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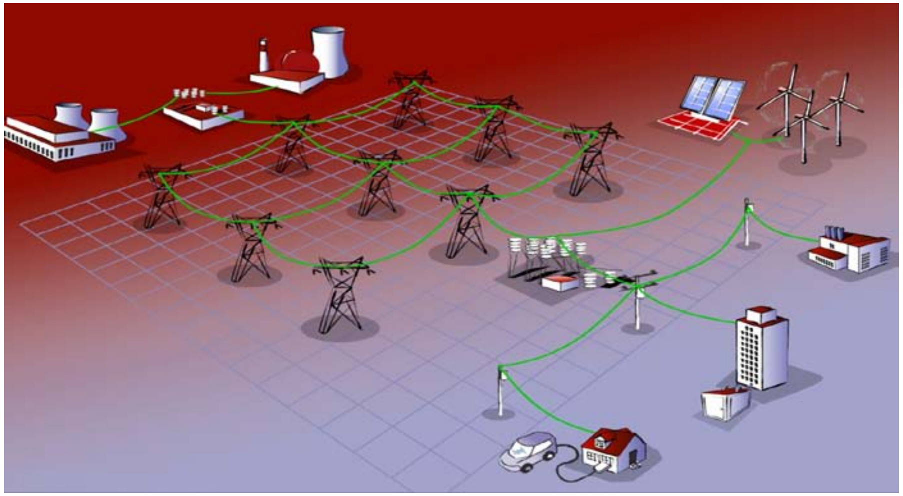

Power System Optimization

Smart Grid, Demand Dispatch and Microgrids

Joe Miller - Smart Grid Implementation Strategy Team Lead

September 27, 2011

DISTRIBUTION APPARATUS SCHOOL & CONFERENCE

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Initial Role – Modern Grid Strategy

Mission – Accelerate grid modernization in the US

- Develop a vision for the Smart Grid
- Reach out to stakeholders to get input and consensus
- Assist in the identification and resolution issues
- Act as an “independent broker”
- Promote testing of integrated suites of technologies
- Communicate concepts to assist interested stakeholders
- Began in January 2005

MGS Concepts form the foundation for the US Smart Grid vision

New Role – Smart Grid Implementation Strategy

Mission – To accelerate the transition to a smart grid through the development of implementation strategies and tools

- **Create a national interest in “Performance Feedback”**
- **Develop Demand Dispatch concept**
- **Continue to communicate and educate stakeholders on fundamental SG concepts**
- **Provide technical support to industry groups as requested**

Continue to act as an “independent broker”

Agenda

- Power System Optimization Today
- Value of “Advanced” Asset Optimization
- Role of the Smart Grid
- Demand Dispatch
- Microgrids
- Q&A

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- *Power System Optimization Today*
- **Value of “Advanced” Asset Optimization**
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What is Optimization?

General Definition

- A broad set of interrelated decisions on obtaining, operating, and maintaining ***physical*** and ***human*** resources for electricity generation, transmission, and distribution that minimize the total cost of providing electric power to all classes of consumers, subject to engineering, market, and regulatory constraints

What other metrics are affected by grid optimization?

Is the System Optimized Today?

Generation
- 47%
- 17,342 units

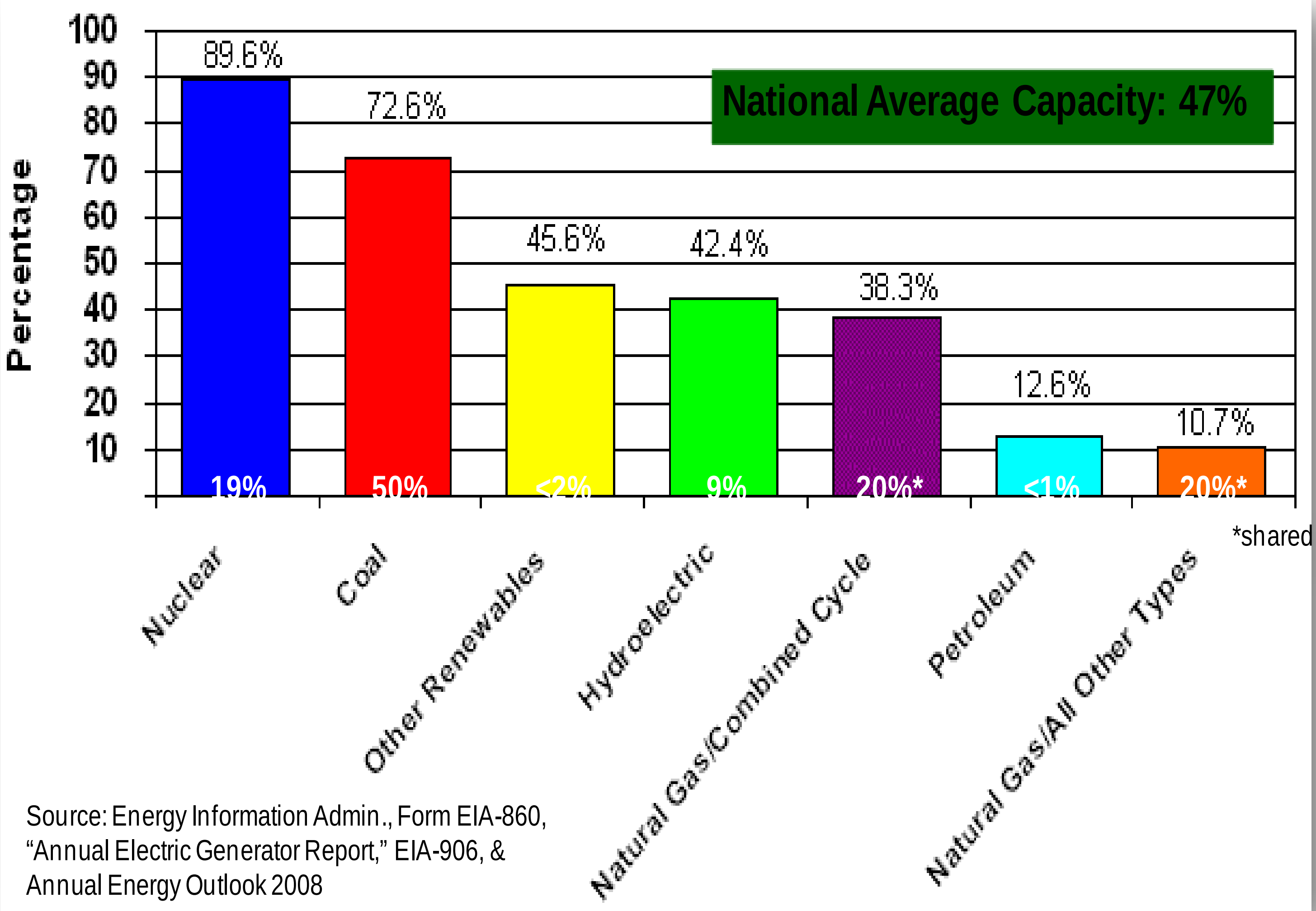
Transmission
- 43%
- 164,000 miles

Distribution
- 34%
- 3 million miles

Consumer Systems
- <1%
- 12.3 M DG

Over 12M DG units on consumer premises representing 170 GW!

Utilization of the Generation Fleet



Source: Energy Information Admin., Form EIA-860, "Annual Electric Generator Report," EIA-906, & Annual Energy Outlook 2008

Utility Business Processes

- **Planning – develop plans for new assets to support increased demand, improved reliability, and new interconnections, etc.**
- **Engineering – design, procure, construct facilities, modify and repair**
- **Operations – monitor conditions, assess impacts, operate reliably and efficiently, dispatch crews and manage switching operations, support repairs**
- **Maintenance - develop and implement programs to reduce corrective maintenance, perform preventive and predictive maintenance, and implement repairs**
- **Customer Service – process meter data into bills, manage revenue, interact with customers to address issues and educate**

