Industry View of the Smart Grid

Smart Grid's goals, key challenges, and the impact on technology

EMS Users' Conference

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CRA Charles River Associates

About CRA

Founded in 1965, Charles River Associates is a leading consulting firm that provides economic, financial, and business management expertise.

The firm has over 550 professional staff across North America, Europe, the Middle East, and the Asia Pacific region. We believe in using a combination of industry experience and rigorous, fact-based analysis in order to provide clients with clear, implementable solutions to complex business problems.

Over the past two years, CRA has worked with 68 of the Fortune 100 companies and 93 out of the top 100 law firms.

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Today's Topics

- The Smart Grid – the economic market view
  - A *collection of technologies* and a *platform*
  - What is all of this technology going to be used to do?
  - What are the components of the Smart Grid?
  - The Smart Grid as a platform, not just technology
- Key Challenges
  - What are the major sticking points to be resolved before we see a Smart Grid-enabled future?
- How customer pricing is the wild card in Smart Grid's evolution
- How will this affect the technology used in the industry?

Smart Grid's Goals

- Economic
  - Greater customer choice
  - Lower consumer costs and production costs
- Reliability
  - Self correcting (distributed intelligence)
  - Adaptive to changes
  - Proactive vs. Reactive
- Efficiency
  - Better system operations
  - Lower transmission losses
  - Information Management & Control
- Security
  - Physical security
  - Cyber security (encryption)
- Environmental
  - Lower emissions
  - Greater control over spatial and temporal patterns
- Customer Choice
  - Energy Management & Presentation
  - Energy Management / Service Cost
  - Residential
  - Commercial & Industrial
  - Opt-In Programs
  - Time of Use rates
- Distributed Resources
  - Renewables & DG
  - Energy Storage
  - Distributed Generation

Different utilities have starkly different views on what Smart Grid comprises

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Where Does Washington Think We're Going?

DOE

- DOE has set out seven characteristics
  - Consumer participation
  - Accommodate generation and storage
  - Enable new products, services, and markets
  - Provide power quality for a digital economy
  - Optimize asset utilization and operating efficiency
  - Anticipate and responds to system disturbances in a self-healing manner
  - Operate resiliently against physical and cyber attack and natural disasters

FERC

- *"Underlying that design will be a new freedom of consumer choice in managing electricity consumption."*
- *"Smart Grid must facilitate the development of a greatly expanded demand response market."*
  - Jon Wellinghoff – FERC Chairman
- *The majority of the benefits of the smart grid [will be] at the retail level, when consumers have dynamic pricing"*
  - Philip Moeller – FERC Commissioner

Different agencies are working towards Smart Grid from two different directions

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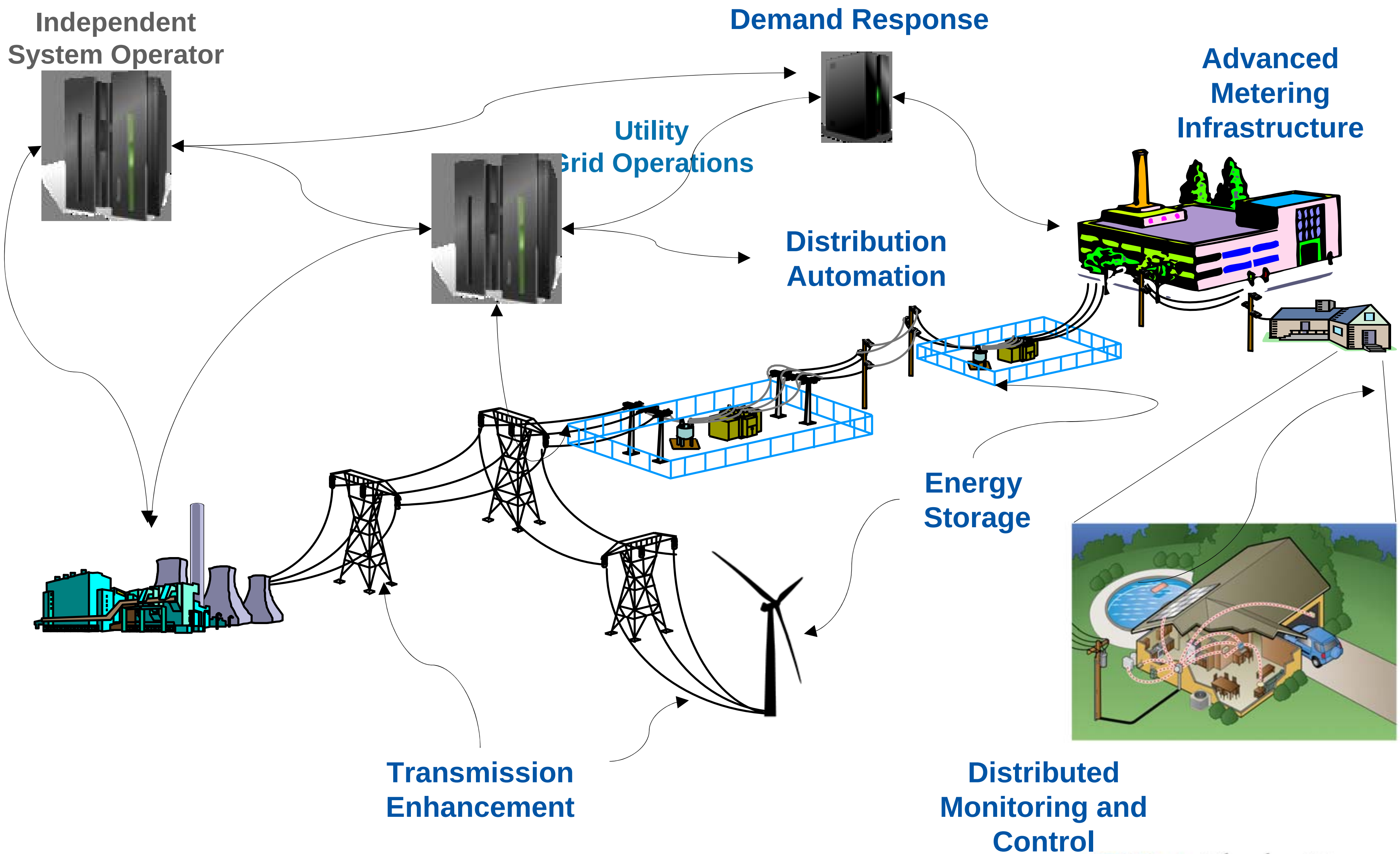
Smart Grid Technologies



