



Modeling System Load using Weather Normalized Load Research Data

Presented by:

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Solution[s]

*to your challenges
of risk and uncertainty*

Association of Edison Illuminating Companies
Load Research Workshop
Orlando, Florida
April 11, 2005



Agenda for the Presentation

Agenda

Concept

- ✓ Drill Down
- ✓ Normal Weather
- ✓ Usage Models

Detailed Steps

- ✓ Daily & Hourly Models
- ✓ Bumps Along the Road
- ✓ Seasons and Day Types

Final Comments

- » Concept
 - ✓ System Drill Down
 - ✓ Normal Weather
 - ✓ Usage Models
- » Detailed Procedural Steps
 - ✓ Daily and Hourly Models
 - ✓ Bumps Along the Road
 - ✓ Seasons and Day Types
- » Final Comments



Statement of Issue/Situation

Agenda

Concept

- ✓ Drill Down
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Detailed Steps

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Final Comments

- » Need to forecast hourly loads in order to model fuel costs and make long-range planning decisions.
 - ✓ Have the EPRI Hourly Electric Load Model (HELM) to build system loads from representative end-use load shapes.
 - ✓ HELM load shapes were not up-to-date for latest available consumption patterns.
 - ✓ Load shapes must be weather-normalized to represent expected load conditions for several years into the future.
- » EPRI's HELM and ICF's Load Vision are models that:
 - ✓ Build up system loads from multiple end uses.
 - ✓ Apply end use load shapes to build up hourly loads.
 - ✓ Allow changing trends in end uses to impact system loads over time.
- » Analyses can also be performed on a spreadsheet.



Overall Concept of Solution

Agenda

Concept

- ✓ Drill Down
- ✓ Normal Weather
- ✓ Usage Models

Detailed Steps

- ✓ Daily & Hourly Models
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Final Comments

- » Establish actual rate class sales by month, day and hour.
 - Residential General
 - Residential Time of Use
 - Small Commercial
 - Medium Commercial
 - Commercial Heating
 - Large Commercial (TOU)
 - Long Island Rail Road
 - Lighting/Traffic Signals
- » Develop daily and hourly equations to predict load at normal temperatures for each rate class based on Load Research Data.
 - ✓ Simple tools and simple regressions.
 - ✓ Magnitude of effort is key factor.
- » Use rate class equations to approximate daily and hourly loads under normal weather conditions.
- » Use weather-normalized load shapes to estimate system load requirements in future years.



