

# Estimating Forward Prices & Their Use by Responsive Devices

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# Goals

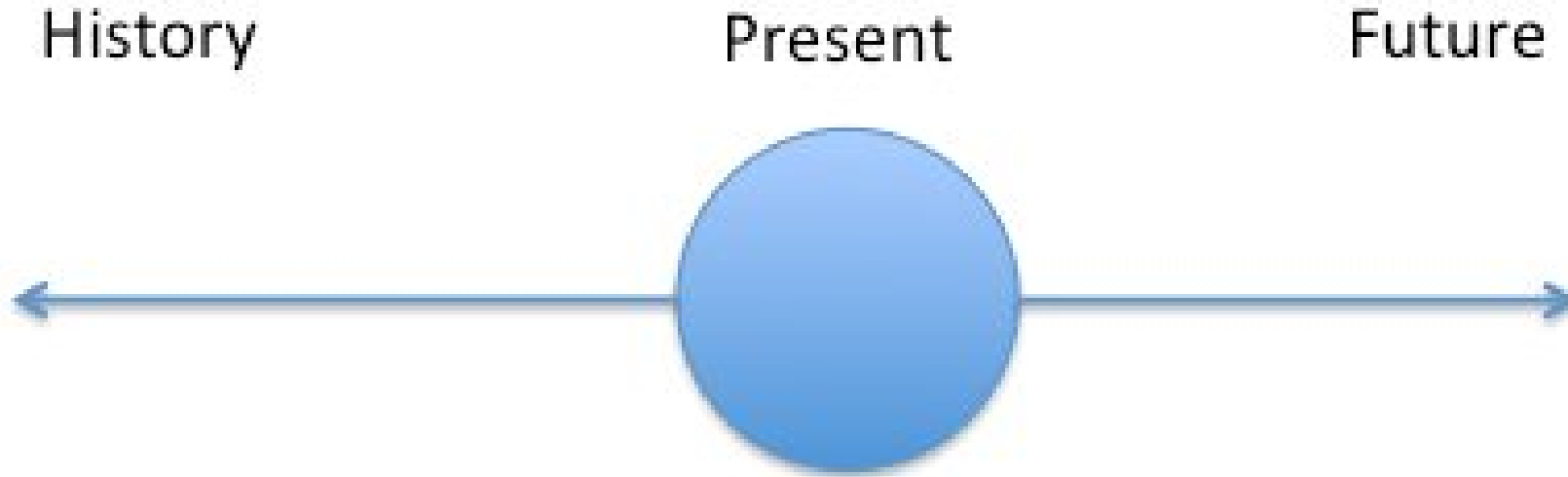
- Motivating the need for demand optimization based on forward prices
- Consider forward prices and indications
- Analyze 12+ months of data on wholesale forward and real-time prices
- Demonstrate that future price indications are already available
- Discuss future work

# Smart Device Challenge

- Problem: Consumers & devices don't see dynamic signals
  - System must meet all foreseeable demand & any contingency
  - 50% generation capacity factor & lower T&D capacity utilization
  - With future requirements, lack of optimization has significant costs
- Opportunity: a large portion of energy use is from:
  - End uses with thermal inertia, e.g. heating, cooling, water heating, & refrigeration
  - Activities that can be scheduled, e.g. clothes drying, dishwashers, vehicle & device charging
  - Increasingly supplemented by distributed storage & generation
- Cost: Standardization & mass deployment cuts cost of devices
- Challenge: Accelerate a high penetration of smart devices & optimize their operation with respect to current and likely future interval signals, consistent with consumer preferences & device capabilities

# Look Forward, Look Back

- The past is known
- The future *MAY* be known, but is usually projected
  - Transactable or not, indicative or actual



Is this a good price?  
How do I know?

