# Look-ahead Dispatch in ERCOT: Case Study

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Join work with Y. Gu (Texas A&M), D. Obadina (ERCOT), and X. Luo (Formerly at ERCOT)

# Outline

- Motivation
- Look-ahead Dispatch Overview
- ERCOT Overview
- Preliminary Case Study Results Based on Benchmark ERCOT System
- Discussion

# The Operational Challenge of Integrating Variable Generation

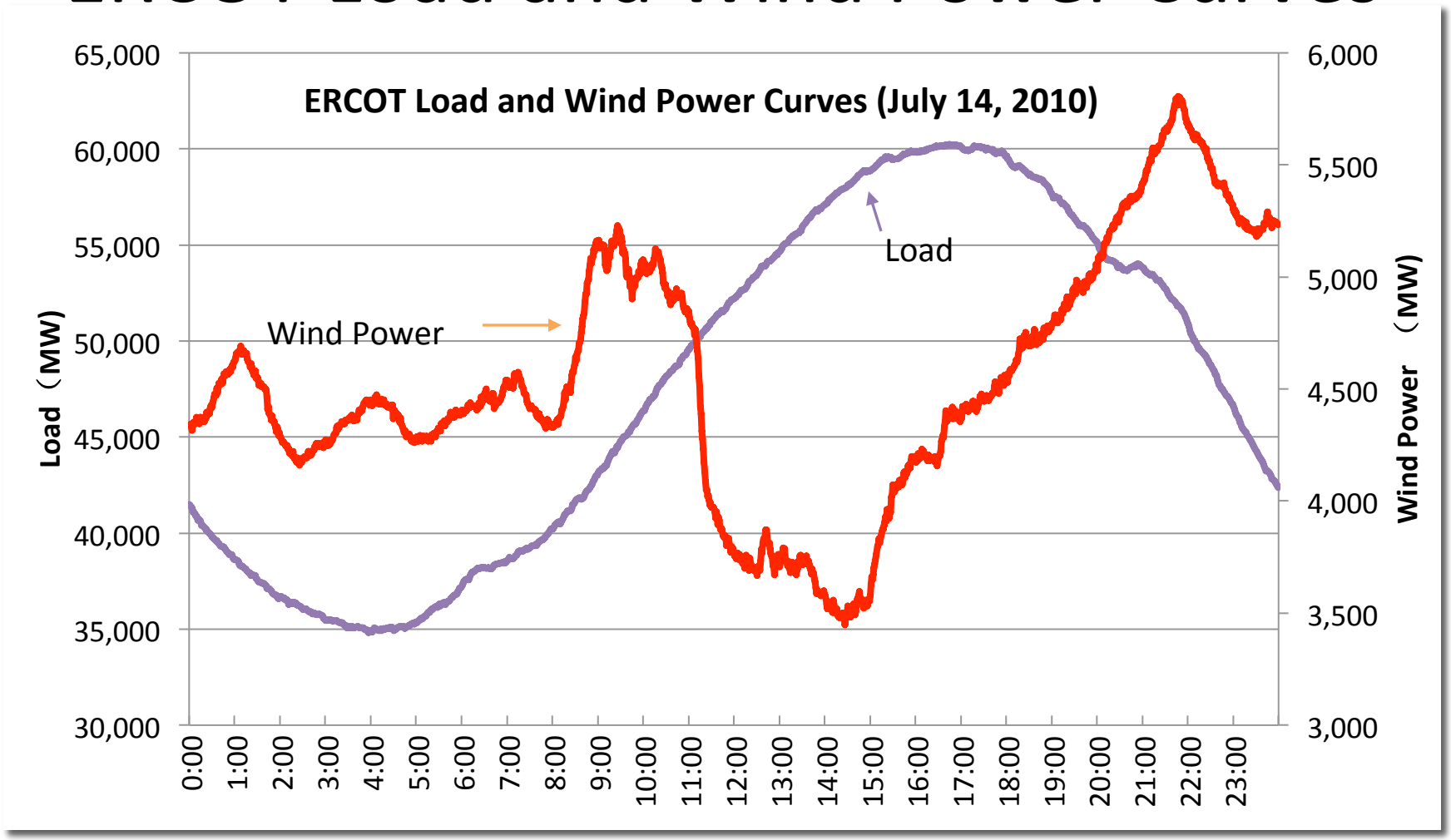
## ERCOT's Doggett: Ramping of wind resources 'keeps me awake at night'

By Kelly Harrington
SNL Interactive
10/04/10

Ask Electric Reliability Council of Texas Inc. President and CEO H.B. "Trip" Doggett to name an area of concern, and he will say it is variable wind resources.

"That is one thing that keeps me awake at night," he said in a keynote address Sept. 29 at the Gulf Coast Power Association's fall conference in Austin, Texas. "Steep ramps from wind resources is one thing that concerns both Dan [Woodfin, ERCOT's director of system planning] and I. I think we have to keep our eye on that."

# ERCOT Load and Wind Power Curves



# With High Wind Penetration [1]

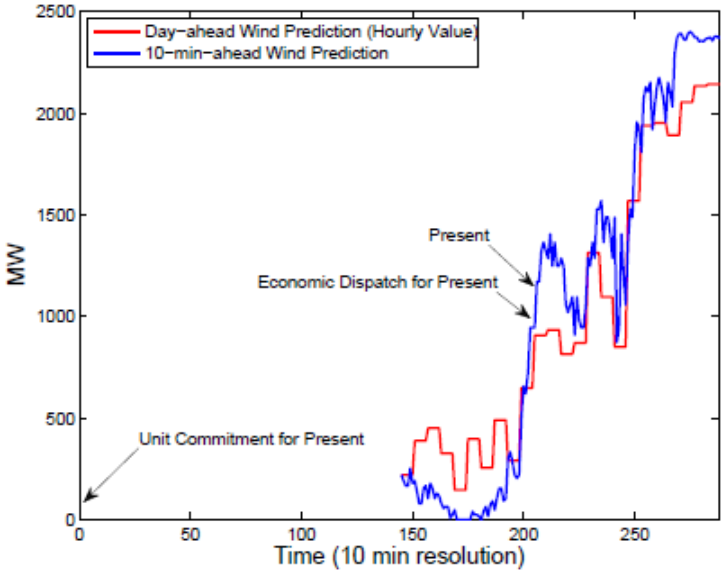



Fig. 4. Day-ahead and 10-min ahead wind prediction, timing of UC and ED functions

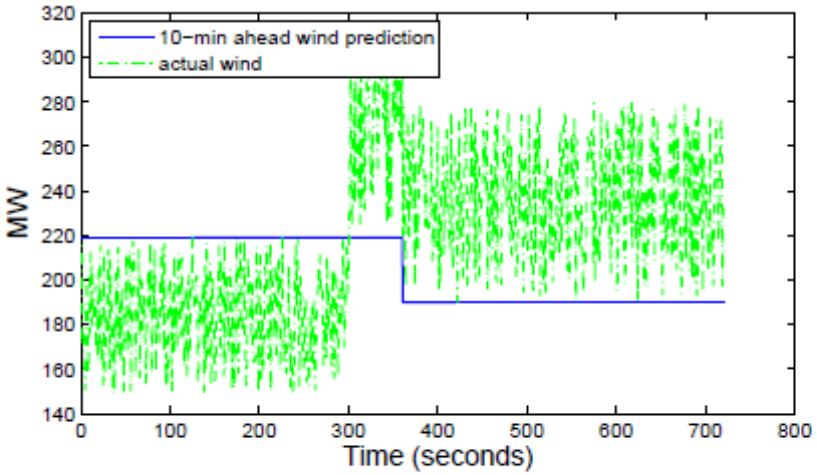



Fig. 5. 10-min ahead wind prediction and second-by-second actual wind

$$P_{Gw}(t) = \hat{P}_{Gw}[H] + \Delta_{Gw_H}(t)$$ (Day-ahead forecast)

$$P_{Gw}(t) = \hat{P}_{Gw}[k] + \Delta_{Gw_k}(t)$$ (10-minute ahead forecast)

$$\|\Delta_{Gw_H}(t)| \gg \|\Delta_{Gw_k}(t)\|$$

$$\|\hat{P}_{Gw}[k]\| \gg \|\Delta_{Gw_k}(t)\|.$$

(*Substantial accuracy improvement* from Day-ahead to near real time)

