Grid Modernization and Smart Distribution Systems

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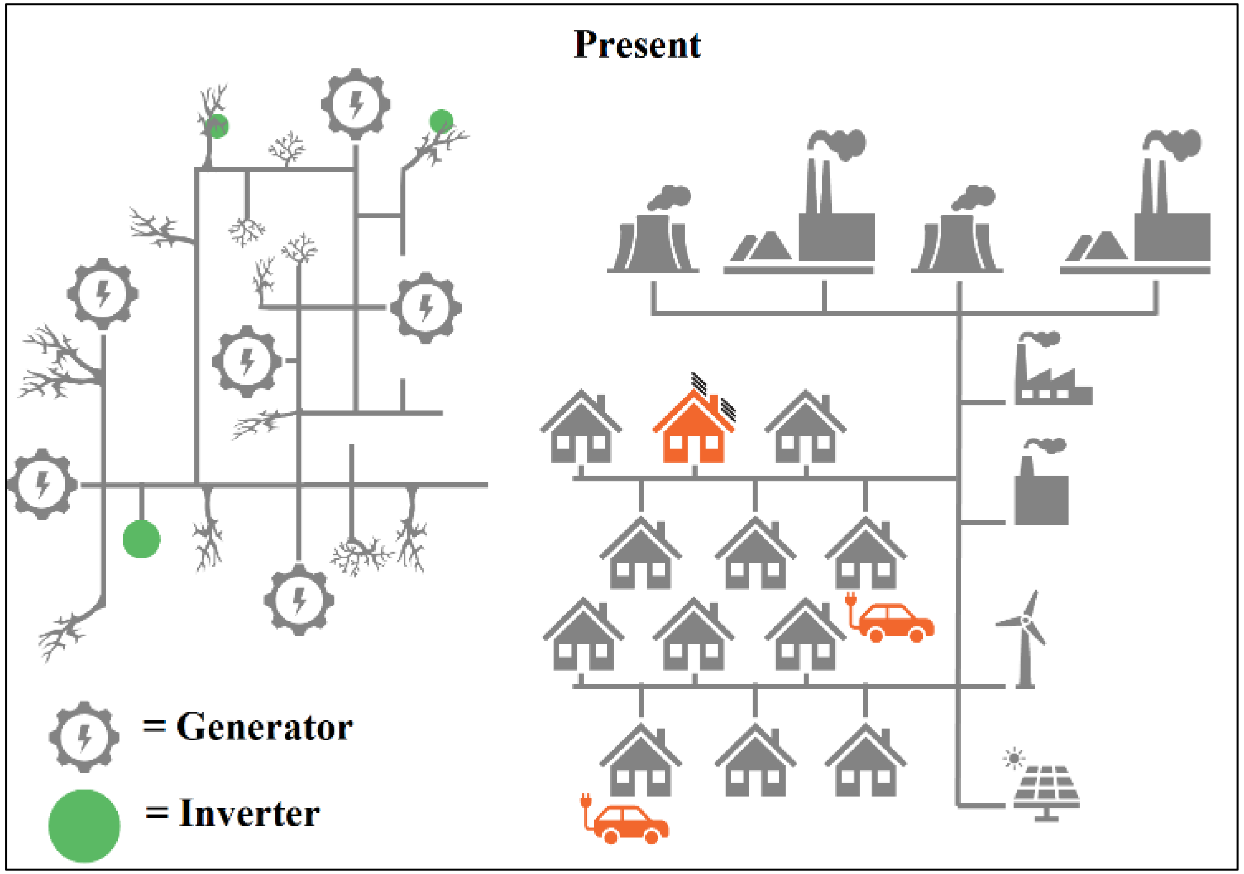
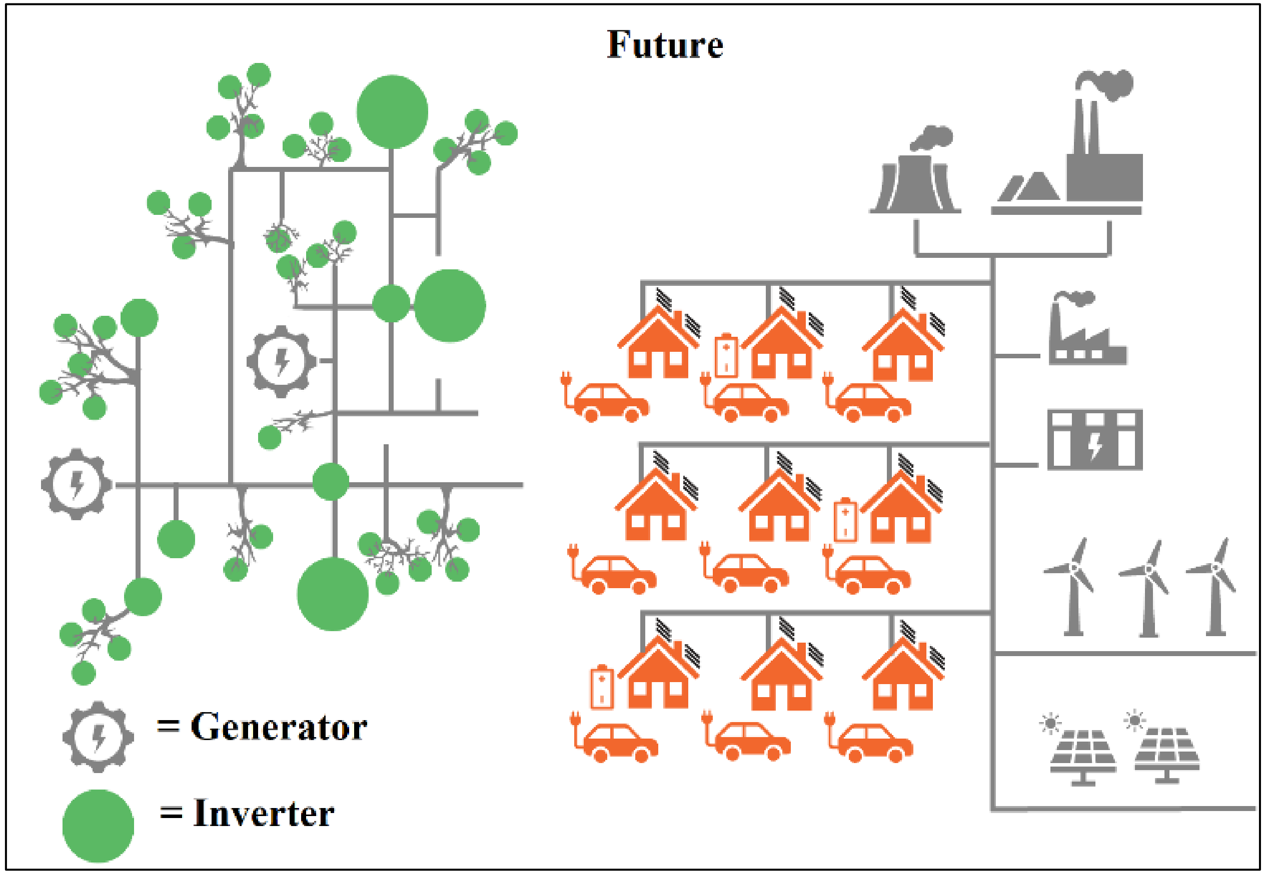
Singapore, Nov. 4, 2022

Grid Modernization Drivers

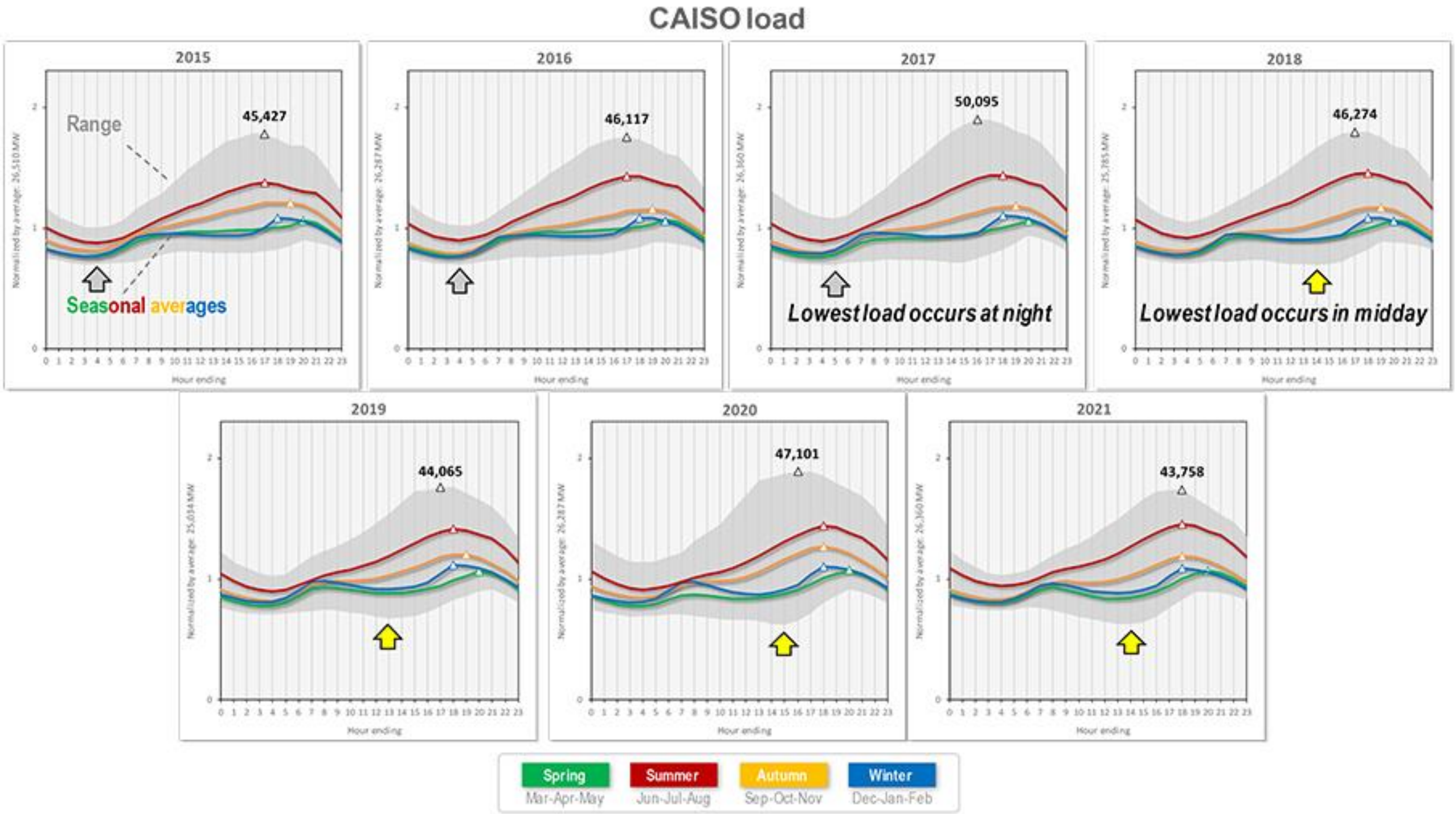
- Evolving expectations of customers regarding reliability and resiliency
- Real-time interactions with consumers
- Increasing dependency of our digital economy on electric power
- Stress imposed to the existing grid by the adoption of new technologies, such as distributed energy resources and transportation electrification
  - Electric power industry in several countries is moving toward carbon-neutral system operation over the next 10-20 years
- Evolving changes to weather patterns (e.g., more frequent and more severe storms and catastrophic events, such as major hurricanes)
- We must address the gap between existing infrastructure and future needs
  - Upgrades will require significant effort, investment, and time
  - Need to prioritize investments and develop roadmap

Distribution System Evolution



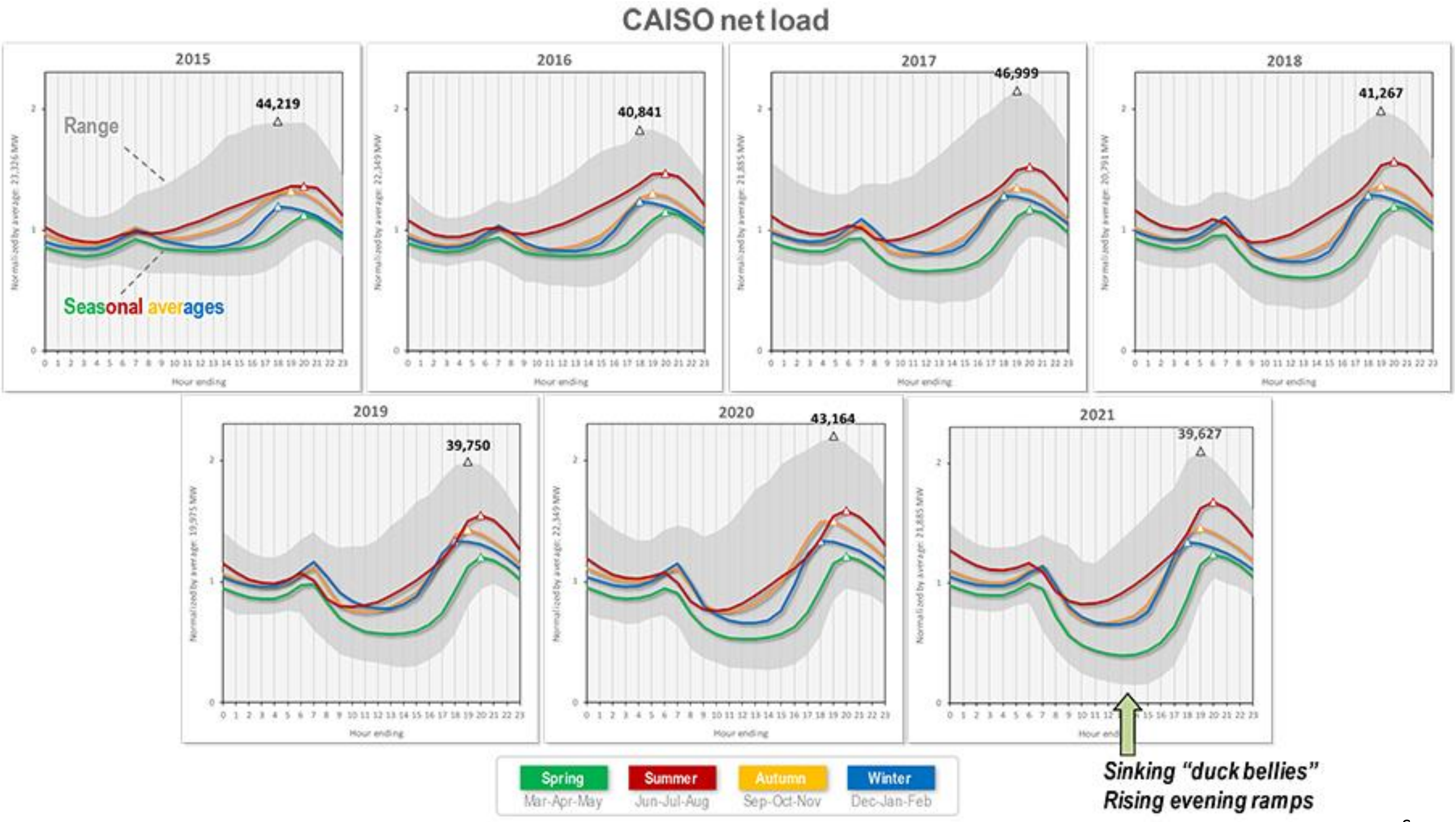


Renewable Generation Adoption



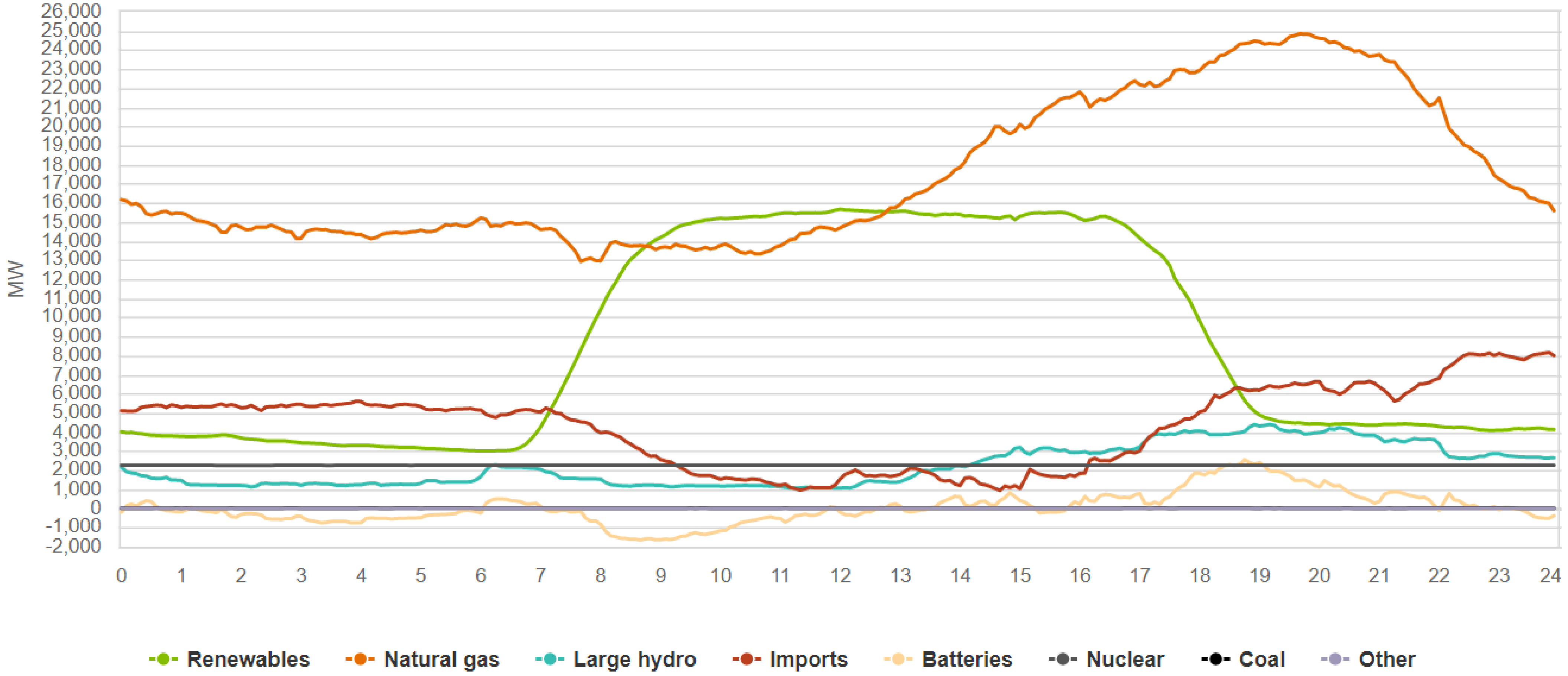
Source: California ISO

Renewable Generation Adoption



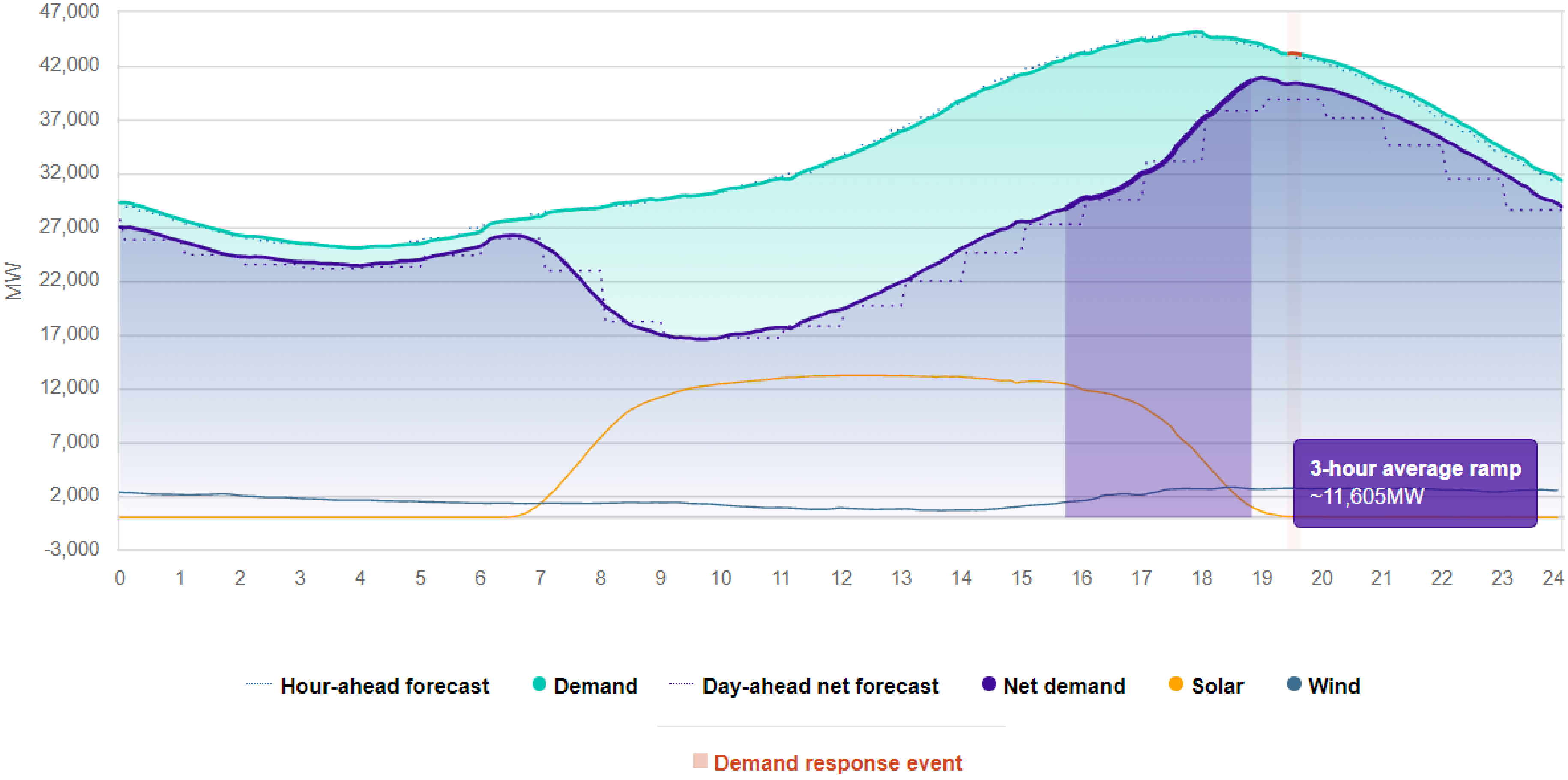
Source: California ISO

Example: CAISO Supply Curves (8/31/2022)



