Northwest Power and Conservation Council

February 13, 2007

MEMORANDUM

TO: Power Committee

FROM: Massoud Jourabchi

SUBJECT: Discussion of Short-term Electricity Demand Forecasting Model and Preliminary Results

At the July 2006 Power 4 meeting, chairman Karier asked that I give periodic updates on the forecasting tools which are being developed by staff. The attached paper reports on the development of a short-term demand forecasting model.

The objective in developing the short-term model was to have the ability to produce hourly and daily forecasts of regional loads three to five years into the future. The tool can be used in developing hourly forecasts for a given forecast temperature, and for resource adequacy metrics where regional load will be forecast under a wide range of temperature conditions that have been experienced by that region in the past.

Using econometric time-series analysis, we developed one daily model and twenty four hourly models for the region. Various functional forms were tested. The models were tested against actual daily and hourly loads for the period 1995 through 2002. The models produced reasonable estimates of historical loads.

The models also were used to develop preliminary weather-normalized forecasts for 2007-2010. The long-term forecast used in the Fifth Power Plan and the short-term forecast were compared for consistency, and although they are derived from different analytical approaches, the weather-normalized forecasts were found to be very close.

Using the developed models we can now estimate the change in load due to a change in temperature. We have found that the relationship between load and temperature is not static and varies by the severity and longevity of temperature deviations. Our analysis indicates that if we experience a cold front similar to what we experienced in January-February 1950, daily loads for January and February would increase by 8000-9000 MWa above normal weather loads, and the daily peaks could increase by 9,000 to 10,000 MW.

We are continuing to refine the short-term model. In the March meeting, I will report on the development of load forecasts that will be used for regional resource adequacy assessment.

Attachment:

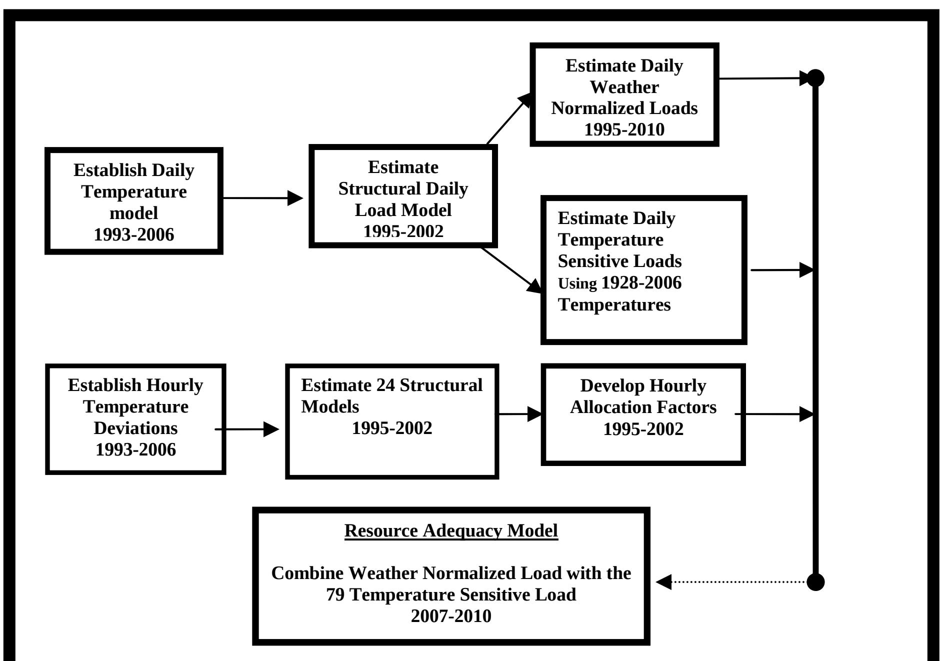
Discussion of Short-term Electricity Demand Forecasting Model and Preliminary Results

February 13, 2007

Objective: Develop short-term model that has the ability to produce hourly and daily forecasts of regional loads three to five years into the future. The main use of this short-term forecasting tool is for resource adequacy metrics where regional load will be forecast under a wide range of actual weather conditions.

The Modeling Approach: We used econometric time-series analysis to develop structural relationships between daily and hourly loads and a number of explanatory variables. We started the process by determining the deviations from normal daily temperatures. Then we estimated the structural relationship between daily regional loads and daily temperature deviations. The econometrically estimated single equation expresses daily load as a function of seasonal, cyclical and economic explanatory variables. The structural relationship is then used to develop two sets of daily load forecasts; a weather-normalized forecast, and a temperature-sensitive forecast. The weather-normalized forecast is driven by cyclical and economic growth variables. The temperature-sensitive forecast is driven by a forecast of the expected temperatures in a given period. The two forecasts are then combined to get a daily forecast. To translate the daily load forecasts into hourly loads we developed 24 hourly models and determined hourly factors for each day using a similar econometric approach and using explanatory variables similar to the daily model.

The diagram below shows the analytic process used in developing the short-term models.



Process flow for Short-term Load Forecasting Models

Functional form:

A structural time series model was adopted to represent the demand for electricity in the region. The general specification of the demand model is represented by

$$L = f(S, W, DE, I) \qquad \textbf{(1)}$$

Where:

L = net average hourly or daily electricity load in the region
S = variables depicting seasonal variations in load,
W = weather deviation variables generated via a regression model,
DE = demographic and economic variables, and
I = indicator or dummy variables.

Data: Datasets used for this analysis included:

1. Hourly regional load for 1995-2002 from Northwest Power Pool,
2. Hourly temperatures for 1995-2006 from Western Regional Climate Center
3. Monthly employment data for 1995-2006 from U.S. Bureau of Labor Statistics
4. Monthly electricity rates data for 1995-2006 from Energy Information Administration
5. Hourly Direct Service Industry aggregate load data for 1993-2006 from Bonneville Power Administration
6. Forecast of quarterly employment by state from Global Insight Inc.

Hourly regional load data for the footprint of the Northwest Power and Conservation Planning includes hourly loads for the entire states of Idaho, Oregon, and Washington, and the western part of Montana. Hourly loads were net of Direct Service Industries' loads. Hourly temperature data were for four regionally representative sites (Portland airport, Boise airport, Spokane airport, Seattle airport).

We tested a number different structural variables and forms. The variables in the final models include daily and hourly temperature deviations, temperature deviations from the day before, maximum temperature from the day before, seasonally adjusted employment, regional electricity prices, and various dummy variables to account for other differences, such as between holidays and weekdays.

