# Electric Reliability, Resiliency, Rates and Region

**PRESENTED TO**

Edison Electric Institute
Transmission, Distribution, and Metering Conference

**PRESENTED BY**

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Charleston, SC
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THE Brattle GROUP

# Contents

**Reliability In Utility Services**

- Reliability In Electric Rates
- Foundational Economics
- Lessons From Resource Adequacy
- Reliability and Risk (to Customers)

# Reliability In Electric Rates

**Breakdown of Cost of Delivered Power**

| Bill Components | Percentage |
|---|---|
| **Fuel and Power Supply** | **70.0%** |
| - Energy | 52.5% |
| - Firm Capacity | 15.8% |
| - Reserve Capacity | 1.8% |
| **Electric Delivery** | **30.0%** |
| **TOTAL** | **100.0%** |

Source:
Analysis of FERC Form 1 data; breakdown between fuel and power supply and electric delivery were rounded for ease of presentation. Breakdown of fuel and power supply based on panel of utility data.

**Reliability "insurance" is included in utility rates – in the form of reserves, redundancies and contingencies**

- Reserve requirements for generating capacity
- N-1 contingencies in transmission
- Redundant equipment and systems and hardened assets built in to distribution system

**How much should customers pay to ensure (highly) reliable electric service?**

**Conversely, how much risk (of outage) should customers bear? And pay for?**

# Foundational Economics

**Incremental benefit (demand) =**
**Incremental cost (supply)**

- Slightly different context than traditional cost-benefit analysis
- Costs can be traced to investment borne by the electric utility
- Benefits may be realized by the utility via efficiency gains or factors which lower overall production costs (and then passed in whole or in part to customers), but…
- … benefits are frequently realized directly by customers in the form of reduced frequencies and durations of outages and measured by the value they place on avoiding outages

# Generating Reserve Requirements

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- Cost of generating reserves are included in the cost of power
- Current RA (planning reserve margin) requirements typically based on "1-day-in-10-year" standard
  - Not defined uniformly (0.1 event per year vs. 2.4 hours per year)
  - Has not been updated in decades
- Translates into 10% or 15% reserve margin

# Reserve Requirements – Costs and Benefits

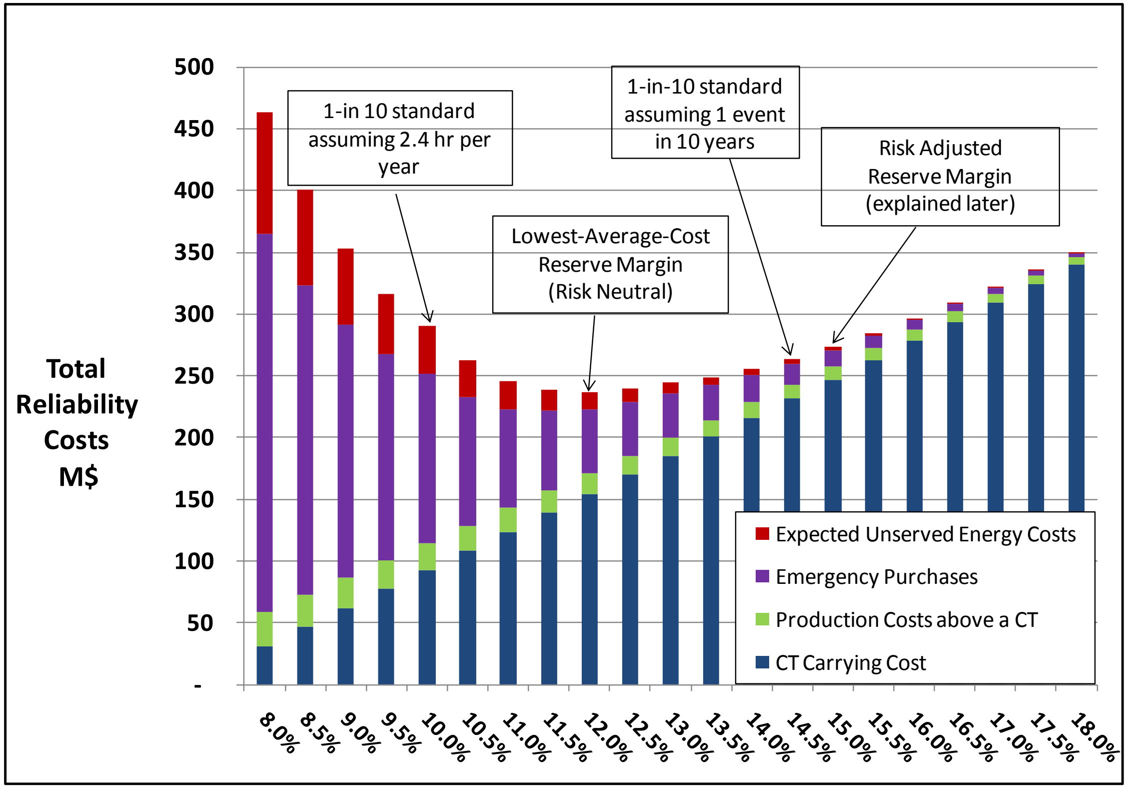
**Are RR set so incremental costs = incremental benefits?**

