Electric Load Forecasting with Holiday Effect

Tao Hong, PhD
SAS Institute

Tao Hong

- Research
- Consulting
- Teaching

Outline

- Introduction
- Background
- Holiday effect
- Case studies
- Beyond this talk

Outline

- **Introduction**
  - Electric Load Forecasting
  - Holiday
  - Motivation
  - Challenges
- Background
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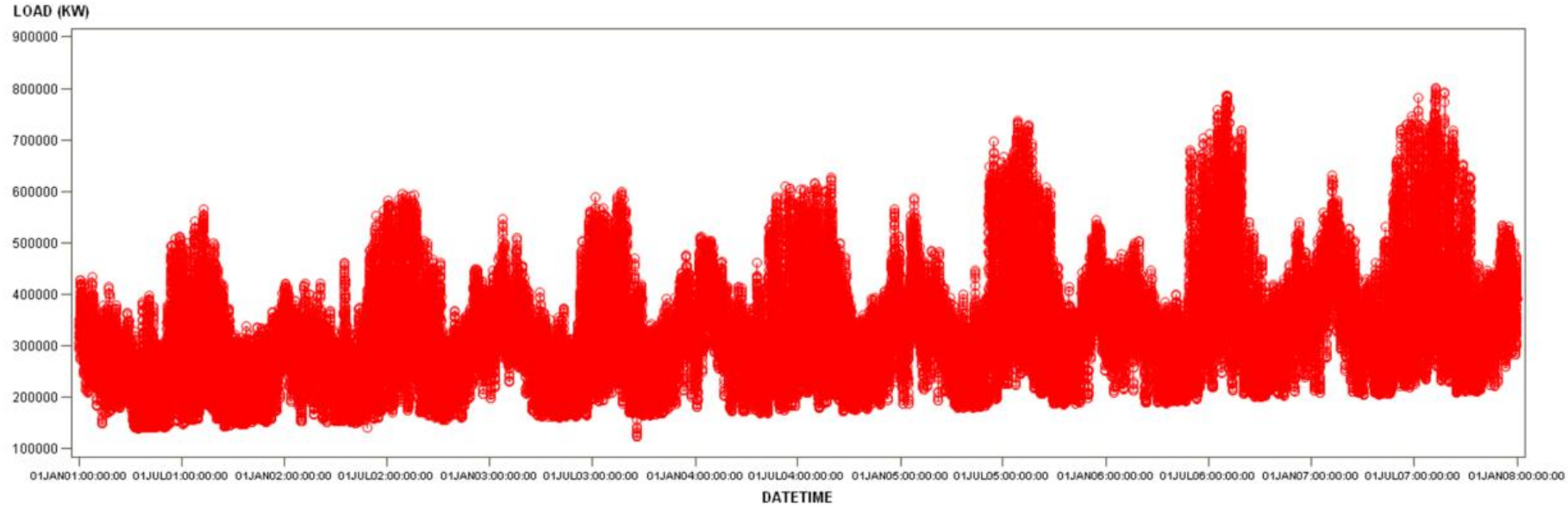
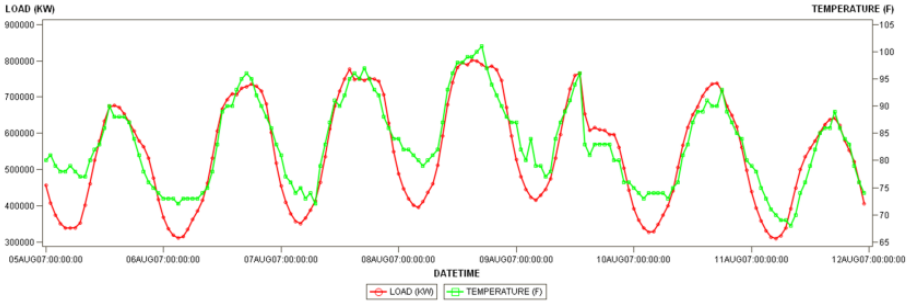
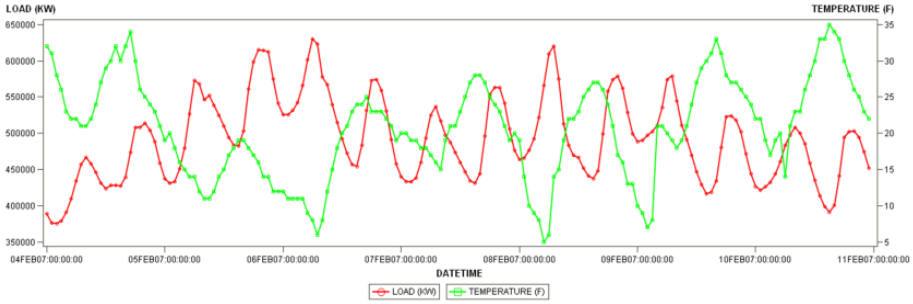
- Case studies
- Beyond this talk