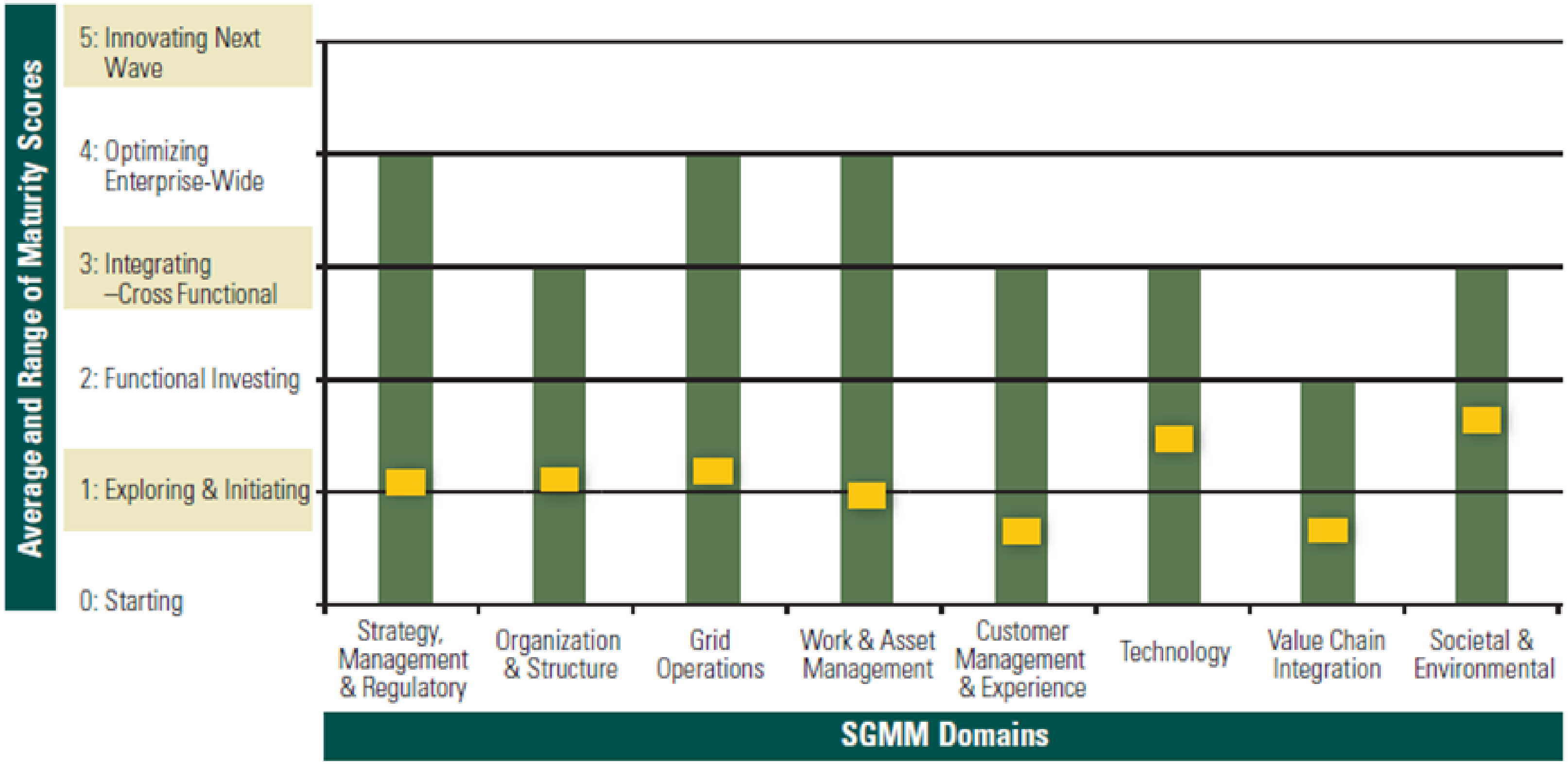
These processes are mature but limited in performance – the Smart Grid provides opportunities to optimize them further

Where are we today?

- Utilities have made slow but steady progress in optimizing their assets
- Progress has been restrained by the limited availability of grid intelligence, granularity of control, and lack of integration of key processes
- Regulatory policy supports asset optimization ("Used and Useful")
- Smart Grid technologies and applications create new opportunities for taking asset management to the next level
- Industry is moving forward with many asset optimization initiatives

Opportunity Exists for Improvement

Smart Grid Maturity Model



Source: Carnegie Mellon University (2009)

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Optimization Metrics

Power System Optimization is aimed at improvements in more areas than cost:

- Reliability
- Efficiency
- Economics
- Environmental Friendliness
- Security

Technology-enabled processes drive power system optimization

Optimization Value Areas

- **Reliability —** *by reducing the cost of interruptions and power quality disturbances and reducing the probability and consequences of widespread blackouts.*
- **Economics —** *by keeping downward prices on electricity prices, reducing the amount paid by consumers as compared to the "business as usual" (BAU) grid, creating new jobs and stimulating the U.S. GDP.*
- **Efficiency —** *by reducing the cost to produce, deliver, and consume electricity.*
- **Environmental —** *by reducing emissions when compared to BAU by enabling a larger penetration of renewables and improving efficiency of generation, delivery, and consumption.*
- **Security —** *by reducing dependence on imported energy as well as the probability and consequences of manmade attacks and natural disasters.*

Optimization Creates Societal Value

Societal Benefits

- Reduced losses from outages and PQ
- Increased grid efficiency
- Downward pressure on electricity prices
- Economic growth and opportunity
- Improved environmental conditions
- Improved national security

Hard to quantify but potentially a tipping point?

Opportunities in Reliability

Reduced losses from power outages and power quality issues

- Reducing the probability of regional blackouts can prevent significant losses to society. The societal cost of the August 2003 blackout was $8.6 billion.
- Reducing by even 20% the cost of outages and power quality issues, which are estimated to be at least $100 billion annually, would save $20 billion per year.

Opportunities in Efficiency

Increased Grid Efficiency

- Reducing T&D Losses, estimated at over $25 billion per year, by even 10% would save $2.5 billion/year.
- Reducing transmission congestion costs, which range from $4.8 billion to as much as $50 billion annually, by 10%, could save up to $2 billion/year.
- Effective integration of electric vehicles can greatly improve the efficiency of grid operations

Economic Opportunities

Downward pressure on electricity prices

- Eliminating or deferring large capital investments in generating plants, substations, and transmission and distribution lines, could reduce overall costs $46–$117 billion dollars over a 20-year period according to a 2003 PNNL report.
- Reducing O&M spending by 10% as a result of Smart Grid operational savings would save up to $4 billion annually.

More Economic Opportunities

Economic Growth

- Creation of new jobs — up to 280,000 to create a Smart Grid alone.
- Demand for new products and services created by Smart Grid related opportunities.
- Creation of new electricity markets enabling society to offer its electricity resources to the market (DR, DG, storage).
- Improved conditions for economic development — economic development depends on a reliable source of electric power.
- Reduced wholesale electricity prices compared with BAU – This reduction will be achieved through a reduction in peak loads and energy conservation.

Environmental Opportunities

- Reduction in total emissions — Through conservation, demand response, and reduced T&D losses, the total U.S. electricity consumption could be reduced by 56 to 203 billion KWh's by 2030 (1.2–4.3%).
- Per PNNL, Smart Grid could reduce carbon emissions by 15% by 2030 (442 million metric tons).
- Deep penetration of electric vehicles – Smart Grid enabled – could reduce CO_2 emissions an additional 3% by 2030 (83 million metric tons).
- Improved public health — The impact of vehicle particulate emissions in urban areas can be reduced as the number of miles driven by CVs is offset by miles driven by electric vehicles.

National Security Opportunities

- Reducing the U.S. dependence on foreign oil through the use of PHEVs could be up to 52% based on a recent PNNL report. This is an equivalent of reducing U.S. oil consumption by 6.5 million barrels per day. According to ORNL, the value of reducing this dependence is $13.58 (2004 dollars) for every barrel of oil import reduced, creating a potential opportunity of over $30 billion/year.
- Reducing the probability (and consequences) of widespread and long-term outages due to terrorist activity could prevent significant societal costs that are immeasurable. (Grid robustness)

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What are the Characteristics of the SG?

- **Enable active participation by consumers**
- **Accommodate all generation and storage options**
- **Enable new products, services, and markets**
- **Provide power quality for the digital economy**
- ***Optimize asset utilization and operate efficiently***
- **Anticipate & respond to system disturbances (self-heals)**
- **Operate resiliently against attack and natural disaster**

What's different with the Smart Grid?

- **De-centralized supply and control**
- **Two-way power flow**
- **Two-way information flow**

Creating the intelligence and capability to optimize:

- ***Reliability***
- ***Security***
- ***Economics***
- ***Efficiency***
- ***Environment***
- ***Safety***

...for all Stakeholders

Integration......Integration.......Integration!

How will the SG improve Asset Optimization?

- **Deployment of integrated technologies**
  - Integrated communications
  - Sensors and measuring devices
  - New advanced components
  - Advanced control methods
  - Improved interfaces and decision support tools
- **Implementation of new applications**
  - Advanced Metering Infrastructure (AMI)
  - Consumer systems
  - Distribution Management System (DMS)
  - Information and Communicating technologies (ICT)
  - Demand response
  - DG and Storage operation and microgrids
  - RTO / ISO process integration

Process Reengineering and integration is a needed prerequisite

Planning Process Limitations

- **Lack of complete time-stamped load data impacts accuracy of load forecasting and often results in early builds of new capacity (AMI, Smart Meters)**
- **Increasing growth of peak loads requires a continuous build-out of peaking units and new capacity projects that are greatly under-utilized (Demand Resources, DR)**
- **Planning tools are not integrated resulting in sub-optimization at the enterprise level (Advanced Analytics)**
- **System data regarding actual system responses to faults (e.g., fuses, reclosers, breakers) may be lacking, hampering the ability to verify the effectiveness of past coordination studies (IED's)**

Engineering Process Limitations

- A single, common engineering model of the electric system is often not integrated and is sometimes incomplete (AM/FM, GIS, DMS)
- The integration of design processes, technologies, records, and data is often incomplete and not shared with all departments that could benefit. (Process Reengineering, SOA)
- The ability of all authorized users to access engineering drawings, maintenance records, and other pertinent data is not fully automated. (MWFM, SOA)
- Limited operational data are available to engineers that could help them improve future designs. (DMS)
- The Design/Build process is often not integrated with the work and resource management processes. (AM/FM, GIS, MWFM)

Operational Limitations

- Distribution operations often lack key operational data needed for situational awareness, problem diagnosis, and forecasting (Advanced sensors, DMS)
- Operational processes and technologies often lack integration with other dependent processes (OMS, weather, crew status and location, engineering records, customer service , etc.) (DMS, MWFM)
- Operational processes have not yet advanced to the level needed to support the integrated operation of distributed resources (Advanced Control Methods, DMS, CVR)
- Operators are often unaware of the health of system assets because that information is often not readily available (Advanced Sensors, CBM)