- "Reasonable level": probability of failure to carry load 1 day in 8 – 10 years. (Calabrese, 1947; Watchorn, 1950)
- Reserve requirements could be lower than 1-in-10 if based on economics of incremental benefits (VOLL) = incremental costs. (Telson, 1973; PGE 1990)
- Optimal reserve requirements may be higher than 1-in-10 if all costs are considered
  - Production related reliability costs
  - Emergency purchase costs
  - Unserved energy costs (EUE and VOLL)
  - (Astrape Consulting and The Brattle Group, NRRI, 2011)

# Reserve Requirements – Costs vs. Value

- Benefit of optimal RR % = overall lower cost to customers
- Estimated impact of EUE (VOLL) is relatively low – because risk of firm load shed events is relatively low
- Major impact of reduced RR is more on cost of purchases of power (emergency) than value of lost load

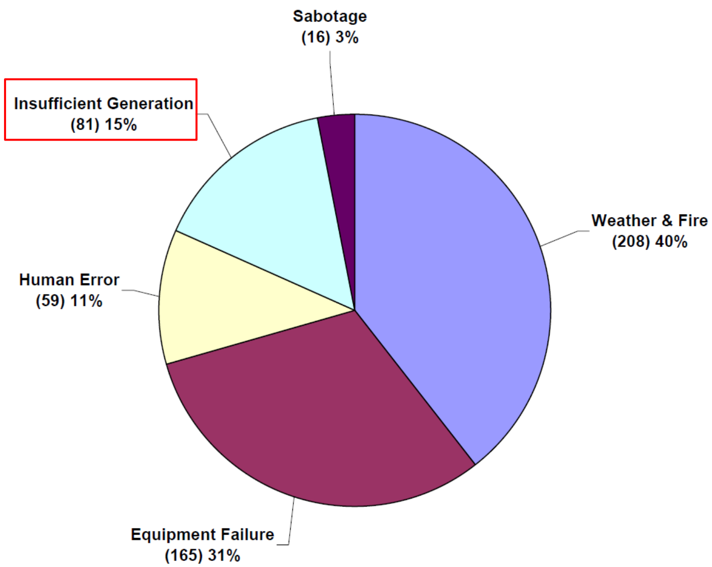
**Cost To Customers Vs. Reserve Requirements**



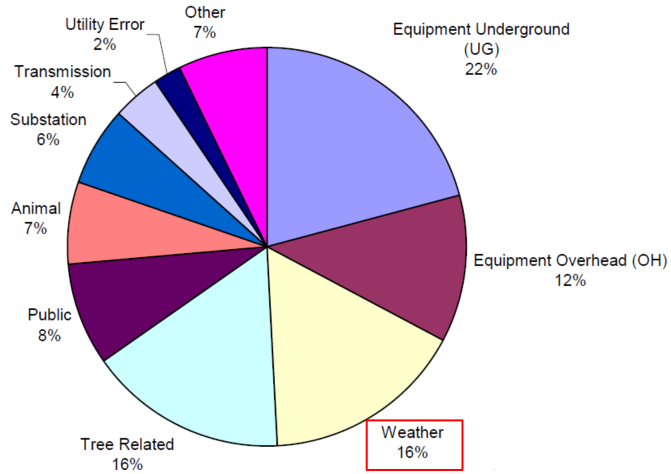

Source: Carden, Pfeifenberger and Wintermantel, *The Economics of Resource Adequacy Planning: Why Reserve Margins Are Not Just About Keeping the Lights On*, NRRI Report 11-09, April 2011.

