

Southern California Smart Grid Symposium  
California Institute of Technology

# Competitive Electricity Markets with Consumer Subscription Service in a Smart Grid World

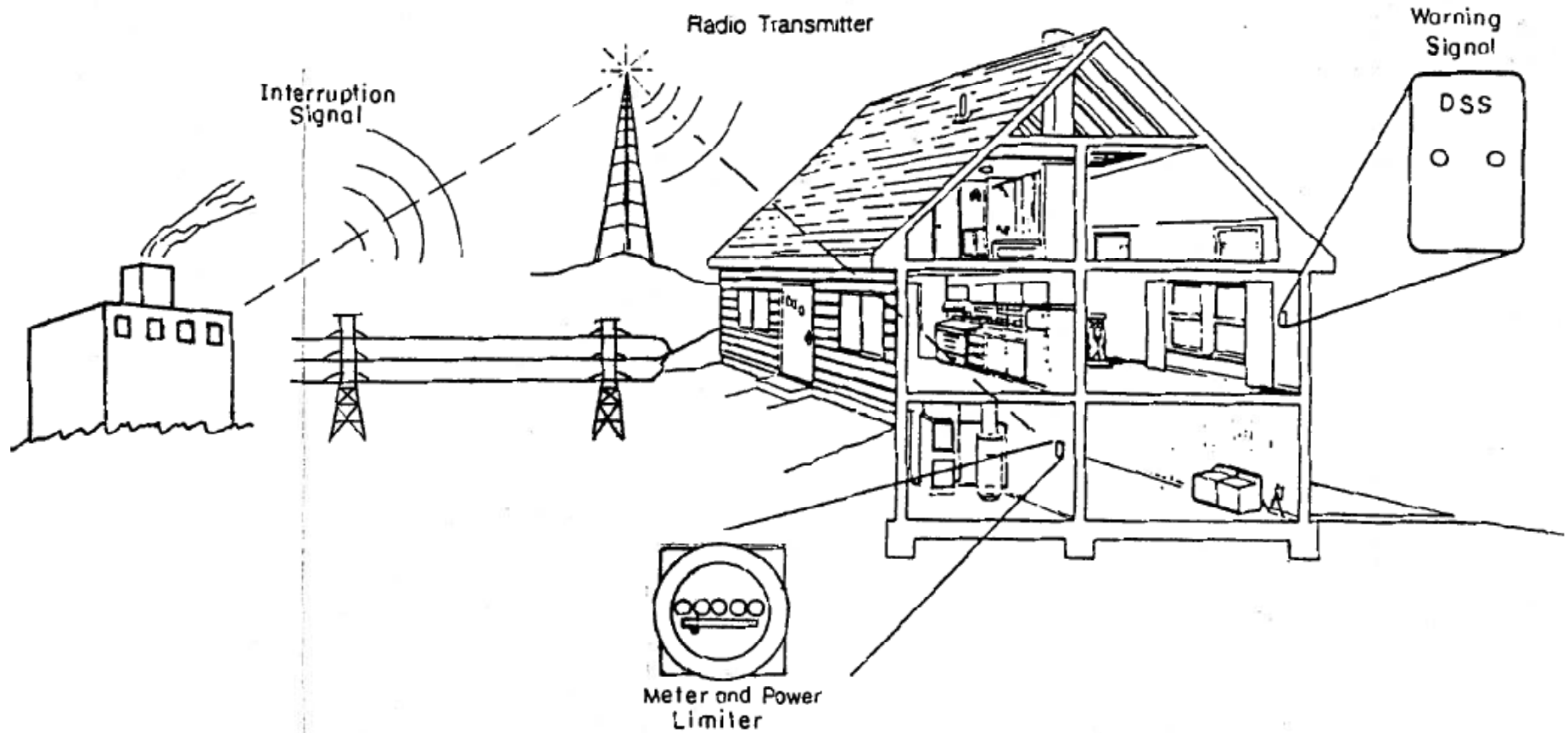
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October 13, 2011

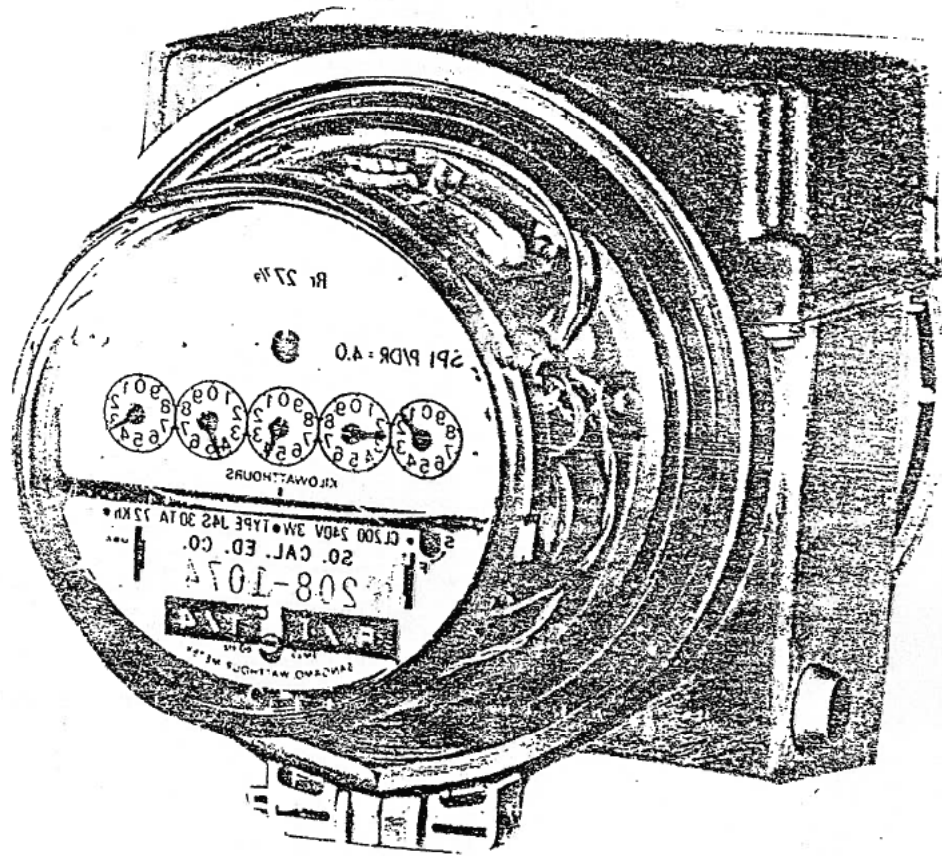


The opinions expressed in the presentation are solely of my own and do not represent the positions of ISO New England or any other organizations.

