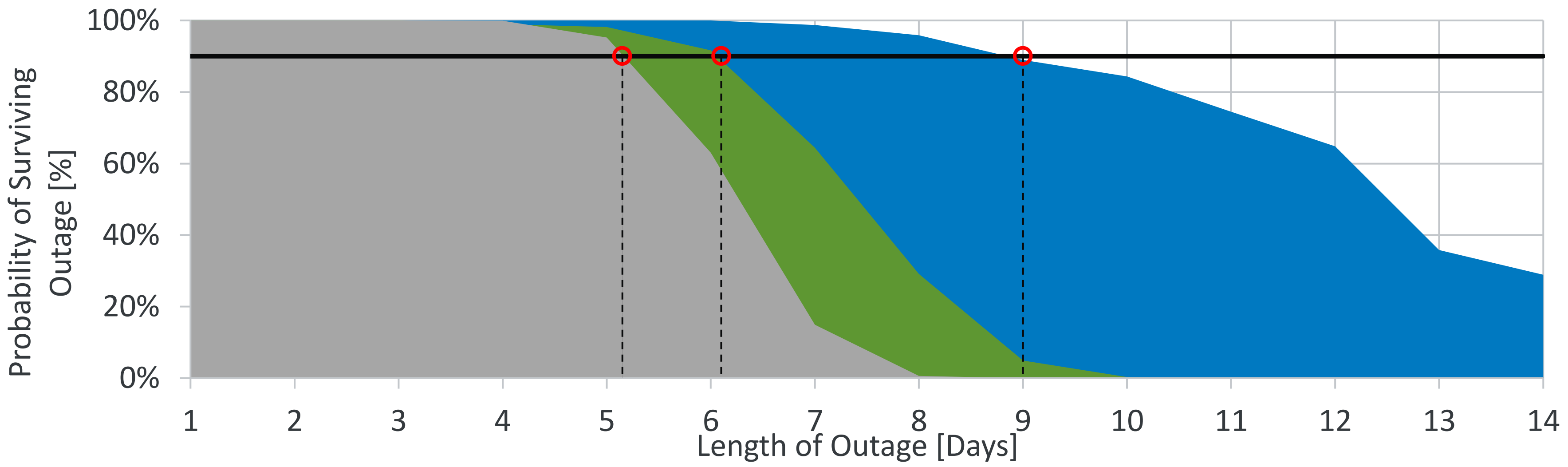
Direct outage costs [$, $/kW, customer type]

Indirect outage costs

https://gridmod.labworks.org/sites/default/files/resources/GMLC1%201_Reference_Manual_2%201_final_2017_06_01_v4_wPNNLNo_1.pdf

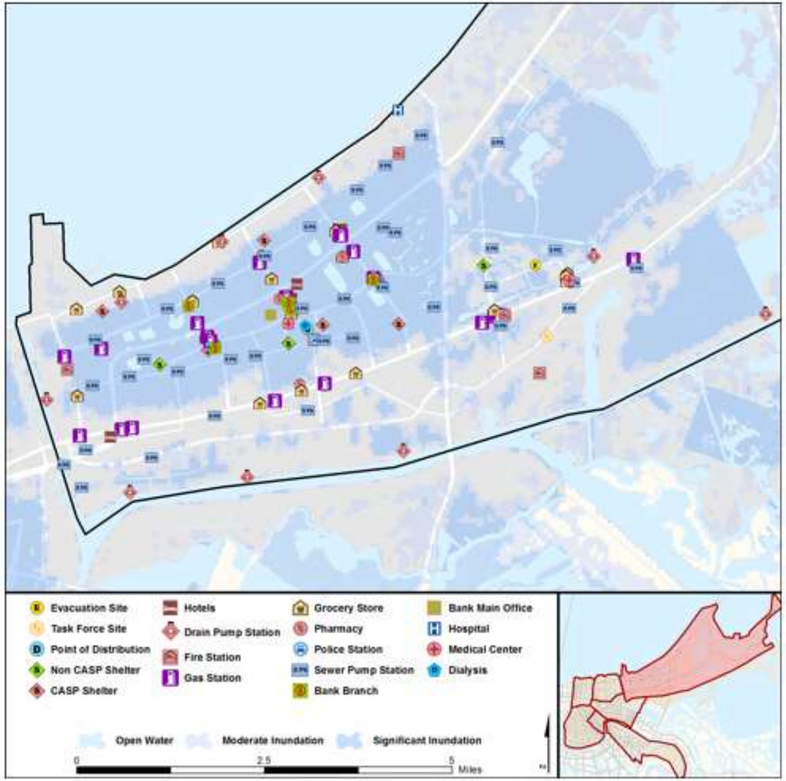
Quantifying Resilience: Days of Survivability

