The National Cost of Power Interruptions to Electricity Customers - *An Early Peek at LBNL's 2016 Updated Estimate*

Distribution Reliability Working Group
2016 IEEE PES General Meeting
Boston, Massachusetts
July 19, 2016

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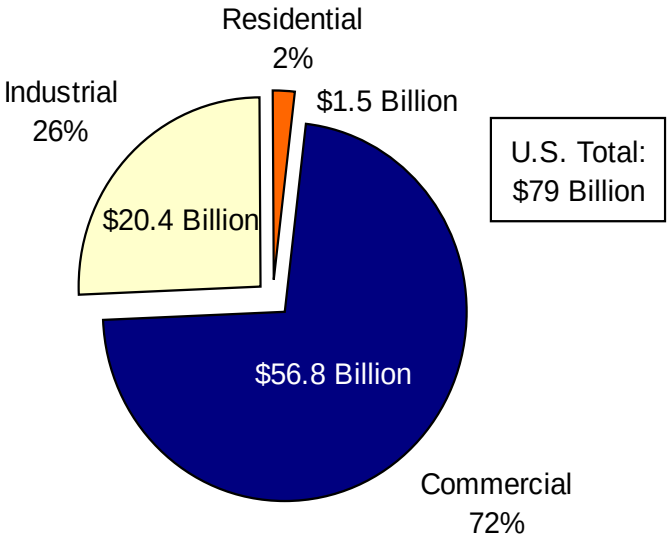
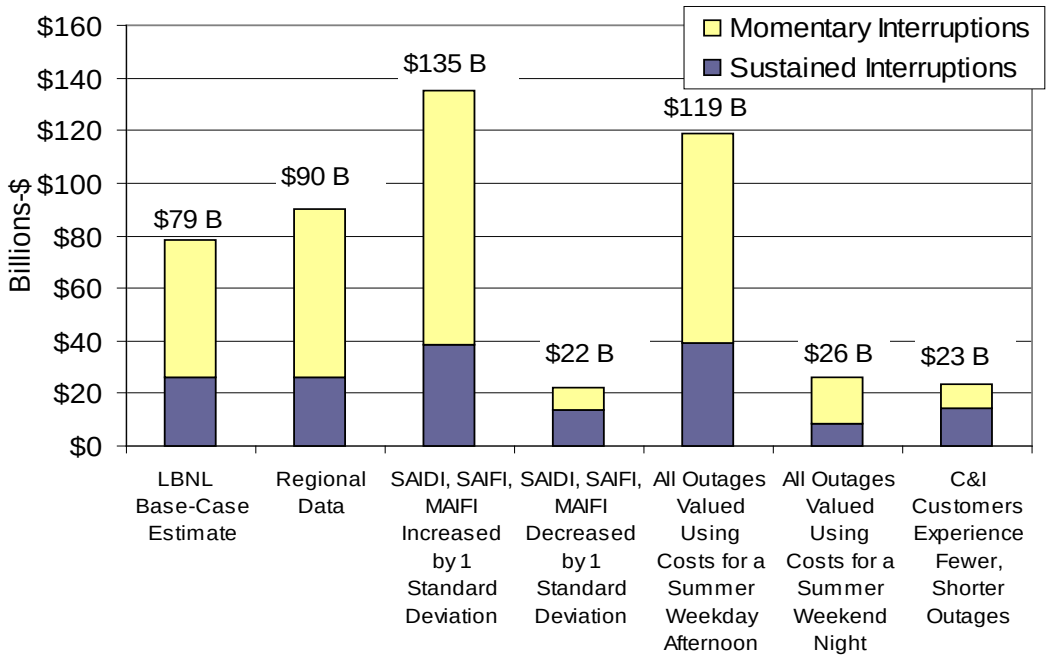
Overview/Background

