Walk-through of long-term utility distribution plans:
Part 1 - Traditional Distribution Planning

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GE Energy Consulting

Distribution Systems and Planning Training for Western States, May 2-3, 2018

Goal of distribution planning

- ► Provide orderly, economic expansion of equipment and facilities to meet future demand with acceptable system performance
  - Deliver power with required frequency (60Hz)
  - Satisfy voltage requirements (within ±5%)
  - Deliver adequate availability (<2 hours out/yr)
  - Have capacity to meet instantaneous demand
  - Reach all customers wherever they exist

… and do it all for the lowest possible cost

Need to plan because it takes time to build capacity

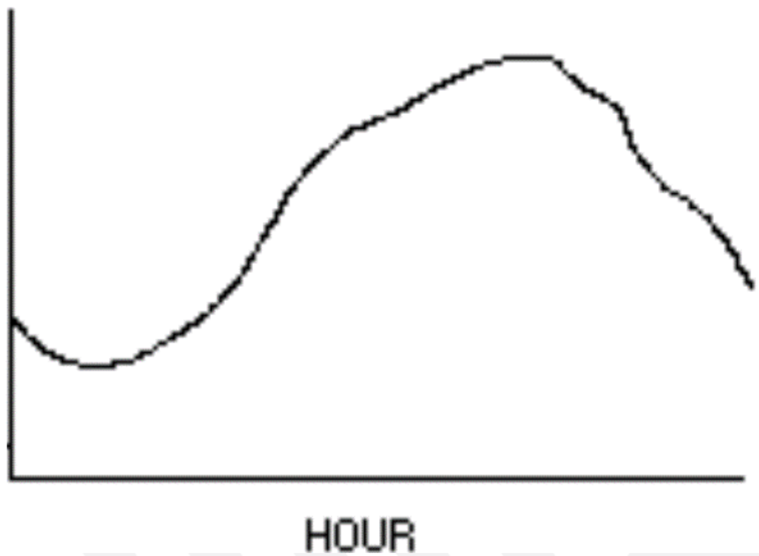
- Effective minimum-cost planning accounts for lead time to deploy T&D assets in developing reasonable alternatives

T&D Level	Lead Time (yrs)
Generation	13
EHV Transmission	9
Transmission	8
Sub-transmission	7
Substation	6
Feeder	3
Lateral	0.5
Service	0.1

Loads and demand drive distribution planning

- Loads vary over time

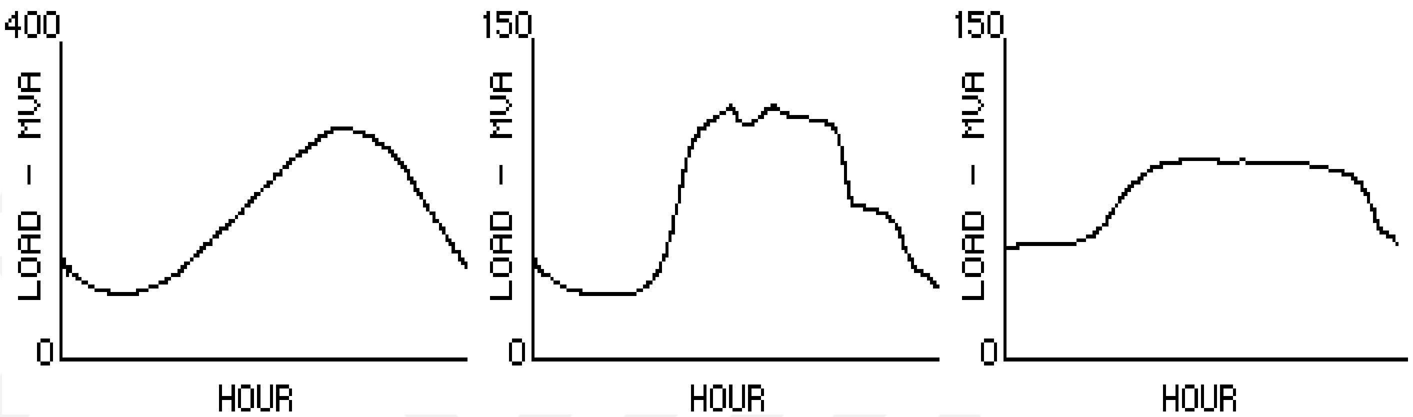
Typical Feeder Load



Typical Customer Load

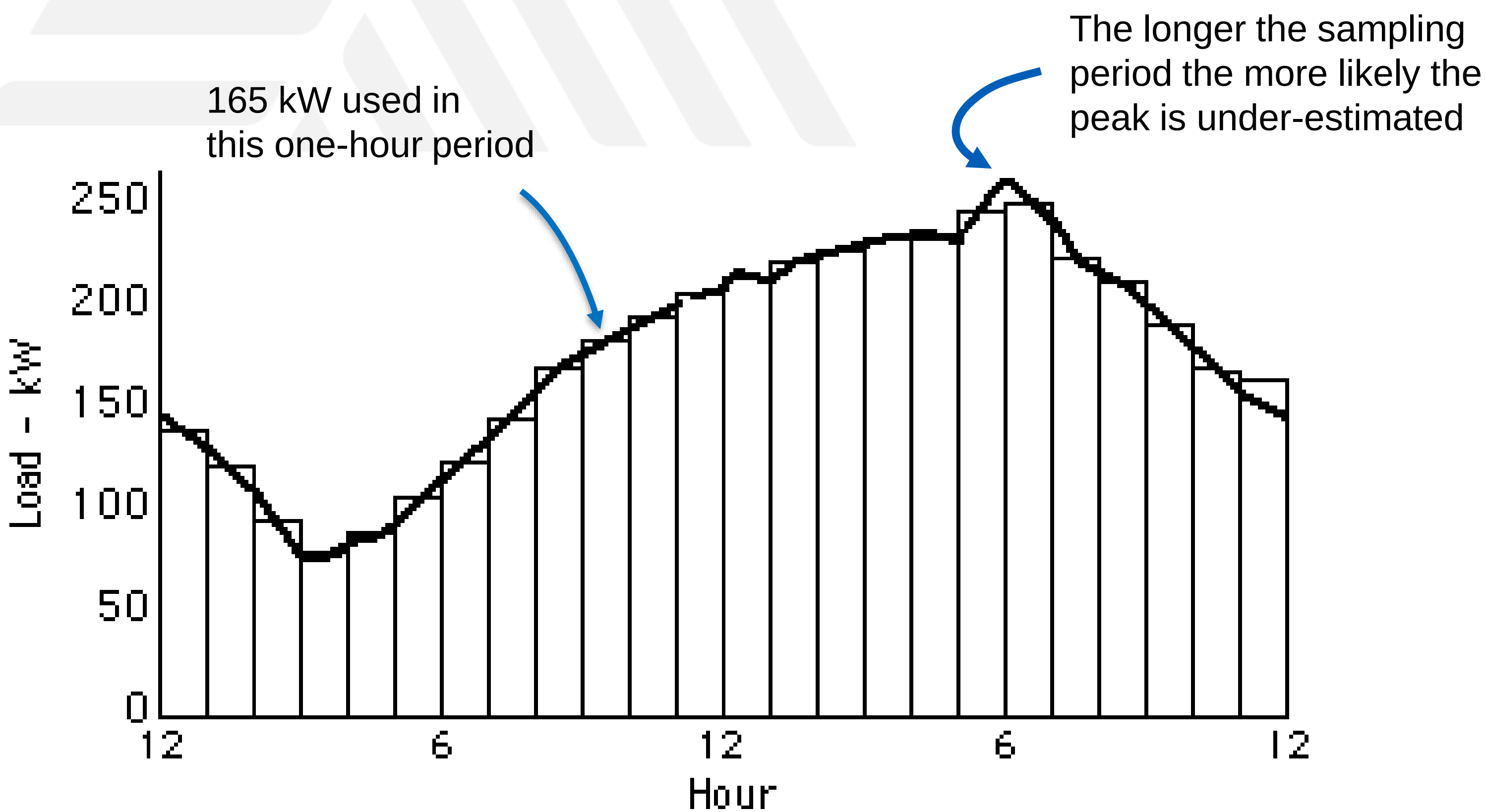
Perceived variability depends of level of aggregation and resolution

Loads Vary by Customer Class



- "Class" is any distinction that is useful for segmentation
  - Residential
  - Commercial
  - Industrial
  - Agricultural
  - Institutional
  - Resort
  - Storage