Electric Load Forecasting







Tao Hong, "*Statistical Models for Electric Load Forecasting*", workshop at the Institute for Advanced Analytics, NCSU, 2011. (Available online: http://sites.google.com/site/hongtao01/courses/smelf)

Electric Load Forecasting

Load Forecasting ≠

- Airline passenger
- Beer consumption
- Water/gas
- Hotel customer
- Retail
- Stock
- ……

Forecasting

Tao Hong, "*100 Years of Load Forecasting: Classics, Challenges and Best Practices with Smart Grid Information*", workshop at CenterPoint Energy, Houston, TX, Mar 6, 2012

Holiday

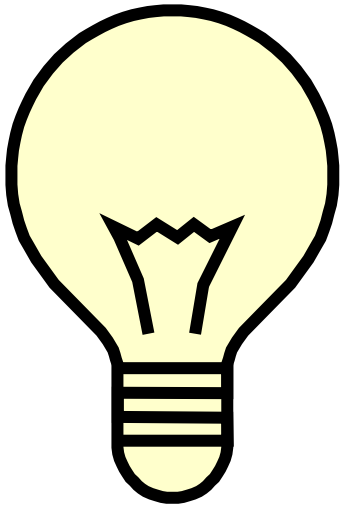
- US Public Holidays Established by Federal Law

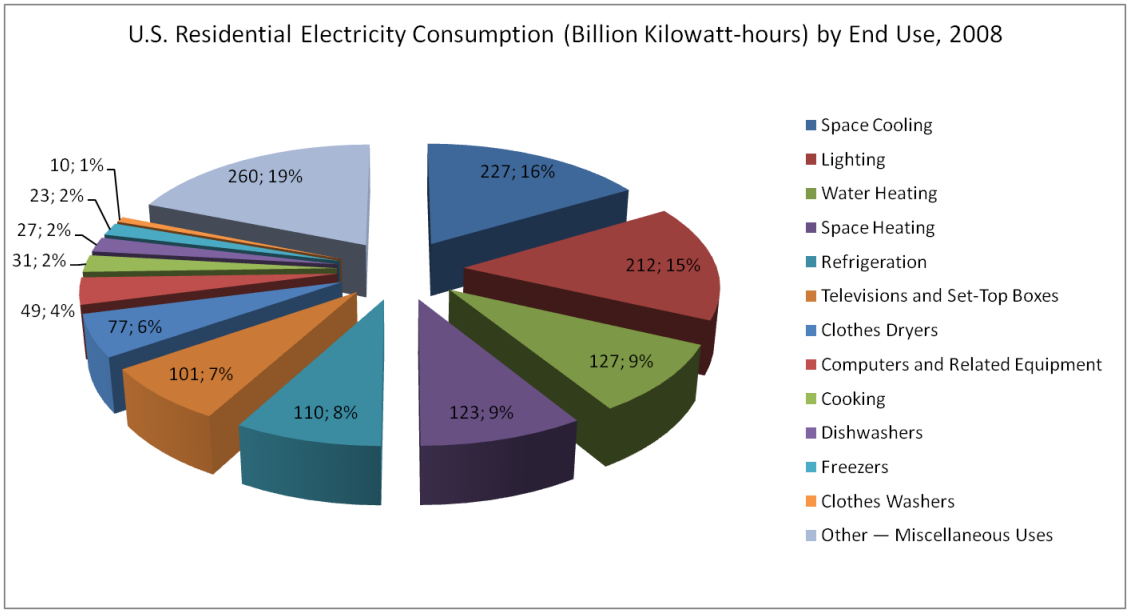
	Date	Official Name
1	Jan 1	New Year's Day
2	3rd Mon in Jan	Birthday of Martin Luther King Jr.
3	3rd Mon in Feb	Washington's Birthday
4	Last Mon in May	Memorial Day
5	July 4	Independence Day
6	1st Mon in Sep	Labor Day
7	2nd Mon in Oct	Columbus Day
8	Nov 11	Veterans Day
9	4th Thu in Nov	Thanksgiving Day
10	Dec 25	Christmas Day