# Loss of Electric Service

### Major Outage Events




### All Retail Outages




| | G & T: 1 to 5% of Outages | Distribution: > 95% of Outages |
|---|---|---|
| ERCOT 1-in-10 | Average CMI = 1 | Average CMI > 100 |

Source:
1. Lave, Apt and Morgan, *Worst Case Electricity Scenarios: The Benefits & Costs of Prevention*, CREATE Symposium, University of Southern California, August 2005
2. Breakdown of outage causation between Generation and Distribution : Brattle estimate
3. CMI in 1-in-10 scenario: *ERCOT Investment Incentives and Resource Adequacy* The Brattle Group, 2011

# Reliability In Perspective

## Unclear – but unlikely – that investments in reserve requirements and distribution reliability reflect the relative risk of customer outages

Generation

**Reserve Requirements**

- Value depends on probabilities concerning system demands
- Low probability of load shedding (likely ~1%)

~ 1% of outages

Distribution

***Reliability* Investment**

- Value from reduced outages under normal conditions
- Majority of "normal" outages associated with distribution ops

Distribution

***Resiliency* Investment**

- Value from reduced outages under extreme conditions
- Lower probability but wide reaching outage events

> 95% of outages

# Clearly Defined Reliability

**Breakdown of Cost of Delivered Power**

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- Reliability in the form of generating reserve margins can be (somewhat) clearly defined and estimated as an element of rates
- A similar (yet slightly less clear) with regard to Transmission
- Difficult to pin down specific areas of reserve reliability in the Distribution system; assessing appropriate level of reliability and investment requires nuanced analysis

**Estimating Value To Customers**

- Value of Lost Load and Willingness to Pay
- Customer Satisfaction

# Incremental Benefits

**Largely realized by customers; *i.e.*, utility investment in reliability typically does not "pay for itself"**

**Benefits can be mapped by a demand curve for incremental investment**

- Approximated by customer willingness to pay (WTP) or
- The value that customers place on avoiding losing load (VOLL)

**Value to customers (of avoiding outages) > price**

**Consumer surplus: difference between WTP and price**

# Value of Lost Load

**VOLL = survey-based estimate of value to various categories of customers by duration of outage event (Berkeley National Lab / DOE, 2009)**

- Total VOLL higher for longer duration events, but lower on unserved kWh basis
- Lower for Residential than Commercial and Industrial (which face lost revenues)

**VOLL can be as high as $95,000 for an 8 hour outage event during a summer day for a large commercial or industrial customer**

# Value of Lost Load

## Much higher than cost – and utility would not charge rates that are equal to VOLL – but indicator of potential benefits

**VOLL For "Anyday" (Average)**
**Berkeley / DOE Study (2009)**

| Interruption Cost | Interruption Duration | | | | |
|---|---|---|---|---|---|
| | Momentary | 30 minutes | 1 hour | 4 hours | 8 hours |
| **Medium and Large C&I** | | | | | |
| Cost Per Event | $6,558 | $9,217 | $12,487 | $42,506 | $69,284 |
| Cost Per Average kW | $8.0 | $11.3 | $15.3 | $52.1 | $85.0 |
| Cost Per Un-served kWh | $96.5 | $22.6 | $15.3 | $13.0 | $10.6 |
| Cost Per Annual kWh | $0.0009 | $0.0013 | $0.0018 | $0.0060 | $0.0097 |
| **Small C&I** | | | | | |
| Cost Per Event | $293 | $435 | $619 | $2,623 | $5,195 |
| Cost Per Average kW | $133.7 | $198.1 | $282.0 | $1,195.8 | $2,368.6 |
| Cost Per Un-served kWh | $1,604.1 | $396.3 | $282.0 | $298.9 | $296.1 |
| Cost Per Annual kWh | $0.0153 | $0.0226 | $0.0322 | $0.1370 | $0.2700 |
| **Residential** | | | | | |
| Cost Per Event | $2.1 | $2.7 | $3.3 | $7.4 | $10.6 |
| Cost Per Average kW | $1.4 | $1.8 | $2.2 | $4.9 | $6.9 |
| Cost Per Un-served kWh | $16.8 | $3.5 | $2.2 | $1.2 | $0.9 |
| Cost Per Annual kWh | $0.0002 | $0.0002 | $0.0002 | $0.0006 | $0.0008 |

Source: Sullivan, M., Mercurio, M., and Schellenberg, J. (2009) *Estimated Value of Service Reliability for Electric Utility Customers in the United States*. Lawrence Berkeley National Laboratory . Table ES-5.