Demand is average value of load over a period



Most distribution utilities sample demand on a 15-60 minute basis

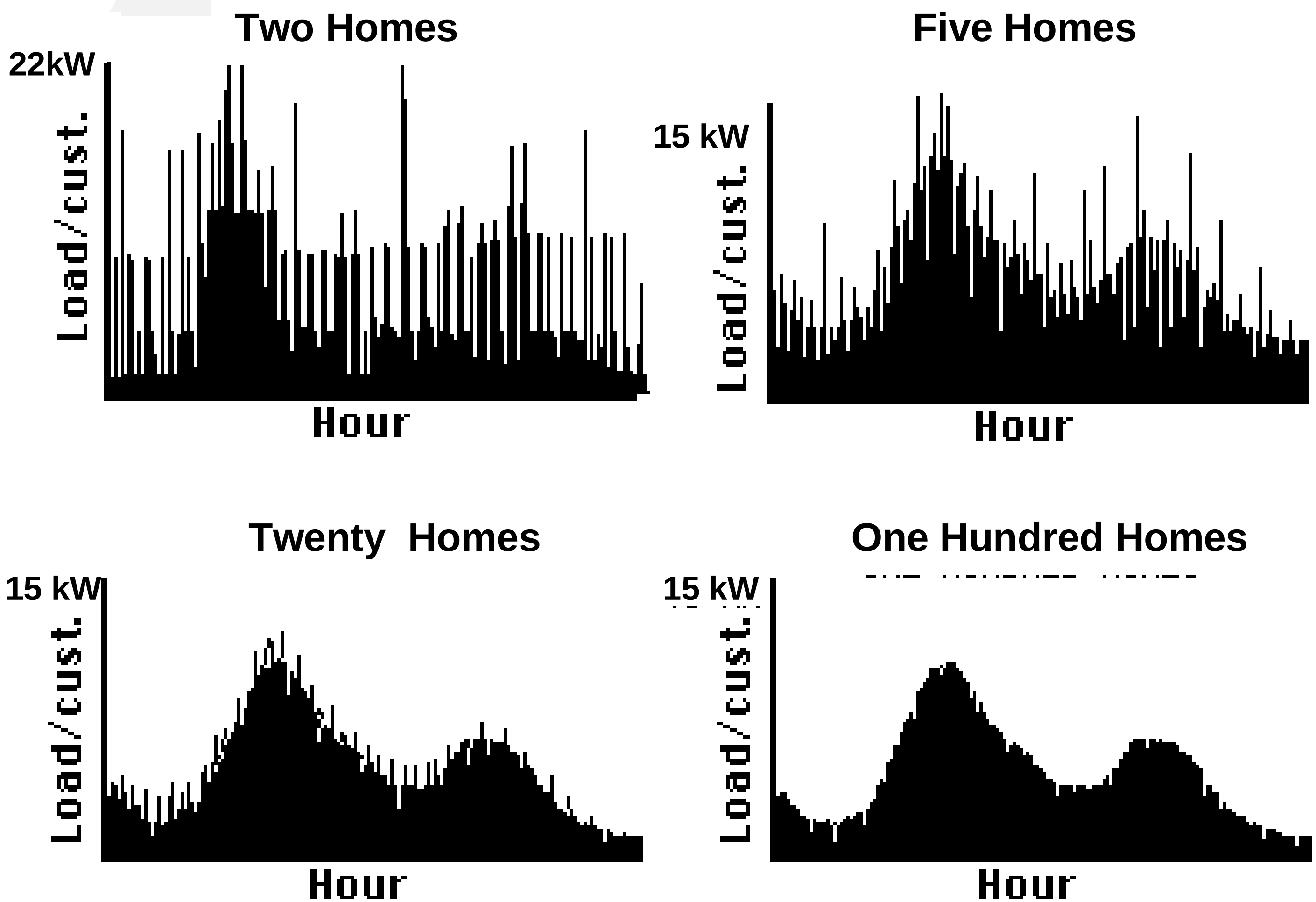
Individual Customer Load

LF = 0.2
CF = 1

- ► As number of customer loads in group increases:
  - Peak demand per customer drops
  - Load profile curve becomes smoother
  - Load factor (LF) increases
  - Coincidence factor (CF) decreases

H. L. Willis and G. B. Rackliffe, "*Introduction to Integrated Resource T&D Planning*"

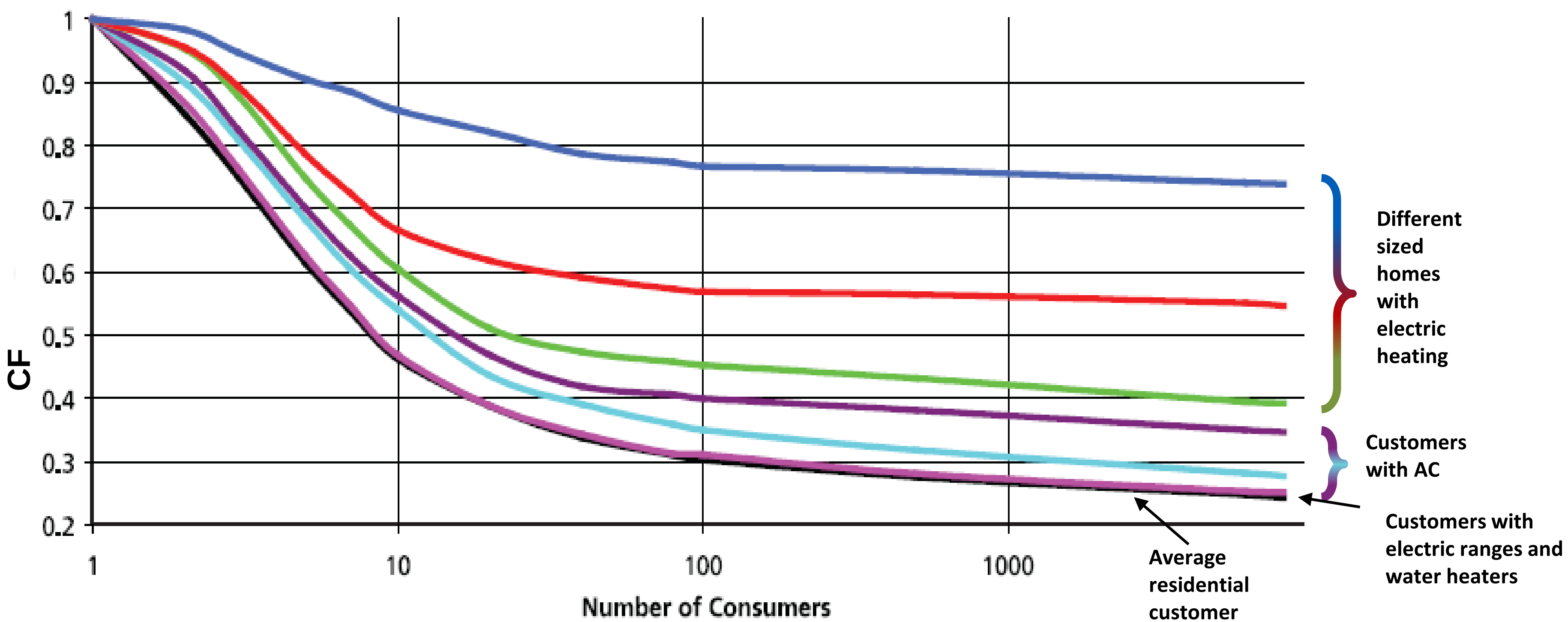
Groups of customer loads



H. L. Willis and G. B. Rackliffe, "*Introduction to Integrated Resource T&D Planning*"

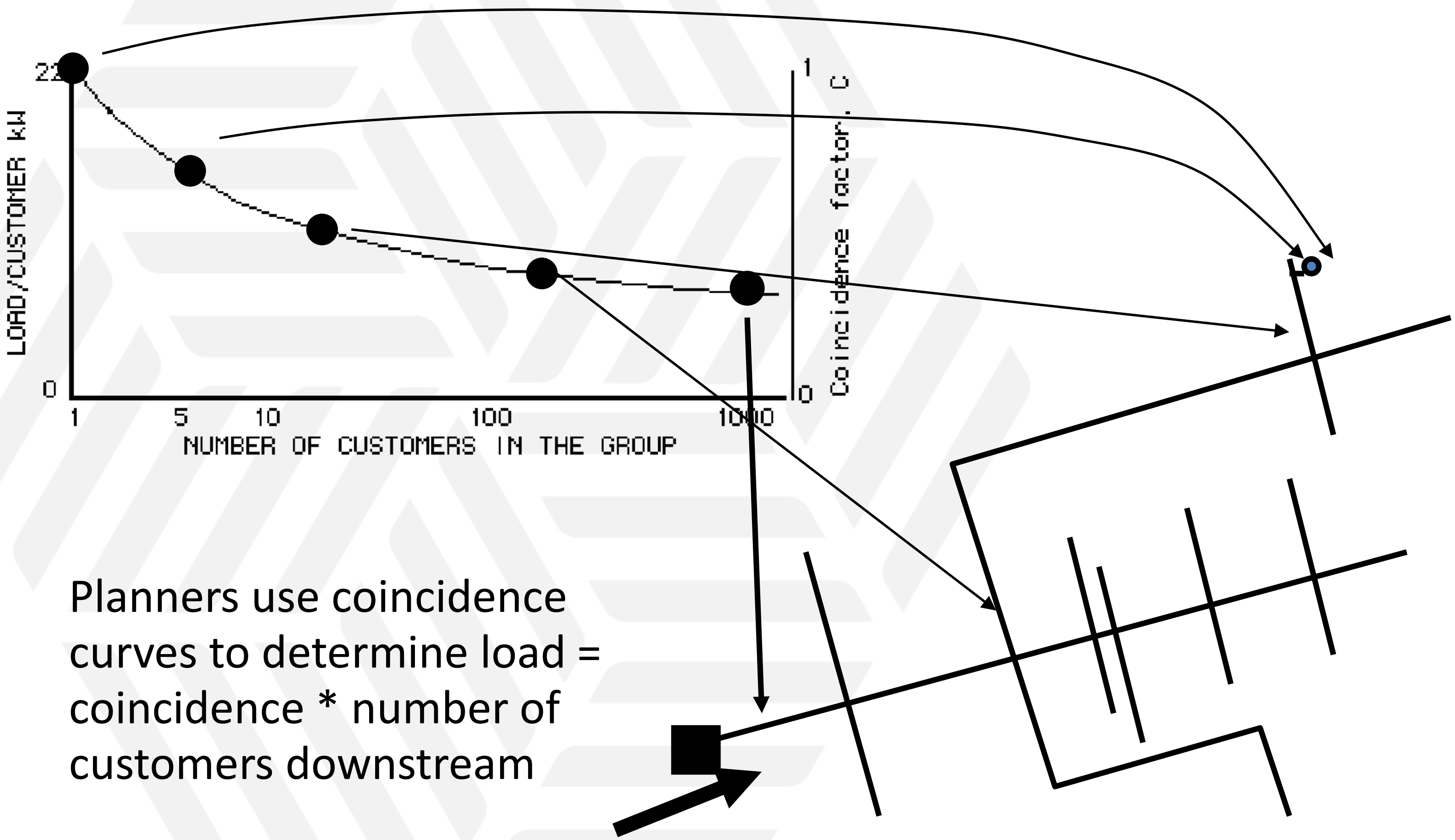
Coincidence curves

- Planners typically develop coincidence curves for various customer types based on load research data



Example of coincidence data from a utility in the Southeastern U.S.

Coincidence application to capacity planning



Planners use coincidence curves to determine load = coincidence * number of customers downstream

H. L. Willis and G. B. Rackliffe, "*Introduction to Integrated Resource T&D Planning*"

Planning for Reliability

► **Two main methods for reliability assessment**

- **Historical**: compute reliability indices using archived data on outages and interruptions
  - Can determine the current system performance
  - May (*carefully*) be used to project future performance
  - Cannot be used for multiple-scenario analysis

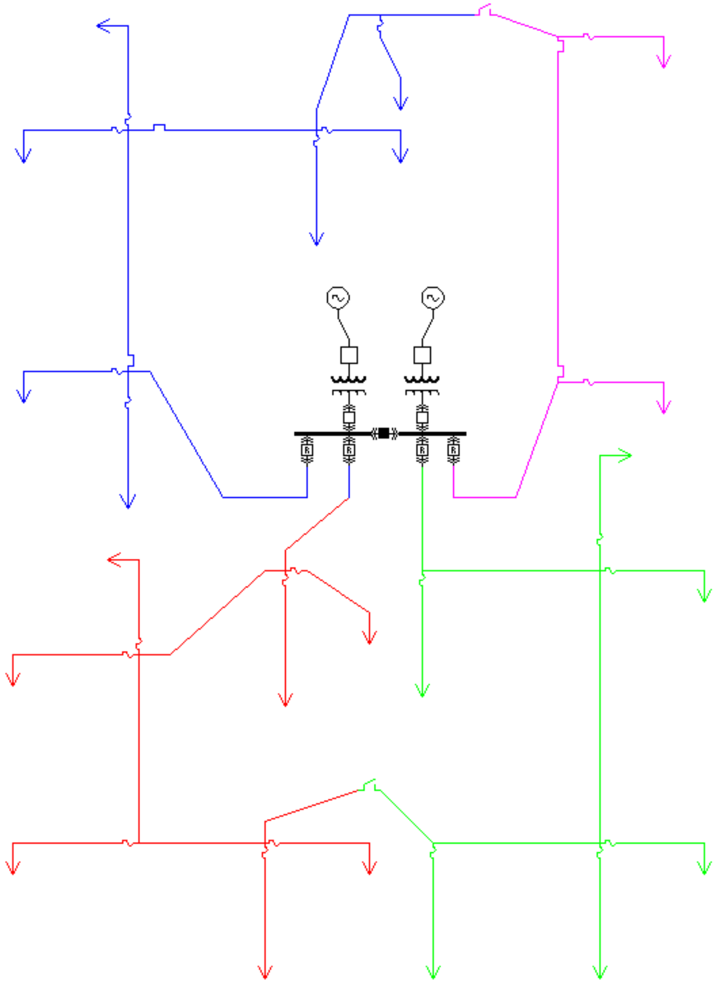
- **Predictive**: assess system reliability using a connectivity model with component reliability data
  - Usually calibrated using historical reliability indices
  - Historical interruption data may be used to represent component reliability
  - Excellent for "what-if" scenarios and project justification

Predictive Reliability Model

- Connectivity is a functionally accurate description of the topographical arrangement capturing diversity of supply, equipment redundancies, remedial actions and mitigating measures.