# Demand Subscription Service



Demand Subscription Service: Radio controlled fuse limits customer's power supply to his subscribed level.



## DEMAND SUBSCRIPTION SERVICE™ SM

### To Restore Your Electrical Service You Should:

- 1.** Immediately turn off or unplug all electrical appliances and devices which may create a hazard if they are restored to service without supervision.

(Examples: electric irons, mixers, fans, workshop equipment and other such household appliances.)

- 2.** Turn off a sufficient number of electrical appliances and devices to reduce your demand for electricity to your Level of Service.

- 3.** Push the "Reset" button which is located on bottom left side of your Demand Subscription Service Device.

If you are unable to restore your electrical service, or if you experience any difficulties with your Demand Subscription Service Device, call \_\_\_\_\_ and identify yourself as a Demand Subscription Service Customer.

Southern California Edison

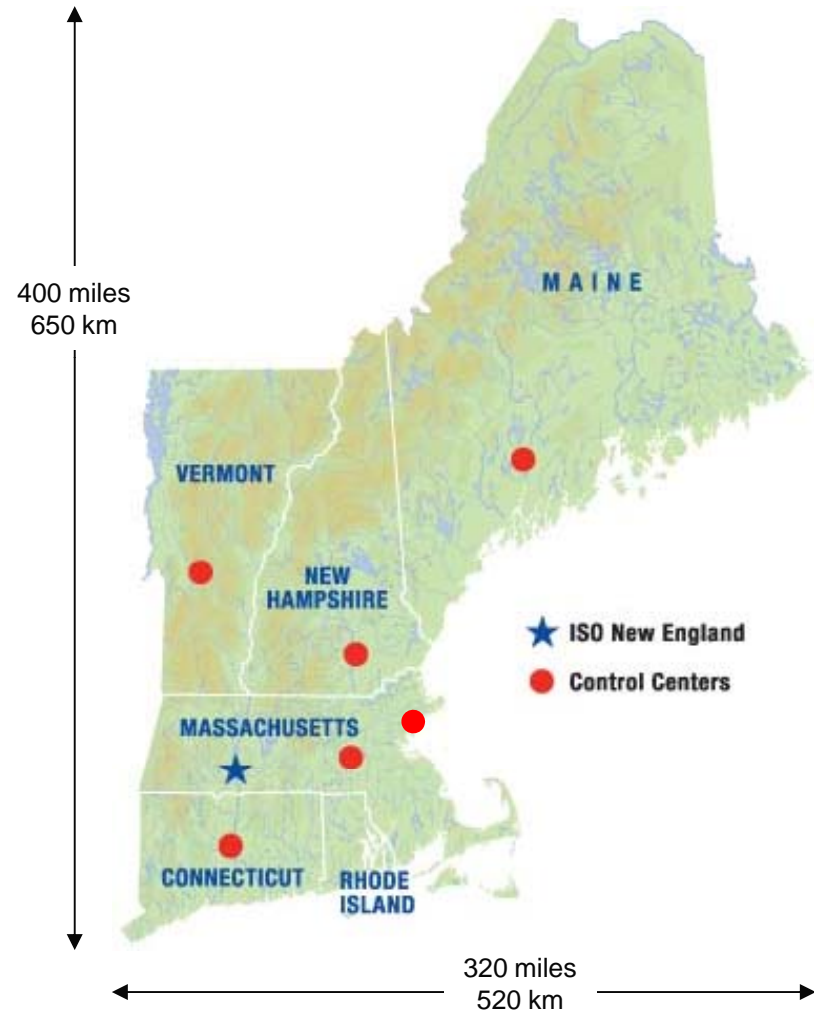


# Wholesale Electricity Markets



# New England's Electric Power System

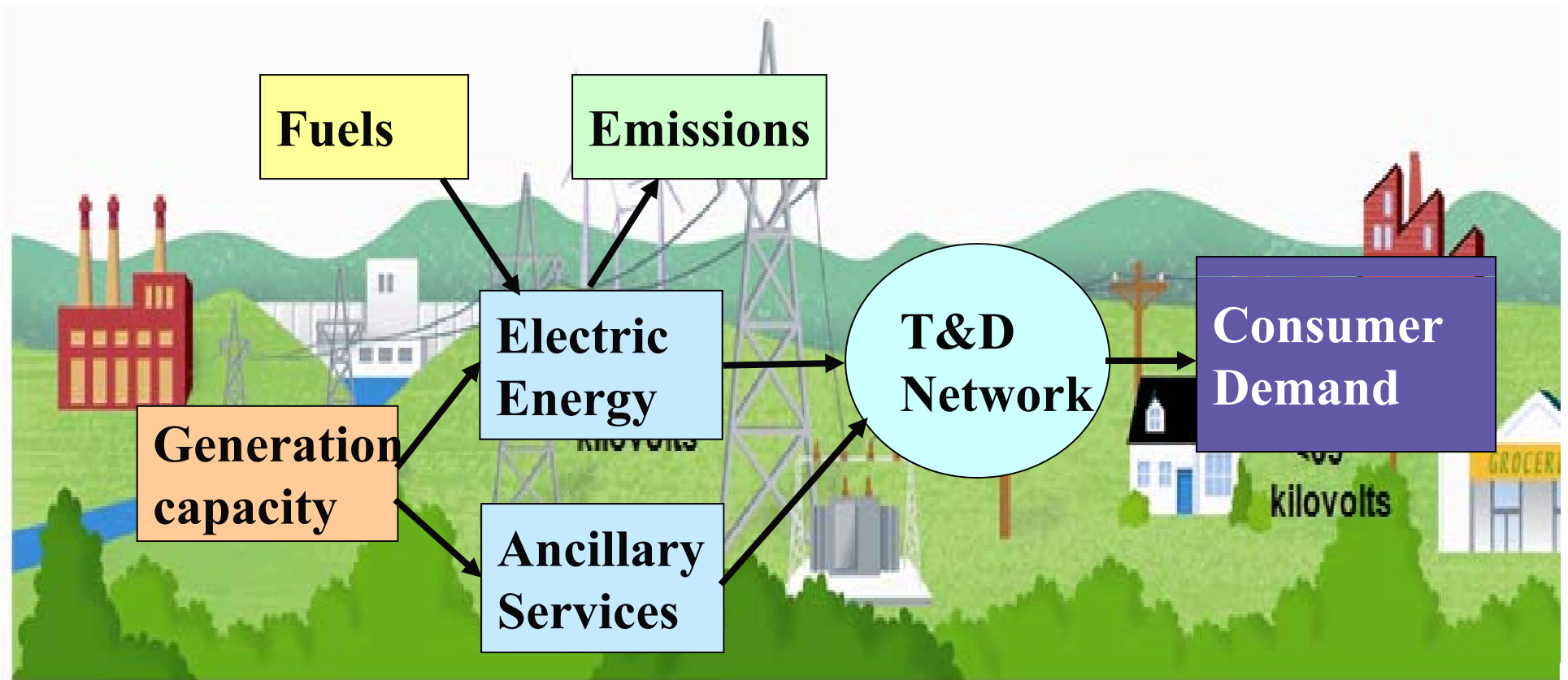
- 6.5 million households and businesses; population 14 million
- Over 350 generators
- Over 8,000 miles of high-voltage transmission lines
- 13 interconnections to electricity systems in New York and Canada
- More than 33,000 MW of total supply (including 1,900 MW of demand-response capacity)
- All time peak demand of 28,130 MW, set on August 2, 2006
- \$12 billion electric energy market (2008)
- More than 400 participants in the marketplace
- \$12 billion annual total energy market value (2008)
- More than \$4.0 billion in transmission improvements from 2002 through 2009 to enhance system reliability; more than \$4.6 billion planned over the next 10 years
- Six major 345-kilovolt projects constructed in four states



