



# Unbundling and Smart Grids—US Experience

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# Outline

- Unbundling of the US energy companies
- Smart Grids initiatives in the US
- Unbundling and Smart Grids
- Opportunities for moving forward
- Need for IT-enabled Rules, Rights and Responsibilities in Support of Efficient Integration of Wind Power and Responsive Demand [PUF Magazine, Dec 09]
- Dynamic Monitoring and Decision Systems (DYMONDS) and Smart Grids: One and the Same [CMU EESG WP-019]

## Unbundling of the US Energy Companies

- No recent developments (except for a few States which have re-regulated)
- States which have restructured have bulk power spot electricity markets; no retail markets
- Utilities still providers of the last resort; TX has competitive Load Serving Entities (LSEs)
- Energy generation traded competitively; LSEs and/or utilities bidding on behalf of their customers; T&D cost+ based; no real markets for relevant derivatives (ancillary services, voltage support, reliability)

# Smart Grid Initiatives in the US

- EPA 2007, Article 13 requires utilities to demonstrate significant reduced demand by 2015
- Many technological advances (renewable DERs, AMIs, PMUs, NIST Inter-operability platform designs)
- Uncertain environmental regulation; subsidies for clean power; difficult to integrate new resources in the existing system
- Stimulus funding for demonstrating smart grids

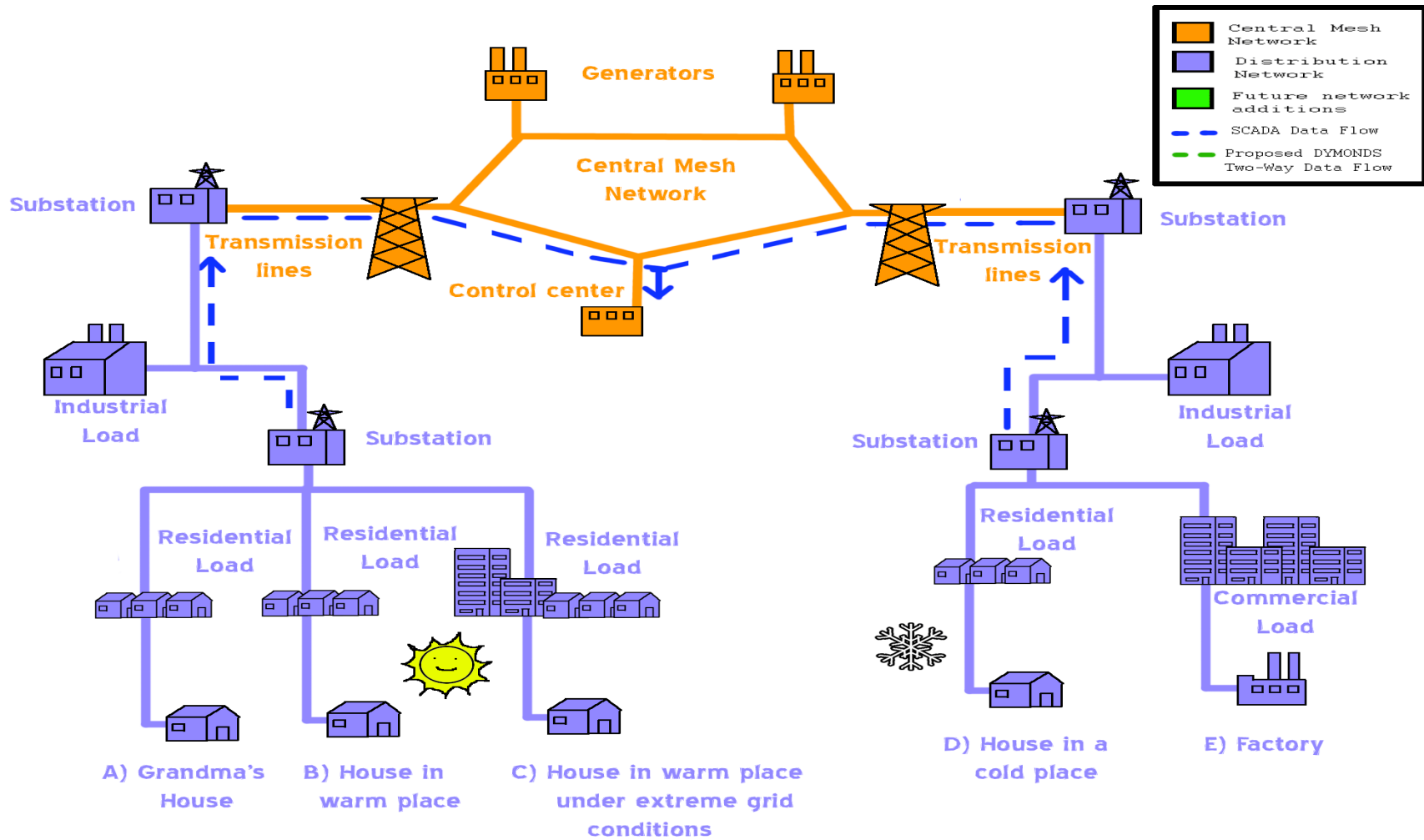
# Unbundling and Smart Grids

- Unlikely to have a sustainable penetration of smart grid technologies (despite their deployment) at value without designing rules, rights and responsibilities (3Rs) to support it
- Asymmetric risk not managed at value
- No incentives to ensure both differentiated reliability of service and enhanced short- and long-term efficiency
- No regulatory mechanisms for sustainable investment in technologies that are key to reconciling reliability and efficiency (JIT, JIP and JIC technologies)

# Need for 3Rs in support of Smart Grids

- Uncertainties huge ---need for distributed dynamic risk management over time, geography and industry participants
- Value of prediction; forward contracts/commitments and their valuation
- Need to differentiate value of technologies w.r.t. their rate of response and availability, and time horizon over which they are committed (value of long-term contracts);
- Incentives to build just enough storage; Adaptive Load Management (self-regulation); sustainable LSEs

# Today's power grid



# Today's Industry Practice

- T not coordinated with D. Knowledge of D power factors particularly poor.
- No on-line voltage adaptation to manage load efficiently.
- D systems are not managed on-line.
- As a result, large reserve needed in case something goes wrong.
- Planning—deterministic for the peak hour.
- No innovative technologies considered, instead only planning based on proven technologies.

