# Integrating Increased Dispatchable Demand Response and Dynamic Price Response into NYISO Markets

Preliminary Findings Reported to the FERC Conference on Market Efficiency June 29, 2011 plus Research Project Final Observations

Presented to: Presented to NYISO PRLWG 11/28/2011

# Overview

- Project Motivation and Objectives
- Approach to Estimating DDR and DP Potential
- Modeling Demand Side Dynamics in NYISO's Market
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- Final Observations

# DDR vs. DP Definitions[1]

- Dispatchable Demand Response (DDR):

  "*Dispatchable demand response" refers to planned changes in consumption that the customer agrees to make in response to direction from someone other than the customer. It includes direct load control of customer appliances such as those for air conditioning and water heating, directed reductions…and a variety of wholesale programs offered by RTOs/ISOs that compensate participants who reduce demand when directed for either reliability or economic reasons…"*

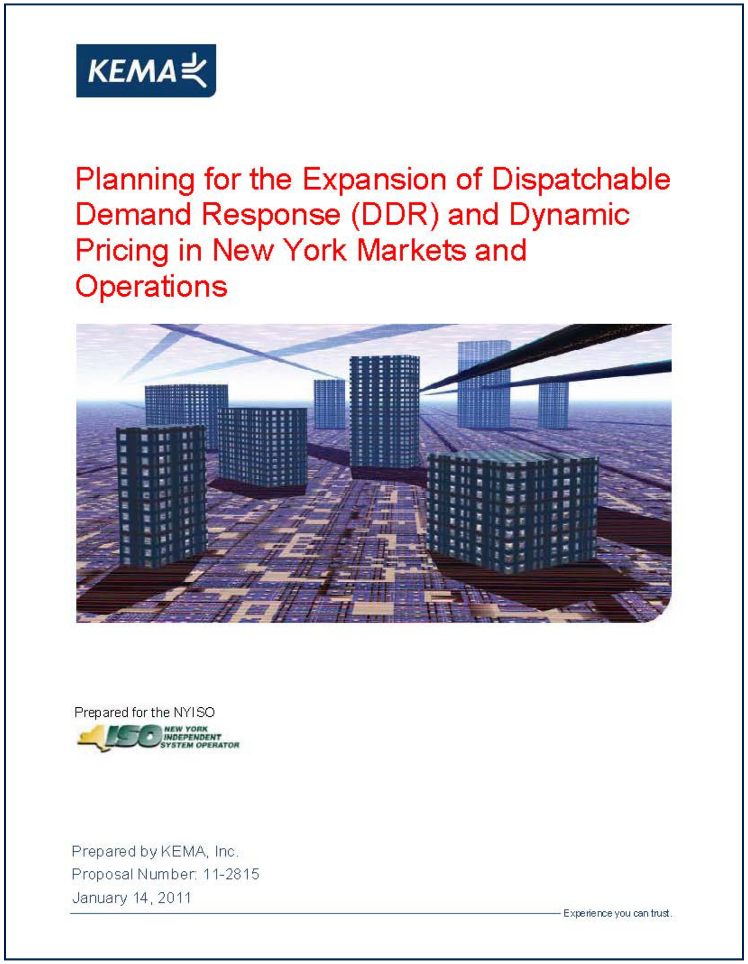
- Dynamic Pricing (DP) response:

  *A "customer decides whether and when to reduce consumption based on a retail rate design that changes over time. This is sometimes called retail price-responsive demand and includes dynamic pricing programs that charge higher prices during high-demand hours and lower prices at other times…"*

[1] Source: FERC's National Action Plan for Demand Response, June 2010 @ http://www.ferc.gov/legal/staff-reports/06-17-10-demand-response.pdf

# Project Motivations

Preparing for dynamic pricing and fully integrating DDR into the markets is a strategic priority for the NYISO



KEMA

Planning for the Expansion of Dispatchable Demand Response (DDR) and Dynamic Pricing in New York Markets and Operations

Prepared for the NYISO

Prepared by KEMA, Inc.
Proposal Number: 11-2815
January 14, 2011

Experience you can trust.

- Explore new entrepreneurial business models that may create opportunities to facilitate growing participation in Dynamic Pricing (DP) programs and Dispatchable Demand Response (DDR) in NYISO markets.

- Understand customer demand side participation in the NYISO wholesale markets through DP and DDR.

# Project Objectives

- Identify Dispatchable Demand Response (DDR) potential
  - Determine what load is “controllable” – how, when, and for how long?
  - Create hourly load estimates by NY utility, rate class, and end use
- Identify specific technologies and key attributes - including latency and response duration - that are necessary to realize DDR potential in New York’s wholesale markets.
- Integrate DDR potential with Dynamic Pricing (DP) in the markets through system dynamics modeling. Examine impact of demand elasticity on system dispatch under various scenarios.
- Identify market and operations impacts and suggest market, program, or other approaches to enable greater demand side participation in wholesale markets.
- Examine impacts of customer self optimization with participation in the NYISO markets.

# What Do We Expect to Learn?

- Understand potential impacts of greater DDR and DP integration
  - Effects on Day-Ahead (DA), Hour-Ahead (HA), and Real Time (RT) markets and prices
  - How to adapt to non-stationary processes on the demand side
  - Where are there robustness issues to manage
  - What are the conditions for preserving DA – HA – RT market convergence
    - Latencies
    - Penetrations of DP and DDR
- Understand where greatest DDR potential lies
  - By end use, performance, technology

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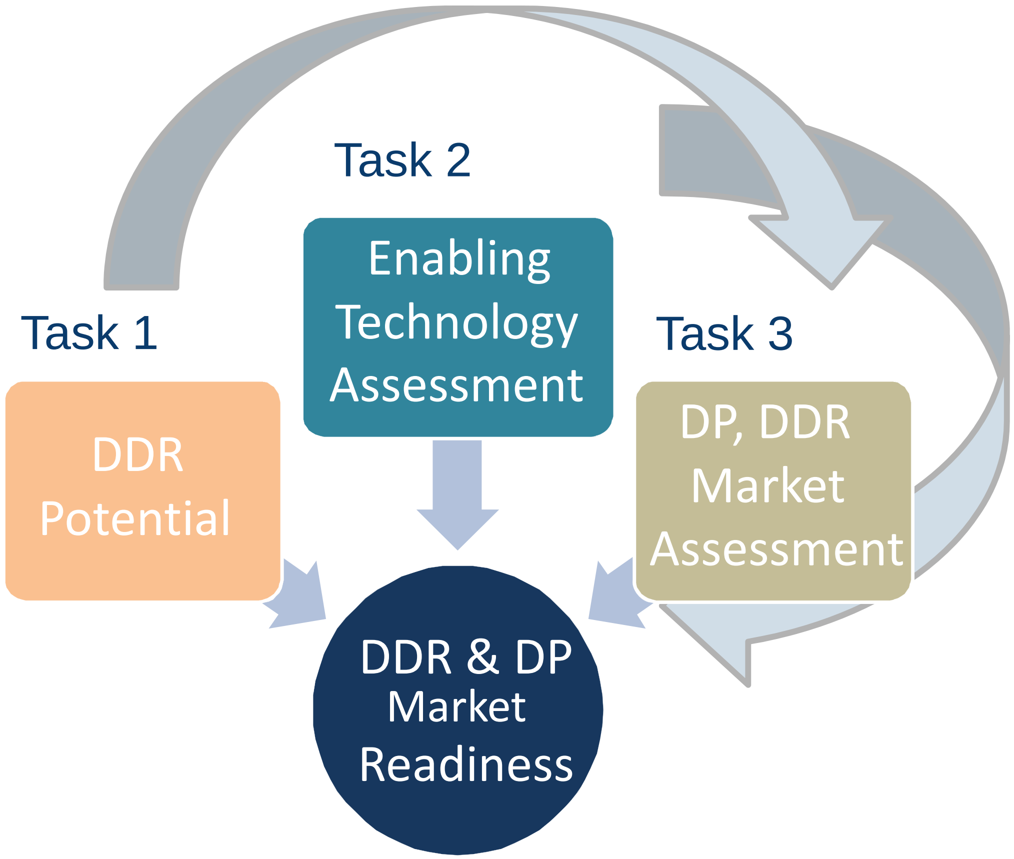
# Project Approach – High Level

Building hourly load shed potential by NY utility, rate class, and end use type (Task 1) is an important input to the DP, DDR market simulation model (Task 3).

Developing a technology roadmap to identify and prioritize the key communications and data technologies to enable the identified DDR potential (Task 2) will be essential to realize DDR potential and meet requirements going forward.