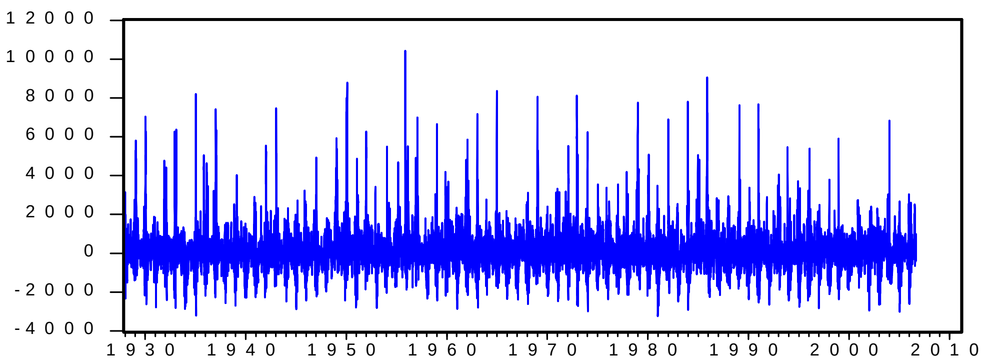
Test of Model Structure:

Using hourly load data for 1995-2002, we estimated 25 structural models, one daily model and twenty four hourly models. Over all the equations were able to explain over 90 percent of the variation in loads in the historical period. We conducted a number of statistical tests and compared the model's projections with actual values. For example, comparison of projected daily peak loads against actual loads found models errors in the +4% to -5% range. The overall error (Mean Absolute Percent Error) for the model was about -.015%. We also compared the model results with the July 20-24th 2006 heat-wave event and found that model results are within 10% of the regional peak estimated for that event.

What we have learned so far:

Using historical daily temperatures, we observe that the coldest winters have occurred in the 1950s and 1960s. The warmest summers have occurred in the 1990s and 2000s.
Using short-term forecasting we estimated the impact on load from deviations in temperature. The figure below shows the range of temperature-sensitive load for each day in the past 79 years. We estimated that there could be a one day 10,000 MWa winter load increase in November if we experienced temperature conditions similar to what occurred in November 12-17, 1955. The regional temperature during that period dipped 26 degrees below normal and resulted in a load spike. Our hourly model shows the single hour peak load can increase by over 12,000 MW. This jump in load is equal to 50% increase over the weather-normalized load for month of November.

Change in Daily Load due to Above Normal Deviations in Temperature (MW)



The following summary table provides a brief background on regional daily average as well as the projected loads under normal weather conditions for 2007 and the load spike for each month for the extreme weather experienced in the past. Note that load swings are larger during winter than summer.

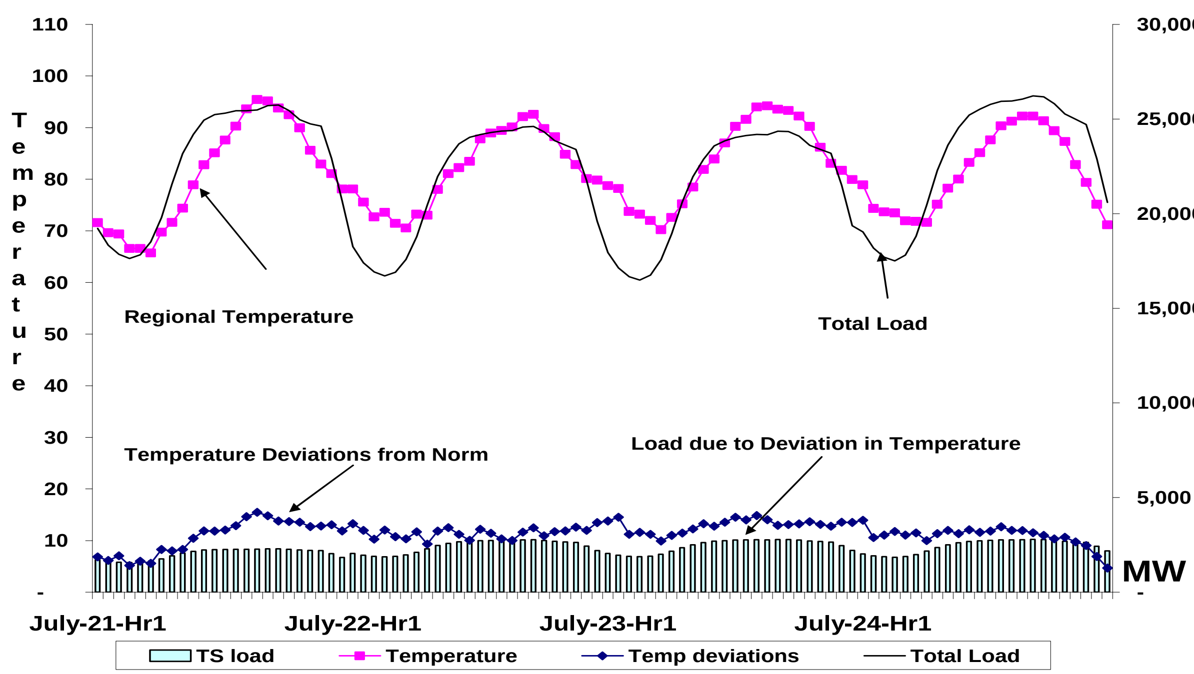
	Average Daily Temperature	Normal Load for 2007 MWa	Year of Extreme Temp Event	Deviation of Daily Temp. From Mean	Change in Daily Load (MWa)	Total Load MWa
January	**35**	**23,533**	**1950**	**-33**	**8,784**	**32,317**
February	**39**	**22,622**	**1950**	**-30**	**8,149**	**30,771**
March	**43**	**21,165**	**1955**	**-23**	**4,685**	**25,850**
April	**49**	**19,767**	**1936**	**-16**	**3,450**	**23,217**
May	**57**	**19,245**	**1965**	**-12**	**1,466**	**20,711**
June	**62**	**19,759**	**1992**	**16**	**2,178**	**21,937**
July	**68**	**20,559**	**2006**	**14**	**2,449**	**23,008**
August	**67**	**20,274**	**1992**	**12**	**1,929**	**22,203**
September	**62**	**19,017**	**1988**	**-12**	**1,364**	**20,381**
October	**53**	**19,735**	**1935**	**-17**	**4,453**	**24,188**
November	**45**	**21,871**	**1955**	**-26**	**10,433**	**32,304**
December	**37**	**23,484**	**1964**	**-24**	**8,365**	**31,849**

July 24th heat-wave event

On July 24th the region experienced its hottest 3-day period of the past 79 years. Boise and Portland temperatures peaked to over 100 degrees. The average regional temperature on Friday July 21st surpassed 95 degrees and for the next three days the daily maximums were above 90 degrees. The following graph shows hourly temperatures for July 21-24 for Portland, Seattle, Boise, Spokane, and the region.

