

# Smart Price Signals for the Smart Grid: *Dynamic Forward Pricing*

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US-CHINA GREEN ENERGY COUNCIL (UCGEC)  
SMART GRID SEMINAR  
PALO ALTO, CALIFORNIA  
APRIL 29, 2009

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# The Internet and the Electric Grid

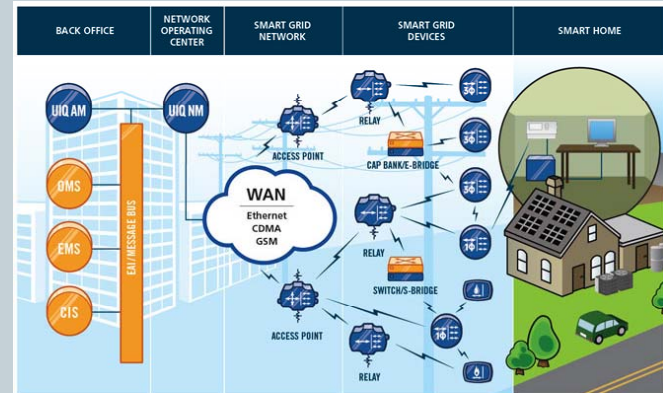
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The electric grid connects hundreds of millions of customers and meters and billions of devices.

Many of these devices will soon be inter-connected on the Internet.

By about 2012 most of California will have communicating smart meters.

The Smart Grid is the merger of the Internet and the electric net.



# Smart Grid Price Signals

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Everybody's vision of the Smart Grid uses "price signals" to devices.

But what are these price signals?

Typically, they are so undefined that they might as well be *smoke signals*.

Proposing practical price signals to operate the Smart Grid is the purpose of this talk.



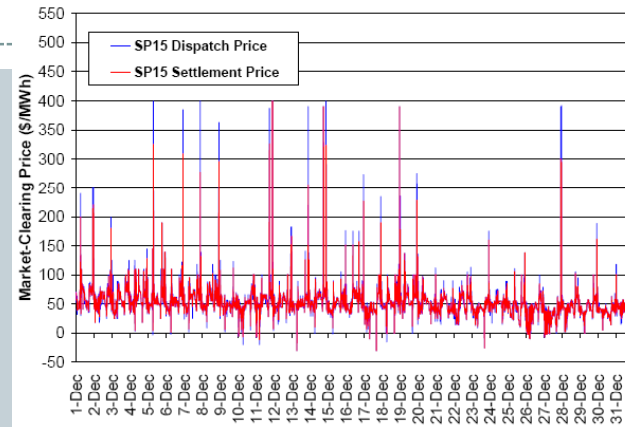
# Power Price Volatility

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*Retail* electric prices today are mostly static (either flat or time-of-use prices.)

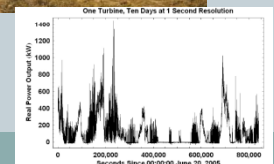
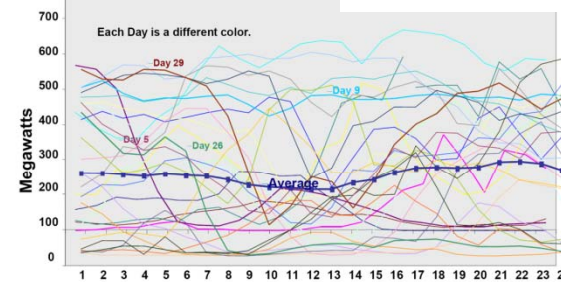
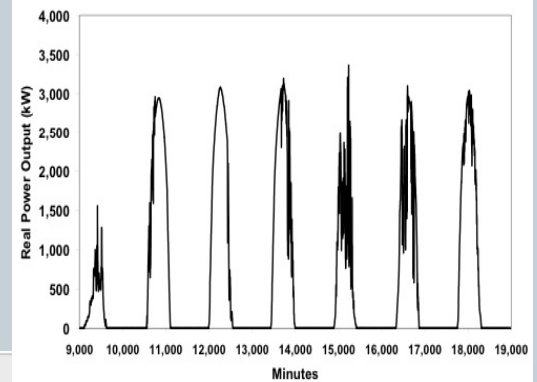
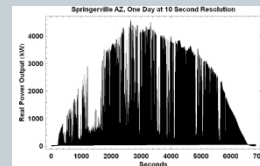
But, five-minute *wholesale* real-time power prices are highly volatile.

With large amounts of wind and solar, price volatility will increase.



Dec 2006  
CAISO  
5-min  
prices

Springerville, AZ 7 days at 1 minute resolution



# Long-Term and Real-Time Pricing

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The Smart Grid needs real-time retail and wholesale prices.

Customers and suppliers want long-term contracts.  
Solution :

- Blocks of power at long-term prices for each time of day and season.
- Power above or below block amounts is transacted at dynamic real-time prices.