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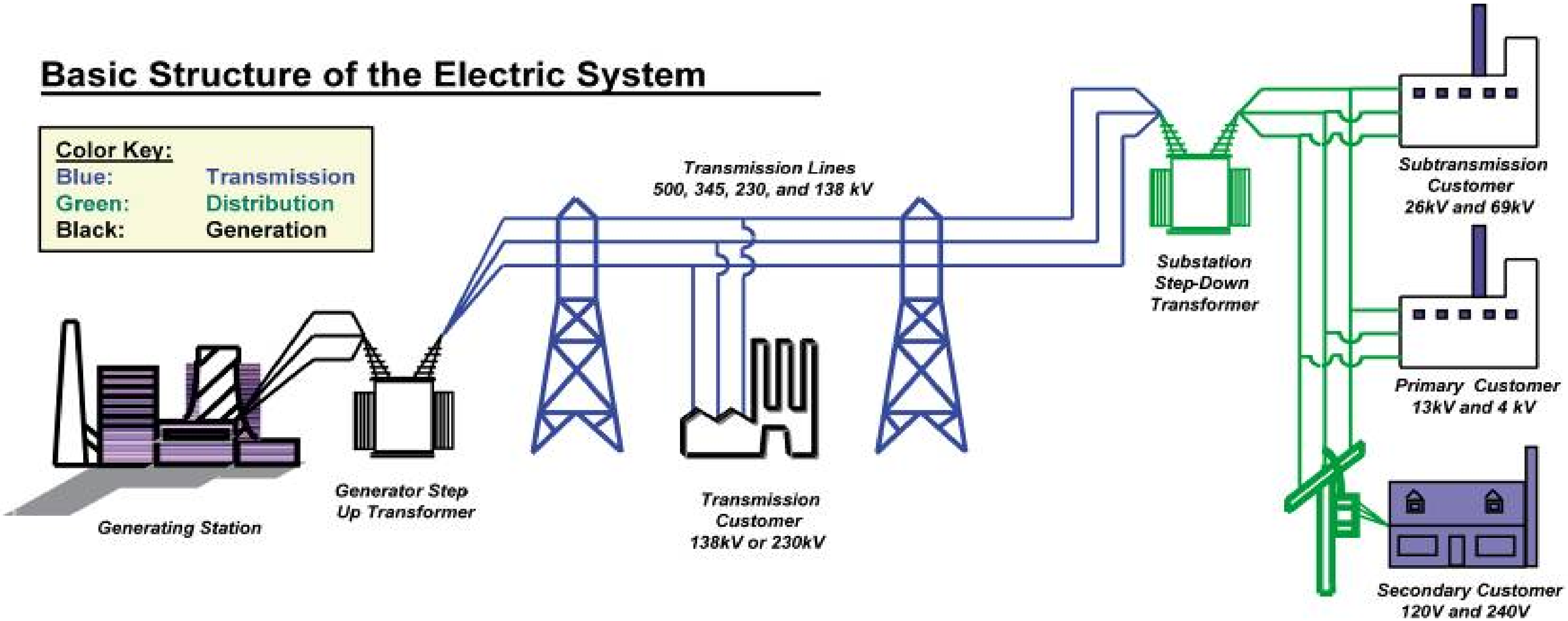
Our Starting Point Today



Source: www.nerc.com

Generation

- Baseload, Mid-Merit & Peaking
- 1,000,000 MW
- 1 billion kWh
  - Coal - 49%
  - Natural Gas - 20%
  - Nuclear - 19%
  - Hydropower - 7%
  - Renewables - 2%

Transmission

- Long Distance
- High Voltage (>230kV)
- Ultra-High Voltage (>500kV)
- 150,000+ Miles
- CapEx: ~$7 Billion

Distribution

- Local Use
- Medium Voltage (<69kV)
- Cities (13kV t0 4kV)
- Neighborhood (120/240V)
- CapEx: ~$17 Billion