# **Greatest Engineering Achievements of the 20st Century,** by National Academy of Engineering

- 1. Electrification**
- 2. Automobile**
- 3. Airplane**
- 4. Water supply and distribution**
- 5. Electronics**
- 6. Radio and television**
- 7. Agriculture and mechanization**
- 8. Computers**
- 9. Telephone**
- 10. Air conditioning and refrigeration**
- 11. Highways**
- 12. Spacecraft**
- 13. Internet**
- 14. Imaging**
- 15. Household appliances**
- 16. Health technologies**
- 17. Petroleum and petrochemical technologies**
- 18. Laser and fiber optics**
- 19. Nuclear technologies**
- 20. High performance materials**

# Power System Modeling: Overview





# Consumers and Markets

- It is not enough to simply liberate the market and assume that people will automatically pursue economic prosperity (Dave Brooks, NYT, 2005)
- If someone tells you to wait for the market to take care of you, it will only make you feel powerless, losing control
- Consumers need to be engaged and have the power to shape their own destiny

*“What if everything is an illusion and nothing exists? In that case, I definitely overpaid for my carpet” --- Woody Allen*

# Challenges for Introducing Innovative Pricing in Retail Market

- Consumers' choices of markets depend on more than information and technology
- Consumers do respond to economic incentives, when they make sense
- Consumers shy away from markets when products are complex, supply is uncertain, prices are volatile, and information is imperfect
- Concerns about low-income consumers may be exaggerated
  - People are often more creative in the marketplace than you think
  - “The Fortune at the Bottom of the Pyramid”, Prahalad and Hart (2009)
- To gain broad support for markets, consumers need to be an integral part of the franchise