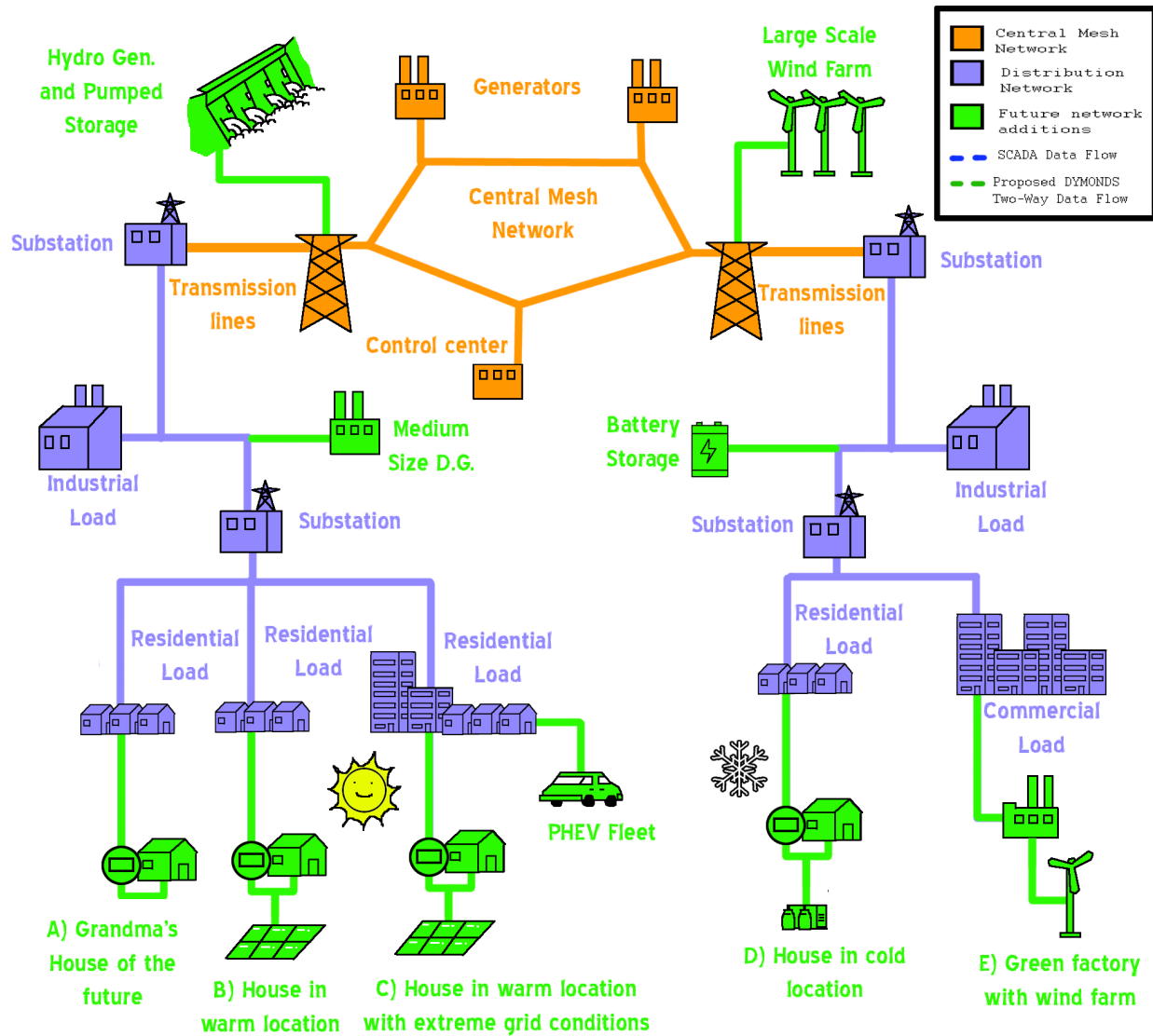
# What is Changing?

- Much more action at the D level due to:  
(1) responsive demand; (2) variable distributed resources (DRs); (3) new security and environmental constraints.
- Much harder to predict supply-demand (SD) imbalance accurately by the control centers without self-commitment by the DRs and LSEs (both short-term and long-term).
- Correlating diverse loads and DRs much harder than in the past (T level cannot assume D-loads known.)

# Key Smart Grid Functionalities

- **Just-in-Time (JIT)** --predictions; dynamic look-ahead decision making
- **Just-in-Place (JIP)** --distributed, interactive, multi-layered
- **Just-in-Context (JIC)** ---- performance objectives function of organizational rules, rights, and responsibilities (3Rs) and system conditions.
- Sample examples of improved performance—on-going work in EESG  
<http://www.eesg.ece.cmu.edu>

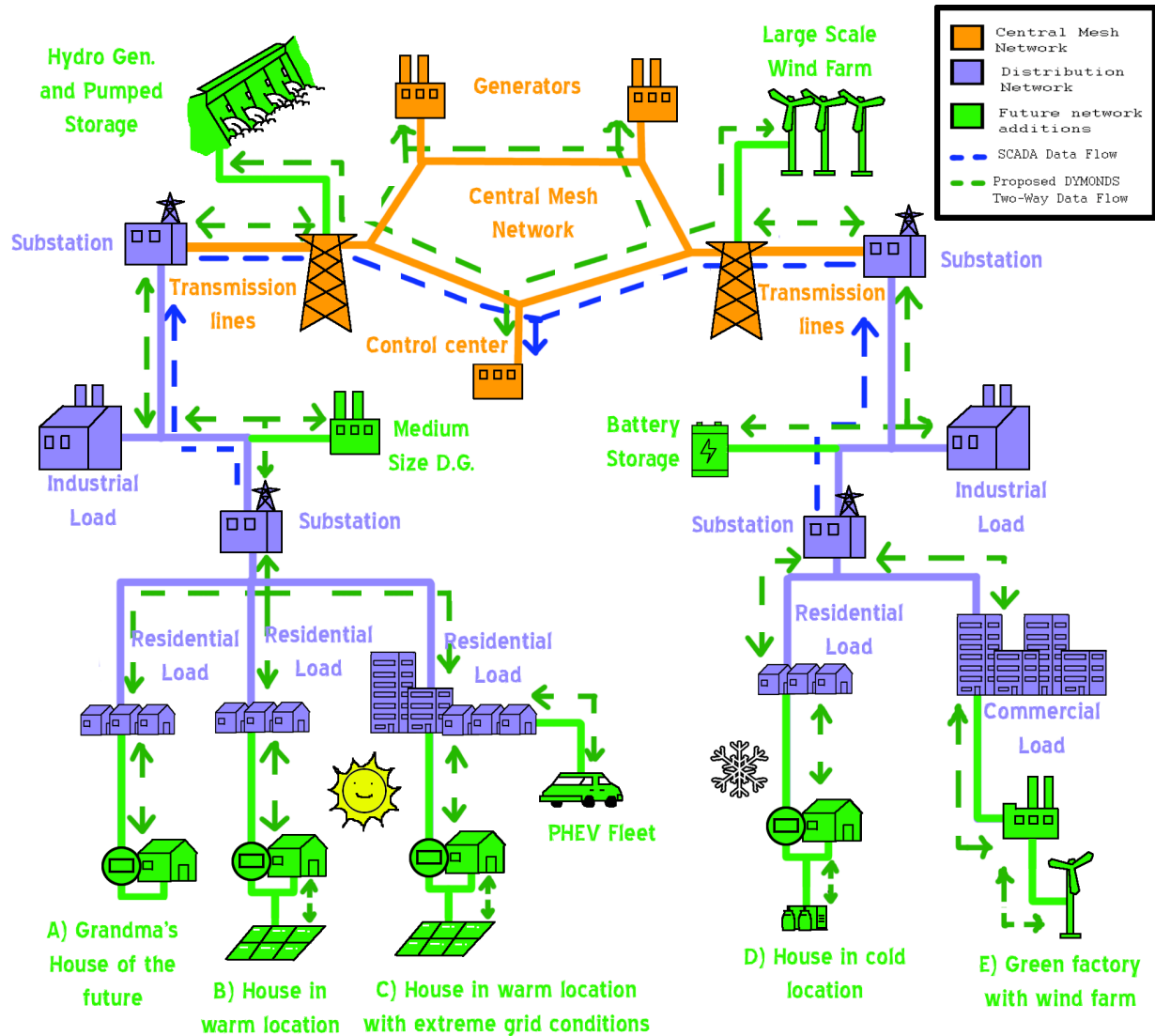
# Future Smart Grid (Physical system)



