Enabling 24/7 Automated Demand Response and the Smart Grid using Dynamic Forward Price Offers

Presented to ISO/RTO Council

by

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Summary: Dynamic Forward Price Offers

Day-ahead hourly & near real-time 5-min LMP forward price offer vectors

- Smart devices self dispatch in response to dynamic forward price offers
- Price offers are dynamically updated in response to previous price offers and current grid conditions
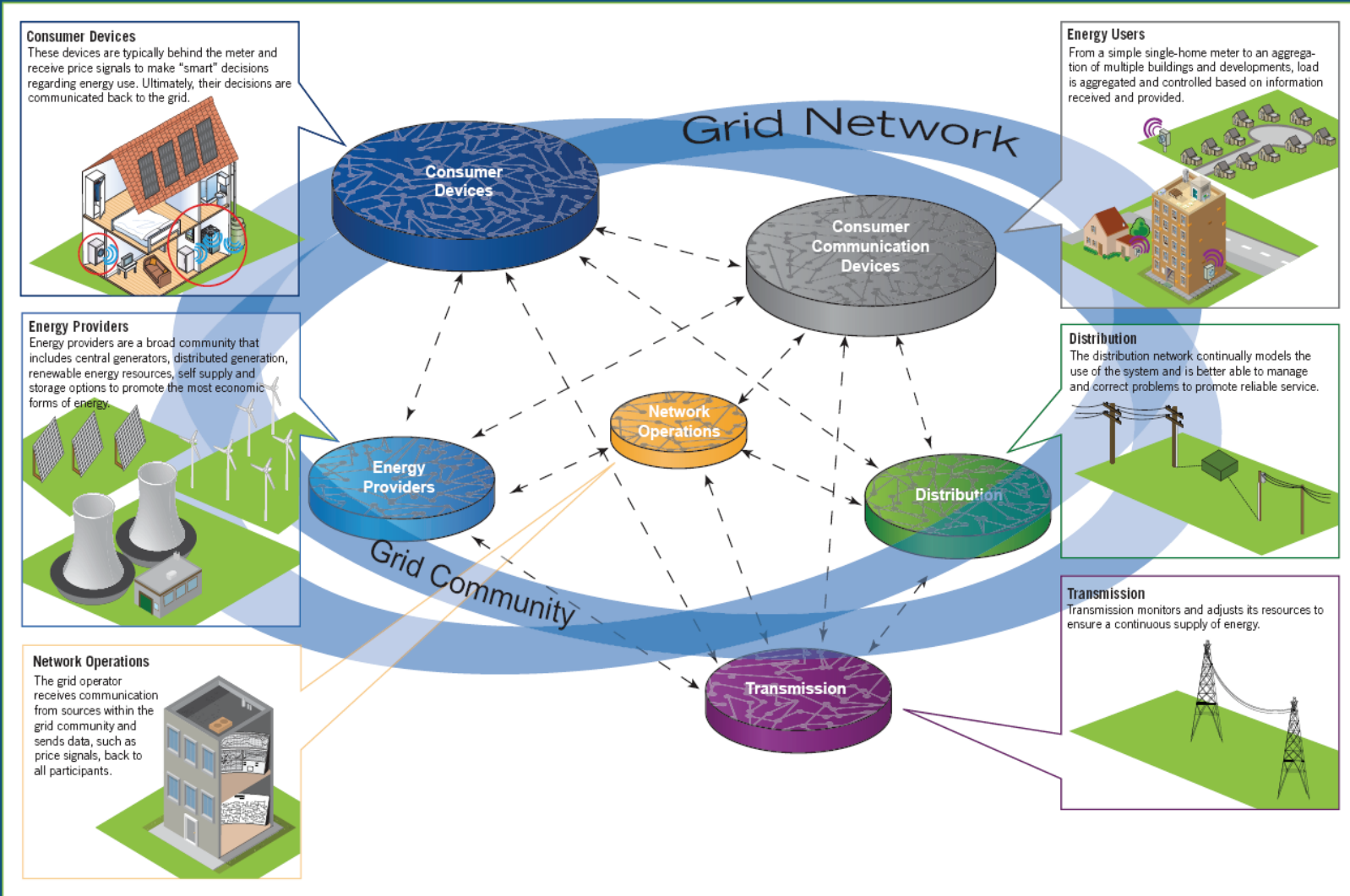
ISO/RTO implementation by