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Smart Grid Transmission Enhancements

Expand Capacity

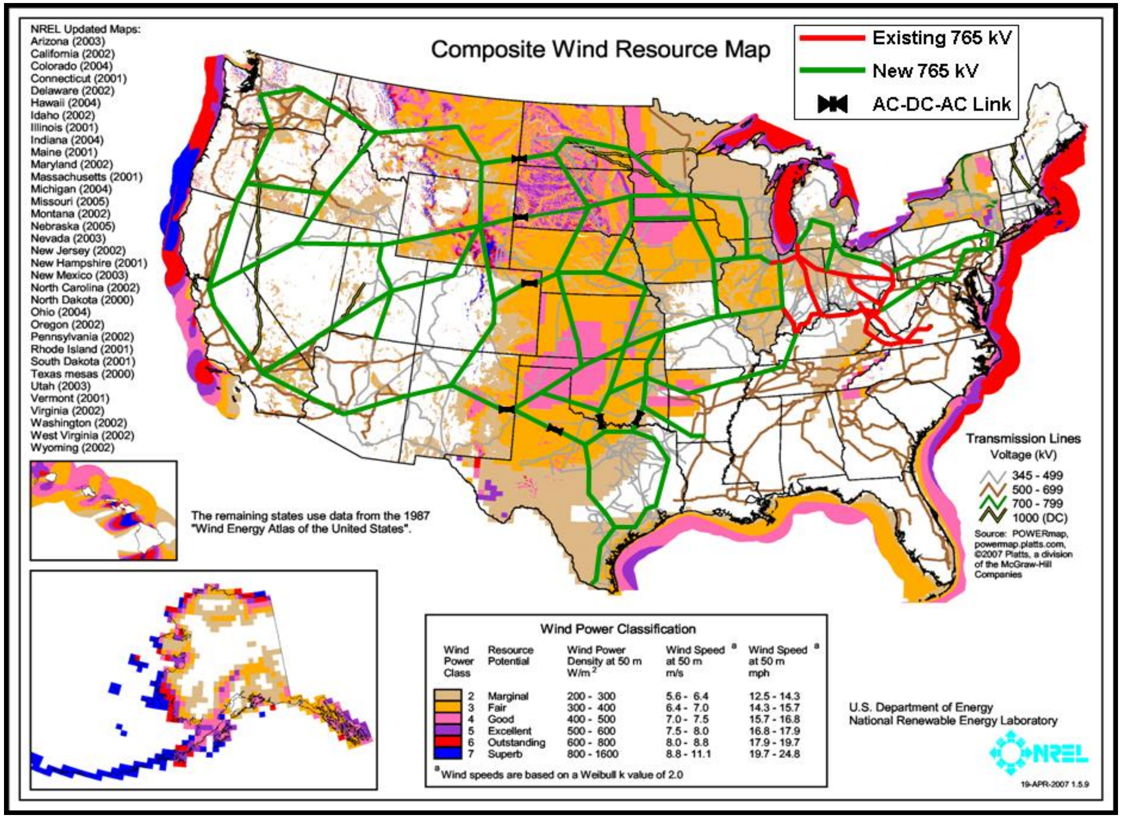
- Better Layout
- FACTS
- Supply Security (Reliability)

Improve Operation

- Wide Area Management Systems
- Communication Infrastructure
- Cyber Security

Renewable Energy

- Long-distance transmission
- Resource rich/poor regions
- Ultra-High Voltage (UHV)



Smart Grid Distribution Enhancements

Self-Healing Grid

- Flexibility of T&D Assets
- Carrying Capacity
- Workforce Effectiveness
- Enable Effective Microgrids
- Semi-Autonomous

Substation Automation

- Substation Reliability
- Proactive Response
- Response Time
- Grid Agents

Communication

- SCADA
- Cyber Security
- 2-way Communication Infrastructure
- Information Management
- Utility Integration / Effectiveness

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Smart Grid Demand Response Enhancements

Incentive Based Programs

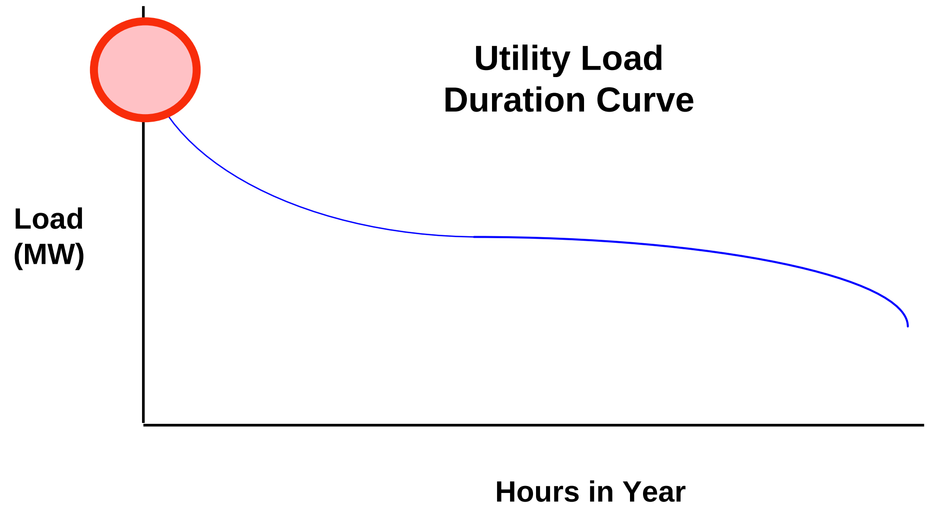
- Direct load control
- Interruptible/curtailable rates
- Demand bidding/buyback programs
- Emergency demand response programs
- Capacity-market programs
- Ancillary services