# Key Problems with Conventional SCED

- Significant need for fast and expensive units (e.g. natural gas)
- Under utilization of slow responding units
- Pollution caused by volatile ramping of fast units
- Consequently, higher O&M cost and avoidable pollution
- No incentives to reduce ramping rate-related costs (socialized UC cost)

# Recent Literature Review

- Wind forecasting techniques constantly improving [Botterud, Wang, Miranda, Bessa 2010] [Xie, Gu, Zhu, Genton, 2011]
- Value of real-time pricing on cost and value of wind power based on *assumed* demand elasticity [Sioshansi, 2010]
- Value of coordinating wind with deferrable loads [Papavasiliou, Oren, 2010]
- Industry transition from static real-time dispatch to look-ahead dynamic dispatch [Ott, 2010]
- Preliminary study of look-ahead dispatch with price responsive demands [Ilic, Xie, Joo, 2011]

Our presentation will be using *real-world data* based on a *look-ahead dispatch model*

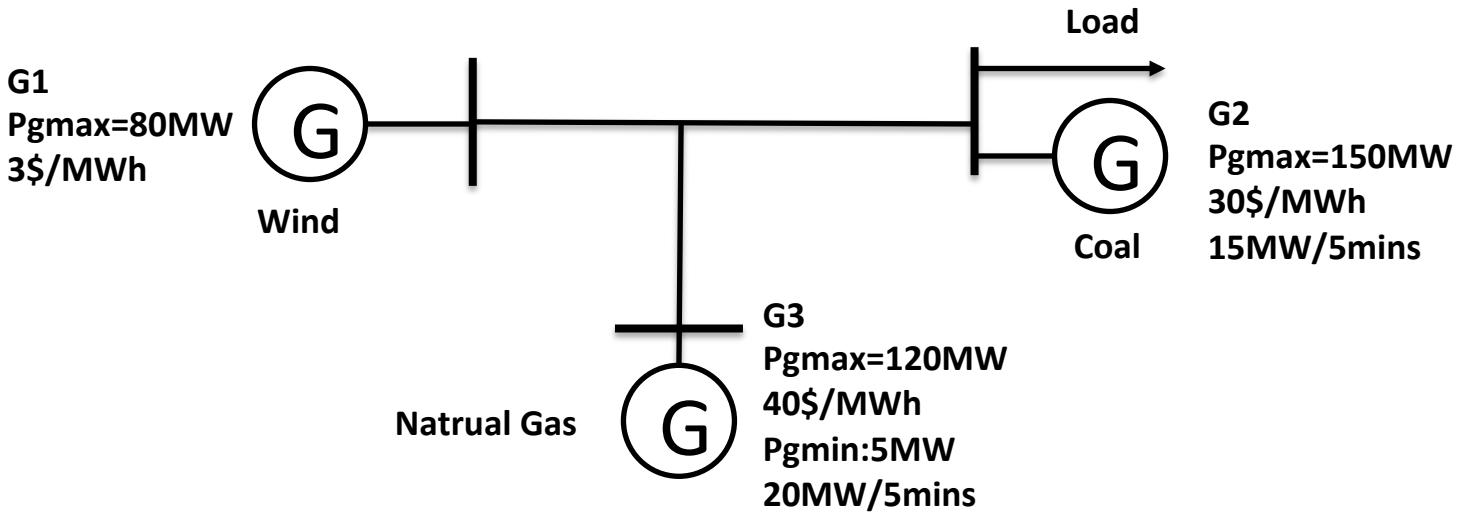
# What We Propose

## Quantifying System Benefits Using *Real-world Data*

Generation
(look-ahead
dynamic dispatch)

C&I price
responsive demand
(from ERCOT)

# Benefits of Look-ahead Dispatch: A Conceptual Example




**Conventional SCED**

| | 0:00 | 0:05 |
|---|---|---|
| Ava. Wind | 65MW | 80MW |
| G1 | 65MW | 60MW |
| G2 | 40MW | 25MW |
| G3 | 5MW | 5MW |
| Load | 110MW | 90MW |

**Total Cost 227.08$**

**Look-ahead Dispatch**

| | 0:00 | 0:05 |
|---|---|---|
| Ava. Wind | 65MW | 80MW |
| G1 | 65MW | **80MW** |
| G2 | 20MW | 5MW |
| G3 | 25MW | 5MW |
| Load | 110MW | 90MW |

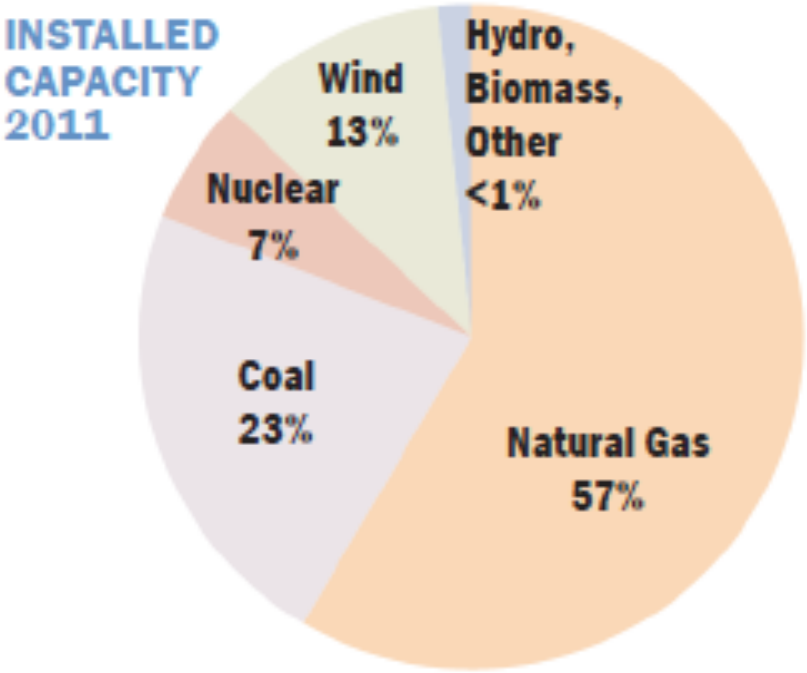
**Total Cost 198.75$**

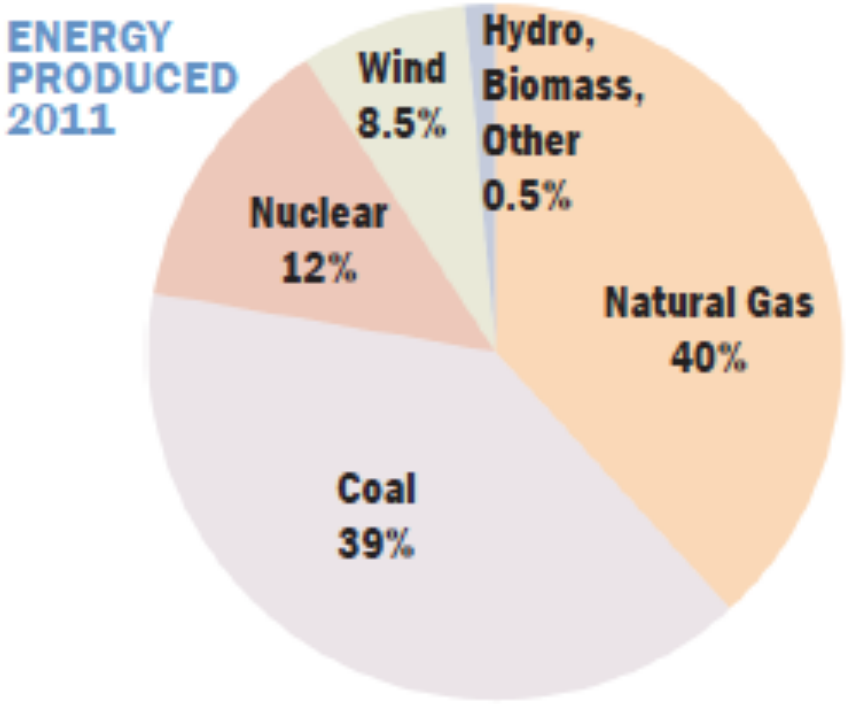
# ERCOT Interconnection

- Single Interconnection, with no synchronous ties to any other region in North America
- 71,800 MW of Generation and 65,776 MW Peak Load System (85% of Texas's electric load)
- Responsible for all transmission equipment operating at 60 kV and above (69, 138, 345 kV)
- Five asynchronous Ties to external regions
  - 1 in North Texas (600 MW), 1 in East Texas (220 MW), 3 to Mexico (. )
- Facilitates competitive markets to help achieve reliability
- Operates as Nodal Market as of 1st Dec, 2010