- building on current LMP systems
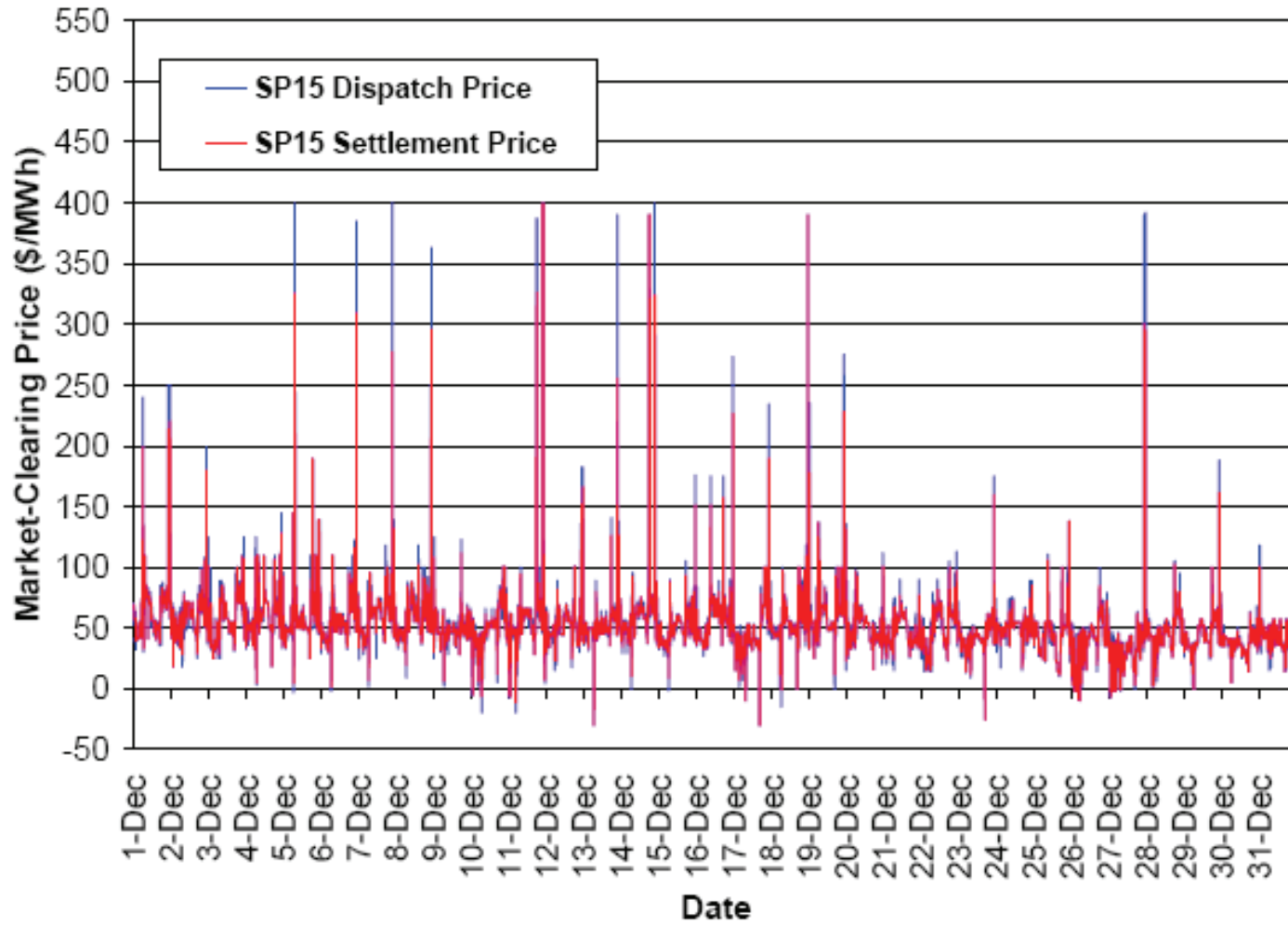- cooperating with LSEs and PUCs

To enable

- 24-7 Auto DR
- Coordination of centralized & distributed generation & storage
- better integration of intermittent renewables
- ties retail demand response prices to wholesale prices
- improved Smart Grid price signals
- potentially improved inter-RTO Coordination

PJM Smart Grid Vision

The Smart Grid...

Consumer Devices
These devices are typically behind the meter and receive price signals to make "smart" decisions regarding energy use. Ultimately, their decisions are communicated back to the grid.

Energy Providers
Energy providers are a broad community that includes central generators, distributed generation, renewable energy resources, self supply and storage options to promote the most economic forms of energy.

Network Operations
The grid operator receives communication from sources within the grid community and sends data, such as price signals, back to all participants.

Energy Users
From a simple single-home meter to an aggregation of multiple buildings and developments, load is aggregated and controlled based on information received and provided.