Using the short-term model we estimated the hourly load for this period. The model estimated that the daily load on Monday July 24th which normally peaks around 23,000 MWa went up by an additional 2,800 MW due to the 14 degree above normal deviation in temperature. The following graph tracks hourly temperatures, temperature deviations from normal, total loads and loads increase due to above average temperatures. We observe that loads follow increase in temperature with some lag.

July 20-24 2006 Heat wave



Preliminary Weather Normalized Load Forecast for 2007-2010

A preliminary forecast of weather-normalized energy and peak capacity for 2007-2010 is shown in the table below. The forecasted energy is compared to the long-term forecast in the Fifth Power Plan. Although the short-term and long-term forecasts are based on totally different analytical approaches, the resulting forecasts are fairly consistent.

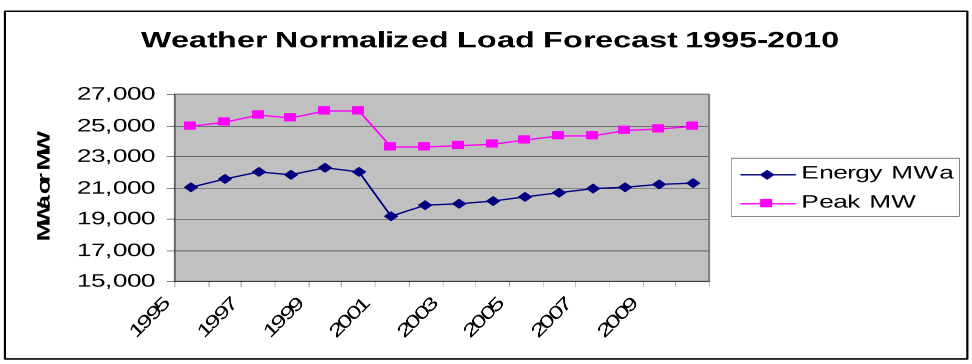
Comparison of 5th Power Plan Forecast and Short-Term Forecast

	Council's Long-Term Model Forecast					Short-Term Model	(Weather-Normalized)
	Low	Med lo	Medium	Med hi	High	Energy MWa	Peak Load MW
2000			19,187			19,547	25,949
2001			18,671			18,906	23,616
2002			18,696			19,454	23,666
2003			19,124			19,560	23,694
2004			19,699			19,829	23,824
2005	18,738	19,428	20,092	20,732	22,040	20,138	24,057
2006	18,748	19,571	20,343	21,102	22,592	20,408	24,323
2007	18,764	19,727	20,607	21,496	23,170	20,613	24,367
2008	18,778	19,880	20,868	21,901	23,777	20,773	24,664
2009	18,810	20,053	21,151	22,322	24,413	20,919	24,800
2010	18,853	20,242	21,460	22,758	25,078	21,052	24,934

Percent Difference in forecasts from short-term and long-term models

	Low	Med low	Medium	Med high	High
2007	10%	4%	0.0%	-4%	-11%
2008	11%	4%	-0.5%	-5%	-13%
2009	11%	4%	-1%	-6%	-14%
2010	12%	4%	-2%	-7%	-16%

Our recent biennial assessment showed that weather-normalized actual load is in the medium-low to medium range of the long-term forecast.



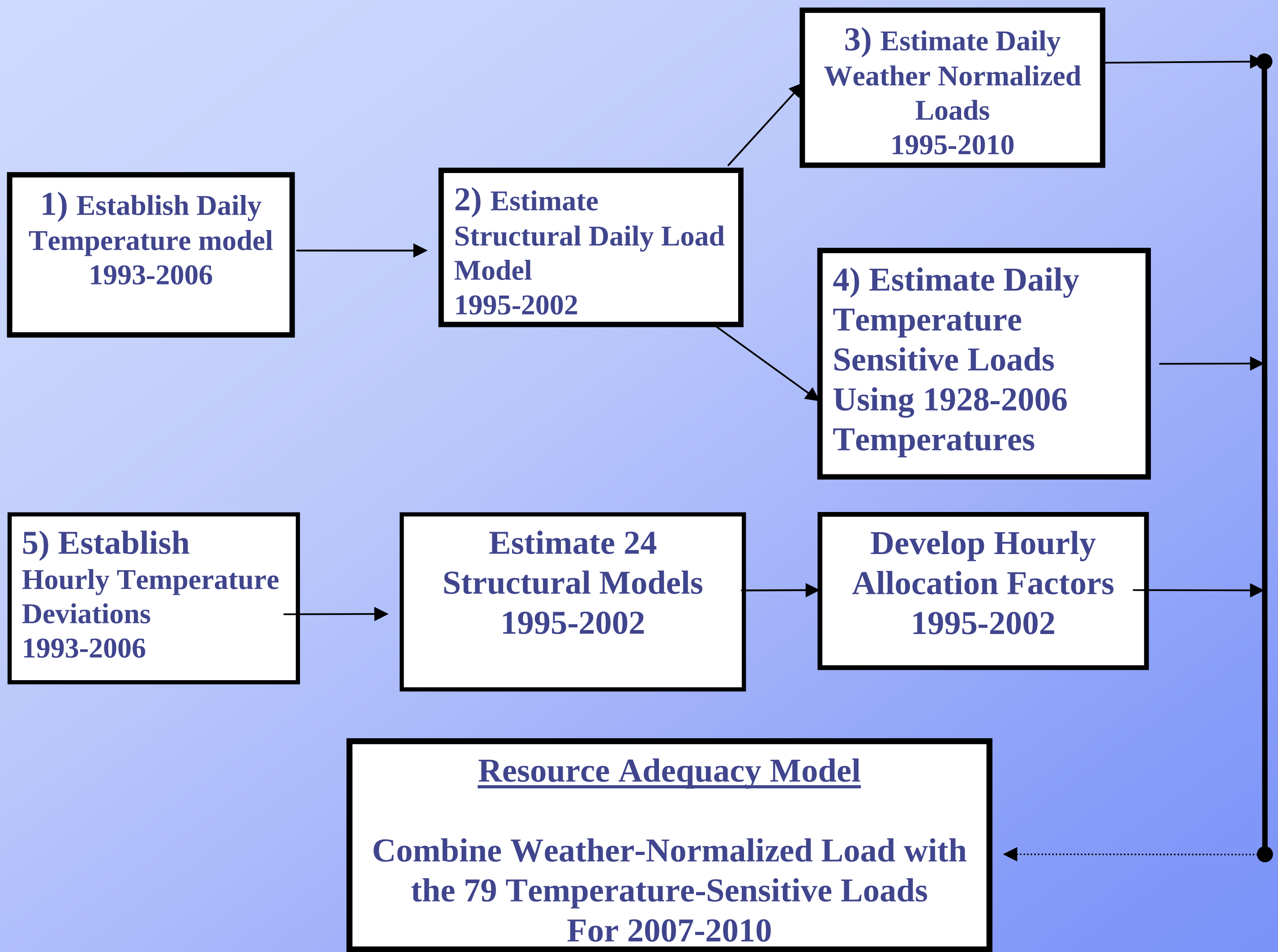
In our presentation next month, we will present the analytical approach and short-term electricity load forecast to be used for resource adequacy work.