# Critical: Transform SCADA

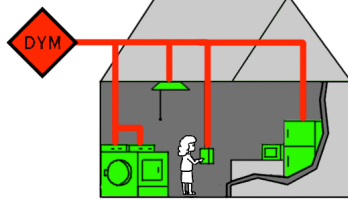
- From single top-down coordinating management to the multi-directional multi-layered interactive IT exchange.
- At CMU we call such transformed SCADA Dynamic Monitoring and Decision Systems (DYMONDS) and have formed a Center to work with industry and government on: (1) new models to define what is the type and rate of key IT exchange; (2) new decision tools for self-commitment and clearing such commitments. [\http://www.eesg.ece.cmu.edu](http://www.eesg.ece.cmu.edu).

# New SCADA

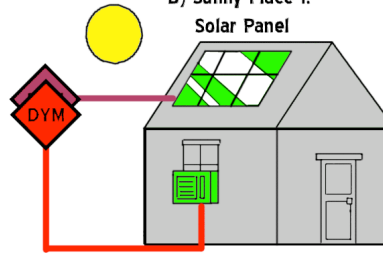


# Smart users

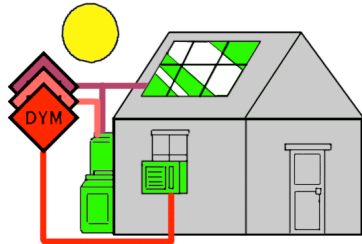
A) Grandma's House:  
Smart Metering, Automation for Appliances



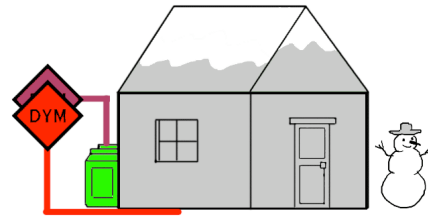
B) Sunny Place 1:  
Solar Panel



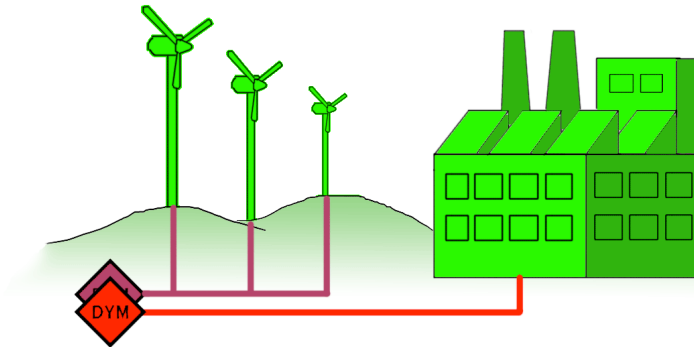
C) Sunny Place 2:  
Solar Panel, Backup Power, Storage



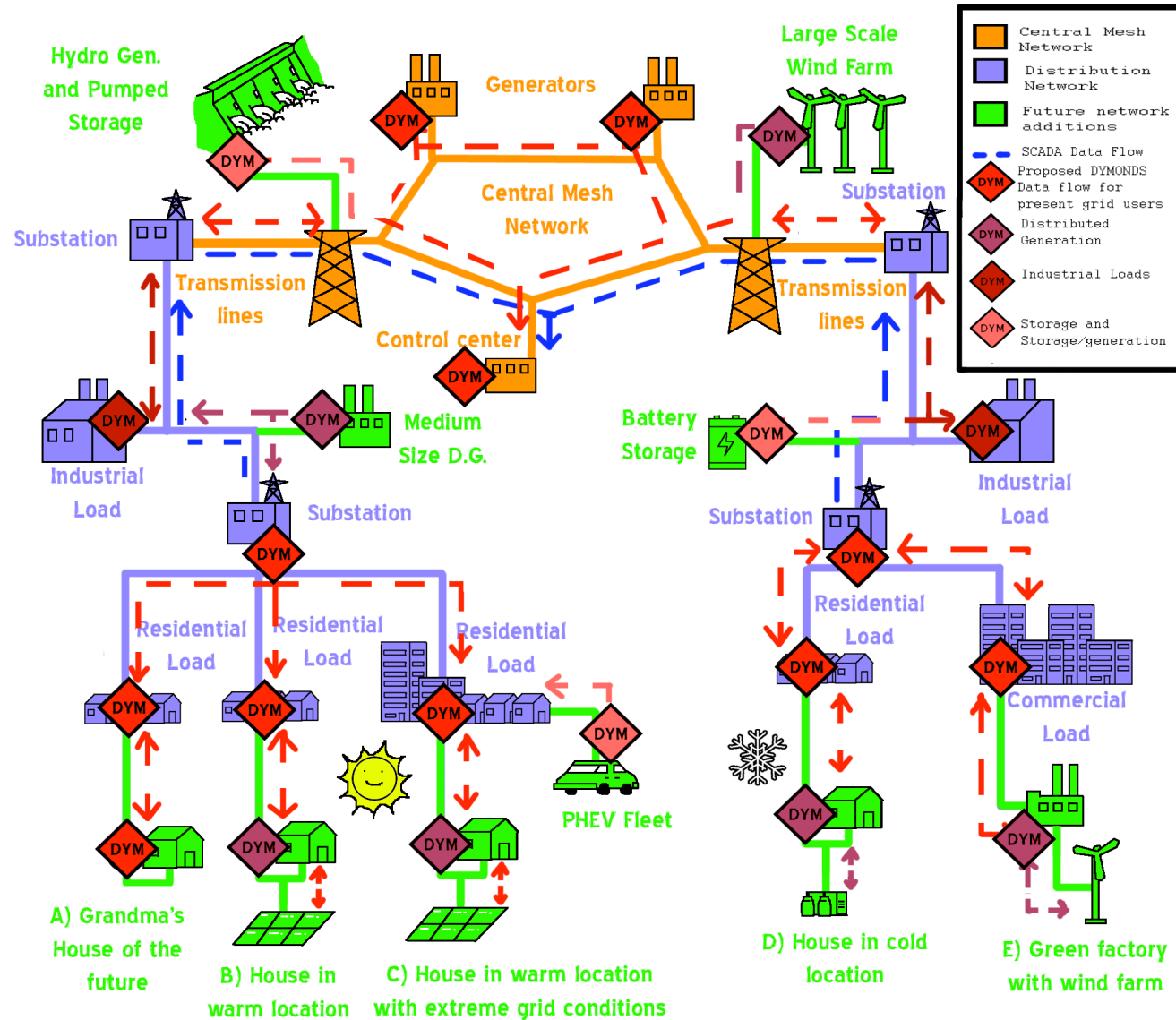
D) Cold Place:  
Backup Power, Micro CHP