Distribution
The distribution network continually models the use of the system and is better able to manage and correct problems to promote reliable service.

Transmission
Transmission monitors and adjusts its resources to ensure a continuous supply of energy.

Grid Network

Grid Community

Consumer Devices · Consumer Communication Devices · Network Operations · Energy Providers · Distribution · Transmission

5-Minute Wholesale Prices
Southern California – Dec 2006

The 24/7 Automated Demand Response Proposal

1. Publish *forward offers (price vectors)* for locational energy & ancillary services

- i.e. every 5-min for several intervals
- every 15 min to the end of the next 1 to 2-hours
- hourly thereafter to the end of the next day
- sub 5-min offers in emergencies

2. Smart devices & energy management systems auto respond

- automatically buy or sell increments of energy at these binding forward offer prices.

3. Locational forward offer prices are *revised dynamically*

- based on the market response and changing conditions
- steps above are repeated as necessary until delivery
- rate of change in price offers & allowed responses may be limited to promote speed and stability of responses

Automating Smart Device Response: Air Conditioner Example

A smart device has a "chip" that models the economics and physics of the device and its environment

- i.e. an air conditioner's temperature setting, outside micro-weather forecast, cooling requirements, power requirements, advanced distributed sensors, adaptive learning, etc.
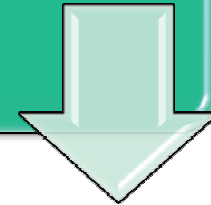
The customer sets a comfort parameter
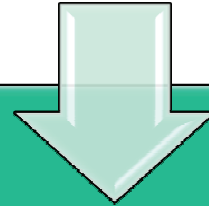
Given the *forward offer price vector*, the smart device operates to

- maximize the net (comfort – cost) of the device's service,
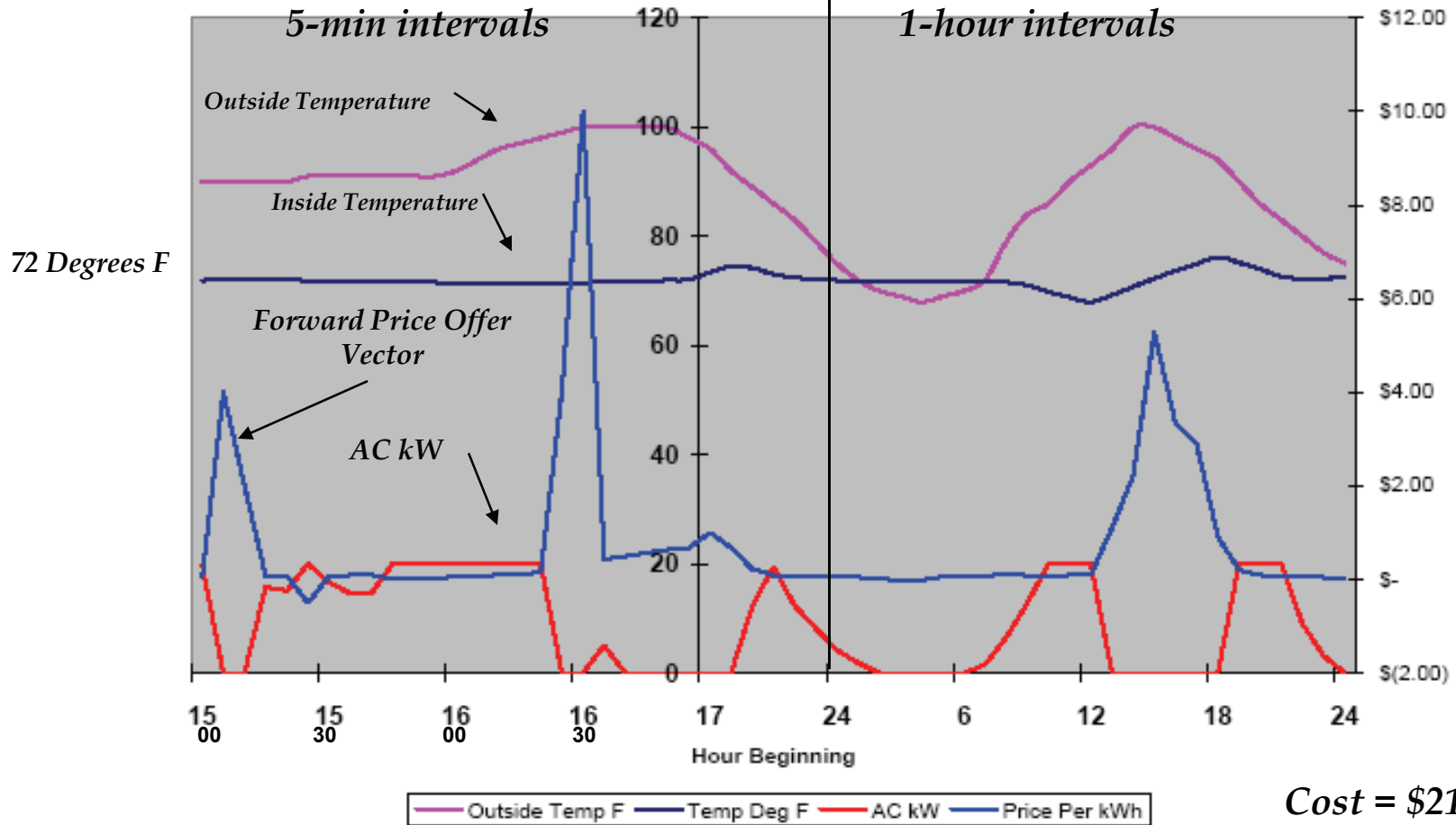- over the next several hours