  Sources: system maps and one-line diagrams, GIS databases, drawing files

- Component data describes the failure, repair and remedial characteristics of individual system components
  - Failure rates, repair times, switching times
  - Sources: utility archives, databases, industry sources such as IEEE standards, papers, and publications



Excellent for developing and evaluating reliability improvement strategies

Example Plan:
Consumers Energy, Michigan

Electric Distribution Infrastructure Investment Plan (2018-22)

Michigan Public Service Commission Order for Case No. U-18014

Requires a **five-year distribution investment and maintenance plan** that contains:

1. **Current state of the electric distribution system:** a detailed description, with supporting data, on distribution system conditions, including age of equipment, useful life, ratings, loadings, and other characteristics
2. **System goals and related reliability metrics**: assessment of performance using industry standards and metrics such as SAIDI, SAIFI, CAIDI
3. **Local system load forecasts**: forecasts of load at the system, area and local levels
4. **Maintenance and upgrade plans**: project categories including drivers, timing, cost estimates, work scope, prioritization and sequencing with other upgrades, analysis of alternatives
5. **Cost / benefit analysis**: analysis considering both capital and O&M costs and benefits

Consumers filed their draft Plan on Aug 1, 2017; Final Plan was filed on April 13, 2018

Trends in Consumers Energy customer expectations

- **Reliability and resiliency**

  Customers increasingly focus on reliability and resiliency in assessment of utility service

- **Security**

  Customers, governments, and utility executives are increasingly focusing on security threats, especially cybersecurity

- **Distributed energy resources (DERs)**

  Customers will continue to pursue adoption

- **Renewable generation**

  C&I customers will continue to desire expanded renewable generation

- **Data proliferation**

  Customers have more access to big data and are making more new, real-time decisions

"meaningfully affect … assets and capabilities required to operate [the distribution system] successfully"

From *Consumers Energy's Electric Distribution Infrastructure Investment Plan (2018-22)*, 8/1/17, https://mi-psc.force.com/s/ Filing U-17990-0416

Distribution Investment and Grid Modernization Focus Over next Five years

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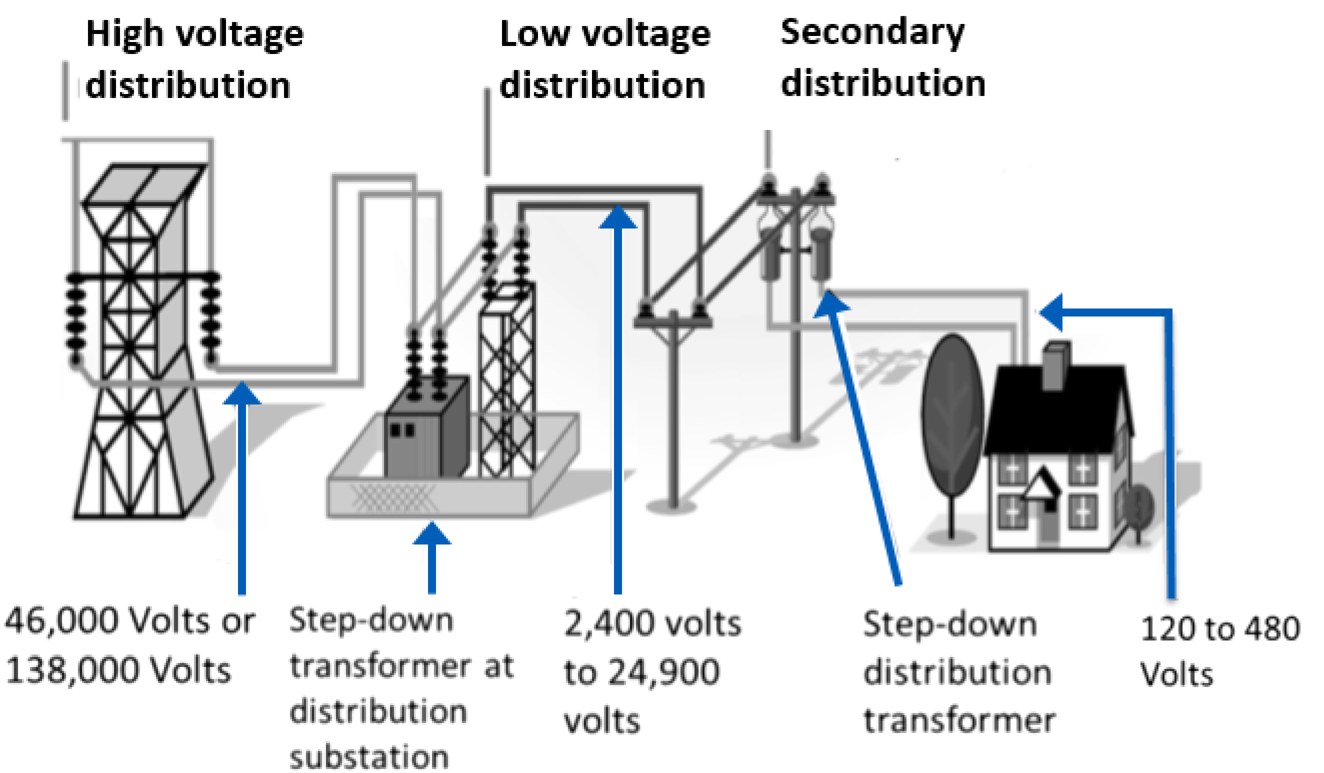
- **Reliability** – Automated re-routing of power flows around an outage and restoration following an outage through FLISR.

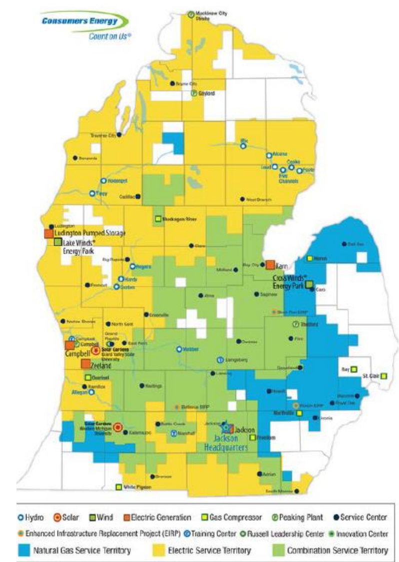
- **Sustainability** – Energy efficiency gains and peak reduction through VVO.

- **Controls** – Enabling increased utility- and customer-owned DERs such as DG and energy storage systems.

System Information

Serves 1.8 million customers in the north, central, and western MI

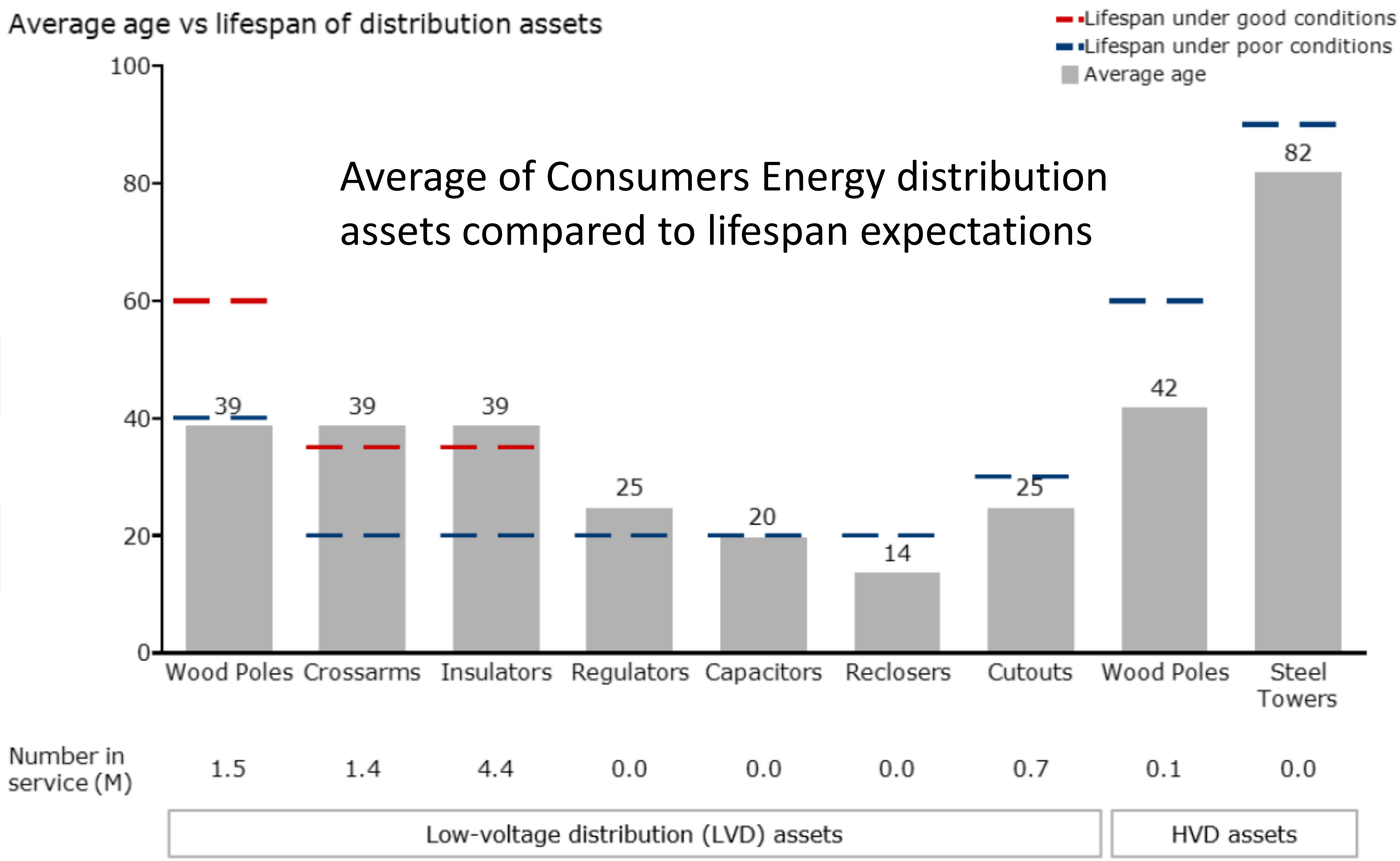




121 subs, 4,641 mi	**1,110 subs**	**56,607 mi (OH), 10,532 mi (UG), 1.5M poles**	**1.8M cust**