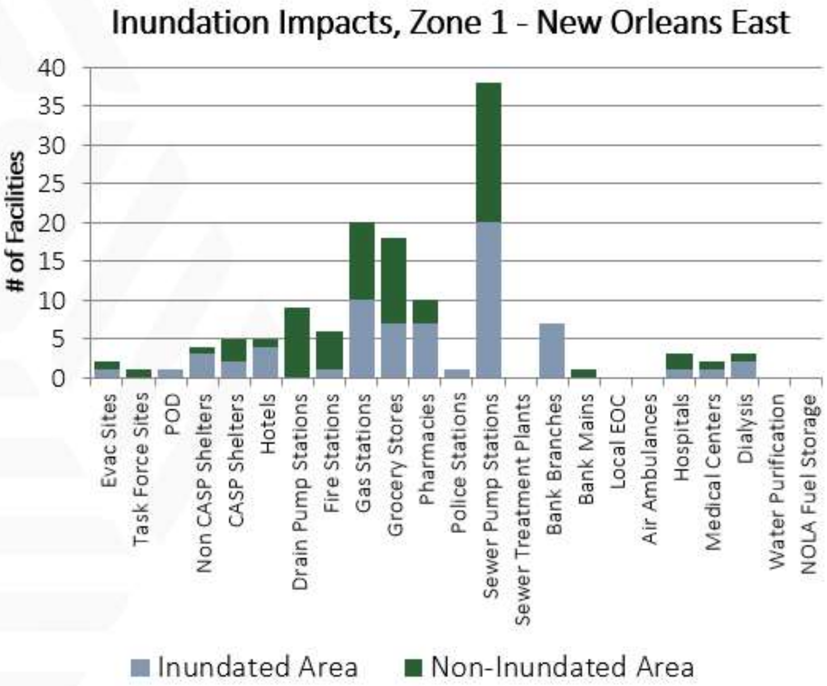
	Generator	Solar PV	Storage	Lifecycle Cost	Outage
1. Base case	2.5 MW	-	-	$20 million	5 days
2. Lowest cost solution	2.5 MW	625 kW	175 kWh	$19.5 million	6 days
3. Proposed system	2.5 MW	2 MW	500 kWh	$20 million	9 days



K. Anderson et al., "Increasing Resiliency Through Renewable Energy Microgrids". SCTE Journal of Energy Management Vol.2 (2) August 2017 pp.22-38. https://www.nrel.gov/docs/fy17osti/69034.pdf

Quantifying Resilience: Community Resilience





https://www.energy.gov/under-secretary-science-and-energy/articles/strengthening-community-resilience-new-orleans

How is Resilience Valued?

- Multiple resources provide data on the costs associated with potential resilience improvements
- Information on the *value* of resilience is limited
  - Metrics should be able to inform costs and benefits
  - We need to know more about what individuals and society are willing and able to pay to avoid the consequences of disruptive events

Table 13. Illustrative costs for selected resilience measures for utility operations.

Example Resilience Measure	General Range or Example Cost	Notes/Sources
Vegetation Management	$12,000 per mile	Depends on the functionality of the existing vegetation management plan in place and the level of vegetation clearing that the utility chooses (tree maintenance, tree removal, enhanced tree trimming vs. routine tree trimming).[37,38,39]
Backup Generators	$20,000 per substation	Depends on the size of the substation and the amount of power needed in a backup situation.[40,41]
Demand Reduction Programs	$50 to >$1,000 per MWh	Includes appliance recycling programs, demonstrations, education initiatives, weatherization incentives, and similar consumer behavior programs.[42]

Table 12. Illustrative costs for selected resilience measures for utility assets.