# ERCOT Quick Facts

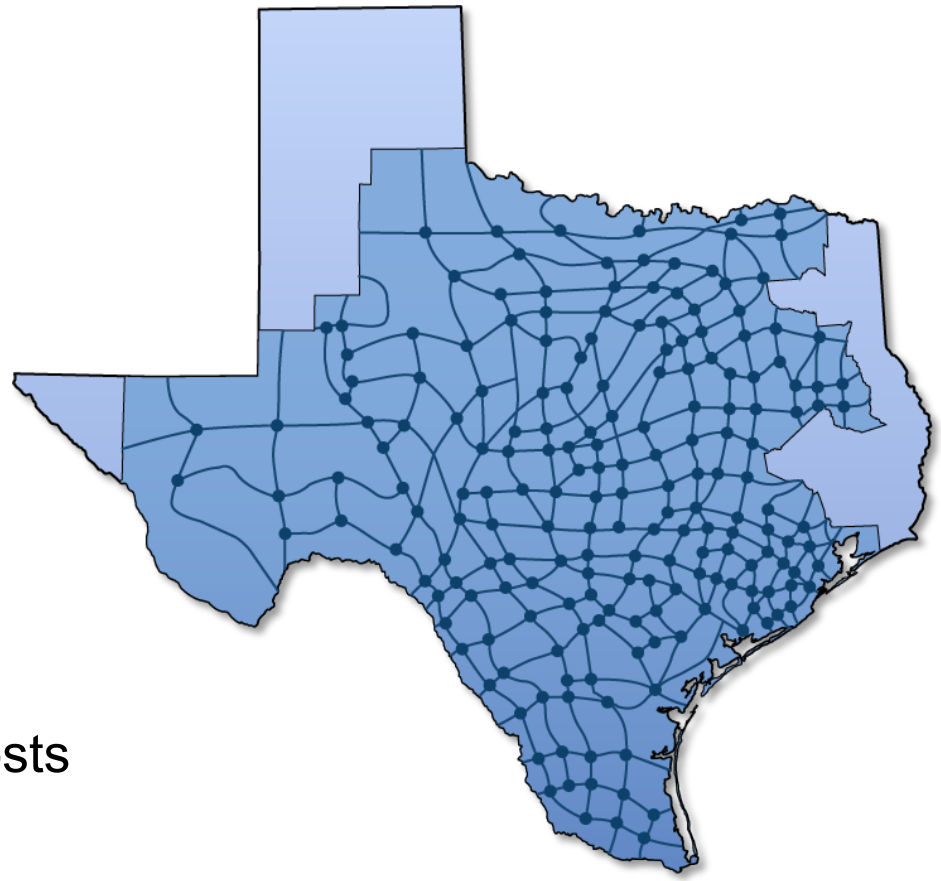
- ❑85% of Texas load
- ❑550 generating units, 3800 stations
- ❑Peak demand: 68379 MW (08/03/2011)
- ❑Wind capacity: ~10,000 MW
- ❑Wind generation record: ***7599 MW*** (03-07-2012), ~22% of load at that time



# ERCOT Nodal Market Design

- **Energy Dispatch**
  - Resource specific offers
  - Resource specific dispatch
- **Goal**
  - Balance generation & demand
  - Manage all Congestion
- **Energy Pricing**
  - Local prices for energy
  - Prices reflect all congestion costs



# ERCOT Nodal System Overview

## CRR Auction

- Annual & Monthly Auctions
- CRR Offers and Bids
- PTP Options and Obligations
- Flowgate Rights

## Reliability Unit Commitment

- Transmission Security Analysis
- Resource commitment
- Day-Ahead RUC
- Hourly RUC

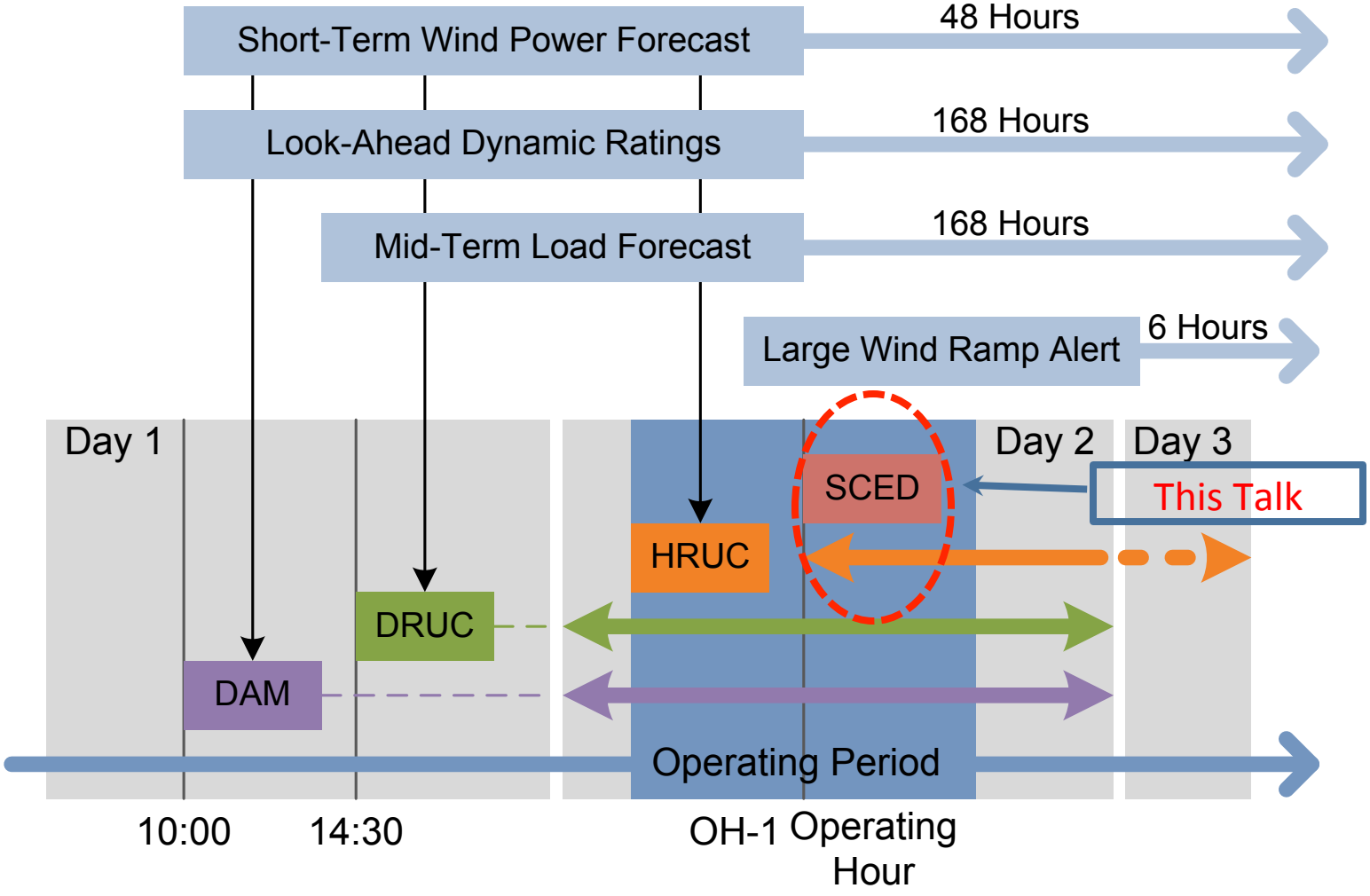
## Day-Ahead Market

- Hourly Market
- Energy Offers and Bids
- Ancillary Service Offers
- DAM PTP Obligation Bids

## Real-Time Operations

- Network Security Analysis
- Security Constrained Economic Dispatch (SCED)
- 5 Minutes Dispatch
- Load Frequency Control (LFC)