E) Green Factory: Automation, Proximity to Wind Farm



# DYMONDS-enabled Physical Grid



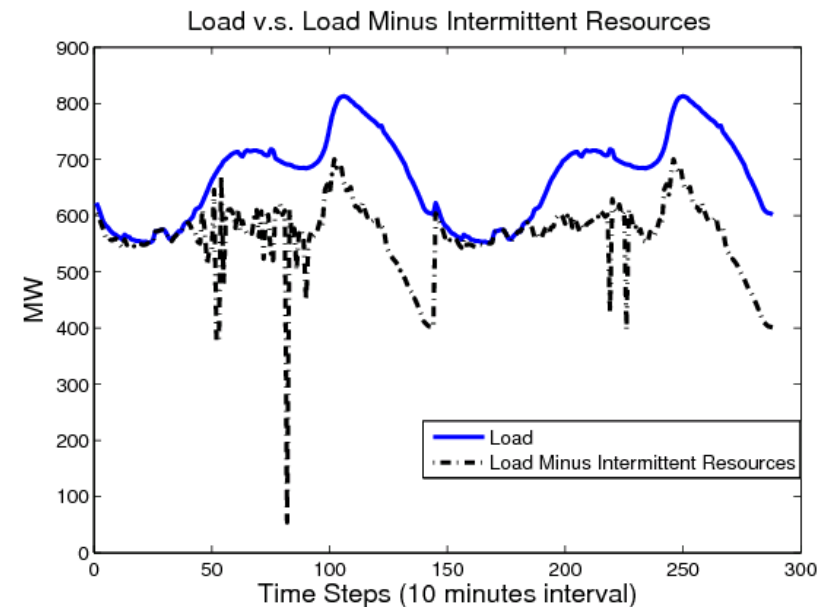
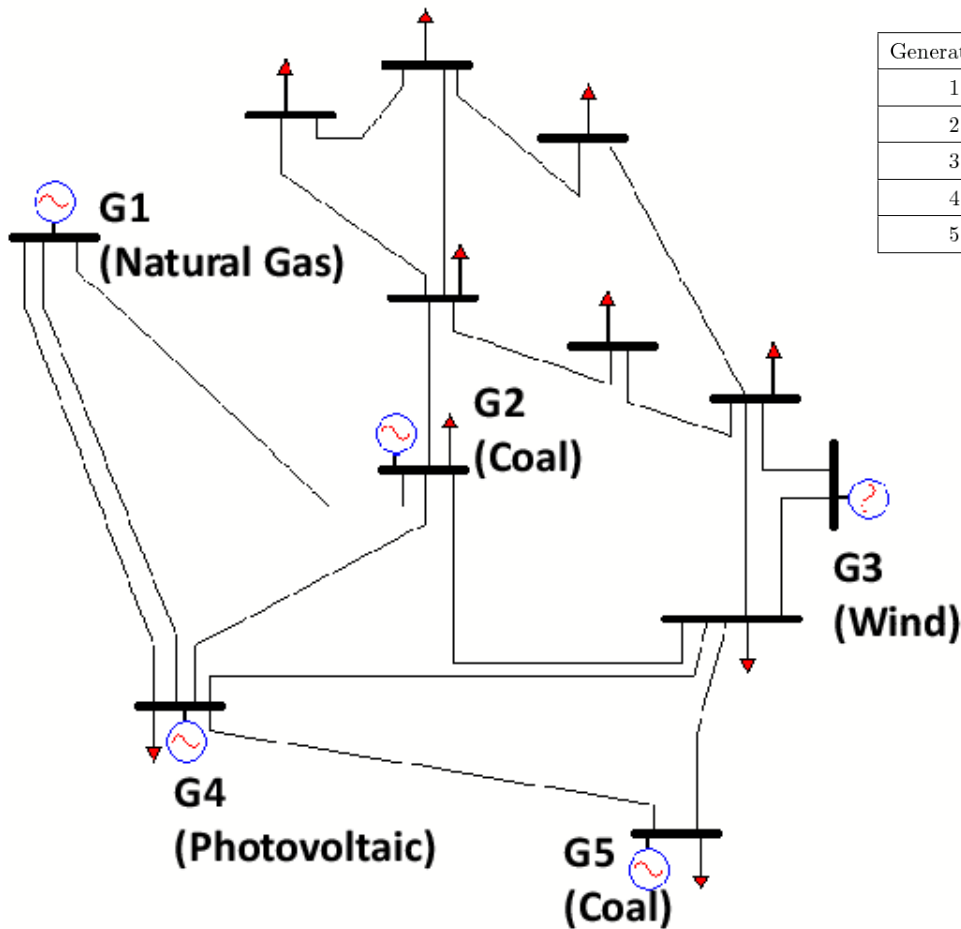
# T&D as an Enabler

- New dispatch of self-regulating resources together will make it possible to fit different pieces of the puzzle together.
- Much more reliance on distributed sensing, actuation and coordinated management of these resources. Real time awareness of D flows.
- No models, no simulations, no decision tools. Without these, it will be much more costly to proceed. R&D ahead of us.