Air Conditioner Operation
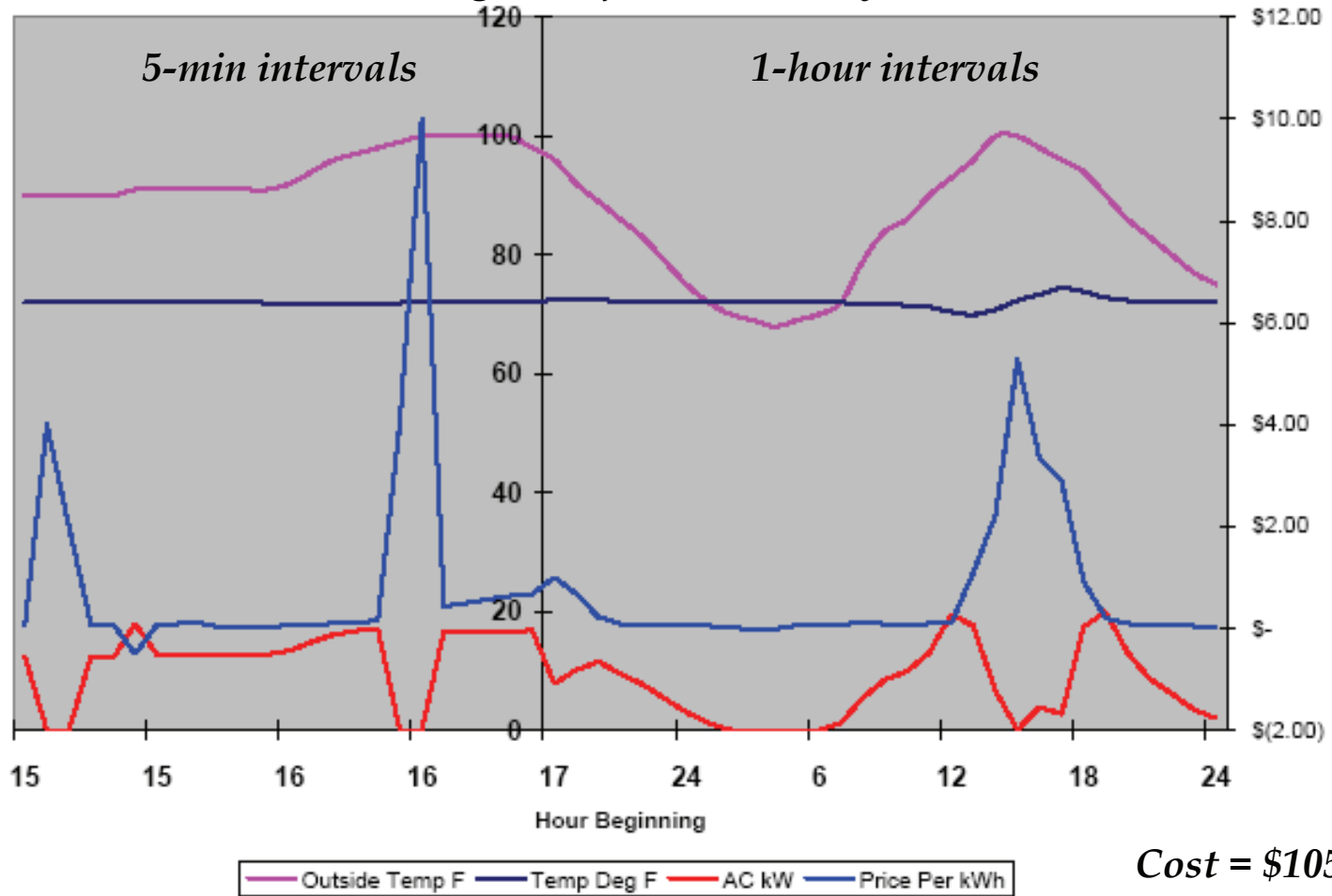
1500 hours

3:00 PM

Today

Next day

5-min intervals

1-hour intervals

Outside Temperature

Inside Temperature

72 Degrees F

Forward Price Offer Vector

AC kW

Legend: Outside Temp F — Temp Deg F — AC kW — Price Per kWh

x-axis: Hour Beginning — 15 00, 15 30, 16 00, 16 30, 17, 24, 6, 12, 18, 24

left y-axis: 0, 20, 40, 60, 80, 100, 120

right y-axis: $(2.00), $-, $2.00, $4.00, $6.00, $8.00, $10.00, $12.00

Cost = $21.00

Air Conditioner Operation

High Comfort Sensitivity

5-min intervals

1-hour intervals

Legend: Outside Temp F — Temp Deg F — AC kW — Price Per kWh

Hour Beginning

Cost = $105.00