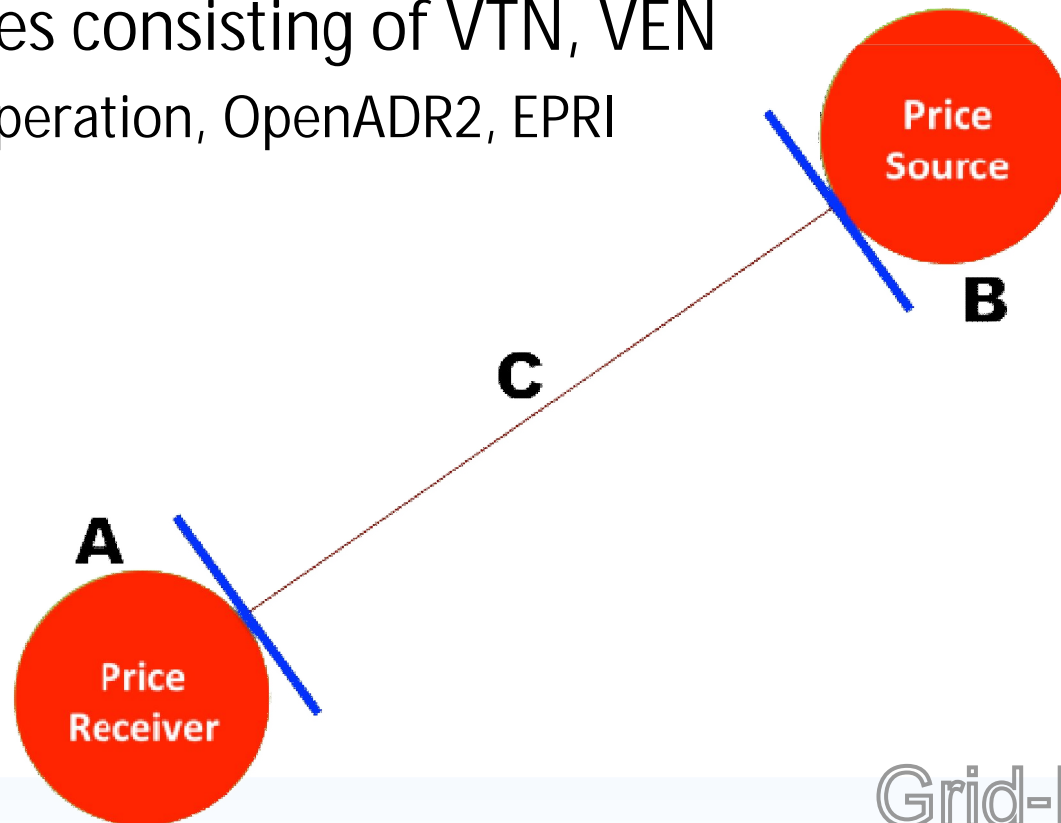
What will be the best price  
For the next 8 time intervals?

# Actionable Prices

- Semantics of Price
  - See Semantics of Price paper/presentation
  - Key dimensions are
    - Real/Nominal
    - Transactable/Not Transactable
- Price-Responsive Nodes
- Want to know the future
  - Or at least project it “reasonably well”

# Decouple Source & Receiver

- Price Source: Streams
  - From producer to consumer of price information
  - May be many producers
  - Will be many consumers
- Price Receiver:
- Nodes & devices consisting of VTN, VEN
  - Energy Interoperation, OpenADR2, EPRI



# Future Price Knowledge

- Horizon – how many time units ahead?



- Price Stream (for this talk) is now into the future
- Benchmark Price (for a time  $t$  and a horizon  $h$ ) is minimum price within horizon  $h$  starting at time  $t$
- Select first interval containing the benchmark price
  - Presume that device would like to run at first economic opportunity

# Price Streams Used

- ISO-NE Next-Day and Real-Time clearing prices
- One hour intervals over 13 months
  - July 1, 2010 through July 31, 2011
  - Plus a bit beyond for look-ahead
  - Same intervals as in our Grid-Interop 2011 Paper  
Abstractions of Price
  - Details in the paper



# Device Behavior

- Device uses one unit of energy for one time unit
- Pseudo-code

## Loop

Consider all prices from the interval just starting to the event horizon

Select the lowest price

Delay operation until the interval associated with the first occurrence of the lowest price