- In 2006, LBNL published the first peer-reviewed assessment of the national cost of power interruptions to electricity customers based entirely on publicly available data
  - Found that data were sparse, poorly understood, and often misinterpreted
- Since that time, LBNL has worked closely with industry, regulators, and federal government to improve understanding, quality, and public availability of information on electricity reliability
  - Actively participated in IEEE DRWG to better understand industry perspectives and research aspects of Standard 1366
  - Developed and promoted use of the Interruption Cost Estimate (ICE) Calculator
  - Reviewed OE-417 and NERC EOP-004
  - Supported modifications to EIA form 861
  - Provided regular, invited briefings to NARUC Electricity and Electricity Reliability Staff Subcommittees
- This presentation is a preview of LBNL's major update to its 2006 study

In 2006, LBNL estimated that power interruptions cost the US $79 billion annually (2002-$)

LBNL's research was the first and remains the only peer-reviewed analysis *based entirely on public data*





LBNL also documented significant uncertainties in its analysis, ranging from $30-130 billion

Source: Hamachi LaCommare, K. and J. Eto. 2006. "Cost of Power Interruptions to Electricity Consumers in the United States." *Energy, the International Journal*. 31:1509-1519.

A Customer-Focused Framework for Estimating the National Cost of Power Interruptions

$$\text{Cost of Power Interruptions} = \sum_{i=1}^{m}\sum_{j=1}^{n} C_{i,j} \times E_{i,j} \times O_{i,j} \times V_{i,j}$$

where,

C = total number of electric power customers in each region and customer class sector
E = the frequency of power interruption events in one year for each region and customer class sector
O = the cost per interruption as a function of outage duration by customer class for each region
V = vulnerability factor
m = the number of customers in each customer class
n = the number of regions
i,j = indices for customer class and region, respectively

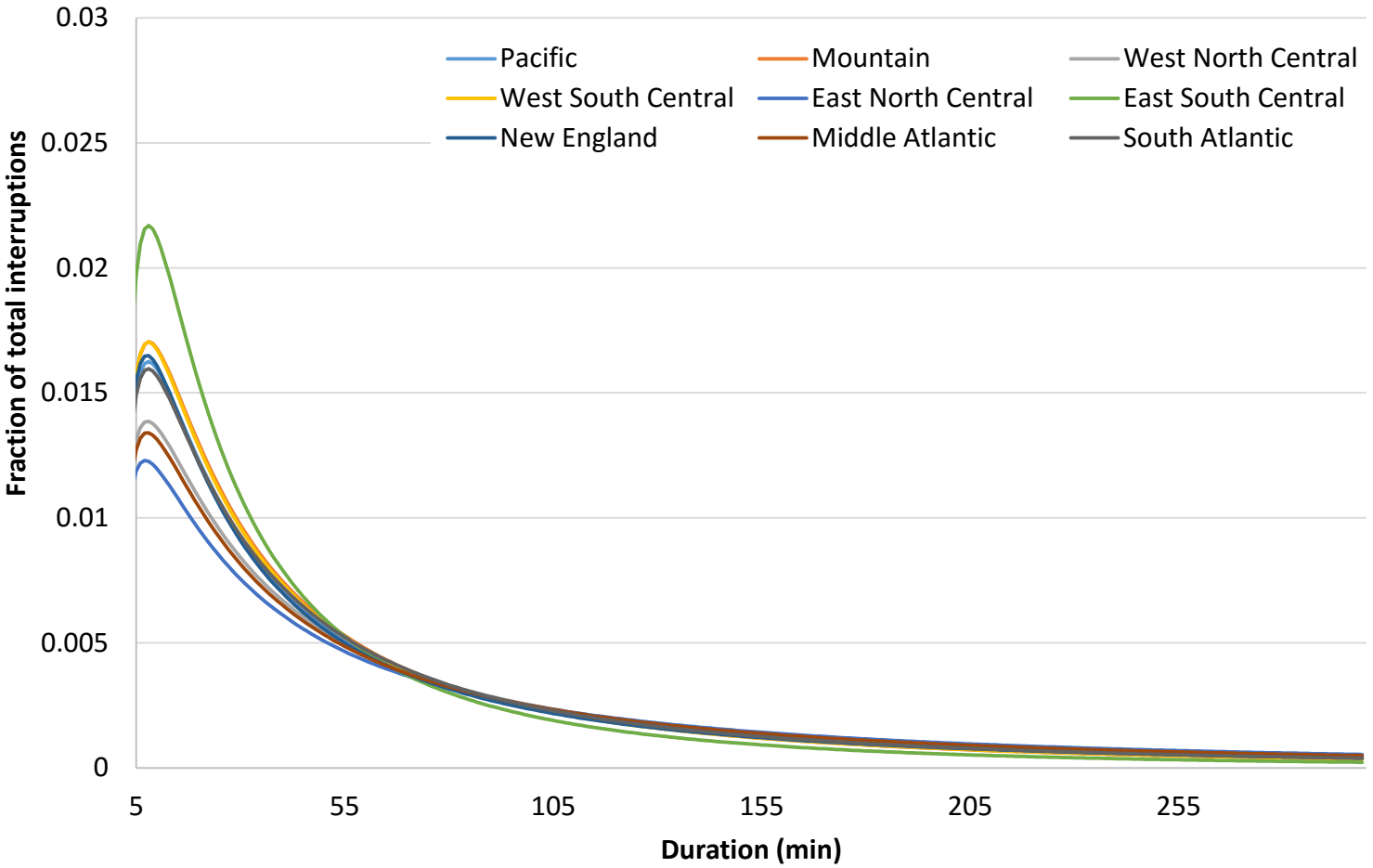
Customer Count by Class (C)