Source: California ISO

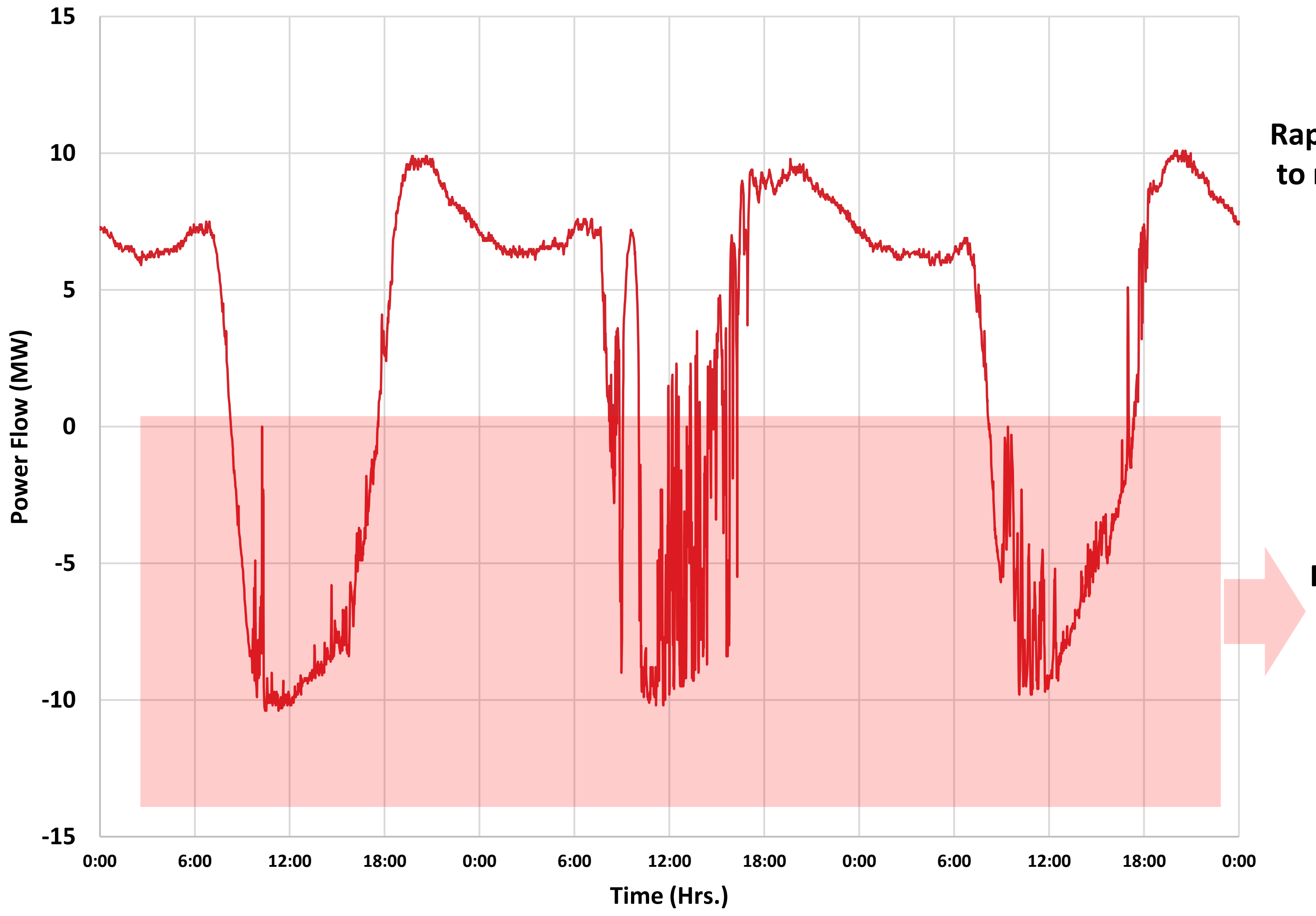
Example: CAISO Demand Curves (8/31/2022)



Source: California ISO

Example: Utility-Scale DER Adoption

Reverse power flow and power flow fluctuations on real distribution substation in Virginia, USA

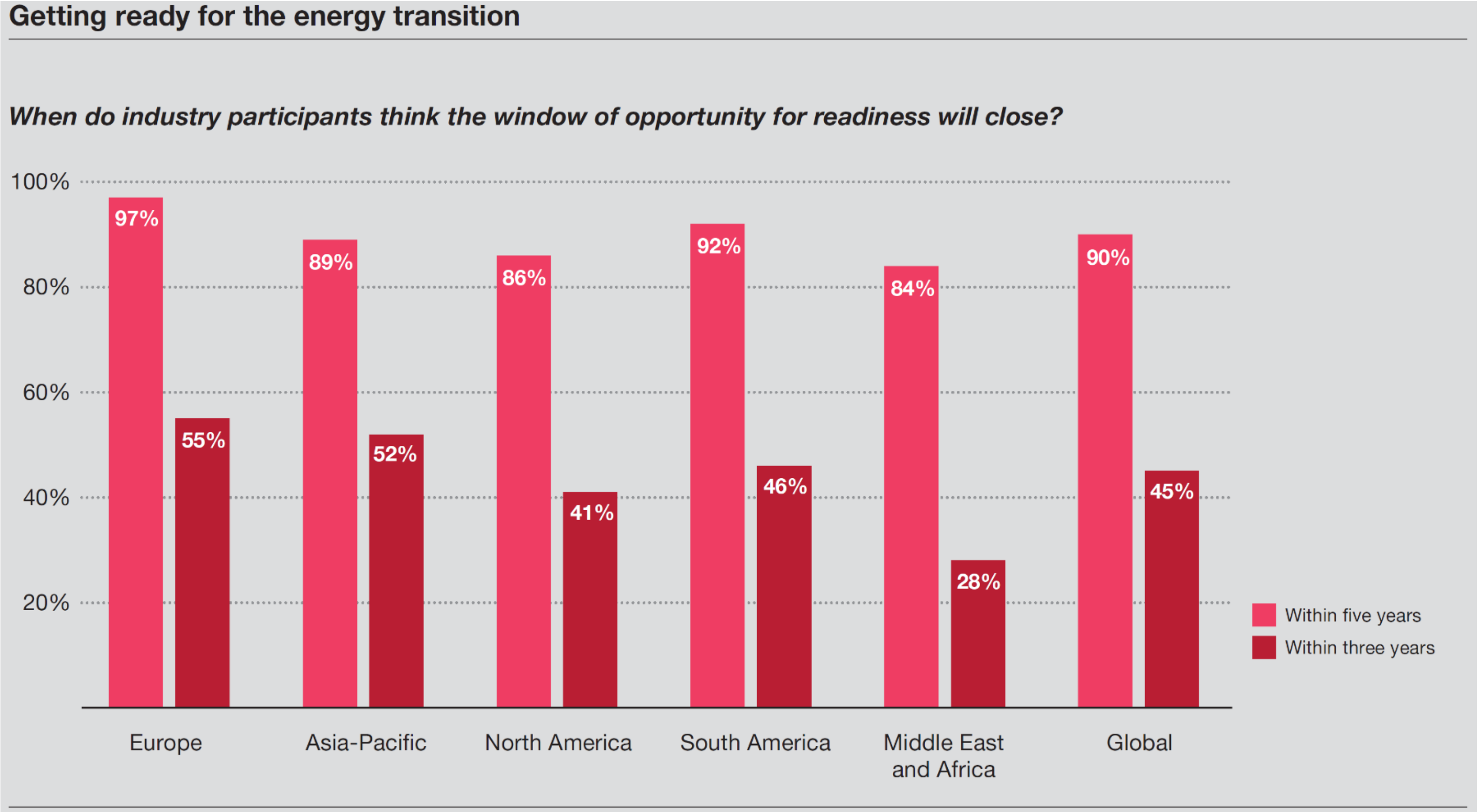


Rapid transition from forward to reverse power flow due to DER output variability

Reverse power flow through substation transformer

An Industry in Transformation

- Consensus is that the next 5 years will be critical for utilities to modernize and be ready to transition into new business models that involve greater and more active participation of DER and modern end users

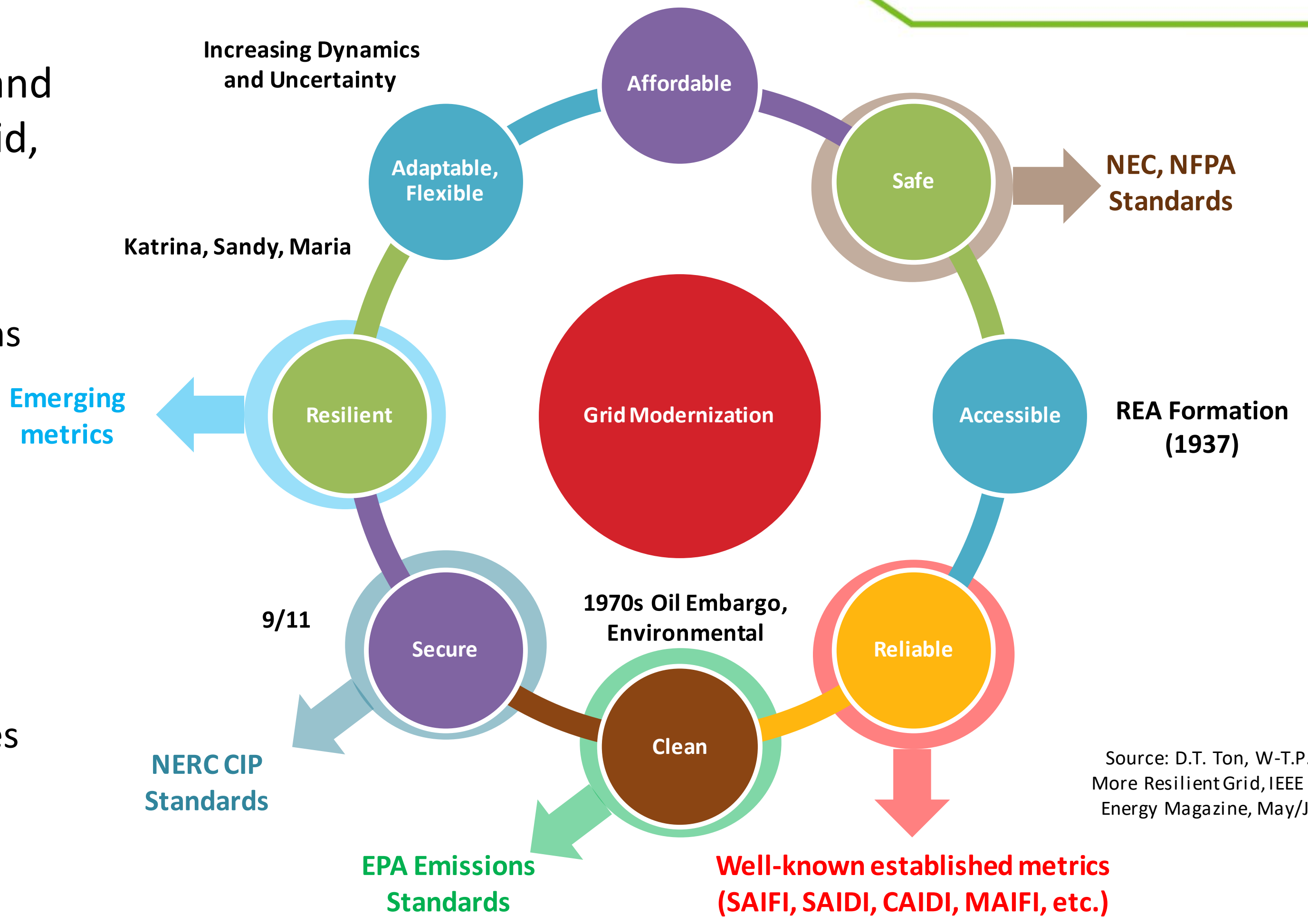


Source: strategy&

Grid Modernization

What is Grid Modernization?

- Grid Modernization enables key capabilities and features required for a modern and future grid, including:
  - Greater **RESILIENCE** to hazards of all types
  - Improved **RELIABILITY** for everyday operations
  - Enhanced **SECURITY** from an increasing and evolving number of threats
  - Additional long-term **AFFORDABILITY** to maintain economic prosperity
  - Superior **FLEXIBILITY** to respond to variability and uncertainty of conditions at one or more timescales, including a range of energy futures
  - Increased **SUSTAINABILITY** through energy-efficient and renewable resources



Source: D.T. Ton, W-T.P. Wang, A More Resilient Grid, IEEE Power and Energy Magazine, May/June 2015

Grid Modernization Drivers

- Key drivers of grid modernization are increasing monitoring, protection, automation and control capabilities, improving reliability and efficiency, and supporting DER integration

What are the most important applications YOUR distribution infrastructure will have to support in the next three to five years?
(Select up to three of the following)

73.7% Distributed energy resources (DER)

56.1% EV charging

49.1% Battery storage

21.1% Telecommunications

14.0% Smart street lighting

1.8% Smart water systems

5.3% Other

3.5% None of the above

Source: B&V

What are the drivers for modernizing YOUR electric distribution systems?
(Select all that apply)

83.9% Increase monitoring, control and automation capabilities

82.3% Improve the reliability of the grid

67.7% Improve operational efficiency and volt/VAR management

50.0% Support distributed energy resources

48.4% Increase customer engagement / empowerment

48.4% Improve cybersecurity

46.8% Network communications

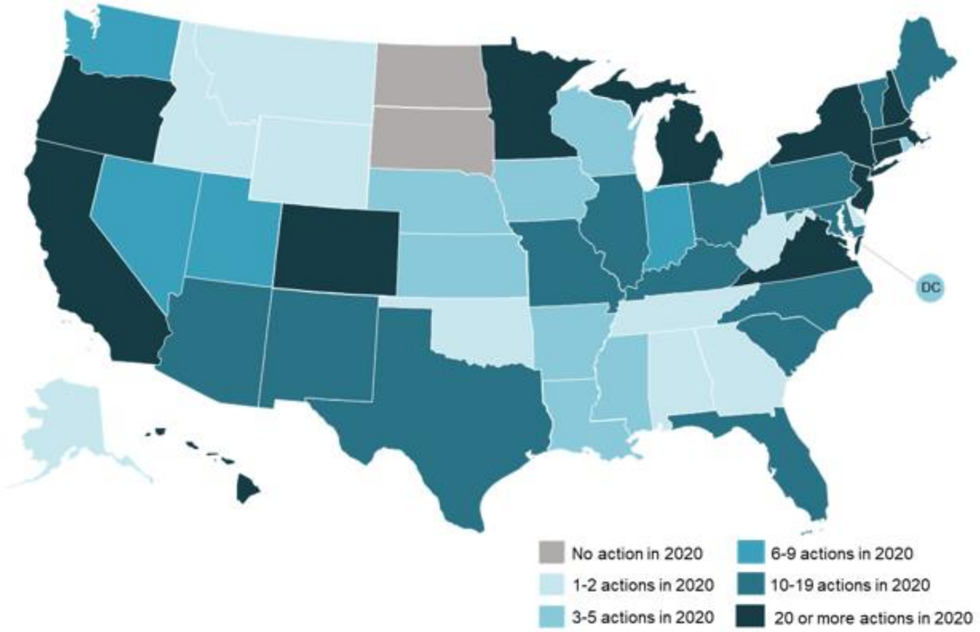
GT40 value chain presence

North America	DER	E-mobility	Smart home	CIES
Ameren	Moderate	Limited	Limited	Limited
AEP	Moderate	Limited	Limited	Limited
CenterPoint Energy	Limited	Limited	Limited	Moderate
CMS Energy	Moderate	Limited	Limited	Limited
ConEdison	High	Limited	Limited	High
Dominion Energy	Limited	Limited	Limited	Limited
DTE Energy	Limited	Limited	Limited	High
Duke Energy	High	Limited	Limited	Limited
Edison International	Moderate	High	Limited	Moderate
Entergy	Limited	Limited	Limited	Limited
Eversource Energy	Limited	Limited	Limited	Limited
Exelon	High	Limited	Limited	Limited
FirstEnergy	Limited	Limited	Limited	Limited
Fortis	Limited	Limited	Limited	Limited
NextEra Energy	High	Limited	Limited	Moderate
PG&E	Moderate	High	Limited	Limited
PPL	Limited	Limited	Limited	Limited
PSEG	Moderate	Limited	Limited	Limited
Sempra Energy	Moderate	Moderate	Limited	Limited
Southern Company	Moderate	Moderate	Limited	High
WEC Energy	Limited	Limited	Limited	Limited
Xcel Energy	Moderate	Limited	Limited	Limited
Europe				
RWE	High	High	Moderate	Moderate
E.ON	High	High	High	High
EDP	Moderate	Limited	Moderate	Limited
EDF	Moderate	Limited	Moderate	Limited
Enel	High	High	High	High
Engie	High	High	Moderate	High
Fortum	High	High	Moderate	Limited
Iberdrola	Moderate	High	Moderate	High
National Grid	Limited	Moderate	Limited	Limited
Naturgy	Limited	Limited	Limited	Moderate
Ørsted	Limited	Limited	Limited	Limited
SSE	Limited	Limited	Limited	Limited
Asia-Pacific				
AGL Energy	Moderate	Limited	Limited	Limited
CLP Holdings	Limited	Limited	Moderate	Limited
Hong Kong and China Gas	Limited	Limited	Limited	Limited
Korea Electric Power	Moderate	Limited	Limited	Limited
Power Assets Holdings	Moderate	Moderate	Moderate	Limited
Tenaga Nasional	Limited	Limited	Moderate	Limited

● High activity ● Moderate activity ● Limited activity

Source: strategy&

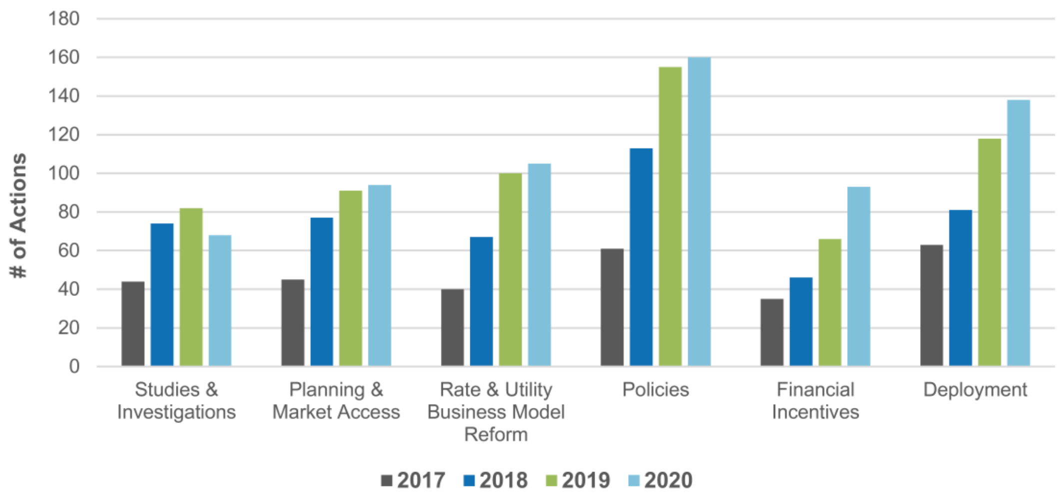
Grid Modernization Activities – U.S.



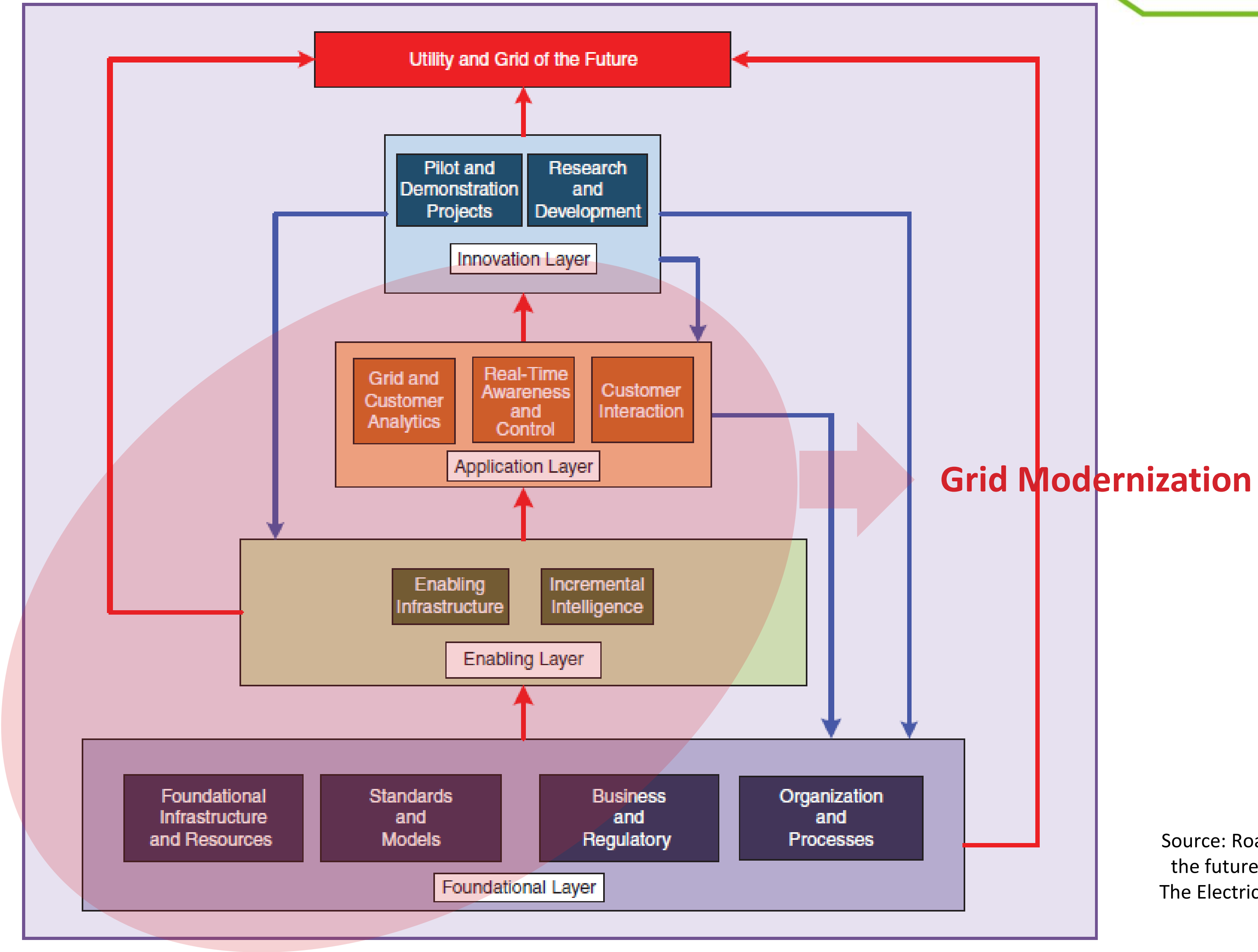
Source: The 50 States of Grid Modernization

Utility Name	Distribution Infrastructure Hardening & Resilience	Advanced Grid Technologies	Transmission Infrastructure Hardening & Resilience	AMI	DER
Ameren Illinois	X	X		X	
Commonwealth Edison (Exelon)	X	X		X	
Consumers Energy	X	X	X		X
DTE Energy	X	X		X	X
Duke Energy Indiana	X	X	X		
First Energy Ohio	X		X		
Northern States Power Company (Xcel)		X			X
Ohio Power Company	X				X
Vectren South	X	X	X		X
Central Maine Power (AVANGRID)		X		X	
Eversource Energy		X			X
National Grid		X		X	X
PECO (Exelon)	X				X
PSE&G	X	X	X		
Duke Energy Carolinas	X	X	X	X	X
Entergy Arkansas				X	
Pepco (Exelon)	X				
Austin Energy		X		X	X
Hawaiian Electric		X		X	X
Public Service Company of Colorado (Xcel)		X		X	
Southern California Edison	X	X			X
Total	13	16	6	10	12

Source: S. Sergici, Grid Modernization: Policy, Market Trends, and Directions Forward, 4th Annual Grid Modernization Forum, May. 2019



Conceptual Framework for Utility of the Future



Source: Roadmaps for the utility of the future, JR Agüero, A Khodaei The Electricity Journal 28 (10), 7-17

Grid Modernization Roadmap

What are the key steps to a grid modernization roadmap?