From *Consumers Energy's Electric Distribution Infrastructure Investment Plan (2018-22)*, 8/1/17, https://mi-psc.force.com/s/ Filing U-17990-0416

Average age of Consumers Energy distribution assets

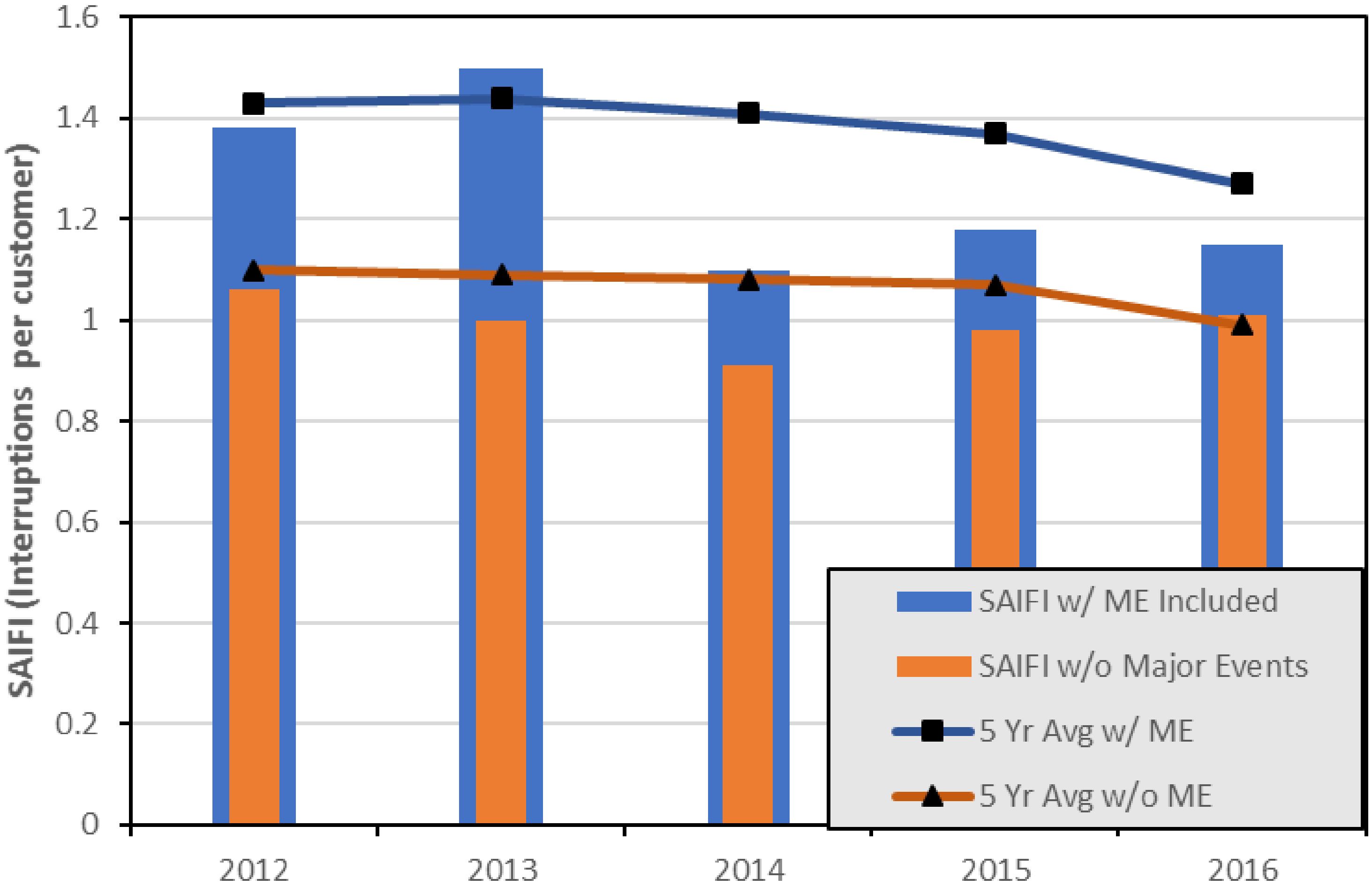


Average of Consumers Energy distribution assets compared to lifespan expectations

Compared to other major U.S. utilities, the age of CE infrastructure is in the third quartile

From *Consumers Energy's Electric Distribution Infrastructure Investment Plan (2018-22)*, 8/1/17, https://mi-psc.force.com/s/ Filing U-17990-0416

Trend in Consumers Energy SAIFI with and without Major Events



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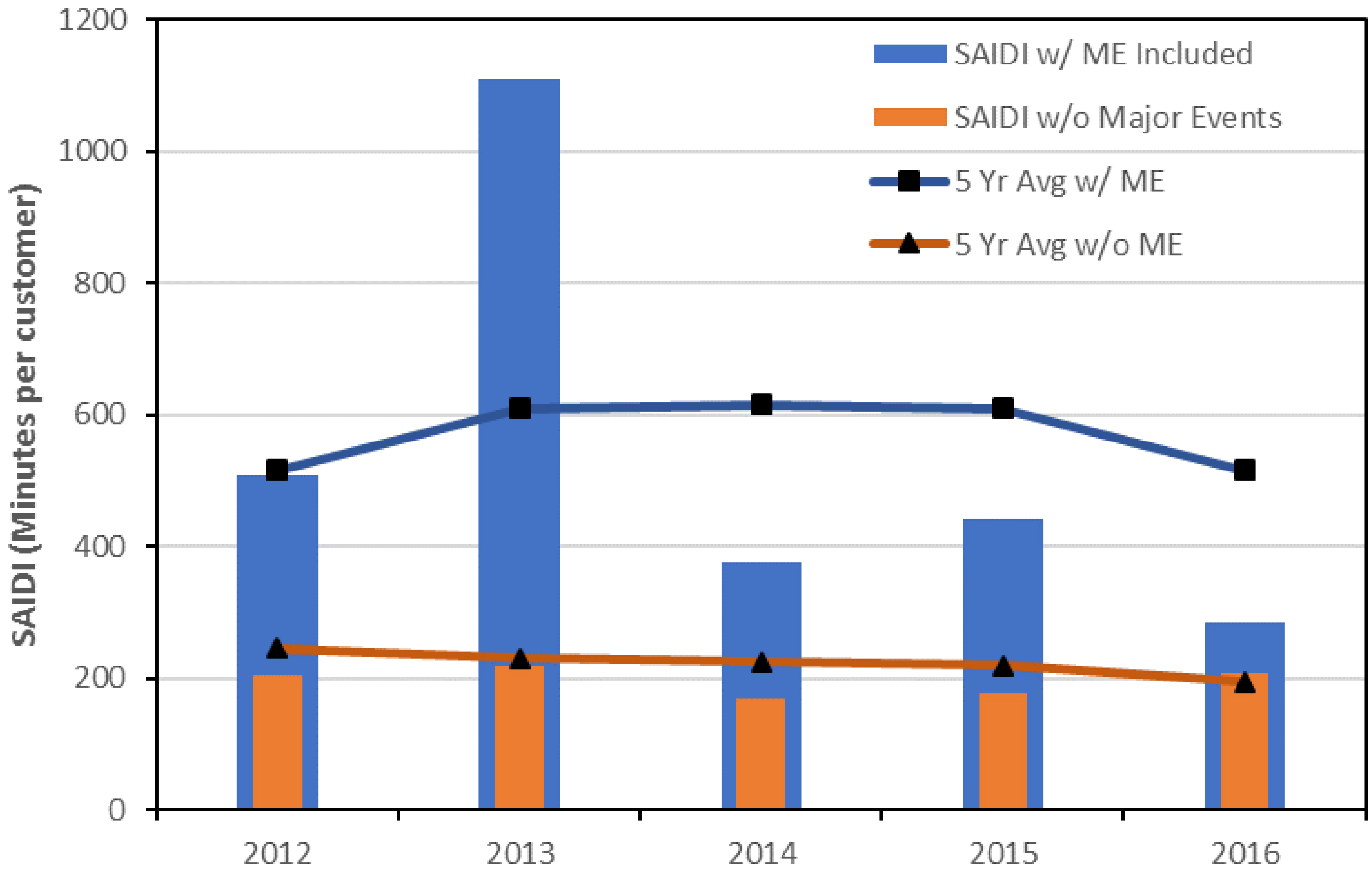
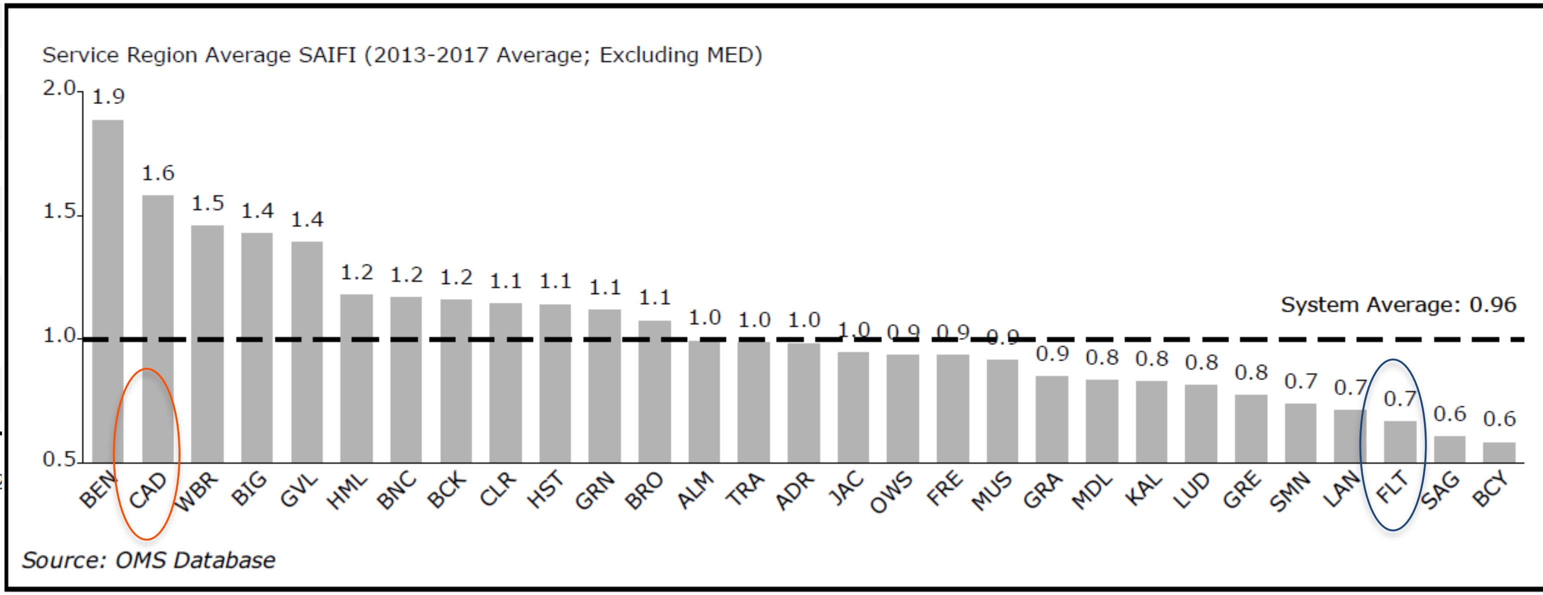
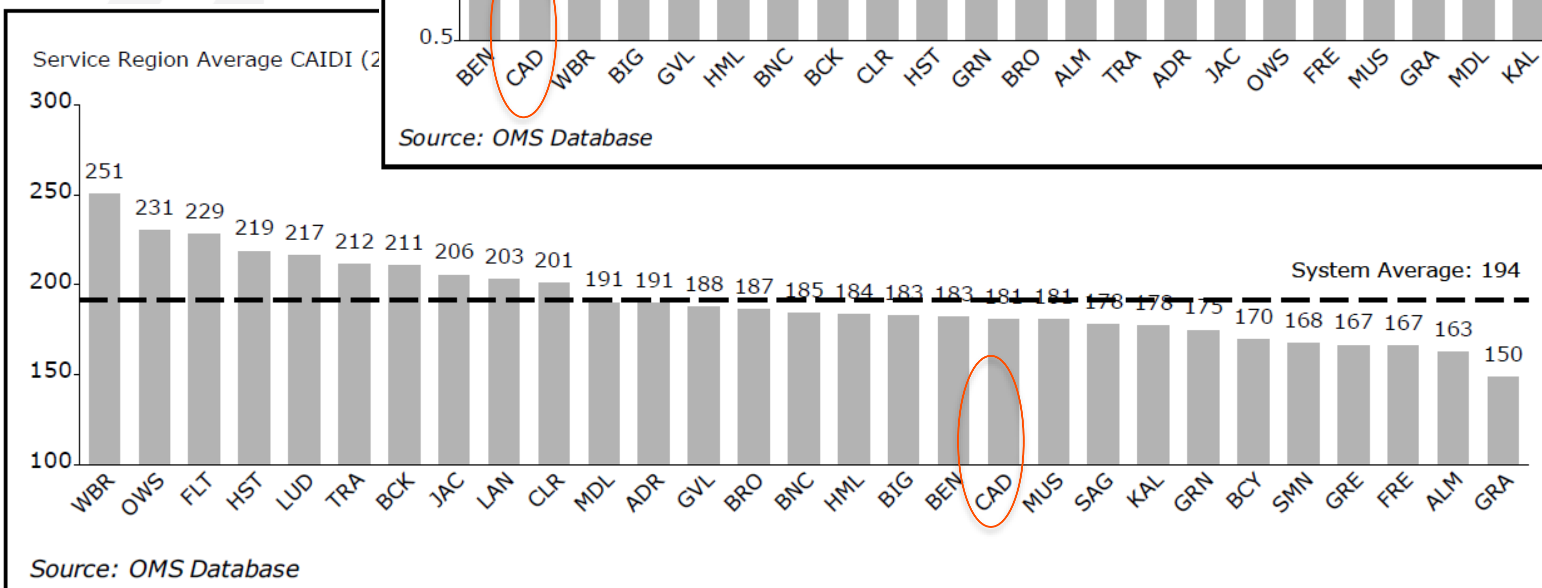
Trend in Consumers Energy SAIDI with and without Major Events