Actual Annual Sales by Month

Agenda

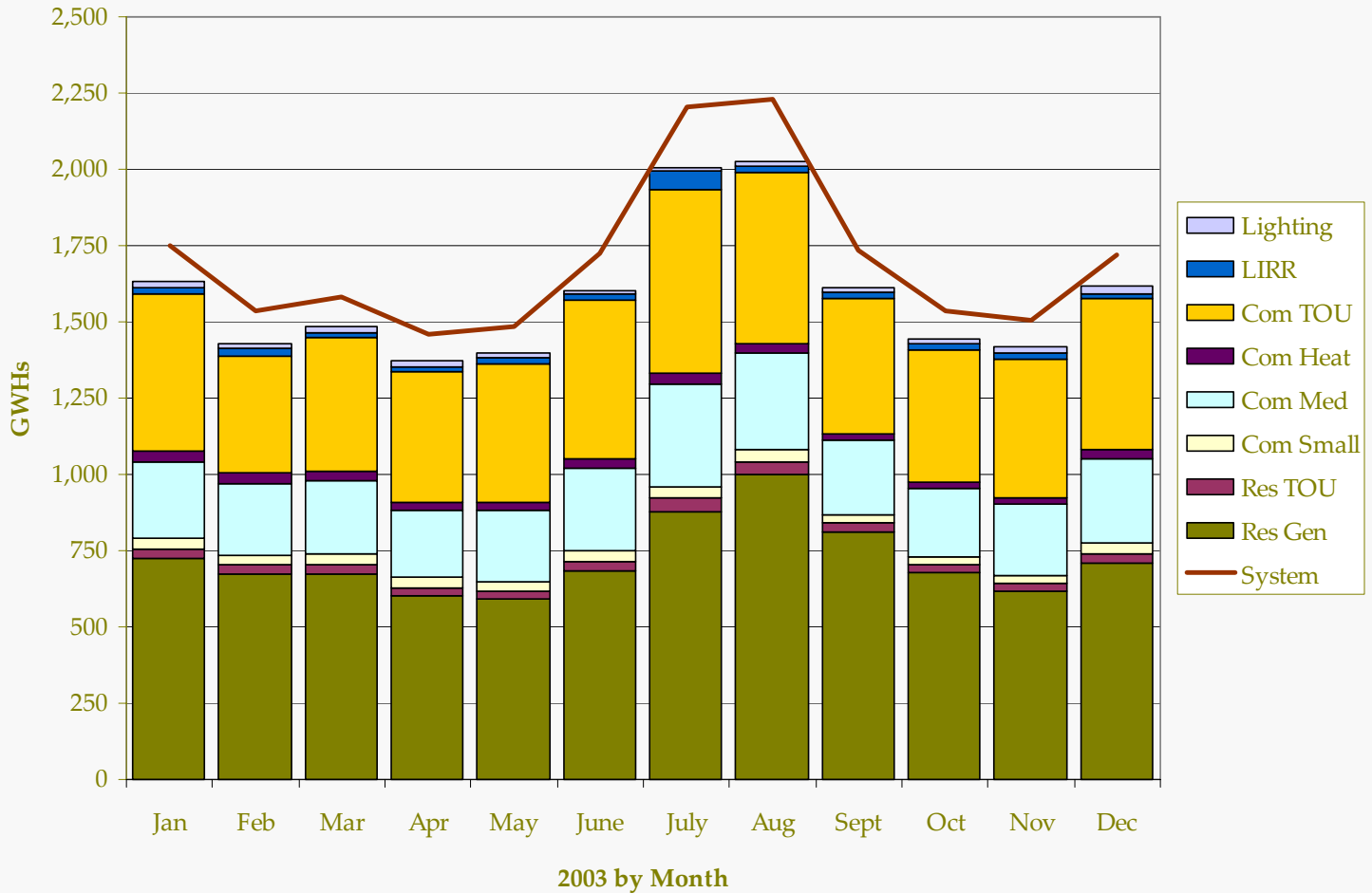
Concept

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Final Comments





Actual Monthly Sales by Day

Agenda

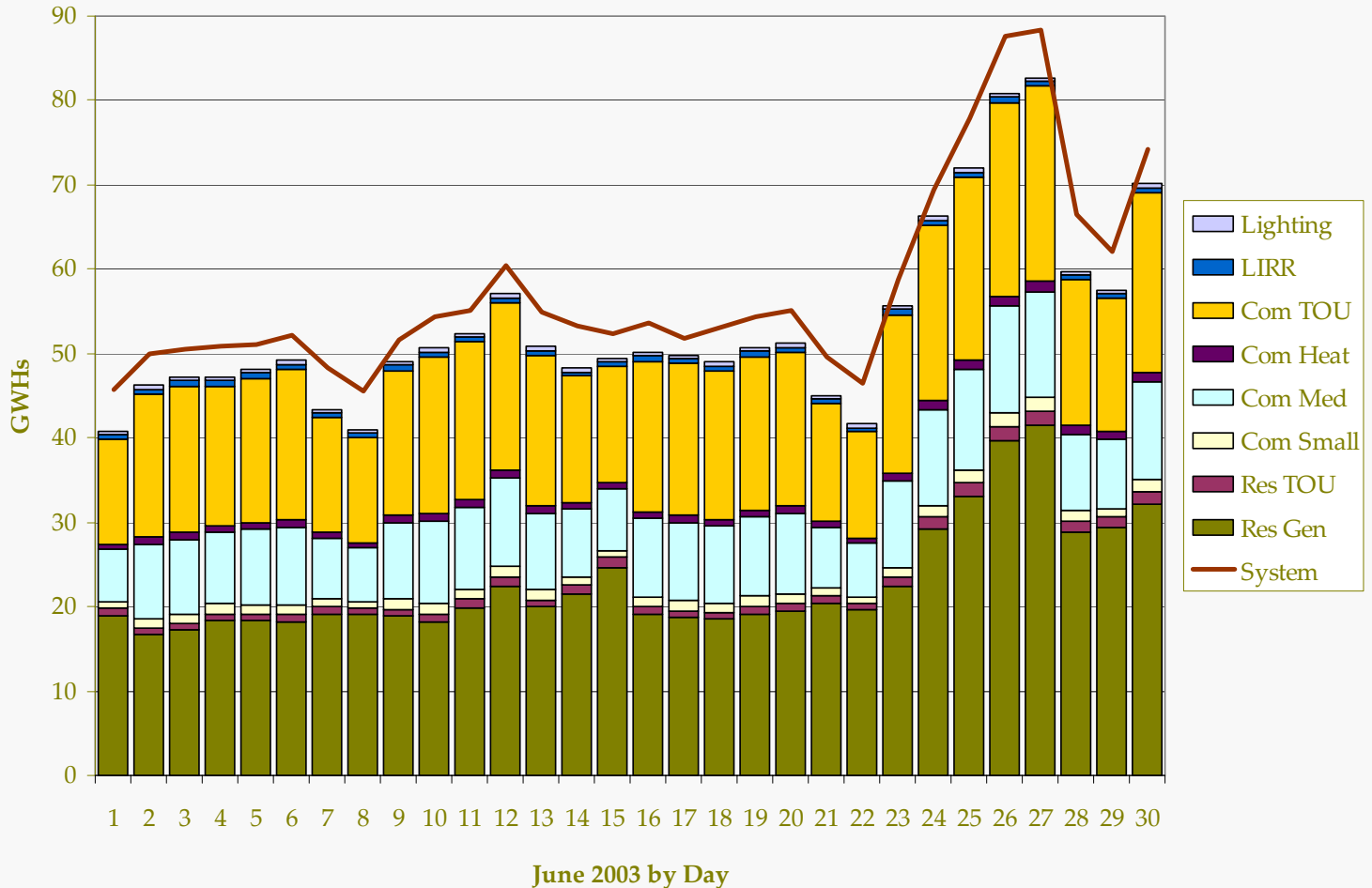