Discussion of Short-Term Electricity Demand Forecasting Model and Preliminary Results

February 13, 2007

Objective

- Create a model to forecast regional loads 3-5 years forward.
- Create a model that can be used for Resource Adequacy
- Needs to be Hourly
- Needs to accommodate a wide-range of temperature conditions.
- Needs to be consistent with to long-term load forecasting model



Process flow for Short-term Electricity Demand Forecasting System

Data Used in Development of Model

- Hourly load data for 1995-2002 from Northwest Power Pool
- Hourly temperatures data for 1990-2006 from Western Regional Climate Center
- Seasonally Adjusted Monthly employment data for 1995-2006 from Bureau of Labor Statistics.
- Monthly electricity rates data for 1995-2006 from Energy Information Administration
- Hourly Direct Service Industry load data for 1993-2006 from Bonneville Power Administration
- Forecast of regional employment from Global Insight.

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Model Structure

- A structural time series model is adopted to represent the demand for electricity in the region .
- The general specification of the demand model is represented by

$$L = f\,(S, W, DE, I)$$

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L = net average daily electricity load in the region

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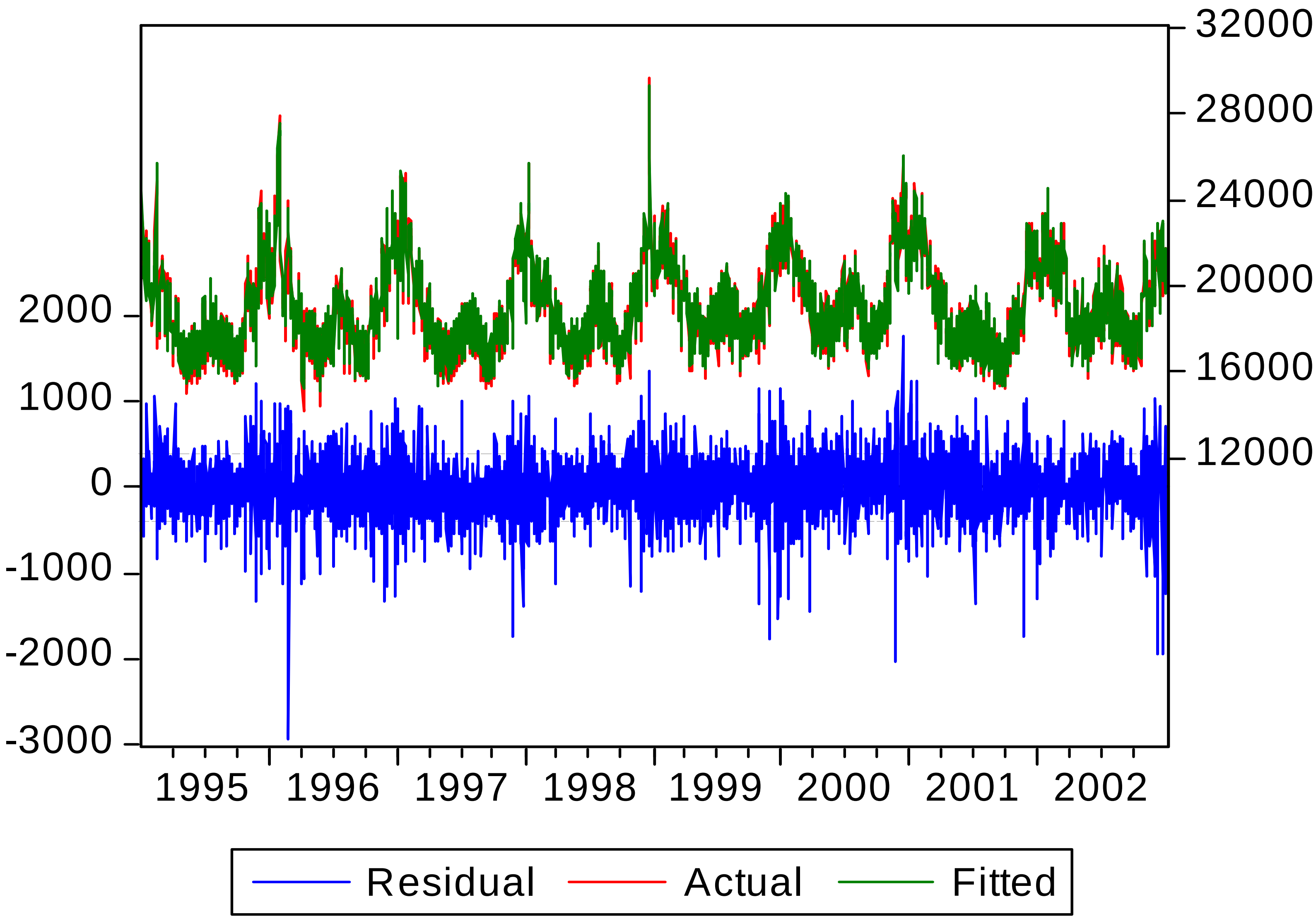
Model Reasonableness



What We Have Learned So Far

- Coldest winters occurred in the 1950s and 1960s.
- Warmest summers occurred in the 1990s and 2000s.
- Change in load due to temperature depends on severity and longevity of the temperature deviations
- A 10,000 MWa Winter single-day swing is possible
- A 12,000 MW Winter peak hour swing is possible
- Winter swings are larger than Summer

