



Real World Distribution Reliability Improvement

December 14, 2022 – IEEE/PES Chicago Chapter

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Audience Poll

Which reliability metrics below are you already familiar with?

- SAIFI
- SAIDI
- CAIDI
- MAIFI
- CEMI
- CEMM
- CEMSMI
- CELID

Audience Poll

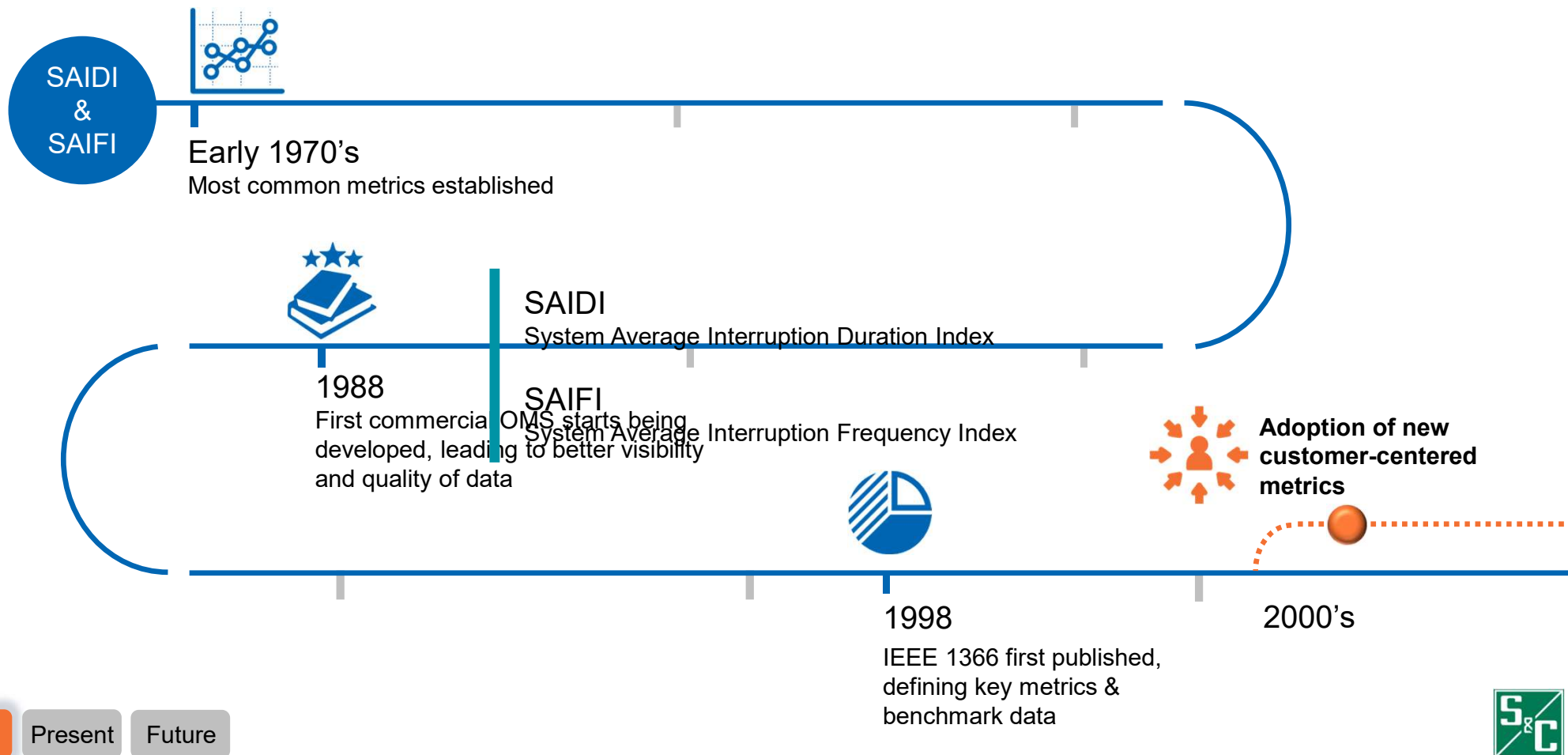
Which reliability metrics below are you already familiar with?

- SAIFI – System Average Interruption Frequency Index
- SAIDI – System Average Interruption Duration Index
- CAIDI – Customer Average Interruption Duration Index
- MAIFI – Momentary Ave. Interruption Frequency Index
- CEMI – Customers Experiencing Multiple Interruptions
- CEMM – Customers Experiencing Multiple Momentaries
- CEMSMI – Customers Experiencing Multiple Sustained and Momentary Outages
- CELID – Customers Experiencing Long Interruption Durations