## Repeat

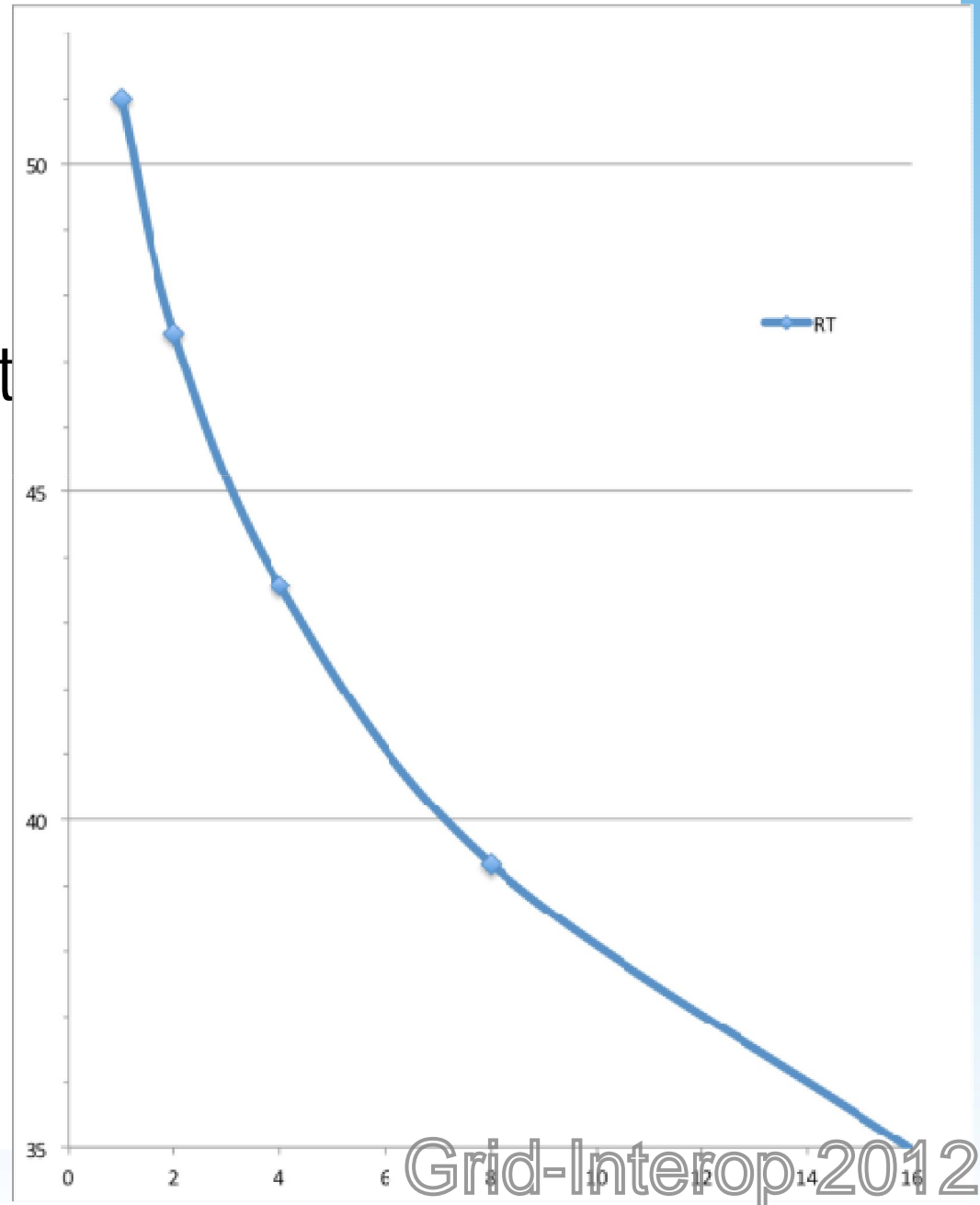
- Selects first interval with the lowest price in the horizon
- Allows composition to real devices

# Experiments Run

- Real-Time (hourly) prices with Benchmark Price computed—Assuming transactions at the hourly Real-Time price, what is the average price paid?
- Day-Ahead (hourly prices)—Assuming transactions at the Day-Ahead prices, what is the average price paid?
- DAselRT (hourly prices)—Use the Day-Ahead prices to select the time to run. Pay at the Real-Time price; what is the average price paid?