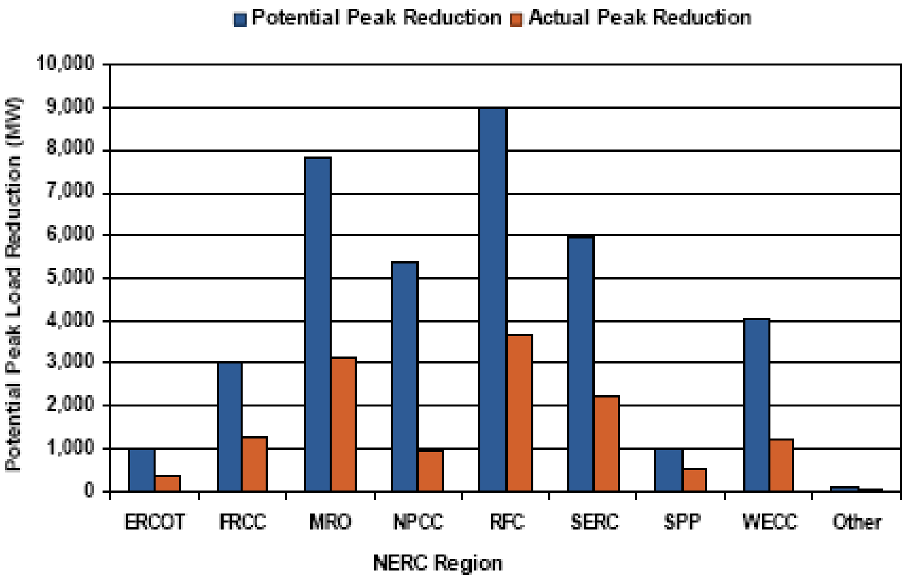
Time Based Programs

- Time-of-use
- Critical-peak pricing
- Real-time pricing
- …but high load does not always equal high prices

Market (2008)

- 8% of US Customers
- Potential Peak Reduction 41 GW
  - 5.8% of Peak





Source: 2008 FERC Survey
Note: Other includes ASCC and Hawaii.

Smart Grid Energy Storage & DG Enhancements

Wholesale Power

- Commodity Arbitrage — *Load Leveling, System Stabilization*
- Ancillary Services — *Frequency Regulation, Spinning Reserves*

Transmission & Distribution

- Asset Deferral — *Postpone Transmission Upgrades*
- Distribution System Stability — *Shock Absorber*
- Stand-by Power — *Substation, NOC, Generating Station*

Renewable Energy

- Wind — *Firm Delivery, Transmission Design*
- Solar Thermal — *Solar Tower, Trough*
- Solar PV — *Off Grid, Time Shift Delivery*

Distributed Resources

- Demand Management — *Peak Shaving, Service Cost Reduction*
- Power Quality — *Islanding, Microgrids*
- Standby-Power — *Telecom, Datacenter, UPS*
- Regenerative Energy — *Port Cranes, Subways*
- PHEV — *Vehicle 2 Grid*
- Home Storage — *Distributed Resources, Back-up Power*

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Smart Grid Dispatch Enhancements

- Integration of demand response into commitment and dispatch cycles
- Advanced system modeling
  - Improved state estimation
- Advanced contingency modeling
  - Incorporation of intermittent (e.g. wind) resources
  - Incorporation of demand response
- Predictive customer behavior modeling
  - What will customers do if we “give them the keys?”
- Emissions constraints
- Integration of greater amounts of potentially incomplete/incorrect data
  - Lower quality standards to end-use points, and a much greater volume
- Integration of locational prices with lower-voltage networks

Key (non-Technology) Smart Grid Challenges

- Dynamic Pricing
  - Will it be implemented at all?
  - Do you *need* dynamic pricing for Smart Grid to be viable?
  - In areas where there's no organized market, how do you set a price?
- Centralized versus distributed control
  - Who gets to control your air conditioner?
- Who pays for it?
  - How are these investments going to be recovered? Who is best suited to make the investments?
- Who owns the data?
  - The data from your consumption may be the most valuable commodity
- Who gets to be a participant?
  - Should third-party players like Google and EnerNOC get the same status as regulated utilities and LSEs?
- Who is in charge?
  - Federal policy sets general direction, but implementation and low-level implementation left to states