Maintenance Process Limitations

- **Automation of data collection processes for maintenance inspections is limited and not integrated with engineering and operations processes (MWFM, DMS, AM/FM, GIS)**
- **Deployment of asset health monitoring devices and associated communication systems is limited. (Advanced sensors, CBM)**
- **Integration of asset health intelligence with operational decisions is limited (knowledge of assets in "stress") (CBM, DMS)**
- **Power quality diagnoses are difficult and time consuming since the installation of temporary instrumentation to trend suspected parameters is often necessary (AMI, Advanced sensors)**
- **Online access to maintenance records and engineering documents is limited (SOA, AM/FM)**

Customer Service Process Limitations

- Customer service representatives (CSRs) are limited in responding to customer questions because data sometimes is derived or comes from the operations or engineering processes (AMI, DMS, SOA)
- "Turn-on and turn-off" requests require a truck roll, labor costs, and delays in satisfying customer requests (AMI)
- Call centers are managed to keep customer wait times to a minimum. Lack of operational information slows down CSRs and can reduce their success rates at satisfying customers (OMS, DMS, AMI, SOA)

Smart Grid Milestones

- **Consumer Enablement**
- **Advanced Distribution Operations**
- **Advanced Transmission Operations**
- **Advanced Asset Management**

The first three milestones enable Advanced Asset Management

Sequence can vary

Consumer Enablement

CE empowers the customer and enables grid interaction

Advanced Distribution

AD improves reliability and enables self healing

Advanced Transmission

AT addresses congestion and integrates with RTO's

Advanced Asset Management

AAM helps utilities reduce costs and operate more efficiently

Consumer Enablement Solutions

- **Smart Meters & 2–way communications**
- **Consumer Portal / Home area network**
- **Meter Data Management**
- **Time of Use Rates**
- **Customer Information System**
- **IT upgrades (SOA)**
- **Customer Education**
- **Demand Response and DER**

CE empowers the customer and supports grid optimization

Advanced Distribution Solutions

- Smart sensors and control devices
- Distribution Management System
- Advanced Outage Management
- Distribution Automation
- Geographic Information System (GIS)
- DER and Micro-grid operations
- Advanced protection and control

Advanced Distribution improves efficiency and enables "Self Healing" and the use of Demand Resources

Advanced Transmission Solutions

- **Substation Automation**
- **Advanced regional operating applications (RTO)**
- **Wide Area Measurement System (WAMS)**
- **Advance materials and power electronics**
- **Hi-speed information processing**
- **Modeling, simulation and visualization tools**
- **Advanced digital protection**

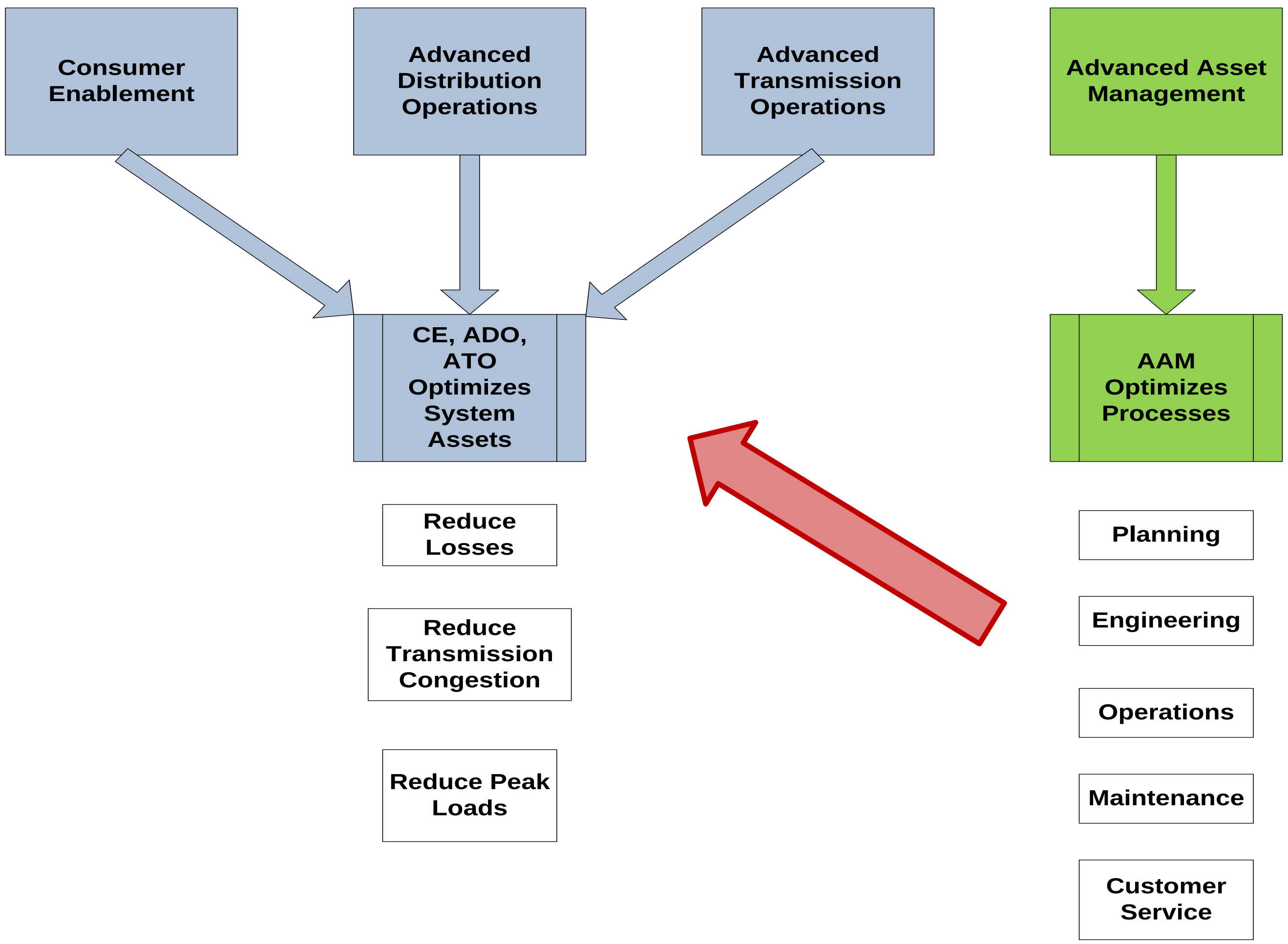
Integrated with CE and AD—AT provides new options for transmission operations

Advanced Asset Management Solutions

- **Advanced sensors**
  - System Parameters
  - Asset "health"
- **Integration of grid intelligence with other processes:**
  - Operations to optimize asset utilization
  - T&D planning
  - Condition based maintenance
  - Engineering, design and construction
  - Work and resource management
  - Customer service

AAM will enable grid optimization to "move to the next level"

Smart Grid Enables Optimization



DMS – A Platform for Optimization

- **Common enterprise network electrical connectivity model**
- **Geographic information system (GIS)**
- **Supervisory control and data acquisition (SCADA)**
- **Customer Information System (CIS)**
- **Engineering Information System (EIS)**
- **Advanced Metering Infrastructure (AMI)**
- **Outage management system (OMS)**
- **Distribution automation (DA)**
- **Conservation Voltage Reduction (CVR)**
- **Condition-based maintenance and asset health monitoring**
- **Workforce Management System**
- **Distribution planning tools**
- **Advanced Network Applications**

The great value of DMS is its capability to display multiple overlays to give users a complete context of various parameters that have been historically separated by utility department processes and technologies (silos).

New Markets Drive System Optimization

- **Aggregators**
- **Energy Service Providers**
- **Financial Systems (PEV transactions)**
- **PEV’s (kwh fuel, V2G, charging stations)**
- **Smart Appliances**
- **In-home Networks**
- **Home Energy Management Systems**
- **Others not yet known**