Concept

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Final Comments





Actual Daily Sales by Hour

Agenda

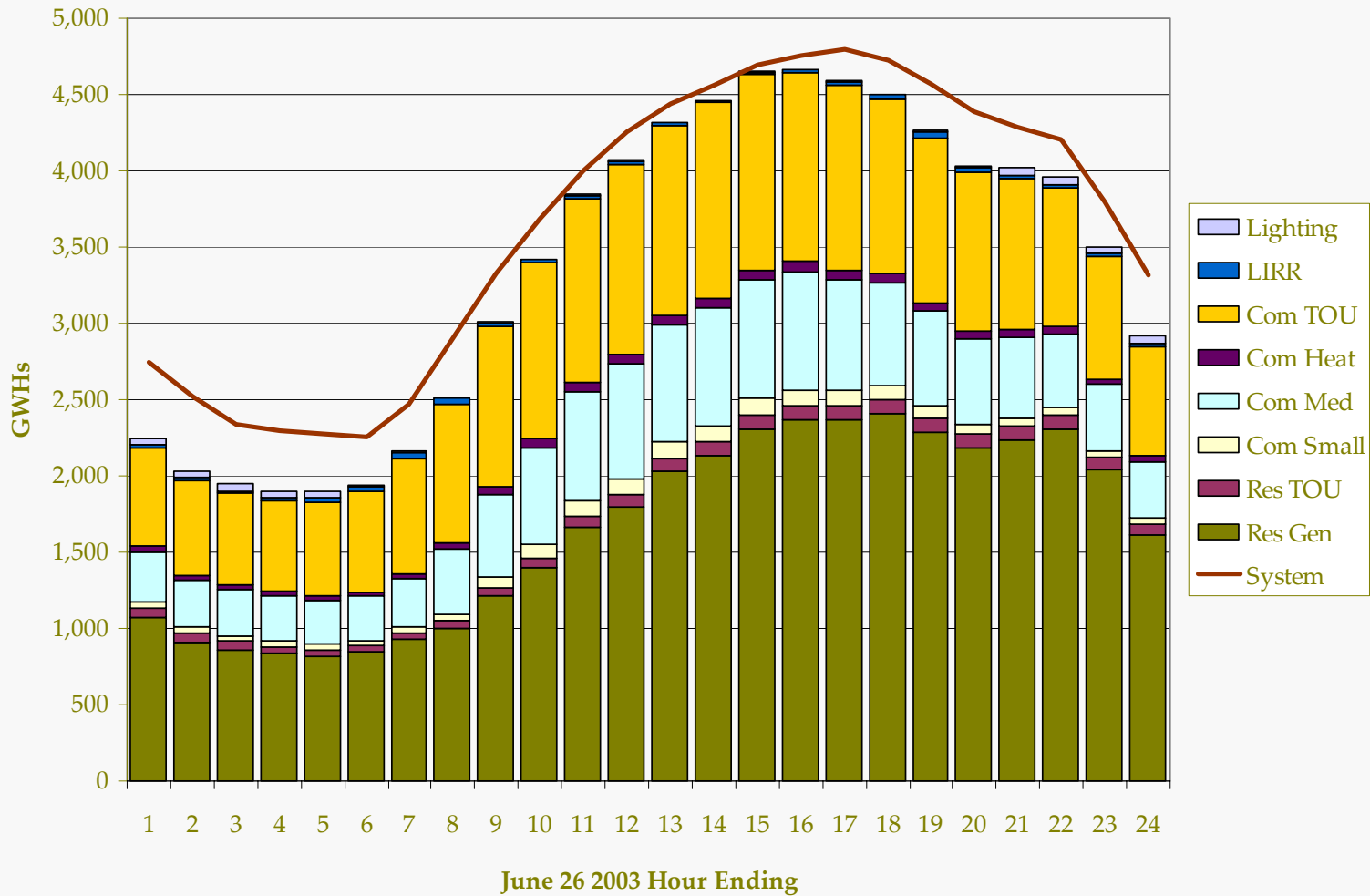
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System Load Build-up Approach