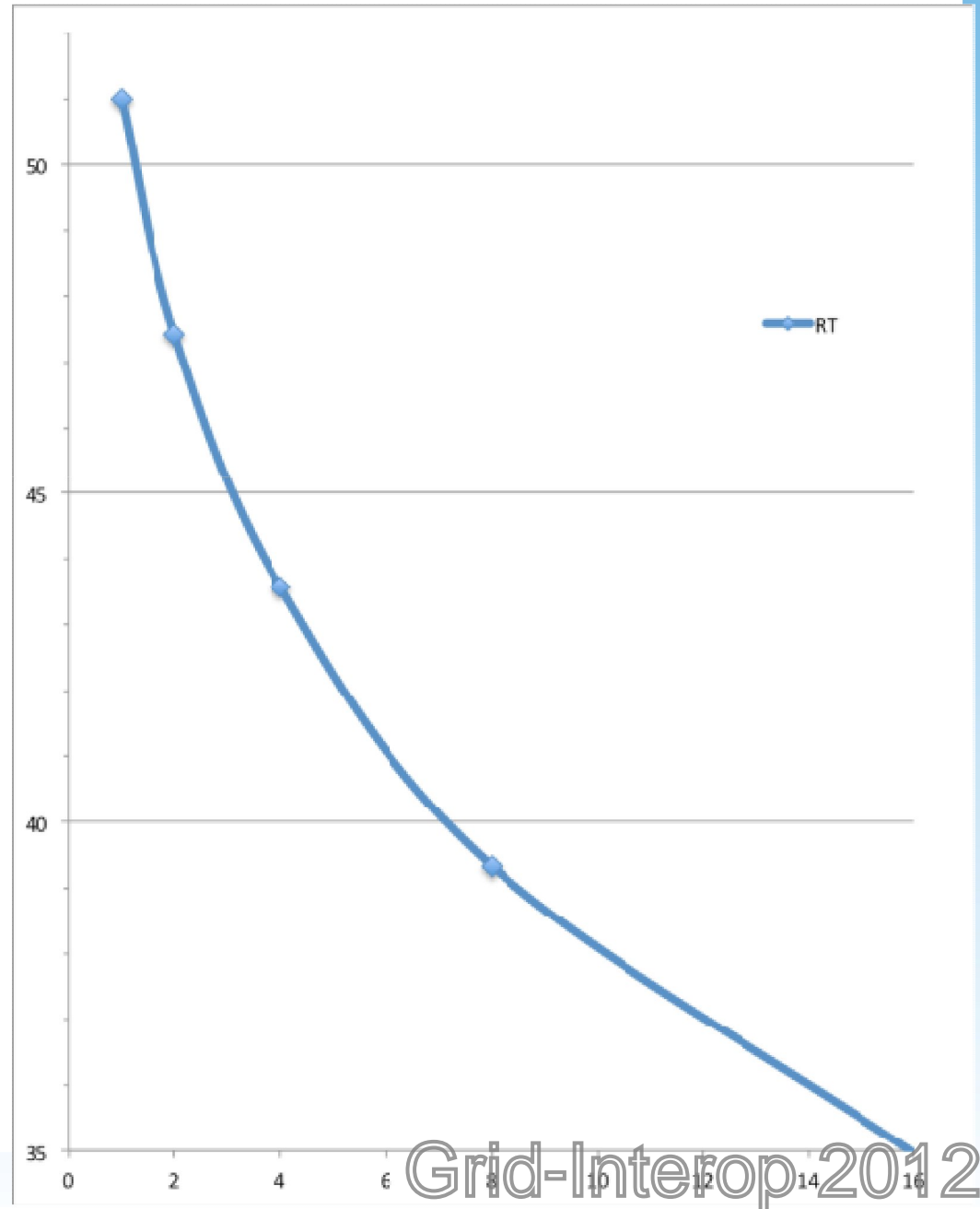
# Real-Time, Future Known

- This analyzed the Benchmark Price with perfect knowledge
  - Select over the data set using the actual future
  - Basis for comparison
  - Average of price paid “now” across entire data set