Based on data from *Consumers Energy's Electric Distribution Infrastructure Investment Plan (2018-22)*,8/1/17, https://mi-psc.force.com/s/ Filing U-17990-0416

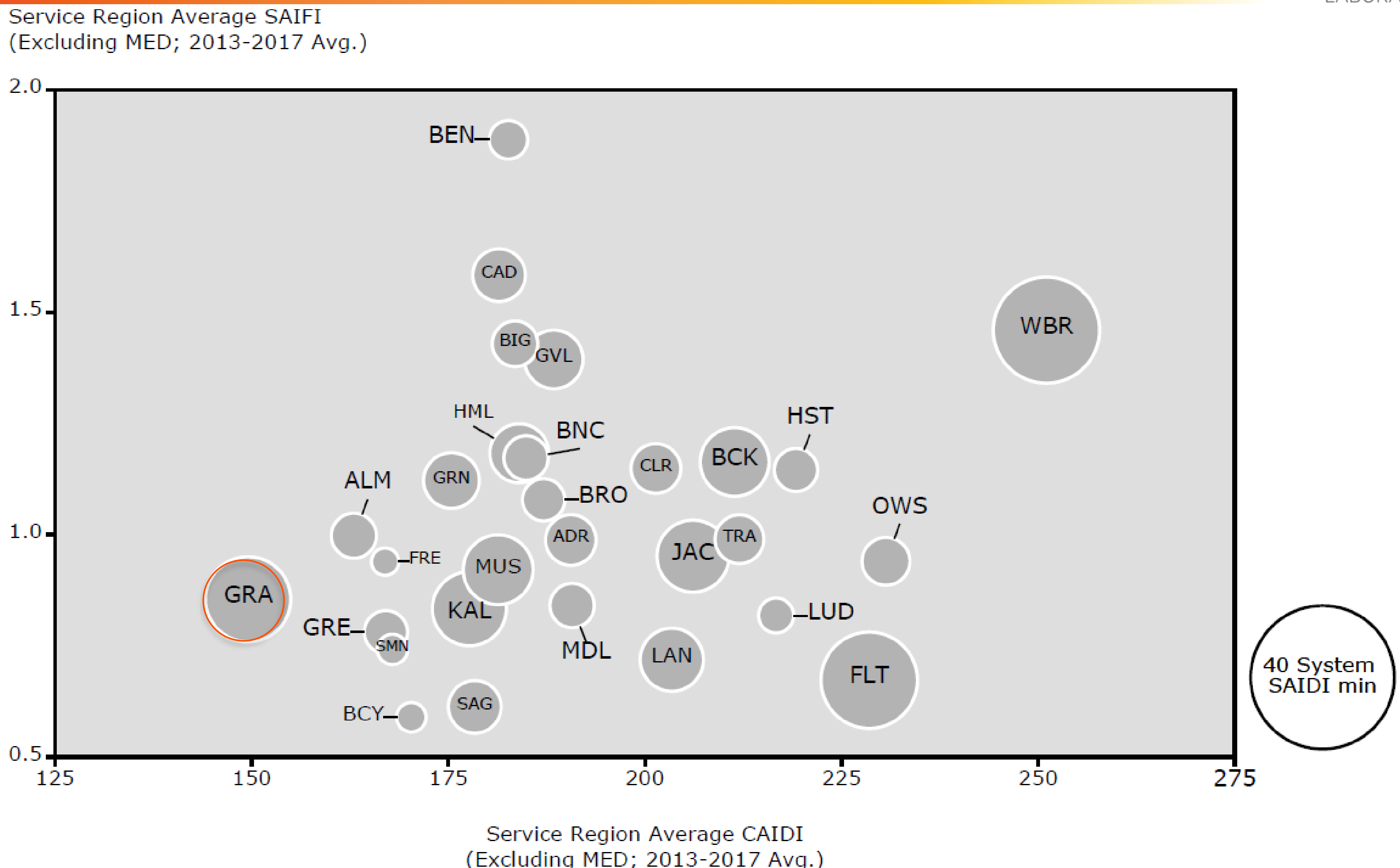
Reliability Statistics by Operating Region





Based on data from *Consumers Energy's Electric Distribution Infrastructure Investment Plan (2018-22)*,8/1/17, https://mi-psc.force.com/s/ Filing U-17990-0416