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Final Comments

- » Mechanics
 - ✓ Establish Daily Normal Weather to reflect full range of daily temperatures.
 - ✓ Develop hourly/daily load models for each rate class, season and day type.
 - ✓ Weather Normalized System Load can be built up from normalized daily and hourly rate class loads.
 - ✓ Monthly and annual loads can be built up from daily and hourly loads.
- » Tools like HELM can simplify or automate this process, but spreadsheets are always an option.



Establishing Daily Normal Weather

Agenda

Concept

- ✓ Drill Down
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Detailed Steps

- ✓ Daily & Hourly Models
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Final Comments

- » To get the most realistic range of daily normal temperatures in each month:
 - ✓ Collect actual daily temperature for the last 10-30 years.
 - ✓ Sort daily temperature from hottest to coldest within each month of each year.
 - ✓ Average the hottest day, second hottest day, etc., to establish daily normal temperature.
- » Match actual days to normal days as hottest to hottest, second hottest to second hottest, ..., coldest to coldest, within each month.
 - ✓ Preserves normal temperatures and degree days within each month.
 - ✓ Establishes temperature patterns for weekdays versus weekends.



Establishing Normal Weather Values

Agenda

Concept

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Detailed Steps

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Final Comments

	Actual		Actual		Normal
	Date	Temp	Date		Temp
	6/26/2003	86.3	6/24/2002	80.8	... 81.8
	6/27/2003	83.6	6/26/2002	80.1	... 80.2
	6/25/2003	83.5	6/27/2002	79.8	... 79.4
	6/24/2003	80.9	6/23/2002	78.9	... 78.3
	6/30/2003	78.3	6/30/2002	78.7	... 77.4
	6/28/2003	74.8	6/25/2002	77.8	... 76.6
	6/29/2003	74.5	6/29/2002	77.5	... 76.0
	6/12/2003	73.3	6/11/2002	76.9	... 75.4
	6/15/2003	72.7	6/22/2002	76.7	... 74.7
	6/23/2003	72.4	6/28/2002	76.4	... 74.1
	6/11/2003	71.9	6/12/2002	75.9	... 73.7
	6/10/2003	70.6	6/1/2002	75.5	... 73.1
	6/14/2003	68.2	6/5/2002	74.0	... 72.4
	6/19/2003	67.0	6/21/2002	72.4	... 71.9
	6/6/2003	66.4	6/10/2002	72.2	... 71.5



Matching Normal Temps to Actual Days

Agenda

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Final Comments

	Actual	Normal		Actual	Normal
Date	Temp	Temp	Date	Temp	Temp
6/26/2003	86.3	81.8	6/20/2003	65.8	71.0
6/27/2003	83.6	80.2	6/9/2003	65.5	70.6
6/25/2003	83.5	79.4	6/16/2003	63.1	69.9
6/24/2003	80.9	78.3	6/18/2003	62.8	69.5
6/30/2003	78.3	77.4	6/8/2003	62.7	69.1
6/28/2003	74.8	76.6	6/5/2003	62.4	68.3
6/29/2003	74.5	76.0	6/13/2003	62.2	67.8
6/12/2003	73.3	75.4	6/2/2003	61.9	66.9
6/15/2003	72.7	74.7	6/3/2003	61.3	66.1
6/23/2003	72.4	74.1	6/7/2003	61.2	65.3
6/11/2003	71.9	73.7	6/21/2003	61.1	64.2
6/10/2003	70.6	73.1	6/22/2003	60.8	63.2
6/14/2003	68.2	72.4	6/17/2003	59.9	61.9
6/19/2003	67.0	71.9	6/1/2003	58.9	60.8
6/6/2003	66.4	71.5	6/4/2003	54.0	58.9