Devices Benefiting from Smart Operation with Dynamic Forward Offers

|			
Air Conditioners	Refrigeration	Electric space heating (incl. heat pump)	Electric water heating (incl. heat pump)
Water pumping (incl. pool pumps)	Plug-in hybrid electric vehicle	Data center dynamic smart cooling	Distributed generation (fuel cells, micro turbines, etc.)
Grid-connected storage	Process heat	Energy Management & Control Systems	

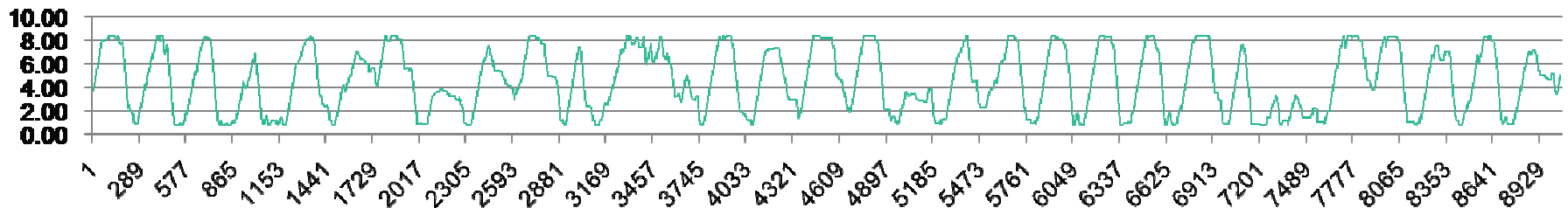# Example: Aug 2006 NYC Storage Device Dispatch Using Forward Offer Prices

LBMP $/MWh
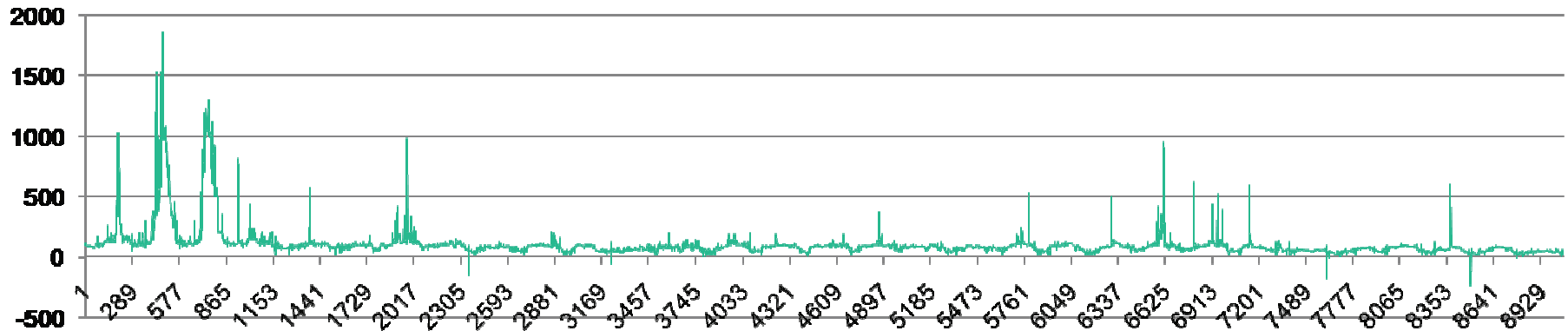
5-min Discharge and Charge - MW
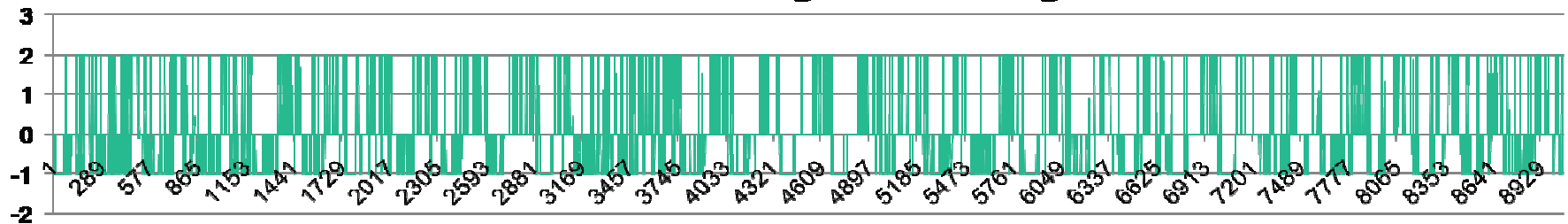
Stored MWh