Impact of Regional Performance on System Metrics

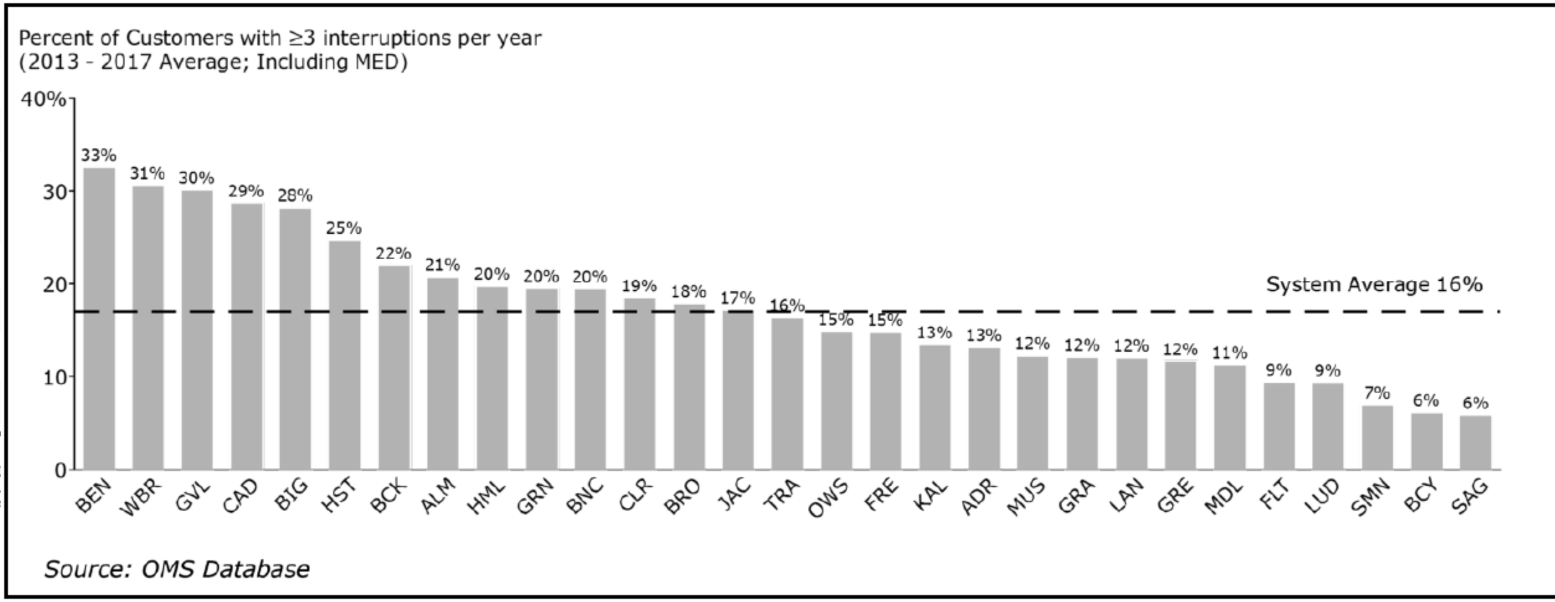


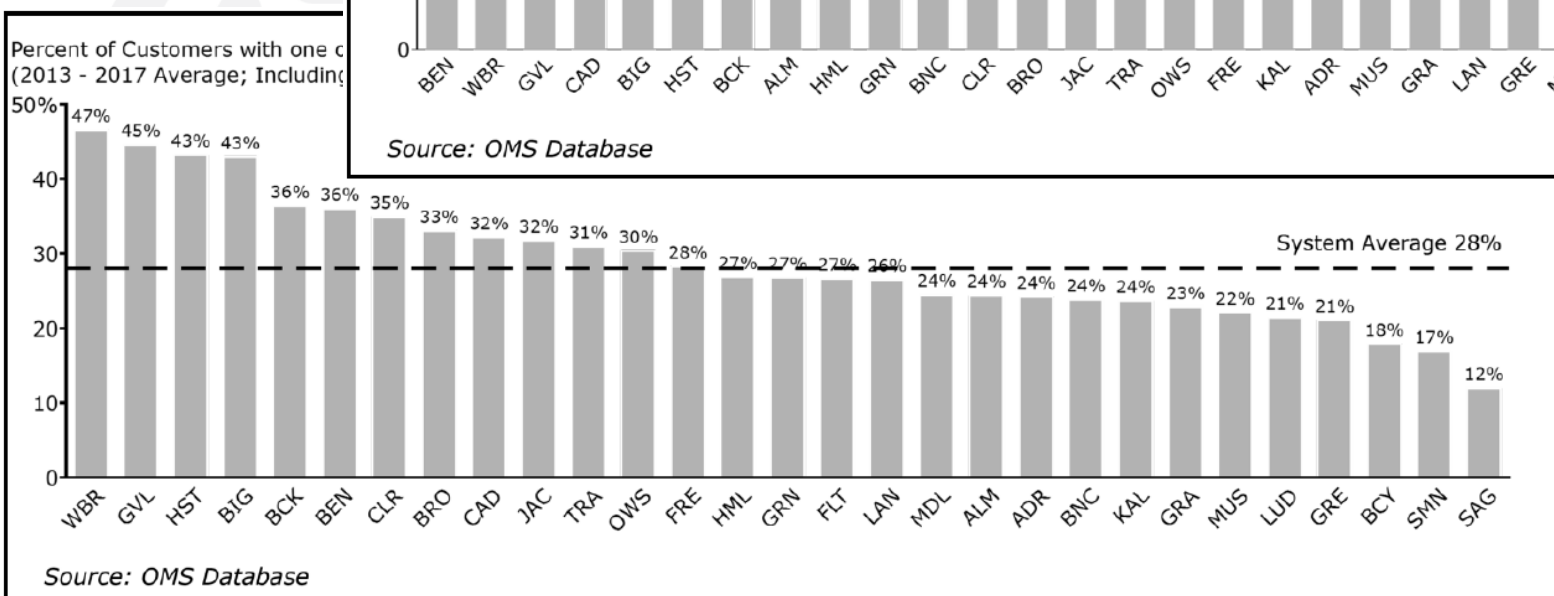
Source: OMS Database

Based on data from *Consumers Energy's Electric Distribution Infrastructure Investment Plan (2018-22)*,8/1/17, https://mi-psc.force.com/s/ Filing U-17990-0416

Additional Measures of Customer Experience

SERVICE REGION AVERAGE PERCENT OF CUSTOMERS WITH ≥3 INTERRUPTIONS PER YEAR

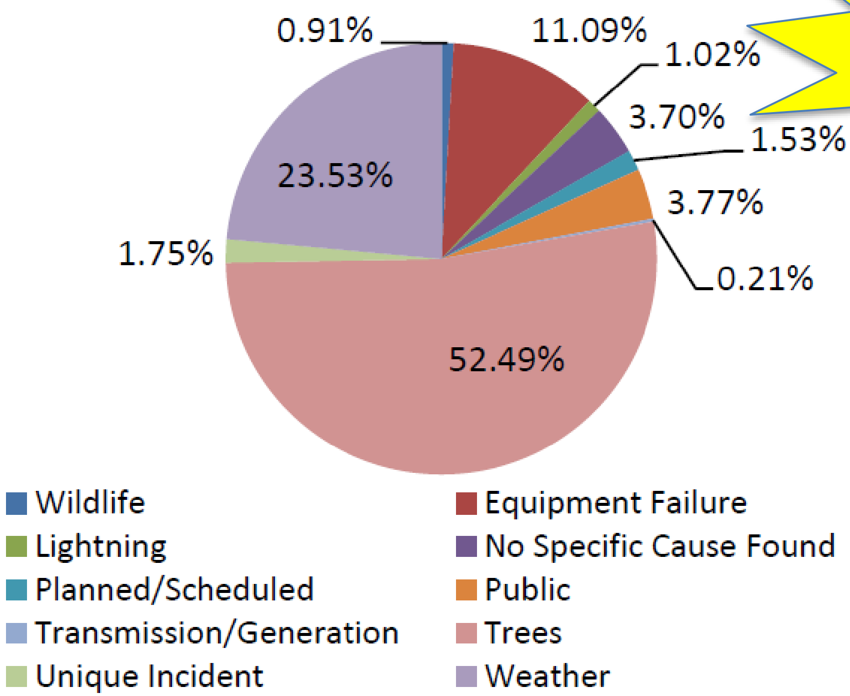




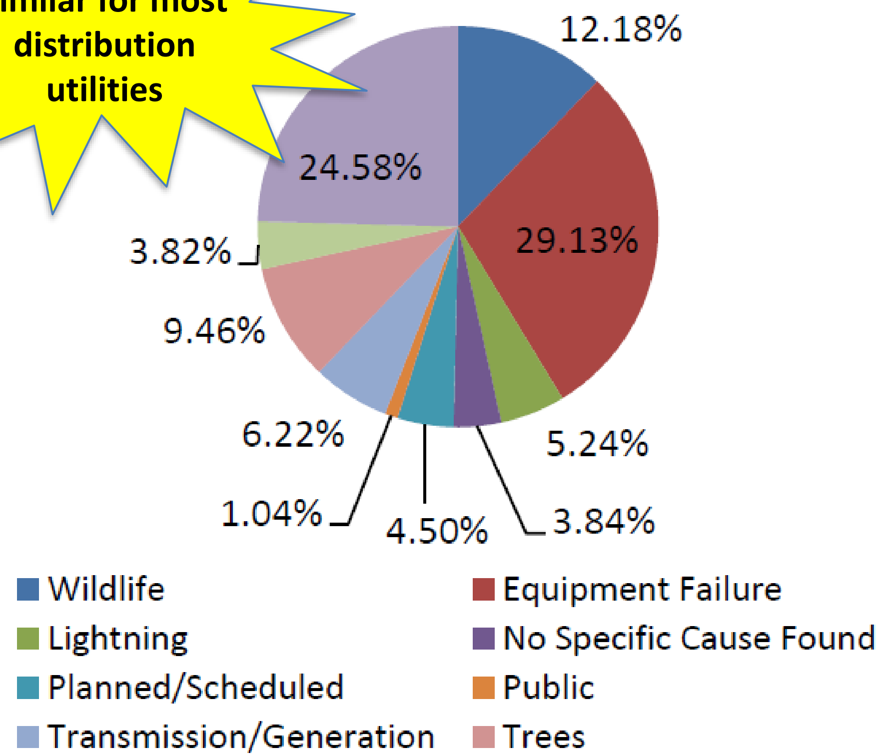
SERVICE REGION AVERAGE PERCENT OF CUSTOMERS WITH ONE OR MORE ≥5 HOUR INTERRUPTION

Based on data from *Consumers Energy's Electric Distribution Infrastructure Investment Plan (2018-22)*,8/1/17, https://mi-psc.force.com/s/ Filing U-17990-0416