Motivation

- Better load forecasting
  - Energy trading
  - Operations
  - Planning
    - » Weather normalization
- Better understanding of customer behavior
  - Demand side management

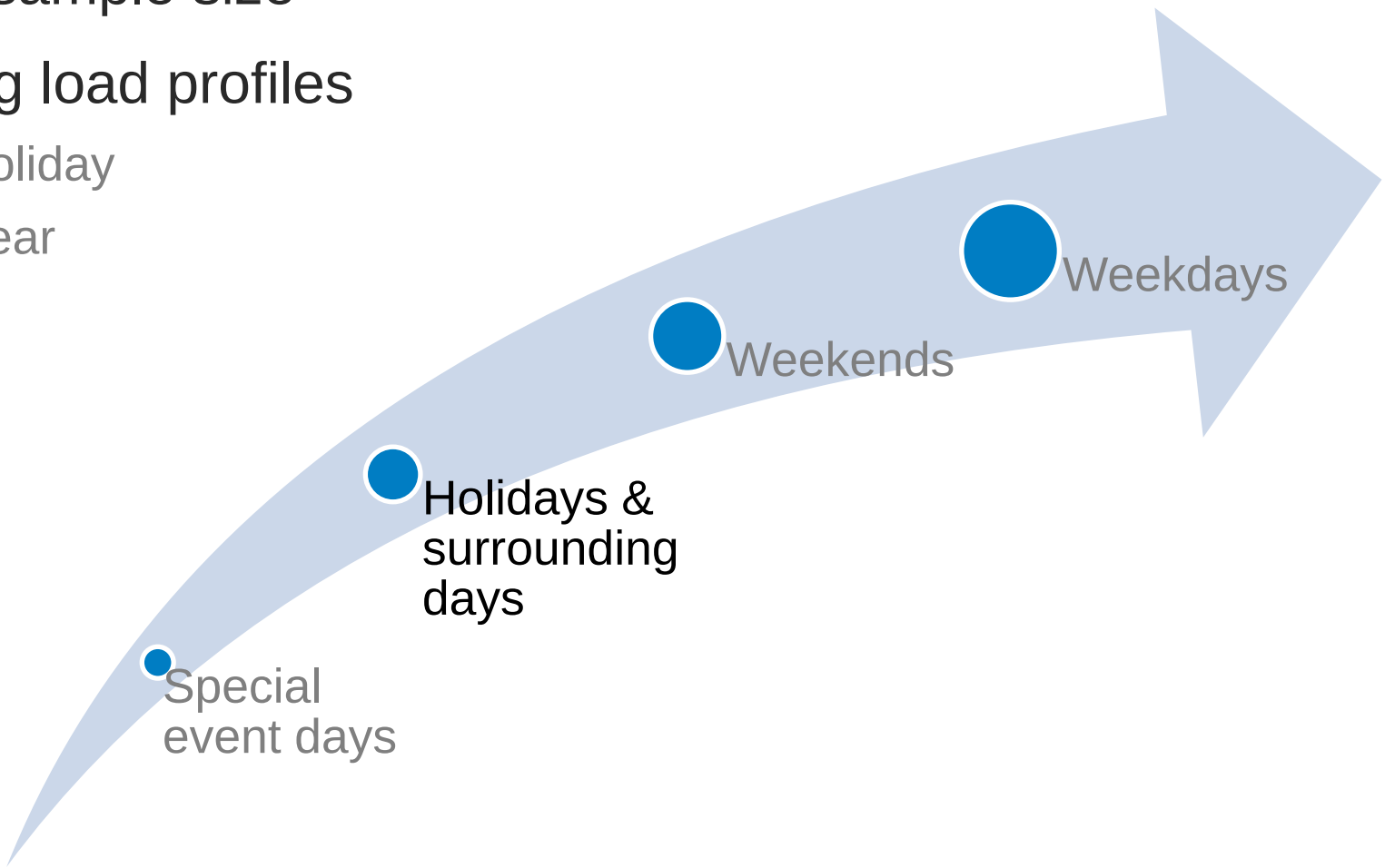
Challenges





Challenges

- Small sample size
- Varying load profiles
  - By holiday
  - By year



Outline

- Introduction
- **Background**
  - Classification
  - General linear models
  - Naïve MLR benchmark
  - Recency effect
- Holiday effect
- Case studies
- Beyond this talk

Classification

Tao Hong, "*100 Years of Load Forecasting: Classics, Challenges and Best Practices with Smart Grid Information*", workshop at CenterPoint Energy, Houston, TX, Mar 6, 2012

Classification – STLF

STLF

- Similar day method
- Statistics
  - Regression analysis
  - Time series analysis
  - Exponential Smoothing
- Artificial Intelligence (AI)
  - Fuzzy Logic
  - Artificial Neural Networks (ANN)
  - Support Vector Machine (SVM)
- Two-stage method

Tao Hong, "*100 Years of Load Forecasting: Classics, Challenges and Best Practices with Smart Grid Information*", workshop at CenterPoint Energy, Houston, TX, Mar 6, 2012

Classification – LTLF

LTLF

- HDD, CDD
- Monthly information by class
  - Billing
  - Customer counts
- Normal weather
- Scenarios
  - Macro economy
  - Technology
  - Generation resources
  - “Global warming”, “Climate change”
  - Heat Island