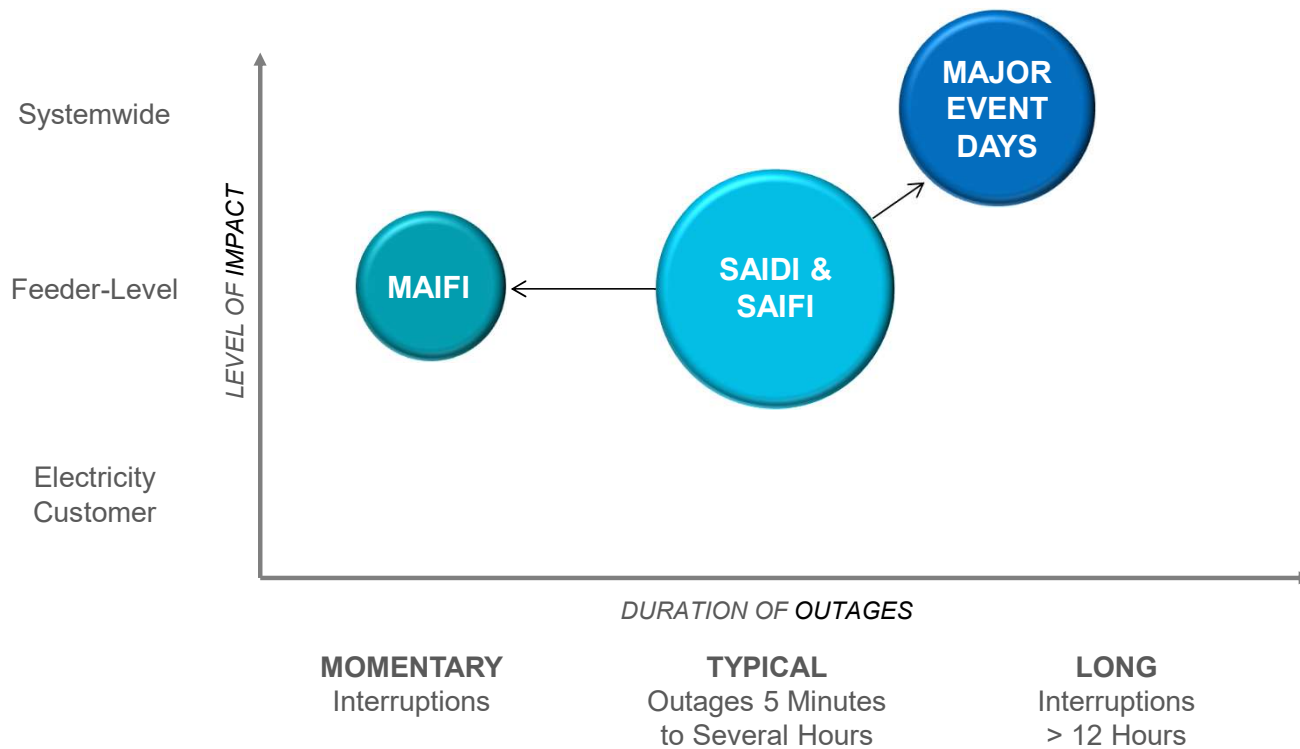
A Look at the Past

- 5 decades of reliability metrics



Most Commonly Used Metrics

- 5 decades of reliability metrics



SAIDI
System Average Interruption
Duration Index

SAIFI
System Average Interruption
Frequency Index

MAIFI
Momentary Average
Interruption Frequency Index

CAIDI
Customer Average Interruption
Duration Index

Past

Present

Future

● Size of Circle = Relative Level of Utility Use of this Metric



A Closer Look at CAIDI

SAIDI	= System Average Interruption Duration Index		
	= $\frac{\text{Sum of All Customer Minutes Interrupted (CMI)}}{\text{Total number of Customers Served (C)}}$	$\frac{229,761,169}{5,241,308}$	43.84
CAIDI	= Customer Average Interruption Duration Index		
	= $\frac{\text{Sum of All Customer Minutes Interrupted (CMI)}}{\text{Total number of Customer Interruptions (CI)}}$	$\frac{229,761,169}{3,678,019}$	62.5
SAIFI	= System Average Interruption Frequency Index		
	= $\frac{\text{Total number of Customer Interruptions (CI)}}{\text{Total number of Customers Served (C)}}$	$\frac{3,678,019}{5,241,308}$	0.70

CAIDI

Customer Average Interruption
Duration Index

=

SAIDI

System Average Interruption
Duration Index

SAIFI

System Average Interruption
Frequency Index

Past

Present

Future



CAIDI

Customer Average Interruption
Duration Index

=

SAIDI

System Average Interruption
Duration Index

SAIFI

System Average Interruption
Frequency Index

	Scenario 1 (base case)
SAIDI (minutes)	80.0
SAIFI (# outages)	1.2
CAIDI (min/outage)	66.7

Past

Present

Future



CAIDI

Customer Average Interruption
Duration Index

=

SAIDI

System Average Interruption
Duration Index

SAIFI

System Average Interruption
Frequency Index

	Scenario 1 (base case)	Scenario 2 (automate, segment, underground)
SAIDI (minutes)	80.0	60.0
SAIFI (# outages)	1.2	0.8
CAIDI (min/outage)	66.7	75.0

Past

Present

Future



CAIDI

Customer Average Interruption
Duration Index

=

SAIDI

System Average Interruption
Duration Index

SAIFI

System Average Interruption
Frequency Index

	Scenario 1 (base case)	Scenario 2 (automate, segment, underground)	Scenario 3 (Let feeder breaker operate and lockout)
SAIDI (minutes)	80.0	60.0	160.0
SAIFI (# outages)	1.2	0.8	4.0
CAIDI (min/outage)	66.7	75.0	40.0