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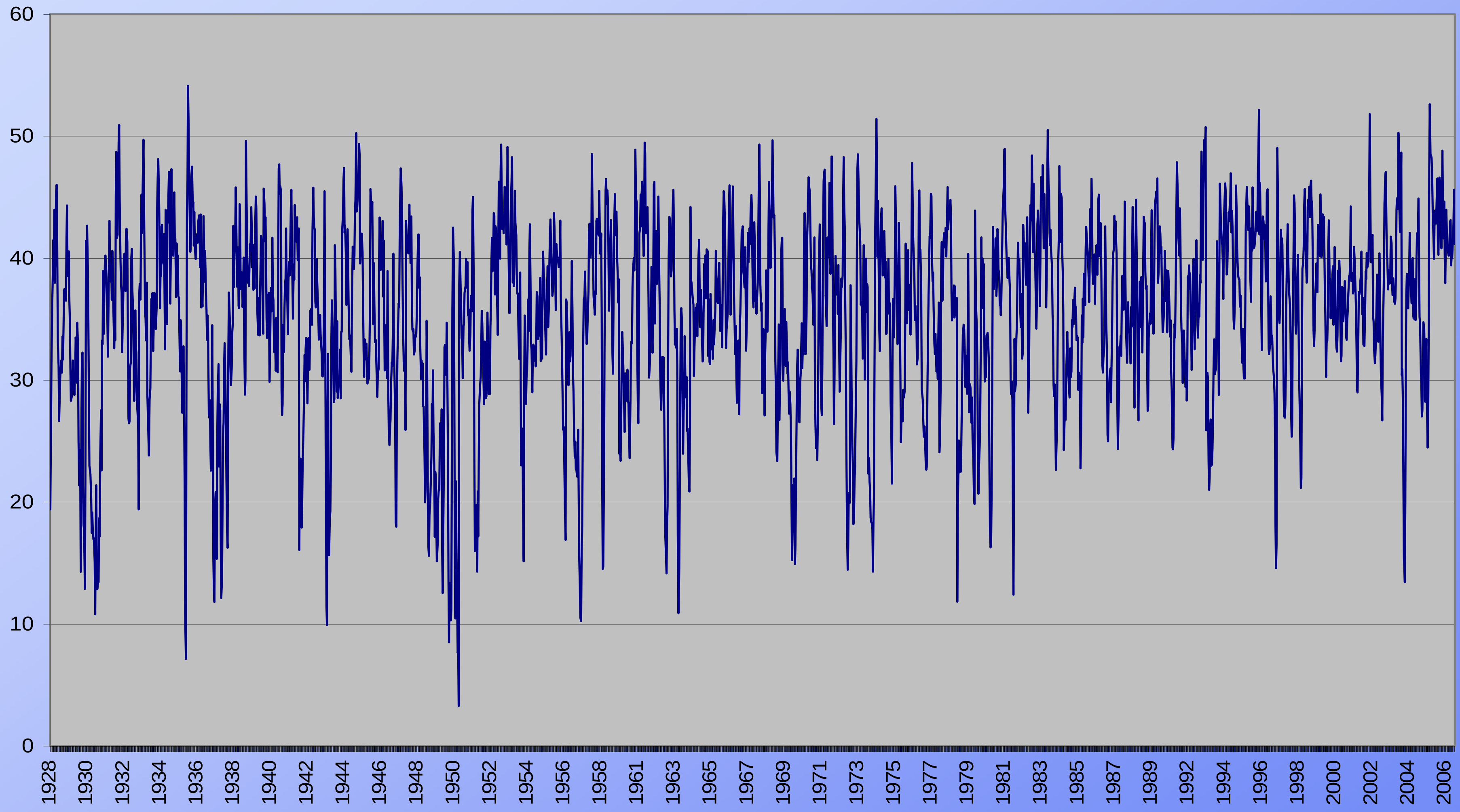
Average Daily Regional Temperature 1928-2006



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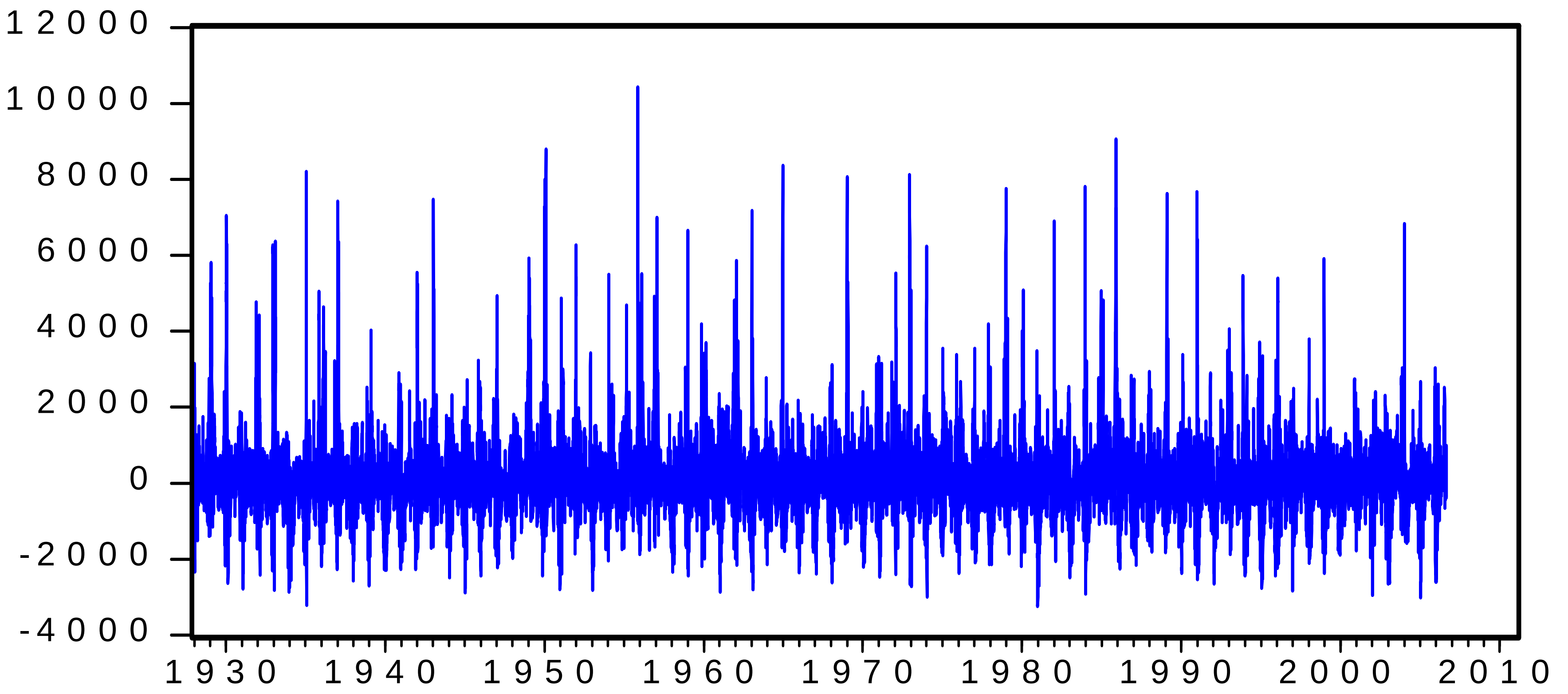
Change in Daily Load due to Above Normal Deviations in Temperature (MW)



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Normal and Deviations from Normal Temperature and Resulting Loads