Example Resilience Measure	General Range or Example Cost	Notes/Sources
Guying	$600 to $900 per pole	[15]
Upgrade Wood Poles	$16,000 to $40,000 per mile	Depends on material (steel is more expensive than concrete); there are many possible upgrades in use (replace entire pole, replace wood cross-arms, reduce spans between poles).[16,17,18]
Submersible Equipment	>$130,000 per vault	Depends on location and type of submersible equipment needed.[19]
Upgrade Transmission Lines	>$400,000 per mile	Depends on specific upgrade.[20]
Substation Hardening	$600,000 per substation	Wide range of cost is available depending on specific hardening measure needed for each location.[21]
Elevating Substations	>$800,000 to >$5,000,000 to elevate	Difficult to determine due to variation in height needed for each location.[22,23]
Reinforce Floodwall	$220,000 per mile	Based on 36-mile Port Arthur seawall. Costs depend on site-specific factors such as material composition, thickness, height, geology, and location of floodwall.[24]
Build New Floodwalls	$4,000,000 per mile	Depends on site-specific factors as noted above.[25]
Undergrounding Distribution Lines	$100,000 to $5,000,000 per mile	Depends on area (urban is most expensive) and new construction or conversion from overhead (new construction is more expensive).[26,27,28]
Undergrounding Transmission Lines	>$500,000 to $30,000,000 per mile	Depends on area (urban is generally more expensive) and new construction or conversion from overhead (new construction is more expensive).[29,30,31]
Install Microgrid	$150,000,000 for 40MW average load	Depends on size of the microgrid and the average load needed; this is a not yet deployed widely so costs are uncertain.[32]
Advanced Metering Infrastructure	$240 to >$300 per smart meter installed	Depends on the size of the network and the number of meters installed; this is a new technology that is still developing, so costs are uncertain.[33]
Marsh Stabilization	$2 per square meter	[34]
Marsh Creation	$4.30 per square meter	[35]

https://www.energy.gov/sites/prod/files/2016/10/f33/Climate%20Change%20and%20the%20Electricity%20Sector%20Guide%20for%20Climate%20Change%20Resilience%20Planning%20September%202016_0.pdf

Methods for Valuing Resilience

1) Cost of an outage
    a. Individual Site Characterization (Customer Damage Function)
    b. National Outage Survey (Interruption Cost Estimator)
    c. Insurance Valuation
2) Cost of other forms of emergency power

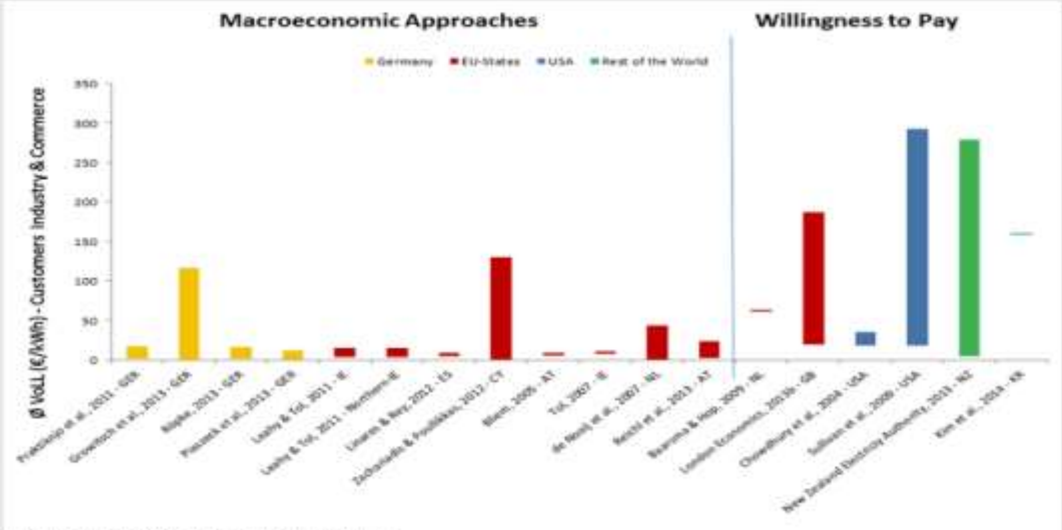
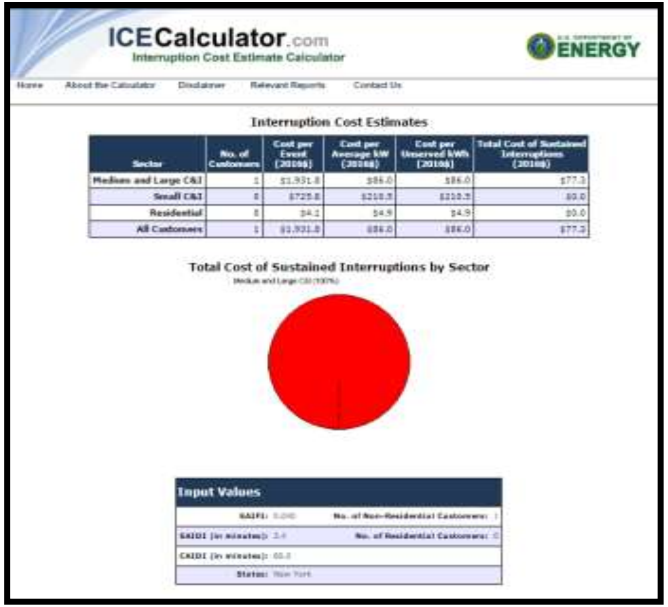


FIGURE 2 | Actual VoLL studies – Economic end users.