# Customer Satisfaction

Key VOLL surveys (Berkeley National Lab / DOE, 2009) are widely regarded and accepted by regulators and policy makers

Customers participate in VOLL surveys infrequently but routinely rate their level of satisfaction

Will utility adherence to VOLL analysis in setting investments in T&D infrastructure lead to high customer satisfaction scores?

**Empirical Analysis**

- Data
- Regression Analysis
- Key Findings
- The Takeaways

# Rates Reliability and Region

**Another look at estimating the importance of reliability to electric customers**

- Summary of analysis and findings included in:
  "Rates, Reliability, and Region," by William P. Zarakas, Philip Q Hanser, and Kent Diep, Public Utilities Fortnightly, January 2013

- Ongoing analysis concerning the trade-offs between cost, reliability and customer satisfaction

- Does careful analysis of the data inform utility managers and regulators answer questions concerning how much to invest in the electric delivery system?

# Data

- ~ 30 utilities with consistent data
- ~ 75% public data; 25% client data (with consent)

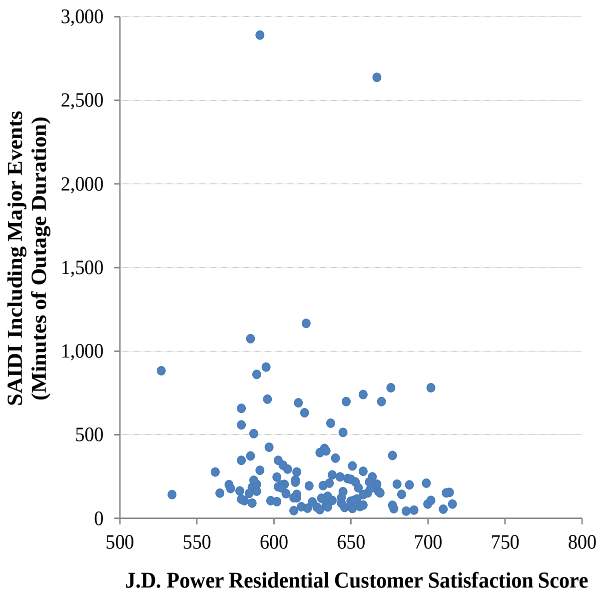
**Summary of Variables Included In Empirical Analysis**

| Variable | Form |
| --- | --- |
| Customer Satisfaction | Annual J.D. Power score (residential customer survey) |
| Reliability (SAIDI, SAIFI, CAIDI) | SAIDI, SAIFI and CAIDI, measured including and excluding major events |
| Price | Annual average residential revenue per kWh |
| Capital Investment In Distribution System | Annual net capital additions |
| Distribution System O&M Expenditures | Annual spending per kWh |
| Customer Service O&M Expenditures | Annual spending per kWh |
| Service Area Density | Population per square mile |
| Geographic Location | Utilities assigned to NE, SE, MW, NW or SW categories |

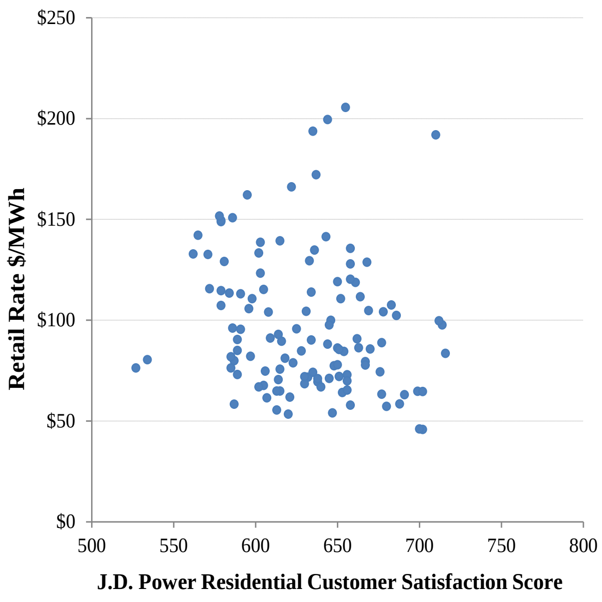
# The "Scatter"