Tao Hong, “*100 Years of Load Forecasting: Classics, Challenges and Best Practices with Smart Grid Information*“, workshop at CenterPoint Energy, Houston, TX, Mar 6, 2012

General Linear Models

- SAS/STAT PROC GLM
- Simple linear regression
- Multiple linear regression
- Polynomial regression
- Interaction regression
- Lagged regression
- Dynamic regression

Naïve MLR Benchmark

$$E(Load) = \beta_0 + \beta_1 * Trend + \beta_2 * Day * Hour + \beta_3 * Month$$
$$+ \beta_4 * Month * T + \beta_5 * Month * T^2 + \beta_6 * Month * T^3$$
$$+ \beta_7 * Hour * T + \beta_8 * Hour * T^2 + \beta_9 * Hour * T^3$$

Tao Hong, et. al., "*A Naive Multiple Linear Regression Benchmark for Short Term Load Forecasting*", 2011 IEEE PES General Meeting, Detroit, Jul 24-29, 2011

Recency Effect

- The most recently presented items or experiences will most likely be remembered best. If you hear a long list of words, it is more likely that you will remember the words you heard last (at the end of the list) than words that occurred in the middle
- Load = f(T, T(t-1), T(t-2), …)
  - Load refers to Load(t), T refers to T(t)
  - i.e., Load = f(trend, calendar variables, T, T(t-1))

Tao Hong, "*Short Term Electric Load Forecasting*", PhD dissertation, Operations Research and Electrical Engineering, NCSU, 2010. (Available online http://repository.lib.ncsu.edu/ir/handle/1840.16/6457)