Settlement Example

Forward Hourly Transactions

	Delta kW	Price $/kWh	Cost $/hr	Meter Cost	
	150	150	0.10	15.00	$/hr
1	140	-10	0.12	(1.20)	($1.20)
2	160	20	0.08	1.60	$0.40	($2.73)

Long-term purchase of 150 kW for this hour settled with suppliers
Meter credit for volume reduction.
Meter charge for volume increase.

		Long Term	$15.00
		Meter	($4.47)
		Net Bill	$10.53

Forward 5-Minute and 15-MinuteTransactions

		5-Min Ending		15-Min Ending				
		5	10	15	30	45	60		
	kW	160	160	160	160	160	160		
3	Price		$ 0.05	$ 0.01	$ 0.05	$ 0.15	$ 0.20		
	kW		200	250	250	120	100		
	Delta kW		40	90	90	-40	-60		
	Delta KWh		3.33	7.50	22.50	-10.00	-15.00		
	Delta Cost		$0.17	$0.08	$1.13	($1.50)	($3.00)	($3.13)	($2.73)

		5-Min Ending				
		50	55	60		
4	Price	$ 0.35	$0.80	$ 0.80		
	kW	95	90	80		
	Delta kW	-5	-10	-20		
	Delta KWh	-0.42	-0.83	-1.67		
	Delta Cost	($0.15)	($0.67)	($1.33)	($2.15)	($4.88)

Ex-Post Real Time

	5-Min Ending													
	5	10	15	20	25	30	35	40	45	50	55	60		
RT Price	$ 0.12	$ 0.13	$ 0.10	$ 0.50	$ 0.50	$ 0.30	$ 0.30	$ 0.40	$ 0.40	$ 0.40	$ 0.40	$ 0.50		
Meter kW	195	175	245	250	250	200	150	130	125	100	90	85		
Delta kW	35	(25)	(5)	0	0	(50)	30	10	5	5	0	5		
Delta kWh	2.92	(2.08)	(0.42)	0.00	0.00	(4.17)	2.50	0.83	0.42	0.42	0.00	0.42		
Delta Cost	$ 0.35	$ (0.27)	$ (0.04)	$ -	$ -	$ (1.25)	$ 0.75	$ 0.33	$ 0.17	$ 0.17	$ -	$ 0.21	$0.41	($4.47)