- Not a clear trend line

SAIDI Including Major Events versus J.D. Residential Customer Satisfaction Score




Retail Rate $/MWH versus J.D. Residential Customer Satisfaction Score



# Regression Analysis

**Summary of Regression Results**

| Variable | Coefficient | t-score |
|---|---|---|
| J.D. Power Residential Customer Satisfaction Score | | |
| Customer Service Expenses | 0.0920 | 1.25 |
| Distribution Expenses | 0.0794 | 1.38 |
| SAIDI including Major Events | -0.2265 | -2.17 ** |
| Population/ Area | 0.0001 | 1.99 ** |
| Retail Rate | -0.0087 | -2.02 ** |
| Net Investment in Distribution | -0.0017 | -1.36 |
| **Regions** | | |
| Northwest | 2.5830 | 4.25 *** |
| Southwest | 2.1967 | 3.73 *** |
| Northeast | 0.6918 | 1.12 |
| Southeast | 2.5193 | 3.96 *** |
| Midwest | 1.8697 | 2.85 *** |

***Statistically significant at 1%
**Statistically significant at 5%
*Statistically significant at 10%

- System reliability significantly explains customer satisfaction scores
- Separate regression: Distribution spending correlated with reliability
- Suggests high levels of reliability requires consistent investment and spending

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- Plays a significant role in explaining why customers rank utilities at a high or low level with respect to customer satisfaction
- Standardized variables: improved reliability could increase customer sat > slight decrease in rates
- Suggests customers may forgive utility if rates go up, as long as they perceive that the service is improving

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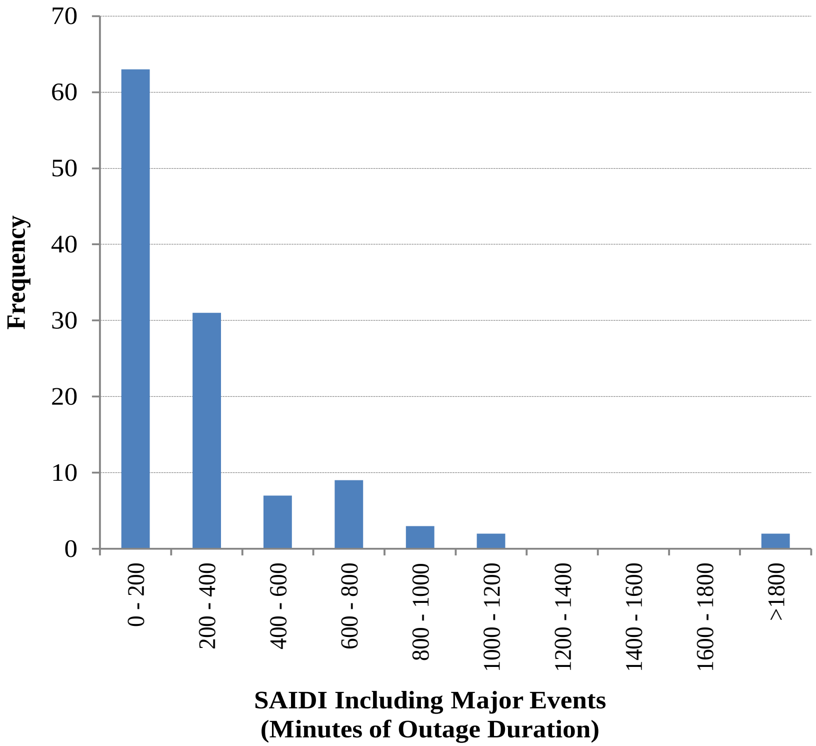
- Largest impact was geography
- Somewhat unexpected finding
- Utilities in the Northeastern U.S. are statistically at a disadvantage compared to utilities located elsewhere in the U.S. when customers rate their levels of satisfaction

# Regression Analysis: Key Findings

- Findings certainly reflect data and measurement issues to some extent (more so than it supports a finding that spending on customer service doesn’t matter)
- Reliable service and reasonably priced delivery services are the common denominators expected by customers
- Location matters – best practices are not always portable
- Recognizing variances may be more important than understanding averages –may be room to meet expectation of customer sub-segments…
- …But customer segmentation by itself is only meaningful if the utility can act to improve satisfaction in those segments

# Regression Analysis: Two Key Takeaways – 1

**Distribution of Duration of Power Outages**
**Utility Panel 2006 - 2011**




## #1 - There weren't any "train wrecks"

- Tight cluster of observations led to low coefficient values
- Some examples of under-investing in specific circuits, but not at system-wide level
- Most instances of major customer sat issues involved resiliency and storm response – and were outside of the data set (> 2011)

# Regression Analysis: Two Key Takeaways – 2

**#2 – Geography doesn't necessarily mean that customer satisfaction is out of the control of a utility**

- Customer satisfaction is largely driven by utility attention to the specific issues facing their unique customer base
- Memory and legacy issues may mean improving low customer satisfaction may take a while
- Deficiencies may fall outside of core investment a
  - *E.g.*, communications and/or customer interactions
  - Even though the Customer Service Expense variable did not provide significant explanation in our regression model