Matching Normal and Actual Weather

Agenda

Concept

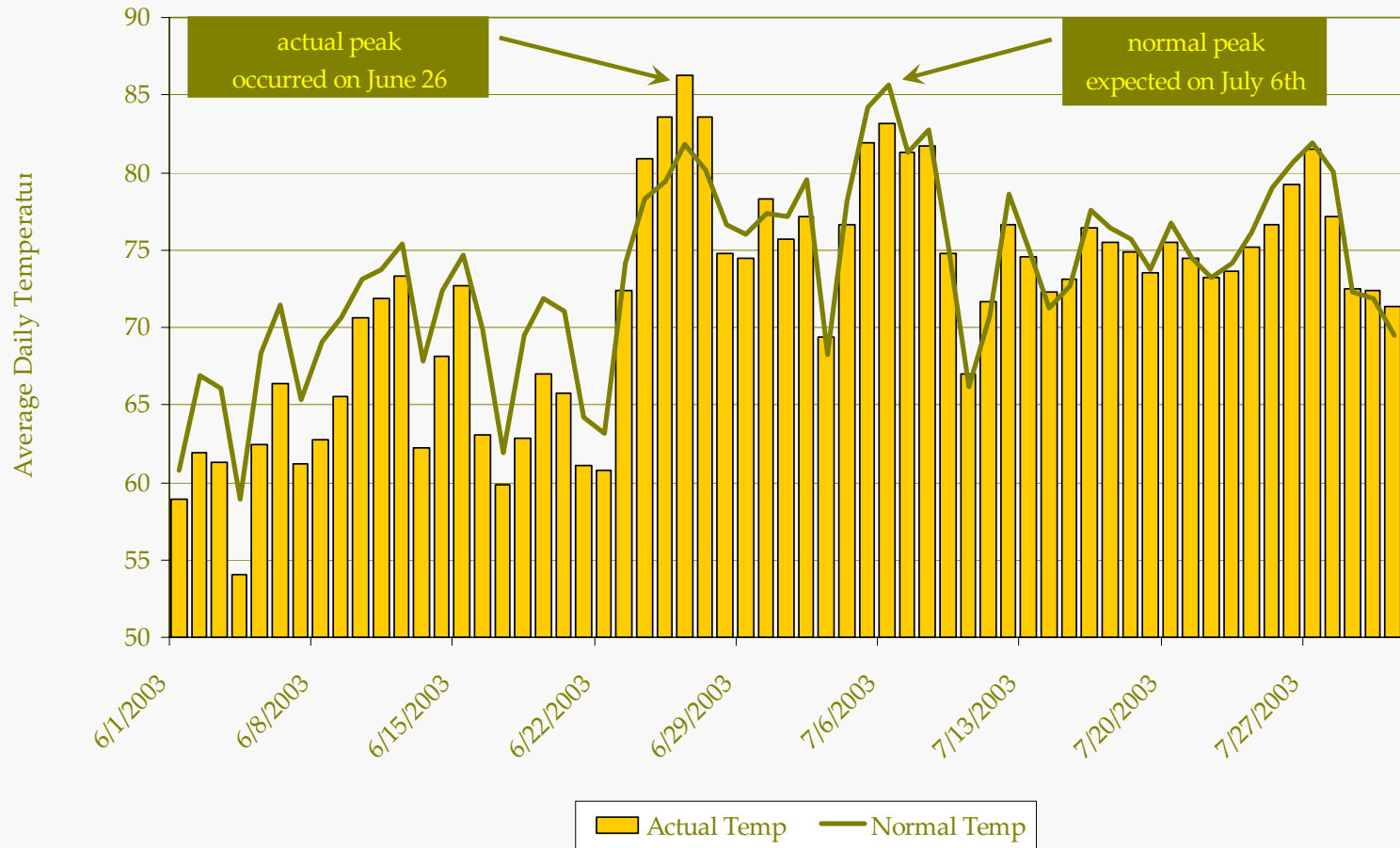
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Detailed Steps