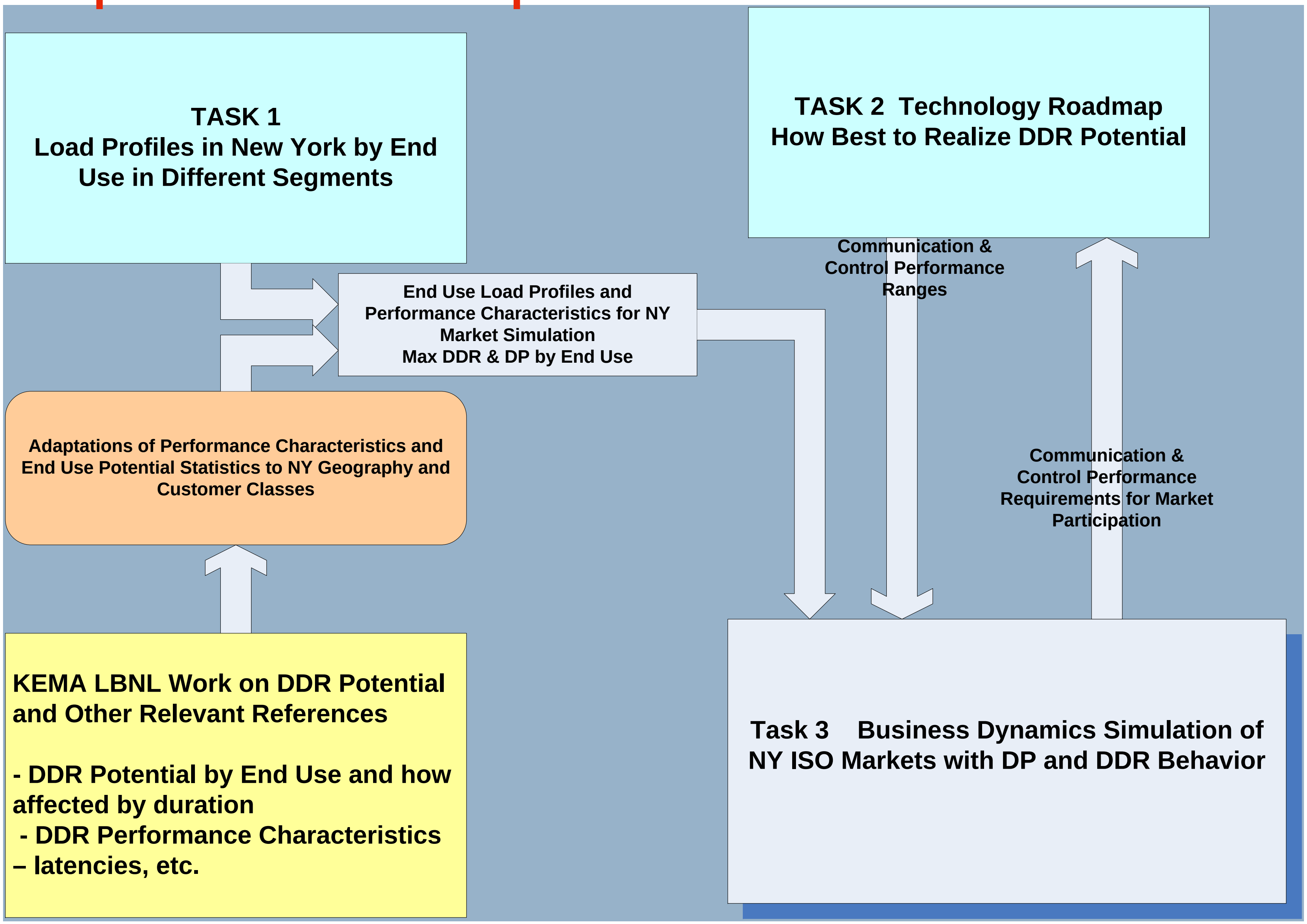
# Key Research Questions

To explore market integration methods and understand market impacts, KEMA derived estimates of potential DDR & DP amounts and then modeled their participation in the markets.

- Where are the greatest potential DR resources and which technologies enable them?
  - By end use, performance, technology
- What are the potential impacts of greater DDR & DP integration into the wholesale market?
  - What are the potential effects on the real time markets* in terms of market prices & supply dispatch over time?
  - Are there critical issues caused by integrating DDR & DP and if so, what are the causes of these issues and how sensitive are the impacts to these causes?
  - What are the conditions for preserving market convergence?
    - e.g., latencies and penetrations of DDR & DP
- Are there ways to successfully integrate DDR & DP?

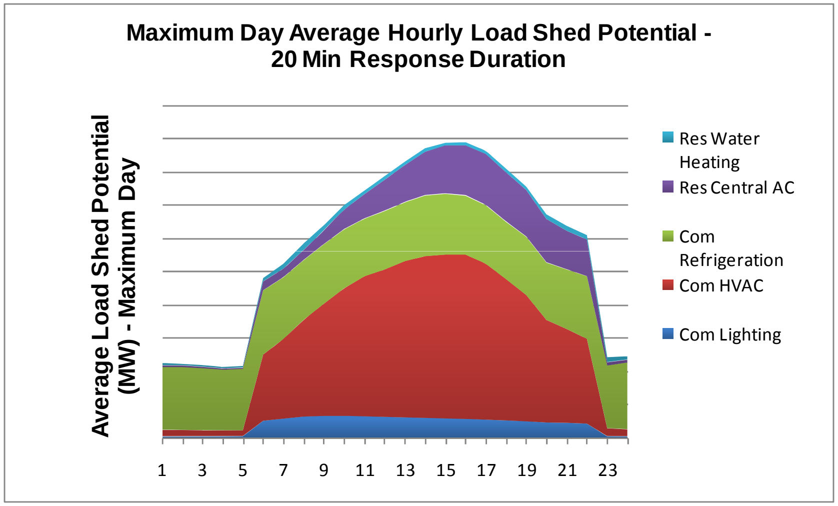
* Includes hour-ahead, fifteen-minute, and five-minute market clearing schemes

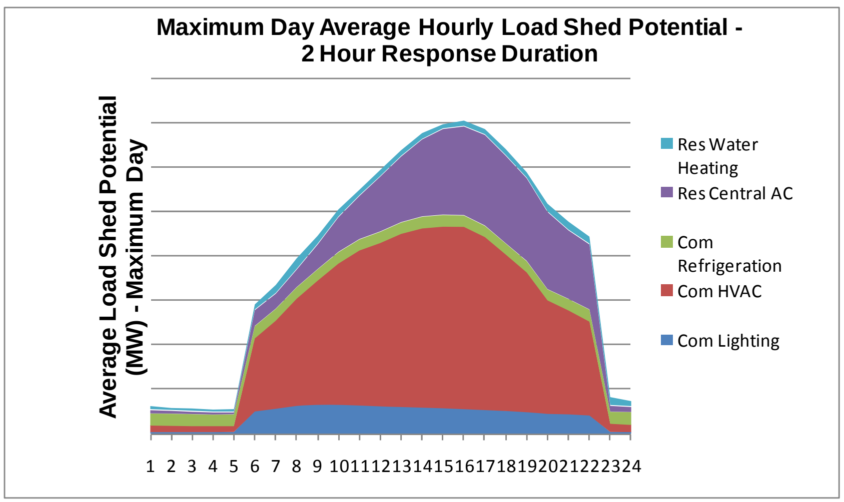
# Inputs and Outputs Overview

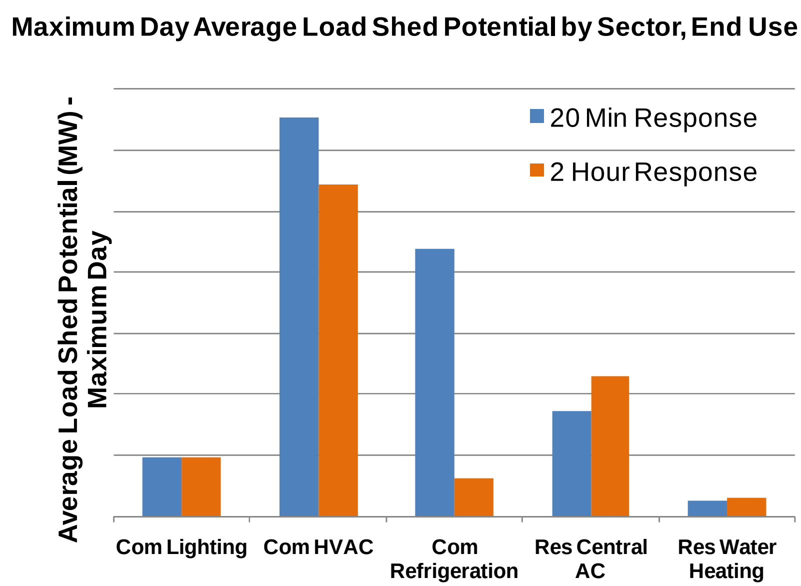


# DDR Potential – (Illustrative)

An example of preliminary, relative output of one day (Maximum System Day) load shed potential by sector, end use, and response duration.



# Task 1 (DDR Potential) - Approach

- **Objectives**: Link derived load reduction potential data (by end use, customer type, day type, and hour) to pricing assumptions and customer response in Task 3; assess DDR potential against market products and requirements including: latency, duration, fatigue, verifiability, certainty / yield
- **Data available**: NY utility hourly load profiles by rate class, day type; KEMA's ADR work with LBNL for CEC
- **Key challenges**: No NY statewide end use load distributions; utility variation in data and format

**Create 8760 hourly average load profiles for key RES, COMM, and IND rate classes**

1. Identify which utility rate schedules (load profiles) to leverage for each customer type
2. Convert day-type loads to 8760 hourly profiles
3. Convert 8760 load profiles to 8760 unitized profiles
4. Develop 8760 average load profile for most recent year

→ **Estimate hourly average load accounted for by key end uses**

1. Leverage CEUS, publicly available data
2. Estimate portion of load associated with lighting, cooling, ventilation, and refrigeration
3. Adjust hourly load by end-use for differences between CA and NYS in the portion of total RES, COMM, IND electric consumption

→ **Estimate load shed capability**

1. Load shed capability = amt of end-use load that can be shed at various hours; portion that is currently or potentially controllable by the ISO
2. Develop rate class and end-use load shapes for typical days with consistent definitions for all utilities
3. Estimate load shed duration and MW by end-use and total load class

# Task 2 (Technology Roadmap) - Approach

- **Objectives**: Link key characteristics of each key technology to Task 3 model to determine how and when DR can be dispatched, controlled, measured, settled
- **Data available**: KEMA assembling from proprietary and public sources
- **Key challenges**: Screening the categories of technologies, and deployment configurations most relevant to DP, DDR dynamics; including the most relevant data; determining variations of technology application by end use or customer segment

**Create, Populate Technology Framework**

- Develop a matrix to identify and compare key technical characteristics of DP/DDR enabling technologies
- Identify relevant technologies by customer segment, end use, and technology type (e.g., communications for information/control; end use control systems; M&V…)

**Identify Key Technology Variables for Task 3 Model Dynamics**

- e.g. response time, latency, duration of load response by technology
- Segment technology inputs by end use type and customer class

**Create DP, DDR Enabling Technology Roadmap based on Task 3 Model Outputs**

- Prioritize enabling technologies (current, potential future) that have the greatest impact on enabling DDR response
- Identify limitations or opportunities for DDR (by end use, customer class) driven by technology deployments

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# Task 3: Dynamic Pricing, DDR Market Assessment

- Market Impact Assessment – how will DP and DDR “fit” together in markets
  - Interaction between DP and DDR at customer end use
  - Impact of load forecast uncertainty on dispatch optimization
  - Settlements
- Market Simulation (using Vensim® software) to explore interactions and design consequences between all wholesale and retail market participants and DR business processes (supply commitment; dispatch)
- Key challenges to address:
  - Simulating behavior of market participants under specific scenarios
  - Price elasticity
  - Assessing implications on market operations, DR program design

# Study Scope

The analysis models the real time energy markets over a 24-hour period. The model is dynamic - it captures the timing of market clearing and market dispatch, generation response, and demand response.