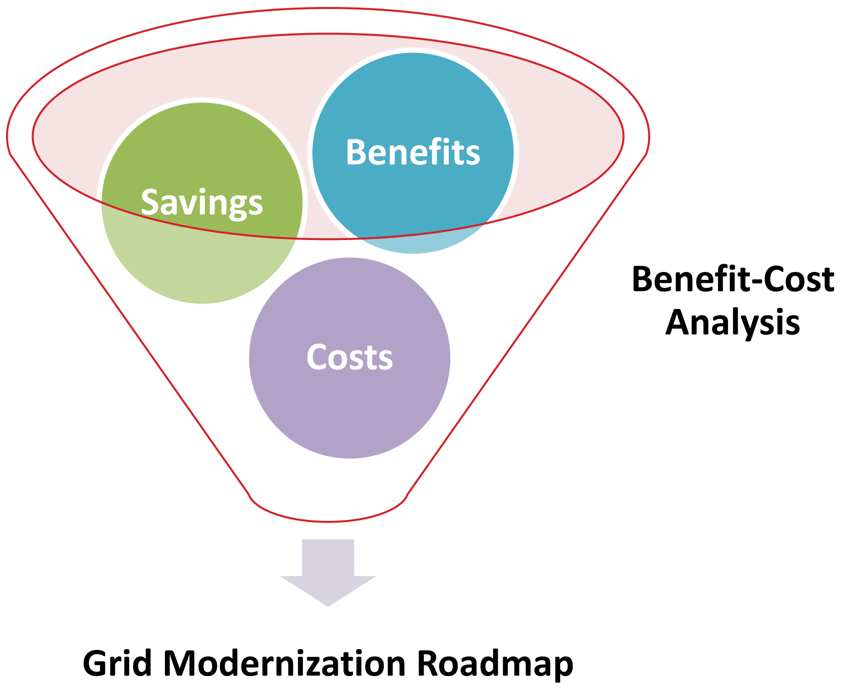
- A Grid modernization roadmap allows implementing these requirements and capabilities in a practical manner based on the utility's goals and vision
- Steps to developing a grid modernization roadmap:
  - Identify key components of utility's vision and goals
  - Develop preliminary list of key programs considered to reach utility's goals
  - Benchmark existing utility practices and preliminary list of programs against industry trends and best practices
  - Conduct benefit-cost analysis to help prioritize programs
  - Develop a final list of prioritized programs for grid modernization
  - Identify "foundational" programs required for subsequent programs to align implementation schedule
  - Create grid modernization roadmap

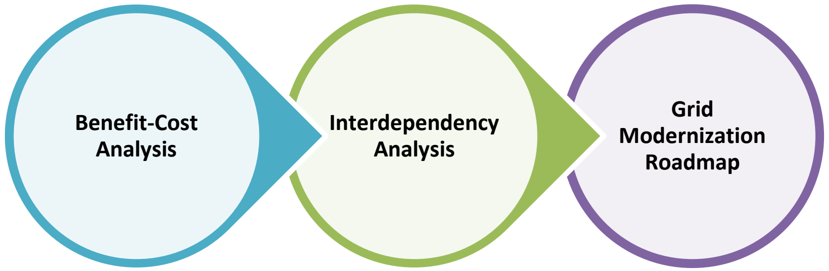
Examples of Grid Modernization Programs

- Programs are defined initiatives to realize a modern grid
  - Includes all initiatives to reach utility and societal goals
    - Includes foundational areas such as telecommunications, GIS, etc.
    - Includes advanced areas such as grid analytics
- To prioritize programs, they are evaluated in terms of:
  - Cost to implement
  - Benefits to utility and society
- Foundational programs are those required for implementation of other programs, such as:
  - AMI smart meters for outage management
  - Telecommunications systems for real-time monitoring and control

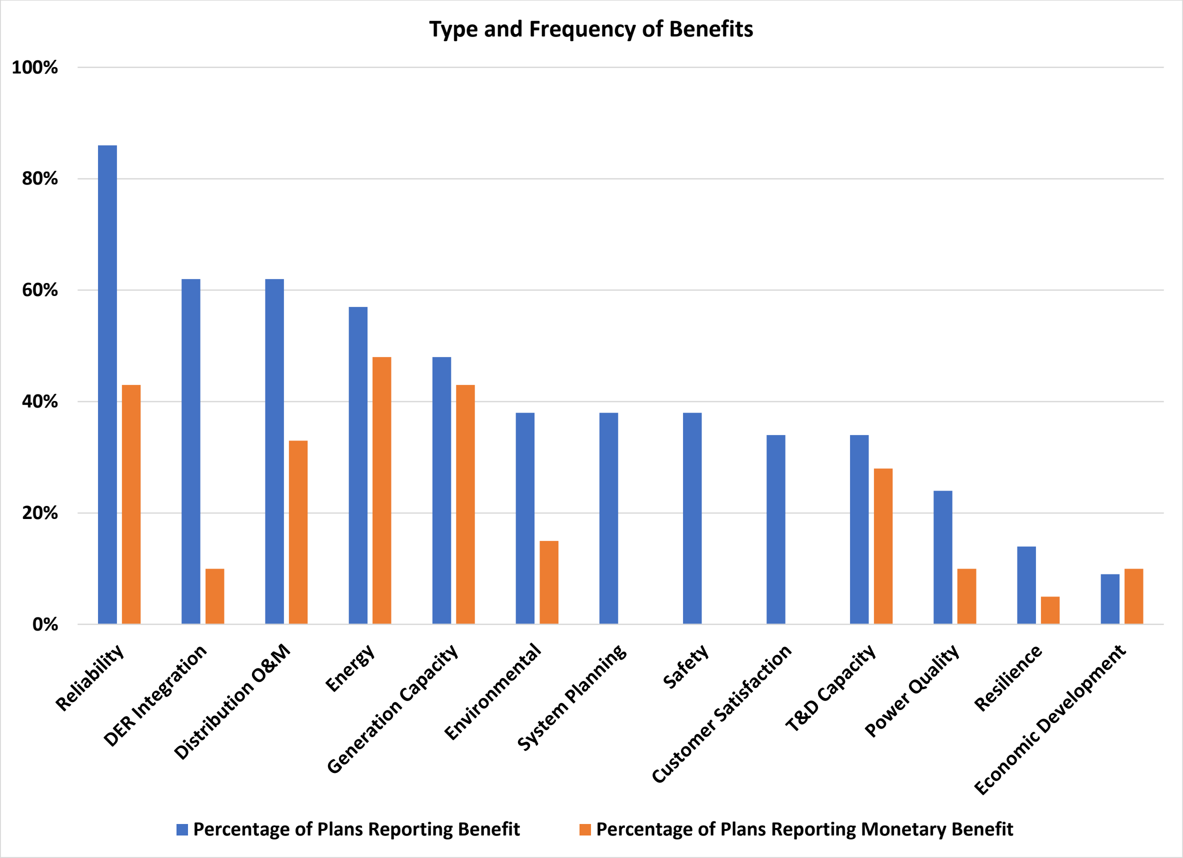
Program Prioritization and Scheduling

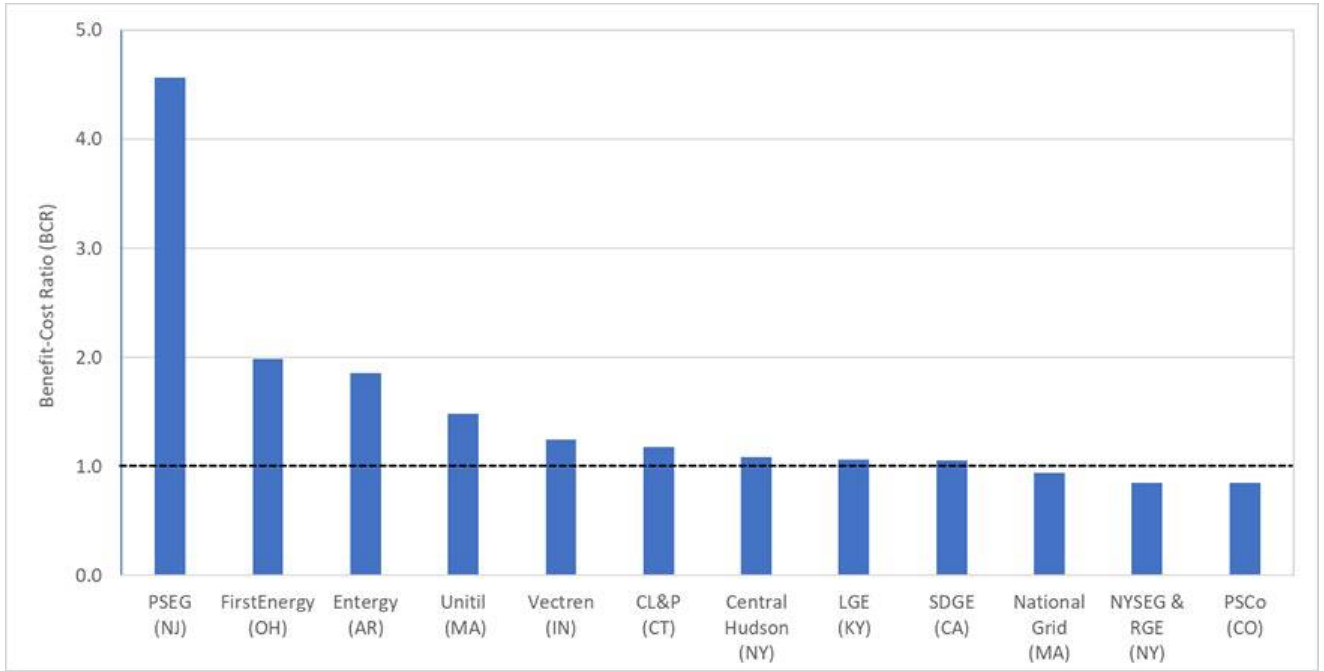
- Each program is evaluated in terms of:
  - **Benefits—**Benefits from implementing the program
  - **Capital costs—**Initial, fixed, one-time investment required to implement program
  - **O&M costs (annual)—**Recurring costs, including operations, maintenance, licenses, etc.
  - **Anticipated savings—**Expected savings derived from program implementation, either one-time or recurrent
  - **Assumptions—**Relevant assumptions used to calculate costs (e.g., unit costs, customer base, etc.)
- Benefit-cost ratios and interdependencies are analyzed to prioritize and schedule program implementation (e.g., foundational programs are implemented first)
- Results are used to develop grid modernization roadmap





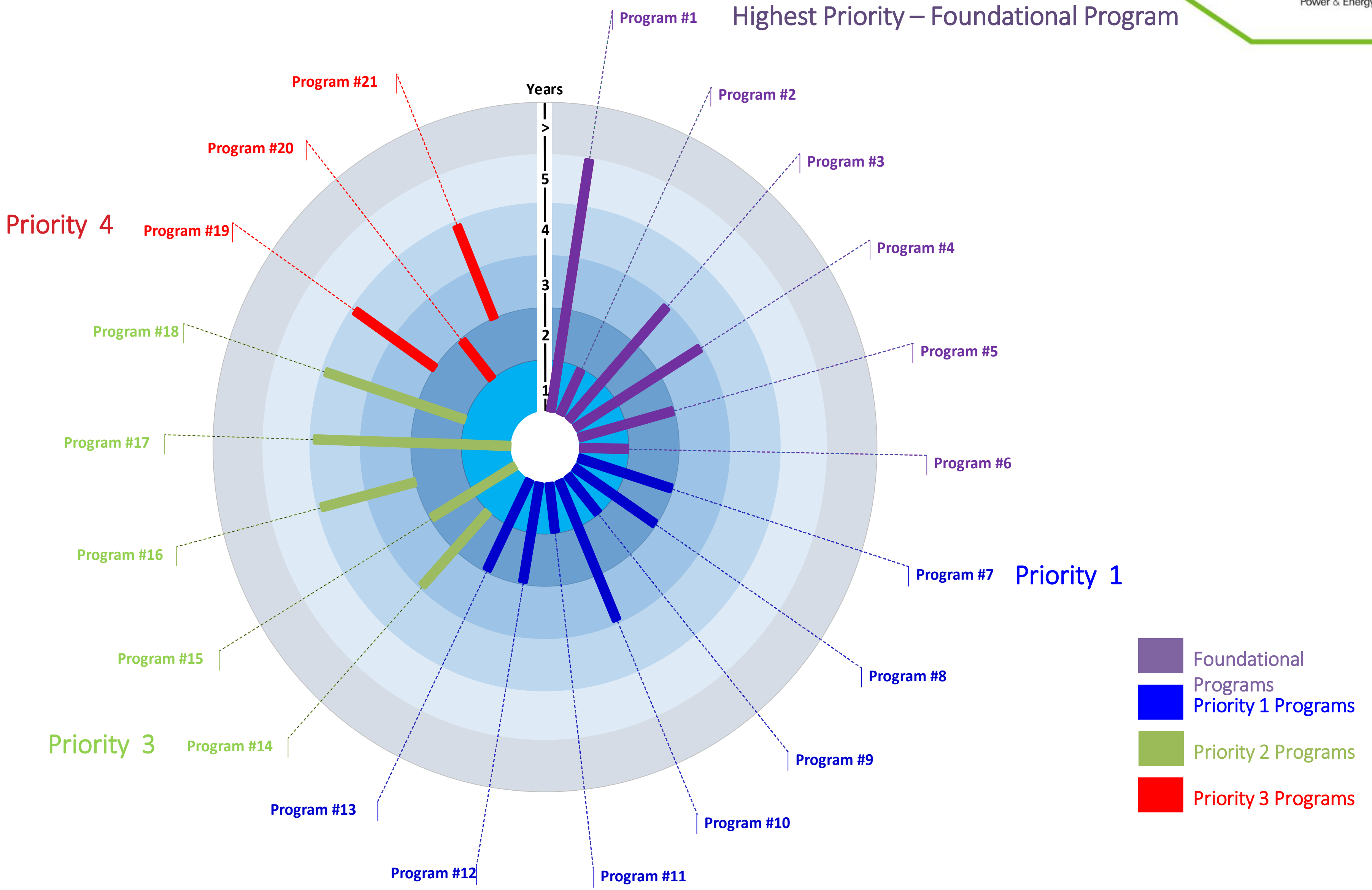
Benefits and Benefit/Cost Ratios Reported by Recent Studies



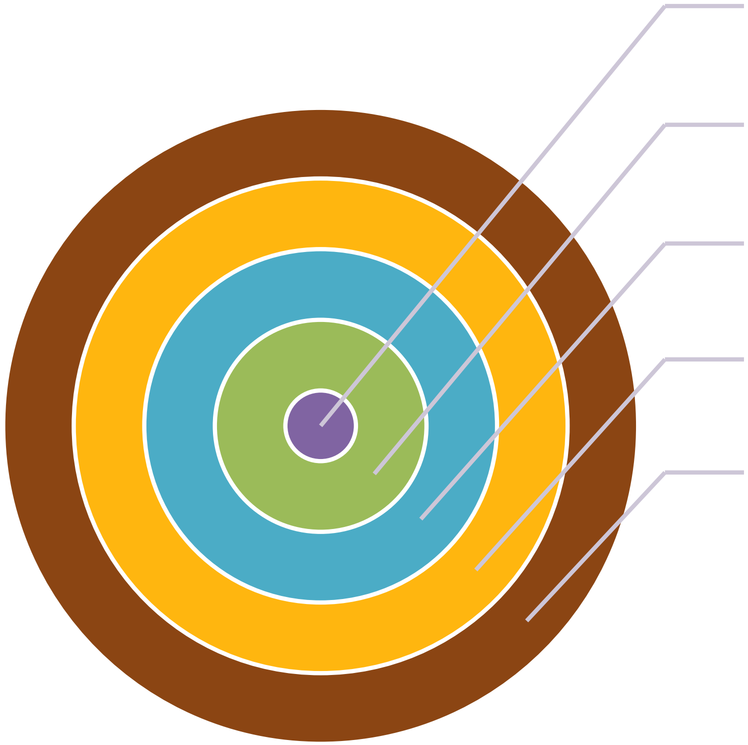


Source: T. Woolf et. al, Benefit-Cost Analysis for Utility-Facing Grid Modernization Investments: Trends, Challenges, and Considerations, Feb. 2021

Grid Modernization Roadmap



Real-Time Distribution Systems Operations



Foundational infrastructure (sensors, controllers, smart meters, DER, switching & protective devices, behind-the-meter IEDs)

Enabling infrastructure (telecommunications and IT systems)

Distribution Automation (feeder, substation, home, building automation)

Enterprise Systems (ADMS, OMS, CIS, MDMS, DERMS, etc.)

Real-Time Distribution System Operations

Sensors and Grid Edge IEDs/Switchgear

ConnectDER: behind-the-meter DER monitoring device

MM3: advanced line sensor and Fault Circuit Indicator (FCI)

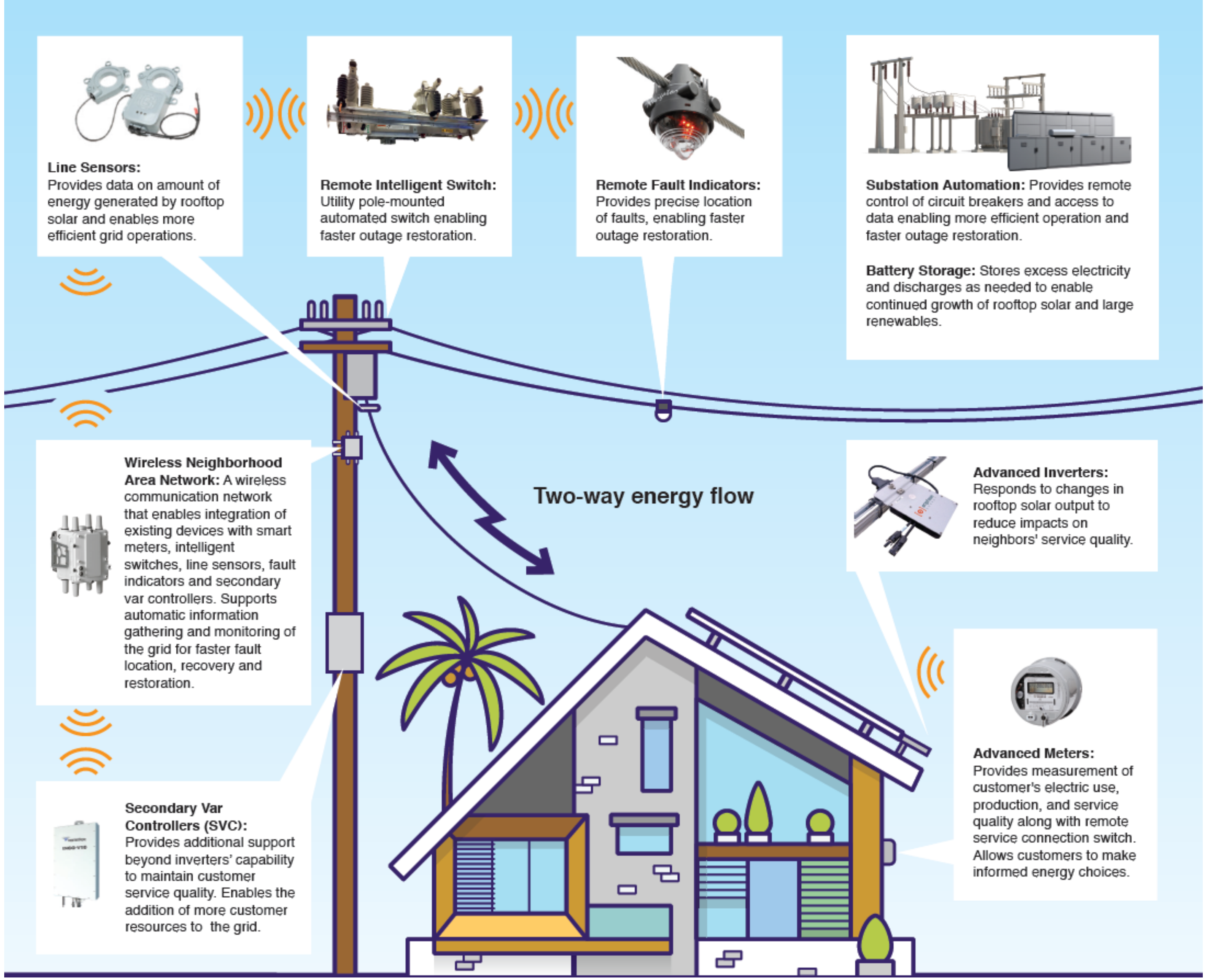
VacuFuse: grid edge (service transformer) self-resetting interrupter