Past

Present

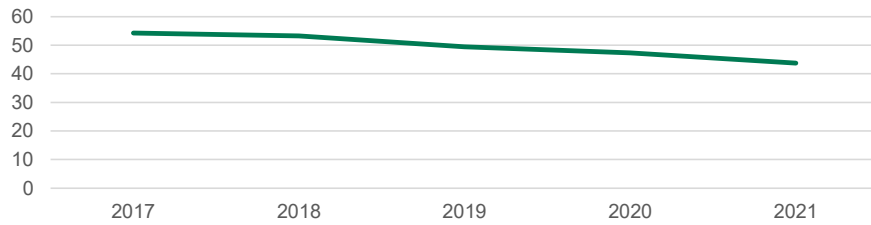
Future



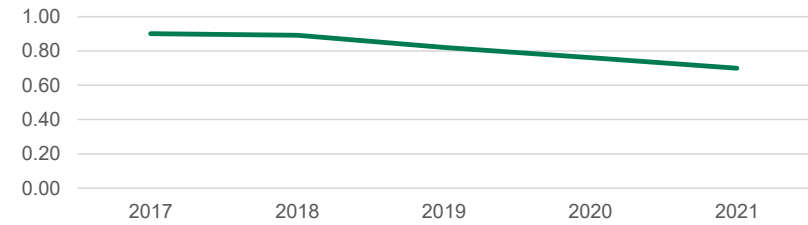
Real-World Example

- SAIDI & SAIFI Improving → CAIDI getting worse

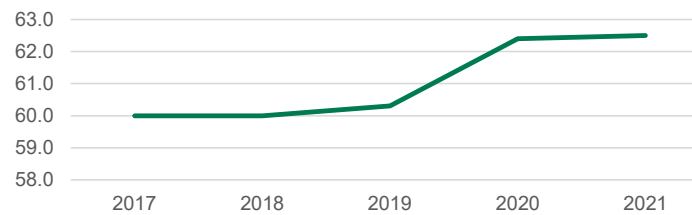
SAIDI - Sys. Ave. Interruption Duration



SAIFI - Sys. Ave. Interruption Frequency



CAIDI - Customer Ave. Interruption Duration



Past

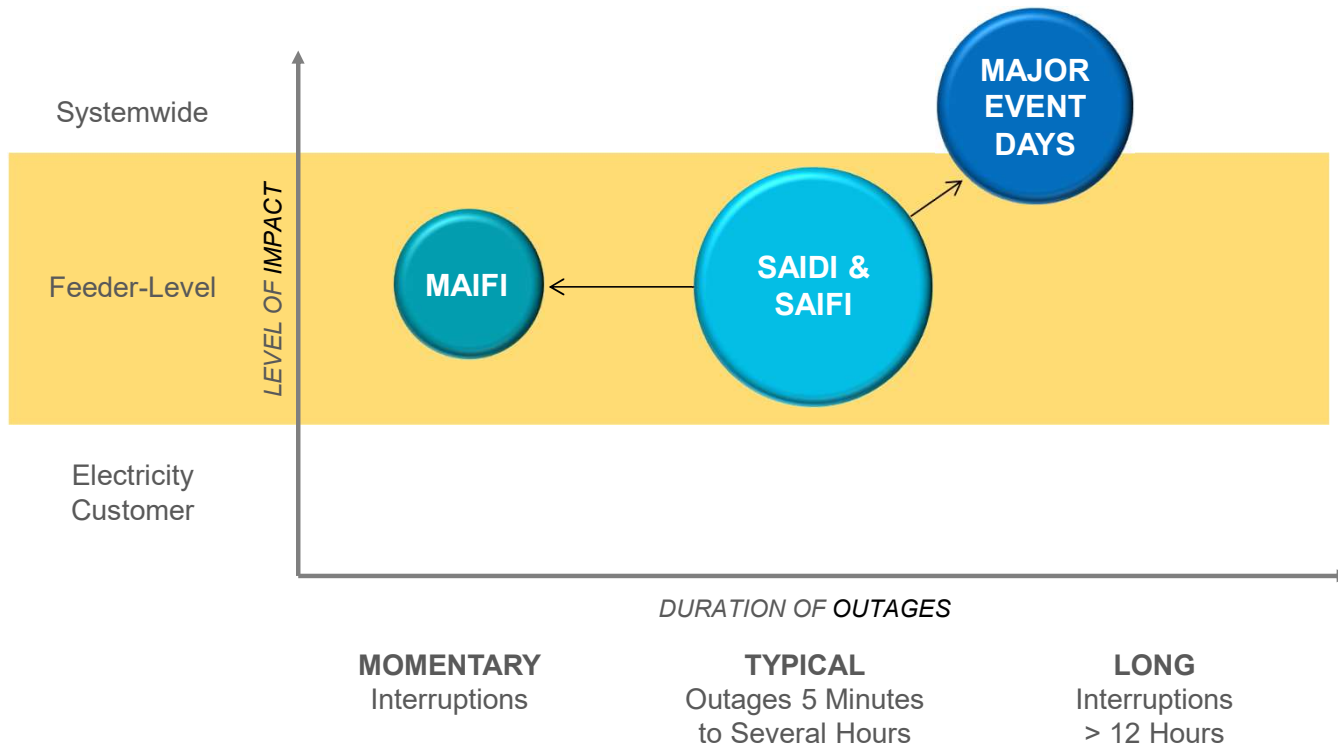
Present

Future



Most Commonly Used Metrics

- Moving Beyond **Average** Reliability Metrics



SAIDI
System **Average** Interruption
Duration Index

SAIFI
System **Average** Interruption
Frequency Index

MAIFI
Momentary **Average**
Interruption Frequency Index

Past

Present

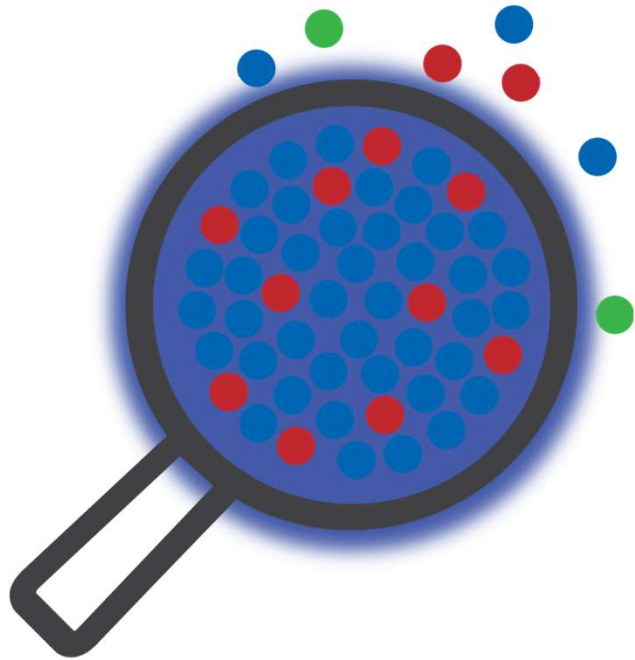
Future

● Size of Circle = Relative Level of Utility Use of this Metric



Why do we have reliability metrics?

- Two big problems with the Big Average Reliability Indices:



Data Aggregation Missed

- Disregard individual customer experiences
- Misses problem areas
- Flawed strategy decisions

Past

Present

Future



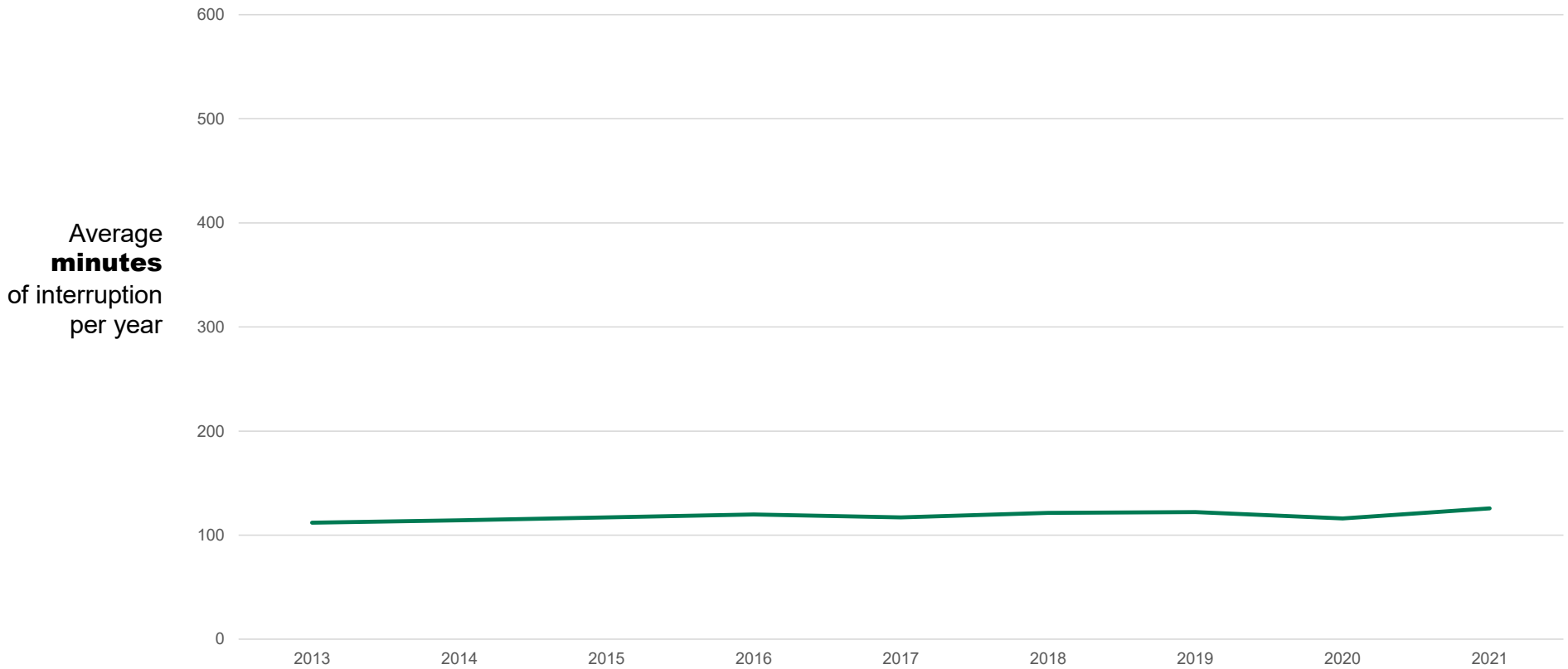
Audience Poll

How do you think US utilities have been performing on SAIDI and SAIFI metrics over the last 8 years?

- Reliability is improving
- Reliability is generally the same
- Reliability is getting worse

Real-World Checkpoint | US Distribution SAIDI (excluding major events)

SAIDI - System Average Interruption Duration w/o MED



Source: U.S. Energy Information Administration, Form EIA-861, Annual Electric Power Industry Report.