- This analysis uses a model focusing on the real time energy markets which presumes that:
  - Generation is able to meet commitments and follow dispatch signals
  - DDR is treated like a generation resource (e.g., DDR dispatch follows a similar process to generation dispatch)
  - Customers who have grid-connected generation and self-optimize their loads according to day-ahead prices are included in the modeling
- The model includes scenarios to vary parameters related to the integration of demand response resources, such as:
  - Which price DP resources are given
  - The amounts of DDR & DP in the market
  - Estimated and actual demand curves
  - Information delays and the dynamic performance of demand resources

# Real Time Energy Market Model Overview

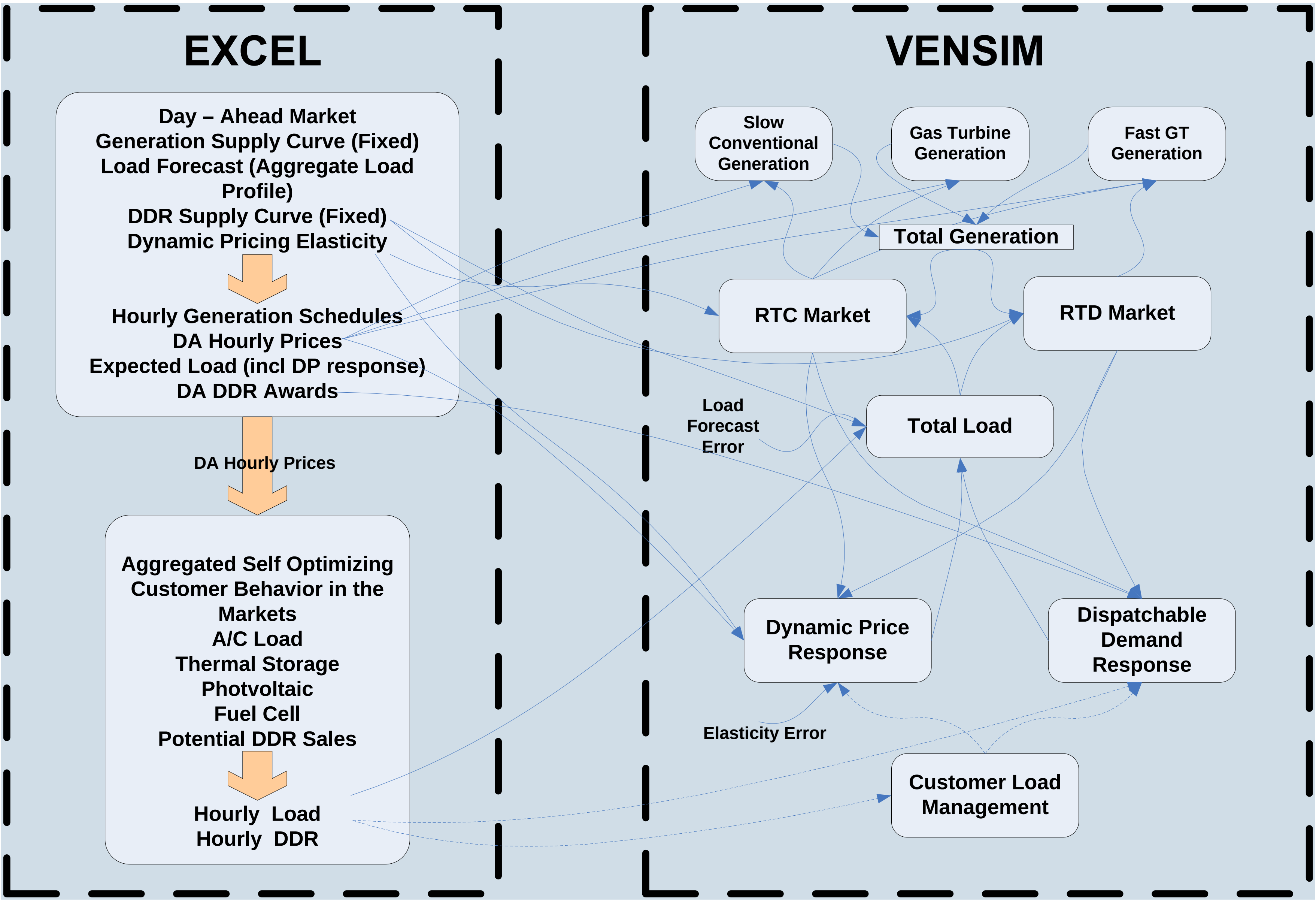
- The real time energy market model runs with a series of inputs as identified in an Excel spreadsheet, which are passed through a day-ahead market clearing model.

- In the real-time model, real time dispatch, price publication, generation ramp up and DDR & DP response are all modeled.

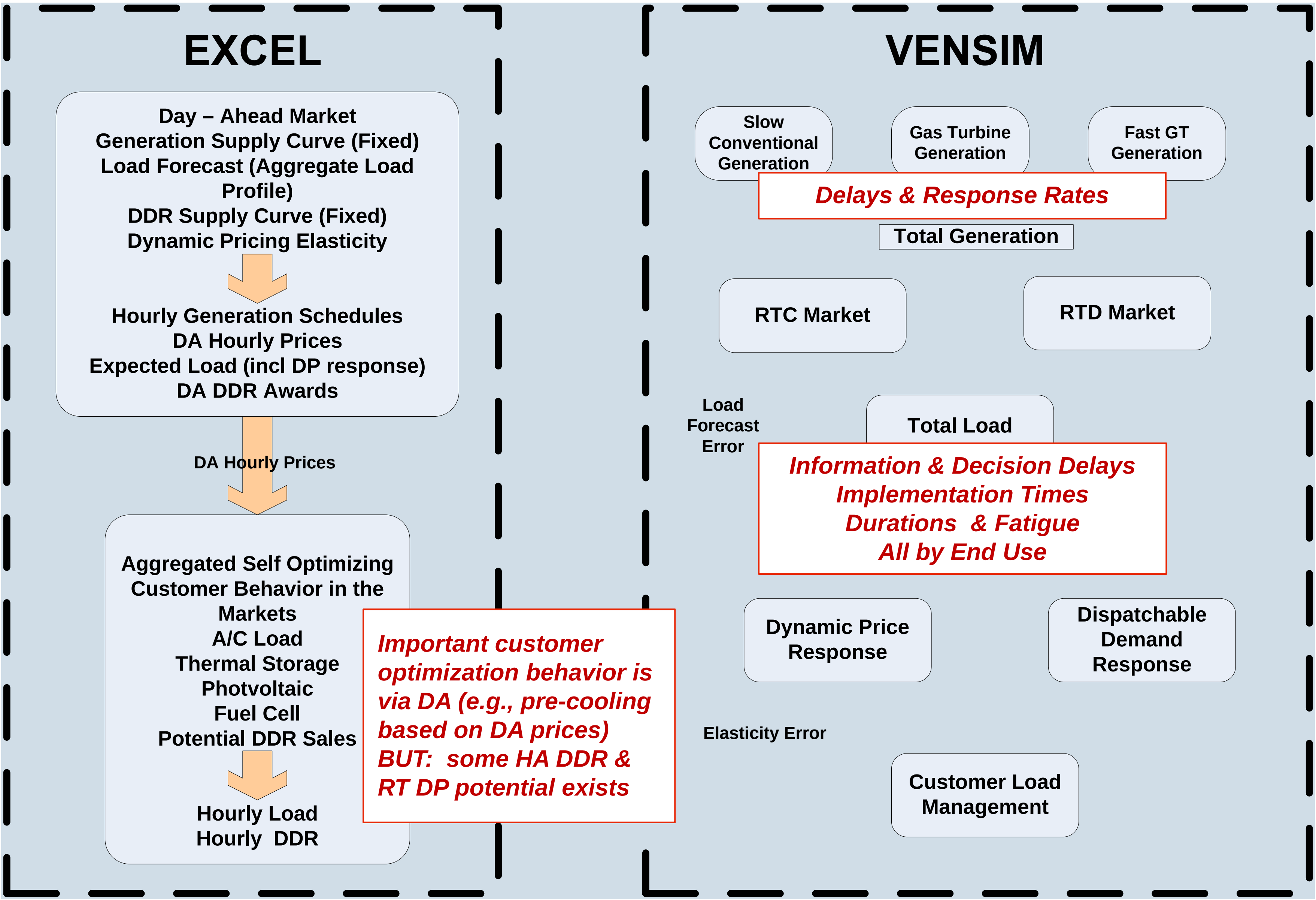
- The behavior of customers who self-optimize their energy loads based on day-ahead prices can be included

- The model consists of a series of feedback loops that drive the behavior of generation and demand resources, which in turn drive the behavior of market dispatch and price publication.