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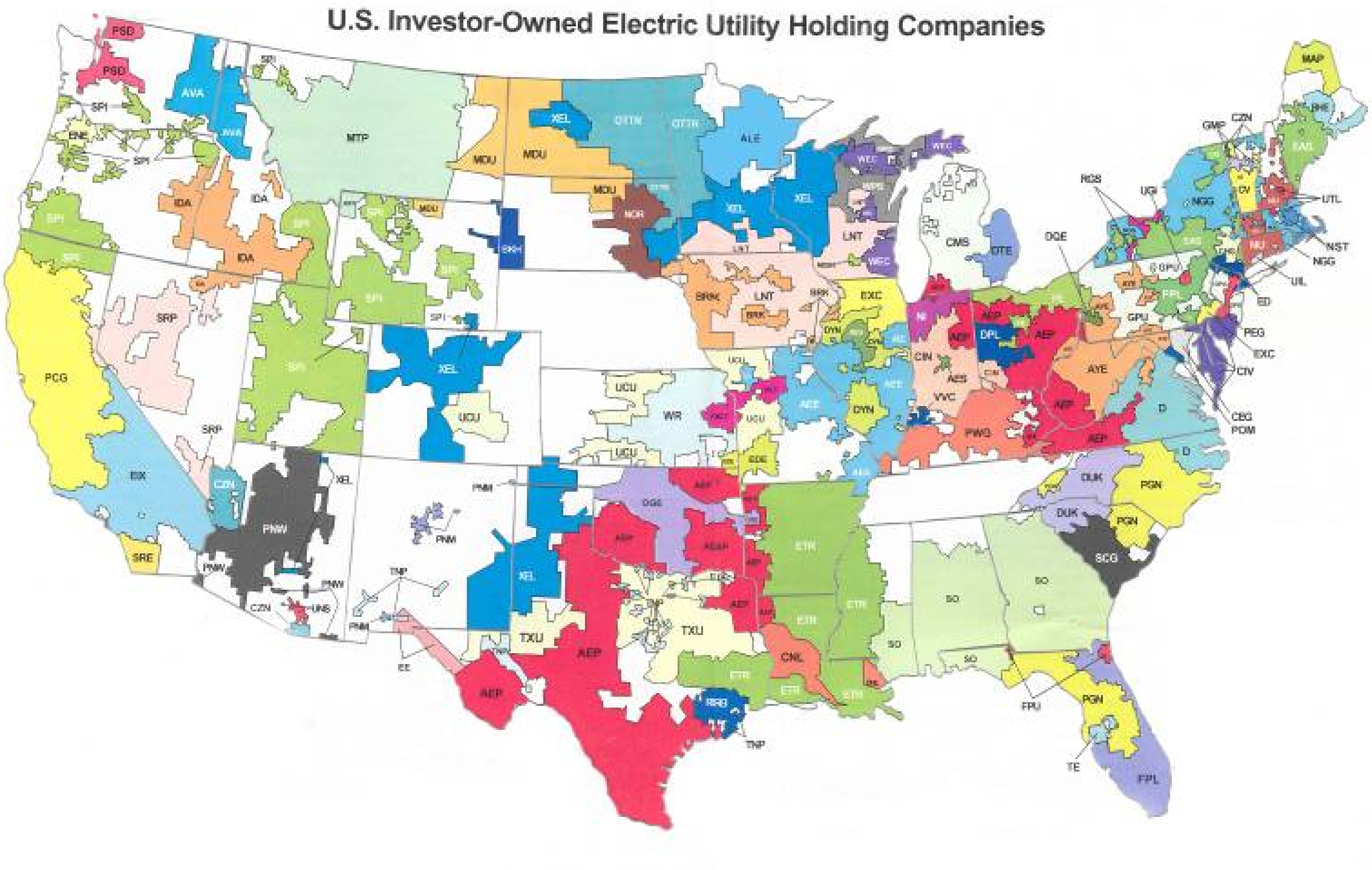
Overlapping Jurisdictions Make Regulation Difficult