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Final Comments

Summer Daily Weather





Daily Usage Depends on Weather

Agenda

Concept

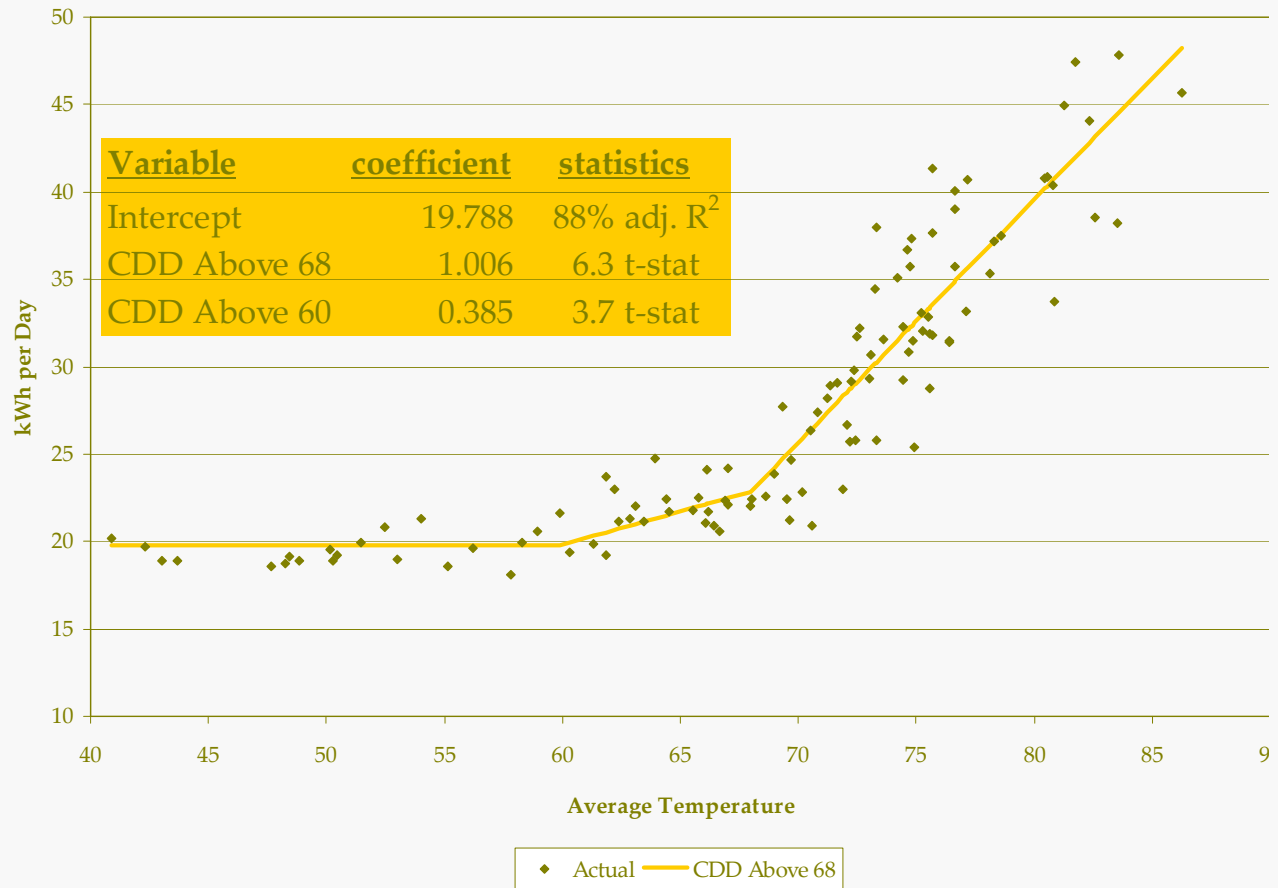
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Detailed Steps

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Final Comments

Residential General Usage on a Summer Weekday





Many Individual Models are Required

Agenda

Concept

- ✓ Drill Down
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Detailed Steps

- ✓ Daily & Hourly Models
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Final Comments

<u>Segment</u>	<u>Season</u>	<u>Day</u>	<u>Models</u>
Residential General	Summer, Winter	Weekday, Saturday, Sunday	6
Residential TOU	Summer, Winter	Weekday, Saturday, Sunday	6
Small Comm	Winter, Summer, Shoulder	Weekday, Saturday, Sunday	9
Medium Comm	Winter, Summer, Shoulder	Weekday, Saturday, Sunday	9
Number of Models			30

<u>Segment</u>	<u>Season</u>	<u>Day</u>	<u>Models</u>
Comm Heating	Winter, Summer, Shoulder	Weekday, Saturday, Sunday	9
Large Comm (TOU)	Winter, Summer, Shoulder	Weekday, Saturday, Sunday	9
Long Island Rail Road	Winter, Summer, Shoulder	Weekday, Saturday, Sunday	9
Lighting	not modeled	not modeled	0
Number of Models			27

57 regression models are required for this example.