Past

Present

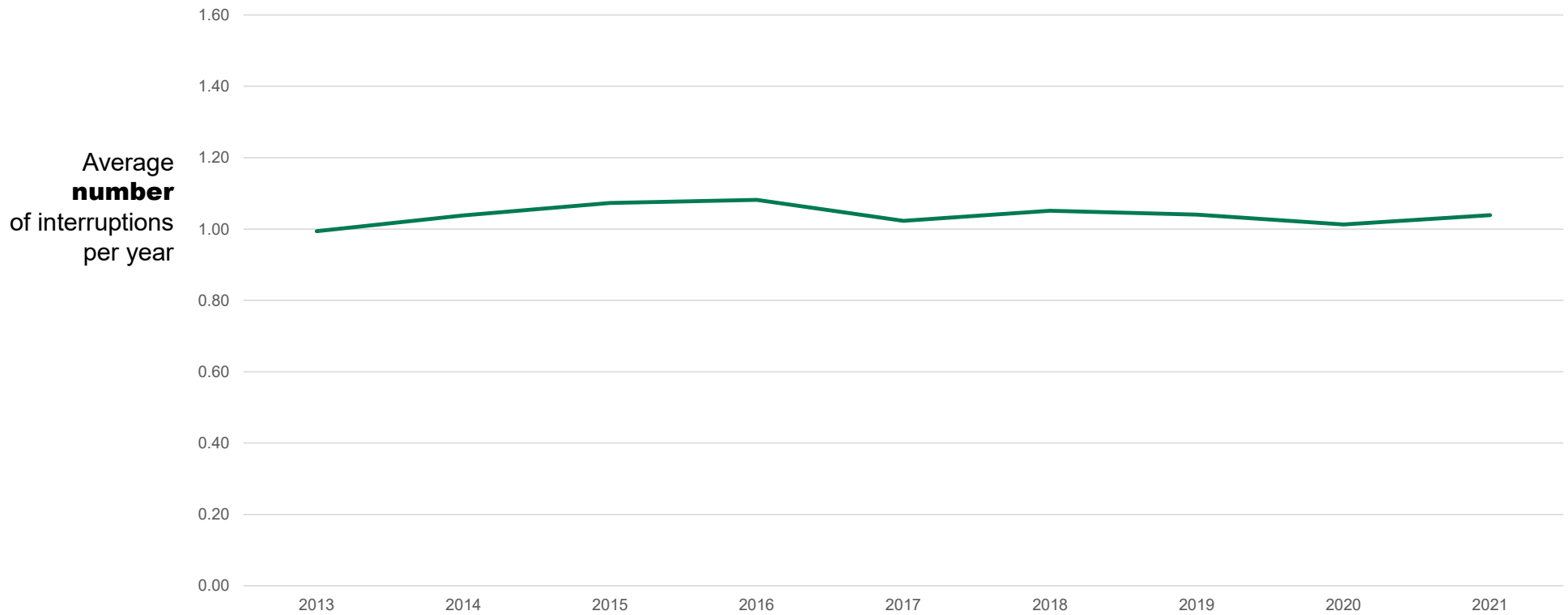
Future



Real-World Checkpoint | US Distribution SAIFI (excluding major events)

- Status quo remains despite efforts

SAIFI - System Average Interruption Frequency w/o MED



Source: U.S. Energy Information Administration, Form EIA-861, Annual Electric Power Industry Report.

Past

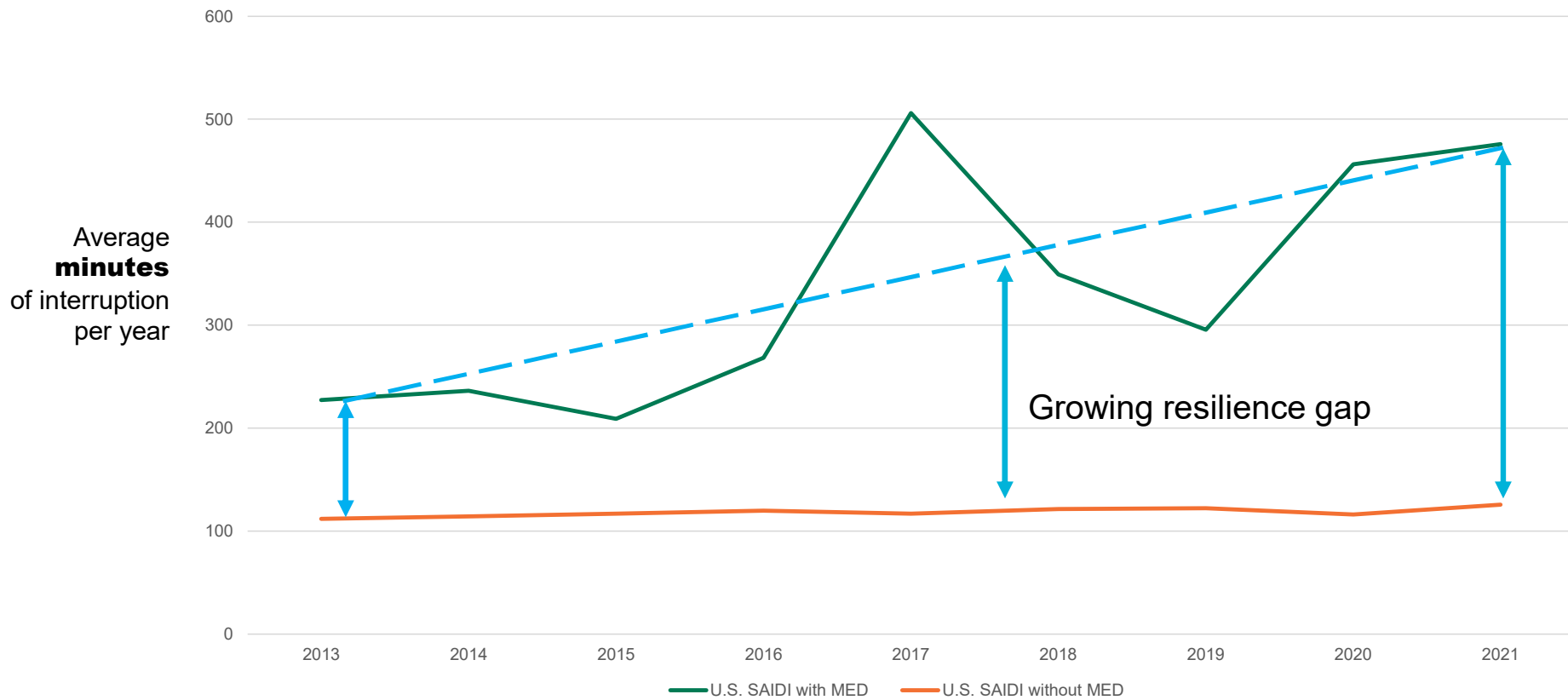
Present

Future



Real-World Checkpoint | US Distribution SAIDI (with & without MED)

SAIDI - System Average Interruption Duration



Source: U.S. Energy Information Administration, Form EIA-861, Annual Electric Power Industry Report.