The Smart Grid is expected to create many new markets

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- **Microgrids**
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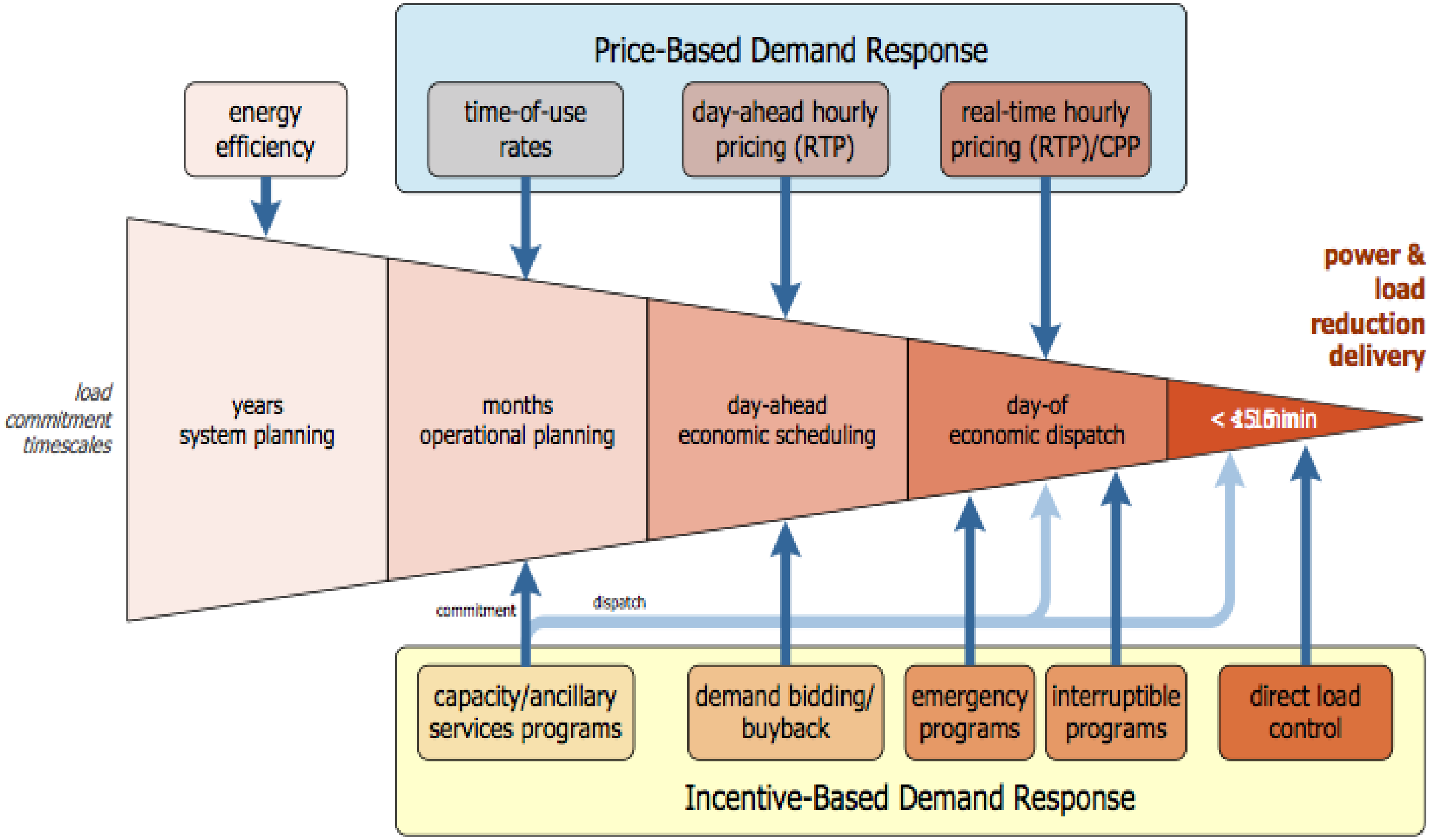
Demand Response is not Demand Dispatch



Source: Energy Central Webcast 4/7/11

Demand Dispatch Definition

"An operating model used by grid operators to dispatch "behind-the-meter" resources in both directions—increasing and decreasing load as viewed at the system level—as a complement to supply (generation) dispatch to more effectively optimize grid operations."

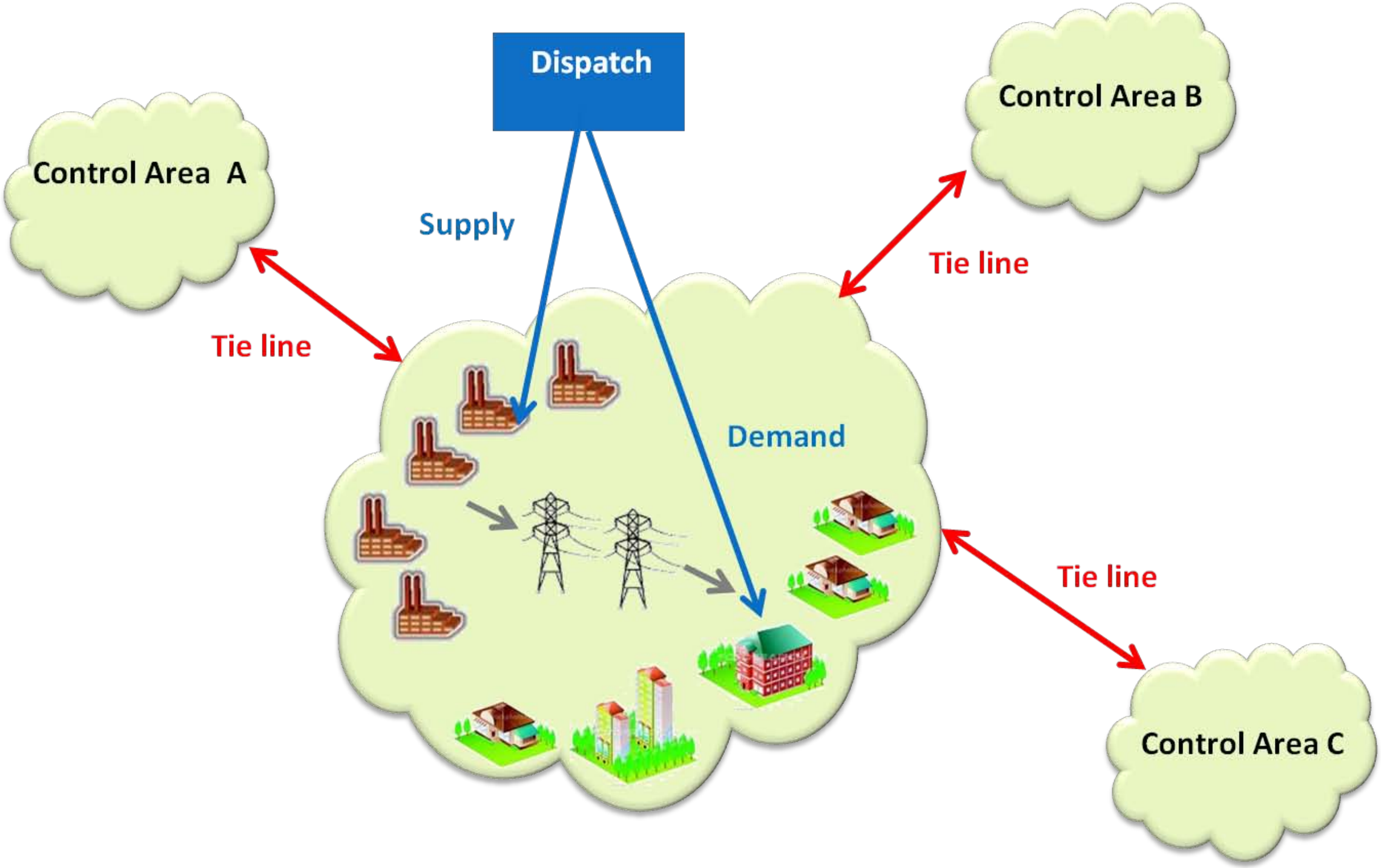
NETL Smart Grid Implementation Team

Demand Dispatch may be the "killer application" that integrates many of the Smart Grid, DR, and Energy Efficiency capabilities