8/21/2007

24/7 Auto-DR Information Flows
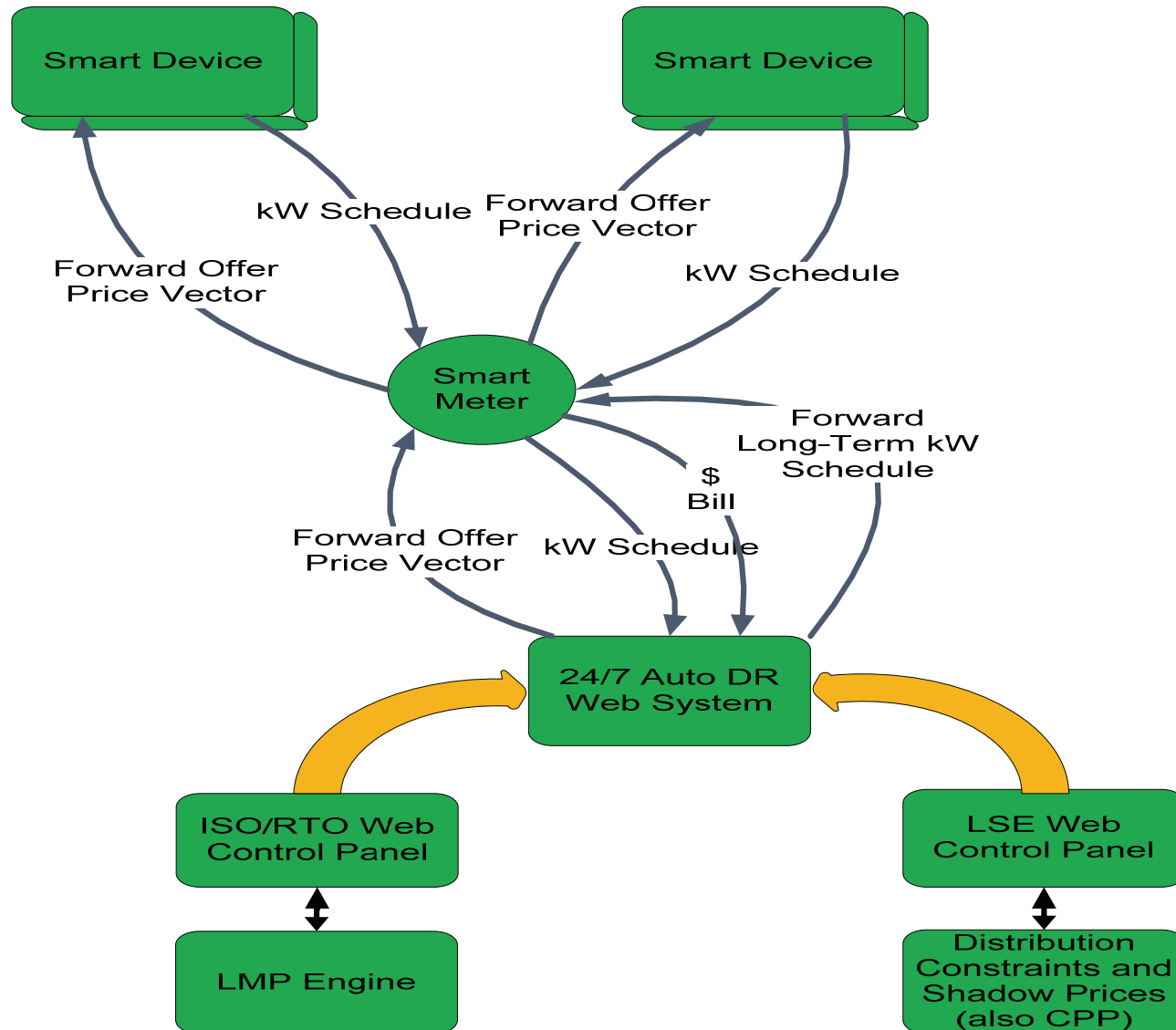
Integrating 24/7 Auto-DR with LMP Markets

Modify DA IFM software to

Transfer hourly LMP prices to 24/7 Auto DR system as hourly forward offer price vectors.	Re-clear DA IFM with standing bids and demand response to recompute schedules and price offer vectors

Modify RTM software to

Transfer 5-min LMP prices to 24/7 Auto DR system as 5-min forward offer price vectors.	Re-clear RTM with standing bids and demand response to recompute schedules and price offer vectors

Settlement for each DA and RT revision

Most settlement calculations done in smart meters or gateways	Previous schedules binding at previous price offers	New transactions are binding at revised price offers

Ultimately central generation and other RTO imports/exports could be allowed to participate with adjusted schedules and bids

Ancillary Services Forward Offer Prices

24-7 Auto DR will reduce long run ancillary service needs

Forward offer prices for ancillary services set by LMP co-optimization of energy & ancillary services

Regulation product definition should recognize faster response of load and storage