Common causes of interruptions for Consumers Energy



Similar for most distribution utilities

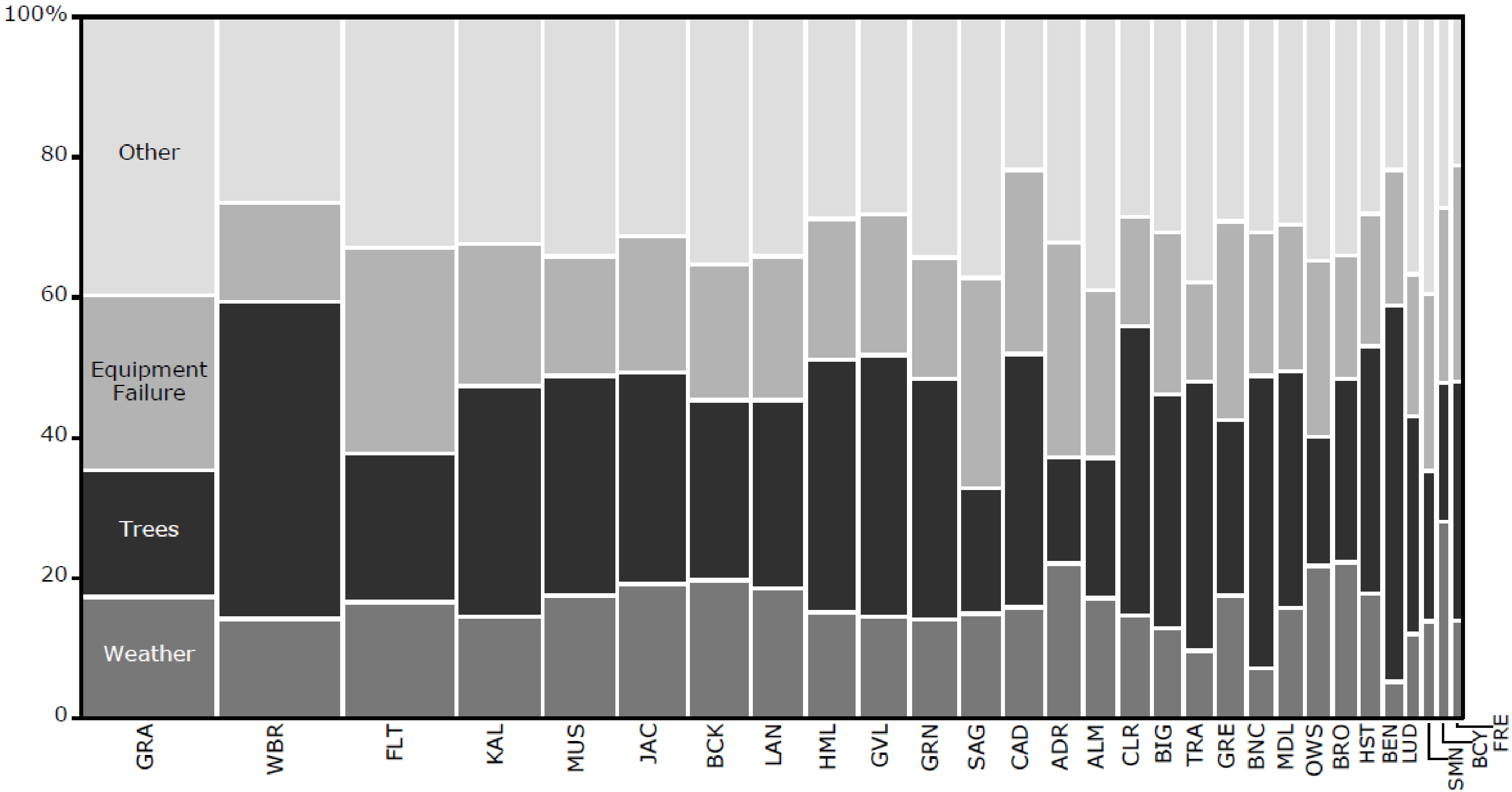


Low Voltage Distribution **High Voltage Distribution**

- Trees and weather account for 75% of LVD outages
- Equipment failures and weather account for over 50% on HVD

Root Causes of Outages by Region

SAIFI Contribution by Incident Cause
(2013-2017 Avg; MED Excluded)



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Consumers Energy Five-Year Electric Distribution Infrastructure Investment Plan (2018-22)

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Plan

Develop circuit-level system planning to better integrate DERs and renewables in order to maximize customer value and control, increase reliability, resiliency and security, and reduce CE's carbon footprint

Build

Tune investment options to meet **future capacity needs**

Wires	Non-wires alternatives
Build substations and lines to meet capacity needs	**Deploy non-wires alternatives** to meet and/or mitigate capacity needs

Maintain

Maintain, repair, and replace grid infrastructure using future technologies to lower costs

Preventative maintenance	Outage response
Ensure system reliability through predictive maintenance	**Respond to outages** while building predictive capabilities

Operate

Foster **next generation distribution operations** capabilities to meet future customer needs and desires

Bridges Phase 1 and phase 2 of Consumers' 15-year plan

First Role: Plan

Plan

Develop circuit-level system planning to better integrate DERs and renewables in order to maximize customer value and control; increase reliability, resiliency and security; and reduce CE's carbon footprint.

► Identify future infrastructure needs to ensure that the system
- Has adequate distribution capacity
- Can effectively integrate DERs where most beneficial
- Can effectively manage frequency and voltage regulation
- Is able to proactively adapt to ensure reliability, resiliency, and safety

► Process relies on load forecasts as primary input

Current Approach to System Planning

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► Identify future supply-side and demand-side resource needs based on load forecasts and the acquisition of various resources

Build HVD system peak load forecast

- Using historical data, economic forecasts and weather data
- 65% confidence interval

→

Allocate forecast to planning areas

- Allocated based on historical growth within each area
- Load flow model developed for HVD system

→

Build LVD system peak load forecast

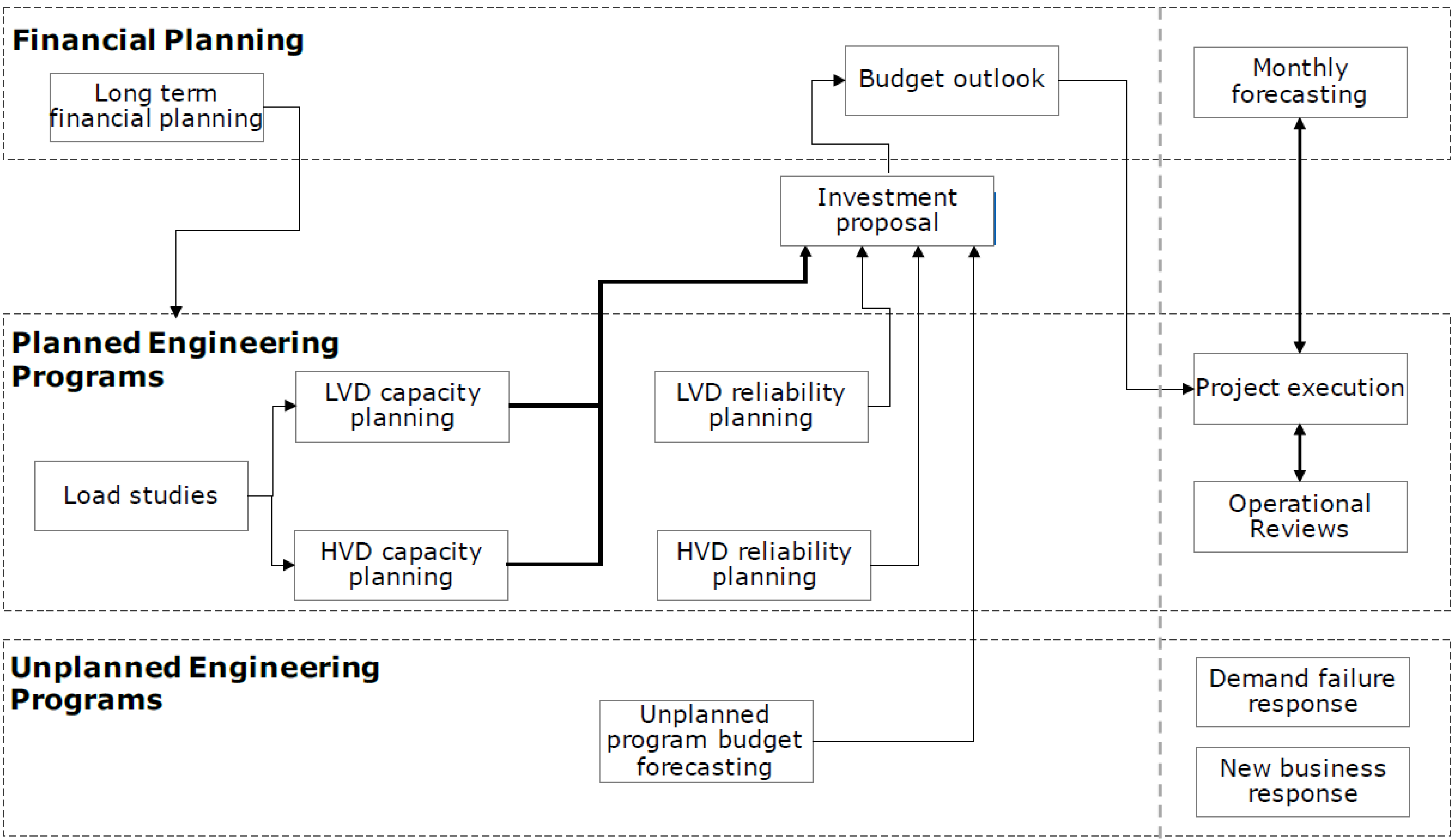
- Allocated based on local substation peak*
- Local load flow model developed in CYME

*Real-time data (SCADA or Distribution SCADA -- DSCADA) is used where available. Otherwise, historical data from manual readings is used

Key planning related expenses

- Future investments to improve planning capabilities:
  - **System Modeling Tools**: Tools that help perform near-real time distribution power flow studies to help streamline interconnection requests for DERs
  - **Data Lake**: Gather disparate data sources (asset, customer, outage, smart meter, DSCADA, etc.) into a single location to be used for advanced data processing and analytical techniques
  - **Grid Analytics "Sprints":** Develop analytical capabilities to perform feeder and circuit level analyses quickly
  - **External Planning Services:** Offer DER planning services for customers and project developers

Electric Distribution Planning Process



Five-year Capital Investment Plan

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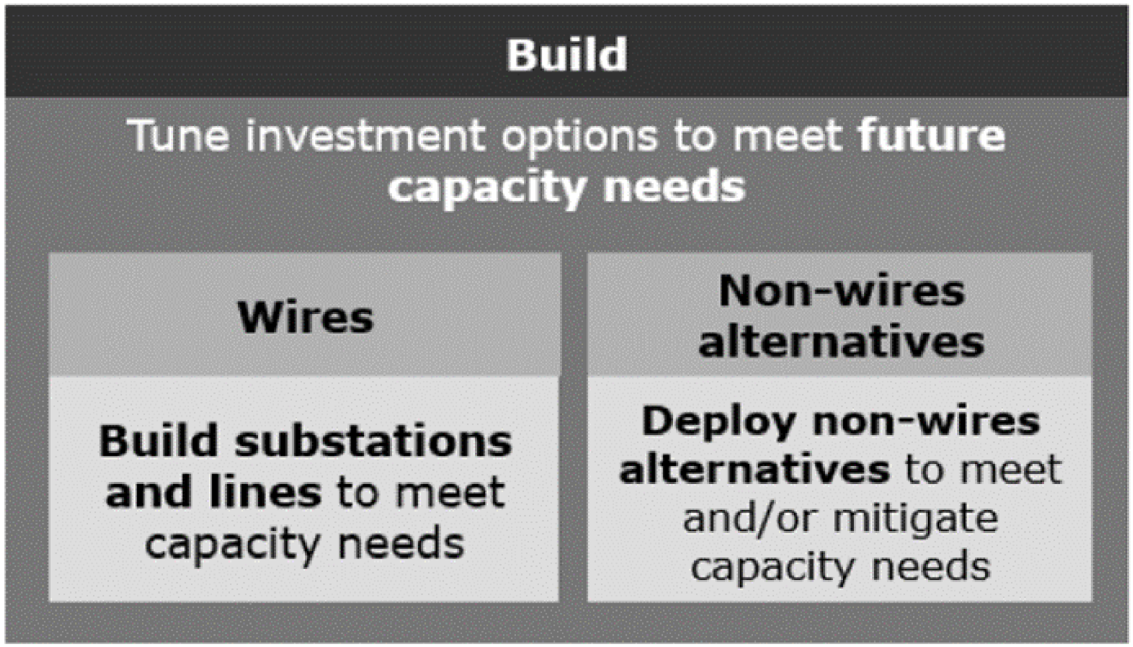
U.S. Department of Energy