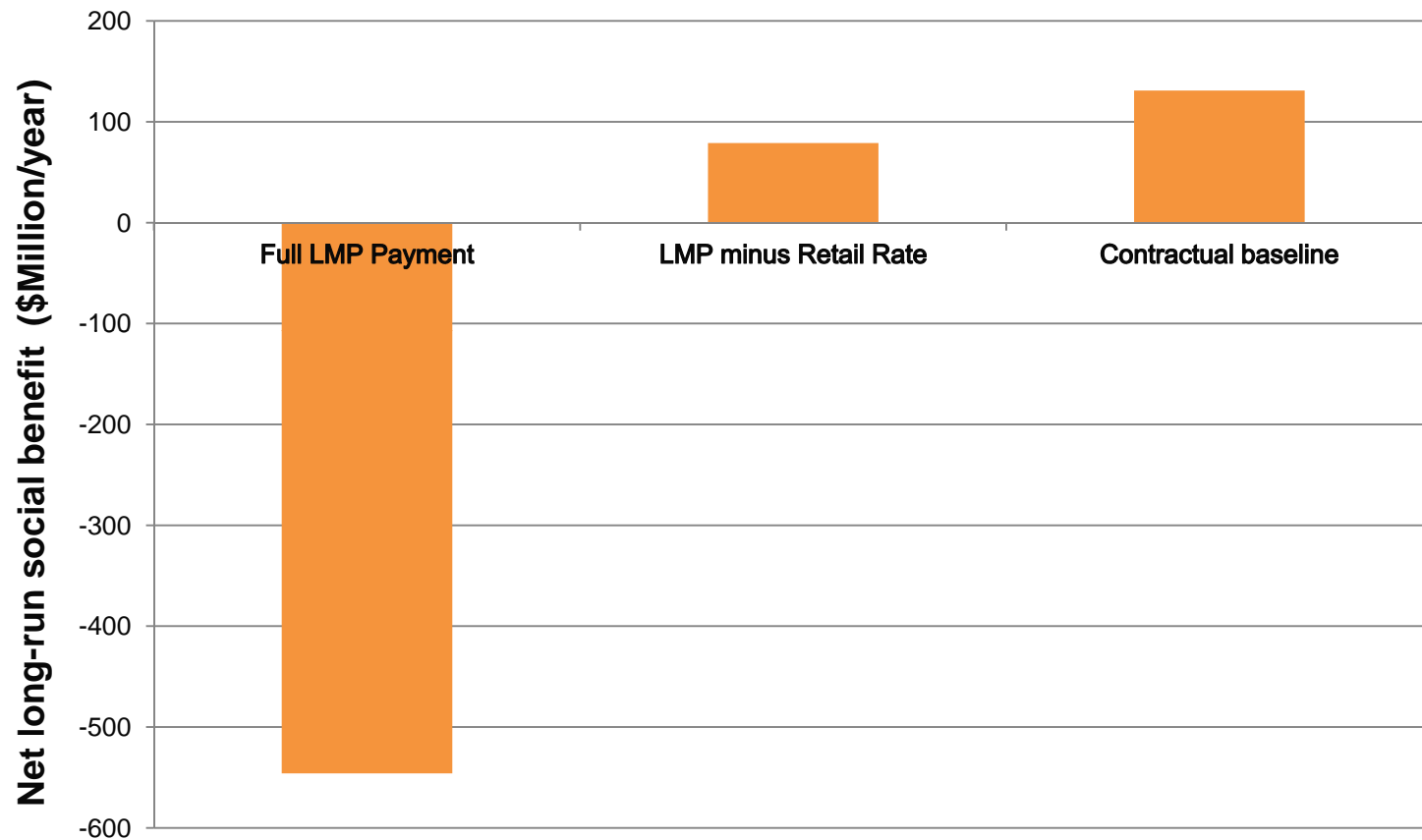
# Key Historical Events

Year	Event	Comment
1978	PURPA introduced competition into electricity supply	Electricity restructuring reflects the technological evolution underlying the industry cost structure from one dominated by economies-of-scale with declining costs to one driven by diminishing returns with increasing costs.
2000 - 2001	California electricity crisis highlighted the risk of electricity markets without price-responsive demand	A critical lesson is that competitive electricity markets are not sustainable, when retail consumers are completely disconnected from wholesale prices.
2005	Energy Policy Act of 2005 mandated demand response	The 2005 EAct gives FERC the Congressional mandate for promoting demand response in organized wholesale electricity markets
2010	FERC issued NOPR on demand-response compensation in organized wholesale electricity markets	The Notice of Policy Rule-making (NOPR) in March produced mixed results. FERC subsequently issued the Supplemental NOPR in September focusing on net benefit test and cost allocation method. FERC is expected to announce the final decision soon.

# Alternative Demand Response Proposals

	<b>Administrative Baseline - Full LMP Payment</b>	<b>Administrative Baseline - LMP less Retail Rate</b>	<b>Contractual Baseline – Full LMP Payment</b>
<b>Demand reduction payment</b>	<b>Wholesale market price (LMP)</b>	<b>Wholesale market price less retail rate (LMP – RR)</b>	<b>Wholesale market price (LMP)</b>
<b>Determination of customer baseline</b>	<b>Based on past consumption levels</b>	<b>Based on past consumption levels</b>	<b>Customer buys the baseline</b>
<b>Allocation of DR costs</b>	<b>Load serving entities and Local distribution company</b>	<b>Load serving entities</b>	<b>No cost allocation is needed</b>

# The Choice of Customer Baseline Could Determine the Merits of Policy Options

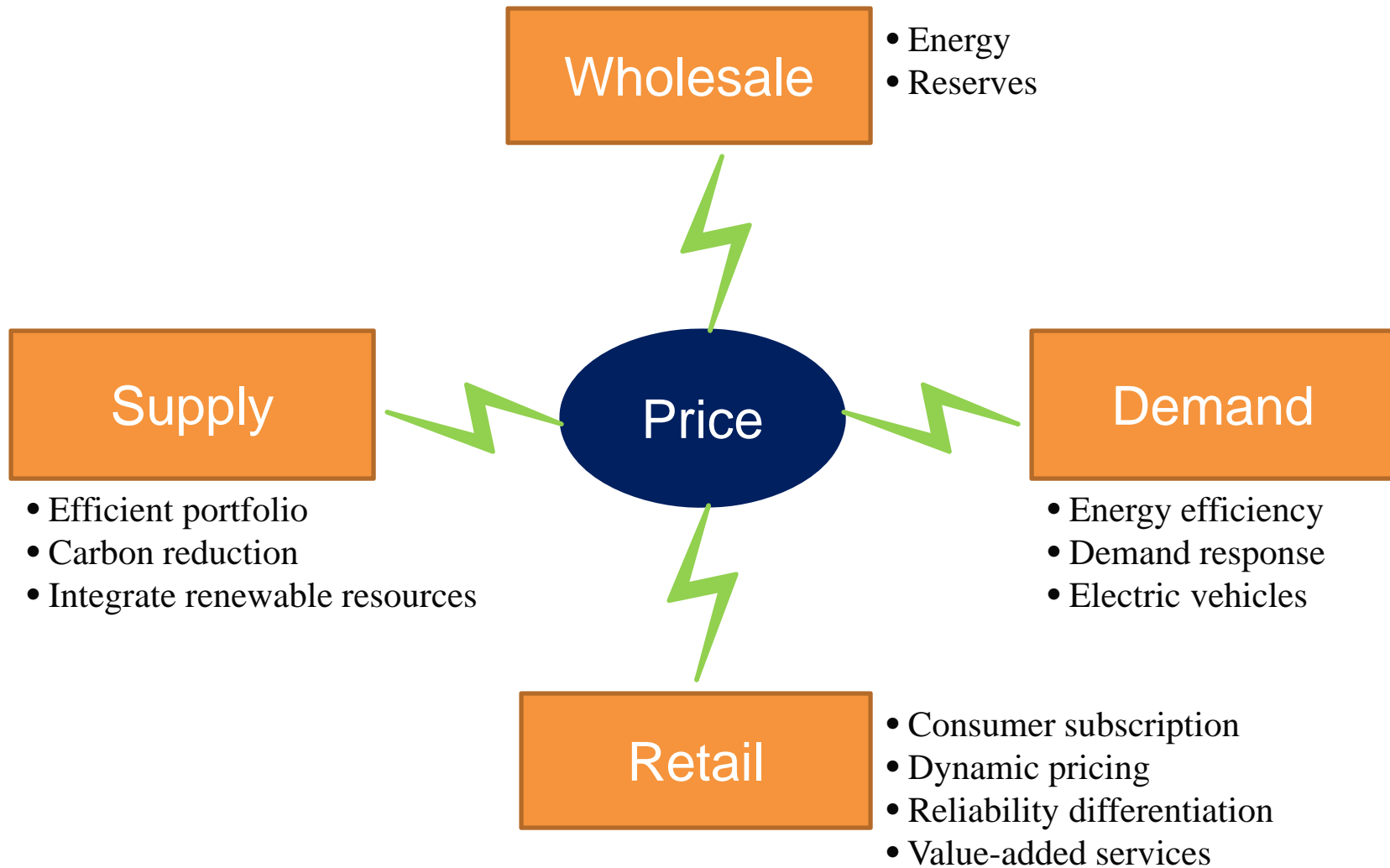


“Demand Response in Wholesale Electricity Markets: the Choice of Customer Baseline”, Journal of Regulatory Economics, 2011

