Moving Beyond an Integrated Grid to an Integrated Energy Network

Aidan Tuohy, PhD
EPRI Grid Operations and Planning
24th MEM Congress
Nov 1, 2018

The Energy System Today is Fragmented

Companies, products, business models, regulation

Integration can Improve Reliability, Increase Efficiency, Create New Opportunities, and Expand Customer Choice

Selected “Global Points of View”

Using Cleaner Energy

- Efficiency emerges across the energy sector
- Efficient electrification is an opportunity toward a cleaner future
- Transportation becomes more efficient and cleaner

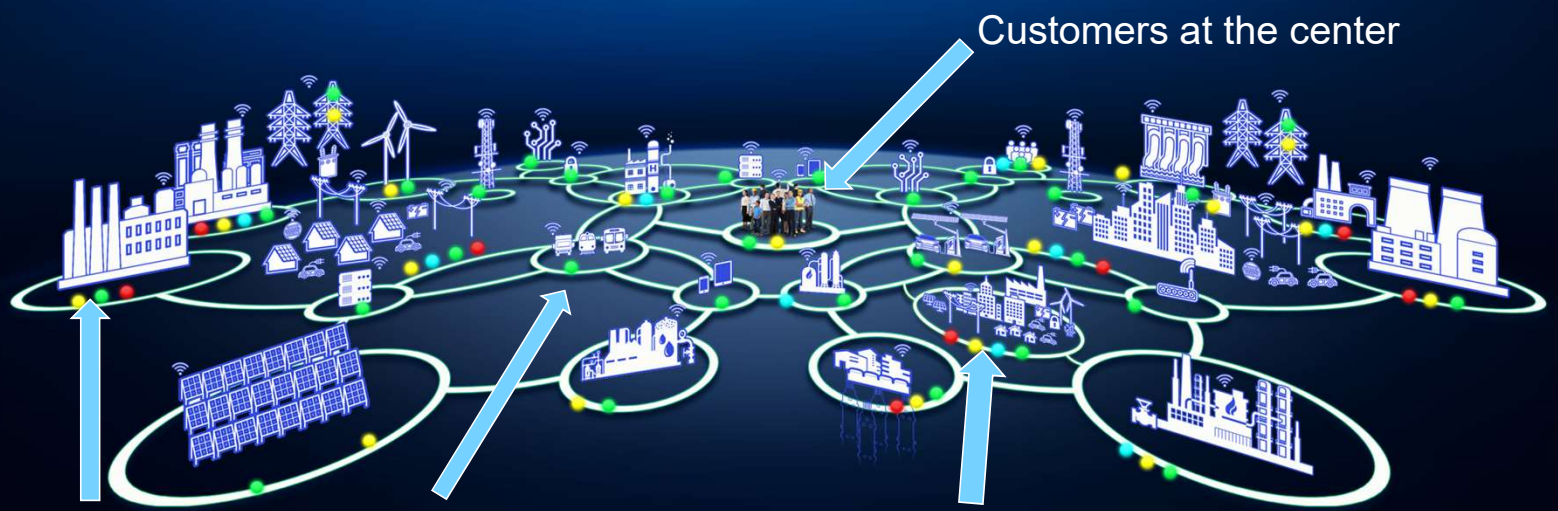
Producing Cleaner Energy

- Energy reduces its environmental footprint
- Central-station generation serves an anchor role
- Renewable energy deploys rapidly

Integrating Energy Resources

- Connections across energy sources important
- Integrated electric grid is key enabler
- Higher expectations for power quality/reliability
- Security/resiliency challenges and opportunities

Integrated Energy Network

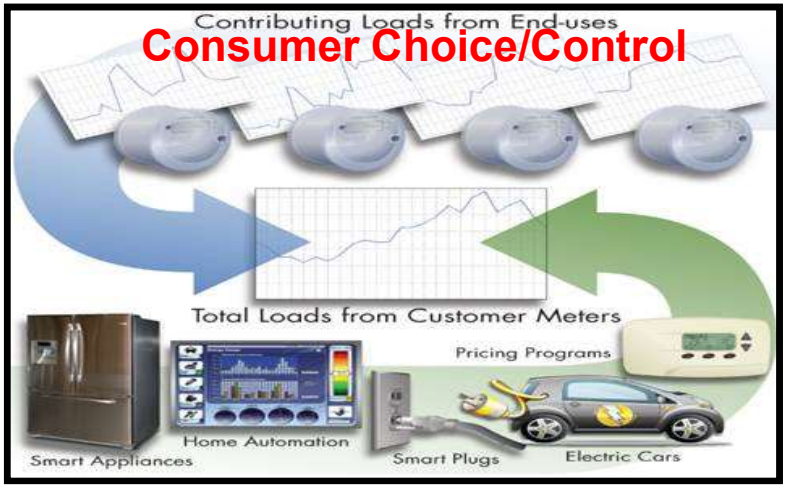


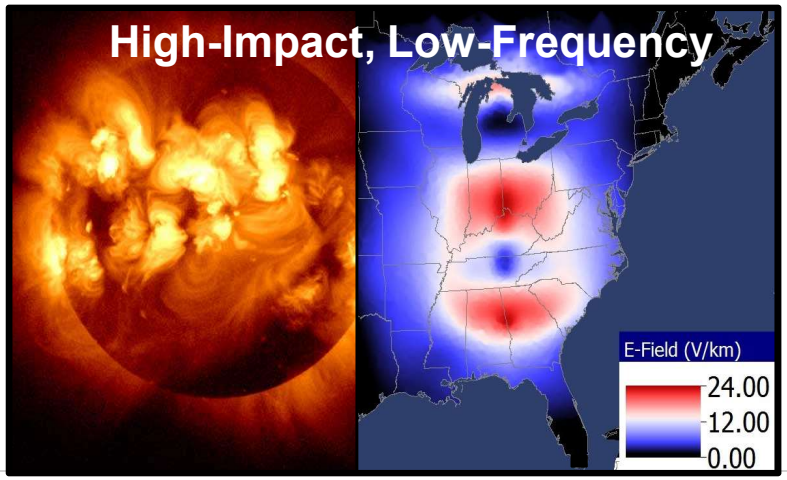
Energy and Natural Resource Systems are Integrated to Provide Reliable, Safe, Affordable, Cleaner Energy and Expanded Customer Choice

EPRI | ELECTRIC POWER RESEARCH INSTITUTE

Transforming Electricity Sector – An Integrated Electricity Grid

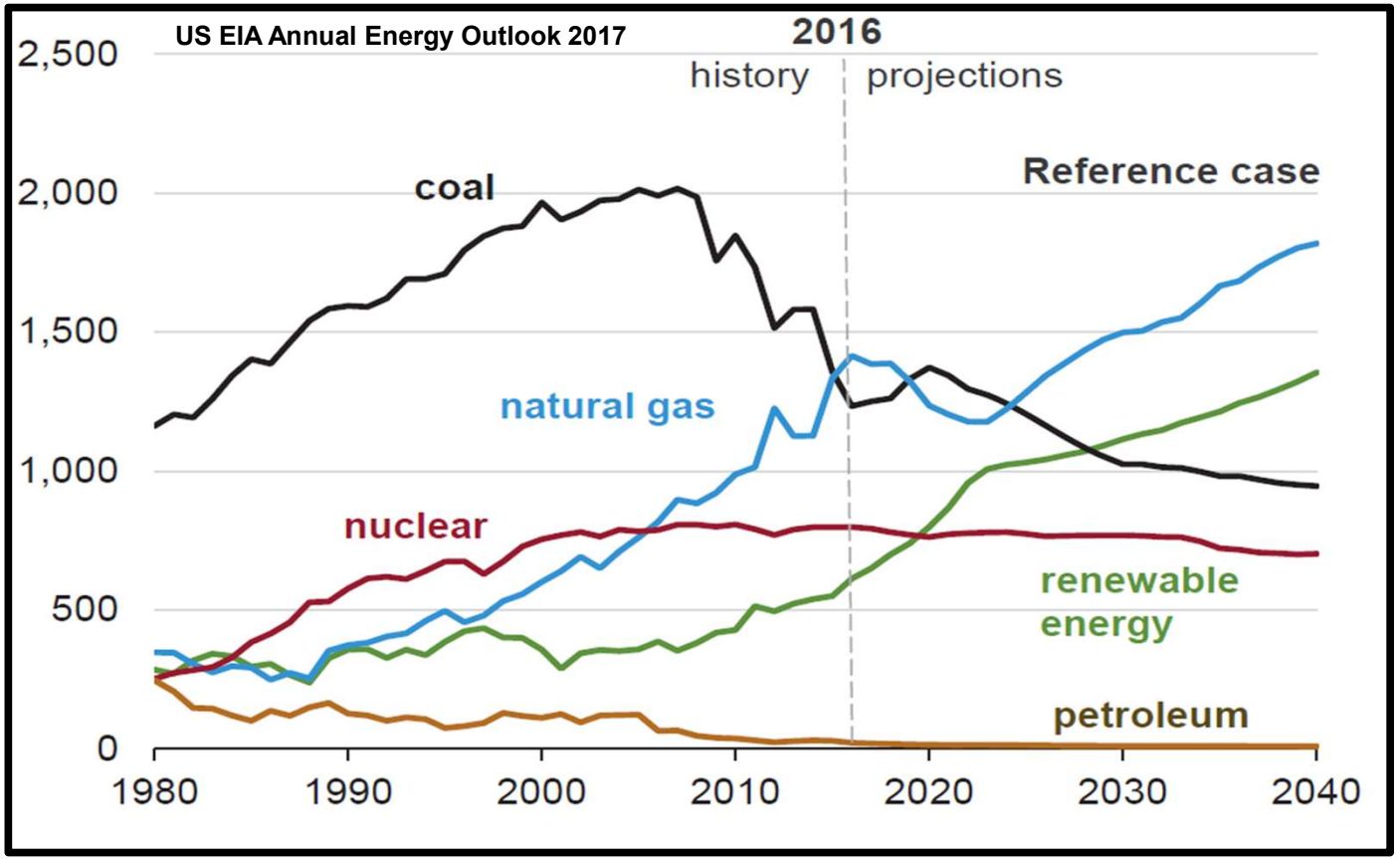
Present Trends Impacting Planning Process