Storage needs energy-neutral 4-sec regulation signals

LSE & PUC Implementation of 24/7 Auto-DR

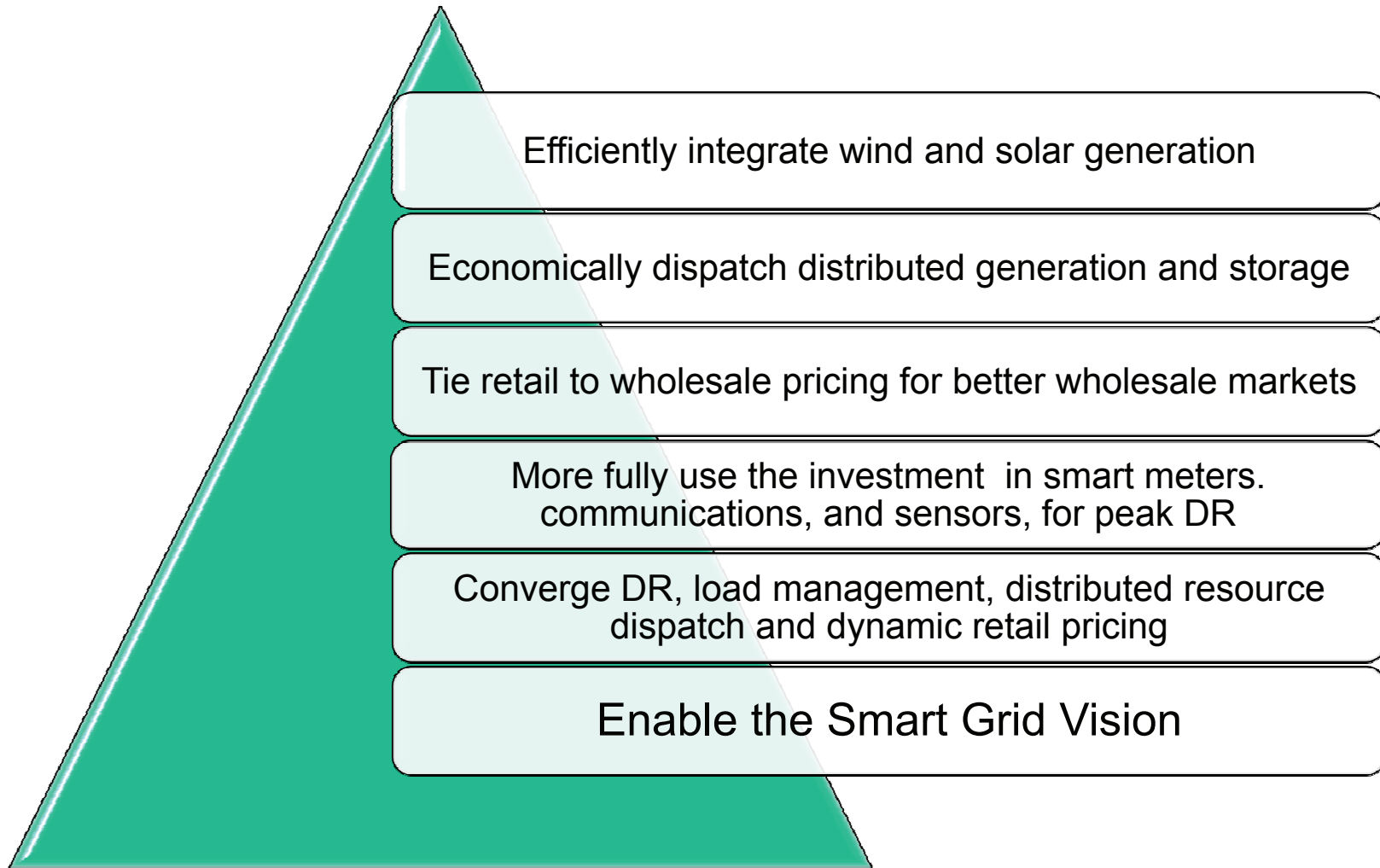## Allow customers to participate in the 24/7 Auto-DR market.

- Long-term supply portfolios set baseline rates for a specified kWh in each hour.
  - The specified kWh could depend on weather but not specific customer usage.
  - The specified kWh could come from more than one supplier.
- Transactions in the 24/7 Auto-DR market are increments to specified kWh and the baseline rates

Retail prices may include adders for

- Marginal distribution costs and losses
- Distribution constraints
- Critical peak pricing

24/7 Auto-DR is a retail dynamic pricing tariff

24/7 Auto DR with Dynamic Forward Offers Can

Efficiently integrate wind and solar generation

Economically dispatch distributed generation and storage

Tie retail to wholesale pricing for better wholesale markets

More fully use the investment in smart meters. communications, and sensors, for peak DR

Converge DR, load management, distributed resource dispatch and dynamic retail pricing

Enable the Smart Grid Vision

Next Steps to 24/7 Auto-DR

Determine interest within ISO/RTOs, LSEs, and PUCs to promote and further define 24/7 Auto-DR.

⬇

Develop a detailed design of an 24/7 Auto-DR system and its interfaces with other systems.

⬇

Encourage an ISO/RTO and an LSE or a third party to implement an initial 24/7 Auto-DR system.

⬇

Encourage the ISO/RTO to fully integrate 24/7 Auto-DR System with its LMP system.