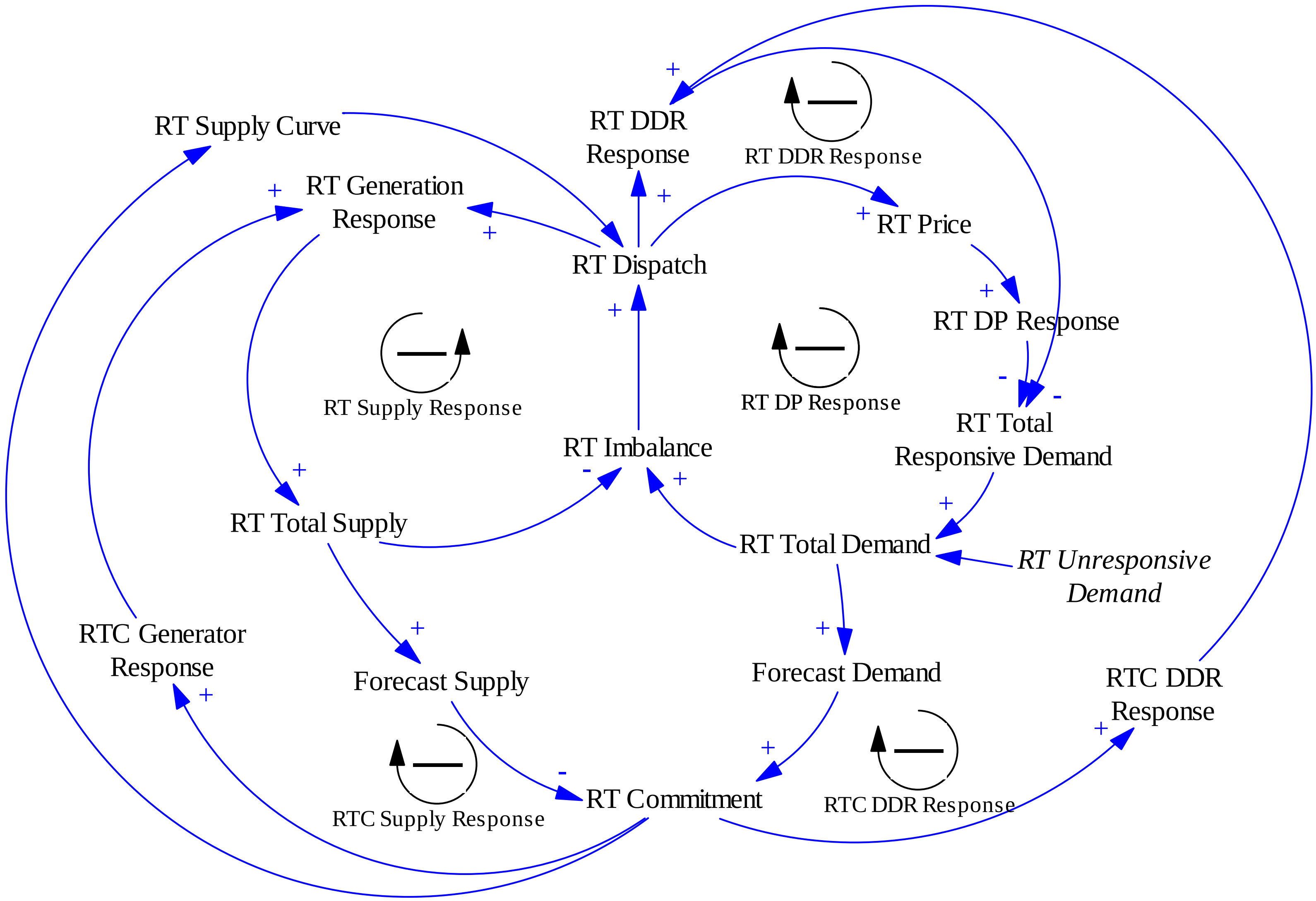
# Task 3 Model Overview



# Task 3 Model Key Attributes



# Real Time Market Model



# Interpreting the Simulations

- The simulations are NOT predictors of price. They are indications of dynamic systems behavior that develops at high DP penetrations.
- DP in the supply-demand process represents a “feedback” loop (load responds to price which causes lower load/supply and acts to reduce price in subsequent market periods – which acts to increase load).
- High elasticities are equivalent to high gains in the feedback loop.
- Long durations and market periods (i.e., demand responding to hourly prices with 60-minute durations) are like delays / phase shifts in the feedback loop and can affect volatility.
- Different penetrations of DP and different price signals used vs. different durations lead to varying feedback loop behavior.  In many of the cases simulated the feedback loop gets stronger over time and price oscillations (and corresponding supply oscillations) grow over time.  In others decreasing load post peak reduces prices and the feedback effects are muted.

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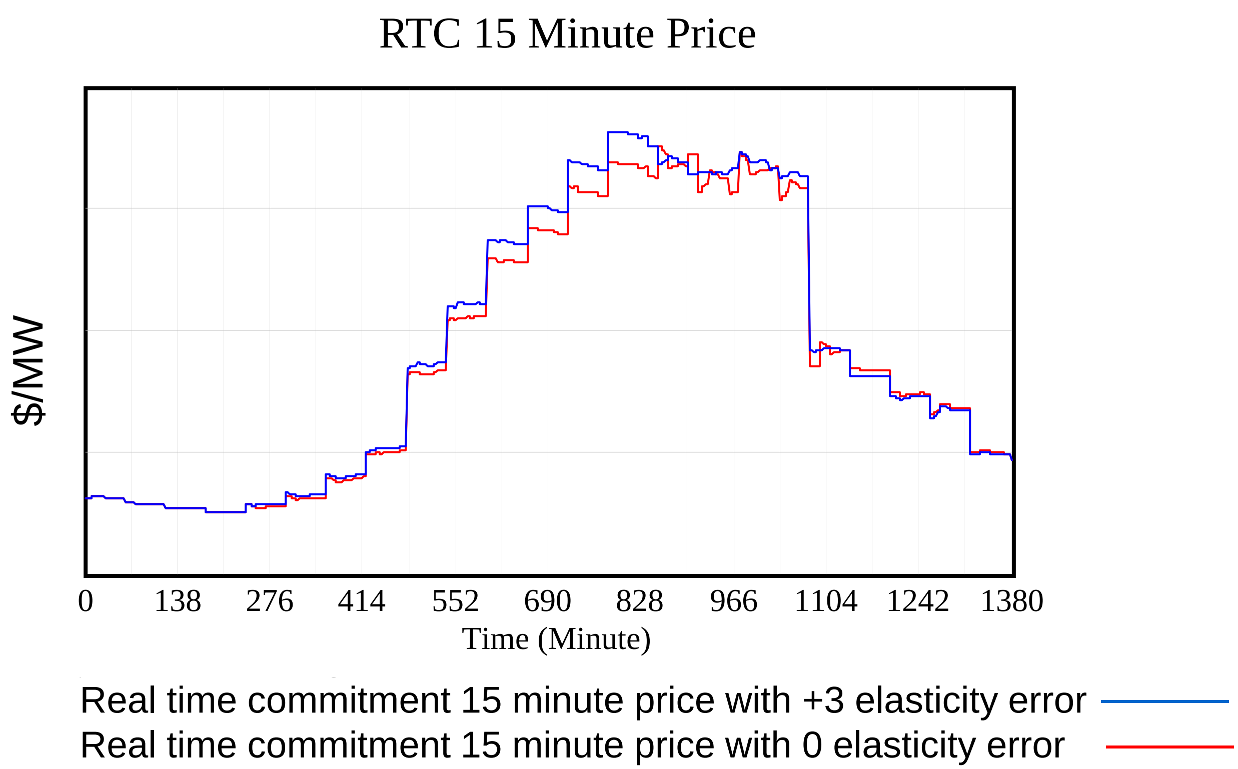
# Preliminary Observations

1. Mis-match of price signal time interval (e.g., Real Time Commitment (RTC) Hourly, RTC 15 min, Real Time Dispatch (RTD) 5 min), with DP response performance characteristics causes price overshoot, oscillations, etc.  One “market” problem rolls over into the subsequent market.

2. DDR (as modeled) is well behaved.

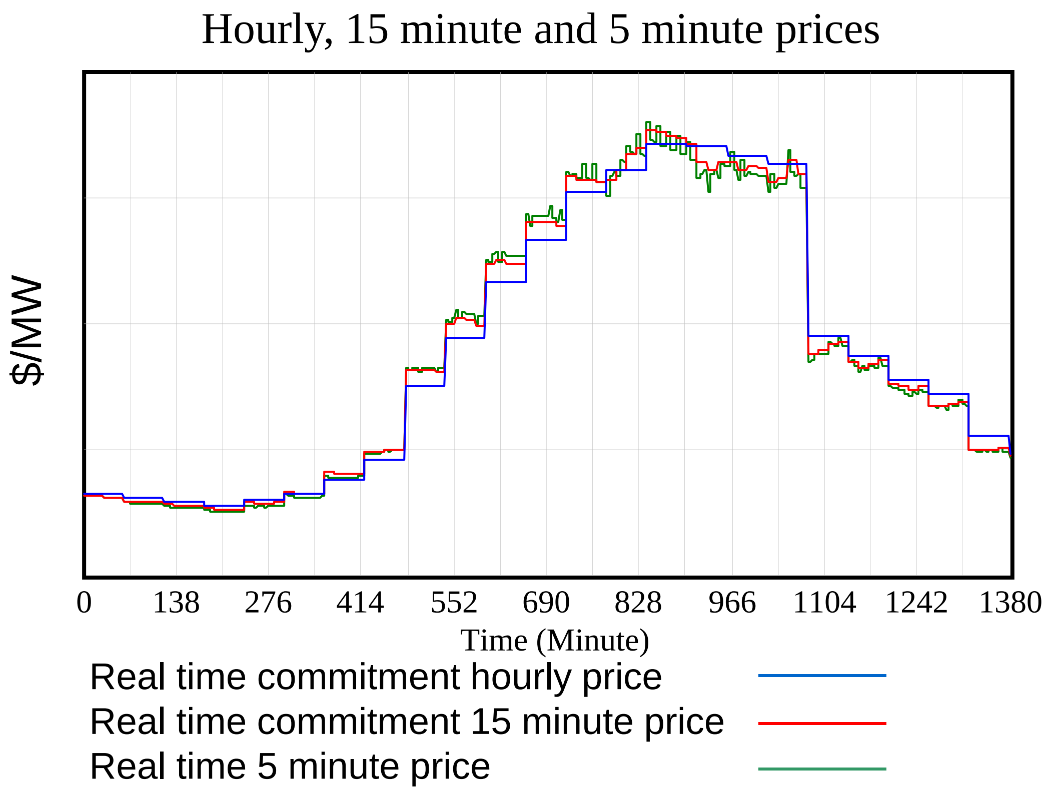
3. Elasticity errors in the DA market will cause problems in the HA, RTC, and RTD markets depending upon the direction and magnitude.

# Impact of DP on Real Time Dispatch (RTD) Price



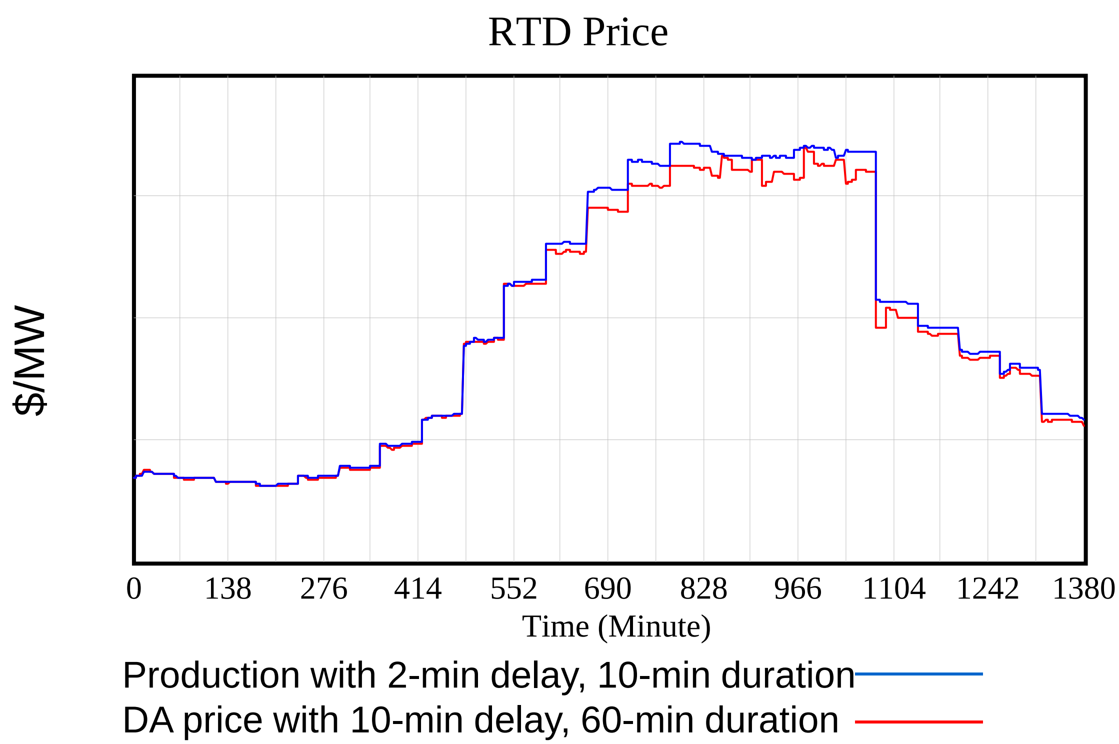

Dynamic pricing is responding to hourly price signal
Delay and duration are 10 and 60 minutes respectively
Real time 5 minute price is plotted for 0-error vs. +3-error
Real time 5 minute price increases due to significant error in elasticity