Past

Present

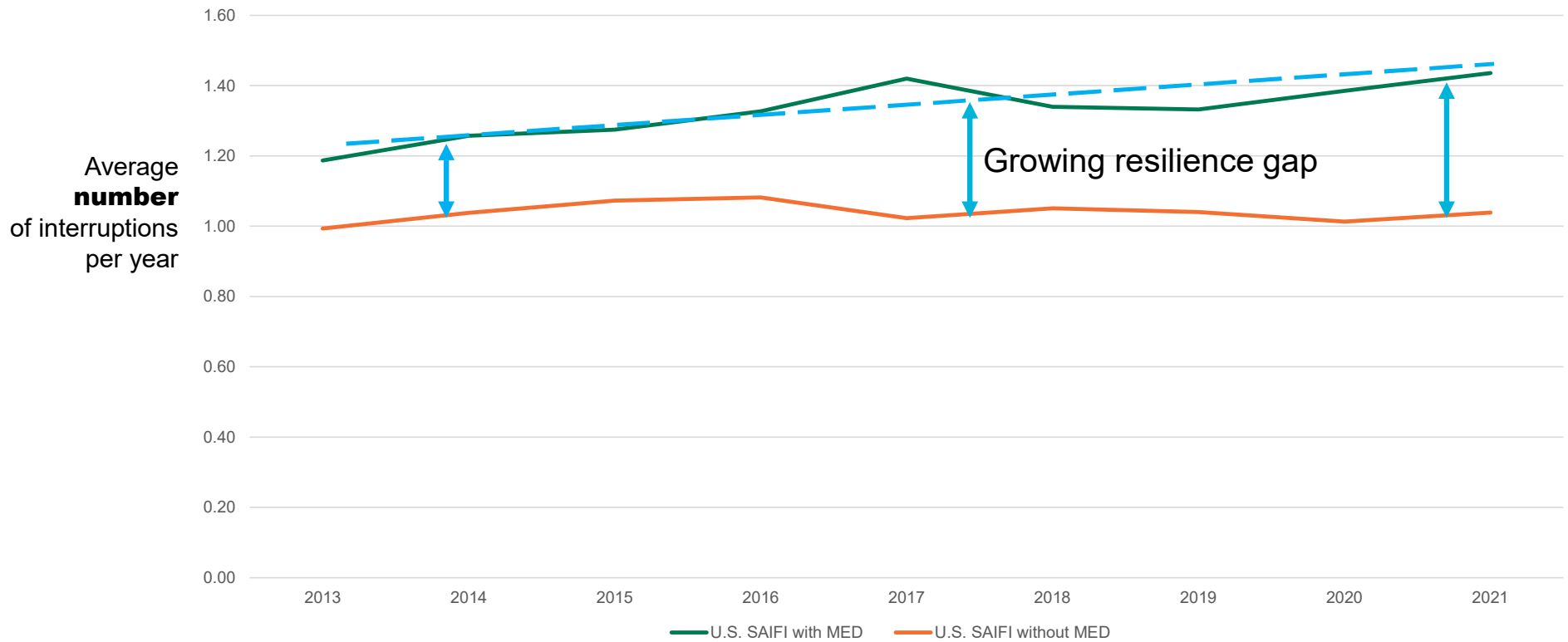
Future



Real-World Checkpoint | US Distribution SAIFI (with & without MED)

- Status quo remains despite efforts

SAIFI - System Average Interrupter Frequency



Source: U.S. Energy Information Administration, Form EIA-861, Annual Electric Power Industry Report.

Past

Present

Future



Real-World Reset



Update Indices

- What to keep
- Add Customer-Centric Indices
- Equity Review



Resilience

- System Hardening
- Redundancy
- Storage
- Undergrounding



Reliability Kickstart

- Segmentation
- To the Edge of the Grid

Recent Times: Changing Energy Landscape

- Meeting the shift to digital



Residential



Manufacturing



Retail

Past

Present

Future



Critical Elements of Grid Performance Metric

SAIFI

Covers how often there are grid outages

+

SAIDI

Covers how long grid outages typically are

+

Customer-focused metric

Important to account for momentary outages

Data should be as close to the customer level as is practical

+

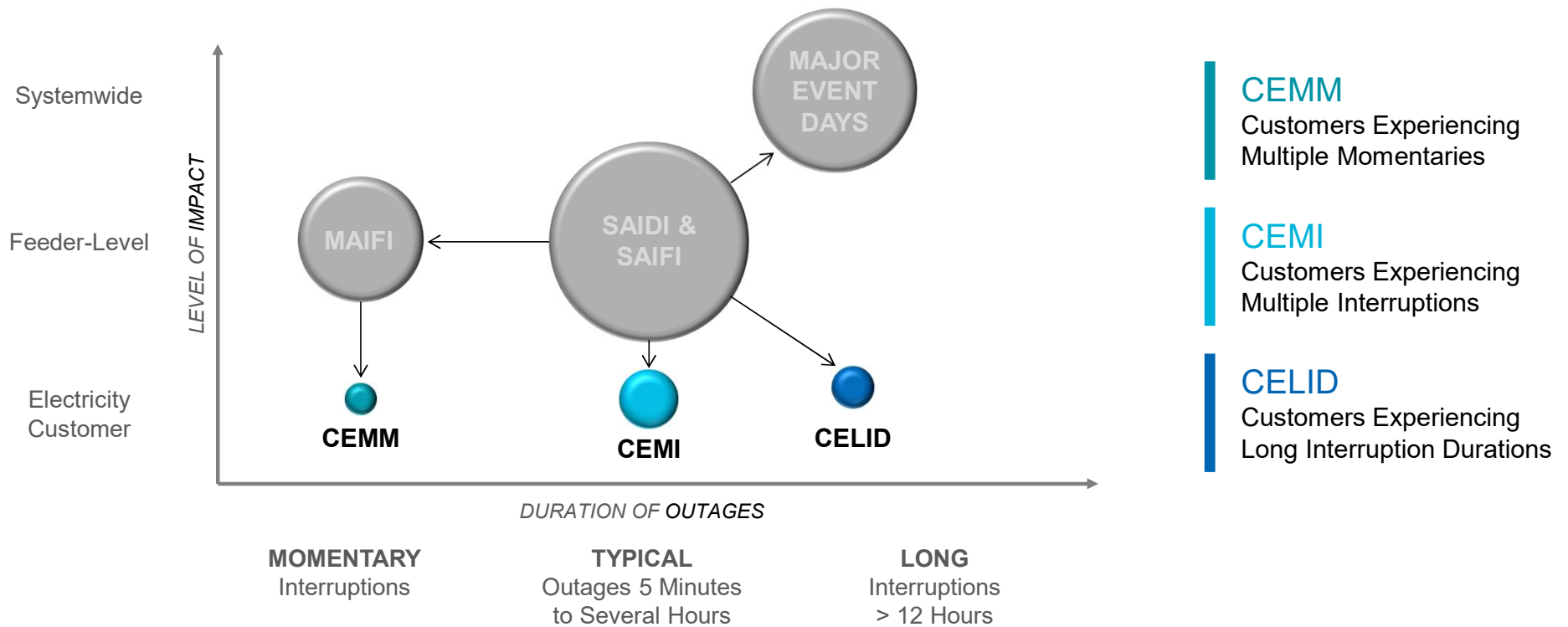
Resilience Metric

Should be more about tracking over time than comparing utilities

Needs to allow utilities to benefit from addressing all aspects of grid resilience