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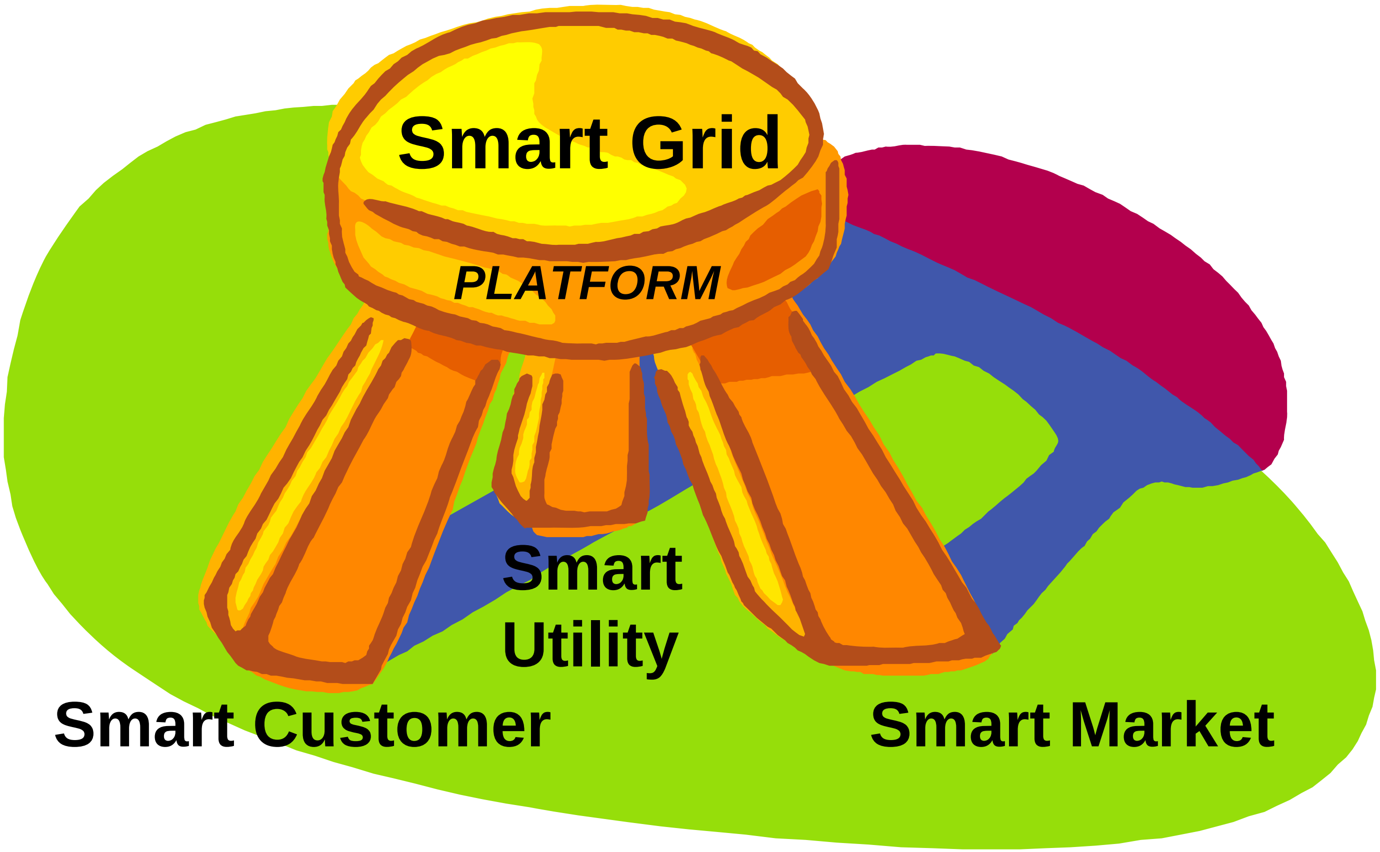
Smart Grid Is More Than Just Technology – It's a Platform With Three Legs



What Are These Three Legs of the Platform?

Smart Customers	Smart Utility	Smart Market

Smart Customers

- Customer focused technology that allow electrical (and energy) consumers to:
  - Observe their real-time behavior,
  - Directly control their electrical consumption
  - Input their decision rules into smart controller applications

Smart Utility

- Utilities that provide
  - Sophisticated monitoring, digital controls and locational pricing signals that bridge between the real-time cost of electricity and the real-time price to consumers

Smart Market

- The market structure built upon a common platform or platforms that allows
  - Integration of technologies, decision logics and information for both the producer and the consumer
  - Creation of a dynamic and economically efficient long-run solution to operation and control of both the producer and consumer side of the electrical grid

Most effort to date has been on the enabling standards, *not* on what Smart Grid is supposed to *do*

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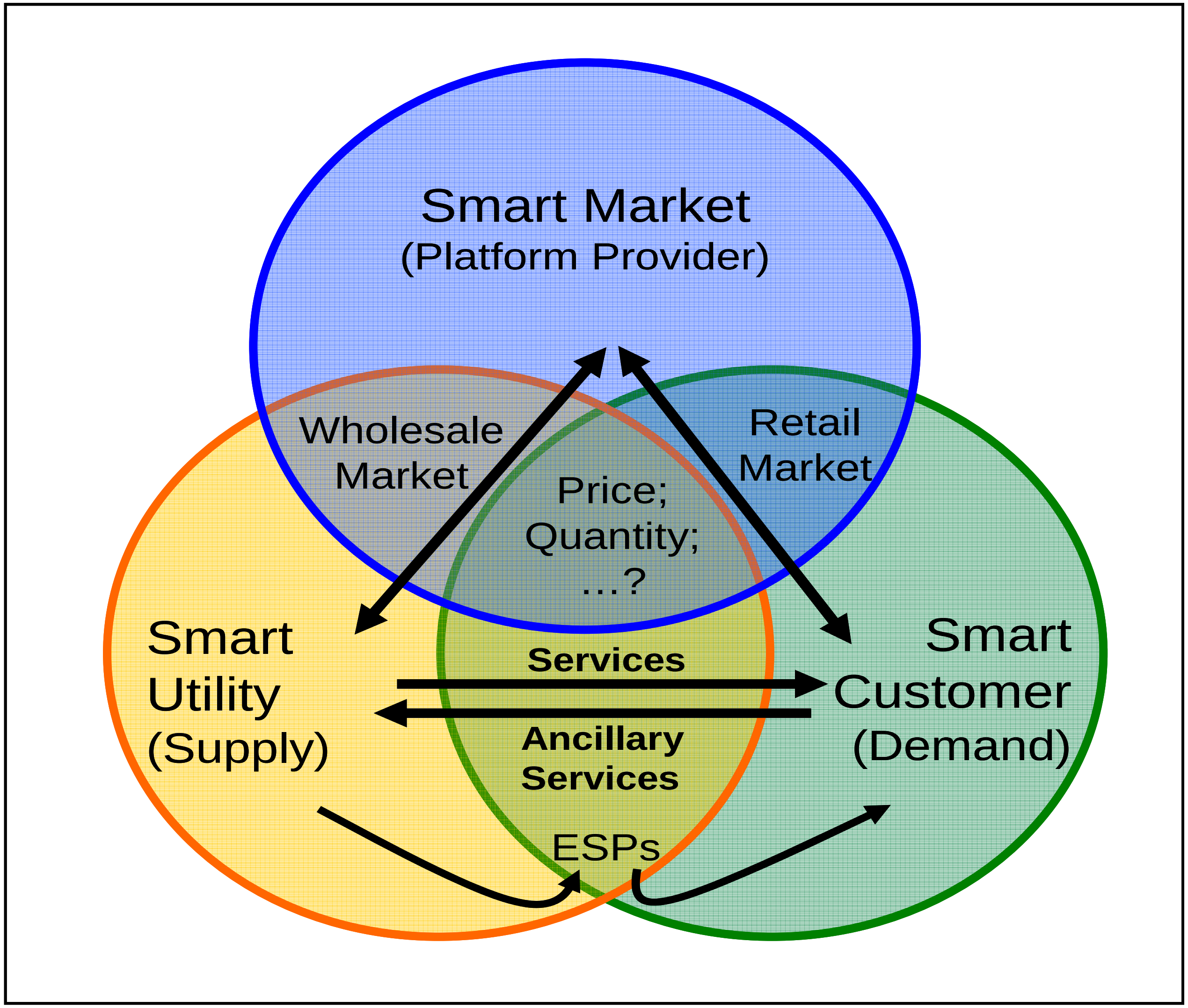
Smart Grid Market and Information Flows