# Price Impacts: Shorter DP Duration & 5-min Signal



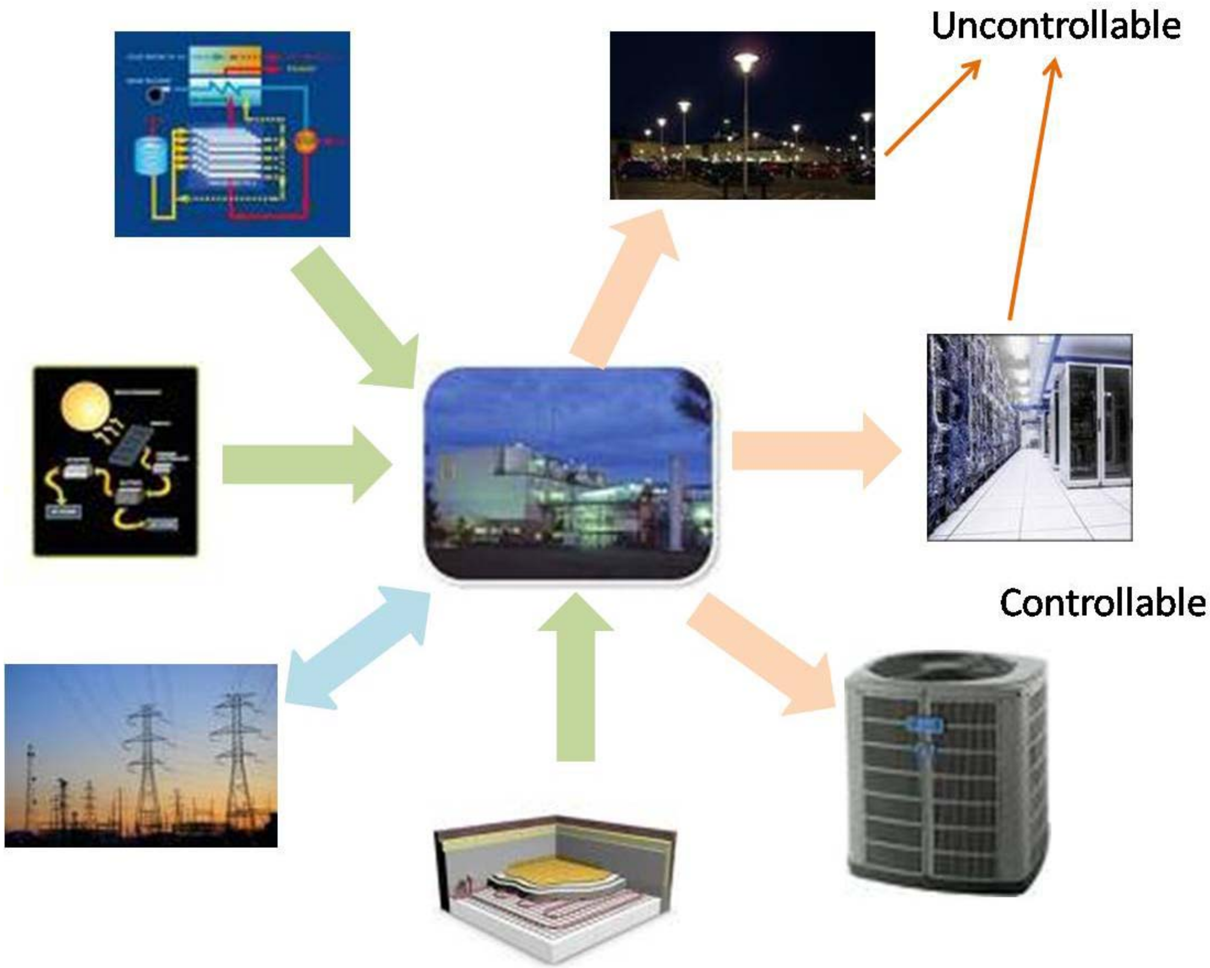

Dynamic pricing is responding to real time 5 minute price signal
Delay and duration are 2 and 10 minutes respectively
All prices are plotted
Real time 5 minute price is not as well-behaved as before because of poor alignment with market price signal. The duration is greater than the price signal period resulting in overshoot and ramping effects

# Impact of DDR Duration on RTD Price




Only DDR is present in the market
Real time 5 minute price is plotted for 2-min delay/10-min duration vs. 10-min delay/60-min duration
Longer duration decreases the real time 5 minute price

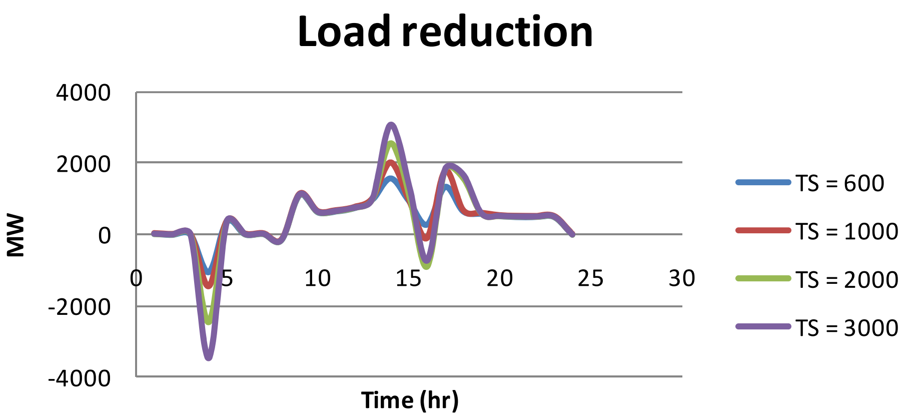
# Commercial Customer Self-Optimization: Model Structure & Components

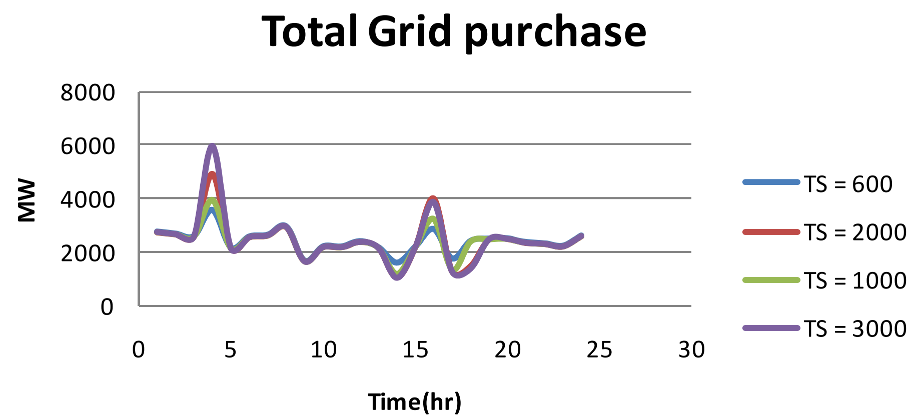


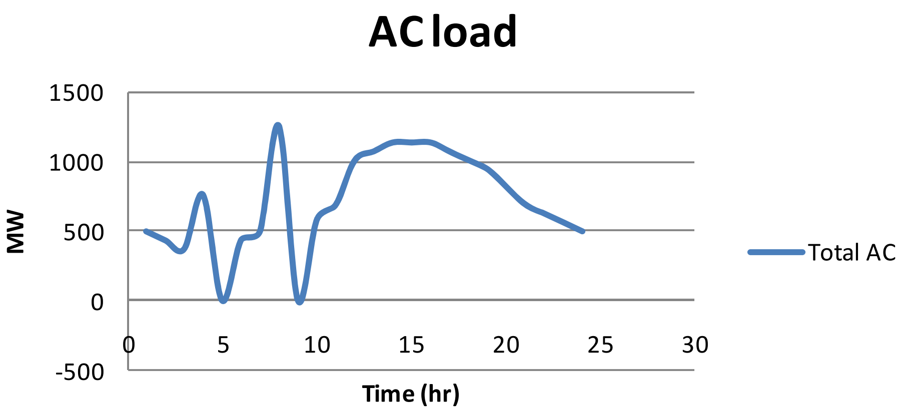

## Components

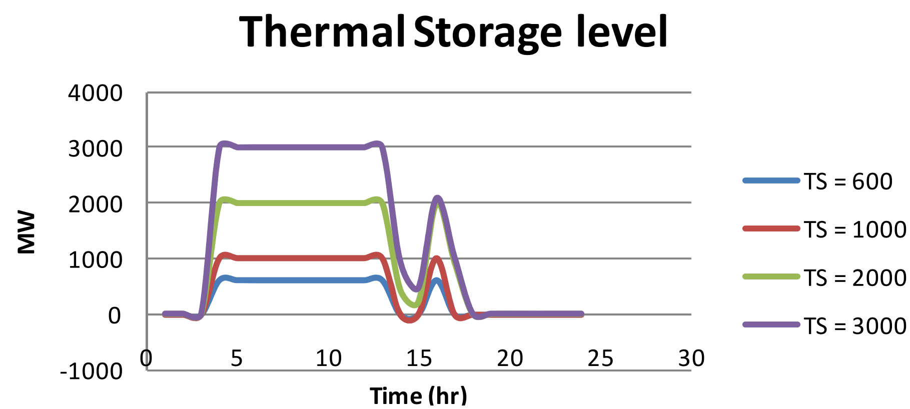
- On-site generation
  - Fuel cell
  - PV cells
- Storage
  - Thermal storage
- Connection to Grid