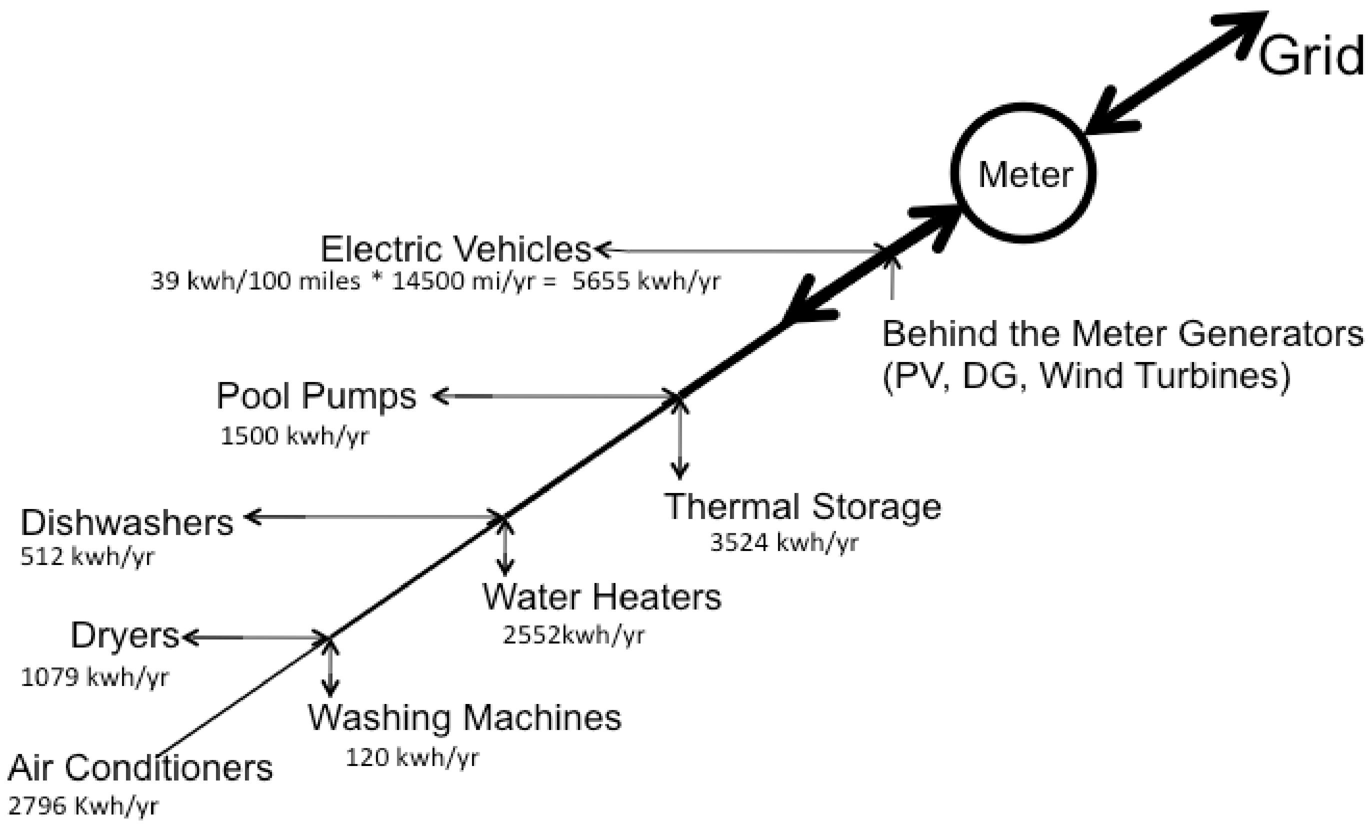
Two Categories of Resources

- **Supply Resources are located on the utility side of the point of delivery (meter)**
  - Central generation
  - Peakers
  - Wind and solar farms
  - Utility scale storage
  - Used by supply dispatch
- **Demand Resources are located behind the point of delivery**
  - Variable load
  - Local generation and storage (wind, solar, EV’s)
  - Used by demand dispatch

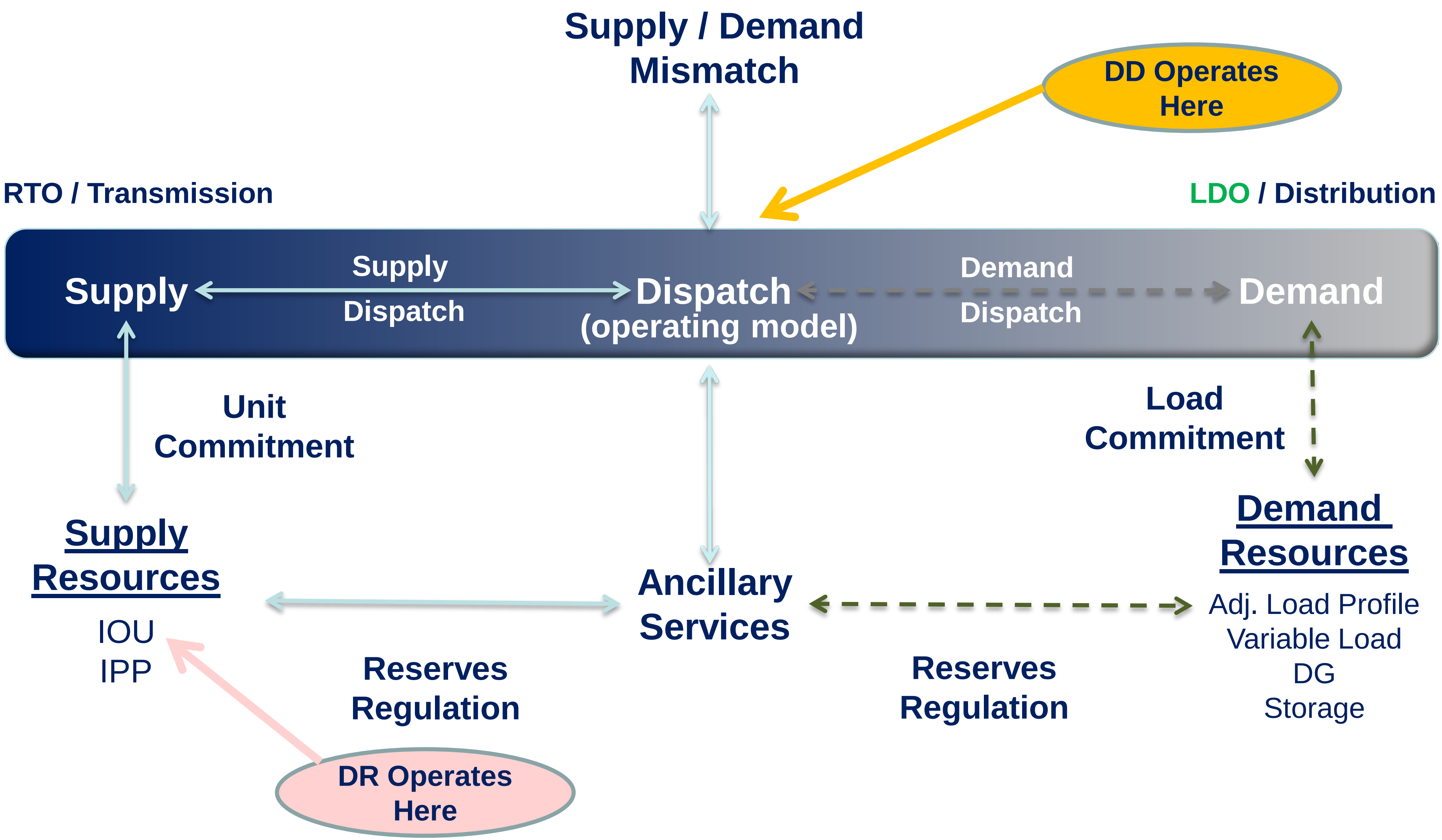
DD – A New Operating Model



Are there enough to make DD work?



Dispatch Spectrum



Consumer Benefits of Demand Dispatch

- ***Financial savings on the retail "power bill"*** received from the "utility" from reduced energy consumption and reduced demand (for customers who have a demand charge.) Anytime the consumer uses less kWh their energy bill will be lower. Anytime the consumer keeps his demand below the "penalty level" it will avoid the demand charge. *This is a savings from the retail slide.*
- ***Revenue earned from market participation*** in the wholesale market through interface with an aggregator, who provides the market interface between the consumer and the wholesale RTO. This revenue can come from the energy, capacity, and ancillary services markets. *This is revenue earned by the consumer from the wholesale market via the aggregator.*
- ***Identification of new and permanent energy efficiency solutions*** that become obvious as variable loads are replaced with more efficient solutions (e.g., rather than modulate the ballasts of lighting from 100 watts to 80 watts as part of Demand Dispatch, just replace the lighting with more efficient, lower wattage lighting.)

Societal Benefits of Demand Dispatch

- ***Incremental downward pressure on future prices over BAU —*** Large capital investments in additional supply resources can be eliminated or deferred, reducing future retail prices to consumers over what they would have been if these investments would have been made.
- ***Reduction in real time wholesale prices —*** By reducing the peak in the real time market, a less costly unit will clear the market, reducing real time wholesale prices. All consumers benefit even though only a small percentage participate in the DD transactions that actually cause the wholesale clearing price to be less.
- ***Ability to increase the future integration level of renewables —*** DD will enable an incremental increase in the amount of variable (renewables) supply resources that can be accommodated into grid operations. This incremental amount of renewables has a corresponding future value in reduced emissions of all types.
- ***Increased use of existing renewable resources —*** DD will enable a higher level of optimization of supply resources to occur in the real time "environmental market" (future carbon or emissions markets). This optimization can be done around minimizing emissions. This is a real time benefit in reducing emissions of all types.

Smart Grid / Demand Dispatch Synergies

SG Characteristic	DD Synergy
Enable active participation by consumers	Will provide *incremental motivation* for consumer participation by creating opportunities to reduce costs, generate revenues, and reduce environmental impacts
Accommodate all generation and storage options	Employs and *encourages the investment in demand resources* and provides a mechanism for increased penetration of renewable resources on the grid
Enable new products, services, and markets	*Creates new markets* attracting consumers and innovations
Provide power quality for the digital economy	Enables applications that can include *control of PQ and voltage regulation* at the feeder level
Optimize asset utilization and operate efficiently	Enables *complete system optimization* by allowing grid operators to dispatch both supply and demand to meet reliability, efficiency, economic, and environmental goals.
Anticipate & respond to system disturbances (self-heal)	Monitors and controls demand resources *enhancing the self-healing nature* of the SG.
Operate resiliently against attack and natural disaster	Monitors and controls demand resources allowing *faster restoration* from outages. Increased penetration of distributed resources *reduces grid vulnerability*

It Won’t be Easy

- **New market rules for DD will be needed**
- **Compelling incentives will be needed to drive consumer participation**
- **Will someone (utilities, aggregators, etc.) step up to build a DD business?**
- **How will the wholesale and retail regulators’ boundaries / jurisdictions be aligned to support DD?**
- **How will DD transactions be settled given the potentially huge number of participants?**
- **Will DD impose new requirements on the Smart Grid communications systems?**

Is it worth it?

Demand Dispatch Status and Next Steps

- DD receiving increased attention across the globe
- Pilot installations are underway but limited
- Additional discussion and deep debate on Demand Dispatch is needed
- Detailed modeling required to understand the quantitative value and to identify appropriate market incentives for all potential players

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- ***Micrograds***
- **Q&A**

What is a Microgrid?