Detailed Procedural Steps

Agenda

Concept

- ✓ Drill Down
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Detailed Steps

- ✓ Daily & Hourly Models
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Final Comments

- » Model Daily Usage by regressing Load Research Data against Weather.
- » Choose Best Regression Model
- » Model Hourly Load Shapes for each rate class
- » Create 8,760 Hour Load Shape
- » Reconcile to Energy Forecast
- » Evaluate Monthly Peak Days
- » Evaluate Monthly Load Duration Curves



Calculating Daily Normal Usage

Agenda

Concept

- ✓ Drill Down
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Detailed Steps

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Final Comments

$$\text{Daily Usage} = 19.788 + 1.006 * \text{CDD Above } 68 + 0.385 * \text{CDD Above } 60$$

				CDD	CDD		
	Actual	Daily	Normal	Above	Above	Normal	
Date	Temp	Load	Temp	68	60	Load	
06/02/03	61.9	19.2	66.9	0.0	6.9	22.4	
06/03/03	61.3	19.9	66.1	0.0	6.1	22.1	
06/04/03	54.0	21.3	58.9	0.0	0.0	19.8	
06/05/03	62.4	21.1	68.3	0.3	8.3	23.3	
06/06/03	66.4	20.9	71.5	3.5	11.5	27.7	
06/09/03	65.5	21.8	70.6	2.6	10.6	26.5	
06/10/03	70.6	20.9	73.1	5.1	13.1	30.0	
06/11/03	71.9	23.0	73.7	5.7	13.7	30.8	
06/12/03	73.3	25.8	75.4	7.4	15.4	33.2	
06/13/03	62.2	23.0	67.8	0.0	7.8	22.8	
06/16/03	63.1	22.0	69.9	1.9	9.9	25.5	



Hourly Usage based on Same Structure

Agenda

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Detailed Steps

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Final Comments

	<u>HR 1</u>	<u>HR 2</u>	<u>HR 3</u>	<u>HR 4</u>	<u>HR 5</u>	<u>HR 6</u>	<u>HR 7</u>	<u>HR 8</u>
Intercept	0.642	0.564	0.534	0.514	0.530	0.592	0.733	0.817
CDD Above 68	0.016	0.013	0.013	0.014	0.013	0.010	0.006	0.015
t-stat	1.693	1.465	1.645	1.827	1.884	1.707	0.989	2.142
CDD Above 60	0.022	0.021	0.018	0.016	0.014	0.012	0.011	0.008
t-stat	3.510	3.641	3.361	3.279	3.084	2.948	2.651	1.758
r-square	65.9%	65.1%	64.2%	65.0%	63.8%	60.7%	48.7%	52.0%

	<u>HR 9</u>	<u>HR 10</u>	<u>HR 11</u>	<u>HR 12</u>	<u>HR 13</u>	<u>HR 14</u>	<u>HR 15</u>	<u>HR 16</u>
Intercept	0.813	0.803	0.785	0.785	0.772	0.760	0.765	0.823
CDD Above 68	0.019	0.030	0.043	0.049	0.051	0.064	0.069	0.068
t-stat	2.463	3.567	4.586	4.600	4.898	6.133	6.663	6.891
CDD Above 60	0.012	0.011	0.013	0.018	0.024	0.022	0.026	0.028
t-stat	2.482	2.104	2.040	2.646	3.521	3.290	3.894	4.340
r-square	63.5%	69.6%	75.9%	78.9%	83.5%	86.4%	88.8%	90.0%

	<u>HR 17</u>	<u>HR 18</u>	<u>HR 19</u>	<u>HR 20</u>	<u>HR 21</u>	<u>HR 22</u>	<u>HR 23</u>	<u>HR 24</u>
Intercept	0.913	1.063	1.211	1.246	1.213	1.153	0.984	0.774
CDD Above 68	0.069	0.080	0.088	0.081	0.065	0.059	0.042	0.030
t-stat	6.856	8.537	11.342	10.833	8.924	7.787	5.402	3.658
CDD Above 60	0.026	0.015	0.001	-0.001	0.008	0.014	0.022	0.025
t-stat	3.953	2.405	0.272	-0.227	1.745	2.860	4.312	4.762
r-square	89.3%	89.6%	90.8%	89.3%	89.2%	89.0%	87.0%	83.5%