Evolution Toward Customer-Centered Metrics

- Meeting rising customer expectations



Past

Present

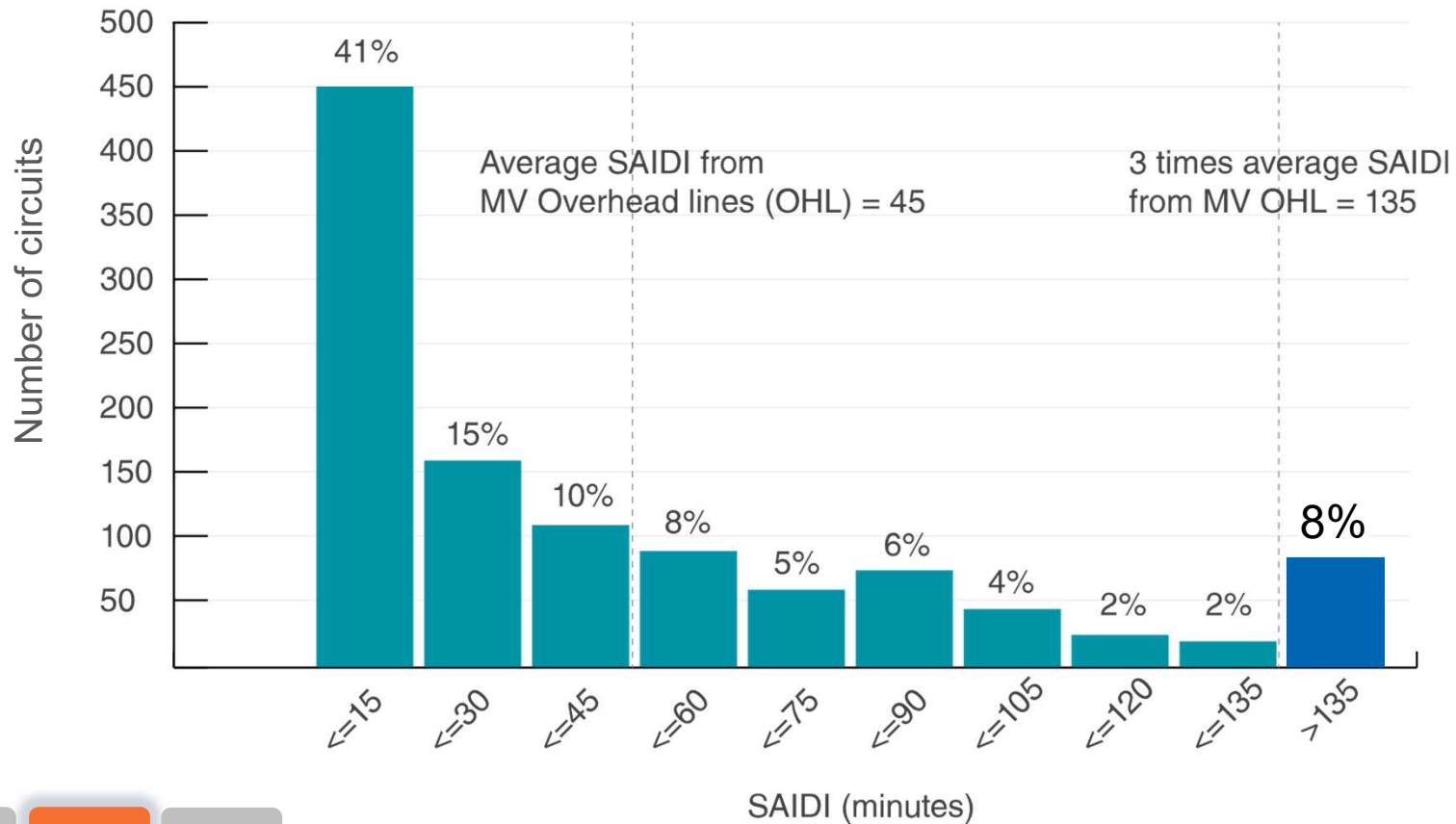
Future

● Size of Circle = Relative Level of Utility Use of this Metric



Evolution Toward Customer-Centered Metrics

- A closer look



8% of circuits experiencing more than 3 times the average SAIDI from MV OHL

Past

Present

Future



M2

Real-World Checkpoint

- Understanding customer satisfaction

Do we know what customers want?

Past

Present

Future



Slide 24

M2 Should this have a graphic or are you okay with a block of text here?
Mirmonde, 5/17/2021

Real-World Checkpoint

- Understanding customer satisfaction

1 outage of
60 minutes



4 outages of
15 minutes each

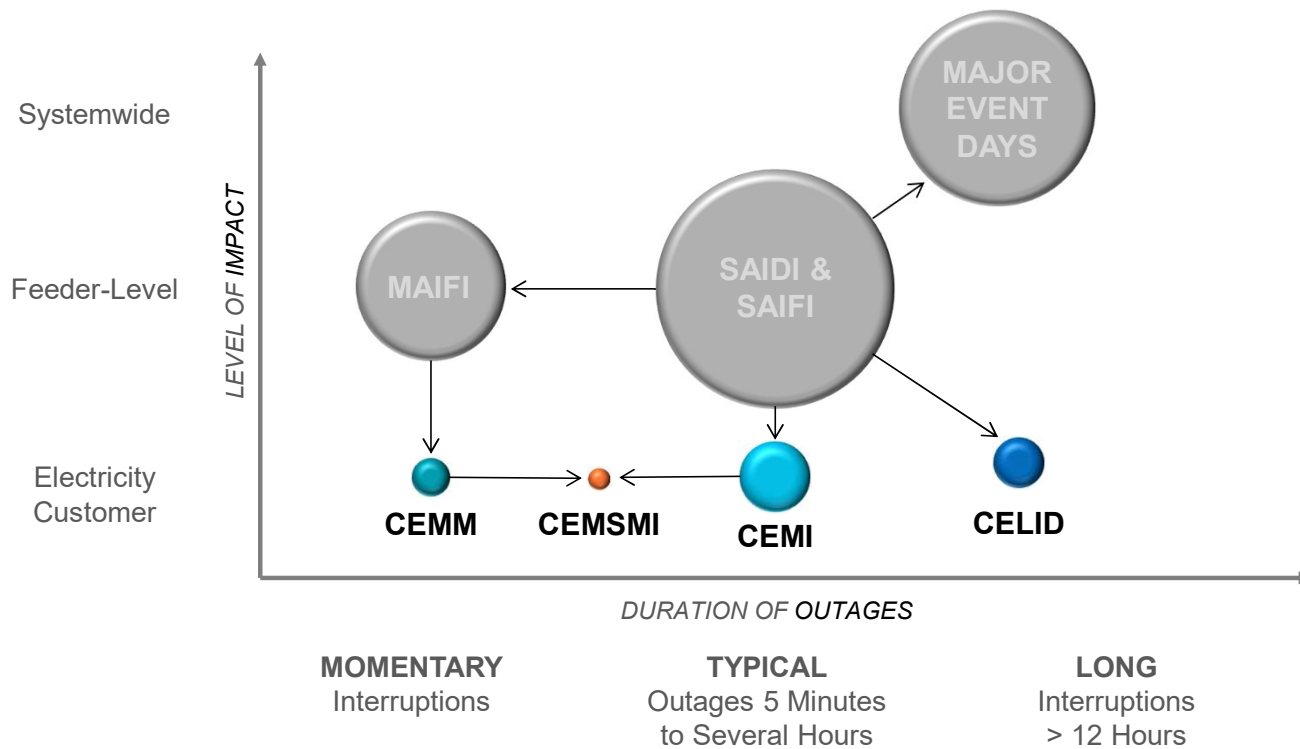
Past

Present

Future



Looking Toward the Future: Every Outage Counts



CEMSMI
 Customers Experiencing Multiple Sustained Interruptions and Momentary Interruptions Events

Past

Present

Future

● Size of Circle = Relative Level of Utility Use of this Metric



Real-World Reset



Update Indices

- What to keep
- Add Customer-Centric Indices
- Equity Review



Resilience

- System Hardening
- Robustness
- Storage
- Undergrounding



Reliability Kickstart

- Segmentation
- To the Edge of the Grid

The Grid is changing.