Optanode: distribution transformer monitoring device

micro-PMU: Phasor Measurement Unit (PMU) for distribution applications

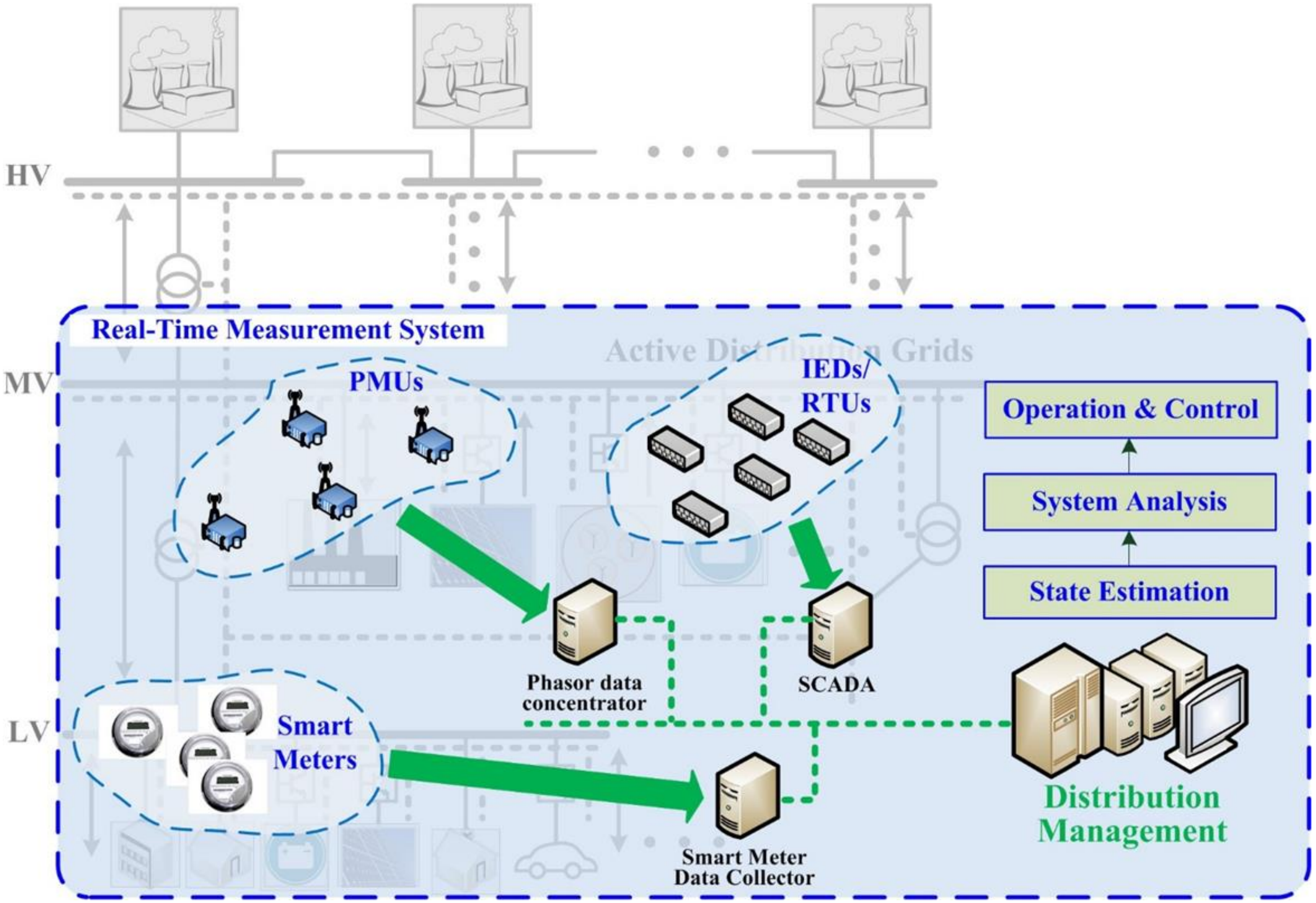
Engo: low-voltage dynamic volt-Var control device

Grid Edge Monitoring and Control

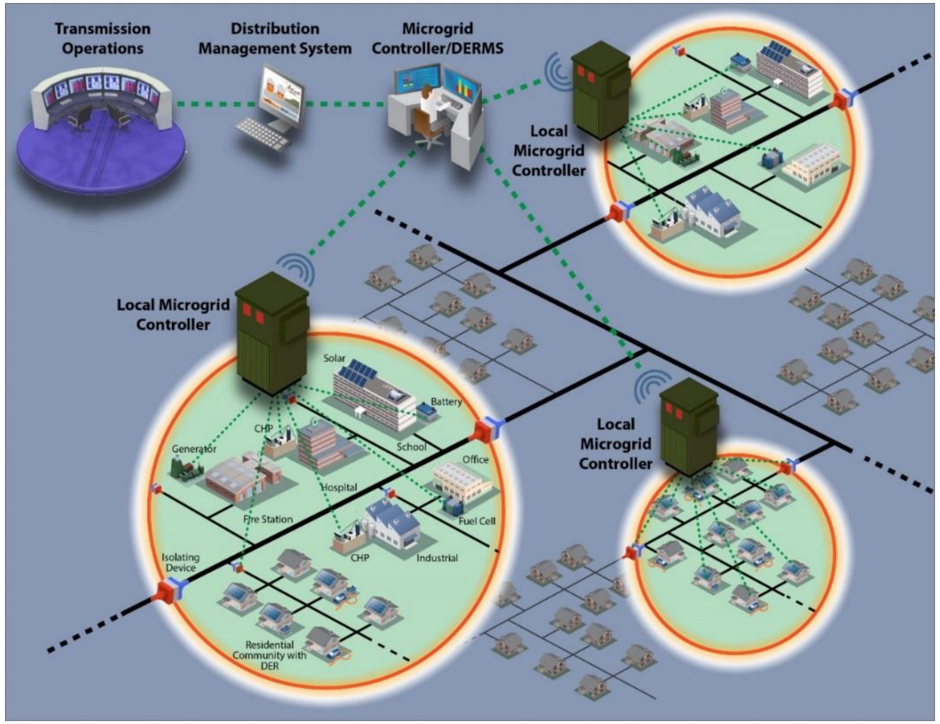


Source: Hawaiian Electric

ADMS and Microgrids

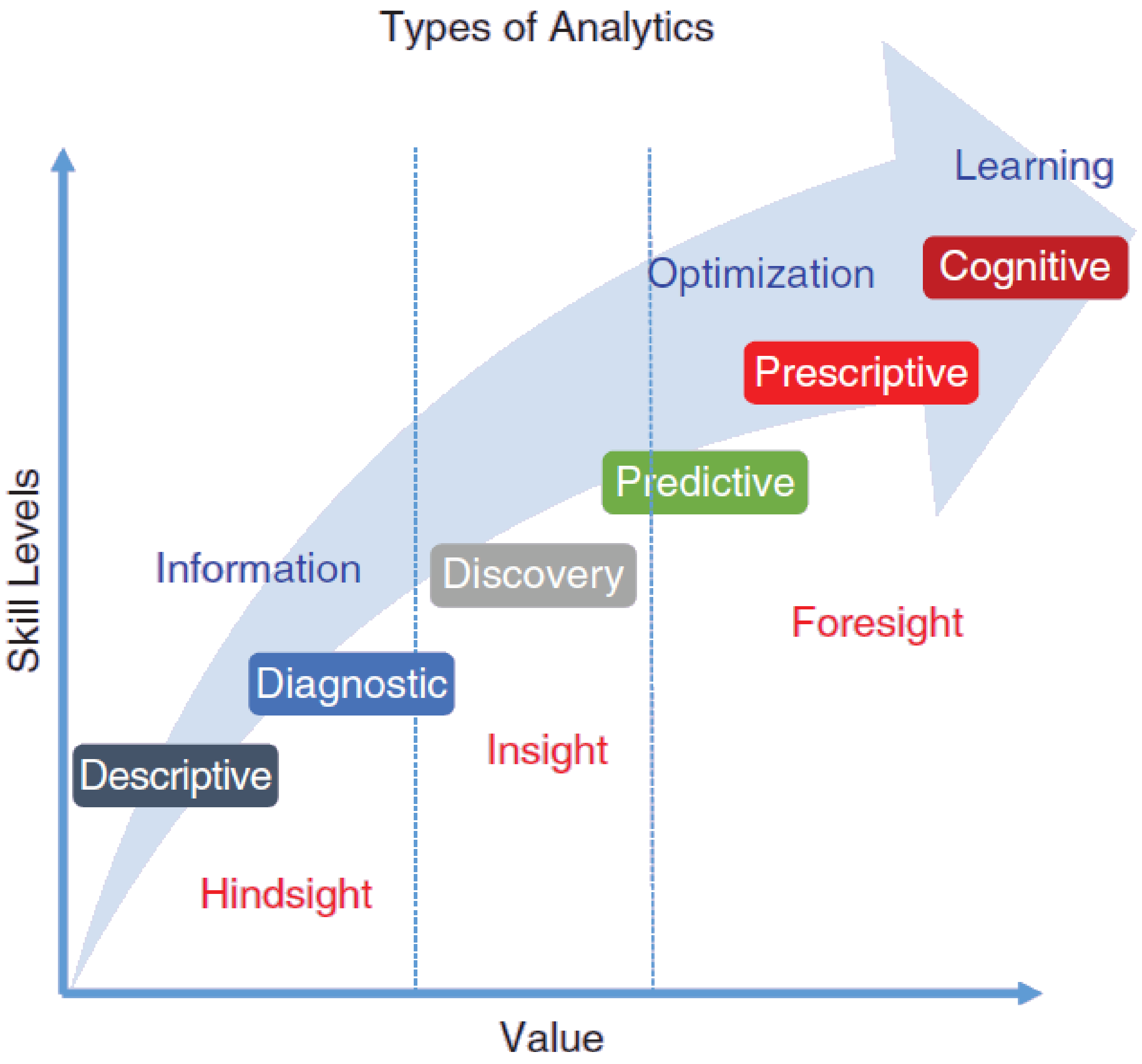


Source: RTWH Aachen



Source: EPRI

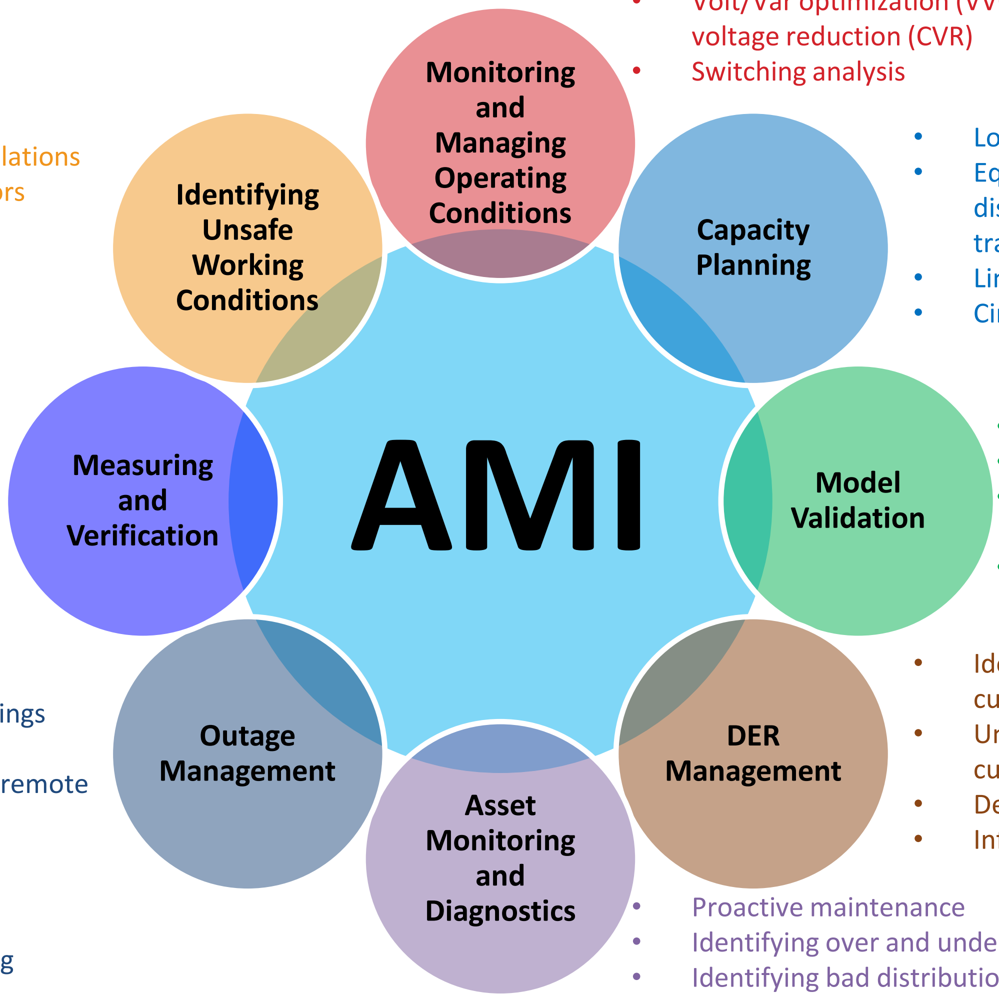
Grid Analytics



- **Descriptive analytics:** describe past performance of distribution grid by analyzing historical data, e.g., use service interruption records to calculate reliability indices (SAIFI, CAIDI, SAIDI, etc.)
- **Diagnostic analytics:** diagnose root-cause of distribution system performance, e.g., to identify the root-cause of service interruptions and equipment outages
- **Discovery analytics:** provide additional insights about distribution grid performance to identify unknown issues, particularly in areas of the grid that traditionally have had limited real-time visibility and awareness, e.g., assess grid edge performance
- **Predictive analytics:** estimate expected distribution grid performance based on historical and real-time data, e.g., estimate potential equipment overloads that might occur as a consequence of extreme weather patterns
- **Prescriptive analytics:** use historical and real time data along with system analysis capabilities to provide recommendations regarding preventive measures that would allow to preclude or minimize performance disruptions, e.g., advice on most resilient system configuration to withstand major weather events.
- **Cognitive Analytics:** Use computational intelligence technologies inspired by human learning (e.g., artificial intelligence techniques such as machine learning, deep learning, etc.) to collect, process, analyze, and manage qualitative (e.g., natural language) and quantitative data from diverse sources. Cognitive analytics may be used to develop adaptive self-learning solutions whose accuracy improves over time.

AMI – How Utilities are Using AMI Beyond Meter Reading

These benefits or use cases cannot be achieved by merely installing the network and meters. Many will require integration with ADMS or other software solutions that allow the data to be analyzed, visualized and paired with other data.



Monitoring and Managing Operating Conditions

- Improved power quality
- Validation of voltage compliance
- Visualizing the data/Increased system visibility
- Volt/Var optimization (VVO) and conservation voltage reduction (CVR)
- Switching analysis

Capacity Planning

- Load forecasting and projected growth
- Equipment investments and upgrades (e.g., distribution transformers, substation transformers, etc.)
- Line loss studies
- Circuit phase load balancing

Model Validation

- Validation of primary circuit model
- GIS and network connectivity corrections
- Mater to transformer mapping/transformer load management
- Phase identification and mapping

DER Management

- Identifying unregistered customer-owned systems
- Understanding the impacts of customer-owned systems
- Determining DER capacity
- Informing policy

Asset Monitoring and Diagnostics

- Proactive maintenance
- Identifying over and underloaded transformers
- Identifying bad distribution voltage regulators and distribution capacitors
- Identifying hot sockets

Outage Management

- Verifying outages through meter pings
- Estimating restoration times
- Service order automation through remote connect/disconnect
- Identifying outage locations
- Determining cause of outage
- Customer communications
- Determine fire-caused outage using temperature data
- Identifying which phase of wires are down

Measuring and Verification

- Reduce/eliminate estimated reads
- Revenue protection
- Reliability metrics
- Demand response verification/thermostat programs
- Demand response and load shifting for EV charging
- Enables new rate options (e.g., time of use and prepay)

Identifying Unsafe Working Conditions

- Identifying unregistered PV installations
- Identifying downed live conductors

Source: Voices of Experience, Leveraging AMI Networks and Data, U.S. DOE

Electrification

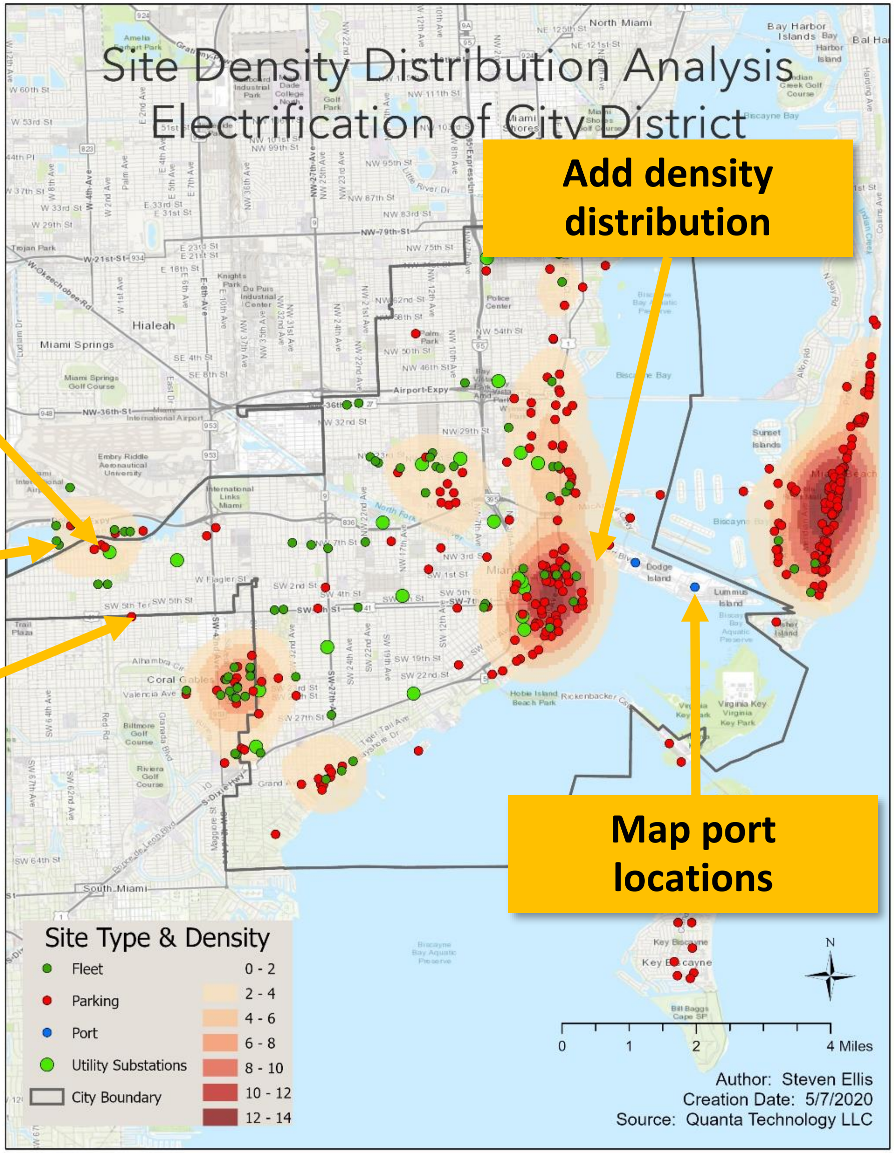
Methodology to localize future, projected charger load impacts on substations in utility territories:

1. Identify and map utility substations via GPS or latitude/longitude coordinates
2. Identify key commercial, retail, and fleet specified territory then estimates corresponding charger load growth
3. Facilities are linked to specific substatio algorithm
4. New load growth from electrification is substation rating and compared against
5. Substations are then ranked against their max rating to determine whether substation is at risk due to load

Map substations

Map fleet locations

Map parking locations



Holistic Planning – From "Snapshot" to Performance Planning

Data & Grid Analytics

- Assess and calculate system performance using accurate, up-to-date, high resolution and abundant data at customer, service transformer and feeder level, and reduce reliance on assumptions and heuristics

Temporal & Spatial Analysis

- Move away from snapshot substation-level analyses (e.g., annual peaks, substation transformers and feeder mains) to time-series spatial analysis at feeder section and service transformer level (high resolution/granularity temporal/spatial analysis)

Holistic Planning

- Holistic approach that considers all distribution planning and engineering aspects together, rather than decoupled (capacity planning, reliability, protection, automation, volt-VAR control, asset management, DER, NWA, and microgrids

Planning & Operations Convergence

- DER proliferation is blurring the traditional boundaries between T&D systems, and between planning and operations of these systems, and leading to T&D planning and T&D operations convergence. This requires the development of new methodologies and new solutions

Coordinated RT&D Planning and Investment Convergence

IEEE PES Power & Energy Society® | IEEE

High Granularity/Resolution Spatial/Temporal Modeling, Simulation & Analysis

Distribution Planning

Integrated Resource Planning

Transmission Planning

GT&D Planning Convergence (e.g., "duck curve")

Models and Software Solutions

Data & Analytics

Telecom & IT/OT

Capacity Planning

Asset Management

Load & DER Forecasting

Volt-Var Control

NWA & Microgrids

DER

Modern & Future End User & IoT

Automation

Value of DER/Grid

Protection & Control

Reliability

Operations

Resilience

GT&D Operations Convergence (e.g., DER voltage & frequency ride-through)

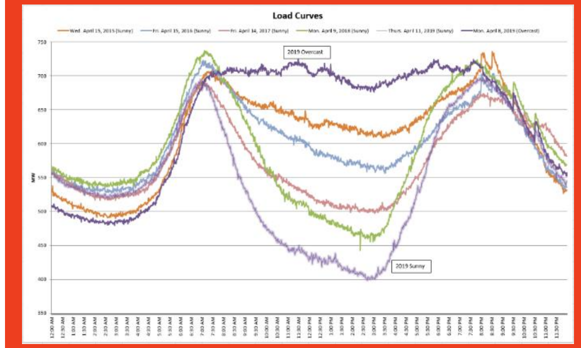
Result is Holistic Investment Prioritization

Distribution Operations

Generation & Renewable Resources Operations

Transmission Operations

Source: VELCO



Transition from deterministic (snapshot) analyses based on annual peak demand of key assets (e.g., substation transformers) to multi-hour (time-series) probabilistic and spatial analysis of demand/production of granular assets (e.g., service transformers)

Integrated Distribution Planning (IDP)

Source: NERC

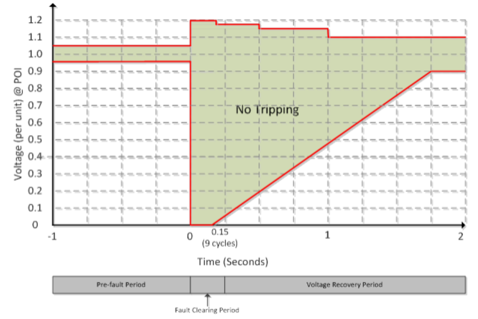
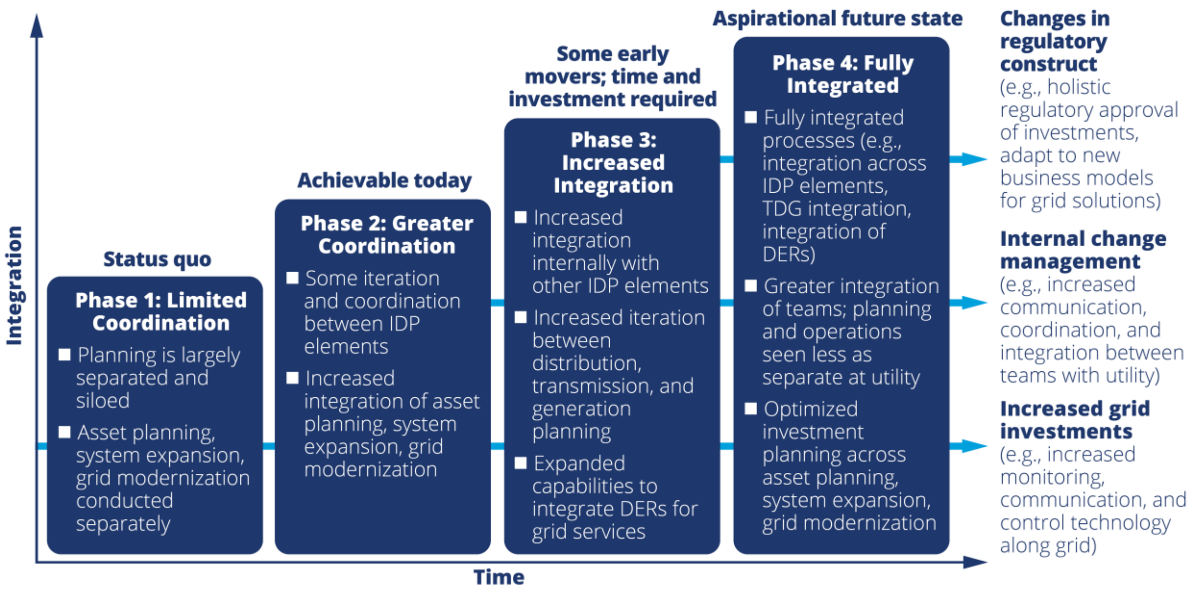