Outline

- Introduction
- Background
- **Holiday effect**
- Case studies
- Beyond this talk

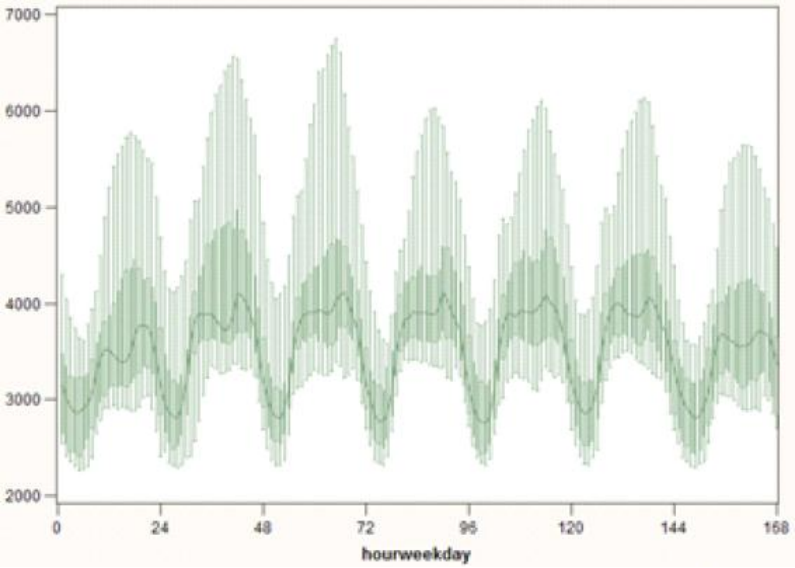
  - Methodology
  - Weekend effect
  - Significant holidays
  - Surrounding days
  - Example

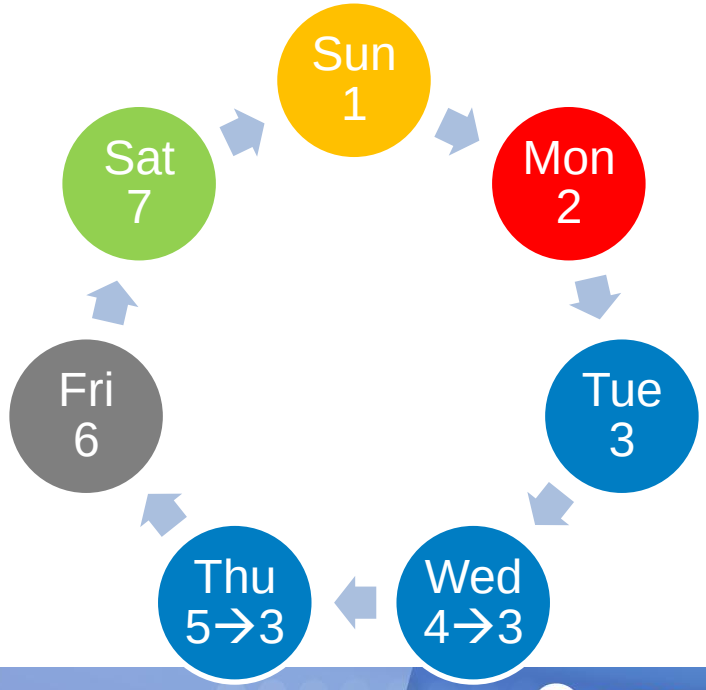
Methodology

- Principles
  - Parsimony, keep it simple, stupid (KISS)
  - Use weekends to model holidays
  - Use weekdays/weekends to model surrounding days
- Steps
  - Weekend effect
  - Identify and model significant holidays
  - Model surrounding days of significant holidays

Weekend Effect

- Group similar days of week together
  - Reduce the levels of the class variable *Weekday*
  - Maintain the same or better forecasting accuracy
  - More samples for each levels
  - Less alternatives for the weekday code of holidays





Significant Holidays

- Significant
  - When alternating the weekday code to weekend, the forecasting accuracy can be improved
- Memorial Day – last Monday in May
  - May behave more like a Sunday than Monday
  - If so, significant
- Columbus Day – 2nd Monday in October
  - A Monday holiday
  - May *not* be different than regular Monday's