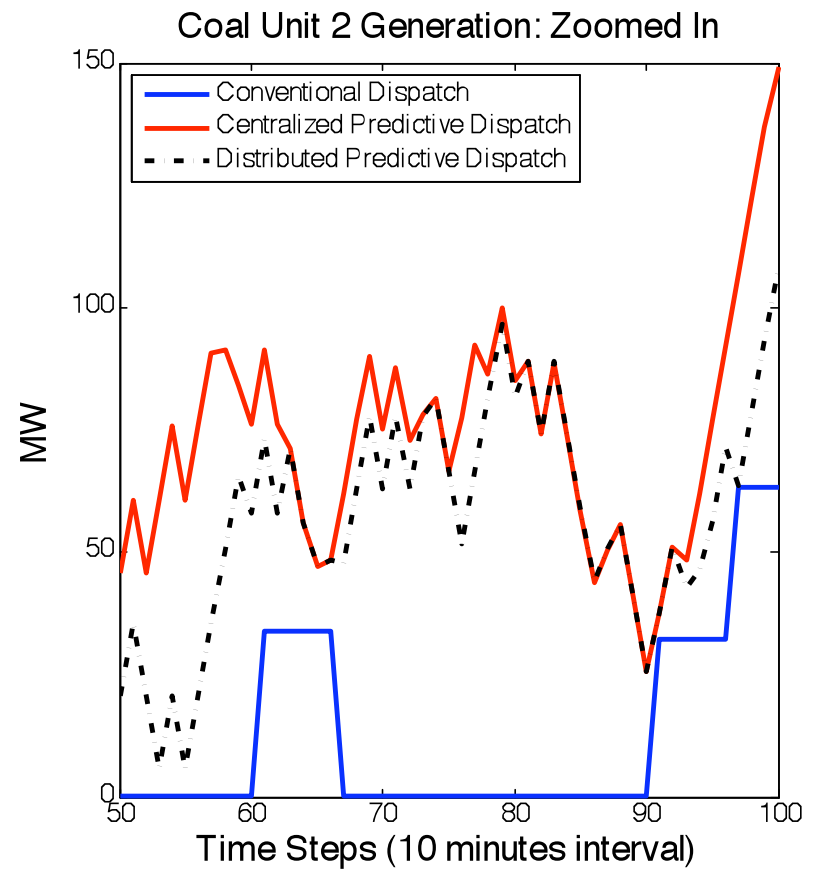
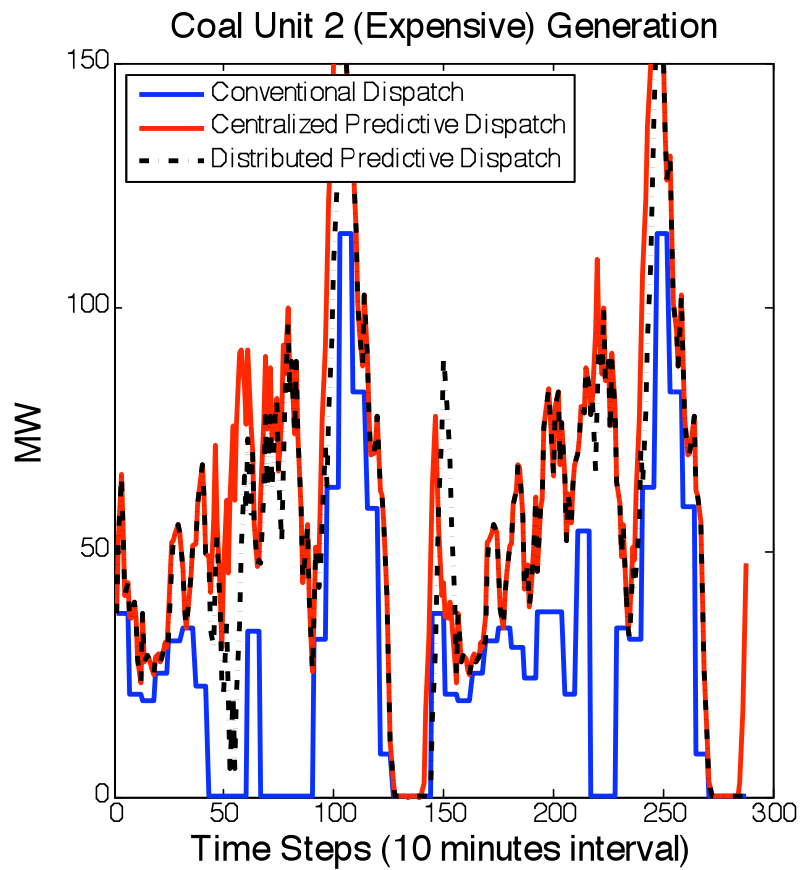
# Wind prediction, look-ahead management using storage (Xie,2009)

Table 1: Generator parameters of the 12-bus system

Generator ID	Type	Min Generation	Max Generation	Generation Cost	Ramp Rate
1	Gas	20	500MW	350\$/MWh	150MW/5 min
2	Coal	20	500MW	150\$/MWh	15MW/5min
3	Wind	0	250MW	0\$/MWh	150MW/5 min
4	PV	0	600MW	0\$/MWh	200MW/5 min
5	Coal	10	500MW	100\$/MWh	10MW/5 min