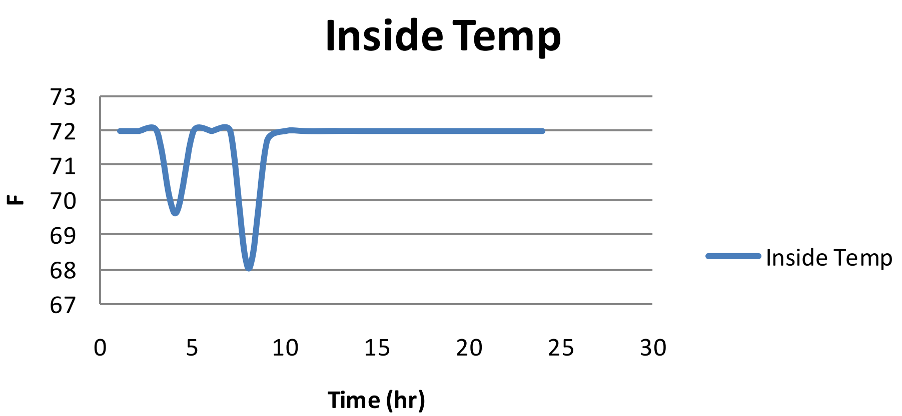
# Self Optimized Load Example

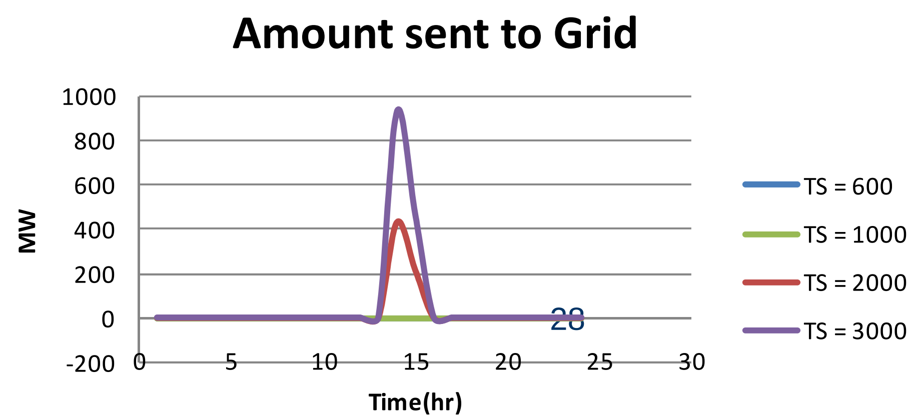


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# First Observation

> 1 The technical and market impacts of integrating DDR & DP depend on: The penetration of each end use/technology; the frequency and timing of the price signal; and the relative duration & latencies of DDR & DP compared to the frequency of the market dispatch & price publication.

1. **When DDR & DP are present, measured demand reflects load forecast error. Instructed DDR response is "known" to the ISO and can be anticipated in market clearing. DP response is autonomous and must be estimated.**

2. **With the presence of DP in the energy market:**
   - Inefficiencies may be introduced by forecast errors related to sampling current load. This is because the current load includes DP responding to the last period's prices but which will change according to the next period's prices.
   - Whether DP shows up in the sampled load depends on its duration, latency and how often it is sampled.

3. **With the presence of DDR in the energy market:**
   - Because DDR is instructed via market clearing and commitment/dispatch, expectations about its presence are better known than DP. Just as dispatch algorithms account for short term load forecast and anticipated generation trajectories in response to schedules and dispatch, these algorithms will have to anticipate already instructed DDR response.

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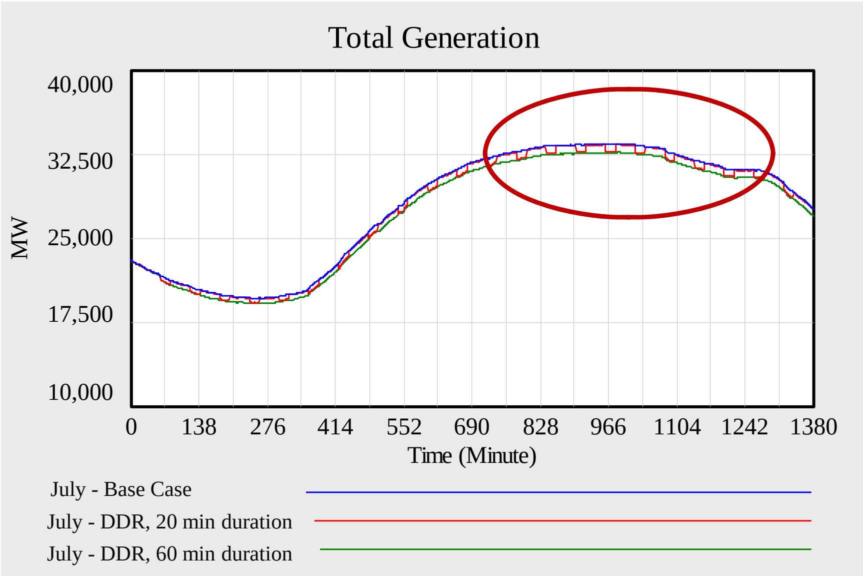
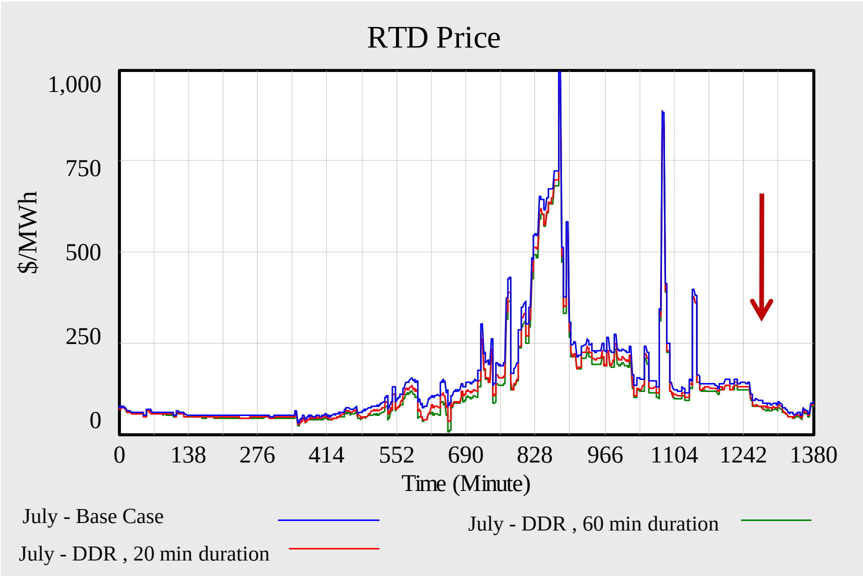



DDR resources are dispatched on the hour (RTCH) & have durations of 20 and 60 min. Shorter duration DDR causes more generation volatility. It also results in less total energy required than w/out DDR & decreases total generation in the RTC 15 min and RTD processes. (the Base Case has no DDR)

Because DDR reduces total energy needs, it also reduces prices below the Base Case prices. The 20 min DDR case causes some RTD volatility as RTD compensates for DDR returning to normal before the hour is up.



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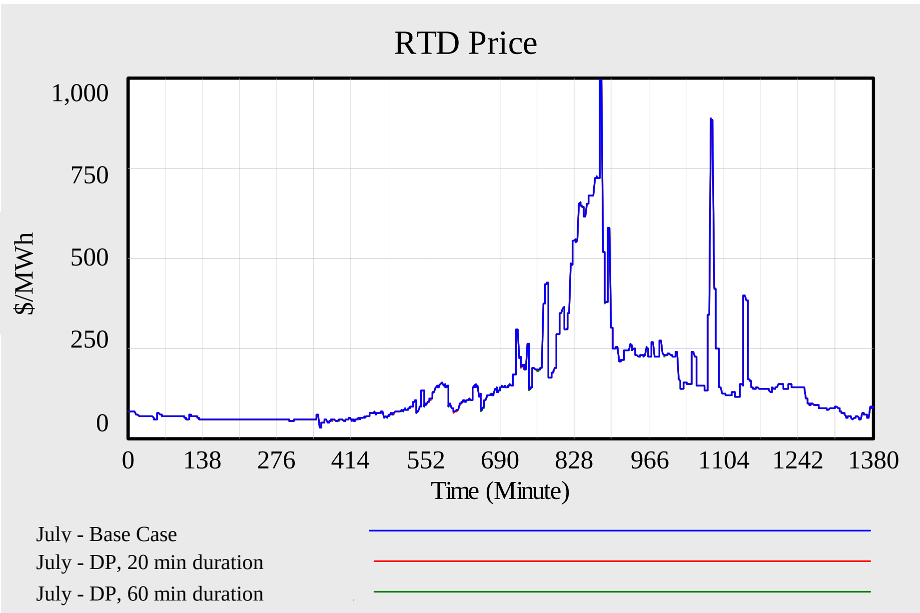
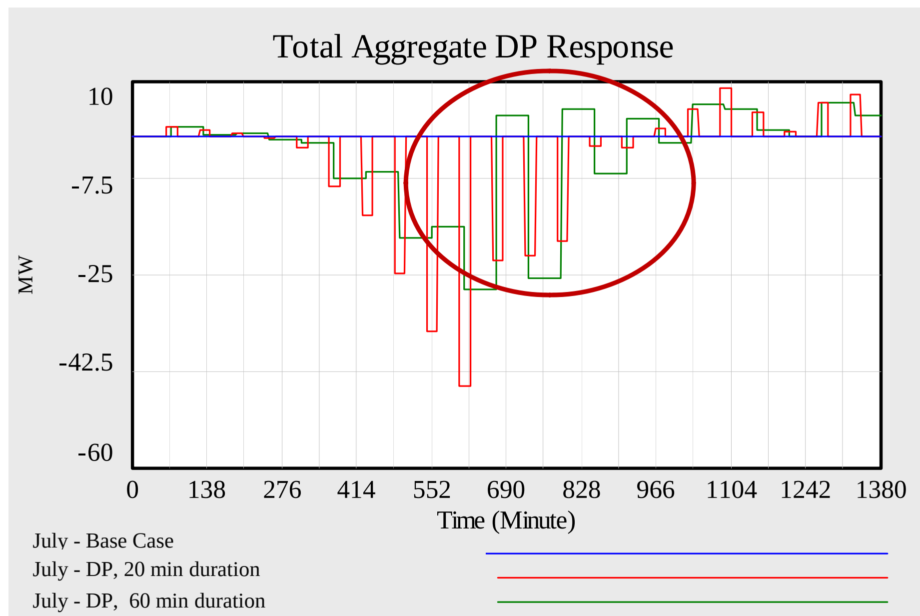



At nominal penetration where DP is responding to hourly prices and elasticity, DP behavior has no significant impact on RTD prices. This scenario assumes the market is not anticipating DP elasticity and price response in the clearing.