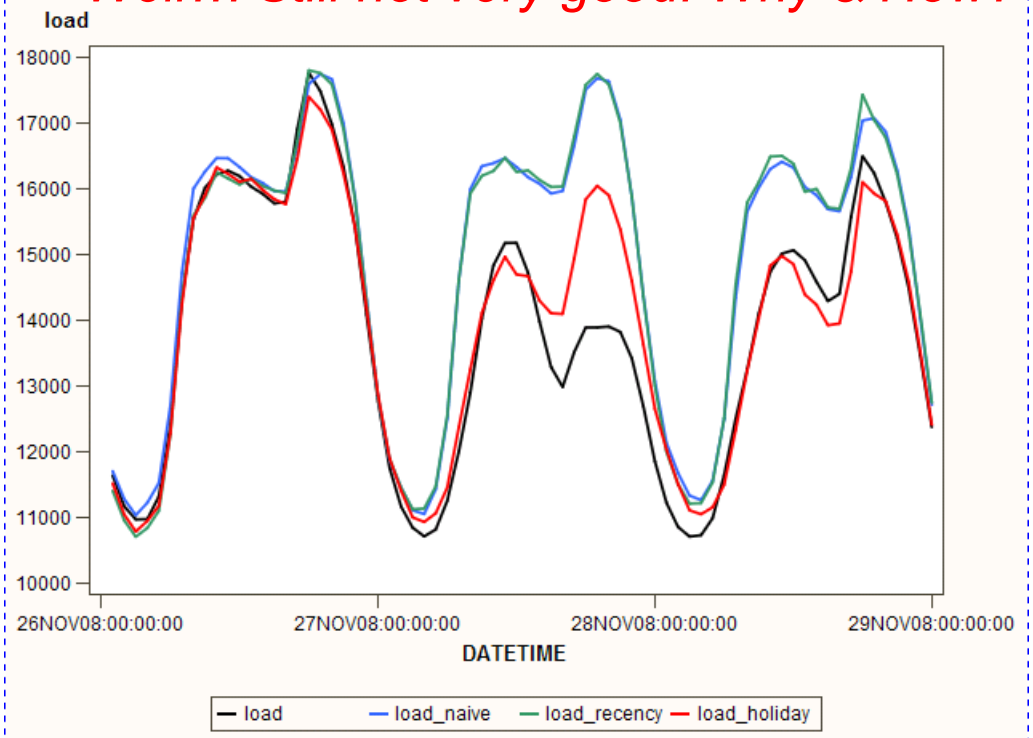
Surrounding Days

- Assumption
  - Only significant holidays impact the surrounding days
- Memorial Day – last Monday in May
  - When behave more like a Sunday than Monday
  - The day after Memorial day may behave more like a Monday than Tuesday
- Thanksgiving Day – 4th Thursday in November
  - Black Friday may behave more like a weekend day than Friday

Example
Thanksgiving Day of 2008, NEISO

- The day before
  - Wed → Fri
- Thanksgiving
  - Thu → Sat
- The day after
  - Fri → Sat

Well… Still not very good! Why & How?



DATE	MAPE_naive	MAPE_recency	MAPE_holiday
11/26/2008	1.7%	1.3%	**0.8%**
11/27/2008	14.6%	14.7%	**5.4%**
11/28/2008	7.8%	8.0%	**2.1%**

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- Holiday effect
- **Case studies**
  - Sample utilities
  - Forecasting accuracy
  - Holidays and surroundings
  - PEPCO vs. BG&E
  - Take aways
- Beyond this talk