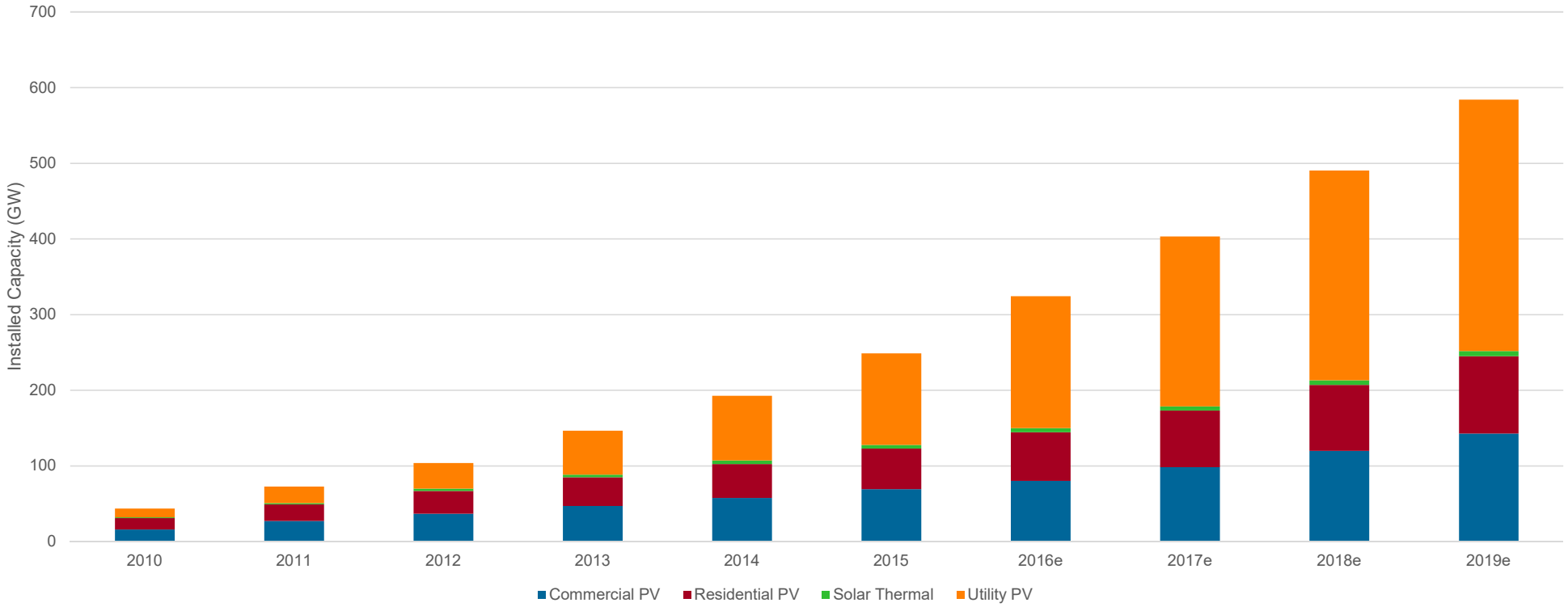


Changing Generation Mix

Gas and central-station renewables continue to replacing coal



Increase in global installed solar capacity



Source: Bloomberg New Energy Finance, illustrated by EPRI

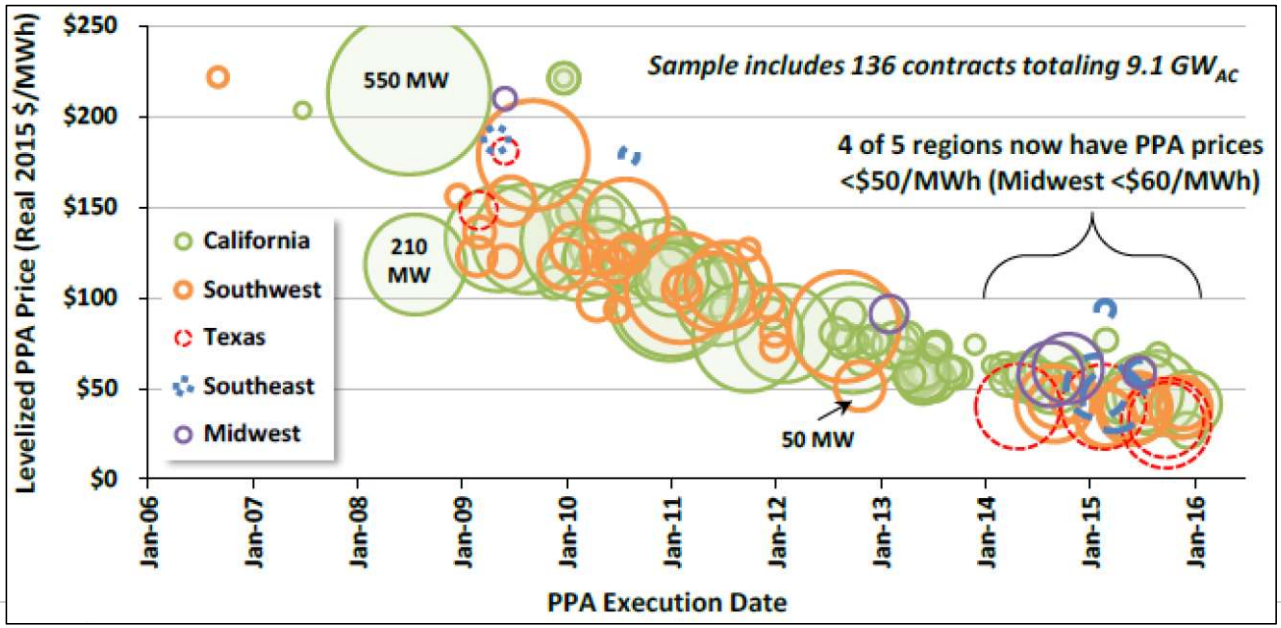
Near term estimates show growth in small-scale as well as utility scale PV

EPRI ELECTRIC POWER RESEARCH INSTITUTE

PV Costs Declining: Economics are a Major Factor in Deployment

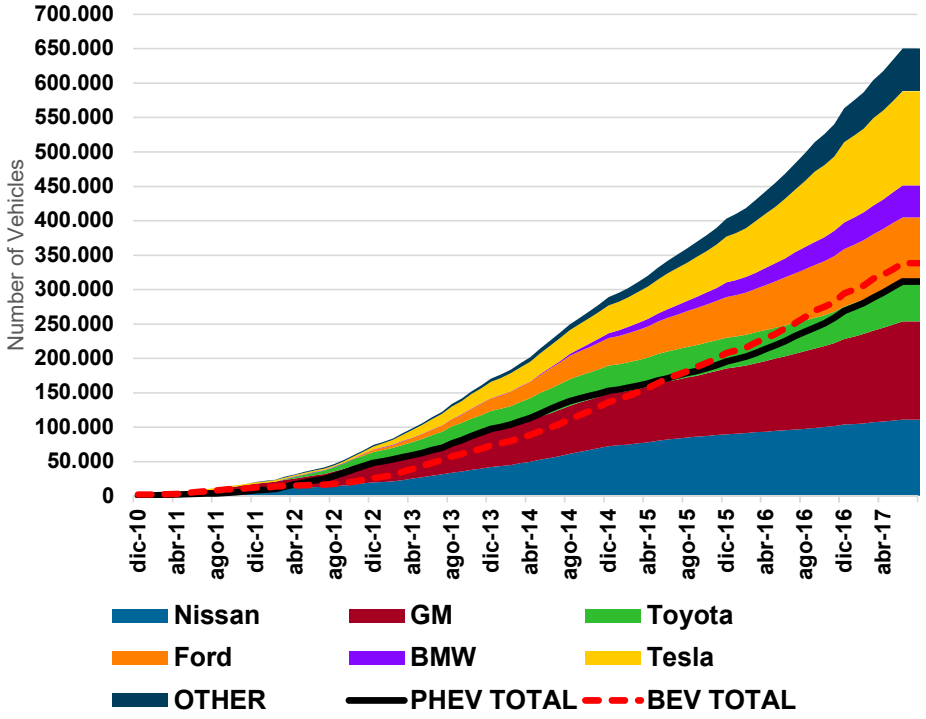
PV Price	Residential	Commercial	Utility-Scale
2007	$8.20/$W_{dc}$	$7.50/$W_{dc}$	$6.20/$W_{dc}$
2017 (Q1)	$2.92/$W_{dc}$	$1.53/$W_{dc}$	Fix: $1.10/$W_{dc;}$ SAT: $1.14/$W_{dc}$
2022E	$1.99/$W_{dc}$	$1.03/$W_{dc}$	$0.79/$W_{dc}$