## Assessing the Value of Utility Investments

- Reliability Investments
- Resiliency Investments

# Investments In Electric Delivery

Breakdown of Cost of Delivered Power

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Source:
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## Upgrades in T&D system, AMI and SG

- Net book value of IOUs ~$300 billion (not replacement value)
- Upgrading aging distribution system + smart grid investment over next 20 years ~$600 billion

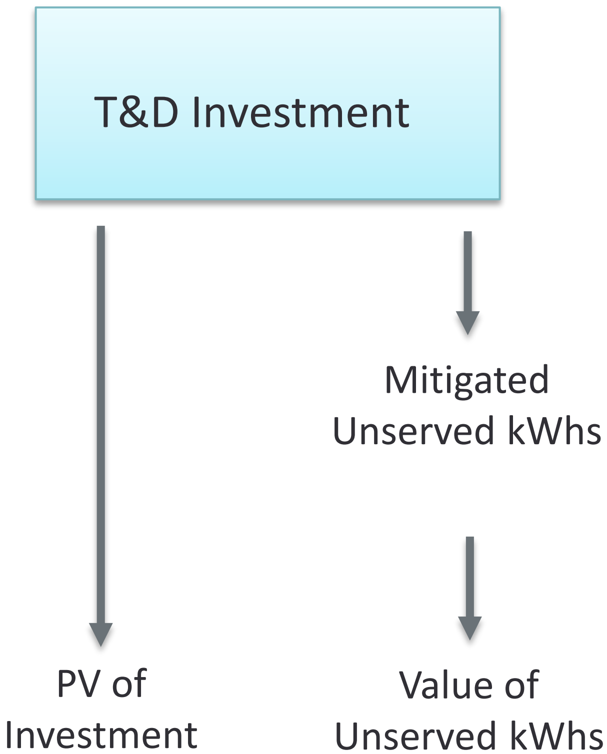
## Additional investments required to bring renewables (wind) to load centers

- New transmission to integrate renewables and maintain reliability: ~$250 billion
- Plus more in flexible backup generation (gas CTs)

## New investments in reliability and resiliency ~ $multi billion per mid-large utility (region-specific)

Sources:
Brattle analysis; *Transforming America's Power Industry*: *The Investment Challenge 2010-2030*, by *The Brattle Group* for the Edison Foundation.
Brattle analysis of FERC Form 1 data; upgrade and replacement estimates based on *Brattle* analysis