# Components of ERCOT Nodal Market



# Benchmark of ERCOT

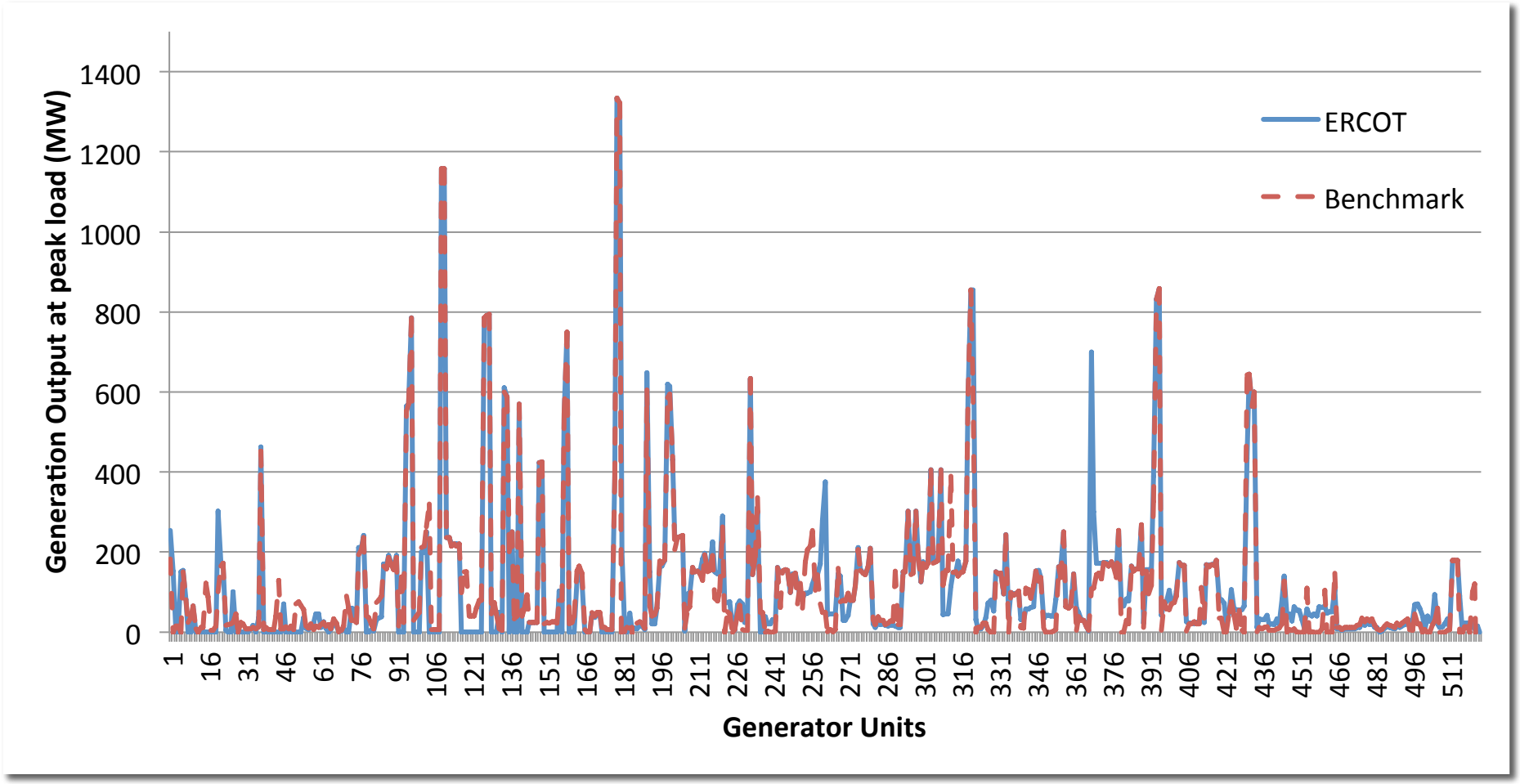



**Figure 1: Generation Output During Peak Load Time**

# Look-ahead v.s. Benchmark SCED

**Table 1: Comparison of Two Dispatch Methods for a Typical Day (Jul 11, 2009)**

| | Benchmark SCED | Look-ahead (30 min) | Difference |
|---|---|---|---|
| Entire Day | $ 26,191,710 | $ 26,144,585 | $ 47,125 |
| Early Morning | $ 3,514,925 | $ 3,506,689 | $ 8,326 |
| Peak Wind Period | $ 1,226,447 | $ 1,219,948 | $ 6,499 |
| Wind Generation (MWh) | 96071 MWh | 96432 MWh | 361 MWh |

Early Morning: midnight-8am, July 11, 2009
Peak Wind Period: 3am-5am, July 11, 2009