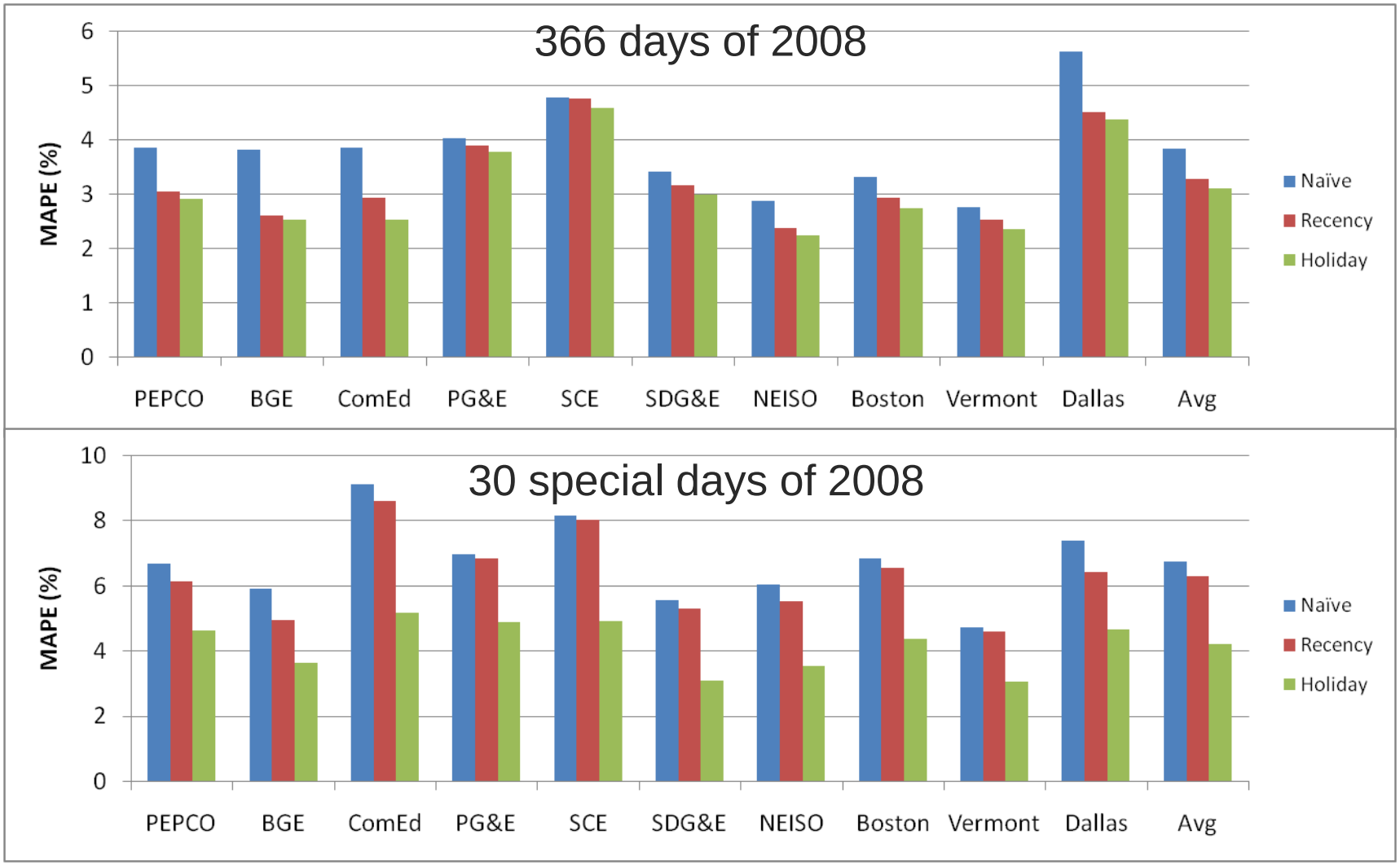
Sample Utilities

- PEPCO – KDCA
- BG&E – KBWI
- ComEd – KMDW
- PG&E – KSFO
- SCE – KLAX
- SDG&E – KSAN
- NEISO
  - Great Boston
  - Vermont
- ERCOT
  - North Central – KSFW (Dallas/Fort Worth)

Multiple weather stations should be used for each utility here!