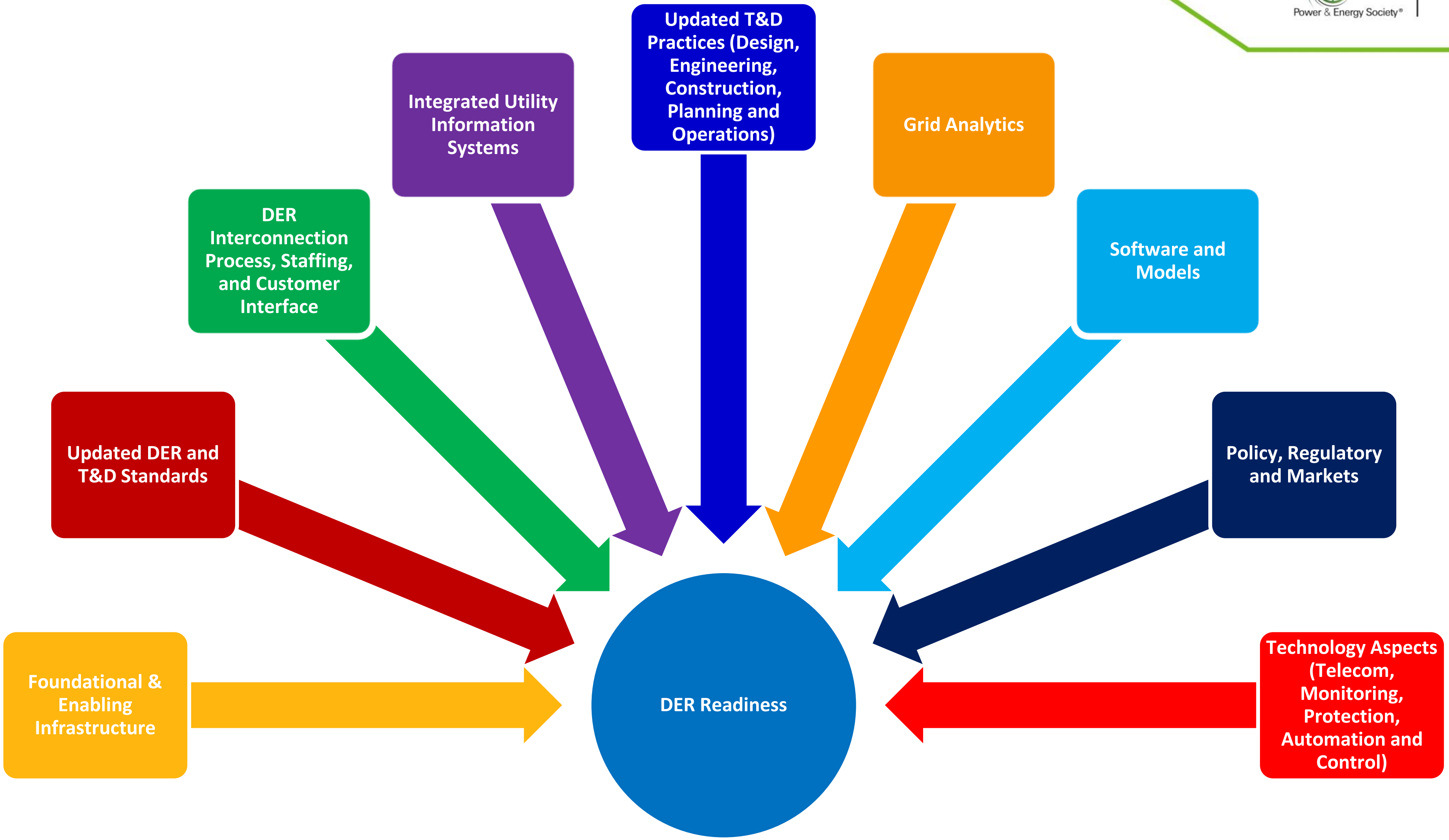
Figure 21: ERCOT Voltage Ride Through Profile [Source: ERCOT]

IDP Roadmap Example – SEPA

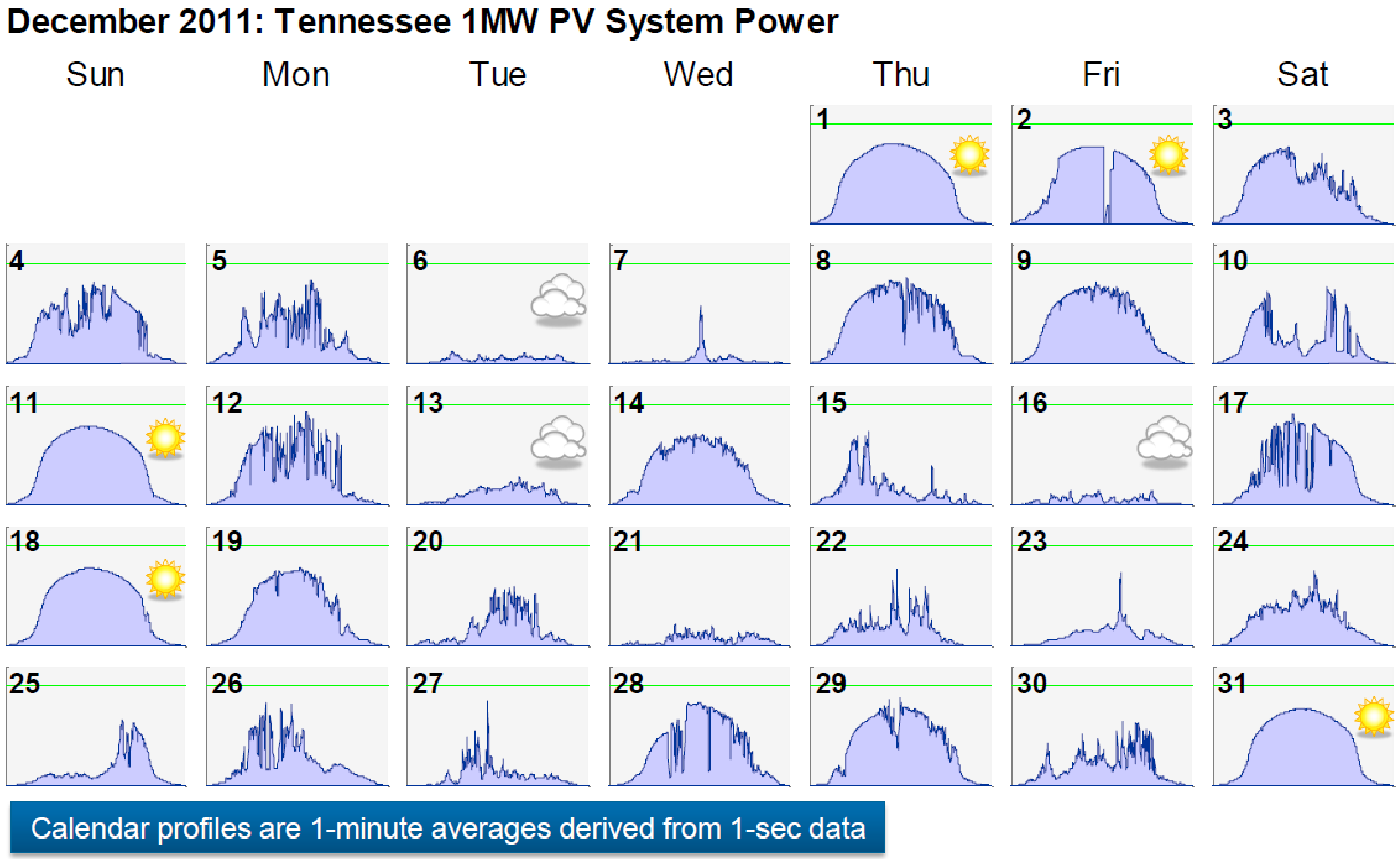


Source: SEPA

DER Readiness Concept



PV DG Integration Challenges



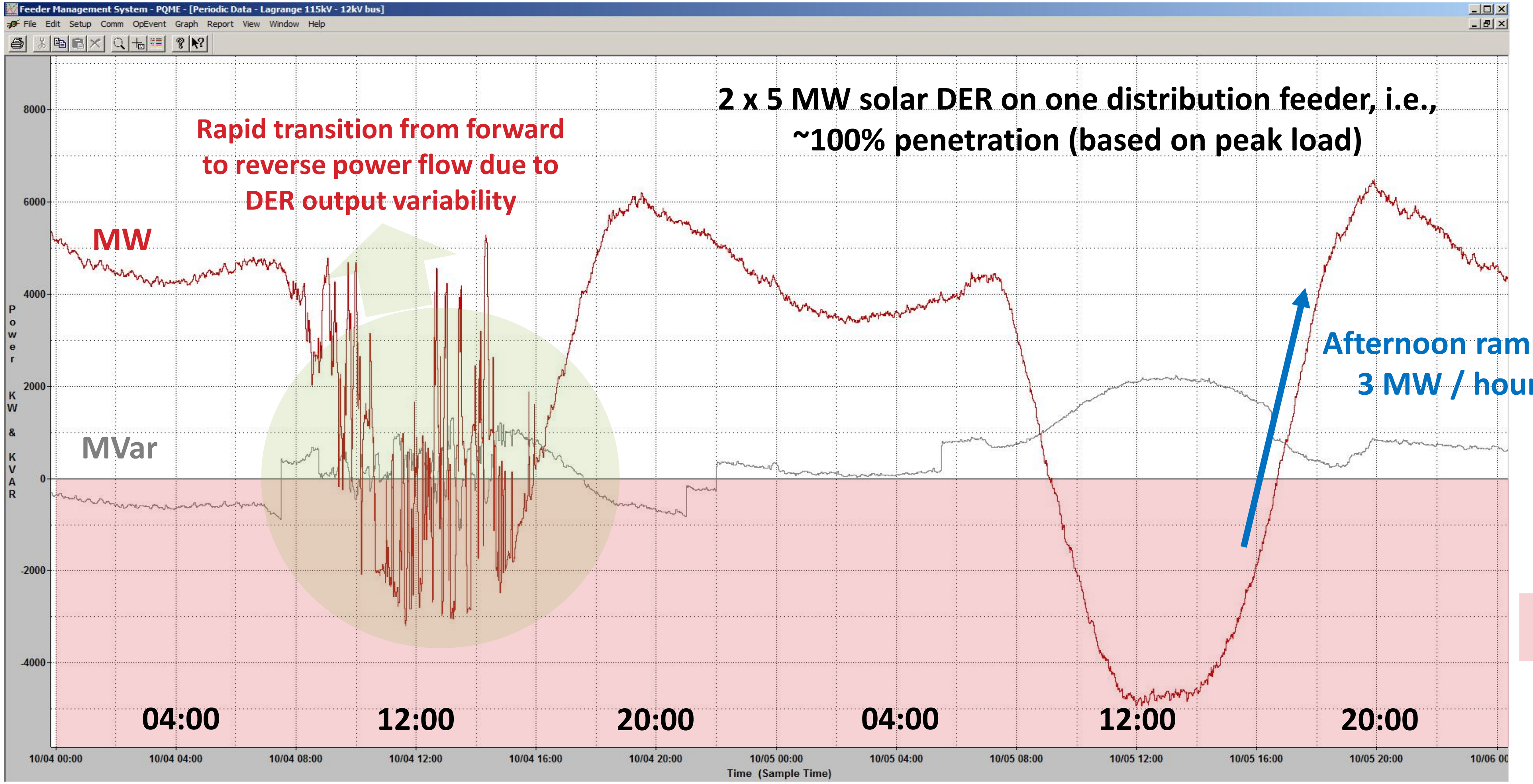
Source: https://www.puco.ohio.gov/industry-information/industry-topics/powerforward/phase-2-exploring-technologies/presentations/tom-key/

What is the industry doing? (1)

- DG proliferation is not a temporary trend, it is a business paradigm shift that is here to stay. Utilities are addressing this challenge from three perspectives
- **Short-term (focus on large DG plants):**
  - Utilities are conducting detailed DG integration studies for large DG plants with the objective of identifying impacts in the distribution system and proposing solutions to ensure seamless integration.
  - This approach is deterministic in nature (it is well-known where and when large DG plants will be interconnected)
  - It solves problems in the short-term but can be criticized as being equivalent to applying “patches” or short-term fixes to the system

Impacts of High Penetration of Utility-Scale PV DG

Duke Energy Progress, Lagrange 115 kV / 12 kV Substation near LaGrange, NC: October 4 & 5, 2014



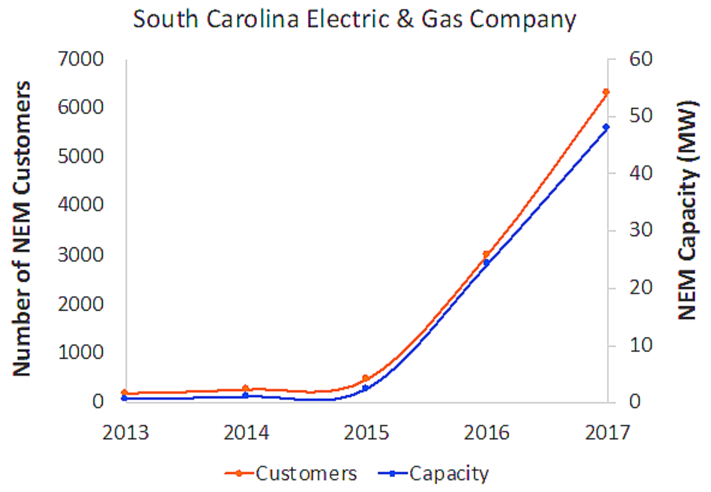
Reverse power flow through substation transformer into 115 kV transmission system

One-minute real & reactive power flow measured at substation bus, 48-hour period

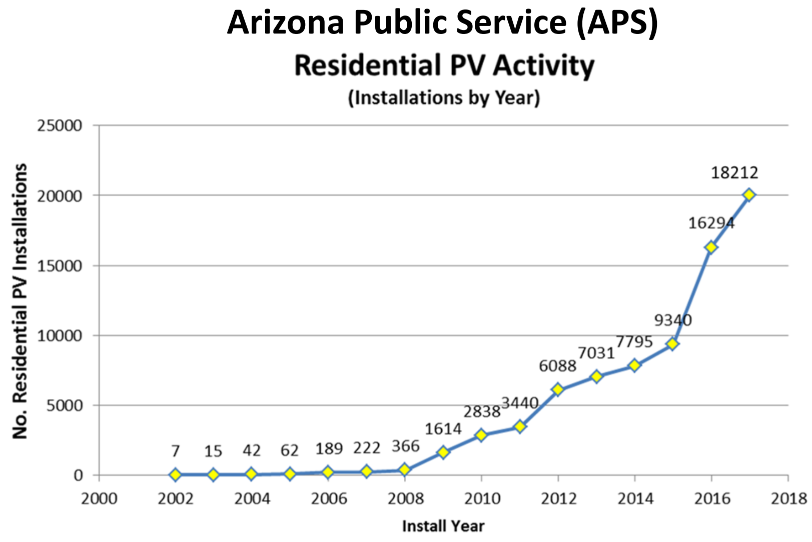
Source: J. Gajda, Creating sustainable and scalable interconnection requirements for high penetration of utility-scale DER on the distribution system, 2017 IEEE PES GM, Chicago, IL

What is the industry doing? (2)

- **Mid-term (focus on large and residential DG plants):**
  - Besides implementing short-term solutions, utilities are also analyzing a variety of proliferation scenarios for residential DG plants
  - This approach is stochastic in nature, i.e., it is not known with certainty when and where residential DG plants will be interconnected
  - Although an individual residential DG plant may not impact the distribution system, the cumulative effect of hundreds or thousands of residential DG plants will certainly affect distribution system planning and operations
  - This allows utilities estimate maximum limits of DG proliferation, identify system upgrades, and plan respective implementation with enough anticipation to account for lead times (e.g., build new feeders and substations)



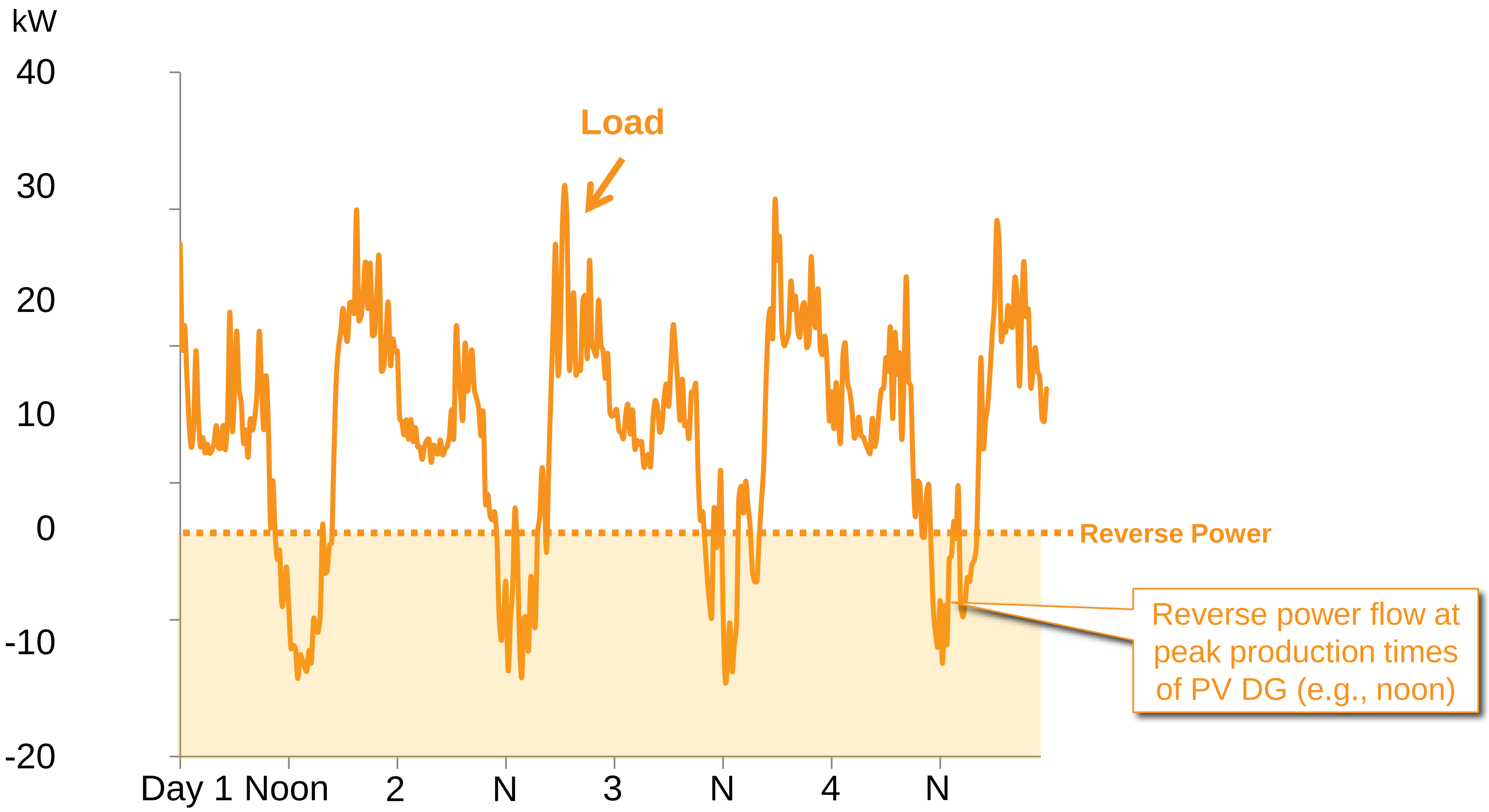
Source: SCE&G



Source: APS

Impacts of High Penetration of Behind-the-Meter PV DG

Overvoltage at service transformer due to reverse power flow caused by residential PV DG in Hawaiian Electric (HECO)'s distribution system



Source: M. Asano, Grid Modernization Applications in a High DER Environment, 2018 IEEE PES T&D Conference and Exposition, Denver CO