# Look-ahead v.s. Benchmark SCED Different Look-ahead Horizon

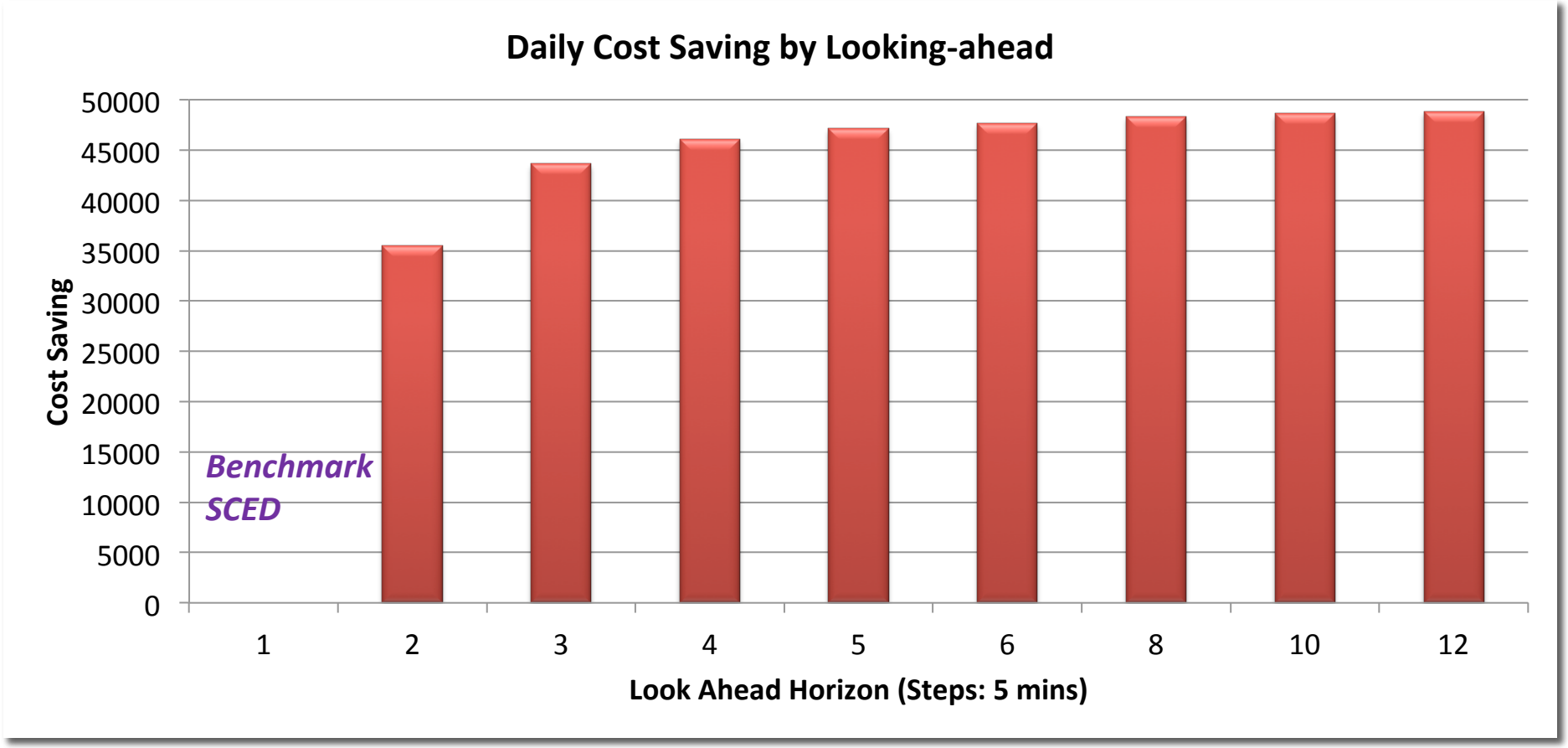



**Figure 2: Look-ahead Horizon Response of Total Savings**

# Look-ahead v.s. Benchmark SCED Computational Time

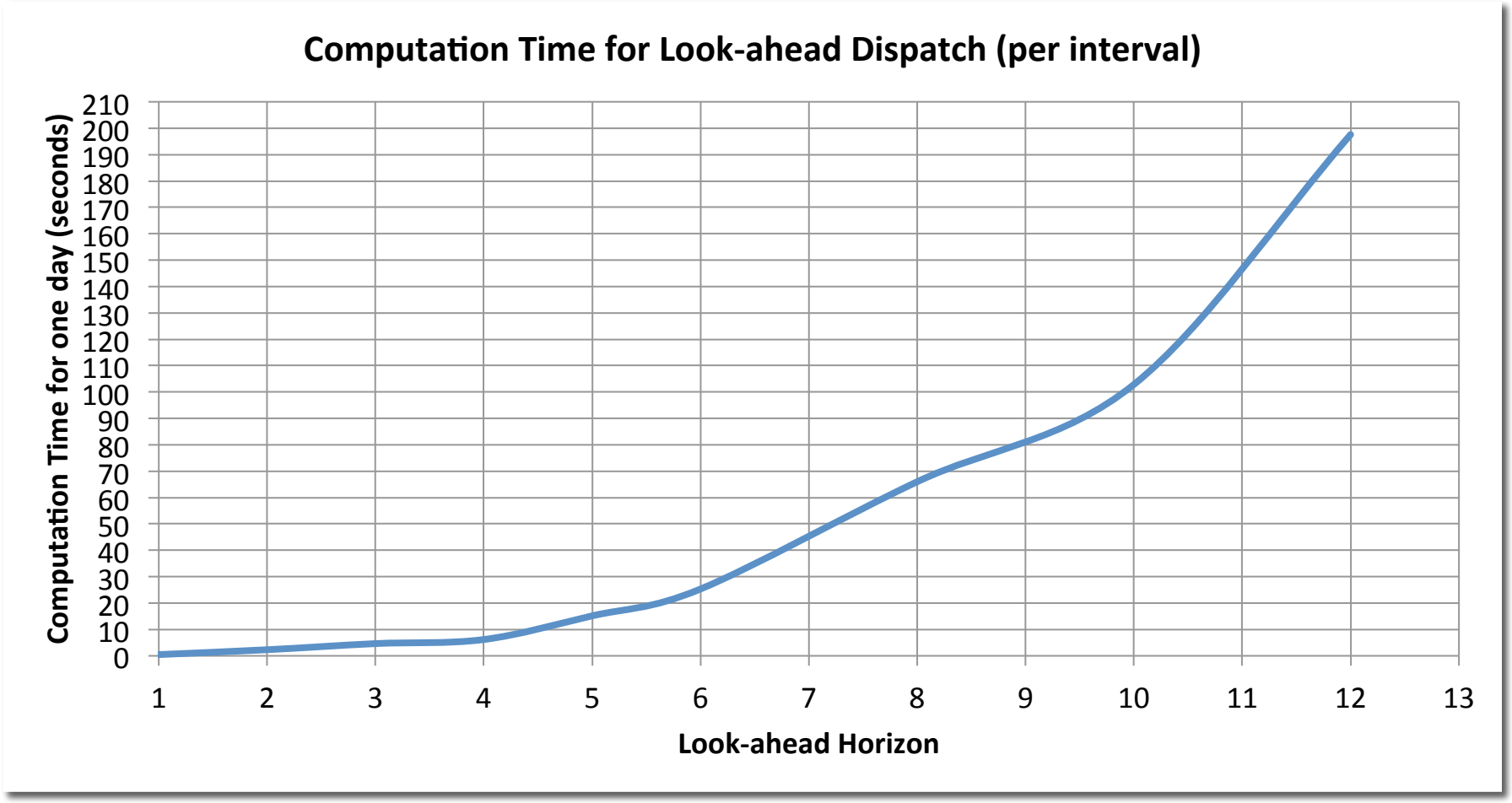



**Figure 3: Computation time over different horizons**

# Look-ahead v.s. Static System Generation Cost at Each Step

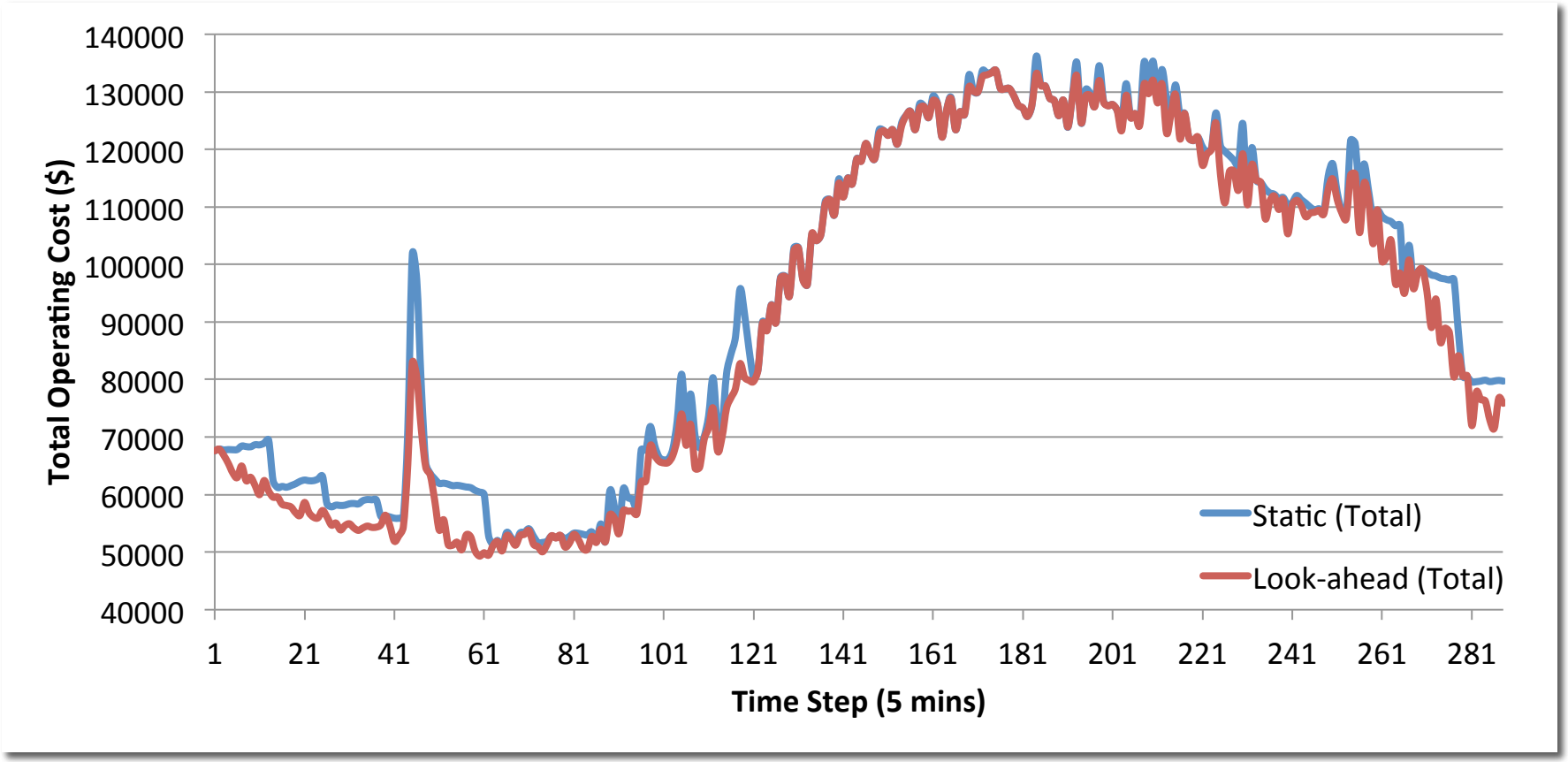



**Figure 4.a: Overall System Operating Cost Profile**

# Look-ahead versus Static System Generation Cost: Zoomed In

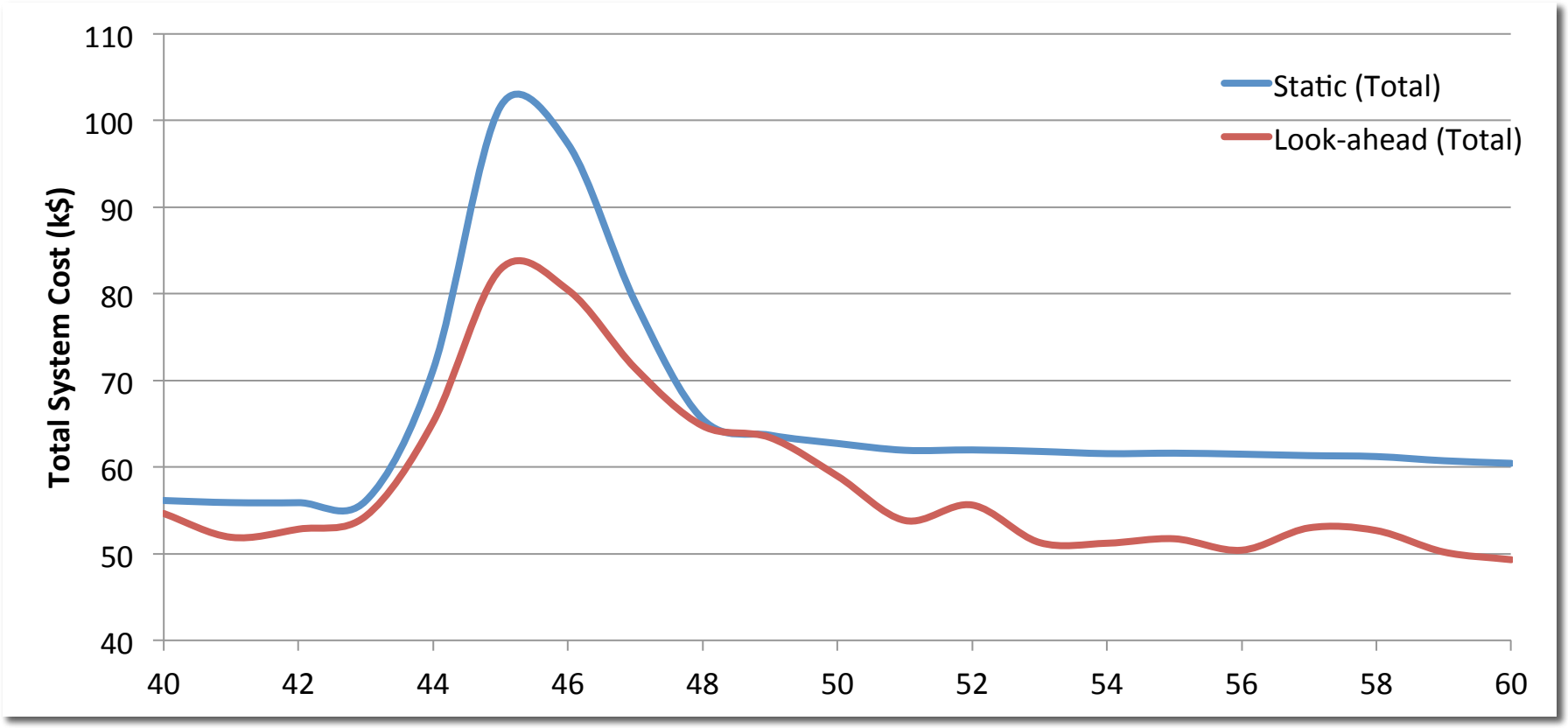