# Benefit-Cost Analysis Framework



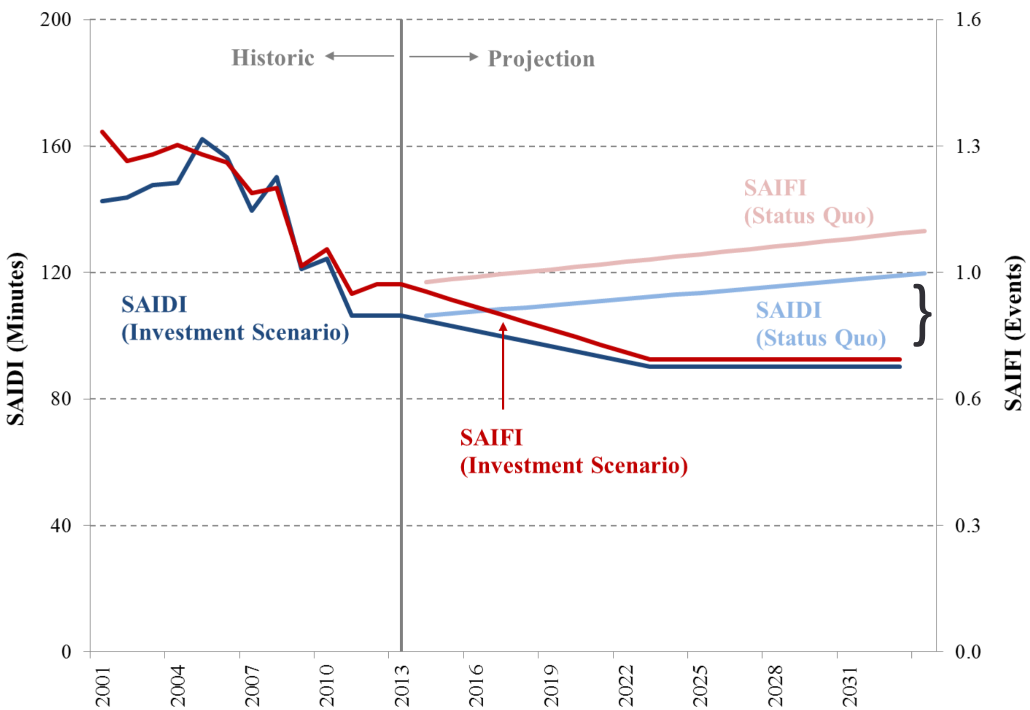

- PV of investment cost is relatively straight-forward exercise, subject to implementation and discount rate uncertainty
- Estimation of benefits involves projection of mitigated losses of load ultimately realized by customers
  - Difference in projecting benefits of reliability and resiliency related investments

# Value of Reliability Investments

- Investments in reliability typically can be measured by improvements in SAIDI-x and SAIFI-x over time
- Status quo SAIDI and SAIFI (*i.e.*, without incremental investments) may result in deteriorating levels of SAIDI and SAIFI
- Difference between status quo and investment cases provides "saved" Customer Minutes of Interruption (CMI) or mitigated unserved kWhs
- Allocated to customer classes allows calculation of VOLL and PV of benefits

# Value of *Reliability* Investment

**Projected SAIDI-x and SAIFI-x**
**Status Quo Case vs. Incremental Investment Case**
**Midwestern Electric Utility**




Source:
Based on analysis for Midwestern U.S. electric utility.

$$\text{SAIDI} = \frac{\text{Sum of customer minutes of interruption}}{\text{Number of customers served}}$$

$\Delta$ SAIDI $\rightarrow$ $\Delta$ CMI

- Outage duration profile
- Allocation among customer classes
- VOLL per class and outage duration

Estimated value of improved SAIDI and SAIFI

NPV when compared to investment schedule

# Value of *Resiliency* Investment

**Investments in resiliency are aimed at bringing service back on line following unavoidable outages (typically caused by extreme weather events)**

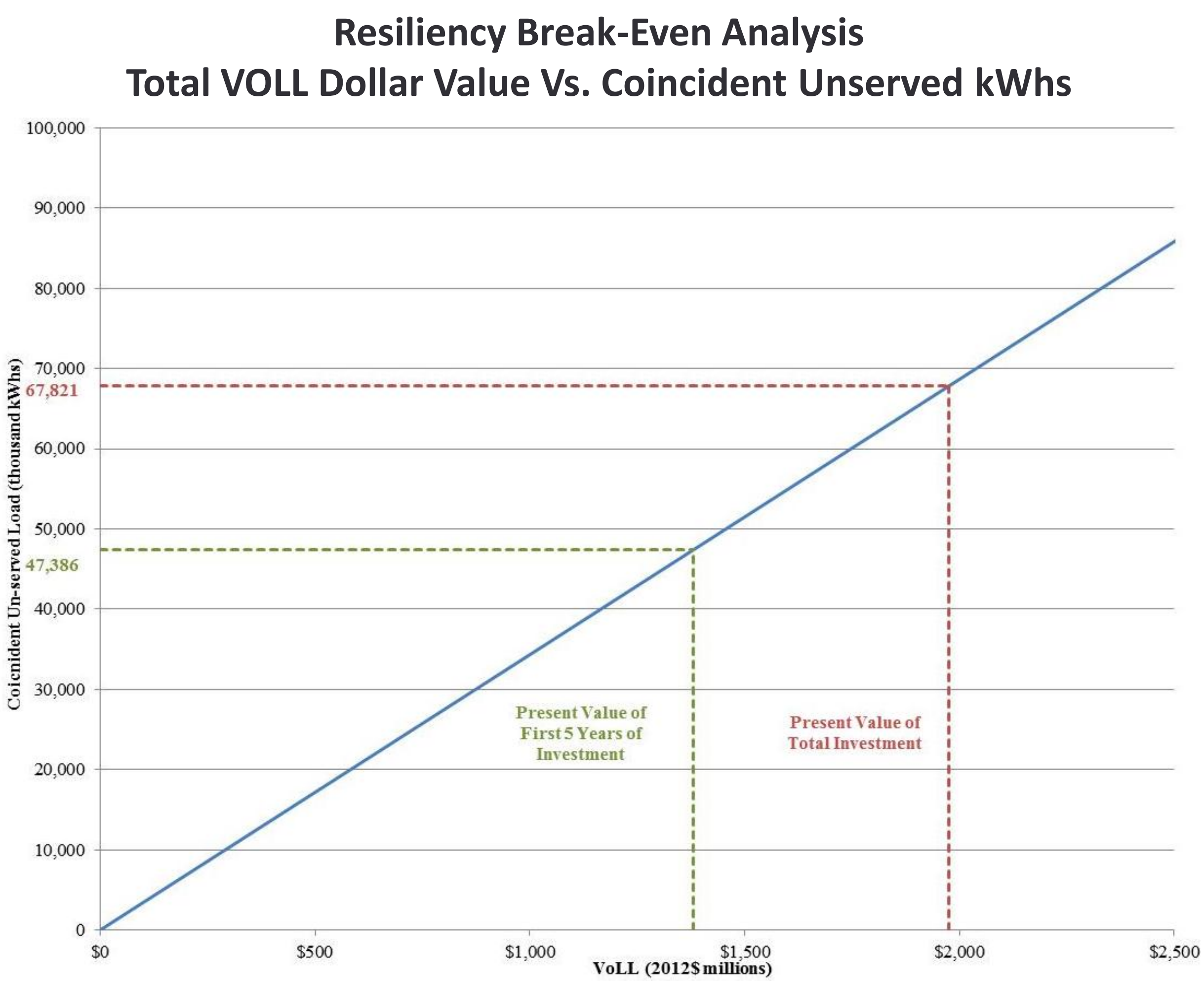
**Frequently involves application of system intelligence and asset hardening**