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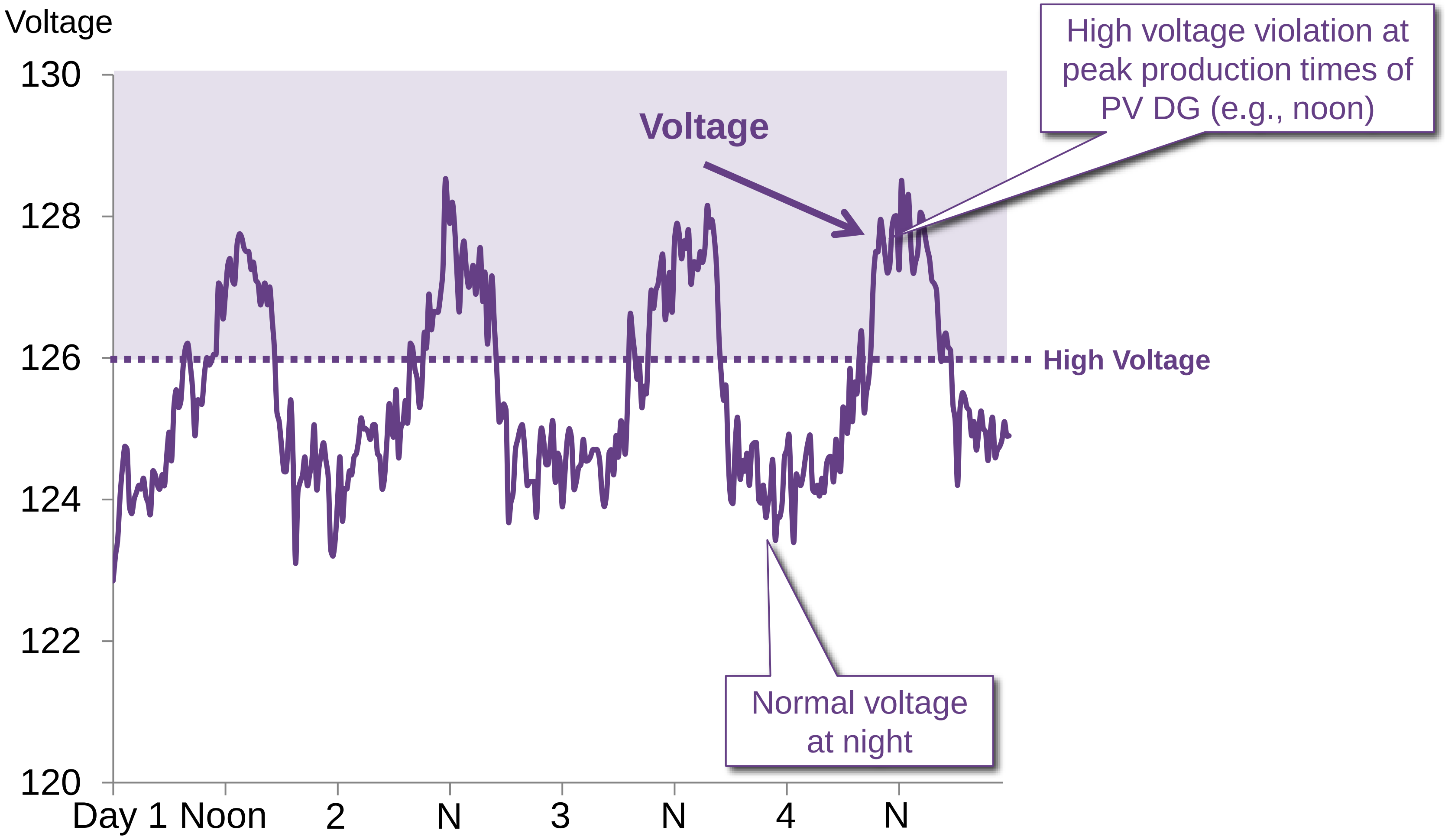

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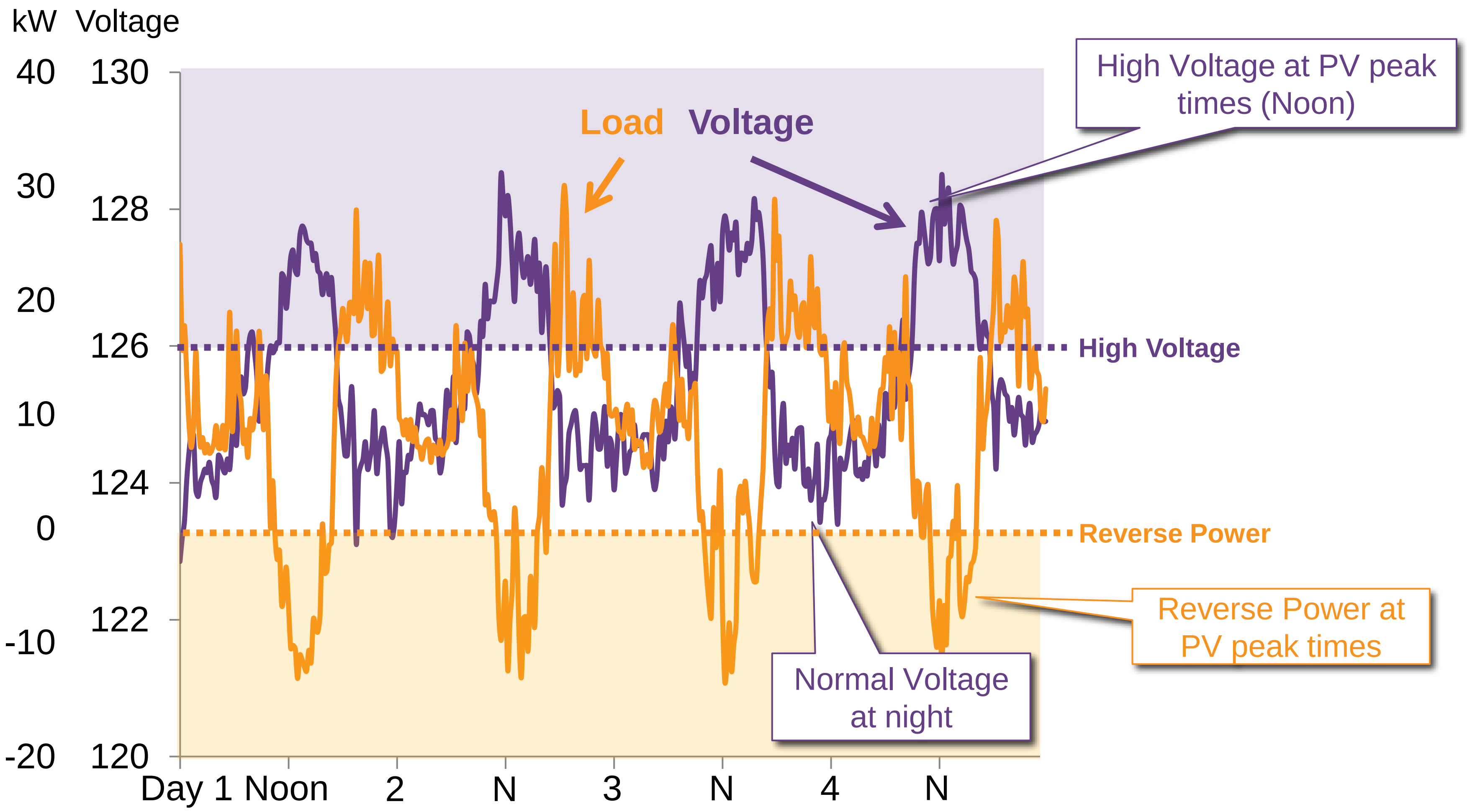
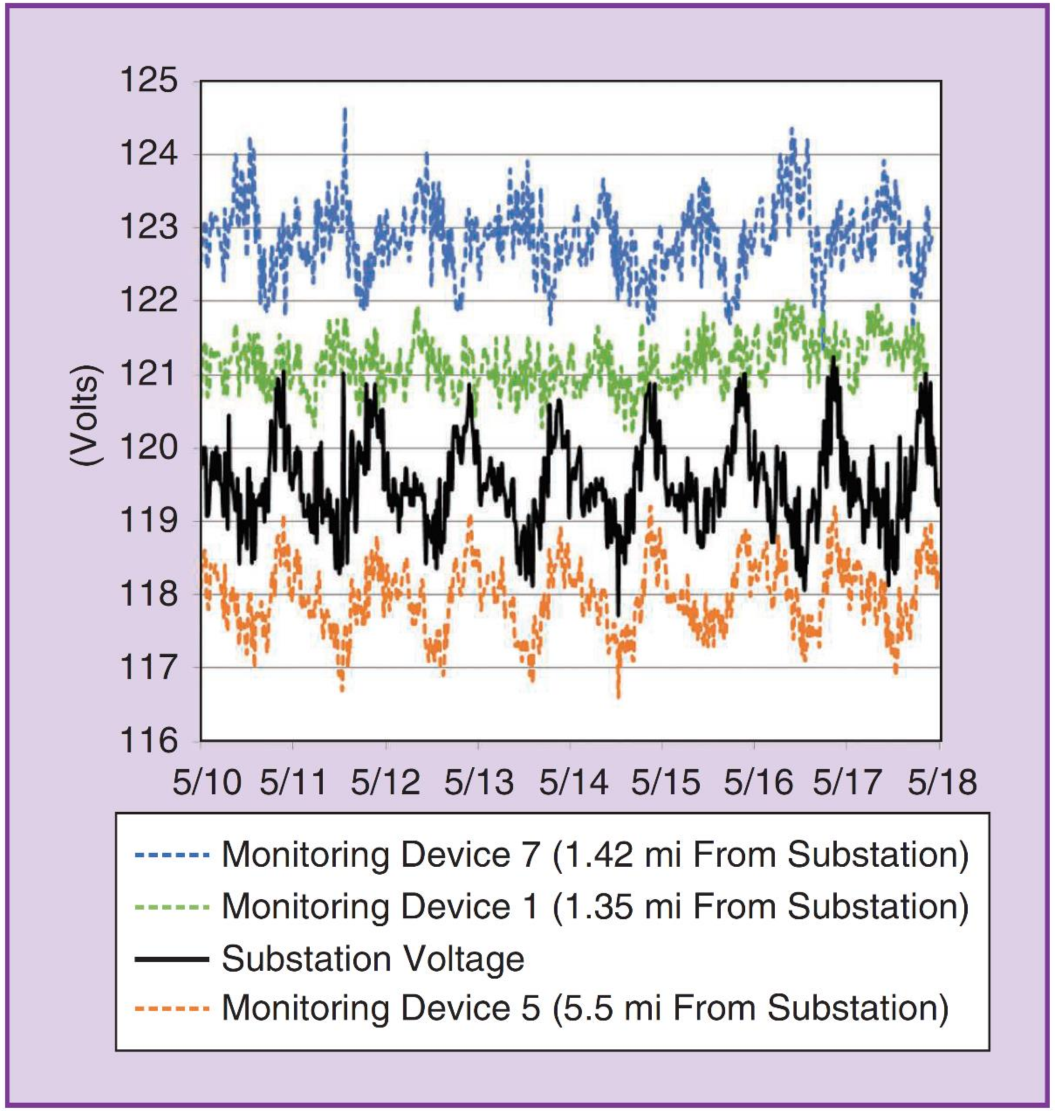
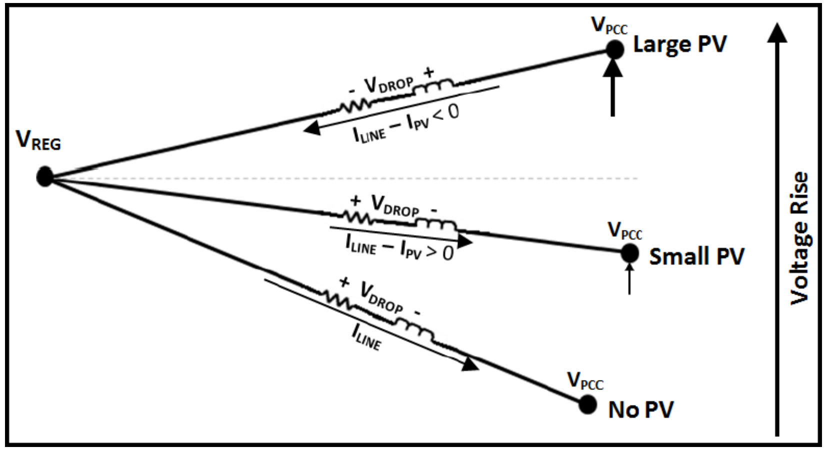


Source: M. Asano, Grid Modernization Applications in a High DER Environment, 2018 IEEE PES T&D Conference and Exposition, Denver CO

Impacts of High Penetration of Behind-the-Meter and Utility-Scale PV DG



Source: M. Asano, Hawai'i's Grid Architecture for High Renewables, IEEE Power and Energy Magazine, Volume 17, Issue 5, Sept.-Oct.-2019

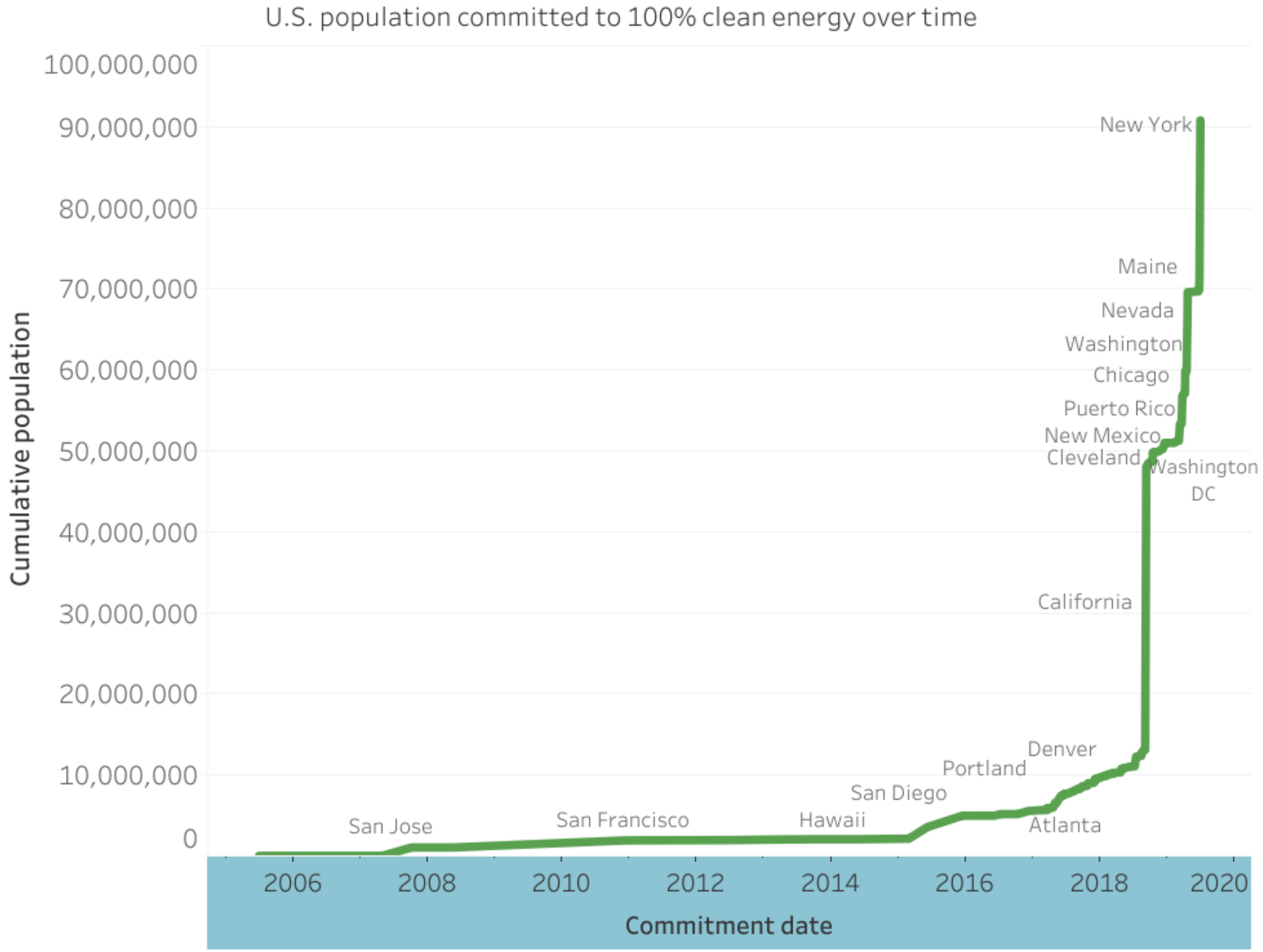


Source: https://www.esig.energy/wiki-main-page/time-series-power-flow-analysis-for-distribution-connected-pv-generation/

What is the industry doing? (3)

- **Long-term (focus on business processes, infrastructure and information systems):**
  - Utilities are updating applicable business processes and practices (e.g., engineering standards, annual planning cycle, load forecasting) to consider DG integration as an intrinsic component of their regular activities
  - Utilities are upgrading distribution assets, information technology, communications, and enterprise system infrastructures to gather and process the data required to operate modern distribution systems with large penetration levels of DG (e.g., sensor, DA and PMU deployment)
  - Utilities are exploring new concepts to fully take advantage of the potential benefits of DG proliferation (e.g., microgrids)
  - Utilities are participating in industry activities to share experiences, and are training their engineers to analyze, plan and operate modern and future distribution systems

U.S. Population Living in States or Cities Committed to 100% Clean Energy

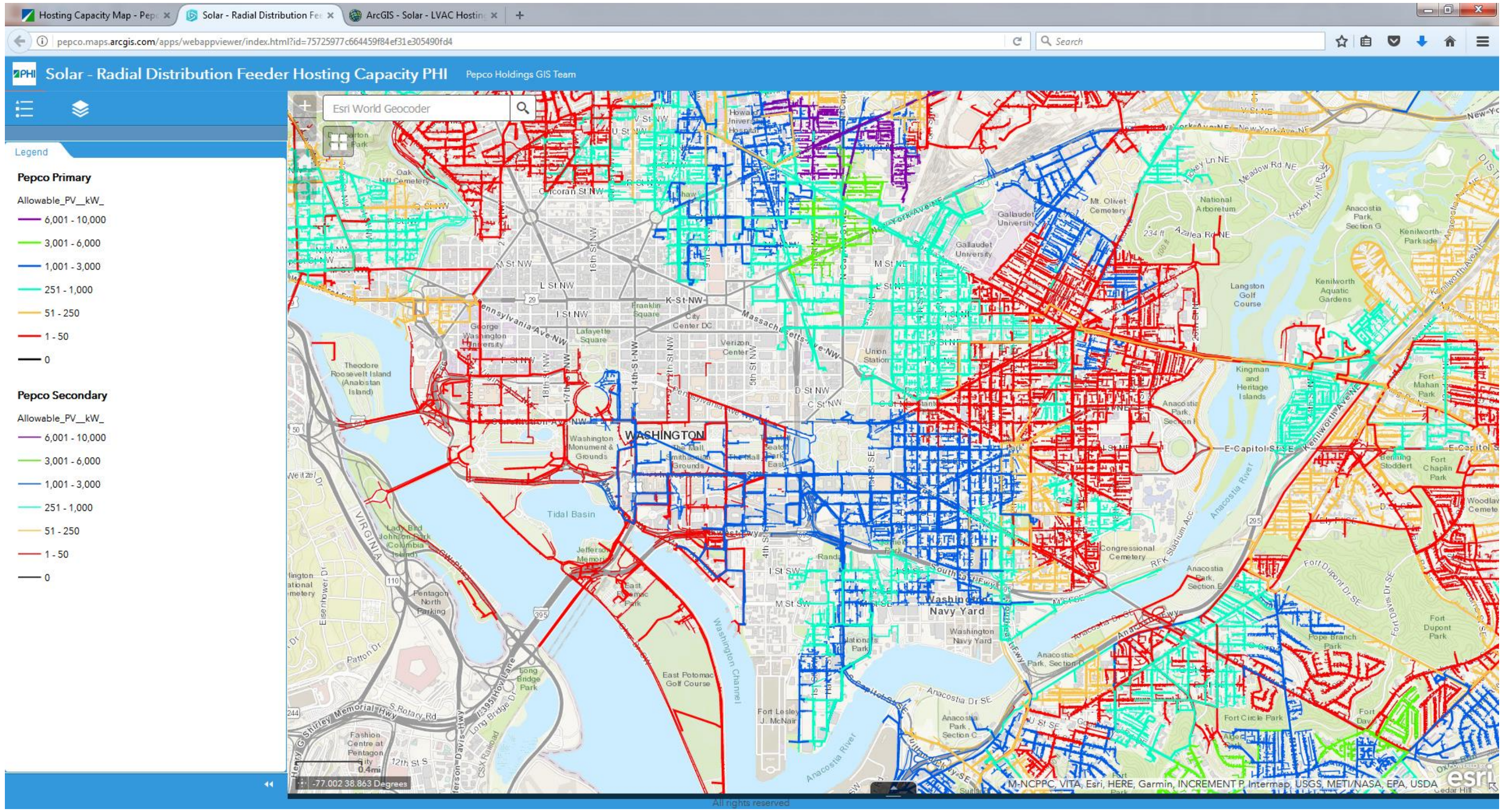


Data sourced using 2016 census. Incremental population for 100% states is reduced by the cities previously committed to 100% clean energy in those states, so as not to double count.