Cyber attacks

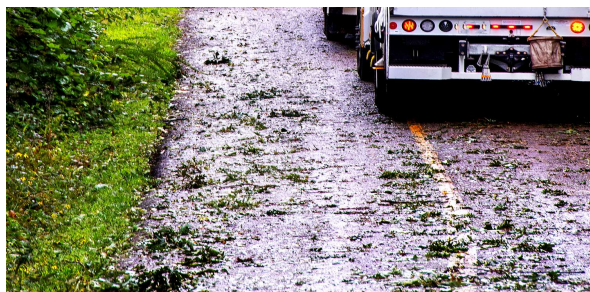


Changing expectations



Changing demand patterns

Electrification



Extreme weather



Ageing assets

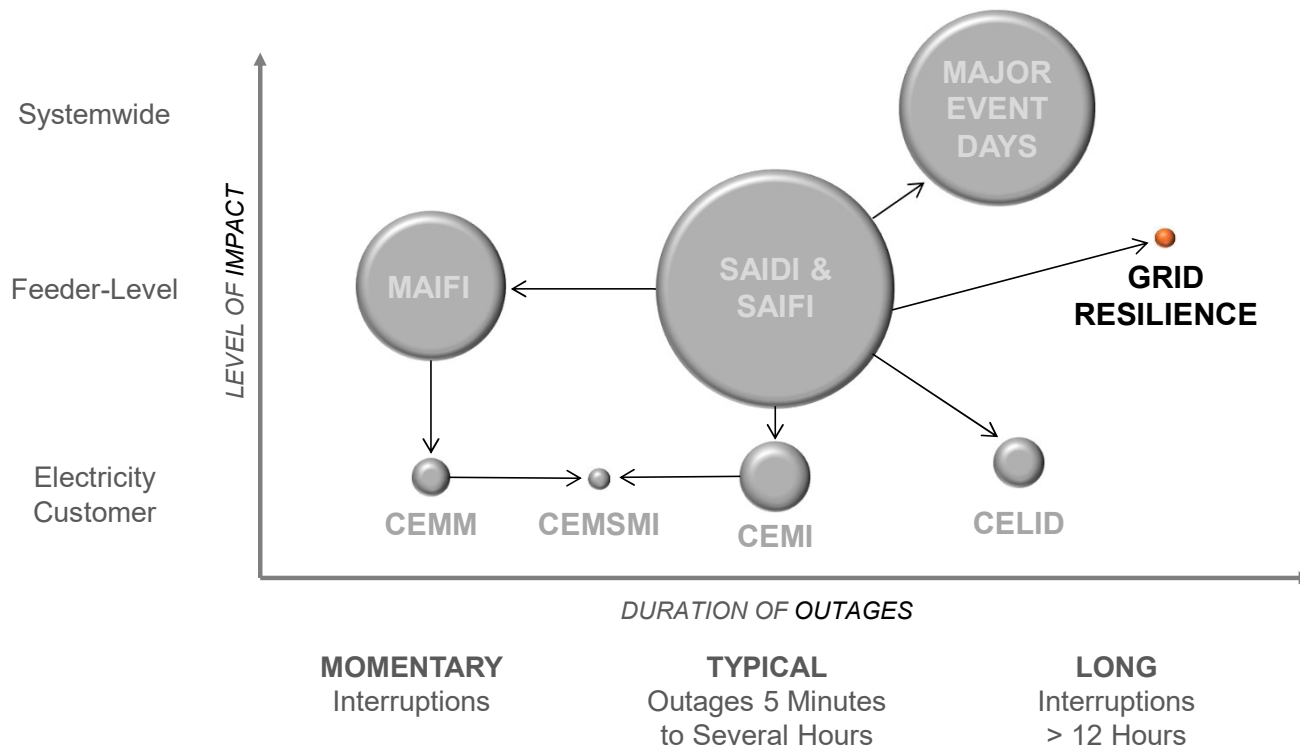


Changing demand patterns

Increased DERs on the system



Looking Toward the Future: Every Outage Counts



MOMENTARY
Interruptions

TYPICAL
Outages 5 Minutes
to Several Hours

LONG
Interruptions
> 12 Hours

● Size of Circle = Relative Level of Utility Use of this Metric

Past

Present

Future



Resiliency - System Hardening

- Pole Inspections
- Pole Upgrades – Steel and Concrete
- Vegetation Management
- Increase Flood Prevention
- Cable Replacement