What we used for the 2004 study	What we've used for the current study	What we would like to use for the next study
Year 2001 customer counts by class using EIA 861	Year 2014 customer counts by class using EIA 861 Note: In 2003, EIA changed its definition of the 'Other' category, which led to a shift the customer count to the commercial from the industrial sector	Better alignment between EIA definitions (C and I) and those used in the surveys that were used to build the ICE Calculator (small/med C&I and large C&I)

Frequency and Duration of Interruptions(E)

What we used for the 2004 study	What we've used for the current study	What we would like to use for the next study
A convenience sample of readily available public data on SAIDI and SAIFI (with major events) and MAIFI averaged over the entire U.S.	2013 and 2014 SAIDI and SAIFI (with major events) collected by EIA from hundreds of utilities weighted and averaged separately for each of the nine U.S. Census regions – SAIDI converted into distributions of event durations using data collected from utility websites Publicly available, yet limited regional information on MAIFI - provenance is not well understood	A statistically representative, yet enhanced SAIDI and SAIFI-like metric that distinguishes among customers by type, and provides a more explicit representation of the duration of interruptions experienced by customers Better information on MAIFI

Re-expressing SAIDI as a Distribution of Outage Durations



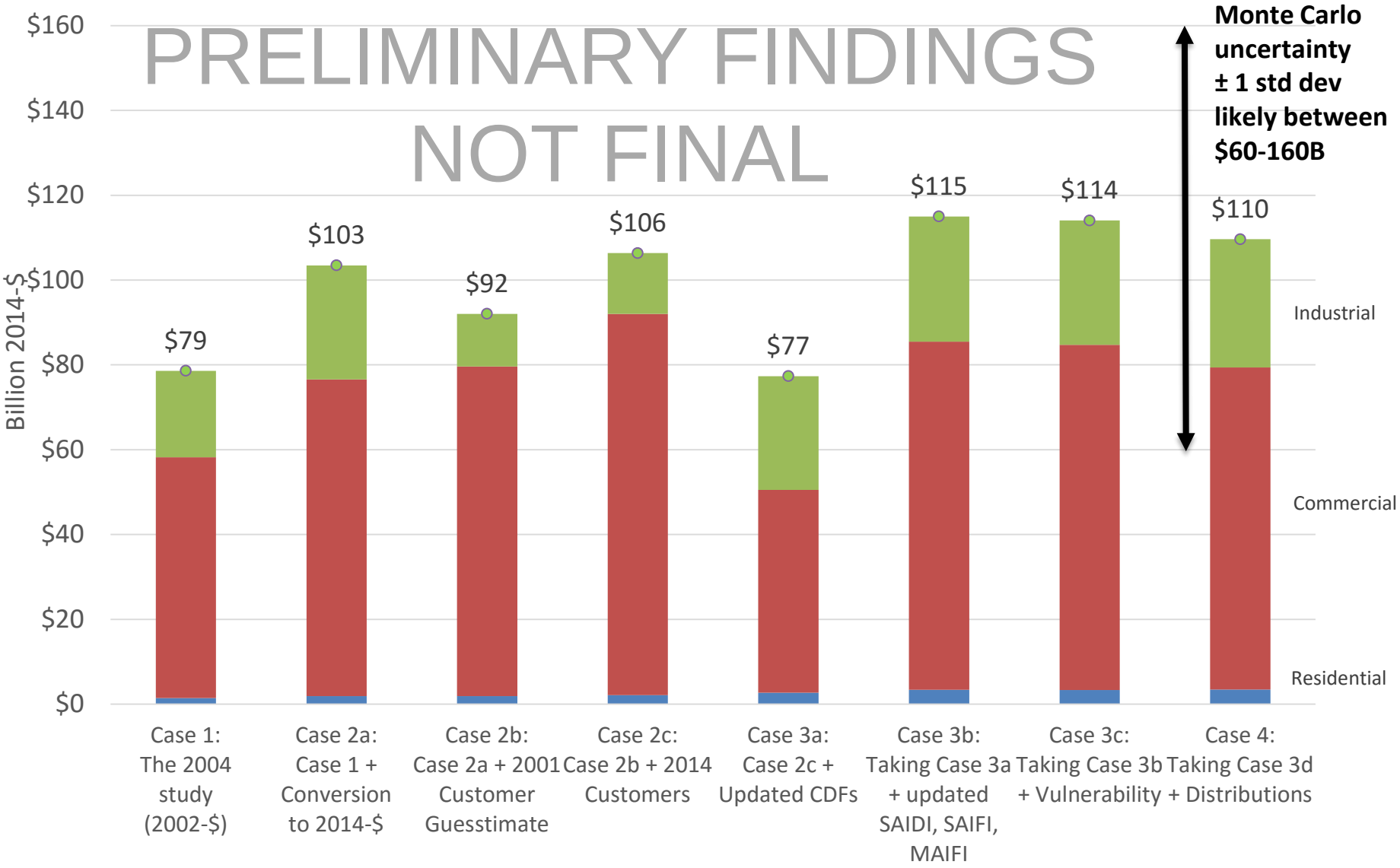
Economic Cost of Interruptions (O)

What we used for the 2004 study	What we've used for the current study	What we would like to use for the next study
A meta-analysis that developed customer damage functions (CDFs) based on 24 utility customer surveys administered by 8 utilities between years 1989-2002	An updated meta-analysis that developed new CDFs based on 34 utility customer surveys administered by 10 utilities between 1989-2012 The CDFs are based on a more advanced, two-part regression model (= the current ICE Calculator)	A current, statistically representative national survey of customer interruption costs that supports regional variations Augmented by a separate cost analysis of long-duration, widespread power interruptions More careful evaluation of the cost of momentary interruptions