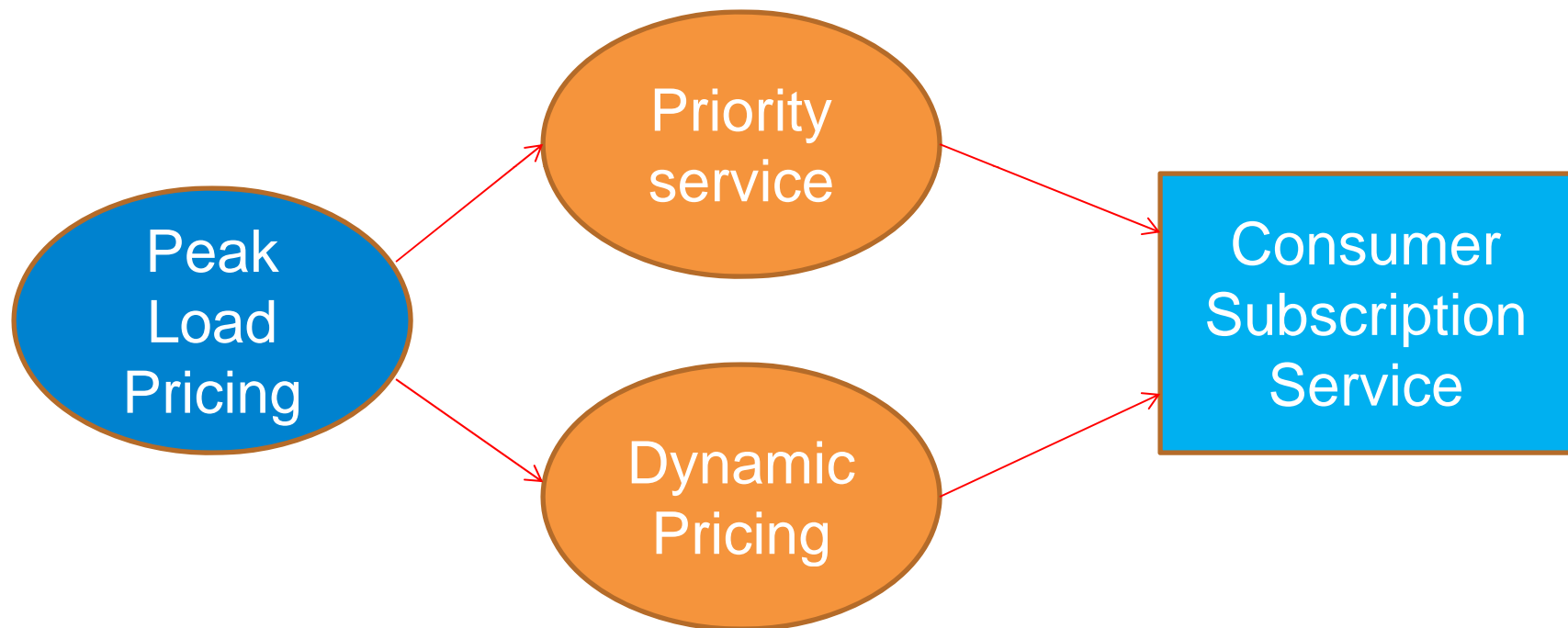
# Barriers Remain for Consumers' Participation in Wholesale Market

- Regulatory and technical barriers
  - Retail rates are disconnected from wholesale market prices
  - Lack of advanced metering infrastructure
- FERC Order 745 is intended to address these barriers
  - Demand response compensation
  - Net benefit test
  - Customer baseline method
  - Cos allocation
- Whether distributed generation behind the meter should be treated as demand response

# Smart Pricing Is Key to Smart Grid



# Consumer Subscription Service Combines Priority Service and Dynamic Pricing into a Unified theory





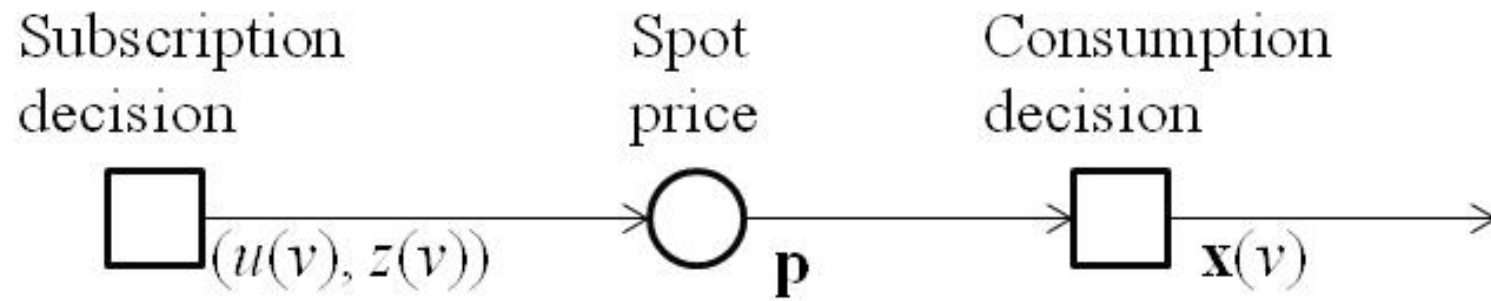
# What is Consumer Subscription Service?