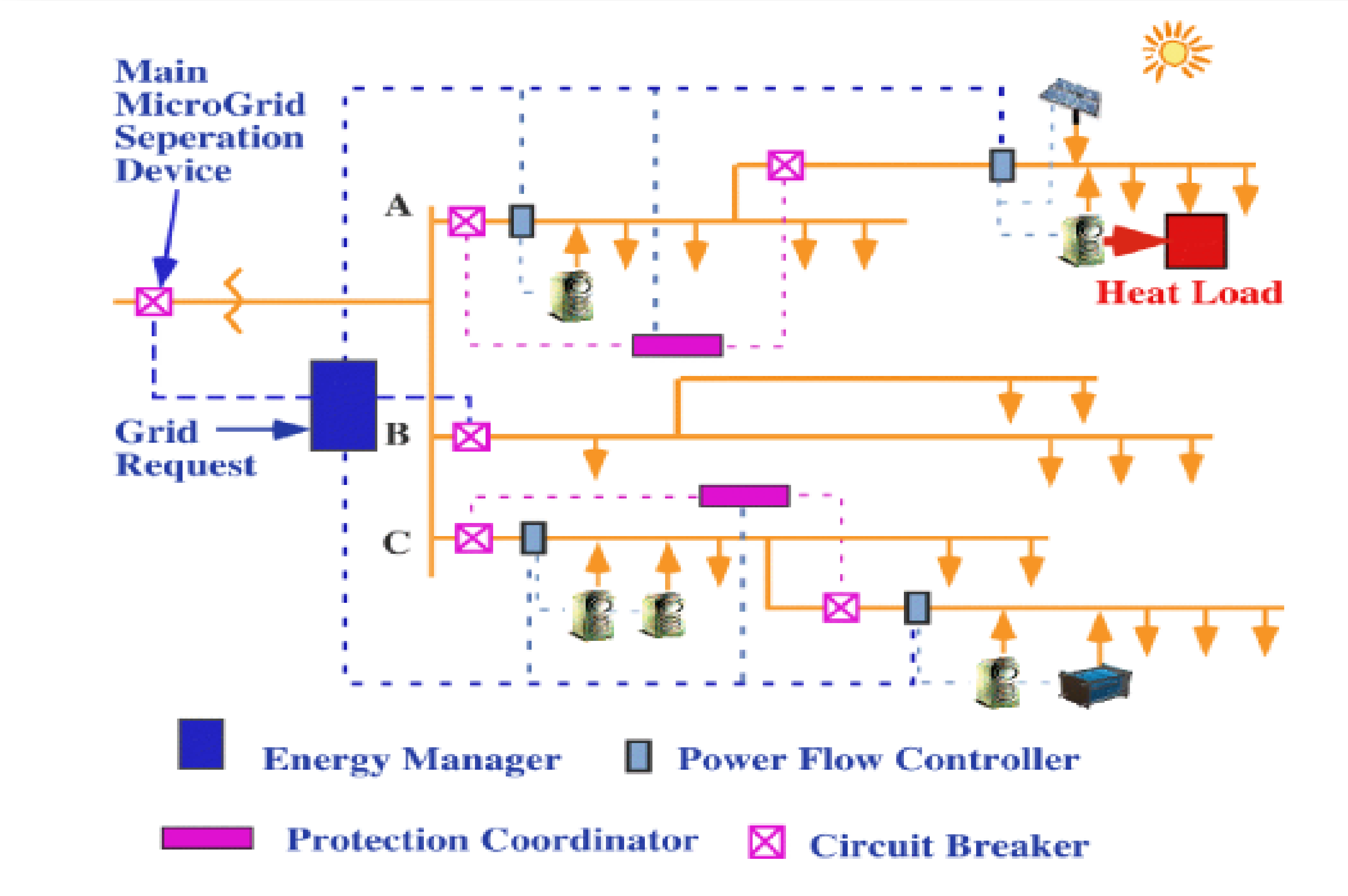
"A **Microgrid** is a group of interconnected loads and distributed energy resources within clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid. A microgrid can connect and disconnect from the grid to enable it to operate in both grid-connected or island mode."

Microgrid Exchange Group, October 2010

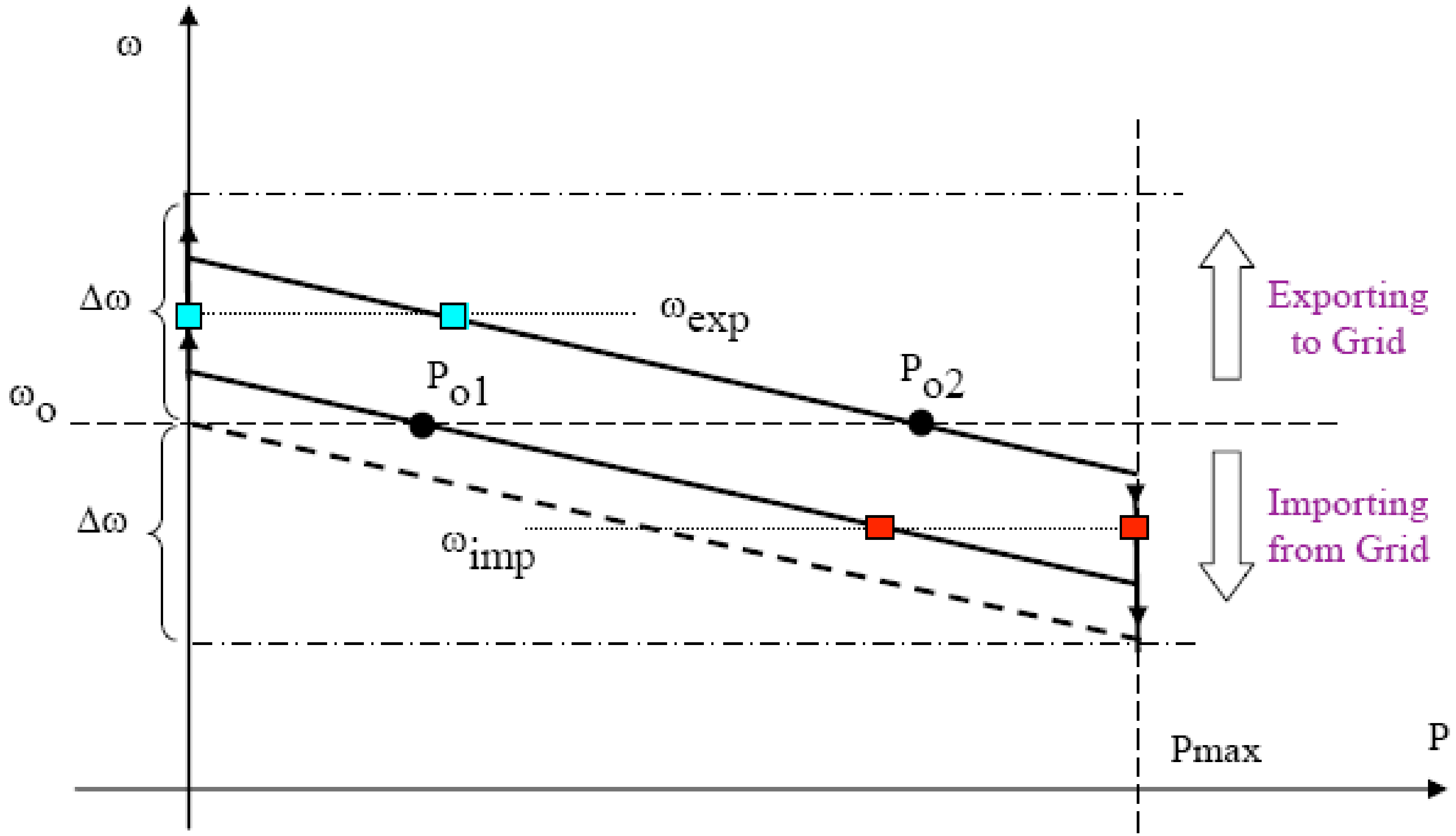
"**Microgrids** are modern, small-scale versions of the centralized electricity system. They achieve specific local goals, such as reliability, carbon emission reduction, diversification of energy sources, and cost reduction, established by the community being served."