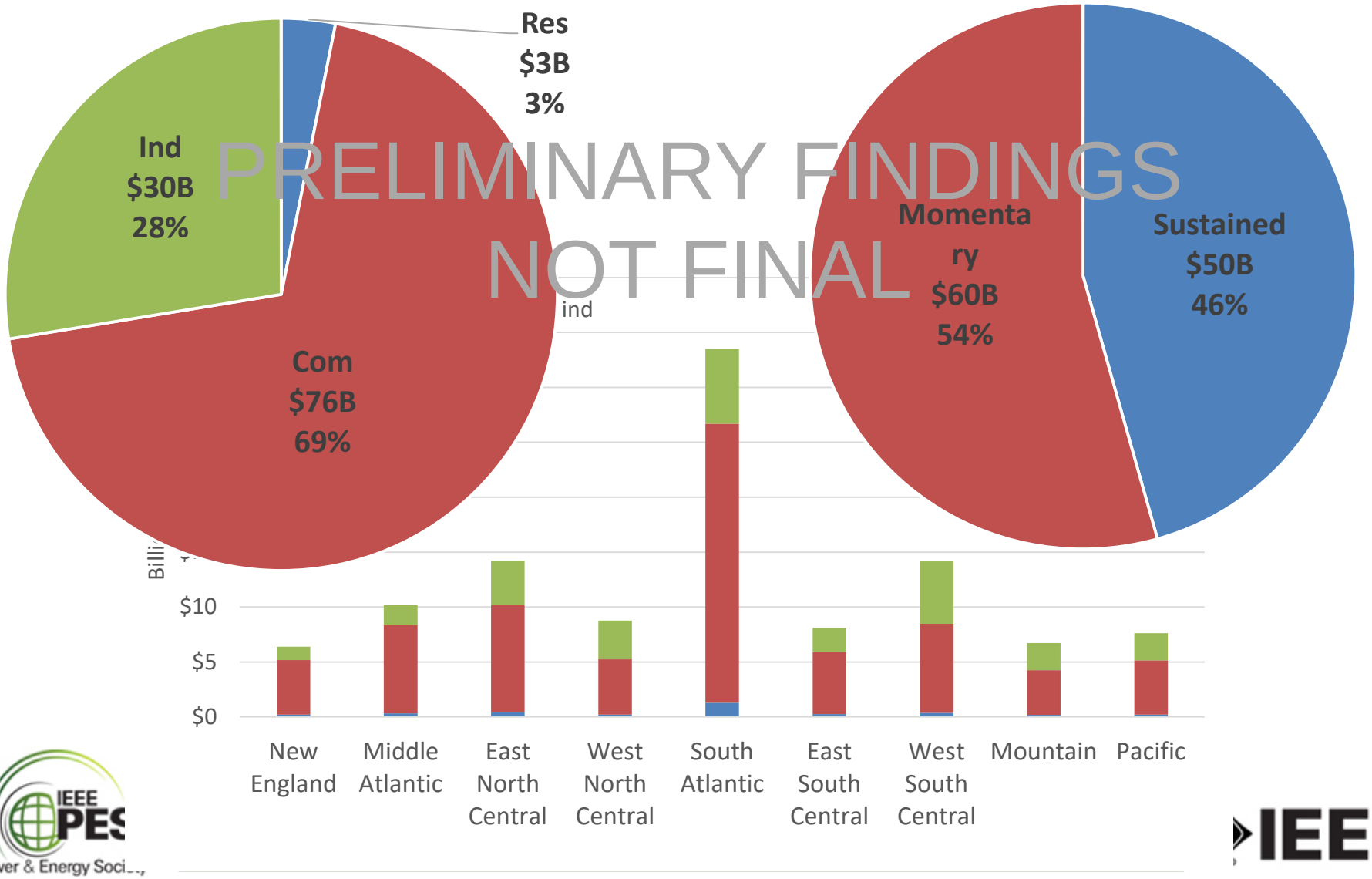
Vulnerability (V)

What we used for the 2004 study	What we've used for the current study	What we would like to use for the next study
In the absence of any data, we assumed all customers were vulnerable to power interruptions	We commissioned a study by Frost & Sullivan (2015) to develop regional market penetration estimates of stand-by generators and UPS systems by customer class	Updated and more granular information on stand-by generators and UPS Augmented by better understanding of resilience of modern electricity consuming equipment

Building Toward an Updated Estimate



Updated National Cost of Power Interruptions $110 billion (2014-$)