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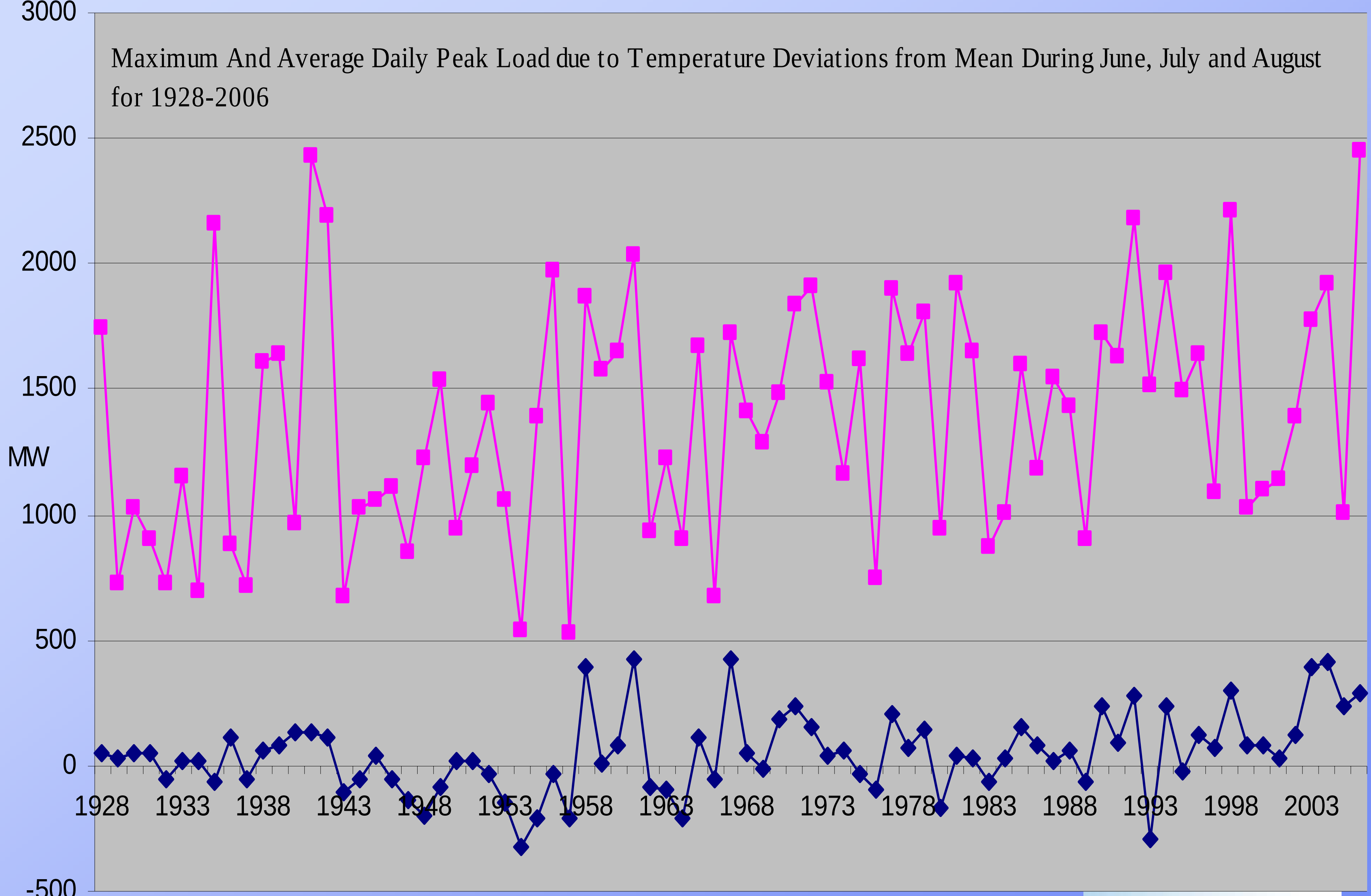

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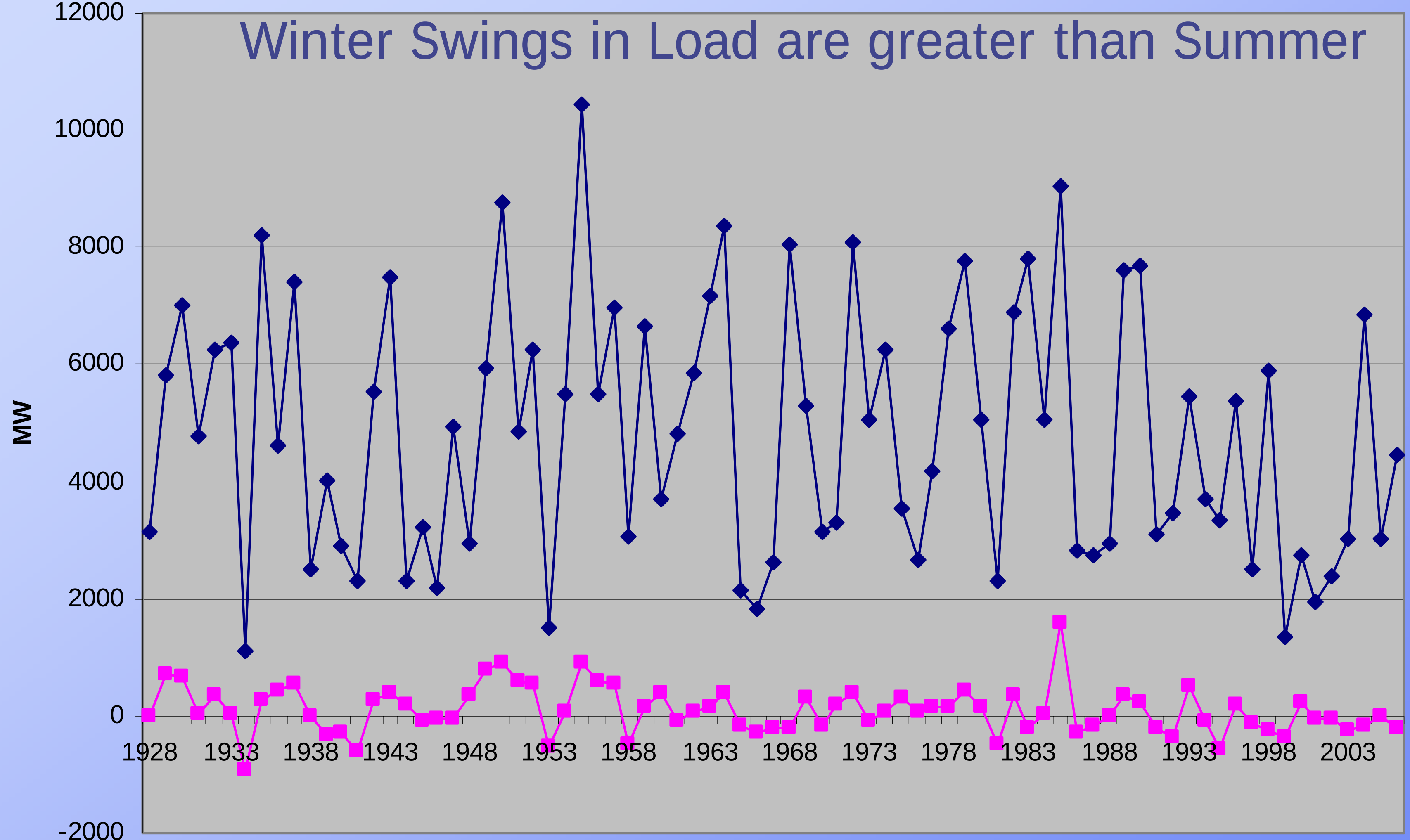
Winter Season Peak and Average Deviations in Load due to Deviations in Temperature