Past

Present

Future



Resiliency - Robustness

- It's not just about keeping the lights on

Improving **Resiliency** requires a **robust distribution system**



Past

Present

Future



Looking Toward the Future

- Maintaining stability with distributed generation



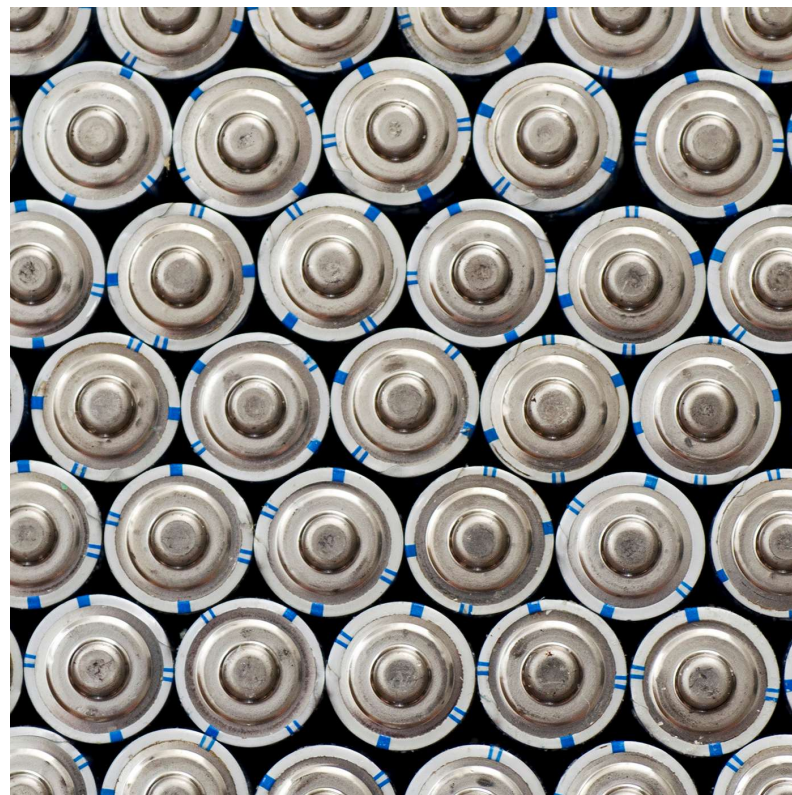
Past

Present

Future

System Hardening - Storage

Battery Storage



Past

Present

Future



Resiliency - Undergrounding

- Where Practical
- Can Create Hybrid Circuits



Past

Present

Future



Real-World Reset



Update Indices

- What to keep
- Add Customer-Centric Indices
- Equity Review



Resilience

- System Hardening
- Robustness
- Storage
- Undergrounding



Reliability Kickstart

- Segmentation
- To the Edge of the Grid



**Time To
Make
Adjustments**

Reliability Kickstart – Additional Segmentation

- Conventional Recloser Loop Scheme



Past

Present

Future



Reliability Kickstart – Additional Segmentation

- Segmentation to reduce the number of customer between automated devices



Past

Present

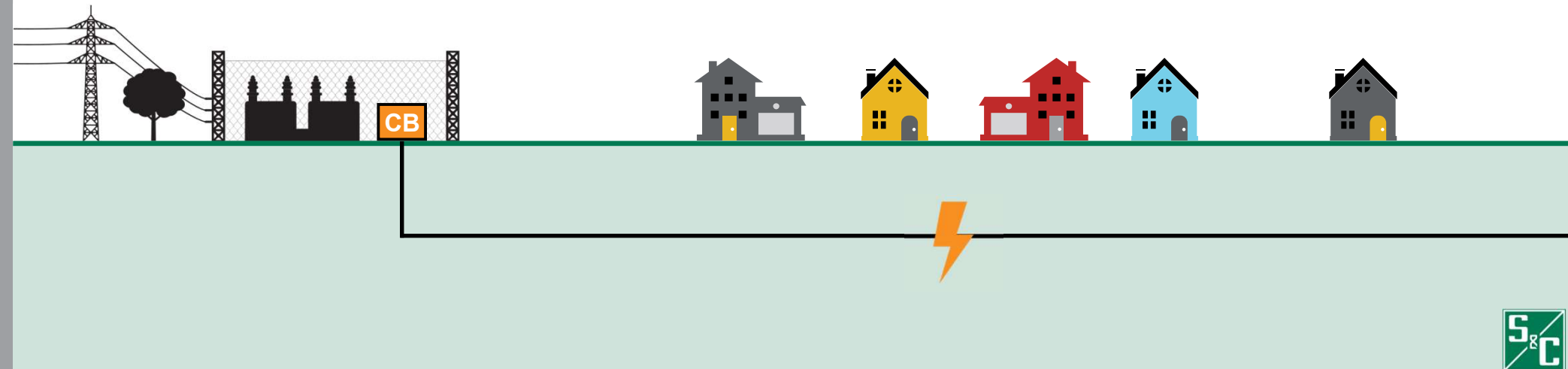
Future



Protection Challenge | **Underground Feeder Sections**



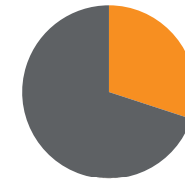
The one-shot-to-lockout (trip and lockout) approach results in an outage of the whole circuit for a fault of any type.



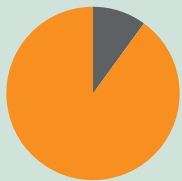
Protection Challenge | Hybrid Circuits



Hybrid circuits force the one-shot-to-lockout approach, resulting in long outages for temporary faults.



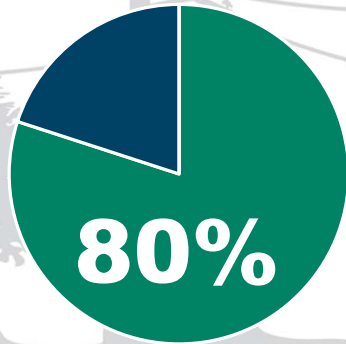
Only a 30% chance overhead fault is permanent



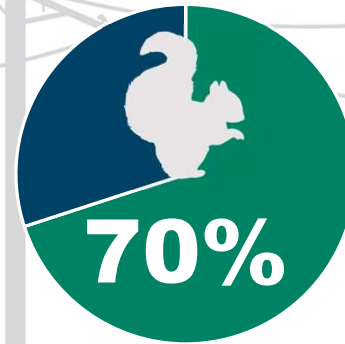
More than a 90% chance underground fault is permanent



Grid Edge - Conventional Lateral Protection Strategies May Not Be Meeting Today's Customer Demands



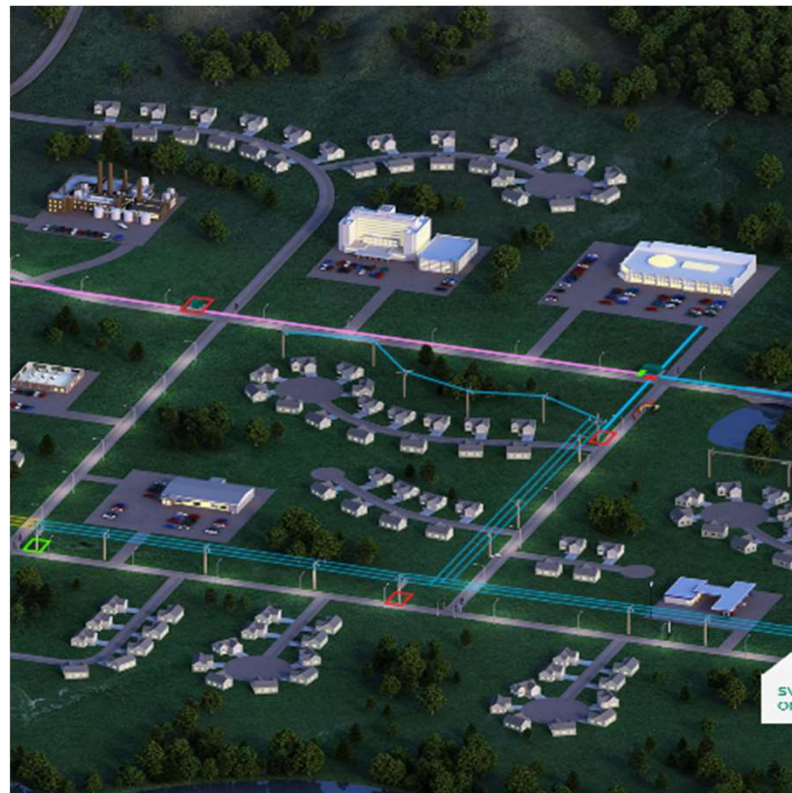
**of faults
are on
laterals**



of lateral fuse operations
are due to **temporary
faults** – unnecessary
sustained outages

Reliability Kickstart – Additional Segmentation

- Guard against blinking other laterals on the feeder



Past

Present

Future



Real-World Reset



Update Indices

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Resilience

- System Hardening
- Redundancy
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- Undergrounding



Reliability Kickstart

- Segmentation
- To the Edge of the Grid

Audience Poll

- Which metrics would be most useful in improving customer satisfaction?



THINK

B E Y O N D