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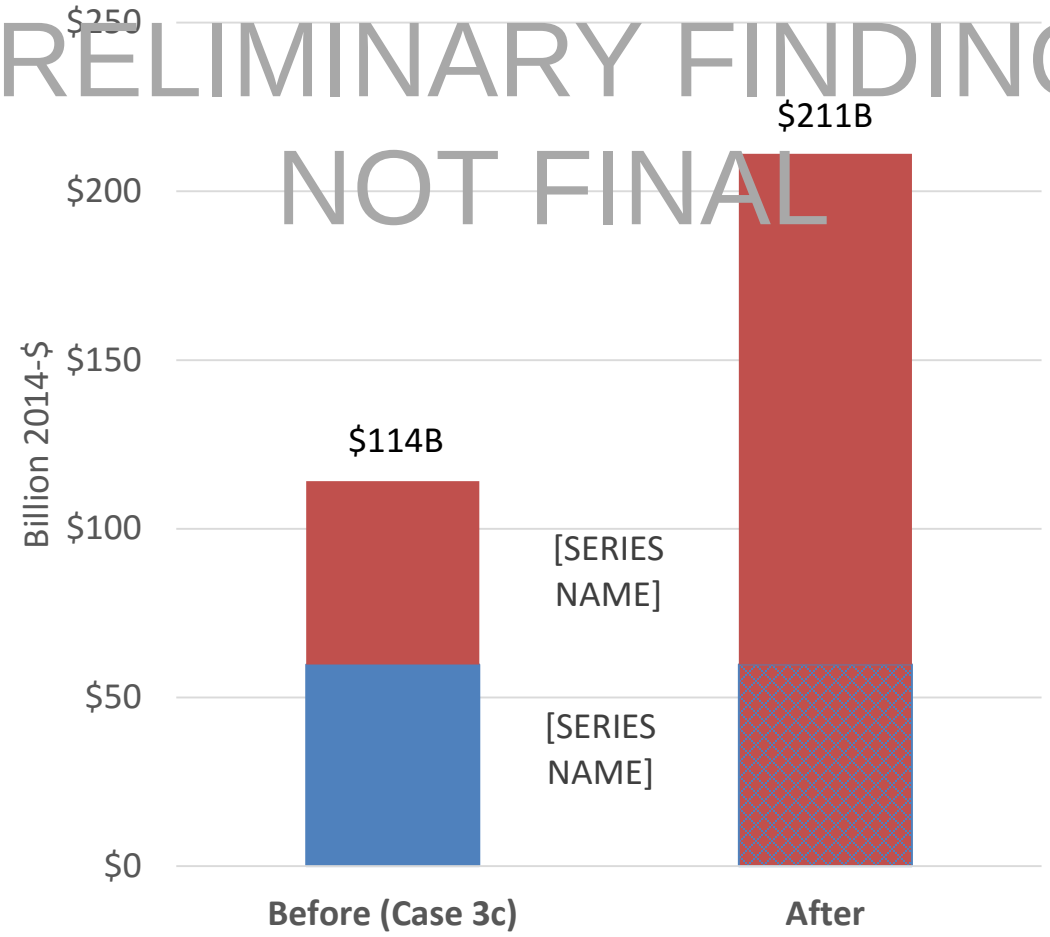
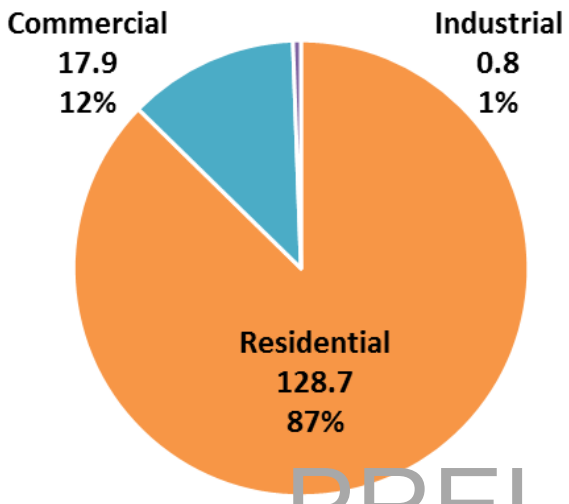
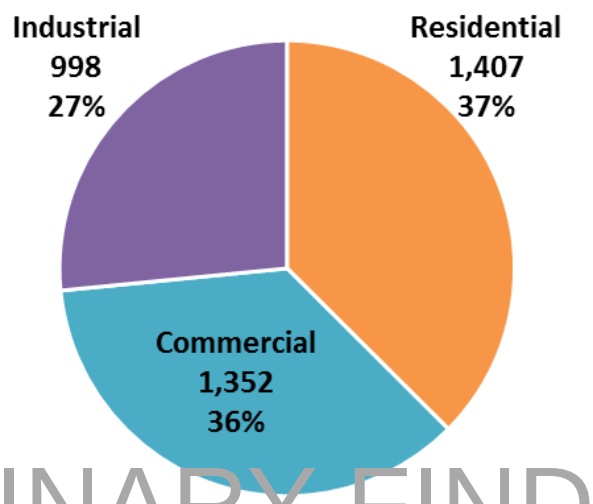
A Different Perspective on the Cost of Momentary Interruptions