Source: https://www.sierraclub.org/articles/2019/08/100-clean-energy-movement-keeps-moving-forward

Examples of Leading Practice Areas

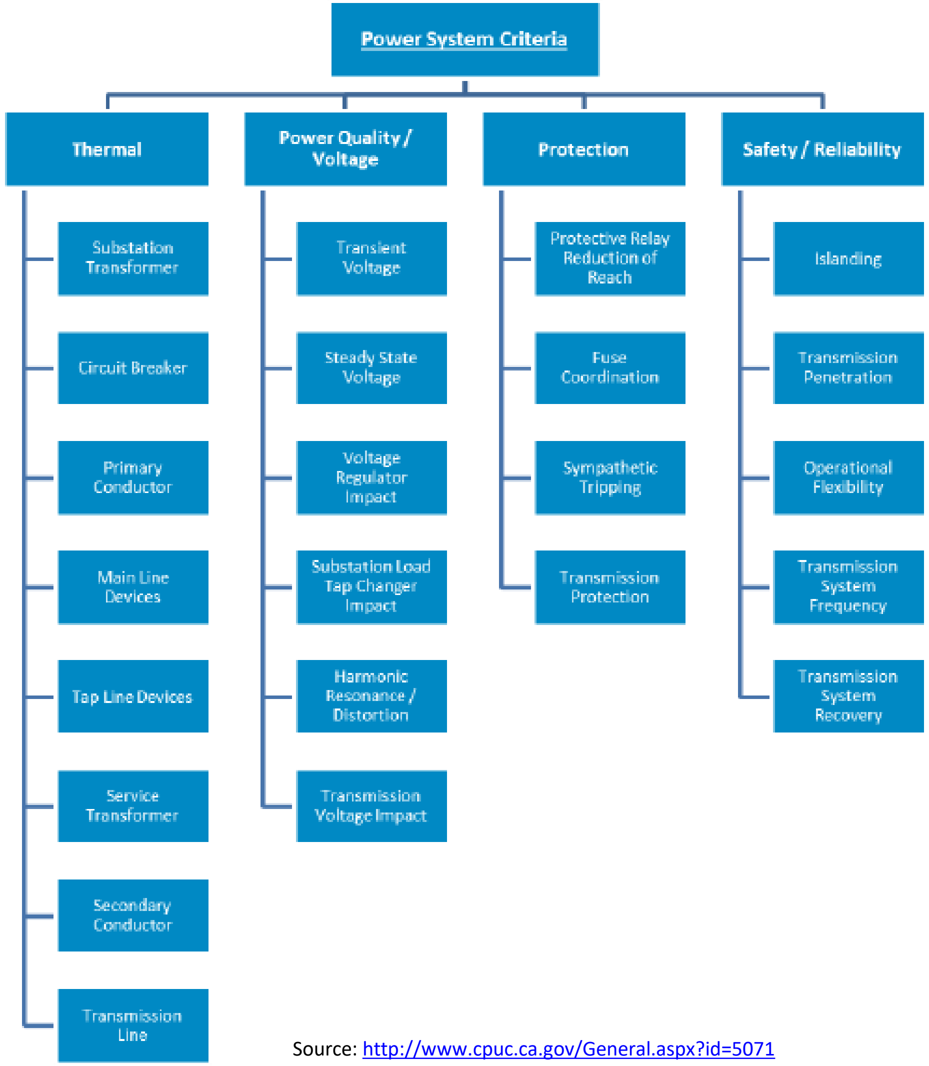
- DER Interconnection Process
- Smart Inverter Standards
- DER Monitoring and Control
- DER Management Systems (DERMS)
- Grid Analytics
- Advanced Distribution Planning
- DER Hosting Capacity
- Spatial Load and DER Forecasting
- Time Series Analyses (8760 hr.)
- Locational Value Analysis



Source: https://www.pepco.com/SmartEnergy/MyGreenPowerConnection/Pages/HostingCapacityMap.aspx

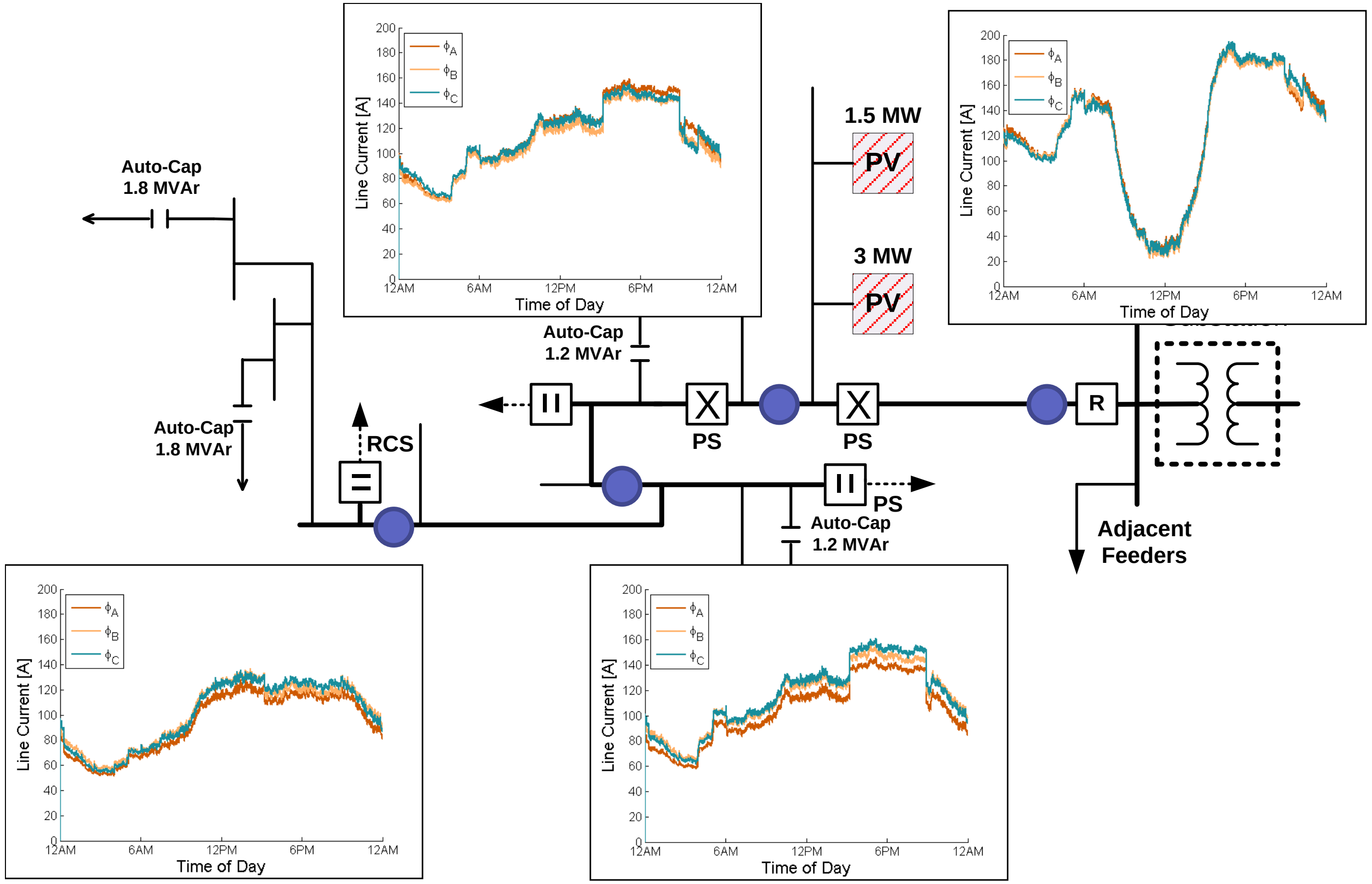
Examples of Leading Practice Areas

DER Hosting Capacity Vision



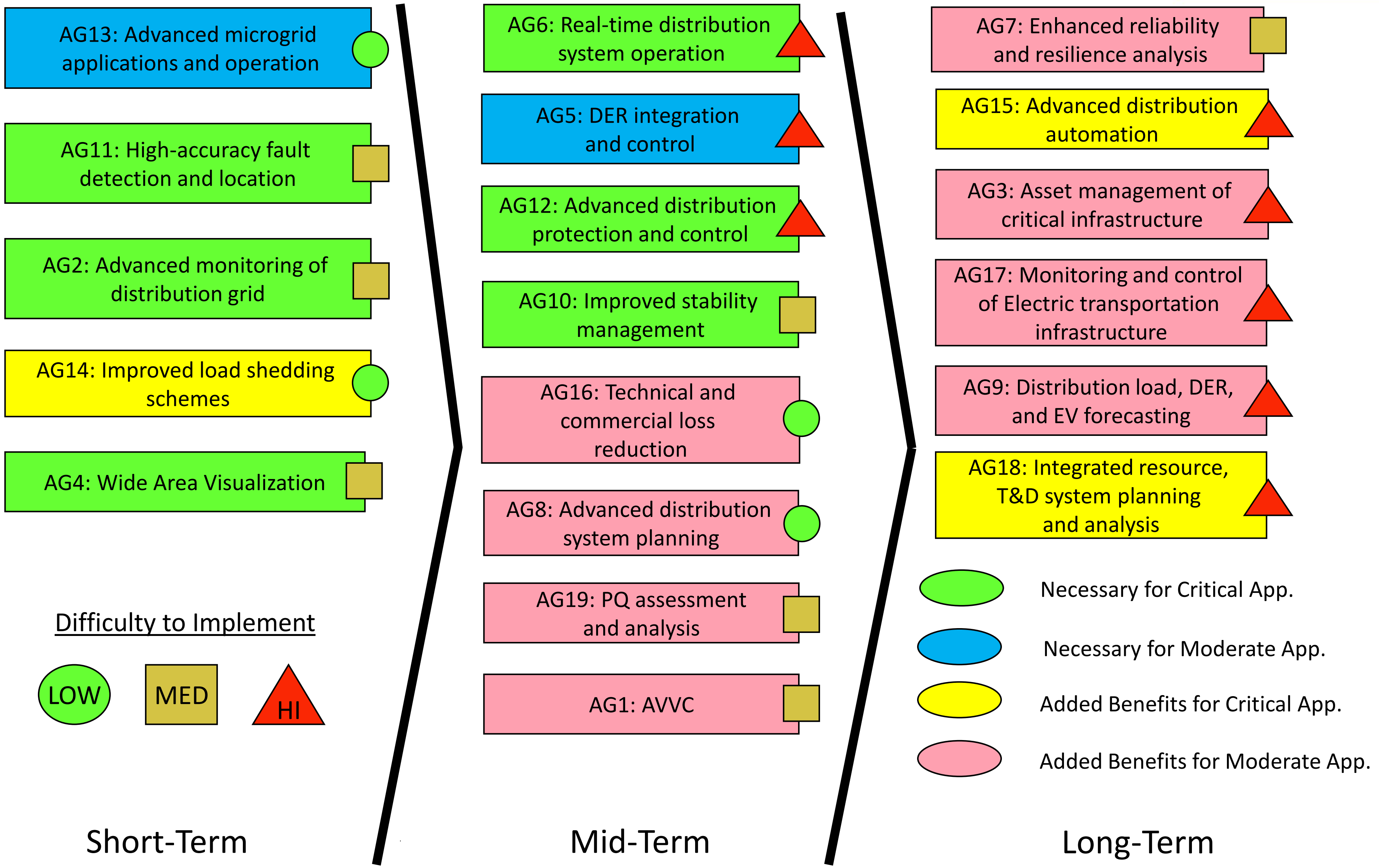
Source: http://www.cpuc.ca.gov/General.aspx?id=5071

High Resolution PV Monitoring

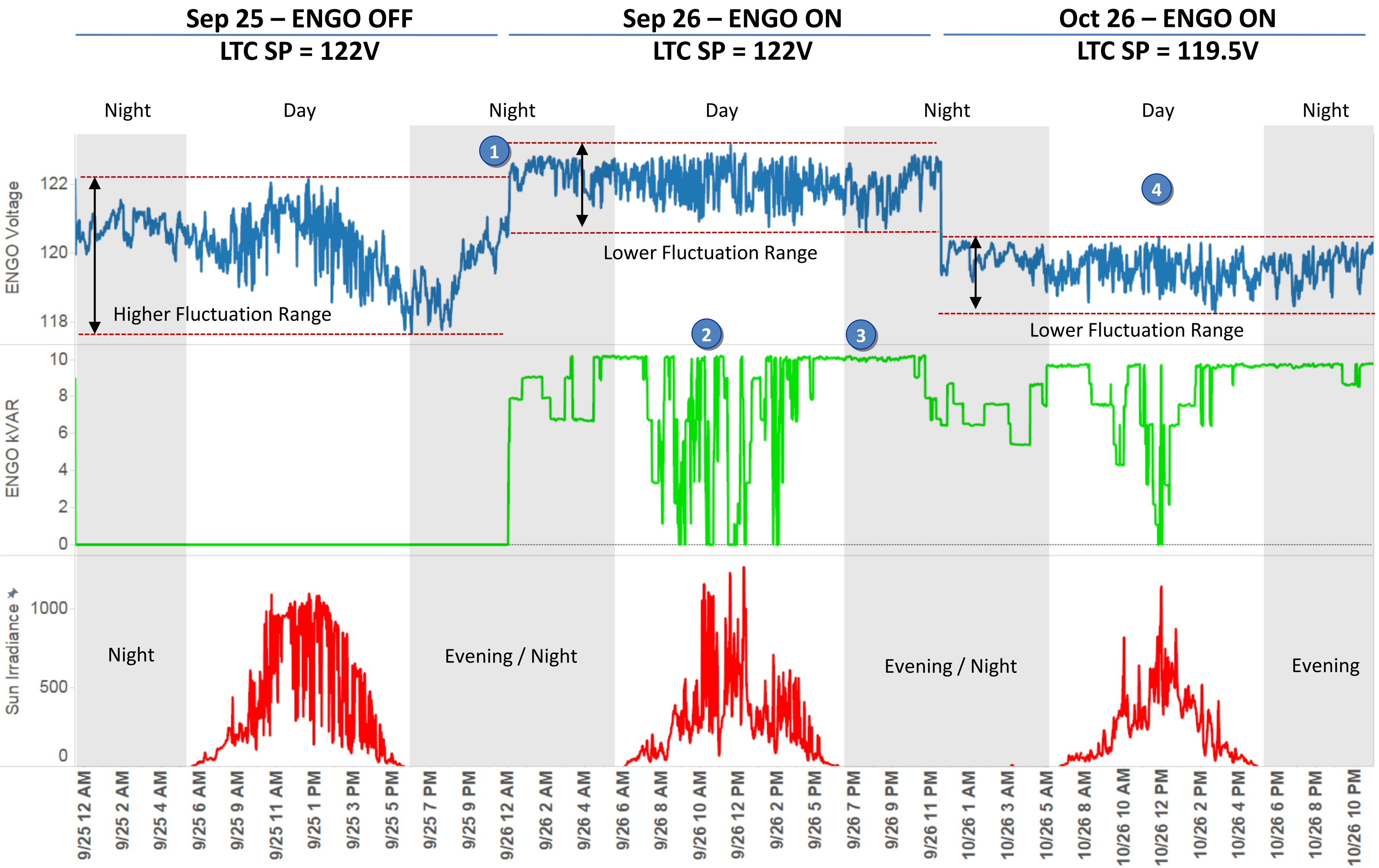


Source: NREL

Synchronized Measurement Technology – Industry Roadmap



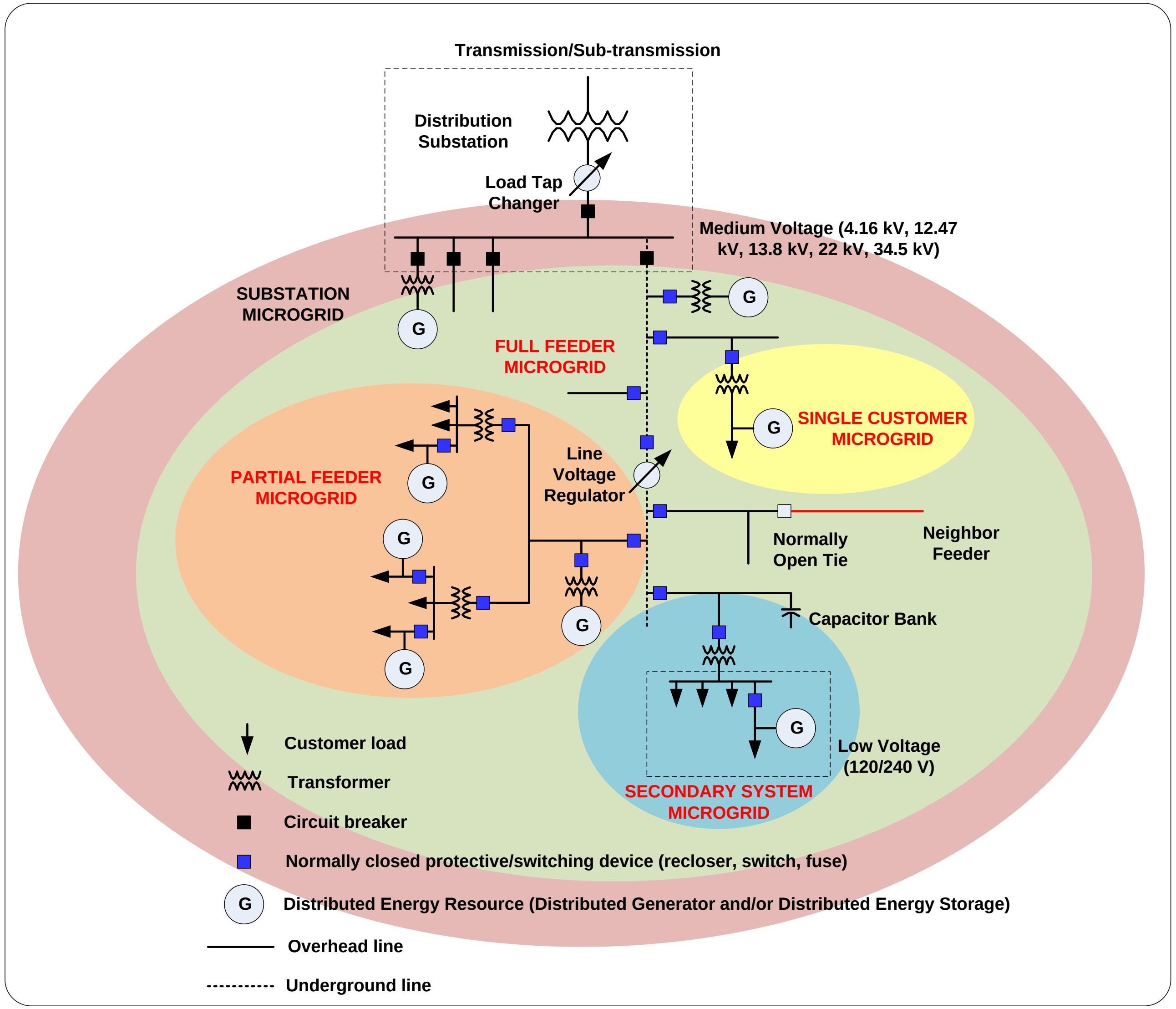
Volt-Var Control at the Grid Edge

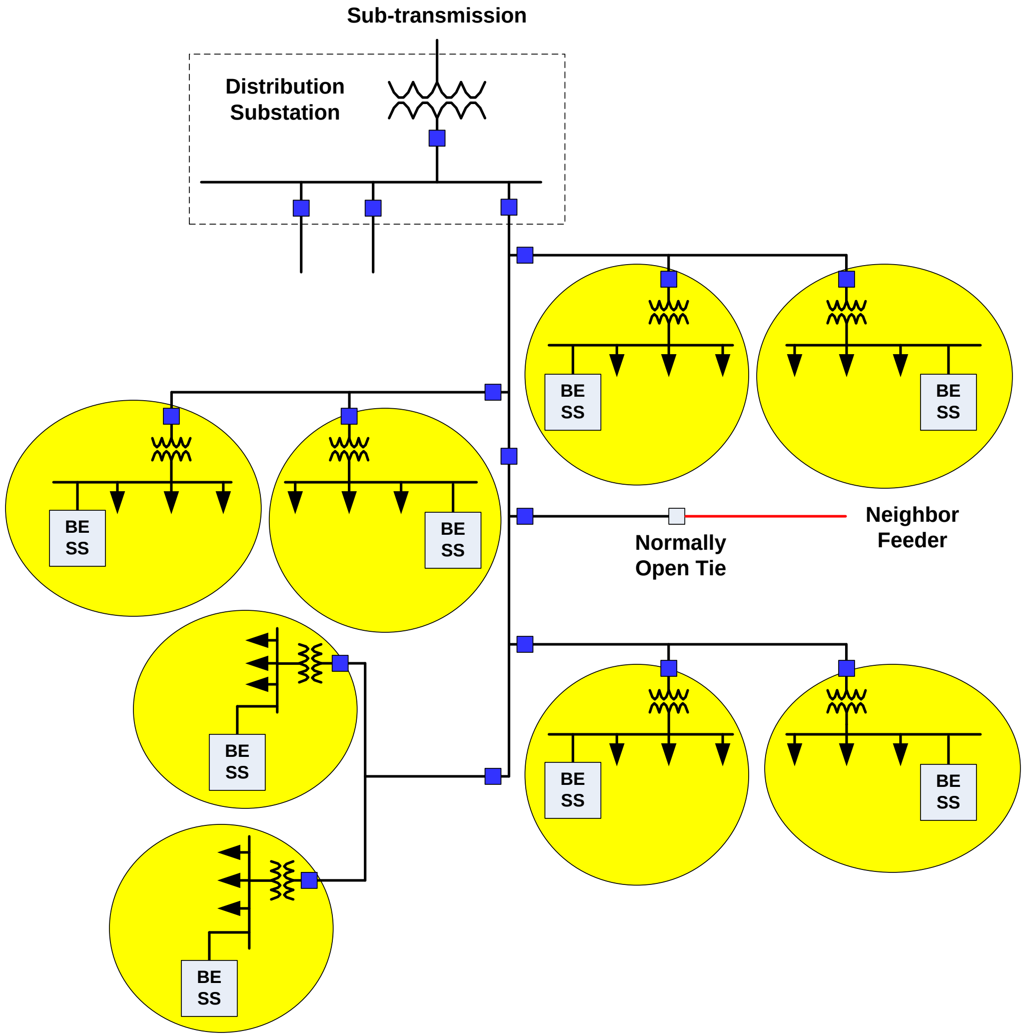


Source: M. Asano, Grid Modernization Applications in a High DER Environment, 2018 IEEE PES T&D Conference and Exposition, Denver CO

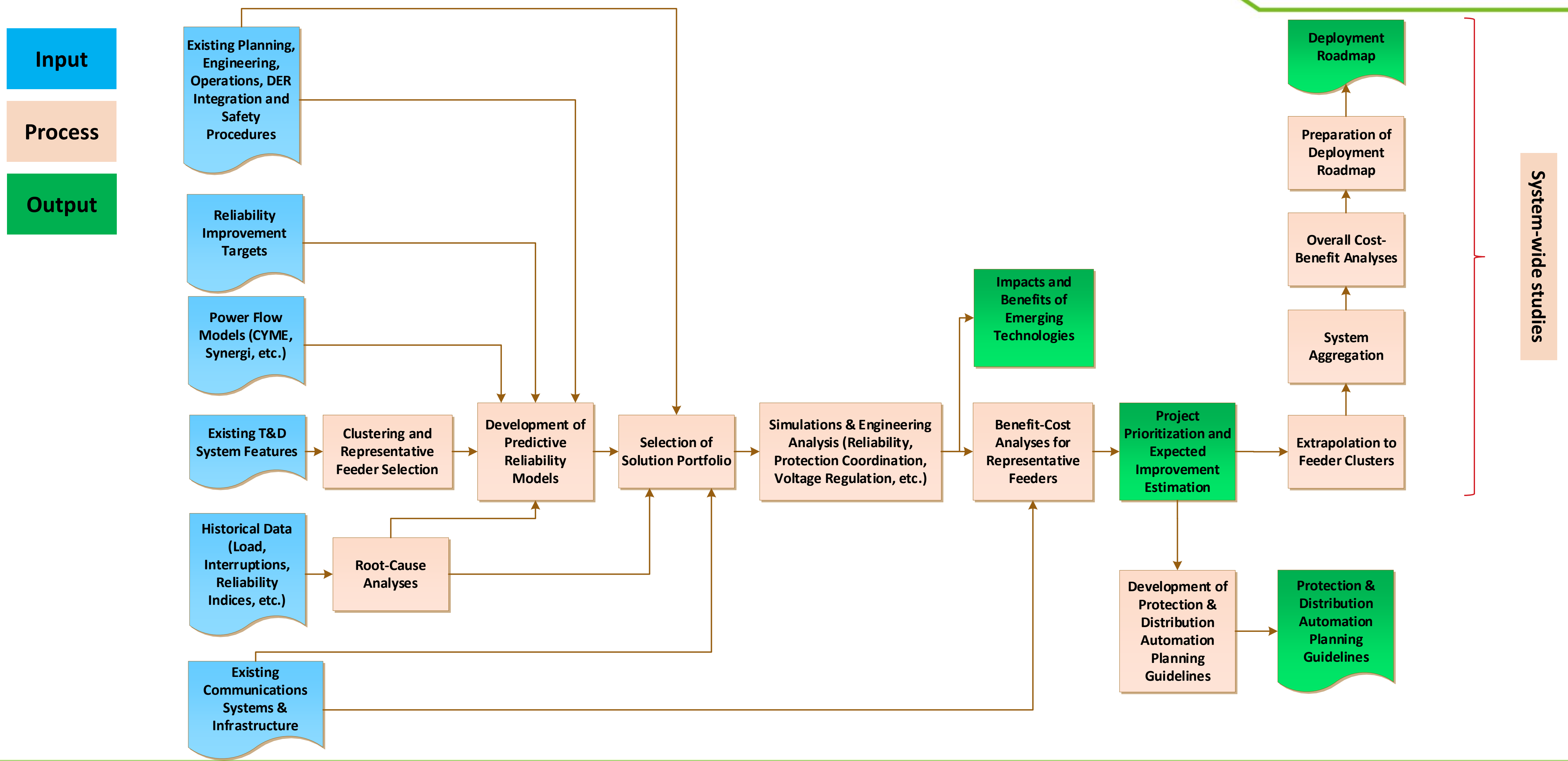
1. **Fluctuation Reduction:** ENGO voltage fluctuation range reduces when ENGO units are active
2. **Daytime Operations:** During the day time, ENGO units provide dynamic VAR support to compensate for PV generation volatility (e.g. cloud cover)
3. **Night Time Operations:** During the night time, ENGO units provide full kVAR support during peak-load times when PV generation is not available
4. **Tap Down LTC to Allow Extra PV Penetration:** ENGO provides voltage support to allow the LTC to tap down permanently which will allow extra PV penetration for the system.