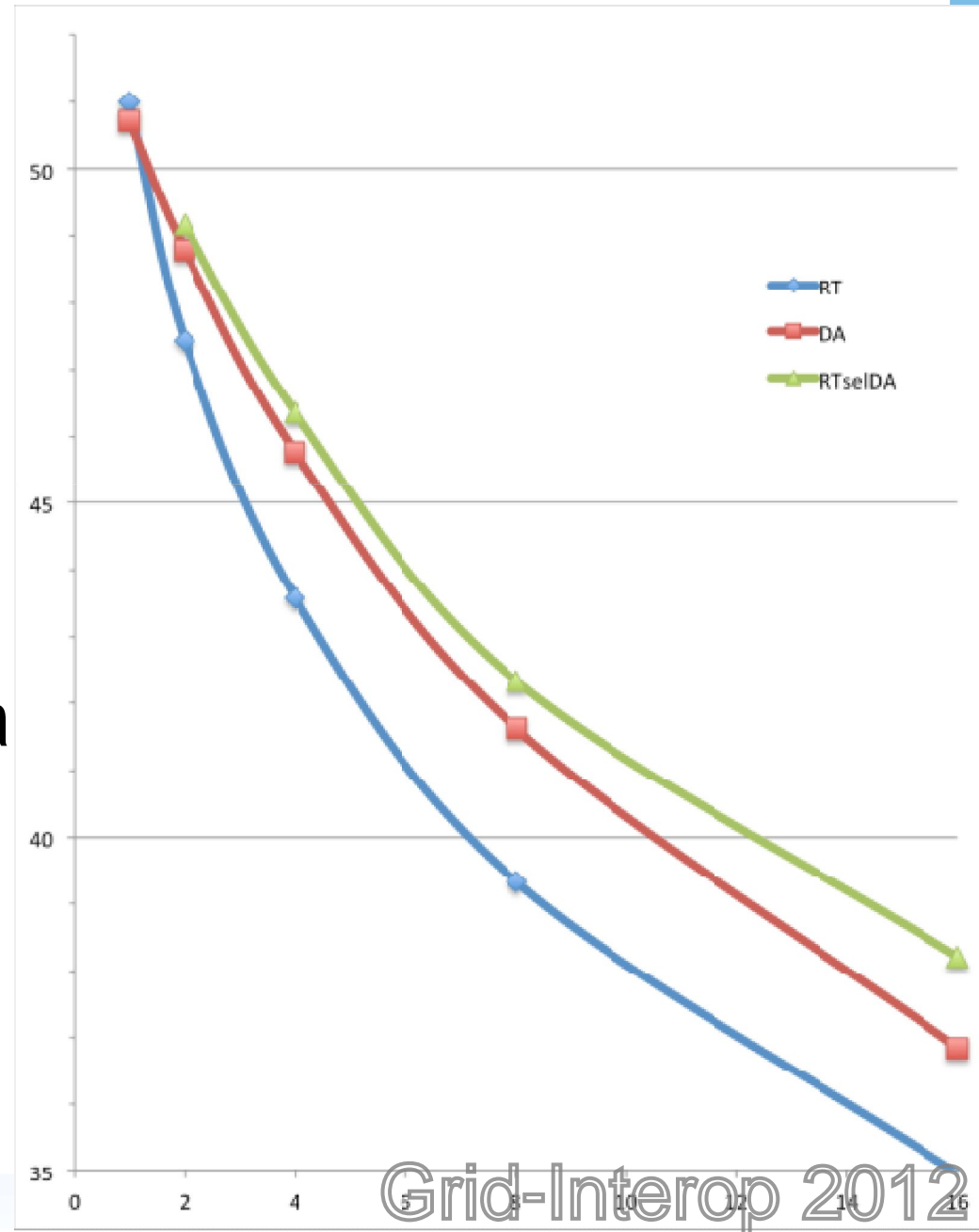
# Real-Time, Future Known (2)

- The larger the horizon the better the price
- Horizon=1 is exactly a price-taker for RT
- 31% benefit (wrt the mean) of horizon=16
- Shows value of indicative prices that are closely related to actual prices