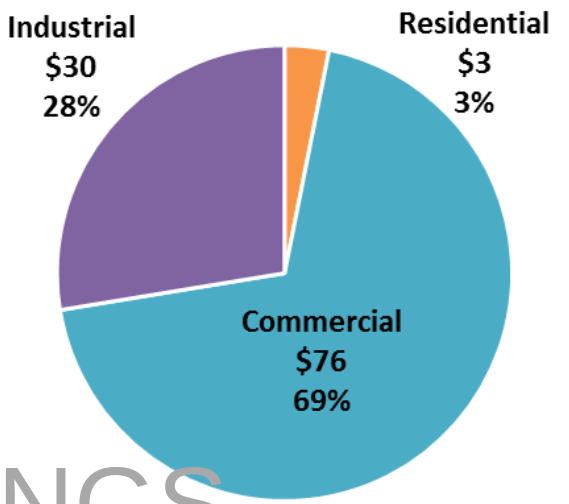


- Momentary interruptions are the result of technology investments by utilities to prevent sustained interruptions
- $60B in momentary interruption costs might otherwise be $157B in sustained interruption costs

A Look Behind the Numbers





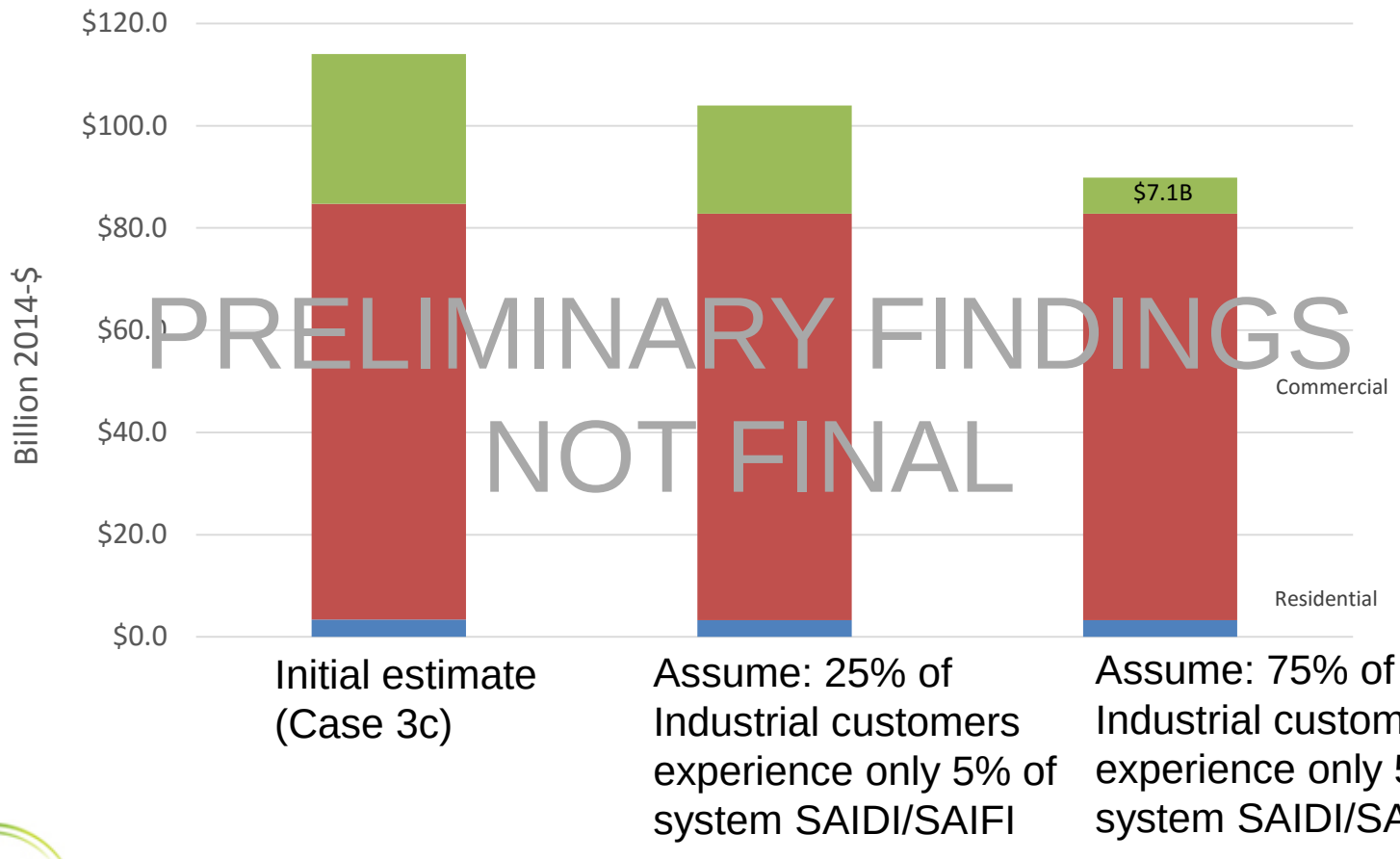


	Residential	Commercial	Industrial
Cost per customer (2014-$/customer)	$23	$4,257	$35,757
Cost per MWh annual sales (2014-$/MWh)	$2	$56	$30

Source: U.S. Energy Information Administration, Form EIA-861, "Annual Electric Power Industry Report.", Form EIA-861S, "Annual Electric Power Industry Report (Short Form)" and Form EIA-923, "Power Plant Operations Report" for Year 2014

A Sensitivity Study on the Cost of Power Interruptions to Industrial Customers

Industrial customers are often served at sub-transmission and transmission voltages



Source: Assumption of 5% of interruptions due to LOS taken from findings in:
Eto, J., K. H. LaCommare, H. C. Caswell, and D. Till, *Distribution vs. Loss of Supply: Identifying the Source of Electric Service Interruptions*, submitted to IEEE Transactions on Power Systems, May 2016.

Summary of *Preliminary* Findings

- LBNL has begun an update to its 2004 study of the national cost of power interruptions
- The update is based on a number of improvements in the public information that is now available, in part due to research sponsored by DOE
- LBNL now estimates – *on a preliminary, not yet final basis* - that power interruptions cost $110 billion per year (2014-$), an increase of more than 30% since our initial, 2004 study
- The ~13% of customers in the commercial and industrial classes account for more than 95% of these costs
- The cost of momentary interruptions continues to account for a substantial portion of these costs

Concluding Remarks

- Power interruptions have economic consequences for customers
- Addressing these consequences is a responsibility that is shared primarily between the customer and its utility, but also in some cases the government at large
- Managing sustained interruptions is a long-standing responsibility of the utility
- Momentary interruptions result from utility actions to manage (i.e., avoid) sustained interruptions
- Managing severe major events is a responsibility that is shared with government
- Customers always have the option to secure (and pay for) higher levels of reliability