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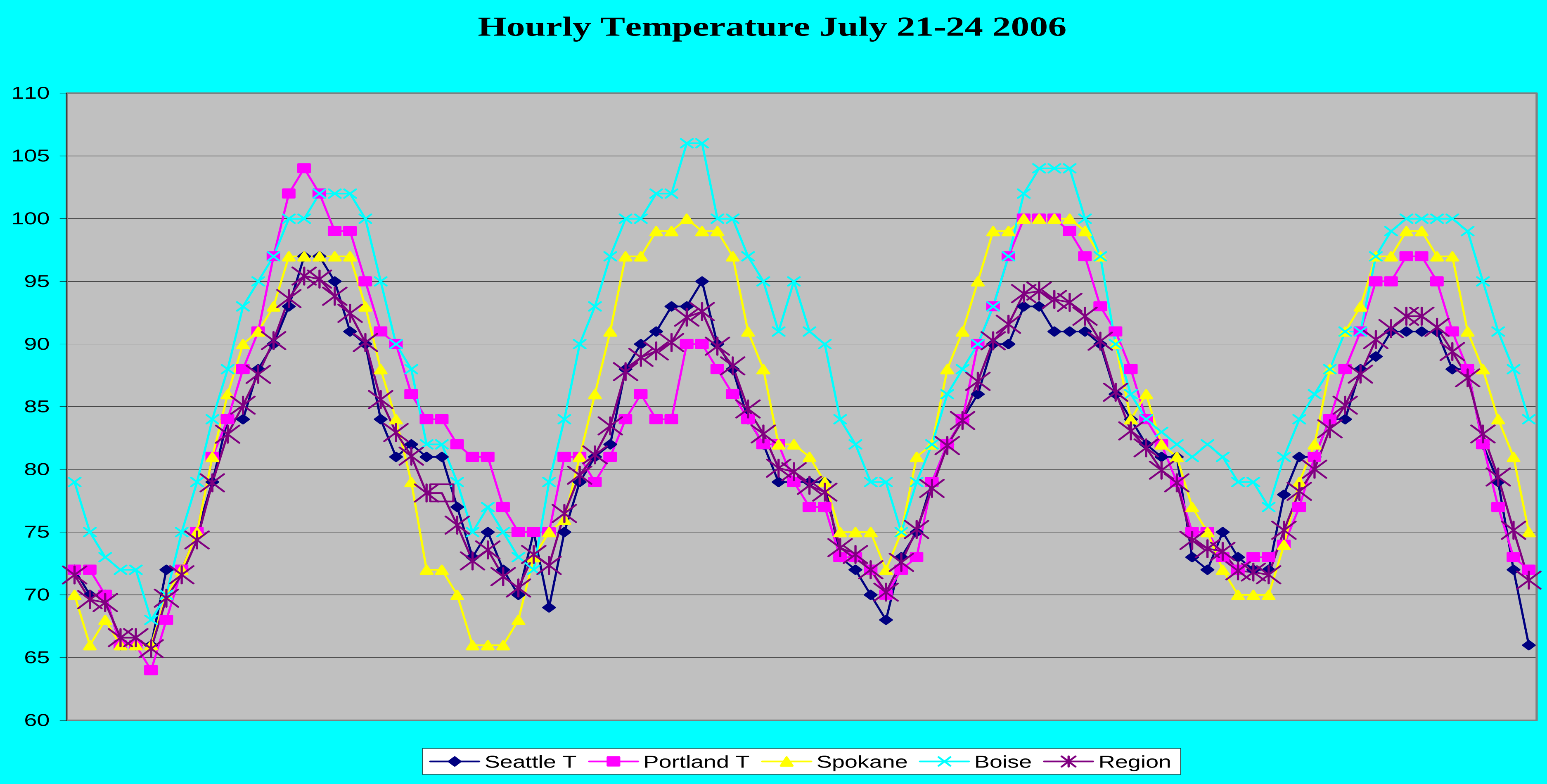
Analysis of July 21-24 2006 Heat Wave