Smart Grid's "Big Picture"

Technology definition	Platform definition	Platform implementation and evolution
• Establishment of standards • Development of technology	• Definition of market structures to support Smart Grid • Definition of roles and rights/responsibilities • Establishment of operating standards and procedures • Establishment of policies for integration of existing and advanced technologies	• Implementation of market structures • Implementation of operational procedures • Incorporation of newer technologies • Development of new applications on the Smart Grid "platform"

We are here

Smart Grid has started down the standards path without a clear vision of what the intended purpose is (but that's probably OK)

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Who (Should) Set Standards and Create the Platform?

Utilities	Competing Standards
• Standards are the first and most important part of the Smart Grid platform – we can't wait around • Utilities already have the first-mover advantage – they're going to set them anyway • Utilities have the money to implement before anyone else, and mitigated risk through rate recovery	• Utilities are very good at financing large, capital-intensive assets through rate recovery • They're not good at innovation • Big telecom advances were made by companies like Qualcomm and Cisco, not AT&T (but is this a good or bad thing – example of GSM versus CDMA/TDMA/etc.)

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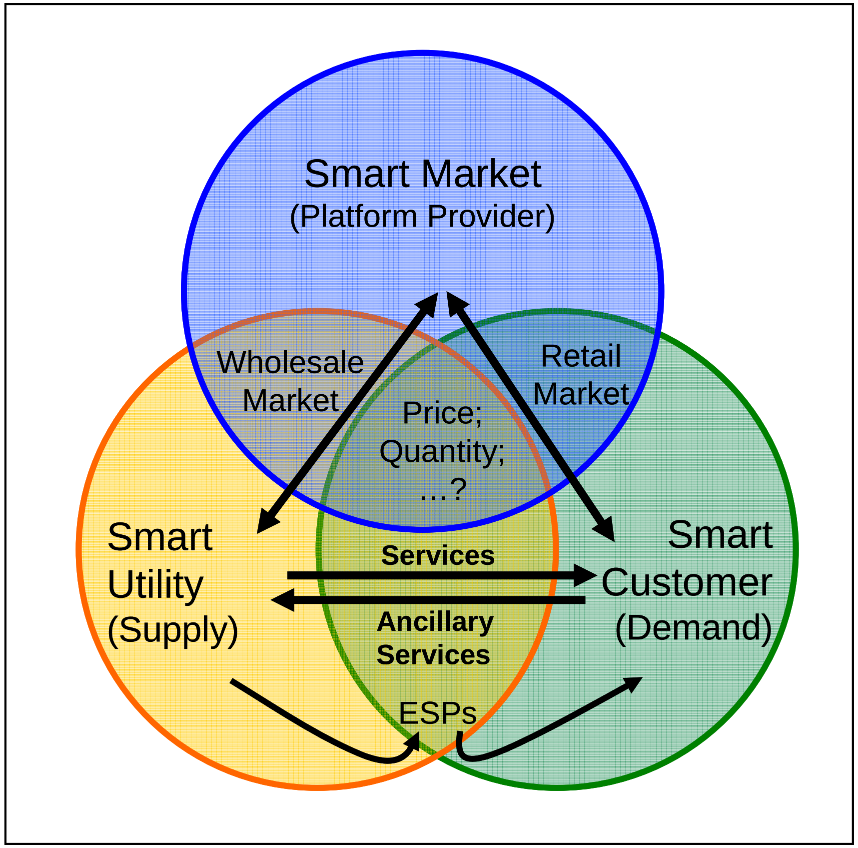
Customer Pricing – the biggest impact on Smart Grid Evolution

- Pricing is the key element that will drive how the grid evolves
  - It's (one of the) the big issue that there's not agreement on
  - More so than other factors, the decision on whether or not to use end-use pricing will drive the evolution of the grid more than anything else
  - Most other reliability and integration uses are likely to occur anyway
- Customer pricing impacts the evolution in several key areas
  - Regulatory acceptance and rate recovery
    - Regulating customer pricing regimes is more difficult, but more attractive
  - System planning and operation – how do you plan for customer behavior?
    - Will customers be unpredictable in their response?
  - Implementation cost
    - Greater cost and complexity to implement customer pricing – how will that slow implementation?