- Consumer subscription service is a two-settlement transactional system
- A consumer prepays specific levels of priority service option contracts at prices fixed in advance
  - The subscribed level establishes a contractual customer baseline
  - A spectrum of strike prices create price-responsive demand
- The difference between the subscribed level and the actual consumption is settled at the real-time wholesale prices
  - sell any unused amount below the baseline
  - buy any extra amount above the baseline

# What is Priority Service?

- The consumer subscription service offers a menu of priority service options,  $M = \{u, P_s(u), s(u), r(u)\}$ .
  - $u$ : service priority
  - $P_s(u)$ : subscription price (ex ante)
  - $s(u)$ : service charge (ex post)
  - $r(u)$ : service reliability
- Each customer subscribes a fixed quantity,  $z$ , of service option  $u$
- Each day, if a service option,  $u$ , is curtailed, each subscriber of the service option is paid  $u$ 
  - The service is curtailed when the spot price,  $\rho$ , in the wholesale market is higher than  $u$

# A Two-stage Consumer Decision Model



# Consumer Subscription Service Options

	Subscription service	Supplemental service
<b>Status quo</b>	<b>Uniform Bundled Service</b>	
Option 1	Uniform Service	Uniform price
Option 2	Uniform Service	Dynamic price
Option 3	Priority Service	Uniform price
<b>Option 4</b>	<b>Priority Service</b>	<b>Dynamic price</b>

# An Example

- Suppose that demand and supply functions are linear:

$$\mathbf{D}(p) = \delta(10000 - 10p)$$

$$\mathbf{S}(p) = \gamma(90p)$$

- where  $\delta$  and  $\gamma$  are uniformly distributed in  $[0,1]$
- Service reliability for consumption with  $WTP=v$ :

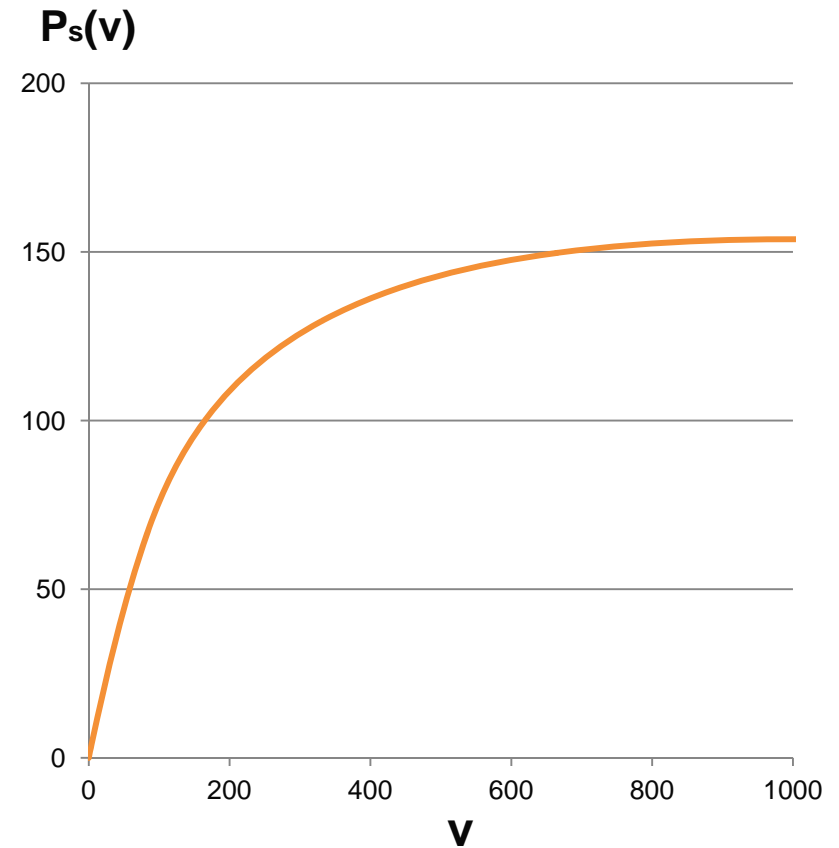
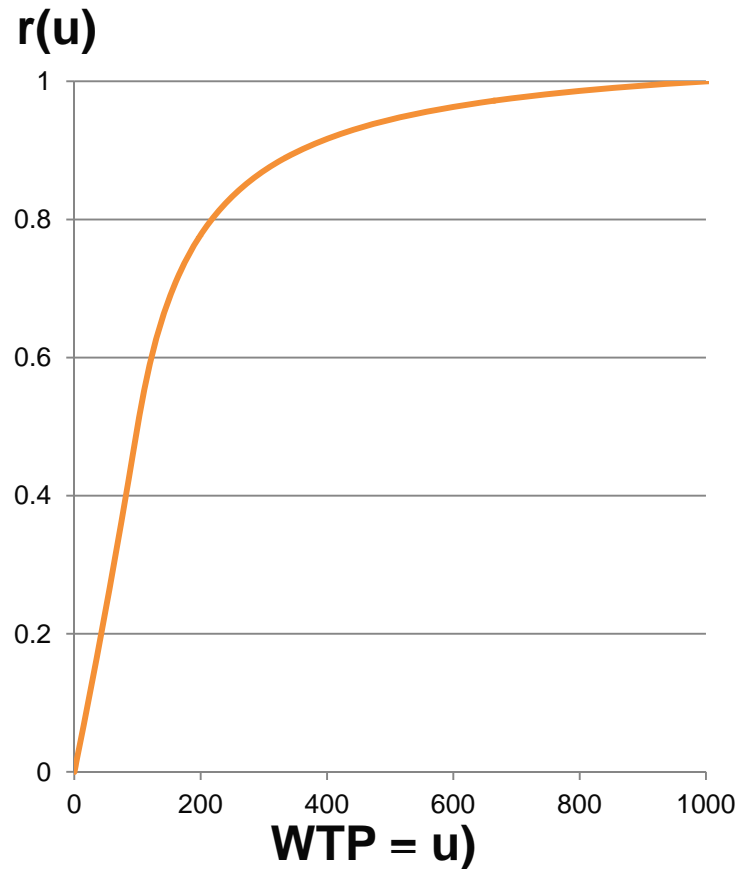
$$r(v) = \Pr\{\mathbf{p} \leq v\} = \begin{cases} \frac{9v}{2000 - 2v}, & \text{if } 0 \leq v \leq 100 \\ \frac{19v - 1000}{18v}, & \text{if } 100 \leq v \leq 1000 \end{cases}$$