Source: GTM Research, *PV System Pricing H1 2017: Breakdowns and Forecasts; Note: National Average Turnkey PV Installation / EPC Price ($/Wdc)*



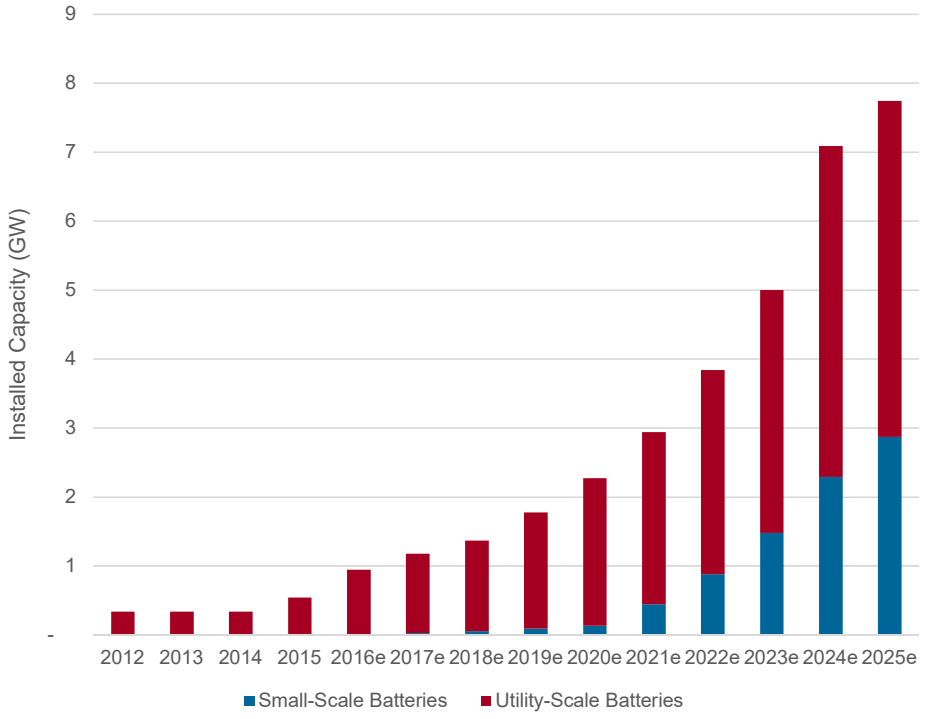
Not just wind and solar PV

Electric Vehicles



Source: EPRI Program on Electric Transportation

Batteries



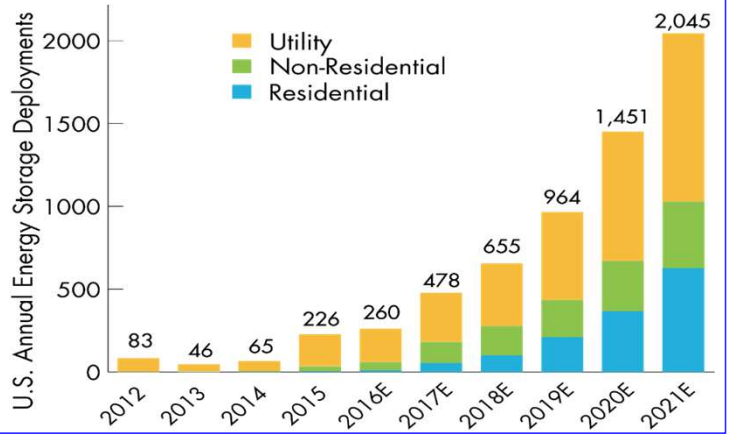
Source: Bloomberg New Energy Finance, illustrated by EPRI

EPRI ELECTRIC POWER RESEARCH INSTITUTE

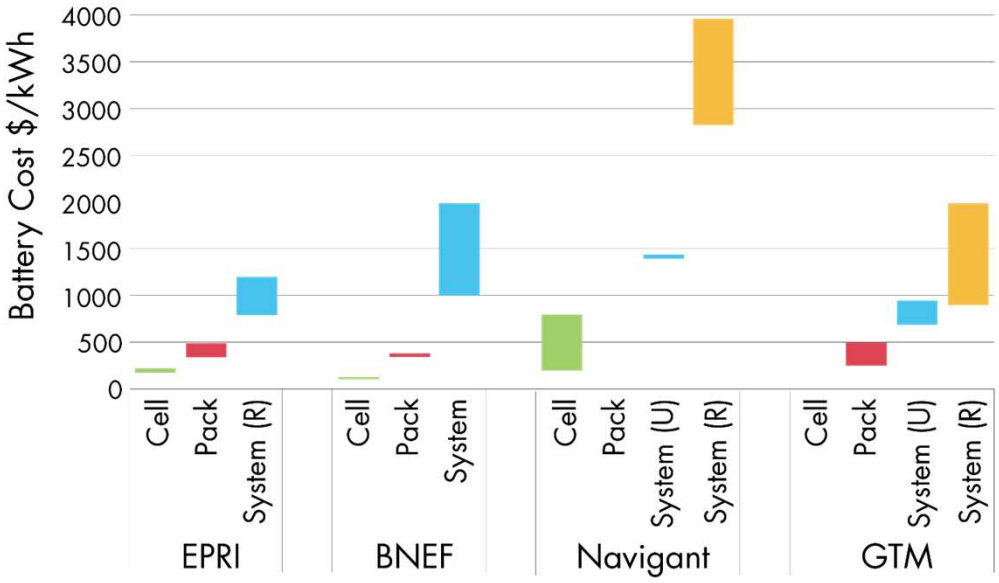
Energy Storage Market Outlook

Battery Energy Storage Systems gain momentum primarily as distribution system and microgrid asset.

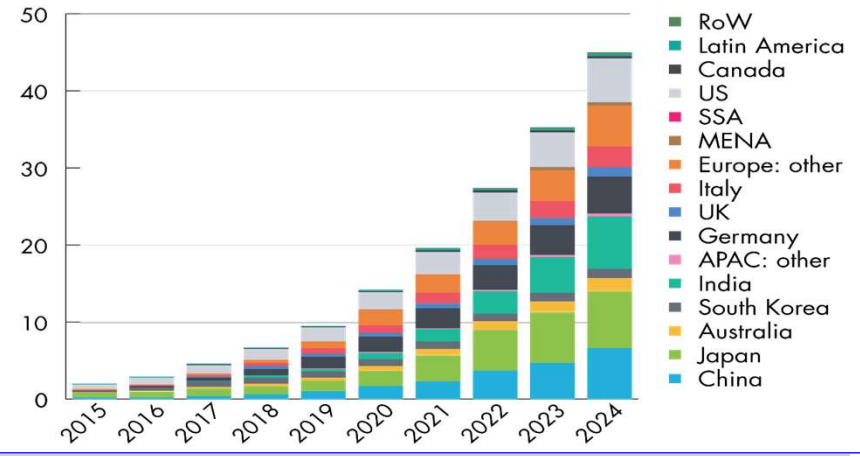
GTM Research: U.S. Annual Energy Storage Deployment Forecast, 2012-21 (MW)



Li-ion Cost Estimates at the Cell, Pack, and System Level ($/kWh)