Hierarchical Microgrids & Distributed Energy Storage



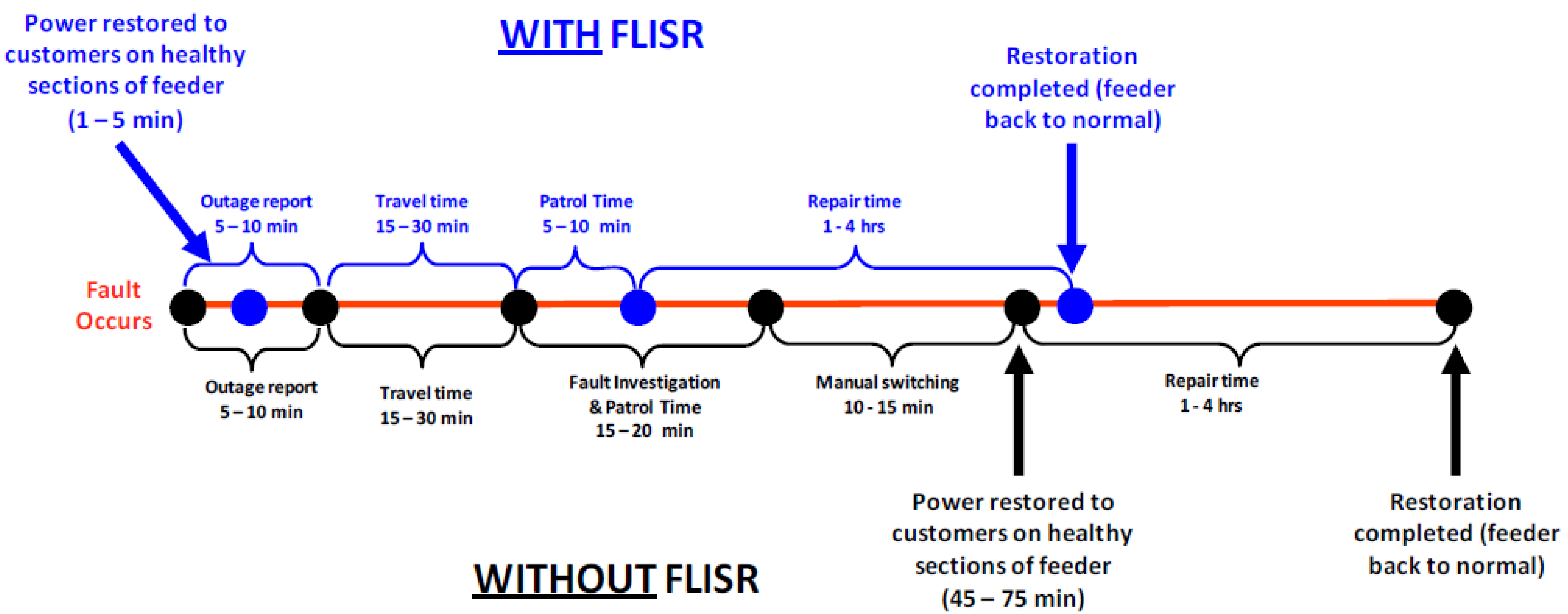


Holistic Reliability, Automation and Protection Modeling & Analysis

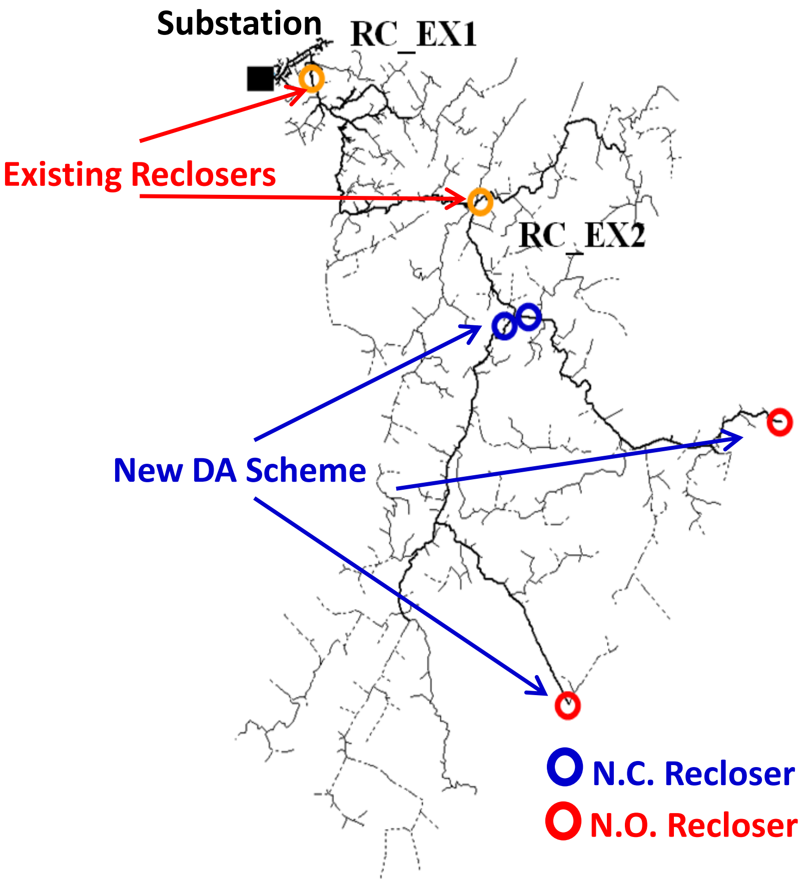


Distribution Automation – FLISR

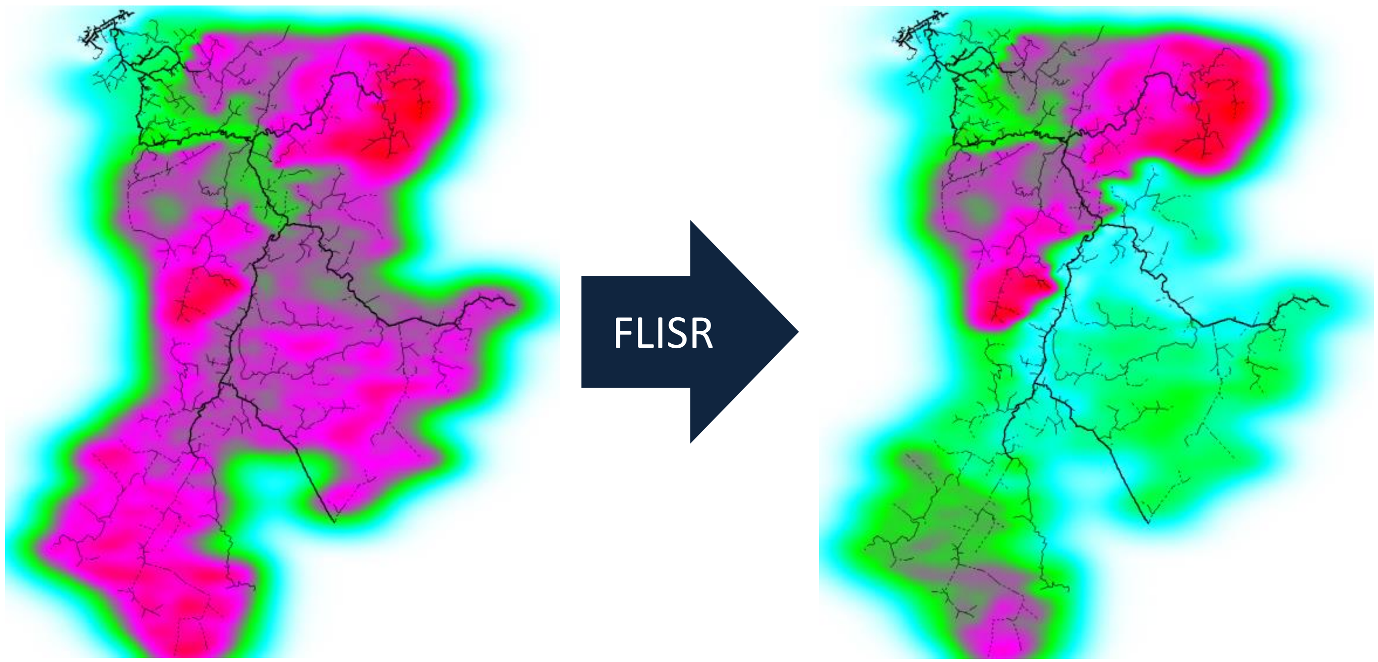
- Fault Location, Isolation, and Service Restoration (FLISR) has been approached as a solution to improve distribution reliability through automation of outage management and service restoration process
  - Focus of FLISR is reduction of frequency and duration of service interruptions at **feeder level**
- FLISR is a foundational technology for an evolving grid and can provide additional benefits



Feeder Reliability Improvement via FLISR

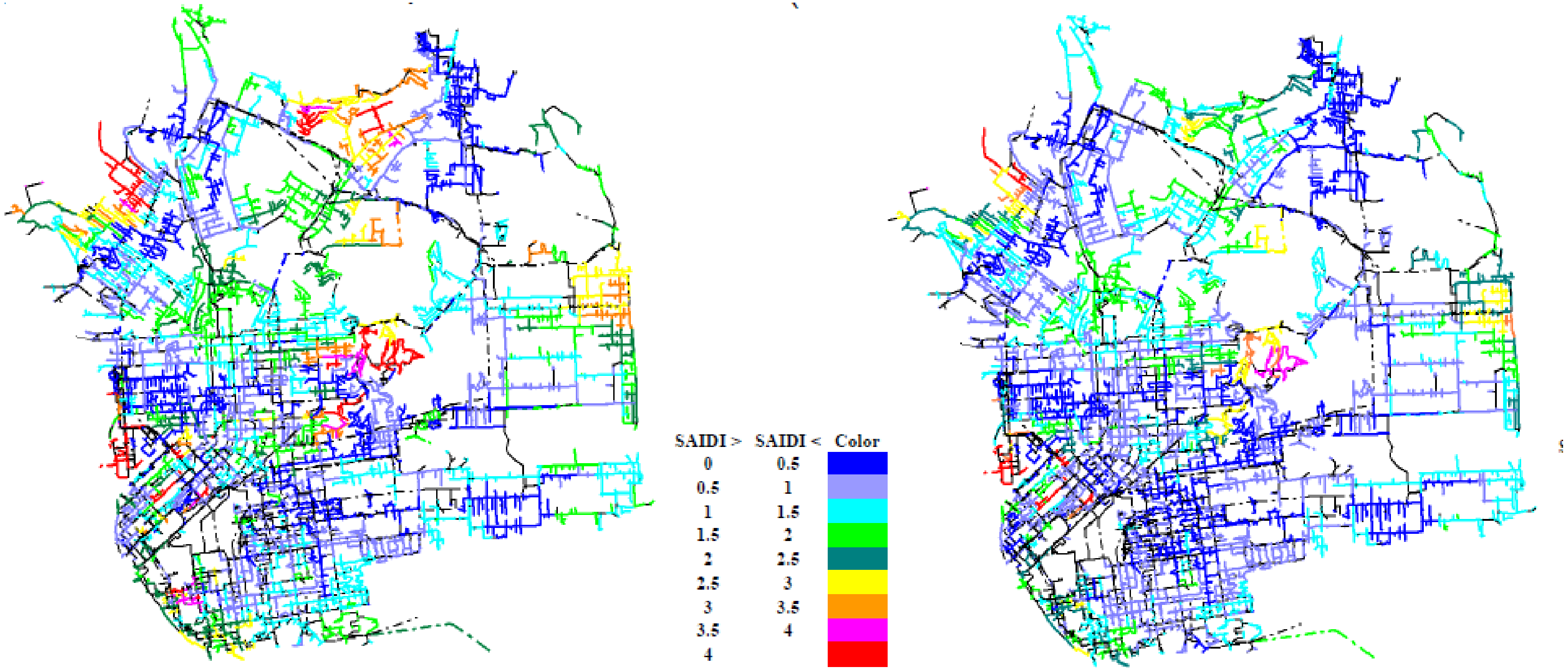


Spatial distribution of expected SAIDI (hr/cust-yr)



Area Reliability Improvement via FLISR

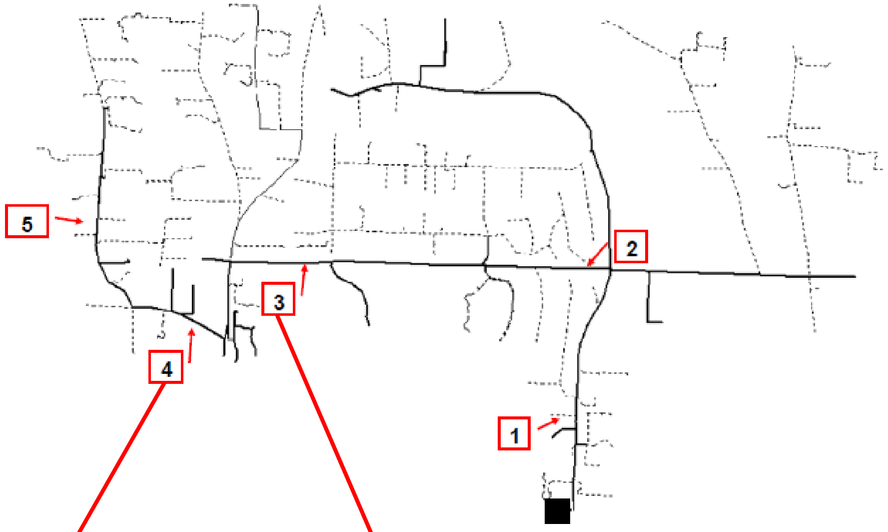
Example: Estimated reliability improvement (SAIDI reduction) due to implementation of distribution automation (FLISR) and other solutions in distribution system



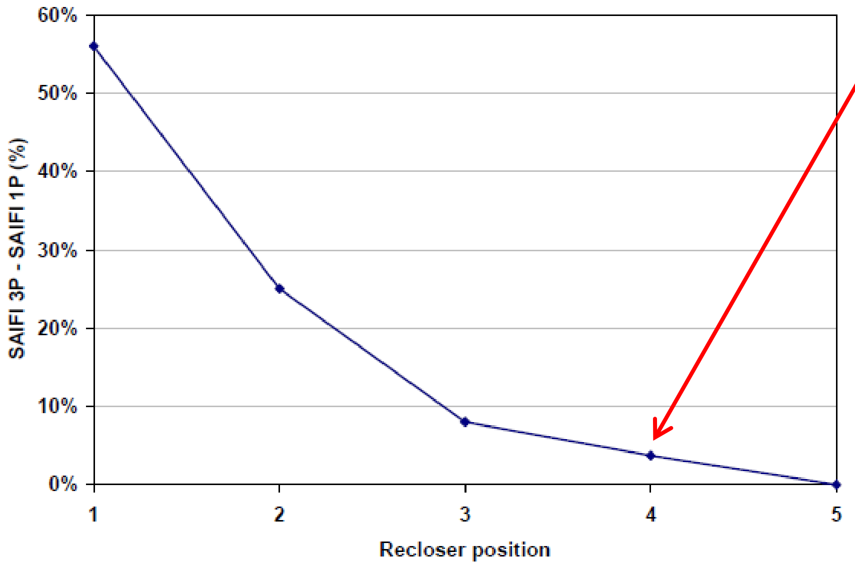
SAIDI before | **SAIDI after**

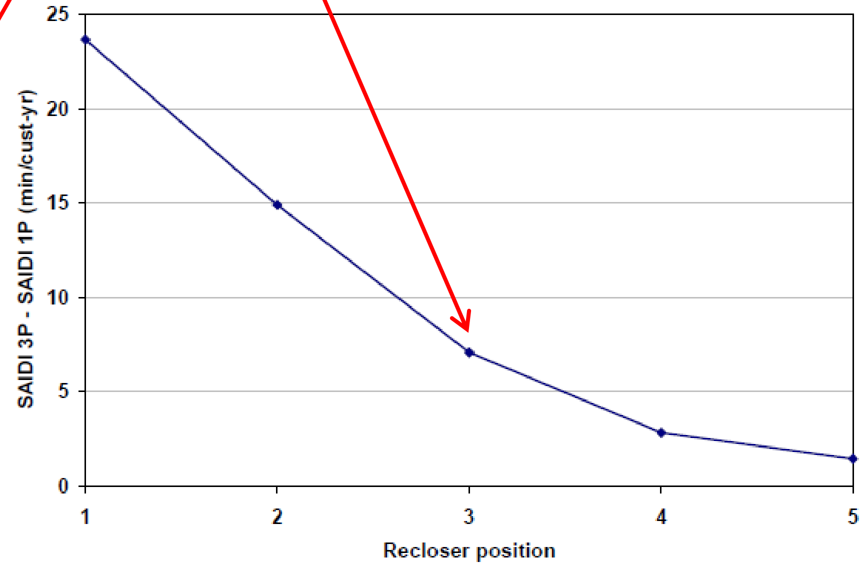
Single-Phase Reclosing and Lockout

Theoretical additional reliability improvement (SAIFI & SAIDI reduction) for different recloser locatior



Benefits are a function of number of downstream customers



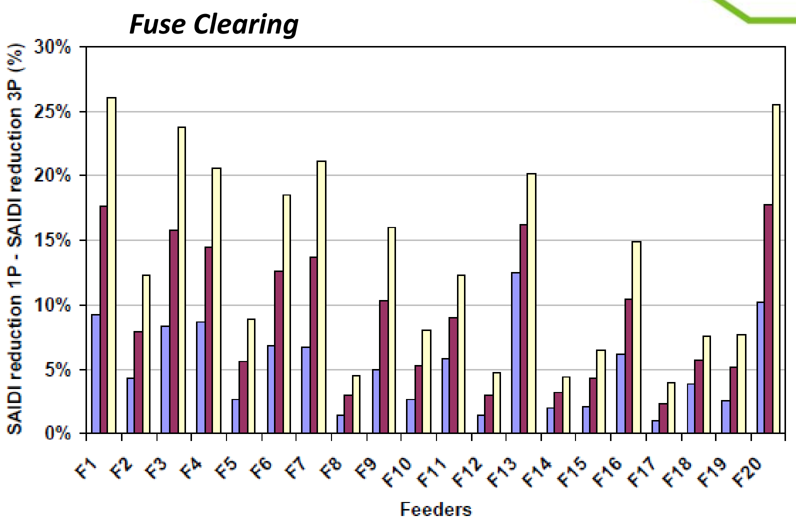


Single-Phase Reclosing and Lockout and Fuse Saving

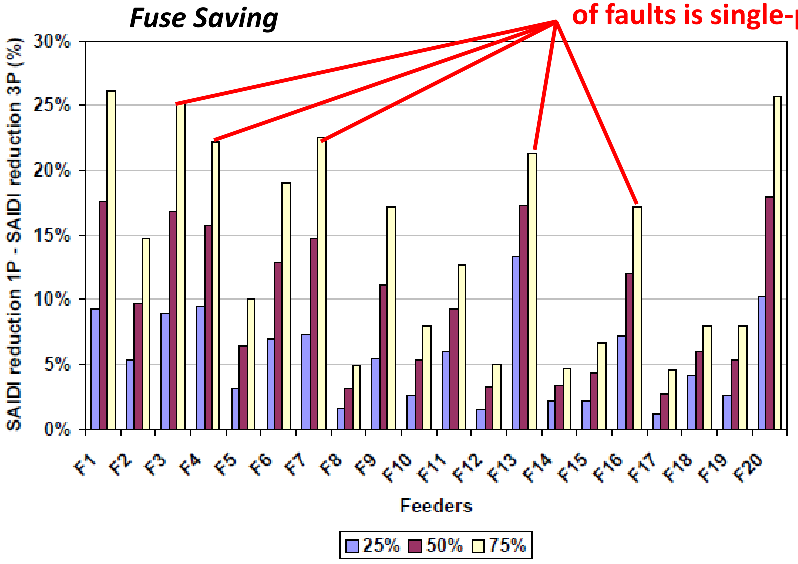
Fuse Clearing

Difference in SAIDI reduction achieved via:
- Single-phase tripping (1P)
- Three-phase tripping (3P)

Fuse Saving



Greater reduction when majority of faults is single-phase



Percentage of faults that are single-phase

Conclusion

- A grid modernization roadmap:
  - Enhances and strengthens grid planning, operations, and engineering activities
  - Identifies and prioritizes key infrastructure investments in support of the utility goals
  - Sets the foundation for transforming and preparing the utility for the future, according to industry leading practices, and outlines key initiatives
- As distribution systems evolve and transform into complex and dynamic active grids due to DER integration, there will be a growing need for real-time operations
- This transformation will require of holistic T&D operations and planning with focus on performance
- Telecommunications, IT systems, big data analysis and AI will play a vital role to enable efficient and effective data collection, processing, storage, and analysis needed for real-time operations and high resolution/granularity spatial/temporal planning
- Distribution modeling, simulation and analysis capabilities should evolve to account and take advantage of these emerging trends and technologies, facilitate planning and operations activities, and ultimately further deliver value to end users

Further Reading

- Modernizing the grid: Challenges and opportunities for a sustainable future, JR Agüero, E Takayesu, D Novosel, R Masiello, IEEE Power and Energy Magazine 15 (3), 74-83
- The utility and grid of the future: Challenges, needs, and trends, JR Agüero, A Khodaei, R Masiello, IEEE Power and Energy Magazine 14 (5), 29-37
- Grid modernization, DER integration & utility business models-trends & challenges, JR Agüero, A Khodaei, IEEE Power and Energy Magazine 16 (2), 112-121
- Roadmaps for the utility of the future, JR Agüero, A Khodaei, The Electricity Journal 28 (10), 7-17
- Grid modernization: challenges and opportunities, JR Agüero, E Takayesu, D Novosel, R Masiello, The Electricity Journal 30 (4), 1-6
- Tools for success: Distribution System Planning in the Smart Grid Era, JR Aguero, IEEE Power and Energy Magazine 9 (5), 82-93
- Improving the reliability of power distribution systems through single-phase tripping, JR Agüero, J Wang, JJ Burke, IEEE PES T&D 2010, 1-7

Thanks!