- The priority price schedule

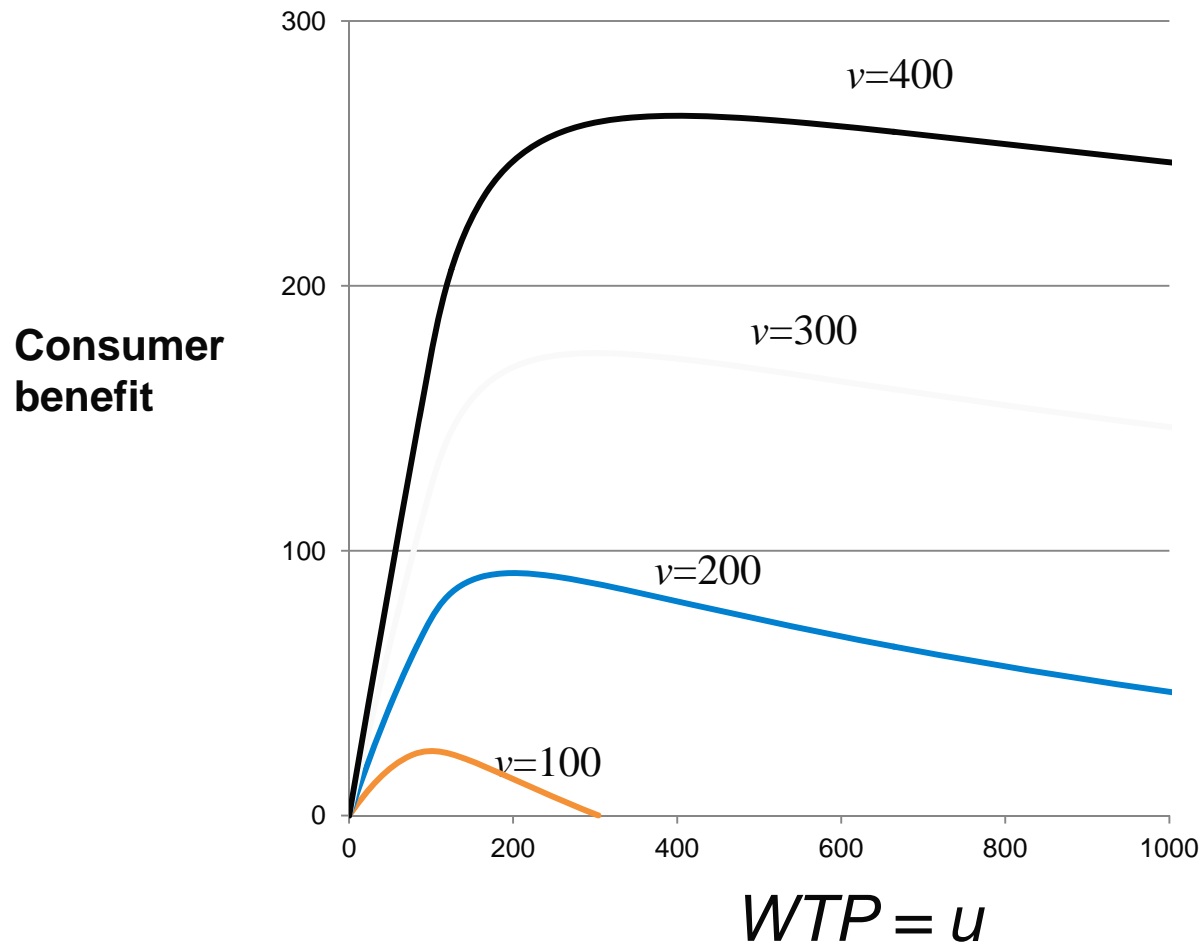
$$P_s(v) = v - \int_0^v r(u) du = \begin{cases} \left(\frac{11}{2}\right)v + (450)\ln\left(\frac{1000-v}{1000}\right), & \text{if } 0 \leq v \leq 100 \\ \left(\frac{-v+10000}{18}\right) + (450)\ln\left(\frac{9}{10}\right) + \left(\frac{500}{9}\right)\ln\left(\frac{v}{100}\right), & \text{if } 100 \leq v \leq 1000 \end{cases}$$

# Constructing Priority Service Menu

$$P'_s(v) = 1 - r(v)$$



# Incentive Compatibility



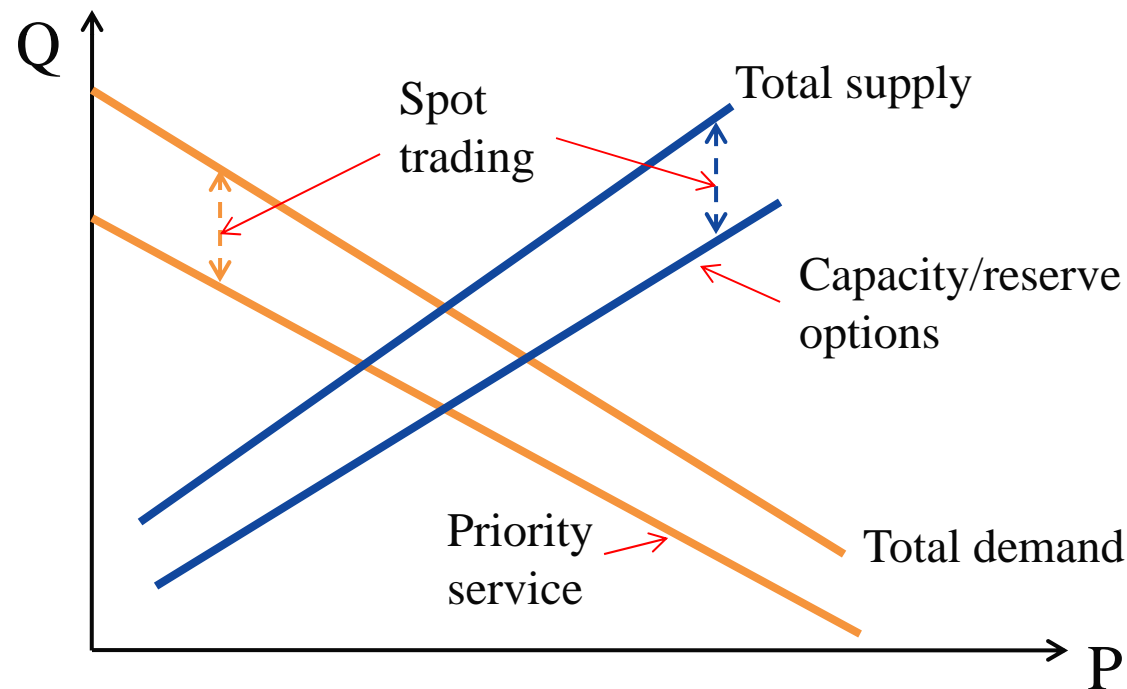
# Consumer Subscription Service Promotes Efficiency and Competitiveness