Tao Hong, et. al., "*Cost of Temperature History Data Uncertainties in Short Term Electric Load Forecasting*", 2010 IEEE 11th International Conference on Probabilistic Methods Applied to Power Systems (PMAPS), Singapore, Jul 24-29, 2010

Forecasting Accuracy



Holidays and Surroundings

	Date	Official Name	Holiday	Before	After
1	Jan 1	New Year's Day	**10**	9	8
2	3rd Mon in Jan	Birthday of MLK Jr.	1	0	0
3	3rd Mon in Feb	Washington's Birthday	3	0	2
4	Last Mon in May	Memorial Day	**10**	0	7
5	July 4	Independence Day	**10**	8	7
6	1st Mon in Sep	Labor Day	8	0	5
7	2nd Mon in Oct	Columbus Day	0	0	0
8	Nov 11	Veterans Day	0	0	0
9	4th Thu in Nov	Thanksgiving Day	**10**	7	**10**
10	Dec 25	Christmas Day	**10**	**10**	9
Total			**62**	**34**	**48**

PEPCO vs. BGE

Official Name	PEPCO			BGE		
	Holiday	Before	After	Holiday	Before	After
New Year's Day	✓	✓	✓	✓	✓	
Birthday of MLK Jr.	✓					
Washington's Birthday	✓					
Memorial Day	✓			✓		✓
Independence Day	✓	✓		✓	✓	
Labor Day	✓			✓		✓
Columbus Day						
Veterans Day						
Thanksgiving Day	✓	✓	✓	✓		✓
Christmas Day	✓	✓	✓	✓	✓	

Take Aways

- Some holidays can be modeled as weekends
- Day code of the surroundings days of holidays can be altered
- Different utilities or zones may have different holiday effects
  - One reason for multi-region forecasting
- Results based on the 10 sample utilities/zones
  - By altering nearly half of the 30 special days
  - Forecasting accuracy of the special days can be improved by 30% to 44% comparing to Naïve MLR

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- **Beyond this talk**
  - SAS BKS course
    - *Electric Load Forecasting*
  - IEEE Working Group on Energy Forecasting

SAS BKS Course

Electric Load Forecasting: Fundamentals and Best Practices

- Introduction to Electric Load Forecasting
- Salient Features of Electric Load Series
- Mulitiple Linear Regression
- A Naive Benchmark for Short-term Load Forecasting
- Customizing the Benchmarking Model
- Very Short-Term Load Forecasting
- Medium/Long-Term Load Forecasting
- Variables, Methods, Techniques, and Further Readings
- Frequently Made Mistakes

Course information webpage: https://support.sas.com/edu/schedules.html?id=1326

IEEE WG on Energy Forecasting

- Scope of work
  - Utility application oriented energy forecasting
  - Focus on practical needs of utilities
  - Data: outlier detection, data cleansing, selection of weather station(s)
  - Inputs: temperature forecast, wind forecast, solar forecast, EV load forecast, customer behavior, demand response activities, loss evaluation
  - Modeling: hierarchical (system-substation-feeder) forecasting, multi-region forecasting
  - Applications (outputs): price forecasting, demand response analysis, planning of demand side management, risk management, weather normalization, loss evaluation

http://sites.google.com/site/hongtao01/ieee-wgef

IEEE WG on Energy Forecasting

- Activities in PESGM 2011, Detroit, MI
  - Practical aspects of electric load forecasting
- Activities in PESGM 2012, San Diego, CA
  - Demand response: analytics, practice, and challenges in smart grid environment
  - Load forecasting and its applications in operations and planning
- Ongoing projects
  - Global Energy Forecasting Competition 2012
  - Benchmarking of STLF accuracy
  - Review of literature and practice of load forecasting
  - IEEE Transactions on Smart Grid – Special Issue on Analytics for Energy Forecasting with Applications to Smart Grid

http://sites.ieee.org/pes-pspic/about-pspi/subcommittees/energy-forecasting/

Tao Hong, PhD

Tao.Hong@sas.com
SAS Institute

www.sas.com