When the DP duration is less than the market dispatch and price publication cycle, a cycle of oscillating DR disappears. Total amounts are low at nominal penetrations.

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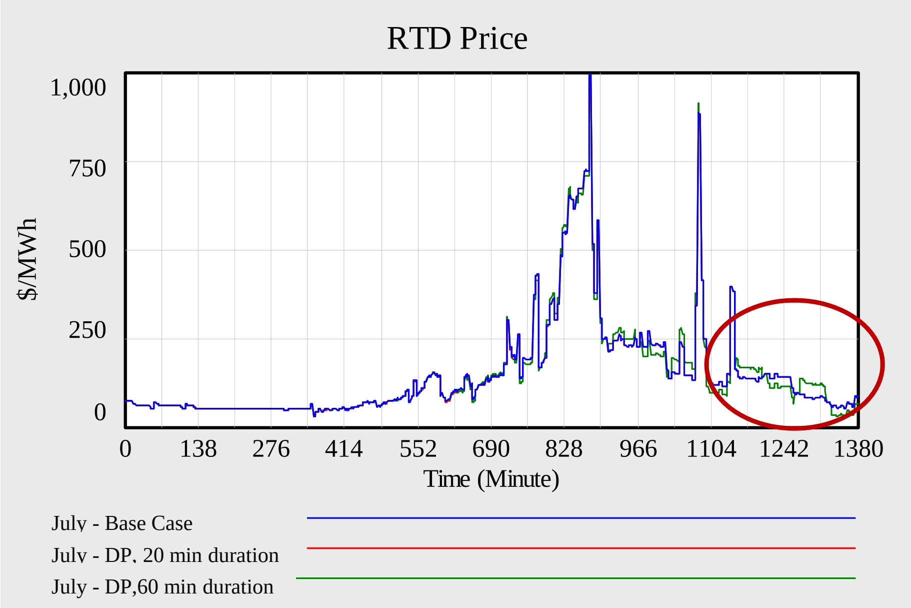
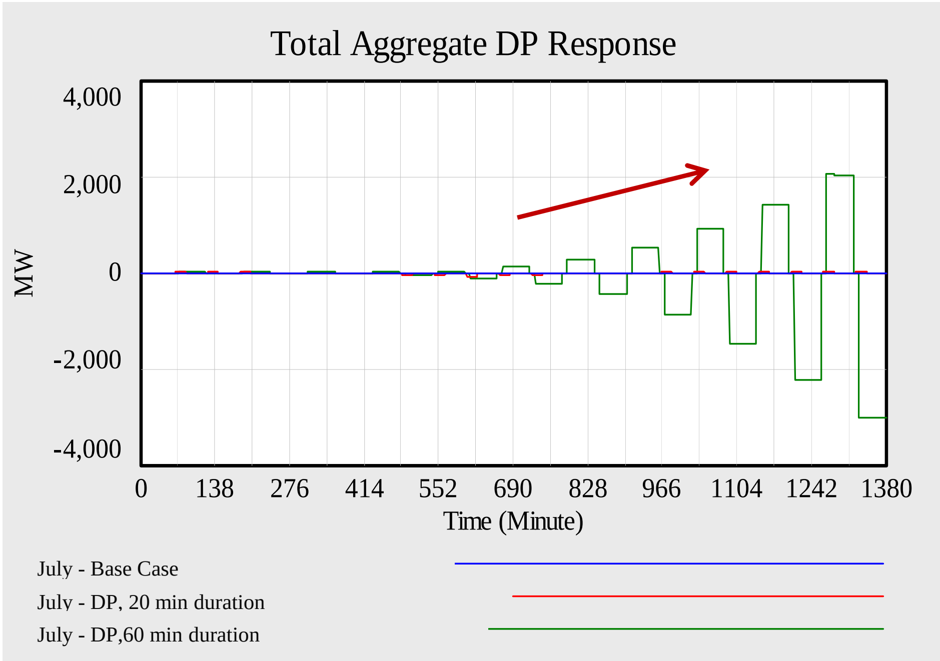



DP responding to an hourly price signal with a 60 min duration affects RTD prices but 20 min durations do not.

At scaled up penetration, DP response becomes unstable as shown when the duration is 60 min. Added to information latencies, this means the market is clearing for load that responded to the prior period price but is not aware of that effect.



# Second Observation

2 DP impacts are very sensitive to DP penetration, demand elasticity, and the accuracy of estimated demand elasticity in the market clearing algorithms.

1. DP adverse impacts on volatility and stability are likely greater when RTD prices are used, compared to other prices. This is because RTD prices are more volatile and are more likely to move the supply & demand curves into regions of high prices & DR. In addition, because many DP resources persist longer than the 5 min period between RTD price publications, RTD prices can drive DR that is out of sync with market clearing processes. This also contributes to price volatility. The creation of adverse impacts with RTD prices depend on the penetration of DP-related response & the duration.[1]
2. Accurately estimating actual demand elasticities can help dispatch processes correctly anticipate DP. Accurate estimation can also help to discern the difference between detecting load forecast error and response to DP. Developing methods for adjusting elasticity estimates, similarly to how load forecast estimates are adjusted, could help limit the consequences of mis-estimating demand elasticity.
3. Many DR resources are better suited to hourly or 15 min prices than to real time (5 min). As such, the relationship between the capability of DR and the prices they are subject to should be given consideration.

[1] If DP durations are on the order of 5 minutes, penetrations would have to be on the order of 1.3 x KEMA's estimated penetration to result in price spikes. If the RTCH price is published for DP response, DP penetrations would have to be greater than the potential levels estimated by KEMA and by the Brattle Group to affect the volatility of RTD prices, though generation would still be caused to ramp. DP duration , which price signal is used and DP penetration all determine whether DP will result in market volatility.

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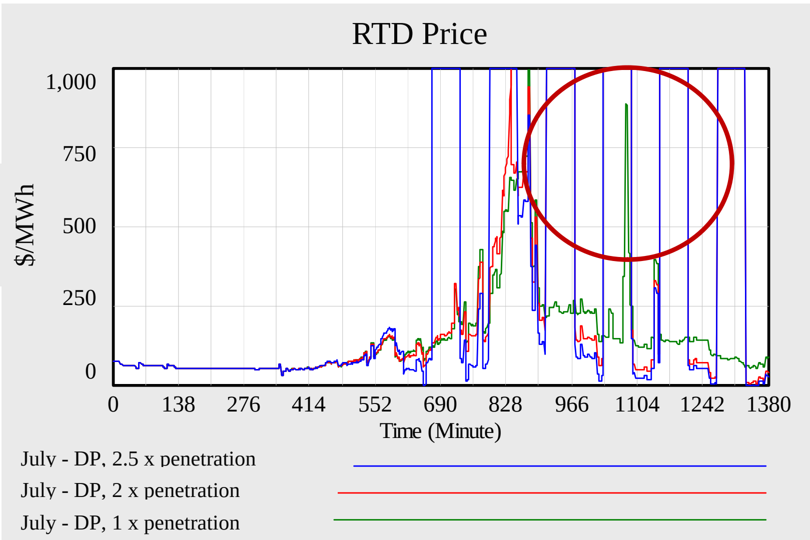
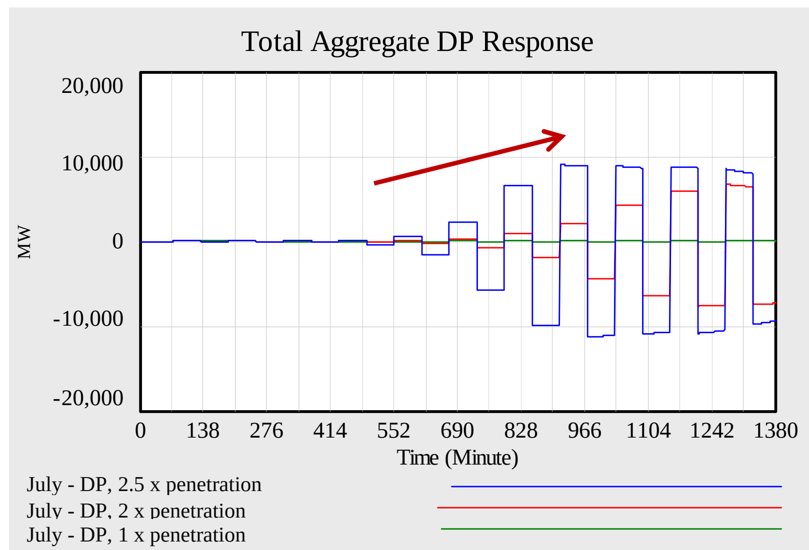



As the amount of responsive DP in the market increases, price potentially increases and can grow to be volatile. The tendency towards volatility is a non-linear process (i.e., a doubling of penetration does not mean a doubling of price or vice versa).

As the amounts of viable DP in the market grow, the oscillations between load increases and drops grow. The increased "penetration" of DP in effect increases the ratio of demand elasticity to supply elasticity and increases instability.