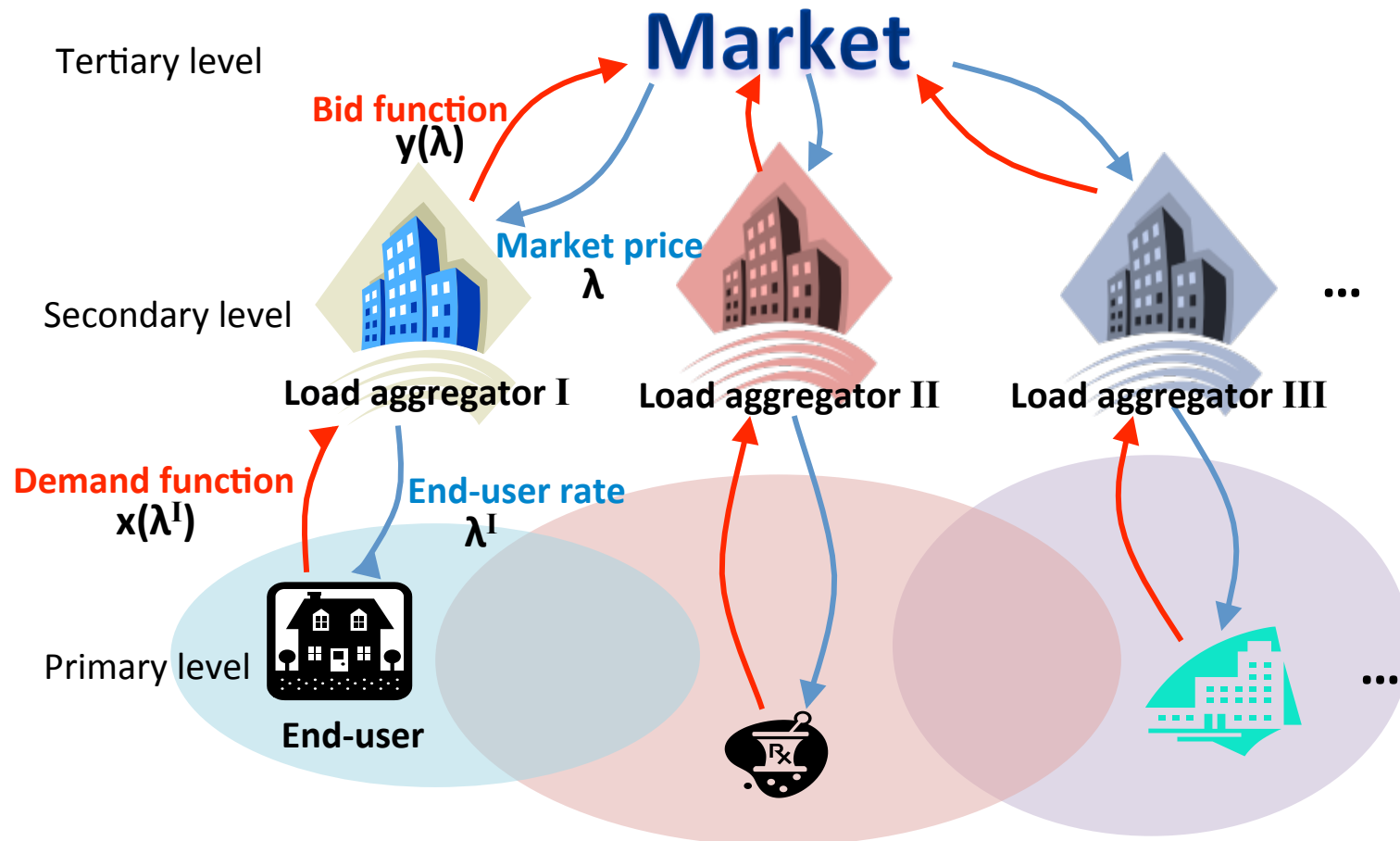


Compare the outcome of ED from both the centralized and distributed MPC approaches.

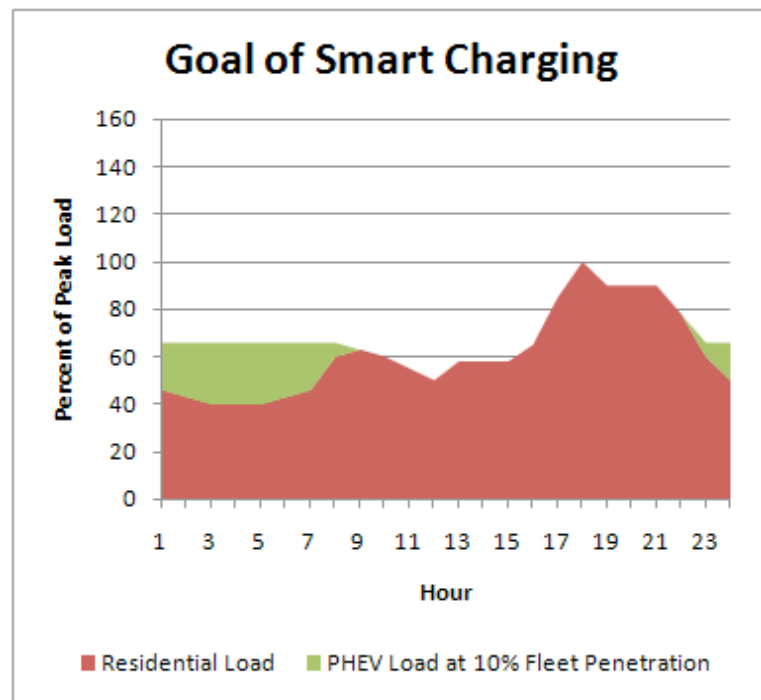
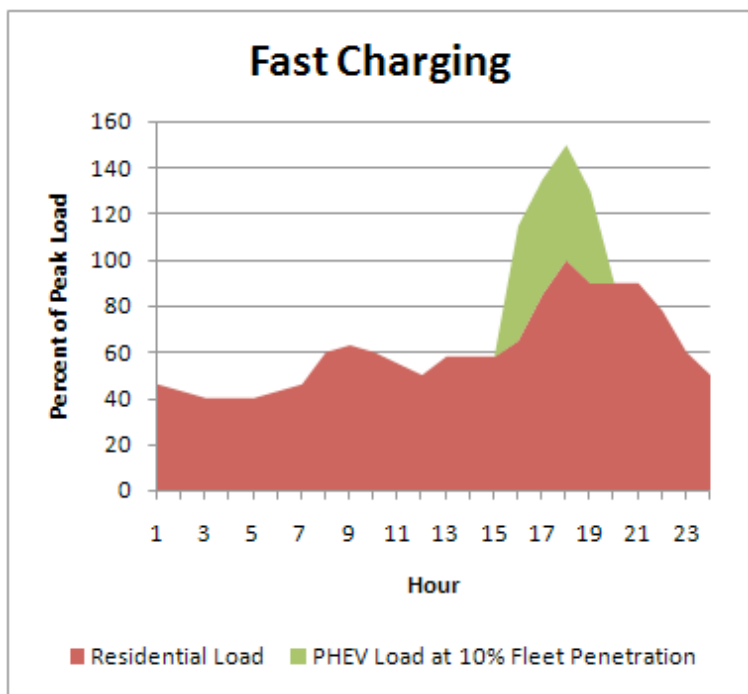