- Costs tend not be justified on operational grounds alone
- Cost justification for Smart Grid investments may come load shifting and EE related benefits

**Assessing value to customers requires analysis of risk and probabilities, more so than for investments in reliability**

- Outage impacts reduced (if event strikes) and VOLL may well exceed investment costs
- Similar to insurance products – which are paid for, but my never be called upon

# Value of *Resiliency* Investment




- Similar to reliability analysis
- But resiliency benefits are less predictable
- Similar to insurance premiums
- Solve for how many major event outages (in CMIs) are required so that VOLL = PV Investment

# Working on improving methodology

**VOLL estimates used in most reliability benefits reflect only "private" values (usually over short time frames) and exclude "social" values**

- Social values = benefit of continuous critical public services
- Police, gas stations, schools, …
- Mainly an issue during prolonged, widespread outages

**Yet it appears that S-VOLL is a particularly important benefit stream in resiliency analysis**

- DG installations, possible mobile, positioned at critical locations after a disruption could mitigate adverse social consequences

  (See Zarakas, Sergici, Graves, PUF Oct. 2013)

# Summary

- Economic framework (incremental benefit = incremental cost) can be applied to investments in reliability and resiliency
- Theoretically, value justified investments should be aligned with customer satisfaction functions, as VOLLs are based on customer willingness to pay
- In practice, implementation issues and VOLL measurement inaccuracies may add challenges to perfecting this alignment
- Additional variables – other than Rates and Reliability – also contribute to customer satisfaction
- Addressing these involves understanding variances more so than meeting average expectations

# Presenter Information

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William Zarakas is a Principal with *The Brattle Group*, an economics and management consulting firm. Bill is an expert in economic, financial, strategic, and regulatory analyses as applied to the electric utility industry. He has led a variety of projects analyzing investments in transmission and distribution infrastructure, smart grid deployment and its optimization, and empirical analyses concerning the factors that influence the level of satisfaction that customers have with electric utilities. He has also conducted analyses concerning the impact of declines in customer demand and the growth of distributed generation on utility financial performance. Bill has authored numerous reports, presentations and articles concerning the issues associated with investments in utility infrastructure, costs and benefits relating to system reliability and resiliency, and the evolving factors that are affecting utility business models.

Bill has worked extensively with electric utilities, telecommunications carriers, industry associations, regulatory commissions, law firms, financial institutions, and governmental bodies. He has testified before state and federal regulatory commissions and courts of law, and has authored reports submitted to governments, regulatory commissions, the U.S. Securities and Exchange Commission. He has also headed management and operations audits of utilities and telecommunications carriers performed on behalf of regulatory commissions.

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The Brattle Group provides consulting and expert testimony in economics, finance, and regulation to corporations, law firms, and governments around the world. We aim for the highest level of client service and quality in our industry.

We are distinguished by our credibility and the clarity of our insights, which arise from the stature of our experts, affiliations with leading international academics and industry specialists, and thoughtful, timely, and transparent work. Our clients value our commitment to providing clear, independent results that withstand critical review.

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