5-Year Plan – Capital Programs										
		Actual			Plan					
All values in $ millions		2015	2016	2017 prelim	2018	2019	2020	2021	2022
1.0	New Business	73	88	97	95	98	103	105	108
2.0	Demand Failures	123	119	156	145	152	150	151	153
3.0	Asset Relocations	28	20	28	27	24	26	26	26
	Total Unplanned	223	226	281	267	274	280	281	287
4.0	Reliability	83	133	111	184	232	193	194	186
5.0	Capacity	44	57	53	51	57	58	59	63
6.0	Tools and Technology	3	4	3	10	11	11	11	11
	Total Planned	129	193	167	245	300	262	264	260
7.0	Cost of Removals	40	42	70	60	62	59	58	57
	Capital Plan	392	461	518	572	635	601	603	605
8.0	Demand Response	0	1	7	9	9	9	8	8

From *Consumers Energy's Electric Distribution Infrastructure Investment Plan (2018-22)*, 8/1/17

Second Role: **Build**



- ► Develop solutions to needs identified by system planning
- ► Incorporate both traditional assets and non-wires alternatives

Current Approach to System Building

► Determine Investment to ensure the entire system meets overall load and peak demand

Determine needs

- Conduct distribution studies
- Power flow analysis
- Reliability assessment
- Planning criteria violations

Identify Solutions

- Load transfer
- Capacity increase
- New LVD substation
- Alternate LVD substation connection
- Non-wires alternatives

Prioritize Projects

- Equipment loading compared to peak capability
- Performance on lines (SAIDI) and projected improvement

System Modeling and Analysis

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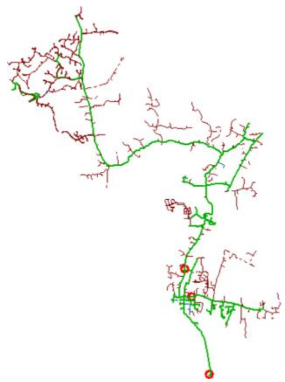
GIS

Device monitoring & control

Customer information system

Equipment database

Planning model



- Network topology
- Equipment
- Phase

- Equipment status
- Control settings
- Load information
- Conductor type
- Device capacity

- Single-phase unbalanced load flow model
- Reliability model

- ESRI ArcGIS
- Intergraph
- GE Small World
- Milsoft WindMilMap
- Schneider EcoStruxur

- CYMDIST, CYME
- SynerGEE, Advantica-Stoner
- WindMil, Milsoft
- PoweFactory, DIgSILENT
- DEW, EDD
- NEPLAN, Neplan AG

Traditional Substation Expansion

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Substation expansion	
Location	Deerfield
Major cause	Customer expansion
Local load	The existing transformer in the substation was loaded to approximately 86% of capability in 2016. The customer's load addition of 1.8MW in late 2017 will place the transformer at 131% of capability in 2018.
Primary options considered	Expand the existing substation Build a new substation Energy efficiency / demand response
Rationale	The existing substation is a small substation that is group regulated. These substations were not built to the current minimum approach distance standards. Working in them without forcing an outage to customers is difficult. The substation expansion project will address the capacity the concerns and ultimately improves reliability to the area. The addition of a new substation was not necessary due to the relatively small nature of the load addition (about 1.5MW of peak load increase), but neither energy efficiency nor demand response were considered viable in this location to achieve sufficient peak load reduction.

From *Consumers Energy's Electric Distribution Infrastructure Investment Plan (2018-22)*, 8/1/17

Non-Wires Alternatives (NWA)

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Two Focus Programs

Demand Response	Energy Efficiency
Since 2010, we have partnered with more than 1,700 Michigan residences and businesses to reduce peak electric demand by approximately 52 MW (majority through our C&I program)	Since 2009, our portfolio of Energy Efficiency programs have saved customers more than $1B in reduced energy bills while reducing peak electric demand by approximately 400 MW

- ► Ongoing NWA project at the Swartz Creek substation to defer a capacity project
- ► Demand Response
  - AC cycling pilot with 1,754 customers, 2 MW in 2016
  - Two time of use (TOU) pilots with 37 employees, enrolling 0.0233 MWs in 2016
  - $20M investment to increase C&I demand response portfolio from 50 MW to 150 MW
- ► Future BESS Pilots
  - WMU Solar Farm (Kalamazoo) - 1MW/1MWhr
  - Circuit West BESS (Grand Rapids) - 0.25 to 0.75 MW
- ► NWA are now an integral part of the supply planning process and part of the Company’s supply plan.

Swartz Creek NWA Pilot

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Non-wires alternative (Pilot)	
Location	Swartz Creek
Major cause	General load growth
Local load	The substation transformer at Swartz Creek has experienced peak loadings of 92%, 94%, 80%, 79%, and 85% from 2012 through 2016. The load appears to be highly dependent upon the weather as no system changes (large transfers or large, new customers) have been observed.
Primary alternative considered	N/A
Rationale	A traditional substation capacity increase would be implemented after an observed overload. Swartz Creek substation was chosen for the NWA (pilot) due to historical loads that have been observed close to capacity, but never over. Piloting an NWA at this location was an opportunity to test an NWA solution's feasibility without risking the equipment or customer reliability due to an observed overload the prior year. The company's NWA pilot at Swartz Creek substation will rely heavily on the existing Energy Efficiency and Demand Response programs in place. The pilot will also make use of the Time of Use and dynamic peak pricing rates that are offered. These programs and rates will be marketed in the community to show off the rebates and long-term cost savings that can be realized. The marketing plan utilized will reach both residential and business customers. The NWA pilot is being run in coordination with the Natural Resources Defense Council (NRDC).

Third Role: Maintain

Maintain

Maintain, repair, and replace grid infrastructure using future technologies to lower costs

Preventative maintenance	Outage response
Ensure system reliability through predictive maintenance	**Respond to outages** while building predictive capabilities

Consistently maintain distribution assets as they age

Current Approach

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▶ Ensure all equipment is operating safely, effectively, and efficiently

Repairing Assets

- Multiple programs covering poles, lines, pole-top equipment, and substation equipment
- Tree trimming and line clearing program
- Programs to reduce customers' average outage duration (SAIDI).

Replacing Assets

- Investments to upgrade deteriorated equipment, to reduce system outages
- Investments for adverse weather
- Investments to build for the future need and demands of our customers.

Outage Restoration

- Restoration management program
- Storm restoration relies on
  - outage management system
  - resource management system
- Continuous feedback loop to improve restoration program

Project Prioritization

- Evaluate reliability projects based on estimated avoidance of outage minutes for the customers impacted by the project
- Projects are prioritized using
  - Cost-benefit ratio analysis
  - Input by engineers and program managers based on experience and knowledge of the system
  - Availability and location of resources
  - Funding
- Reliability Analytics Engine ("RAE") used to analyze outage data outage data
  - Produces ranked list based on line performance and opportunity for improvement

Repair/Replacement Programs

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- Pole inspection and replacement
- Line inspection and replacement
- Tree trimming
- System protection
- Substation inspection
- Substation maintenance and reliability
- Demand failures
- Storm restoration

Five-Year O&M Plan

5-Year Plan – O&M Programs									
		Actual			Plan				
	All values in $ millions	2015	2016	2017 prelim	2018	2019	2020	2021	2022
1.0	Net O&M Assoc. with Construction	-2	1	-3	0	0	0	0	0
2.0	Reliability	40	54	53	55	56	59	63	67
3.0	Ops, Metering, Service Restoration	89	76	83	69	77	77	78	79
4.0	Field Operations	23	19	22	20	20	20	21	22
5.0	Grid Management & SEOC	3	3	5	6	6	6	7	7
6.0	Planning & Scheduling	3	4	6	6	6	6	6	6
7.0	Operations Performance	0	1	2	2	2	2	2	2
8.0	Operations Management	7	8	6	7	7	7	7	7
9.0	Engineering & Ops Support	2	2	3	4	4	5	4	4
10.0	Engineering & System Planning	12	10	9	9	10	11	11	11
11.0	Joint Pole Rental	2	2	2	2	2	2	2	2
	O&M Plan	**180**	**180**	**189**	**179**	**190**	**196**	**201**	**207**
12.0	Energy Efficiency & Demand Response	78	79	121	128	127	130	134	135

From *Consumers Energy's Electric Distribution Infrastructure Investment Plan (2018-22)*, 8/1/17

Fourth Role: Operate

Operate
Foster **next generation distribution operations** capabilities to meet future customer needs and desires

► Actively manage the distribution system at all times to
- Minimize cost
- Ensure safety
- Improve reliability and resiliency
- Allow customers more control over their energy supply and consumption

Current and Future System Operations

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Current System Operations

- Power flow analysis tools
- Customer call triangulation
- SCADA
- Four hours of analysis to run CYME report and interpret the results
- Limited capability to perform switching
- Limited interactions with DER

Future system operations

- Operations increasingly complex
- Digital capabilities enable real-time system view
- integrated ADMS allows enhanced operations, better tools to assess, monitor, analyze and control
- Sensors and AMI increase situational awareness and system control

"Increase situational awareness and automate manual processes, shifting operations from being reactive to proactive"

Key operations investments

- **Grid Communication**: Reliable, high-speed, high-capacity, wired and wireless communications platform based on internet protocol to connect all substations and distribution grid devices
- **Substation and Line Automation**: DSCADA, distribution automation, device controllers, and line sensors to optimize power flow and performance and avoid outages
- **Unified System Control Center**: Consolidating System Control Center (SCC) personnel and developing a Distribution Control Center (DCC). consolidating operations support functions such as Operating Technologies, Data Center, Security, Real-Time Engineering, Applications Support
- **Advanced Distribution Management System**: Consolidated grid management applications including Volt-VAR optimization; conservation voltage reduction; and fault location, isolation, and service restoration
- **Communications Device Management System**: Operational platform to enable system-wide communications by collecting information from multiple grid device technologies
- **Data Management**: Accurate system model and processes to maintain the integrity of model data provides the foundation for ADMS and other distribution applications

Key Take-Aways

- Almost $5 billion invested in electric distribution over past decade by Consumers Energy
- Investments in physical grid infrastructure (poles, wires, relays, transformers, etc.) provide the necessary foundation for upgrading grid capabilities
- Grid modernization goals cannot be met if if new technology is deployed on existing aging infrastructure
- Must coordinate advanced capabilities with physical grid infrastructure upgrades
- This will allow advanced communications and intelligent applications to manage the grid as a fully integrated bi-directional system

Any Questions?

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