BOTH EFFICIENCY AND RELIABILITY MET

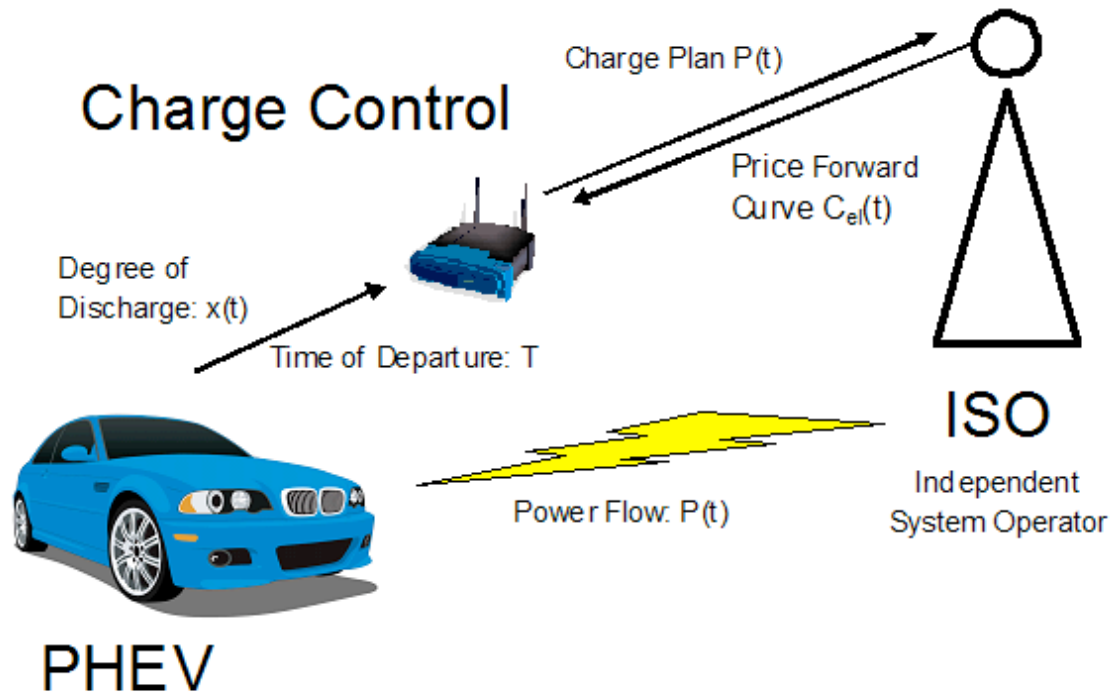
# Adaptive Load Management (Joo, 2009)



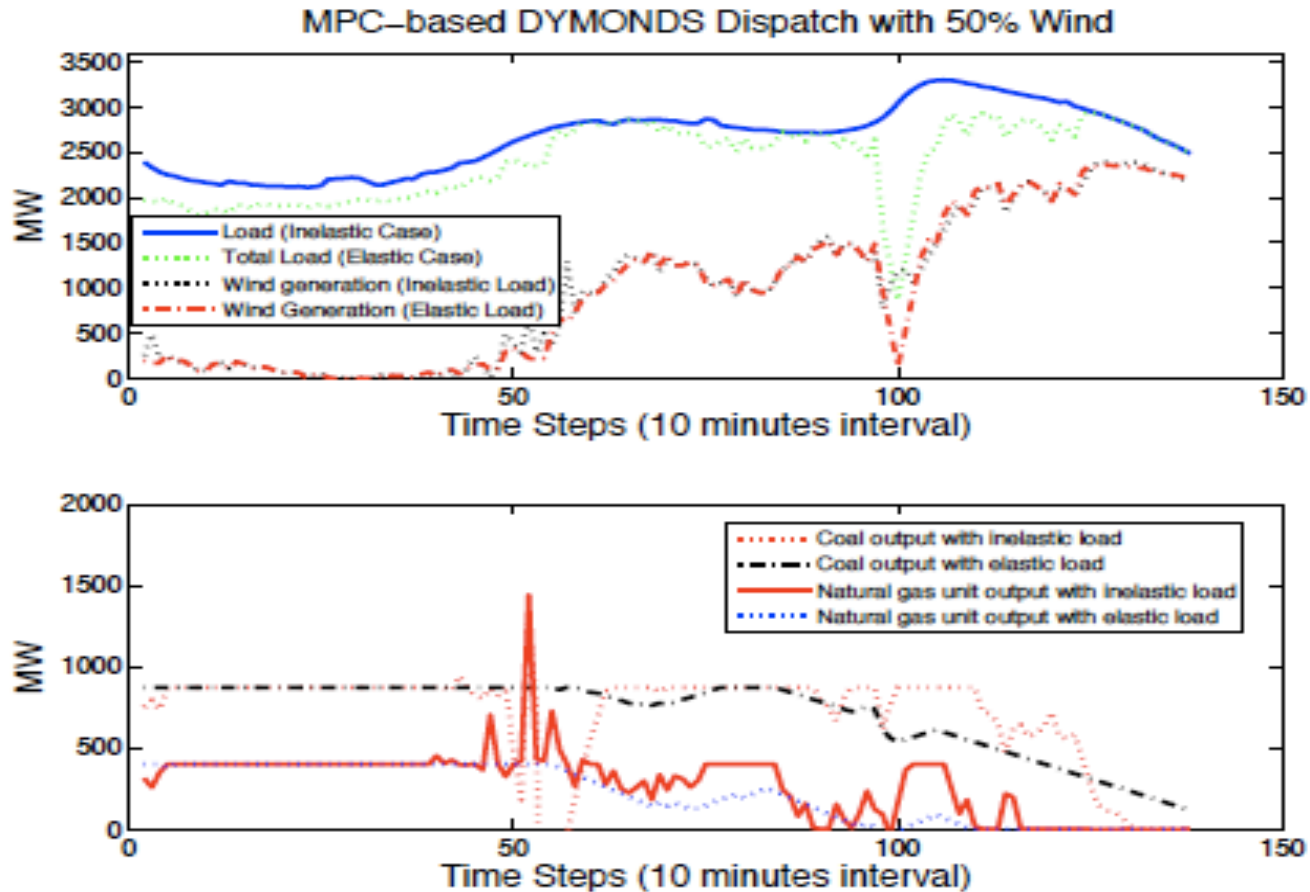
# Optimal Control of Plug-in-Electric Vehicles: Fast vs. Smart (Rotering)