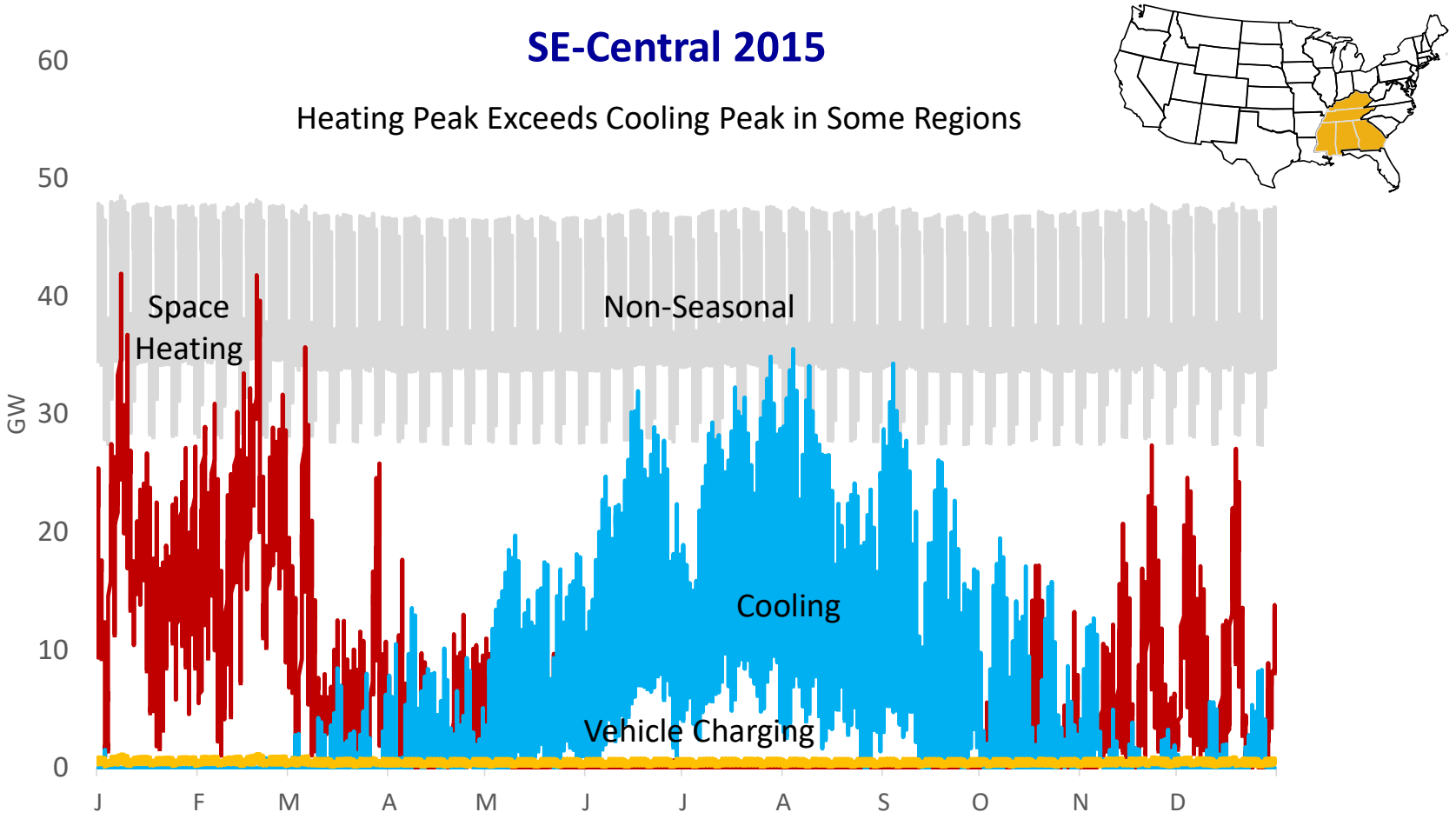


BNEF: Global Installed Capacity Forecast, 2015-24 (GW)