The Galvin Electricity Initiative

CERTS Microgrid One-Line Diagram



Local Controller Characteristics



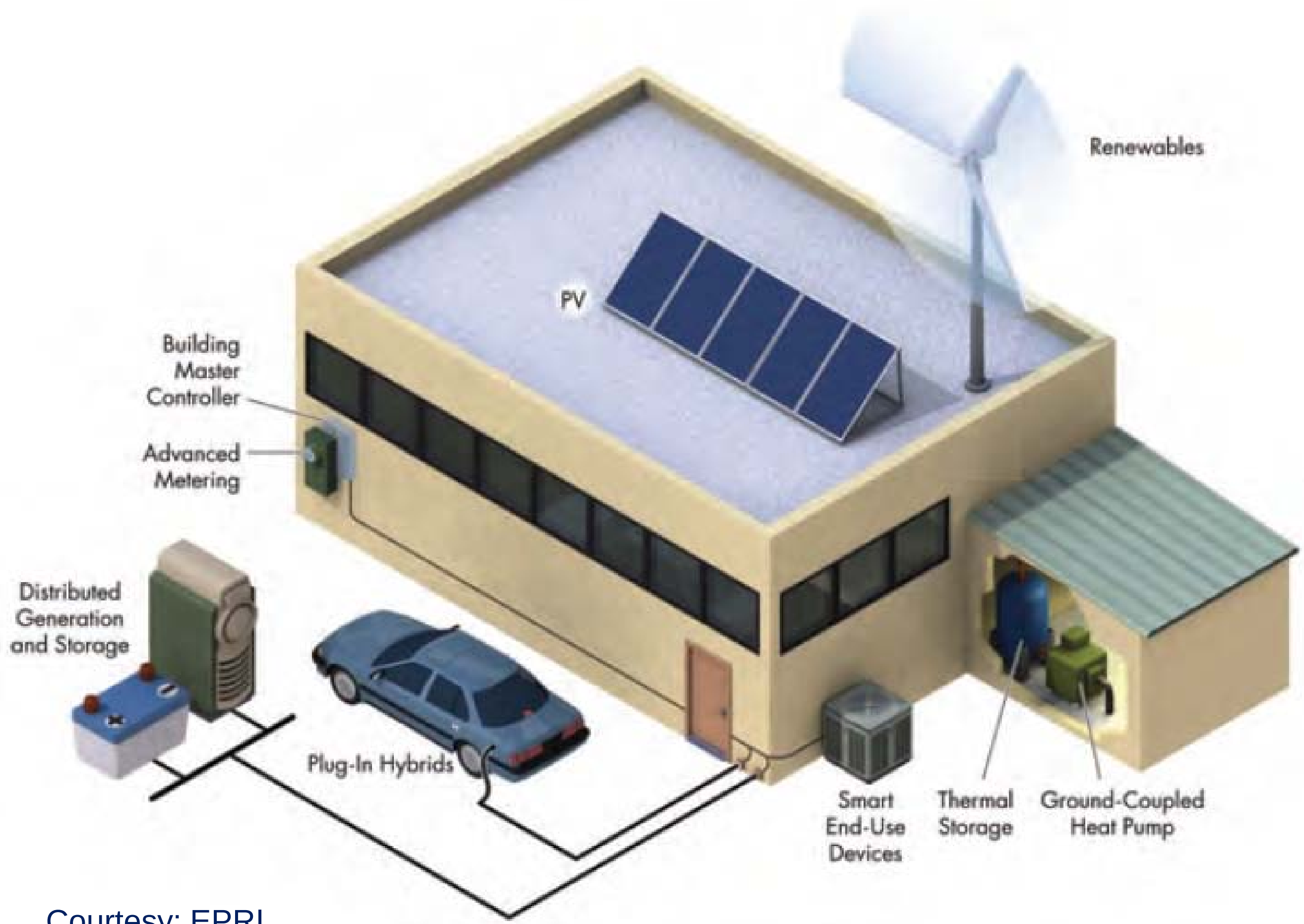
Power vs. Frequency Droop

Various Configurations Possible

- **Consumer Microgrid—demand resources on consumer side of the point of delivery, single consumer (e.g. sports stadium)**
- **Community Microgrid— multiple consumers with demand resources on consumer side of the point of delivery, local objectives, consumer owned, (e.g., campus, etc.)**
- **Utility Microgrid—supply resources on utility side with consumer interactions, utility objectives**

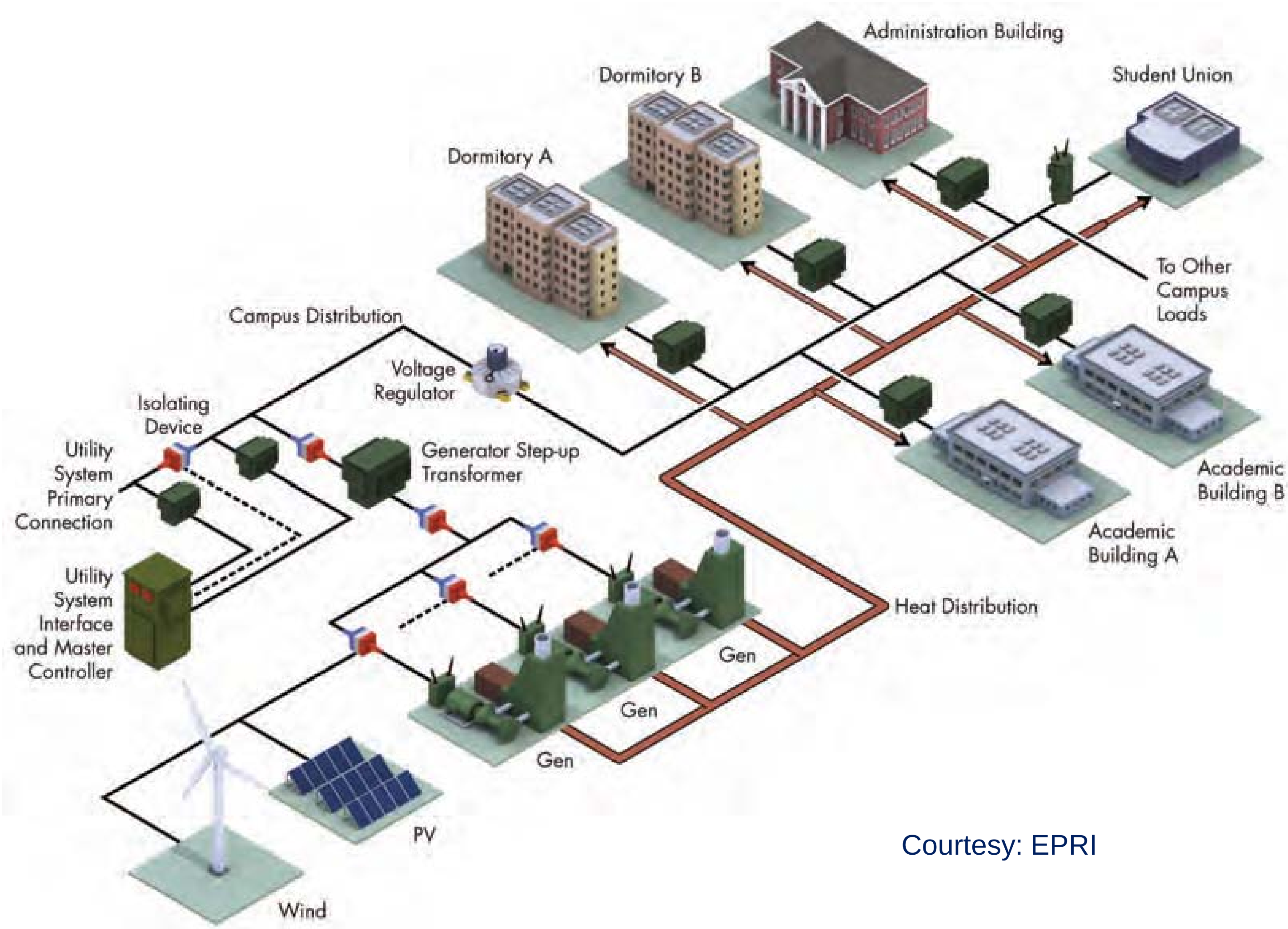
Microgrids are "Local Energy Networks"