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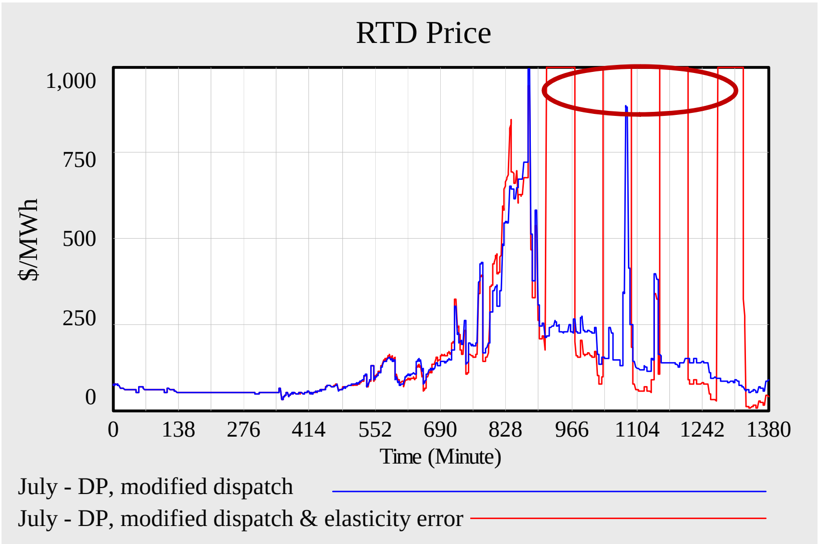
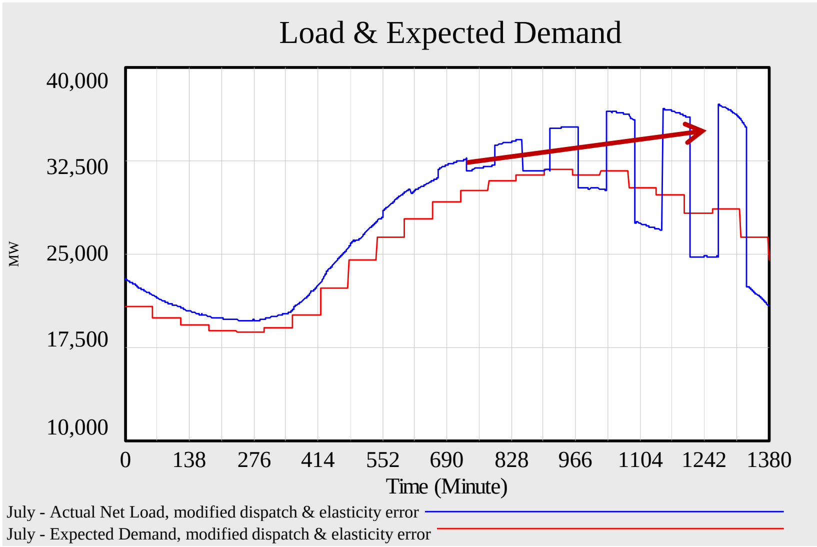


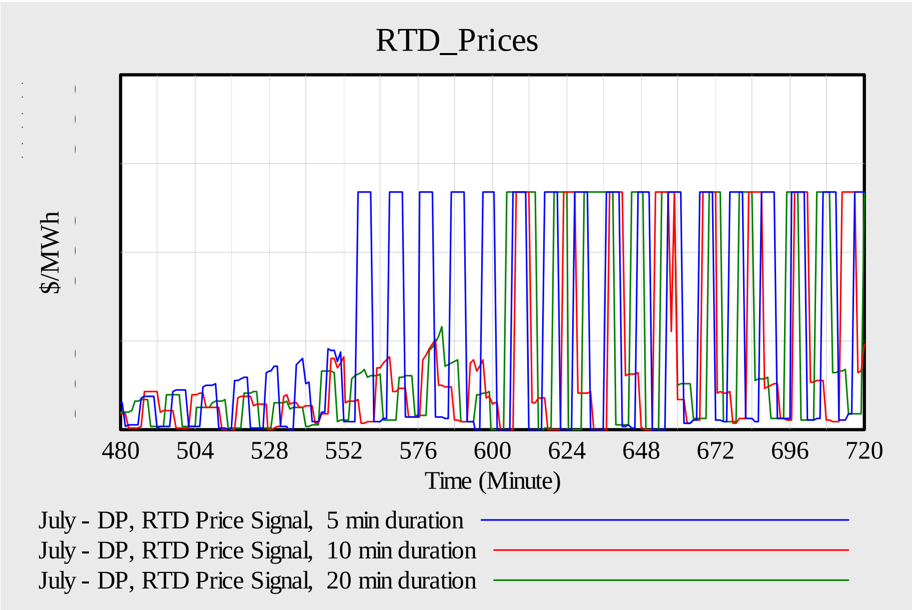

Price volatility from DP can be mitigated with a modified dispatch that expects an amount of DP in current demand & anticipates DP in response to upcoming prices. However, where DP penetrations are high, and elasticity estimates have high error, price volatility can be exacerbated. In the curve on the left, the market clearing estimates the demand elasticity in the clearing algorithm. When they are aligned, prices behave as without DP.

Because dispatch processes do not ever 'know' the actual DP amounts, wrong assumptions about DR can made. Continuing with erroneous assumptions about demand elasticity can drive actual load & estimated load further apart. Here the actual net load includes unstable DP response. The anticipated DP response is shown in red.



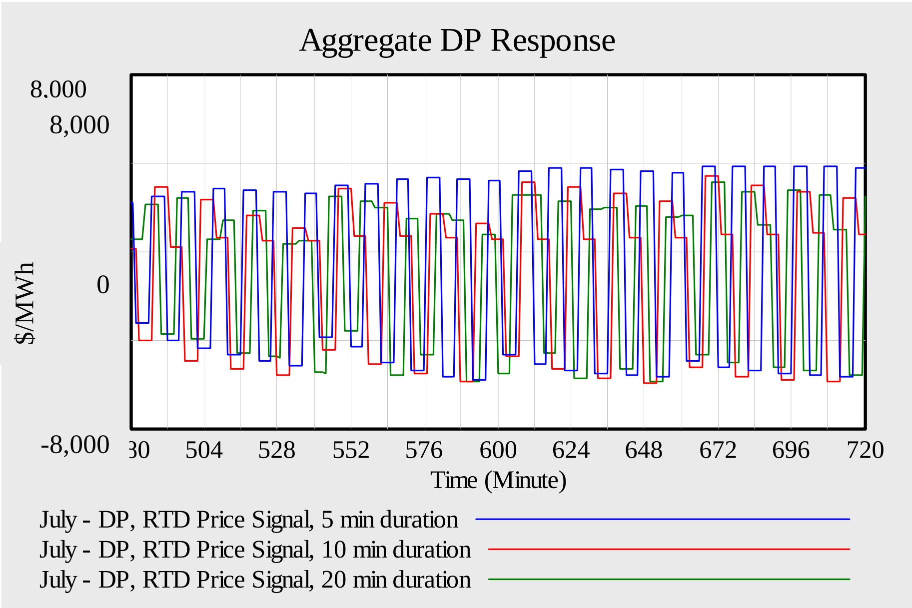
# Responding to RTD

2 DP impacts are very sensitive to DP penetration, demand elasticity, and the accuracy of estimated demand elasticity in the market clearing algorithms.




DP durations that are significantly shorter than the market price periodicity will aggravate instabilities as shown.

DP durations that are longer than the market periodicity cause severe oscillations in DP response.



# Third Observation

**3** Customers who self-optimize can pose challenges for the energy market.

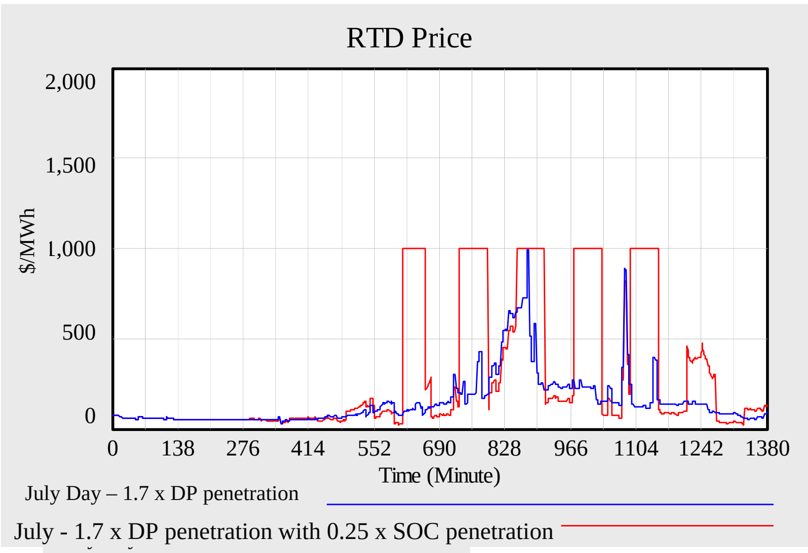
1. Self-optimizing customers (SOC) can optimize their loads against day-ahead prices and have an impact on intra-day markets by creating a complex effect similar to not estimating elasticity correctly.

2. Unpredictability in SOC load is in part due to differences in typical elasticities:
   - A negative elasticity in one time period has an associated positive cross-elasticity at a different time period. This is due to their use of storage and/or on-site generation which increases flexibility for limited amounts of time. Because the amounts shifted are modeled to be of equal magnitude, the positive elasticity will be larger in magnitude than the negative elasticity by a ratio related to the price ratio of the two hours.
   - Because the storage amount is limited, the elasticity at one hour may be very high and at the next hour near zero as all flexibility was utilized in the hour with the highest price.

3. SOC load profiles vary from traditional profiles:
   - An ability to shift their peak towards off-peak hours to avoid high prices means that their evening loads can be higher. This is due to flexibility in usage caused by storage and/or on-site generation capacities.
   - With higher evening loads, self-optimizing customers have additional demand response potential in the evenings.

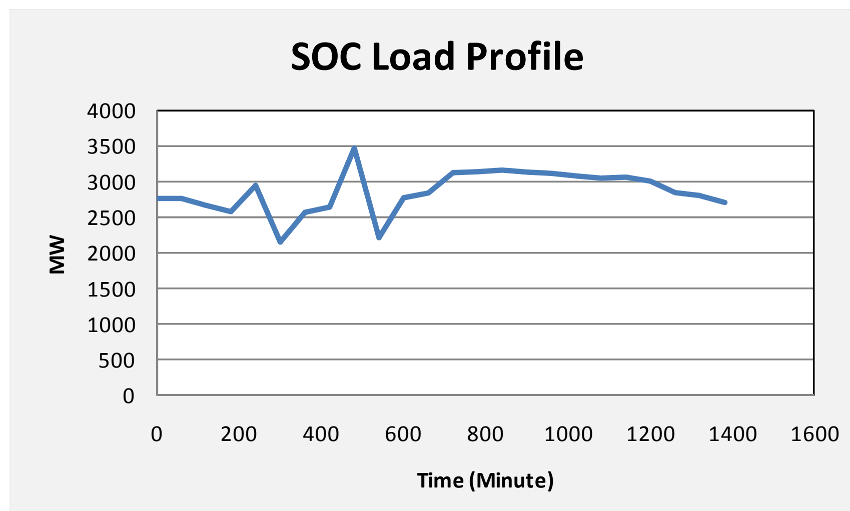
# Third Observation

3 Customers who self-optimize can pose challenges for the energy market.




Even with small penetration of self-optimizing customers (e.g., 400 MW), RTD prices may become volatile. These customers adjusted their generation, storage, and demand profiles in response to published day-ahead prices. This caused complex "load forecast" errors as load was time shifted *after* the prices were cleared.

The unfamiliar load profile of self-optimizing customers can make their demand difficult to predict. It is sensitive to intra-day price spreads, individual resource configurations, and intra-hour weather in the case of photovoltaic generation.



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