Full incentives to respond to real-time prices and participation in real time transactions is voluntary.

Both restructured and vertically integrated power systems can implement retail real-time pricing.



# System Operator Pricing

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System Operators (ISOs and RTOs) use complex centralized optimization and bids to compute prices.

- Real-time prices are published several minutes to hours or days *after* each 5-minute interval passes.
- To act on the real-time price you have to bid into the ISO's real-time markets and have the ISO control your device.



# Complexity and the Smart Grid

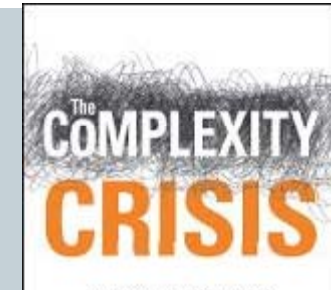
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ISO optimization systems are straining under the complexity of their current mission.

- New ISO systems in California and Texas cost hundreds of millions each and ten years to build.
- Even the most powerful computers are not enough.

Centralized control of billions of customer devices by an ISO is impossible.

- The Smart Grid will fall short from the cost of its own complexity if we attempt central control.



# Dynamic *Forward* Pricing

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Forward real-time pricing provides binding offer prices for each 5-minute interval published by an operator or virtual operator *before* each 5-minute interval.

- Smart devices and generators, buy or sell at these prices and the transaction is binding.
- Customers and devices choose whether and how to respond to prices.

As grid conditions change the forward prices increase or decrease to balance supply and demand for the 5-minute interval.

The ISO or virtual operators manage the price adjustment process in response to changes in device schedules to balance supply and demand within grid constraints using grid-wide data and models.

- Instantaneous loads only need the current forward 5-min price.
- Inertial loads and generation such as heating, cooling and storage need a set of forward prices.

**\$ the  
PRICE  
is  
Right**



# Smart Responses to Dynamic Forward Pricing

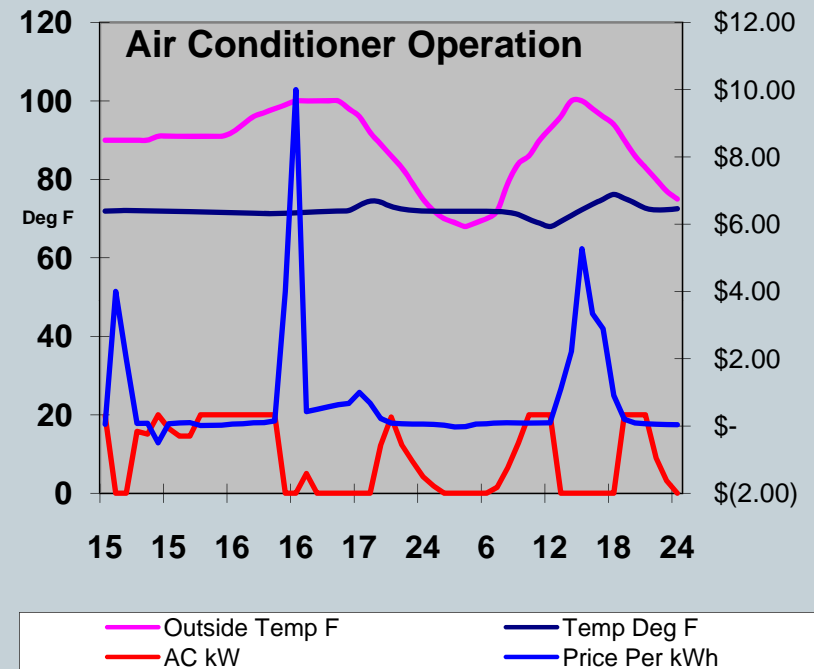
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Smart air conditioner thermostats frequently receive the current set of forward prices.

- Smart thermostats efficiently cool the building taking into account, weather, building thermal inertia, customer comfort preferences and more.

As dynamic forward real time prices change, the timing of power use changes.

- Customers pay or get paid for the scheduled power changes at the new prices.



# Storage Needs Dynamic Forward Pricing

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Grid-scale storage is needed for integration of large amounts of wind and solar.

- Central optimization by the ISO of storage is impossible.
- Dynamic forward prices allow smart storage to decide how much to store or deliver in each interval and to change instantly upon receipt of new prices.

Plug-in vehicles with storage need dynamic forward prices.

- Based on forward prices, a vehicle is charged at the lowest cost perhaps with excess renewable generation.
- When prices are high the vehicle may sell power to the grid.
- If vehicles attempt to charge at the same time, prices increase causing some vehicles to be charged at a different time.
- This is the only practical way to manage millions of vehicles.



# Smart Take Away

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Dynamic forward pricing provides is the *only* practical coordination signals for the Smart Grid.

Any other approach will cause the Smart Grid to fail to fully achieve its goals and cost more because of its own complexity.