**Figure 4.b: Overall System Operating Cost Profile (Zoomed in)**

# Look-ahead v.s. Static
# Natural Gas Output in a Typical Day

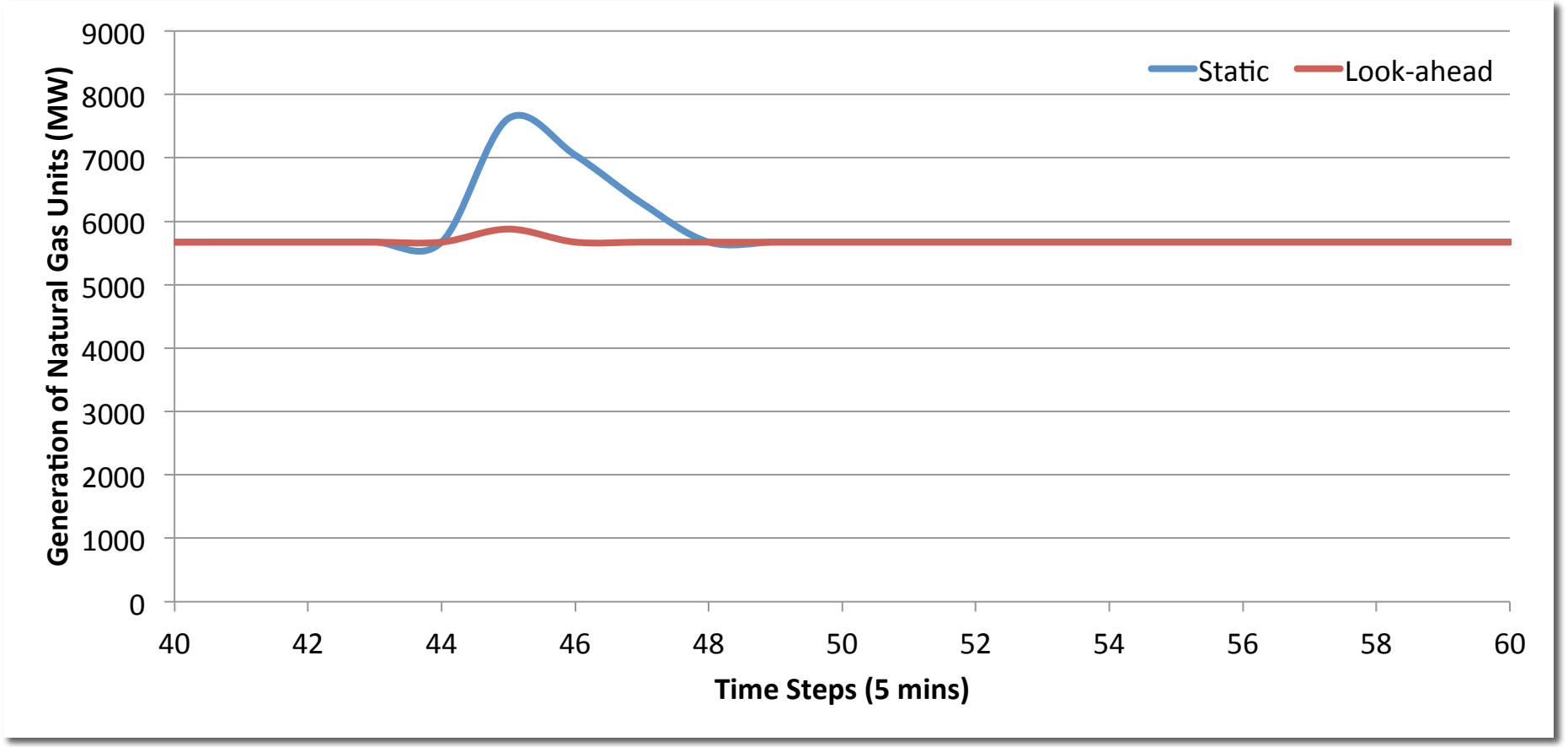



**Figure 5: Generation of Natural Gas Units (Zoomed in)**

# Look-ahead v.s. Static Coal Generation in a Typical Day

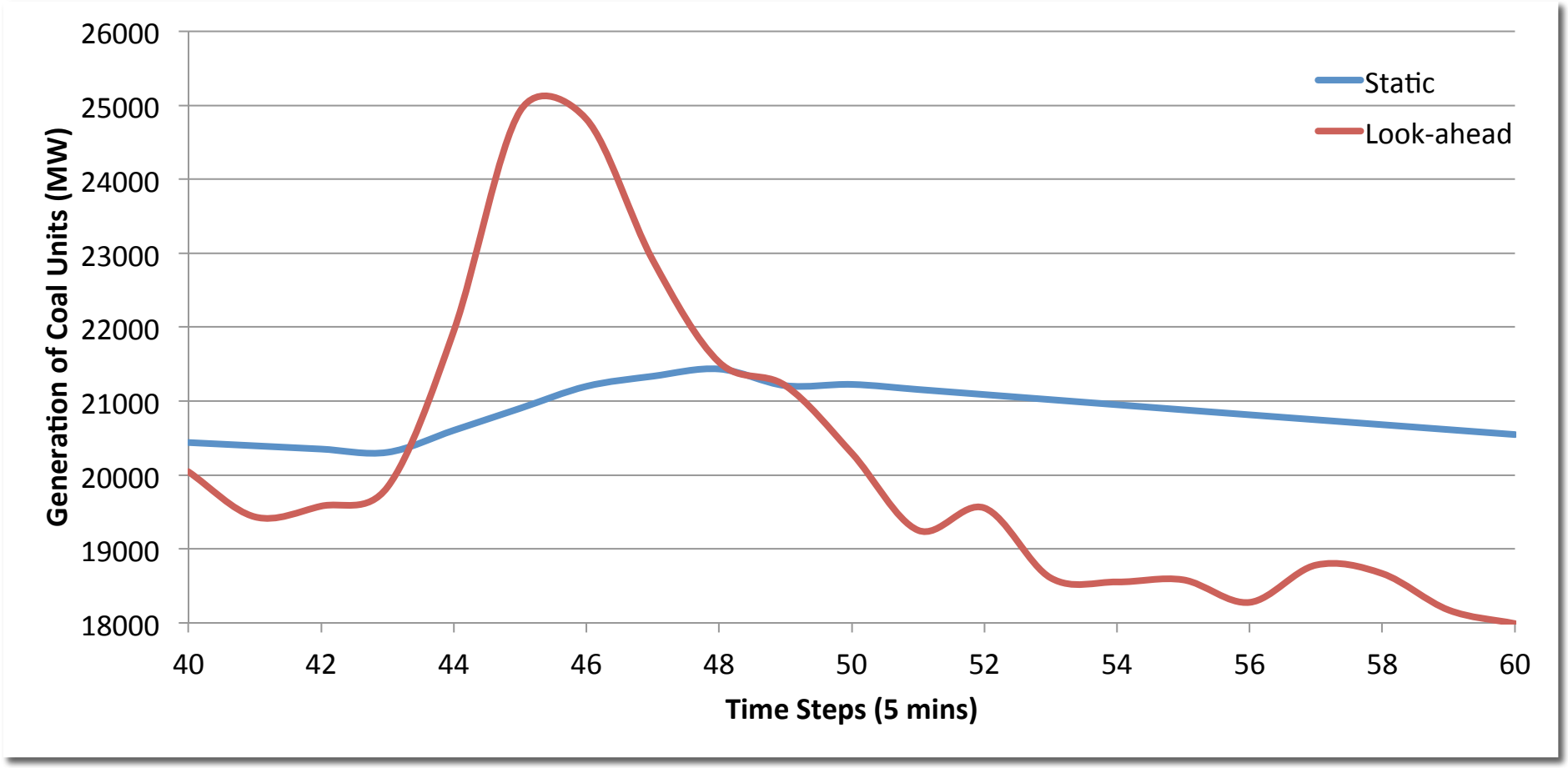



**Figure 6: Generation of Coal Units (Zoomed in)**

# Look-ahead v.s. Static Wind Generation in a Typical Day

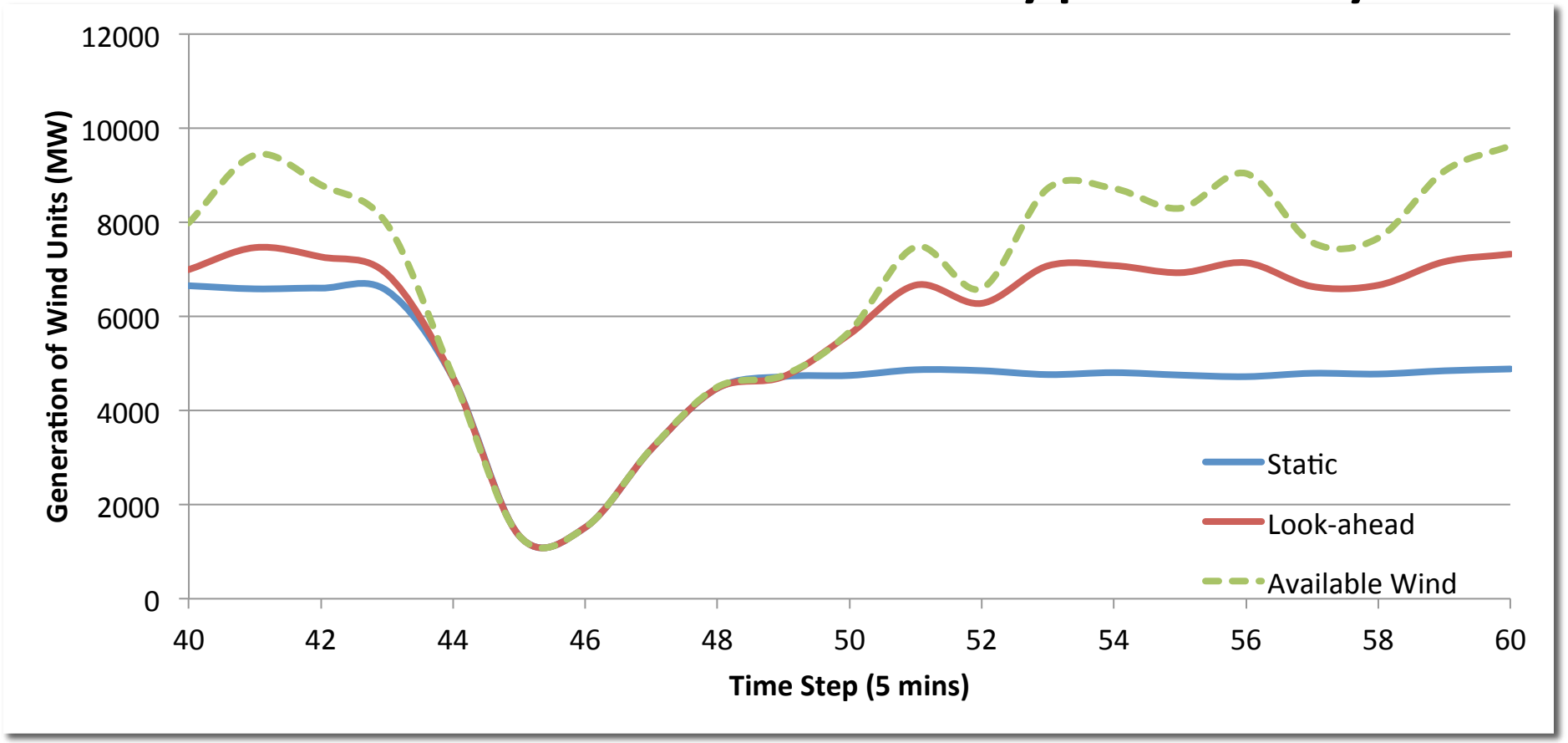



**Figure 7: Generation of Wind Units (Zoomed in)**

# Nodal Price: Look-ahead v.s. Static Economic Dispatch

Four typical buses are selected for detailed nodal price study.

| Bus Number (ERCOT) | Bus Name | Base kV | Area Number/ Name | Zone Number/ Name |
|---|---|---|---|---|
| 1626 | LEON5_9 | 69 | 2 NORTH | 5 NORTH_CE |
| 5396 | CALAVER_ | 22 | 4 SOUTH | 6 SOUTH_CE |
| 6272 | ABOV2A | 69 | 1 WEST | 8 WEST |
| 8104 | LANCTYPM | 138 | 3 HOUSTON | 1 COAST |