Consumer Microgrid



Courtesy: EPRI

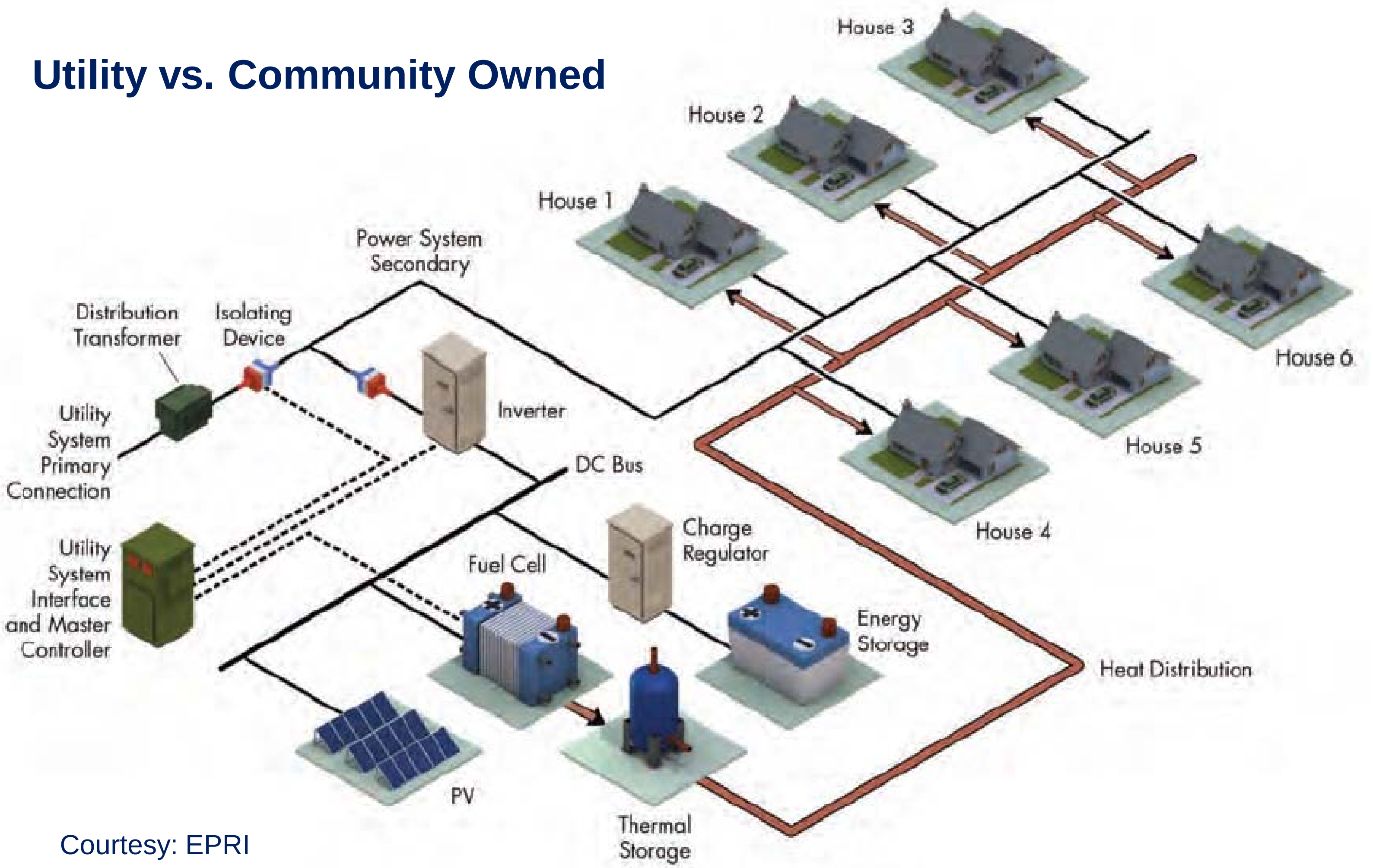
Community (Campus) Microgrid



Courtesy: EPRI

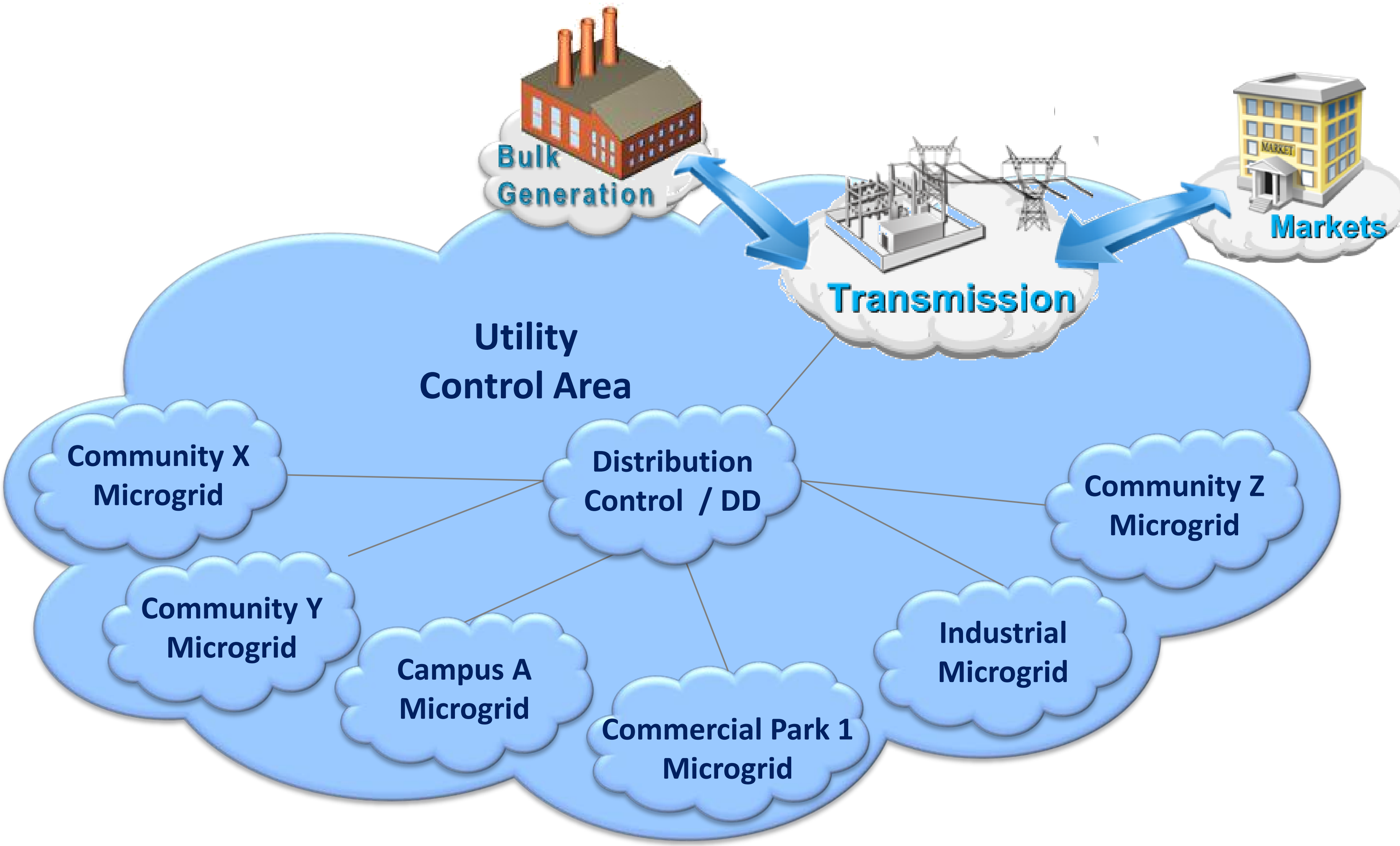
Utility Microgrid

Utility vs. Community Owned



Courtesy: EPRI

A Possible Future Distribution Architecture



Why Microgrids?

"…the current system has become incapable of meeting the growing needs of twenty-first century consumers. One solution to this problem is to expand the role of smart microgrids that interact with the bulk power grid but can also operate independently of it in case of an outage or other disturbance." *The Galvin Electricity Initiative*

"These [projects] will help to increase reliability in our electric grid by defraying both the cost and effort associated with upgrading distribution lines or adding new generation capacity to meet peak electrical load, furthering our ongoing efforts to increase national economic and energy security." *DOE Assistant Secretary Kevin Kolevar, April 2008, regarding the microgrid project winners*

"While still mainly an experiment, microgrids could grow to be a significant, if still small, portion of the smart grid market. That's according to Pike Research, which projects that microgrids will grow to a $2.1 billion market by 2015, with $7.8 billion invested over that time." *Jeff St. John, GreenTech Media, October 2009*

Role of Microgrids

- **Address local reliability challenges**
- **Address local economic issues**
- **Support environmental stewardship**
- **Enable energy arbitrage**
- **Aggregate control of multiple sources (DG, storage, consumer DER, DR, switches, Cap Banks, DA, etc.) and loads**
- **Act as demand resource for Demand Dispatch**

Microgrids are a "mini-application" of Demand Dispatch

Some Potential Applications

- Sports Stadiums
- Municipalities
- Commercial Parks
- Industrial Complexes
- University Campuses
- Military Facilities
- Utilities
- “Communities”

Microgrid Components

- Microgrid master controller (software brains)
- Device Controllers
- Distributed generation
- Energy storage
- Variable Load
- Energy and ancillary services market
- Broadband communications

Microgrid Master Controller

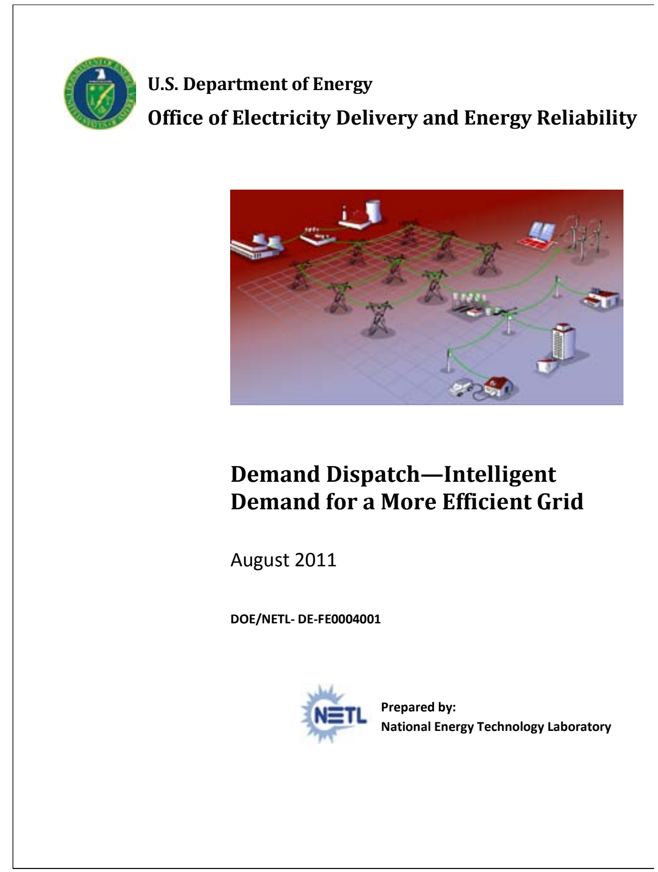
- **Microgrid master controller (MMC) – the brain – actively control electric supply and consumption 24/7**
- **Objectives**
  - Optimize economics
  - Optimize reliability
  - Reduce carbon footprint
- **Interfaces with local device controllers for reliability**

Please Contact the SGIS team

Visit:

http://www.netl.doe.gov/smartgrid

For more information and to provide your input



U.S. Department of Energy

Office of Electricity Delivery and Energy Reliability

Demand Dispatch—Intelligent Demand for a More Efficient Grid

August 2011

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Prepared by:
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