Remember that Diagram from a few slides back?

- Right now, the industry is oriented towards the Smart Utility
- To enable the full Smart Grid platform, some form of pricing information is required



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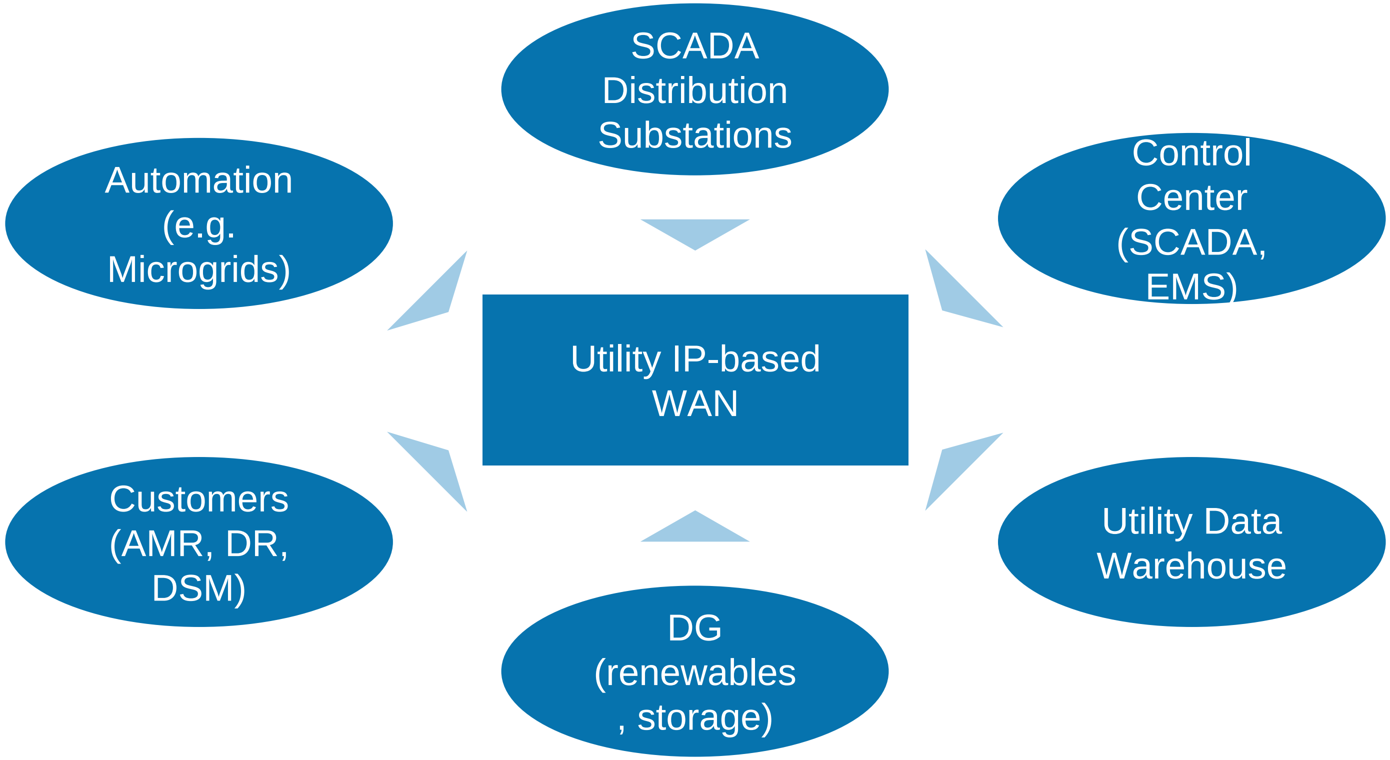
Future Data Flows and Requirements



Future technologies will require near-ubiquitous IP connectivity everywhere

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Key Impacts on Technology

- Greater capital requirements
  - Much greater bandwidth requirements
  - But storage capacity scales very rapidly – bandwidth is much more expensive and capital-intensive
- The last mile may not be the problem
  - The volume of data between the control center and substation is much larger than between the substation/center and customers
  - Losing connections with a small group of customers unlikely to raise issues – how reliable is reliable enough?
- Need for a knowledge-management lifecycle for AMI and advanced substation equipment
  - Making sense out of all the new data generated
- Greater integration of operational and market systems
  - Not only within the control center, but between RTOs and LSEs
- Not necessarily easier in a mature market-system
  - Vertical integration and homogeneity have benefits, at least in a confined radius
  - Greater speed and ease of implementation may help vertically integrated regions help control the evolution

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