- Consumers may prefer uniform pricing over dynamic pricing only because they are averse to price volatility or are beneficiaries of cross subsidization and want to keep it
- Consumer subscription service is Pareto superior to uniform service and pricing, with no losers
  - For risk-averse consumers, priority service Pareto dominates uniform service
  - In equilibrium, all risk neutral consumers would switch from uniform pricing to dynamic pricing
- A portfolio of options with a spectrum of strike prices increase demand elasticity, or create demand response, in the wholesale market



# Linked Wholesale and Retail Markets

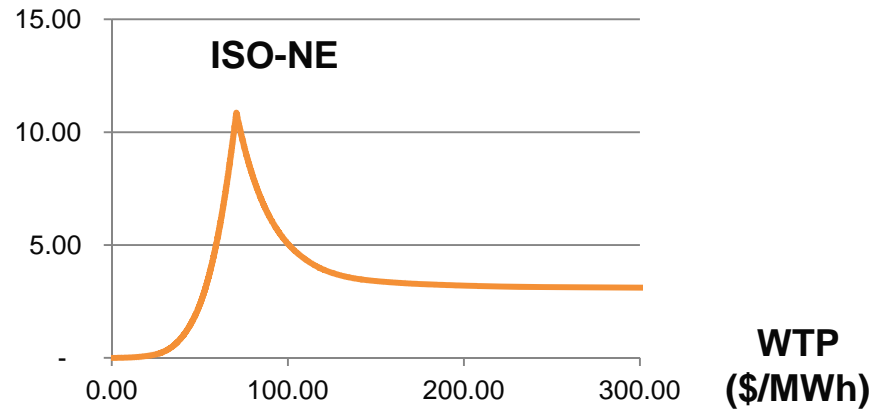
- Priority service and capacity option contracts form elastic demand and supply curves that foster competitive market prices on which these contracts are based



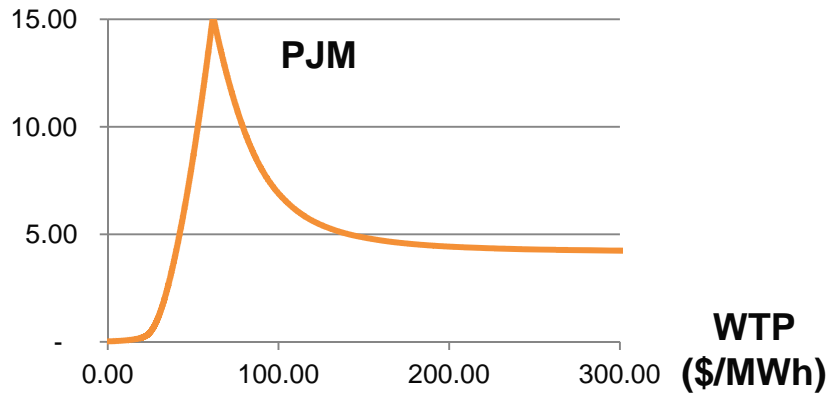
# Priority Service Dominates Uniform Service: Illustrative Results

**Net benefit**  
 = Consumer surplus for Option 4  
 – Consumer Surplus for Status Quo  
  
**WTP = Consumer's willingness-to-pay**

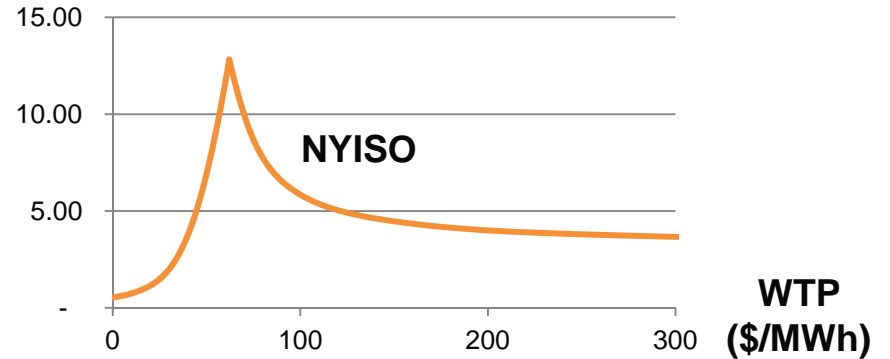
Net benefit (\$/MWh)



Net benefit (\$/MWh)



Net benefit (\$/MWh)



# AMI Cost Benchmarks

Utility	Year	Meters (millions)	Hardware (millions)	Total Capital (millions)	Hardware per meter	Total Capital per Meter
DLCO	1996	0.6	\$60	-	\$99.23	-
Virginia Power	1997	0.5	\$44	-	\$97.78	-
PREPA	1998	1.3	\$130	-	\$100.00	-
ENEL	2000	30.0	\$2,673	-	\$89.10	-
JEA	2001	0.7	-	\$150		\$214.29
PPL	2002	1.3	\$112	\$160	\$86.15	\$123.08
Bangor Hydro	2004	0.1	\$7.50	\$15.0	\$68.18	\$136.36
TXU	2005	0.3	\$19	\$38	\$75.60	\$150.00
PG&E	2005	9.8	\$721	\$1,328	\$73.57	\$135.48
SDG&E	2006	2.3	\$199	\$329	\$86.43	\$143.04

Source: Utilipoint International

# Demand Response and Renewable Energy Resources

- Renewable resources should be viewed as a substitute to base-load technologies but is complementary to peak generation technology
  - “Efficient pricing and investment in electricity markets with intermittent resources”, Energy Policy, 2011
- Dynamic pricing with price-responsive demand shifts energy consumption from peak to off-peak periods, increasing the need for base-load and renewable technologies

# Closing Remarks

- Consumer subscription establishes a platform that allows consumer engagement and expedites innovative retail service offerings
- It enables efficient connection between wholesale and retail markets
- It fosters consumer choices from a menu of differentiated service options
- Research is needed for risk management and consumer choice models that feature large-scale, dynamic distributed decisions, with multi-stage stochastic and often non-convex structures