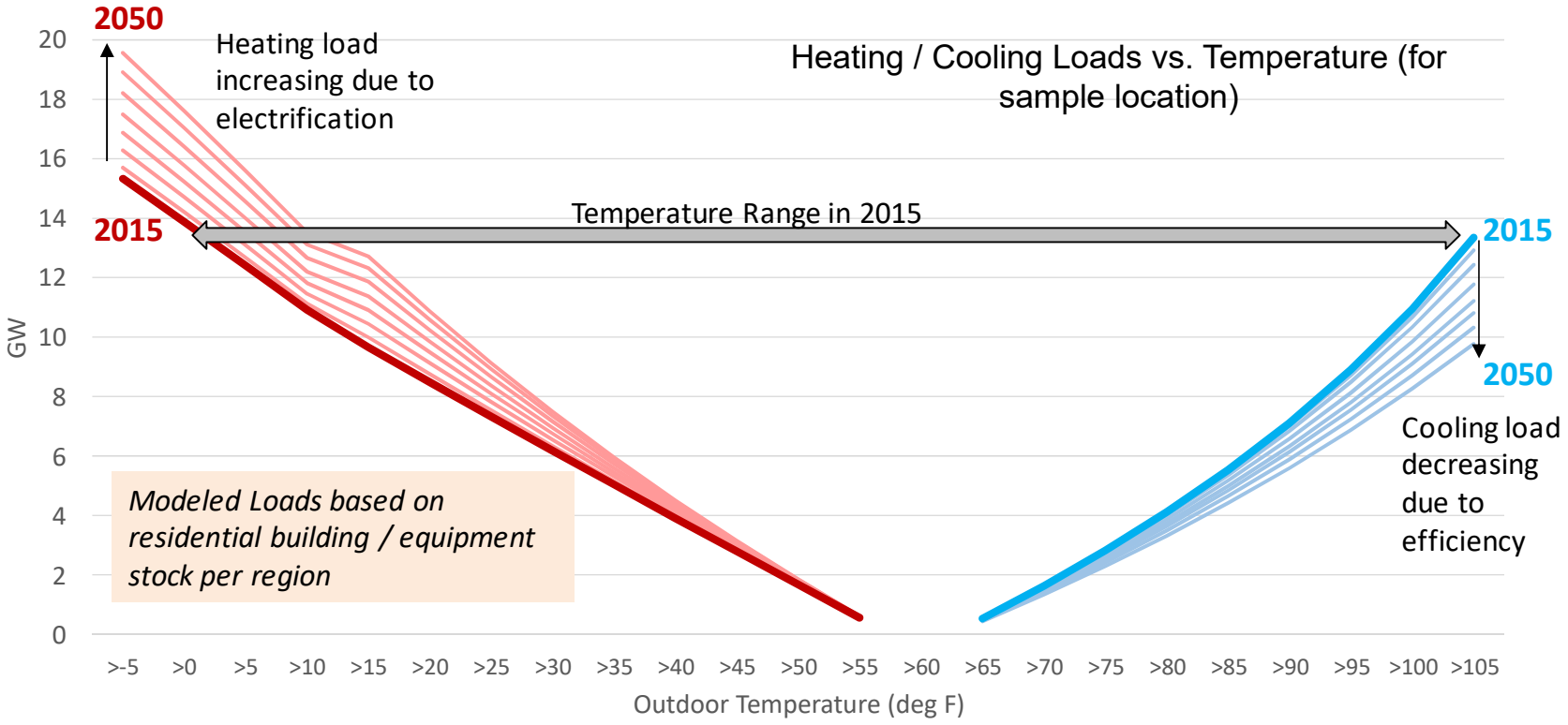
EPRI ELECTRIC POWER RESEARCH INSTITUTE

Load Shape Changes…Electrification and Efficiency Impact



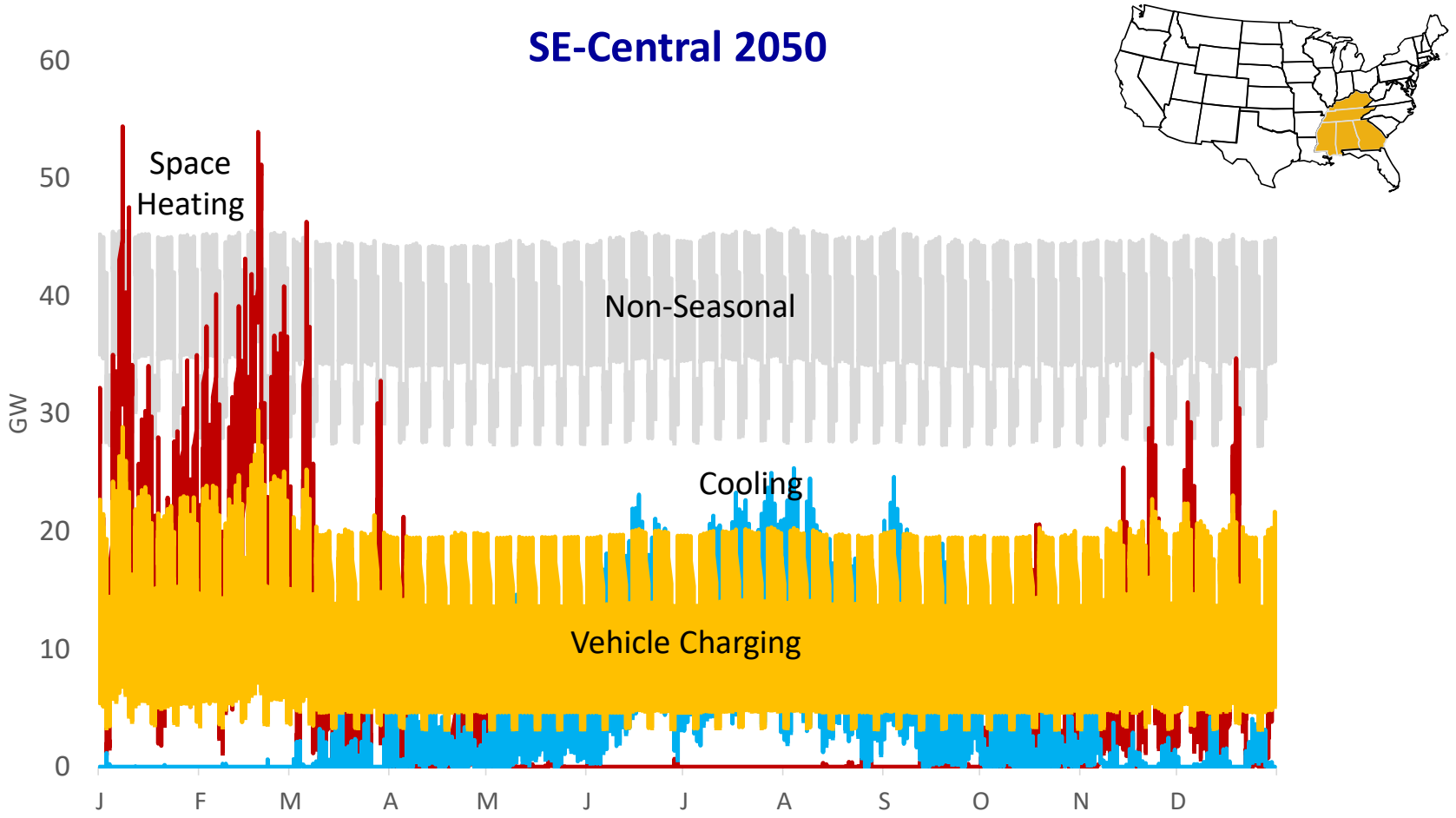
EPRI ELECTRIC POWER RESEARCH INSTITUTE

Potential Load Shape Changes…
Electrification and Efficiency



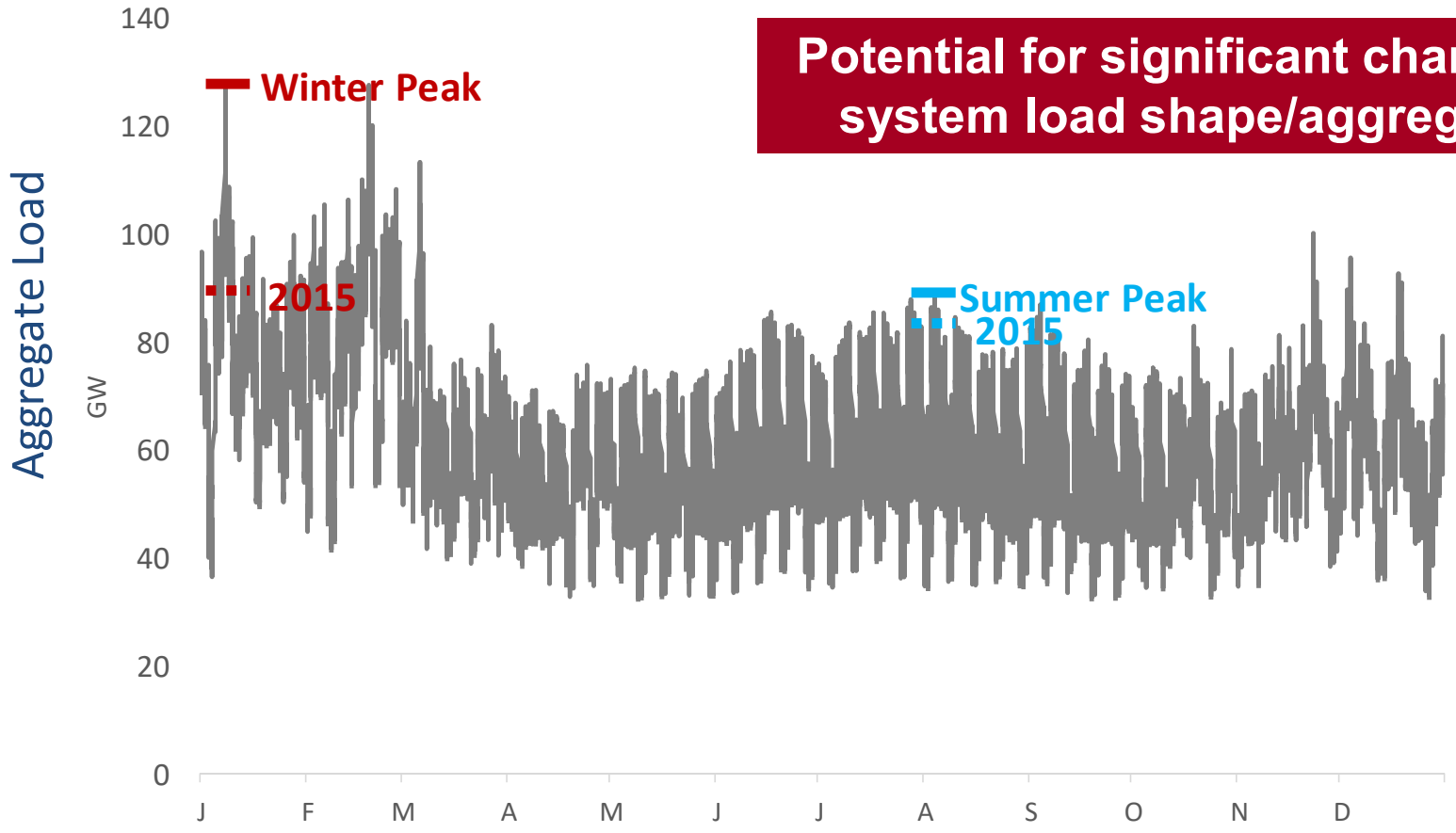
EPRI ELECTRIC POWER RESEARCH INSTITUTE

Load Shape Changes…How Will This Impact Supply Mix/Grid Assets?



EPRI ELECTRIC POWER RESEARCH INSTITUTE

Potential Load Shape Changes…
Electrification and Efficiency

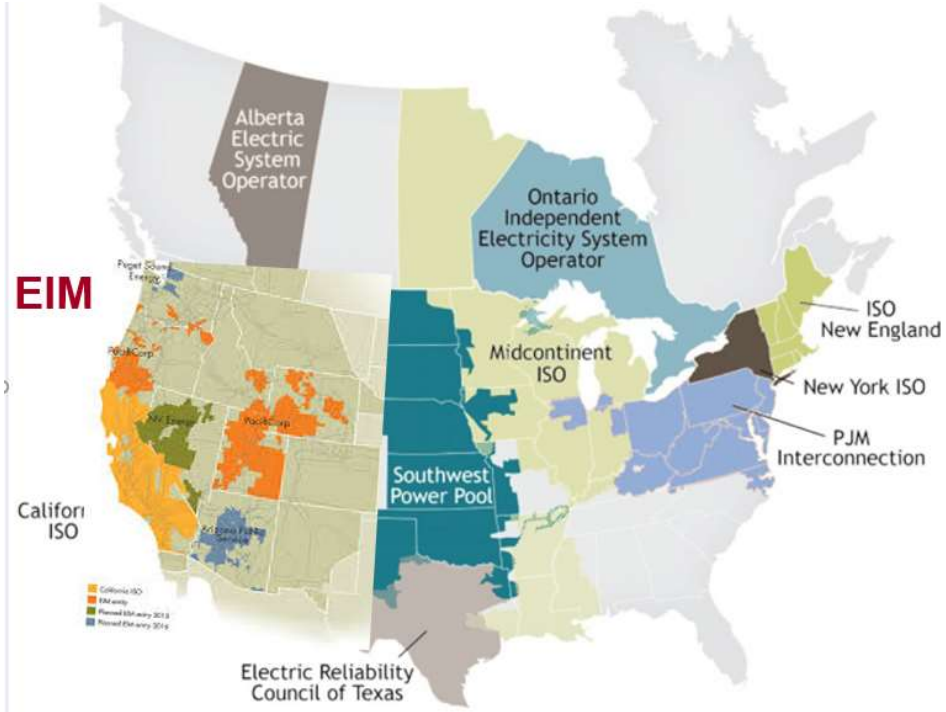


Potential for significant change in 2050 system load shape/aggregate peak.

EPRI ELECTRIC POWER RESEARCH INSTITUTE

Evolving wholesale markets

- More resources for fewer periods?
- Incentives for flexibility?
- Incentives for “essential reliability services”?
- What is the right price?
- Interfacing transmission/wholesale with distribution/retail?
- Changing resource mixes: Technology agnostic vs. realism?
- Simplicity vs. complexity?



(Source: Southwest Power Pool)

Resiliency and Restoration in Context of HILF Events

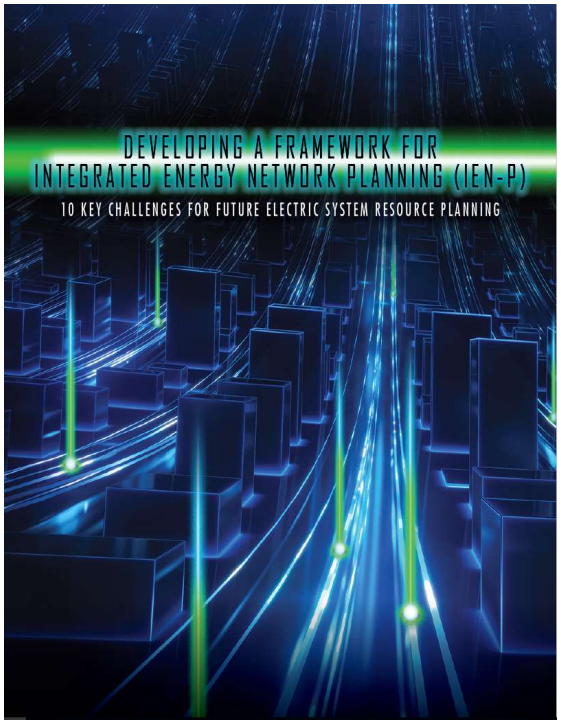
- HILF events can cause wide-scale effects.
- Voltage collapse and damage to long-lead time components can occur over wide areas.
- Black start paths can be disrupted and/or damaged.
- Interdependencies between sectors (electricity, gas, etc.) can be critical.
- **New questions to answer:**
  - How will the system respond to a given HILF event?
  - How can the impacts be mitigated?
  - How can recovery efforts be expedited?
  - What are the relative benefits of improving resiliency?