# Day-Ahead, Pay Real-Time

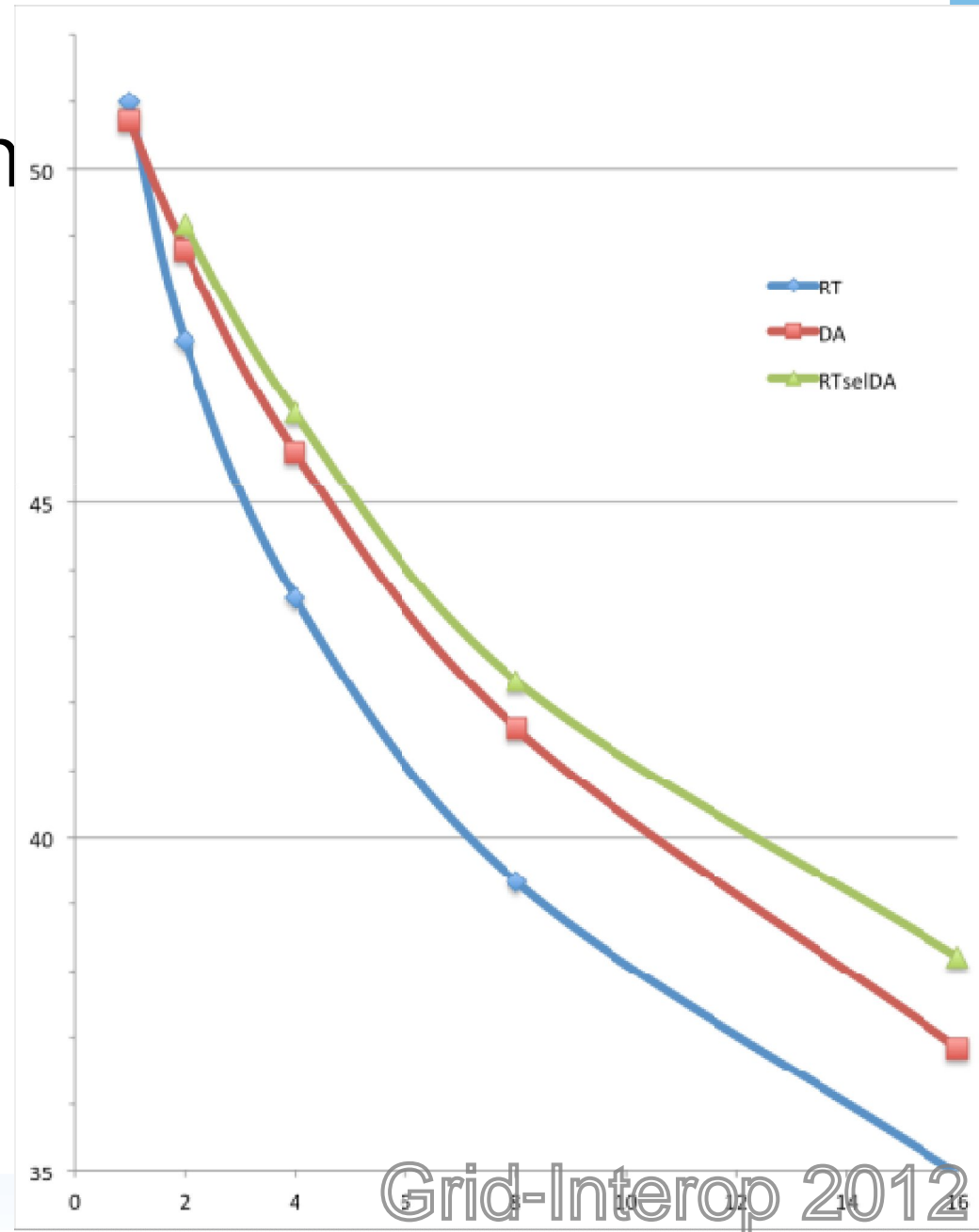
- To evaluate economic value of day-ahead
- **CONDITION:** Day-Ahead and Real-Time prices must be correlated with shortage and surplus
  - NOT true in e.g. California
  - Future work to extend analysis to other markets than ISO-NE



# Day-Ahead, Pay Real-Time (2)

- Mean for RT h=4 is only slightly higher than for DA/RTseIDA h=8
- Means that using DA can do as well as RT with roughly double the horizon

Note: Higher order Statistics computed and compared in full paper



# Conclusions

- Can use existing Day-Ahead wholesale markets (in many circumstances) today to provide value of proposed new “indicative” markets
- Transactable forward prices increase certainty
  - ERCOT considering an “Hour Ahead Market” (HAM) which will be installed between the DAM and the RTM
- Can use this model and extend to real devices/nodes/VENs