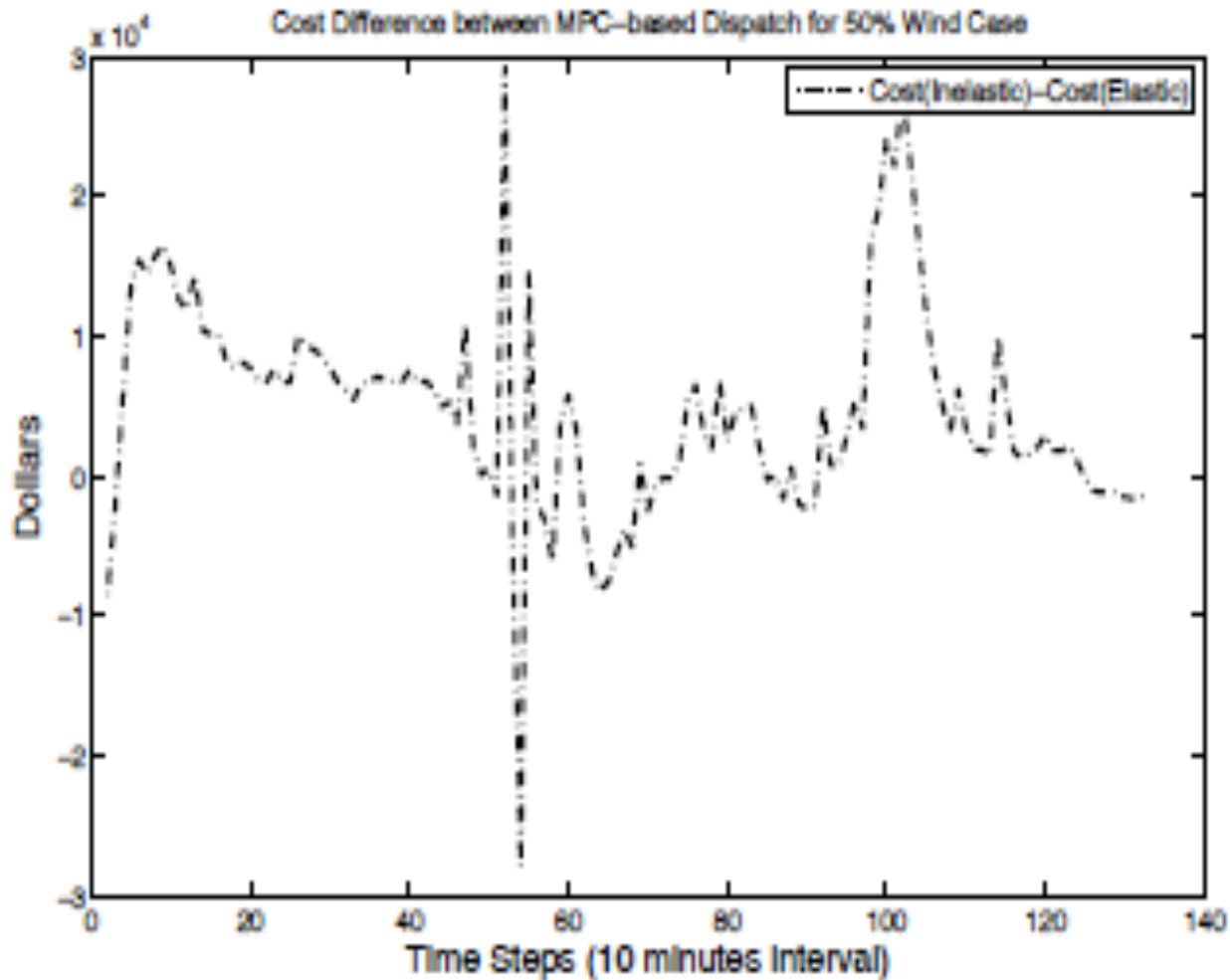
# Information flow—Fantastic Use of Multi-layered Dynamic Programming



# Integrating >50% Wind [1]



# Potential Savings with Self - Committing Dispatch



# ALM not Direct Load Control

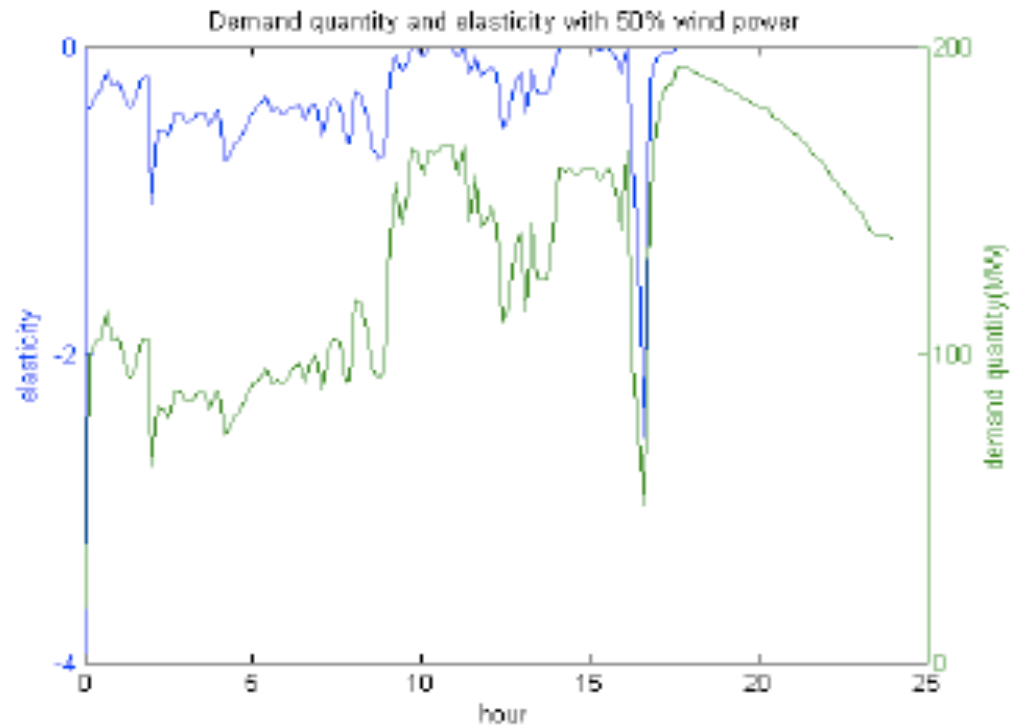


Fig. 24. Price elasticity of demand and demand quantity(MW) with 50% wind penetration

# Planning Needs for the Changing Industry

- The uncertainties are unacceptably high for the system operators to take the risk.
- Instead distributed long-term energy/capacity bids by the LSEs and power plants, and the T&D providers.
- LSEs offer what they need and WTP; suppliers offer what they need to build and provide in the future and at which price.
- System operators clear these long-term bids.
- Distributed long-term risks over all participants and at value.

# Closing remarks

- There exists now a highly unusual window of opportunity to introduce modern electric energy research and education programs.
- Obvious societal needs
- We will waste this opportunity without a full understanding of
  - the potential of embedded IT-enabled intelligence in the new resources, and
  - the role of multi-layered multi-directional coordination within the complex novel network architectures.
- It is essential to pose the design and operation of new electric energy systems as the problem of multiple performance-driven cyber-physical systems over various contextual, temporal and spatial phenomena.

# Electric Energy Systems Group (EESG)

<http://www.eesg.ece.cmu.edu>

- A multi-disciplinary group of researchers from across Carnegie Mellon with common interest in electric energy.
- Truly integrated education and research
- Interests range across technical, policy, sensing, communications, computing and much more; emphasis on systems aspects of the changing industry, model-based simulations and decision making/control for predictable performance.