EPRI | ELECTRIC POWER RESEARCH INSTITUTE

How do we plan for an Integrated Energy Network?

Integrated Energy Network Planning Challenges

Category	Key IEN Planning Challenge
Modeling the Changing Power System	1. Incorporating operational detail 2. Increasing modeling granularity 3. Integrating generation, transmission & distribution planning 4. Expanding analysis boundaries and interfaces 5. Addressing uncertainty and managing risk
Integrating Forecasts	6. Improving forecasting 7. Improving modeling of customer behavior and interaction
Expanding Planning Boundaries	8. Incorporating new planning objectives and constraints 9. Integrating wholesale power markets 10. Supporting expanded stakeholder engagement



Available on EPRI.com here:

https://www.epri.com/#/pages/product/000000003002010821/?lang=en

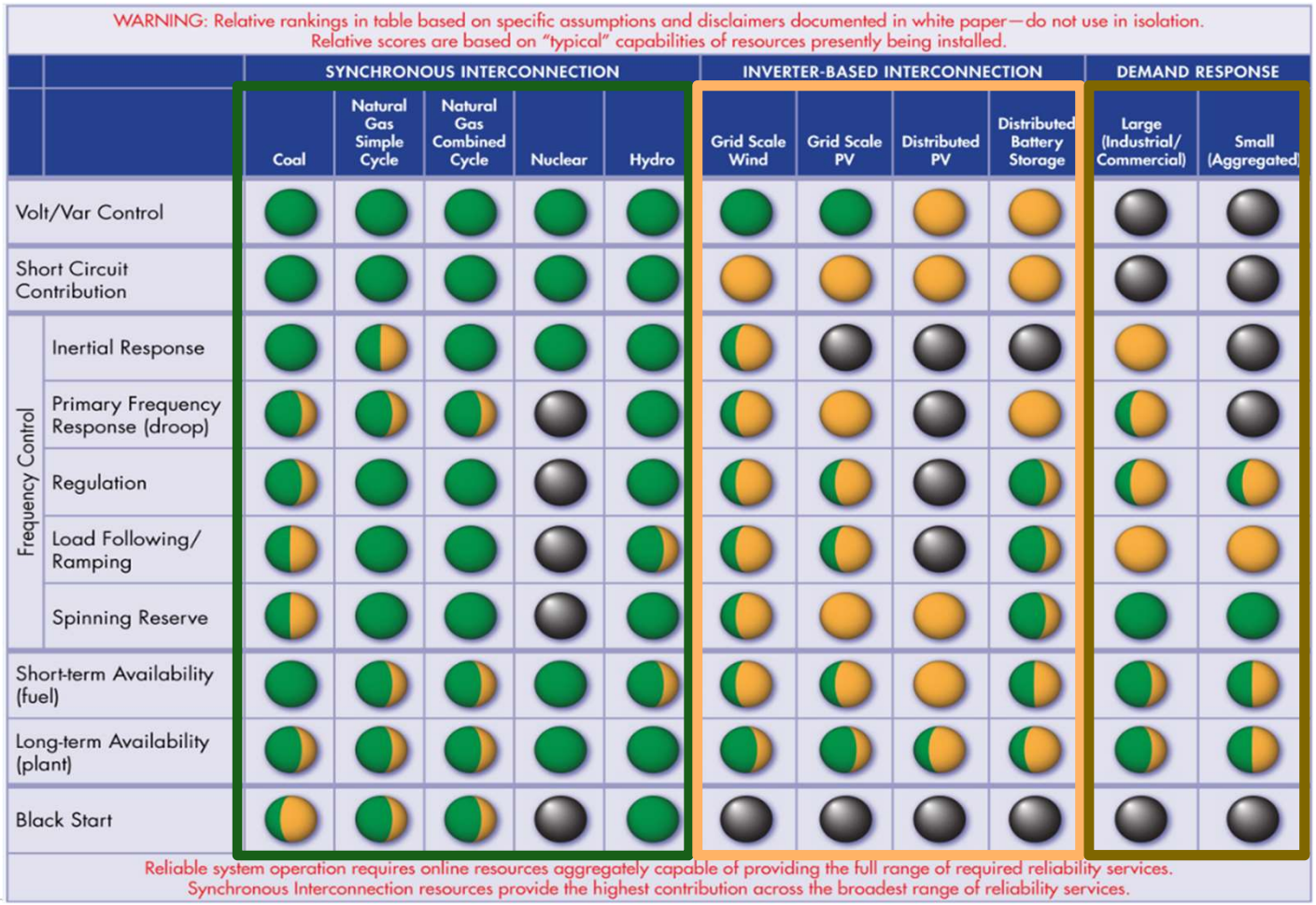
EPRI is aligning its future R&D to address the IEN-P challenges (ien.epri.com)

Relative Reliability Contributions for Various Resources

- **Must Ensure Reliability when considering new Resource Mix**
- **Not all Resources equal in Reliability Capability**
- **Synchronous resources broader & deeper ability to support reliability**
- **Reliability is not only consideration: Diversity, Economics, Emissions, and others…**

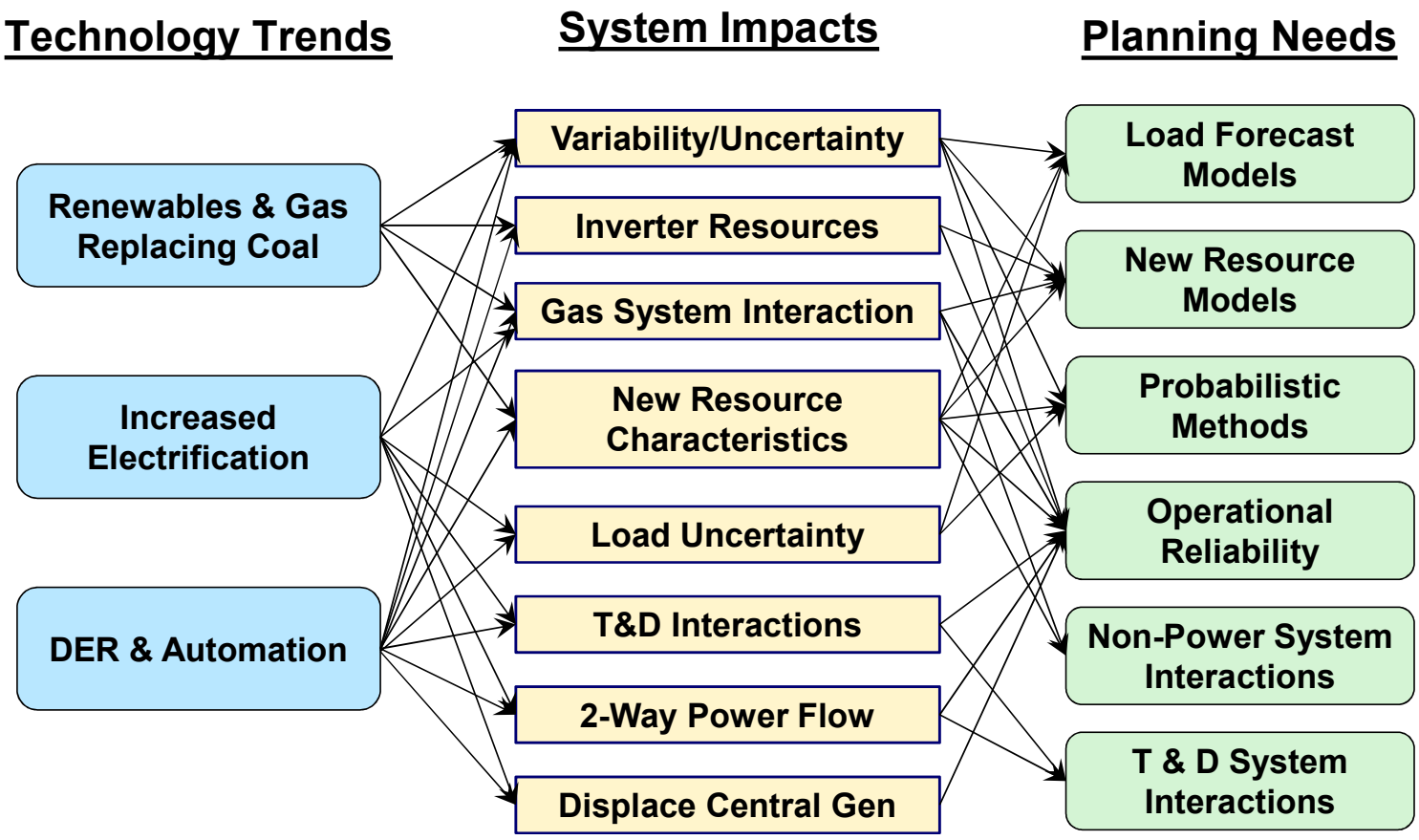
EPRI whitepaper (2015):
Contributions of Supply & Demand Resources to Required System Reliability Services (3002006400)