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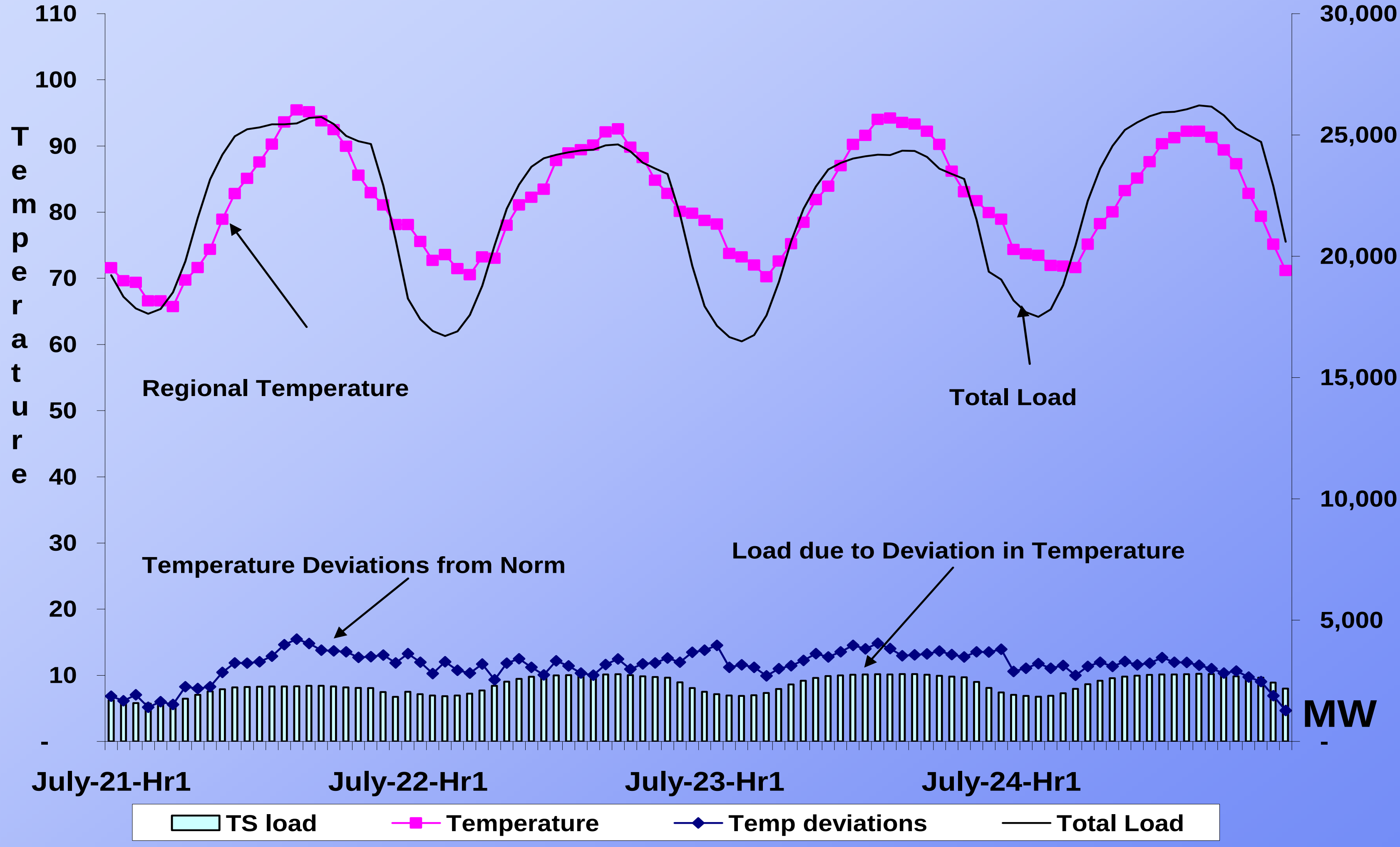
Temperature
110
100
90
80
70
60
50
40
30
20
10
-
30,000
25,000
20,000
15,000
10,000
5,000
-
MW
Regional Temperature
Total Load
Temperature Deviations from Norm
Load due to Deviation in Temperature
July-21-Hr1
July-22-Hr1
July-23-Hr1
July-24-Hr1
TS load
Temperature
Temp deviations
Total Load

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Consistency of Long and Short-term Models

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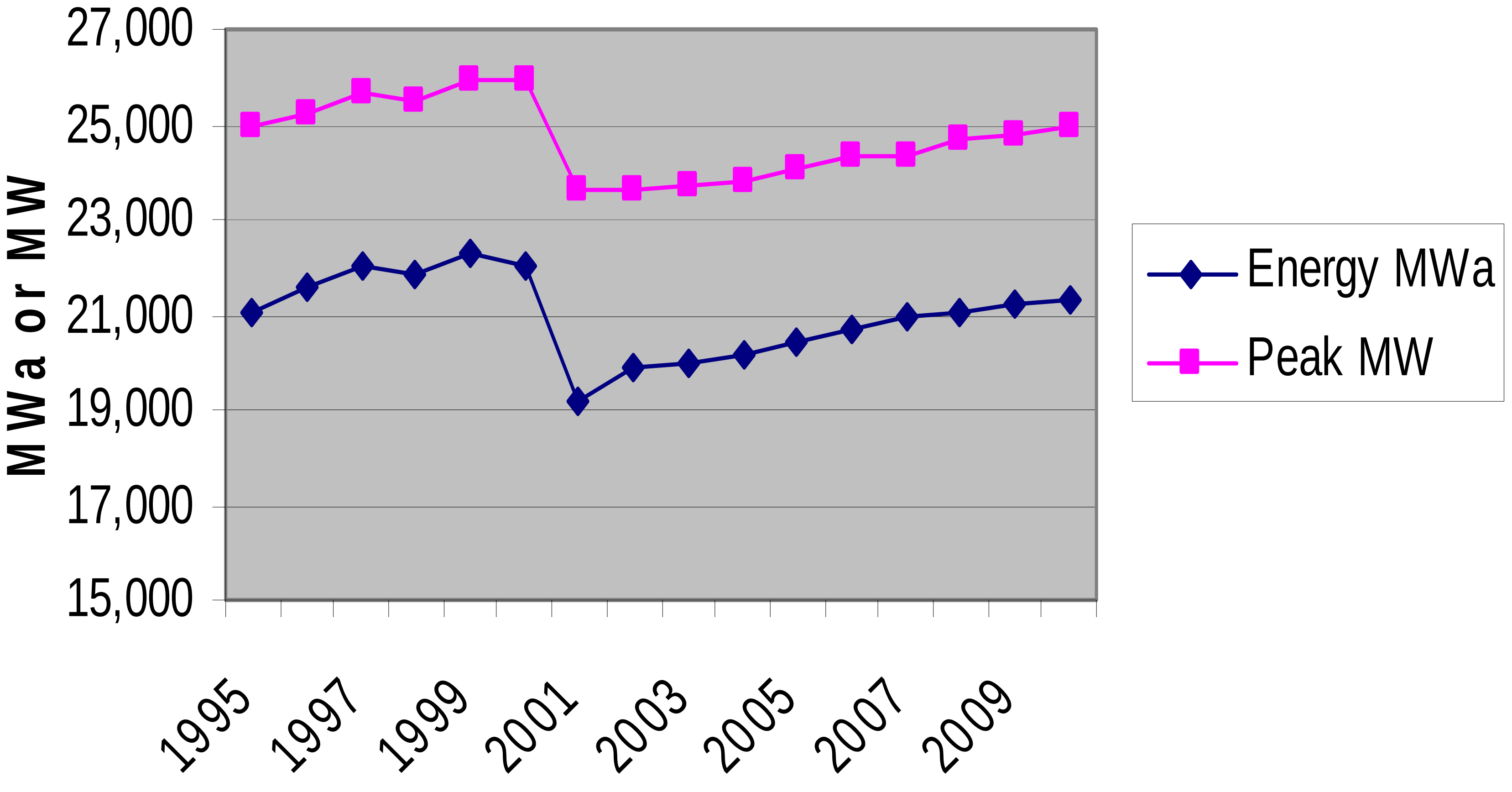
Weather Normalized Load Forecast 1995-2010



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March 2007 Meeting

- Progress Report on Load Forecasts for Resource Adequacy Analysis

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