Schroder (2015). *doi: 10.3389/fenrg.2015.00055*

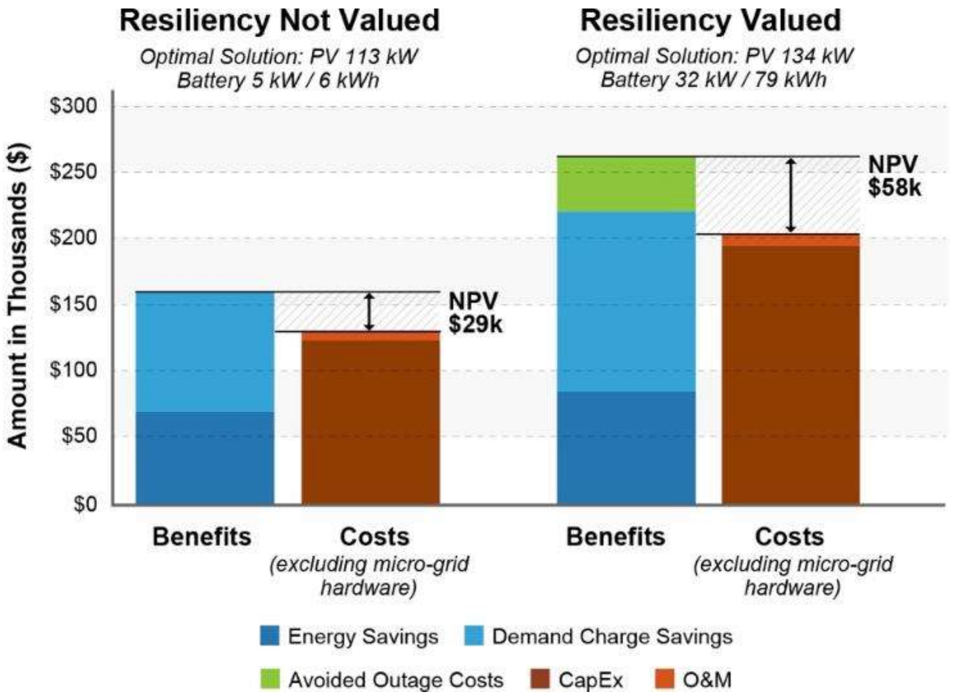


https://icecalculator.com/home

How Could Energy Decisions Change When Accounting for a Value of Resilience?

Implementing a value of resilience into a least-cost optimization can influence the “optimal” PV+storage system at a given site:

- Increases PV capacity
- Increase in battery size and duration
- Increases the overall NPV



Laws, N. D., K. Anderson, N. DiOrio, X. Li, and J. McLaren (2018). “Impacts of valuing resilience on cost-optimal PV and storage systems for commercial buildings.” *Renewable Energy,* Volume 127, November 2018, pages 896-909. https://doi.org/10.1007/s12667-018-0314-8

Methods for Monetizing System Resilience

1) Grid services
2) Monthly resiliency payment from site host
3) Reduction in insurance premiums
4) Incentives

Value streams for RE+storage

	Service	Description	Grid	Commercial	Residential
Driven by Utility Rate Structure	Demand charge reduction	Use stored energy to reduce demand charges on utility bills		✓	✓
	Energy arbitrage	Buying energy in off-peak hours, consuming during peak hours		✓	✓
Utility/Regional Programs	Demand response	Utility programs that pay customers to lower demand during system peaks		✓	✓
	Capacity markets	Supply spinning, non-spinning reserves (ISO/RTO)	✓	✓	
Not Applicable for BTM storage	Frequency regulation	Stabilize frequency on moment-to-moment basis	✓	✓	
	Voltage support	Insert or absorb reactive power to maintain voltage ranges on distribution or transmission system	✓		
	T&D Upgrade Deferral	Deferring the need for transmission or distribution system upgrades, e.g. via system peak shaving	✓		
Value Varies	Resiliency / Back-up power	Using battery to sustain a critical load during grid outages	✓	✓	✓

Source: https://www.nrel.gov/docs/fy17osti/70035.pdf

For every $1 invested, $4 saved in avoided cost

Summary and Conclusions

- Information is readily available for the *costs* associated with various resilience investments
- Quantifying the *value* of resilience is a much more challenging task due to:
  - A lack of universally accepted metrics
  - The context-specific nature of benefits
  - The necessary data and detailed quantitative analysis needed to accurately determine the benefits associated with a given investment
- There are limited options for monetizing resilience
- Understanding how to value and monetize resilience is critical for implementation

Thank you!

www.nrel.gov

Kate Anderson, kate.Anderson@nrel.gov

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