Update coming soon



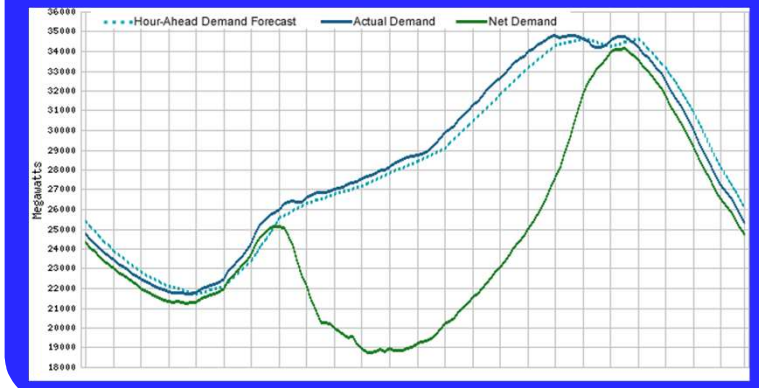
EPRI ELECTRIC POWER RESEARCH INSTITUTE

Emerging System Characteristics & Planning Impacts



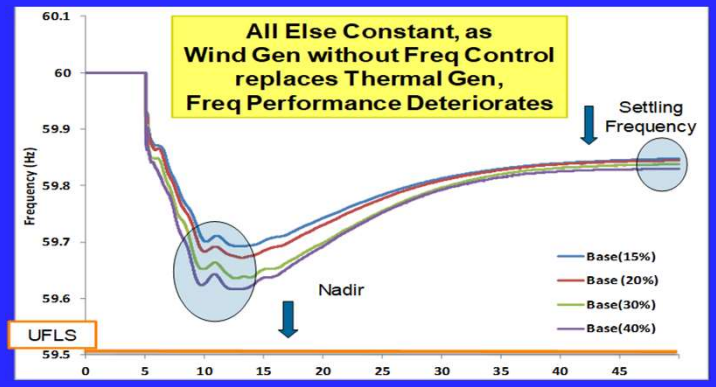
Variable and/or Distributed Energy Resources (VER/DER)

Variability and Uncertainty

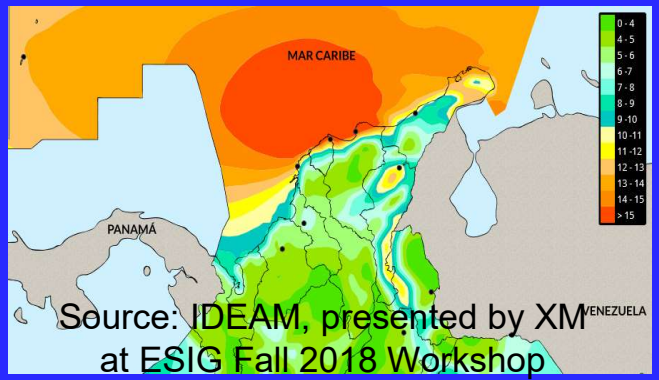


VER/DER unique characteristics that drive planning and operational challenges.

Inverter Interface



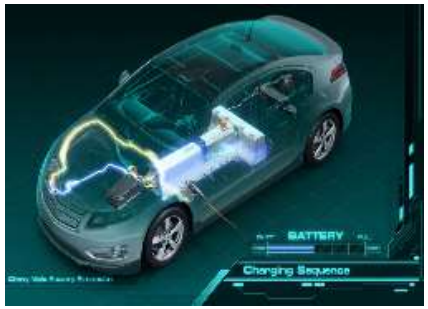
Resource Location



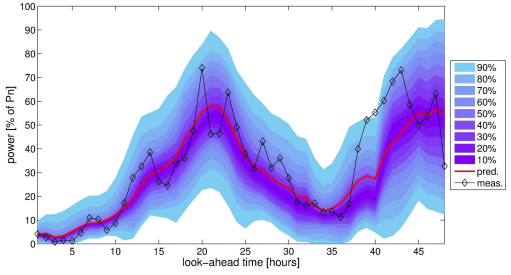
Source: IDEAM, presented by XM at ESIG Fall 2018 Workshop

ISO Role in Energy Systems Integration

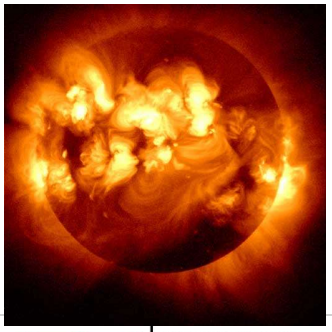
- Markets
  - Incentivizing new sources of flexibility
  - Increased linkages with gas markets
  - Microgrid and DER integration



- Operations
  - Visibility and control of distributed sources of energy and capacity
  - Situational awareness and operator tools to manage increased levels of uncertainty



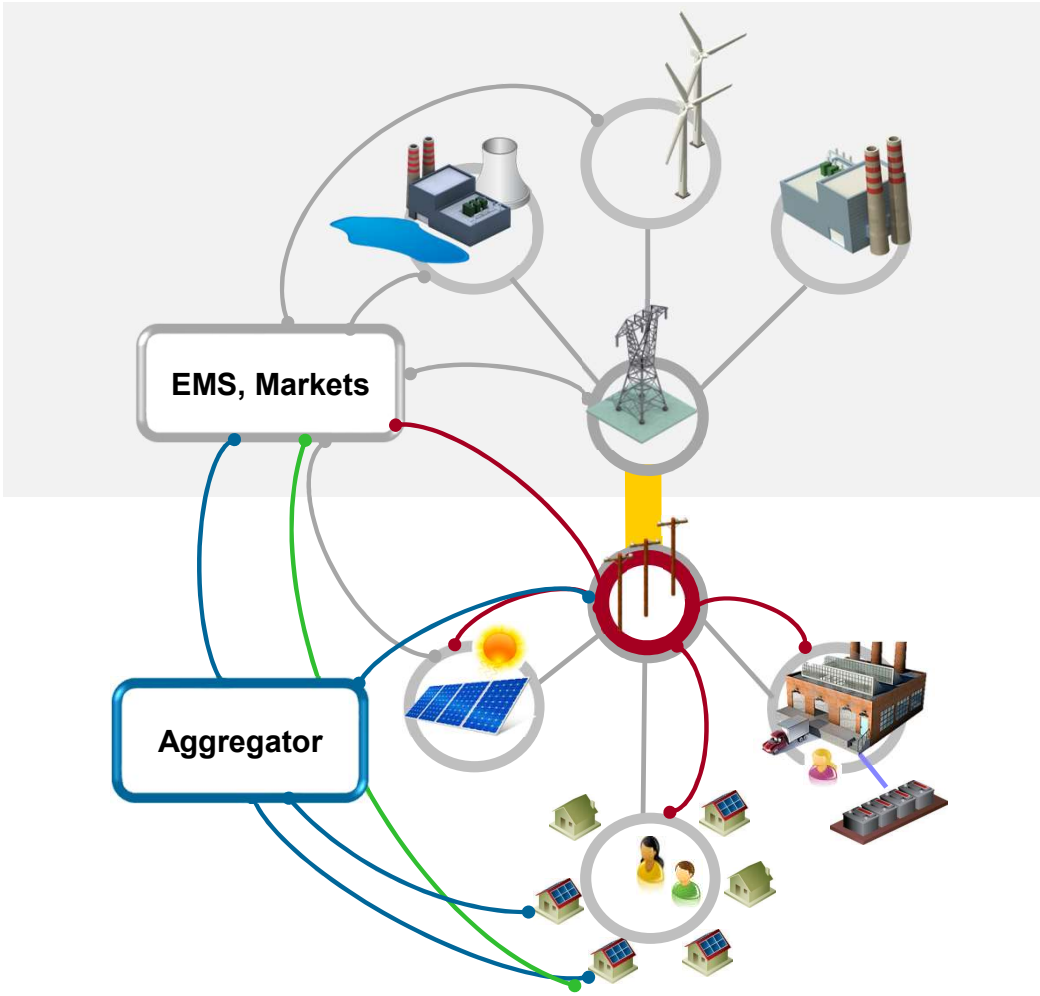
- Planning
  - Coordinated planning considering how events in other sectors impact transmission
  - Resiliency to high impact low frequency events – cyber, physical and extreme weather



EPRI ELECTRIC POWER RESEARCH INSTITUTE

Changing Transmission and Distribution Interface

Proliferation of distributed resources providing energy and A/S to the bulk system require closer integration across the T & D interface



Implications

- Market design
- Modeling/planning coordination
- Visibility/operations coordination
- Controls paradigm/architecture

Advanced distribution planning tools for integrating DER

DRIVE

EPRI's DRIVE tool:

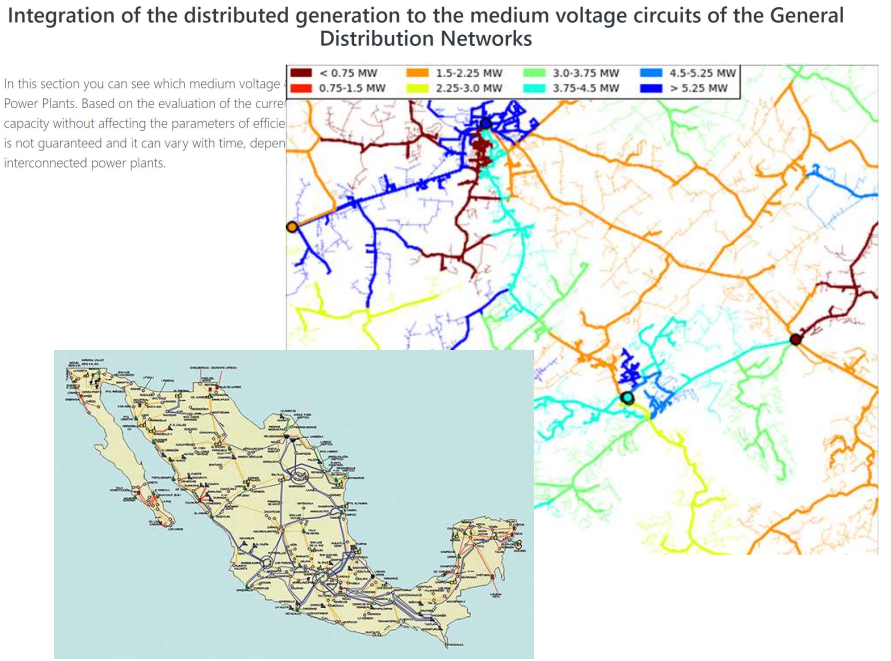
- Enables planners to efficiently and effectively evaluate the technical impacts of DER on distribution systems

Example Application in Latin America (Mexico/CFE)

- Instrumental to meet a Regulatory Order to determine hosting capacity for distribution systems
- DRIVE used to analyze 11,000 feeders across CFE service territory

Value:

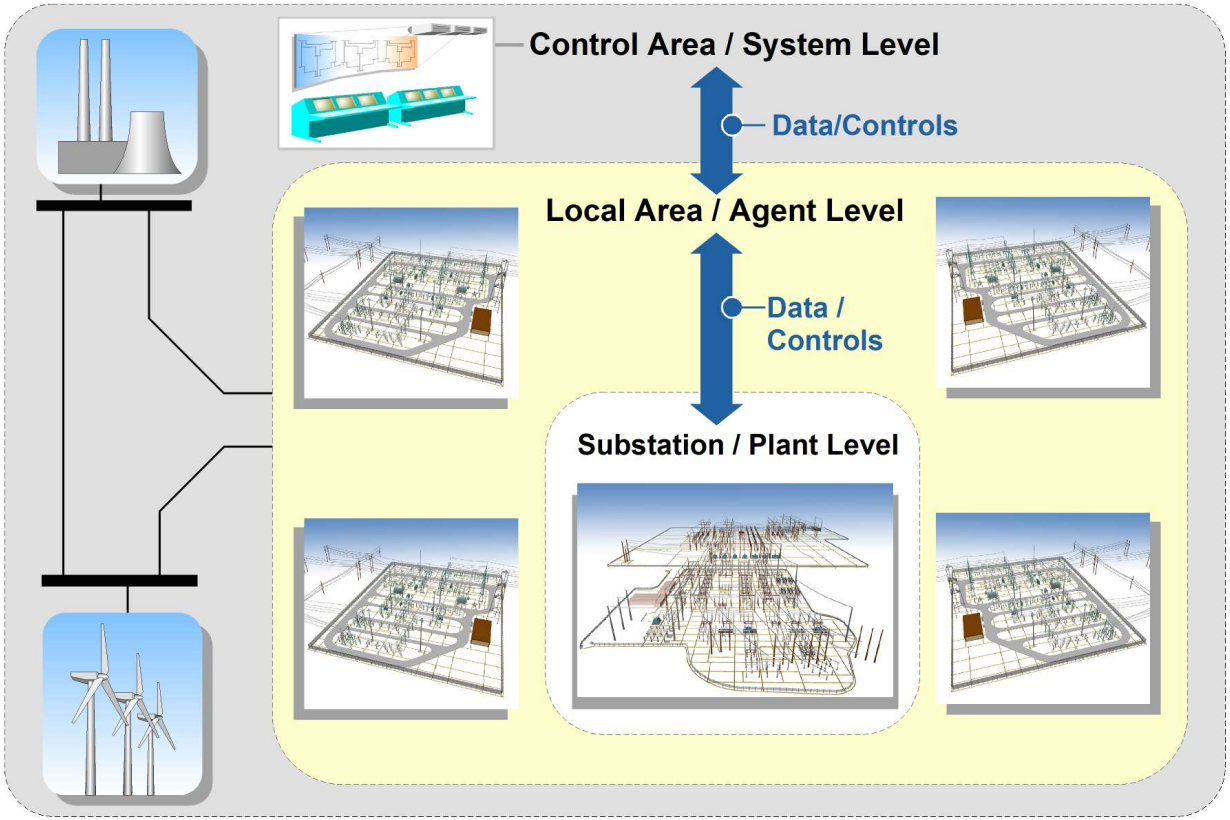
- Efficiently facilitate the interconnection of distributed generation
- Bridge the gap between the utility and its customers
- Provide a level of consistency in how a hosting capacity analysis is conducted and discussed across the industry



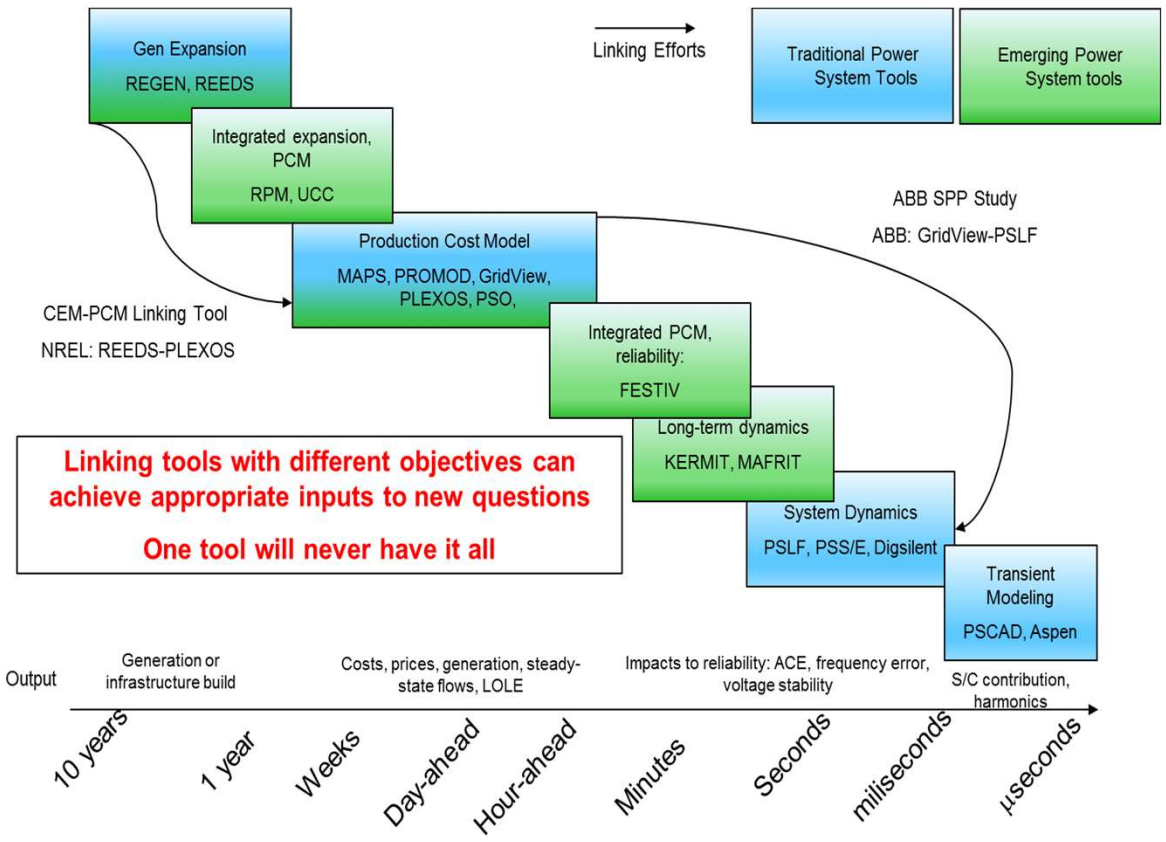
EPRI ELECTRIC POWER RESEARCH INSTITUTE

Next Generation Transmission Grid Monitoring & Control

- Increasing # controllable devices (wind/PV, power flow controllers, HVDC)
- Fully utilize new resource control capabilities
- Advanced sensing/metering and comms (e.g., PMUs, sub automation, et. al.)
- Autonomous operations with human oversight



New Planning Paradigm Needed



- Interaction between Resource and T&D planning tools
  - Spatial/temporal granularity
  - T&D infrastructure costs?
  - Operational issues included?
- Interdependent systems
  - gas, transport, water, etc.
- Probabilistic methods

Integrated Energy Network

Imagine an energy future where all forms of energy can be optimally integrated to connect customers with safe, reliable, affordable, and clean energy resources

Together…Shaping the Future of Electricity