# Nodal Price: Look-ahead v.s. Static Economic Dispatch

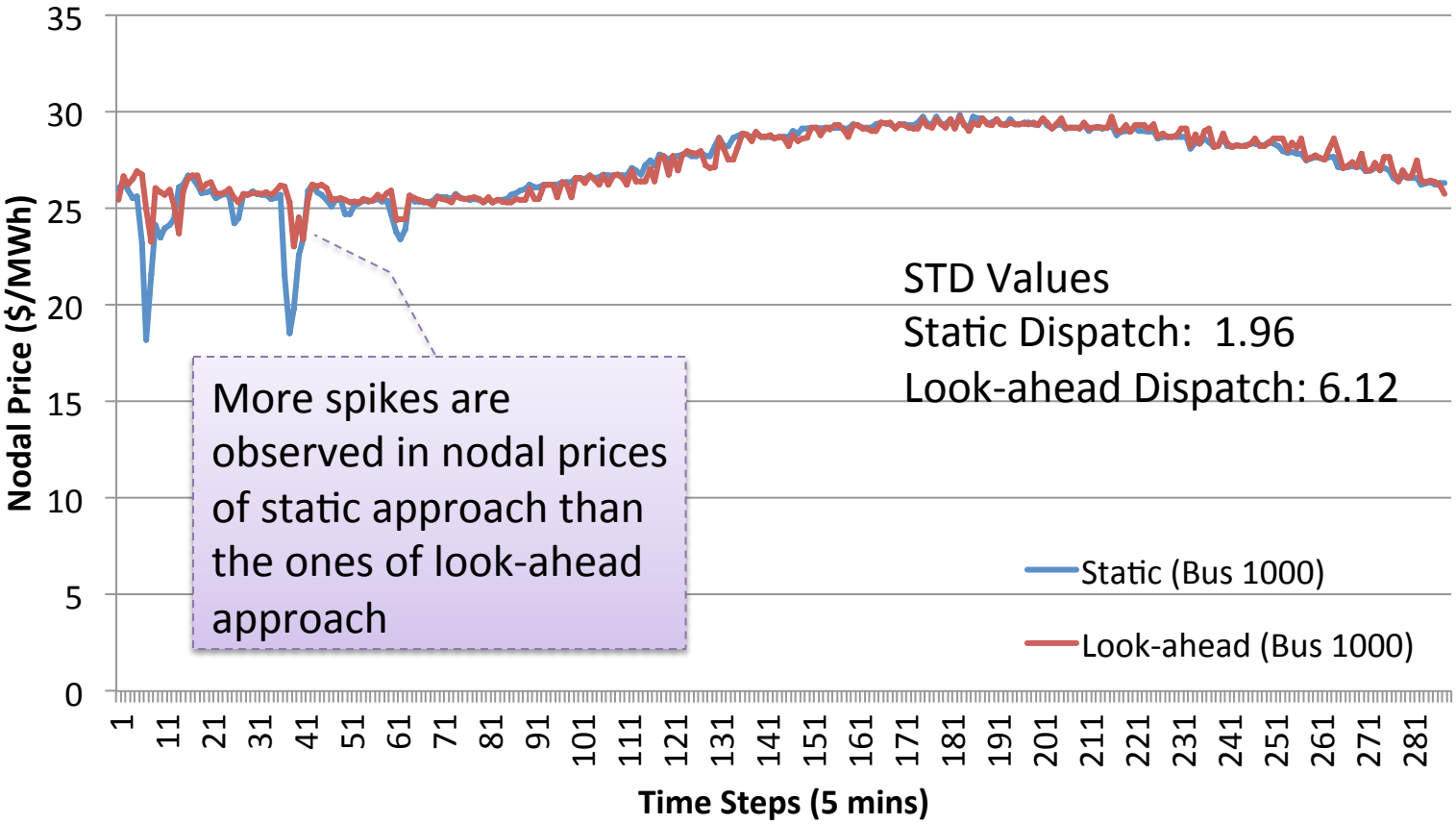



**Figure 8: Nodal Prices at Bus 1626 on July.16th**

# Nodal Price: Look-ahead v.s. Static Economic Dispatch

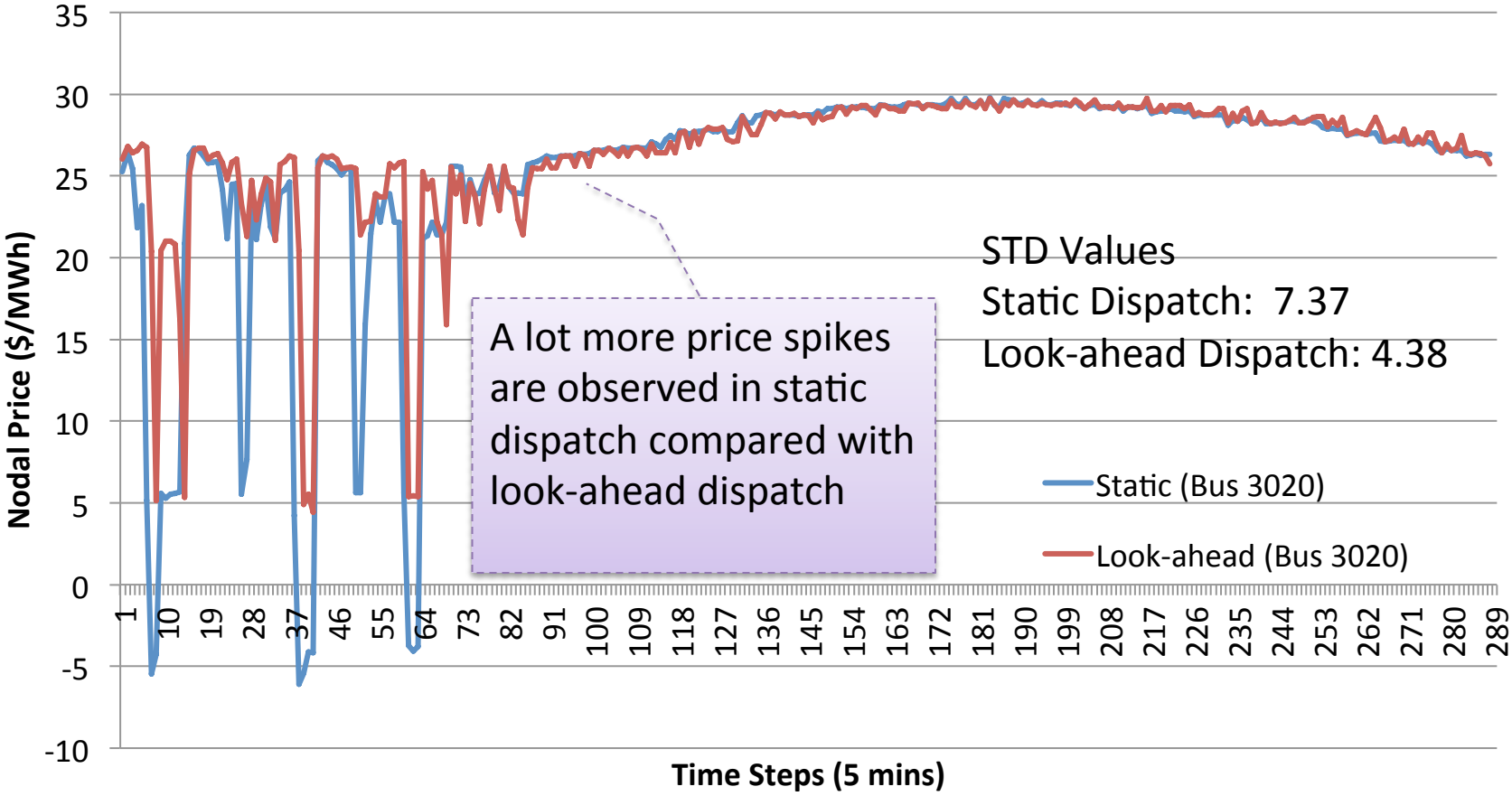



**Figure 10: Nodal Prices at Bus 6272 on July.16th**

# Nodal Price: Look-ahead v.s. Static Economic Dispatch

## *Preliminary finding:*

- Look-ahead dispatch leads to a *more smoothed* nodal price pattern
- The nodal prices at selected buses may be *higher* under look-ahead dispatch than in static dispatch

# Summary

- Preliminary study shows the potential benefits of look-ahead dispatch in
  - Reducing the need for fast responsive units during wind ramping
  - Reducing the overall generation cost
- Observations for discussion
  - Look-ahead horizon: tradeoff b/w computational cost and improved economics efficiency
  - Impact on market price: does look-ahead lead to more smoothed nodal price [7]? What should be a good price incentive for inter-temporal variations? More work needs to be done!

# Ongoing Work

- Empirical study of look-ahead dispatch with *price-responsive* demands at ERCOT [6]
- *Spatio-temporal* wind forecast for look-ahead dispatch with forecast uncertainty and infeasibility handling [7][8]
- Coordination of wind and storage (explicit and implicit) for *joint provision of energy balancing and frequency regulation* services [9][10][11]
- Multi-scale integration of *physics-based* and *data-driven* models of distributed resources for ubiquitous energy storage services [12]

# Acknowledgement


- Data


- Financial Support


# References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# Thank You

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