Normal Daily Sales by Hour

Agenda

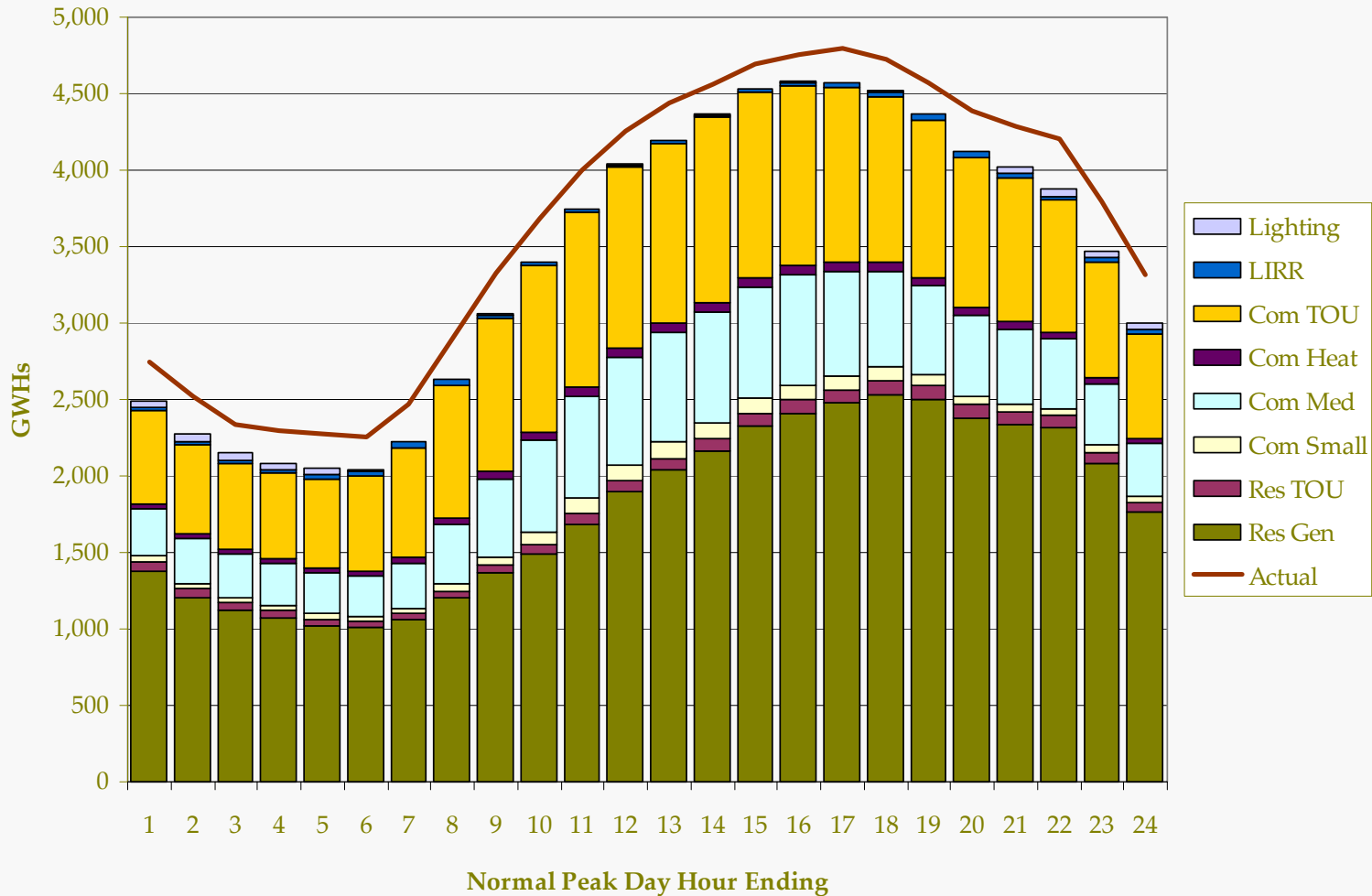
Concept

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Detailed Steps

- ✓ Daily & Hourly Models
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Final Comments





Actual and Normalized Daily Use

Agenda

Concept

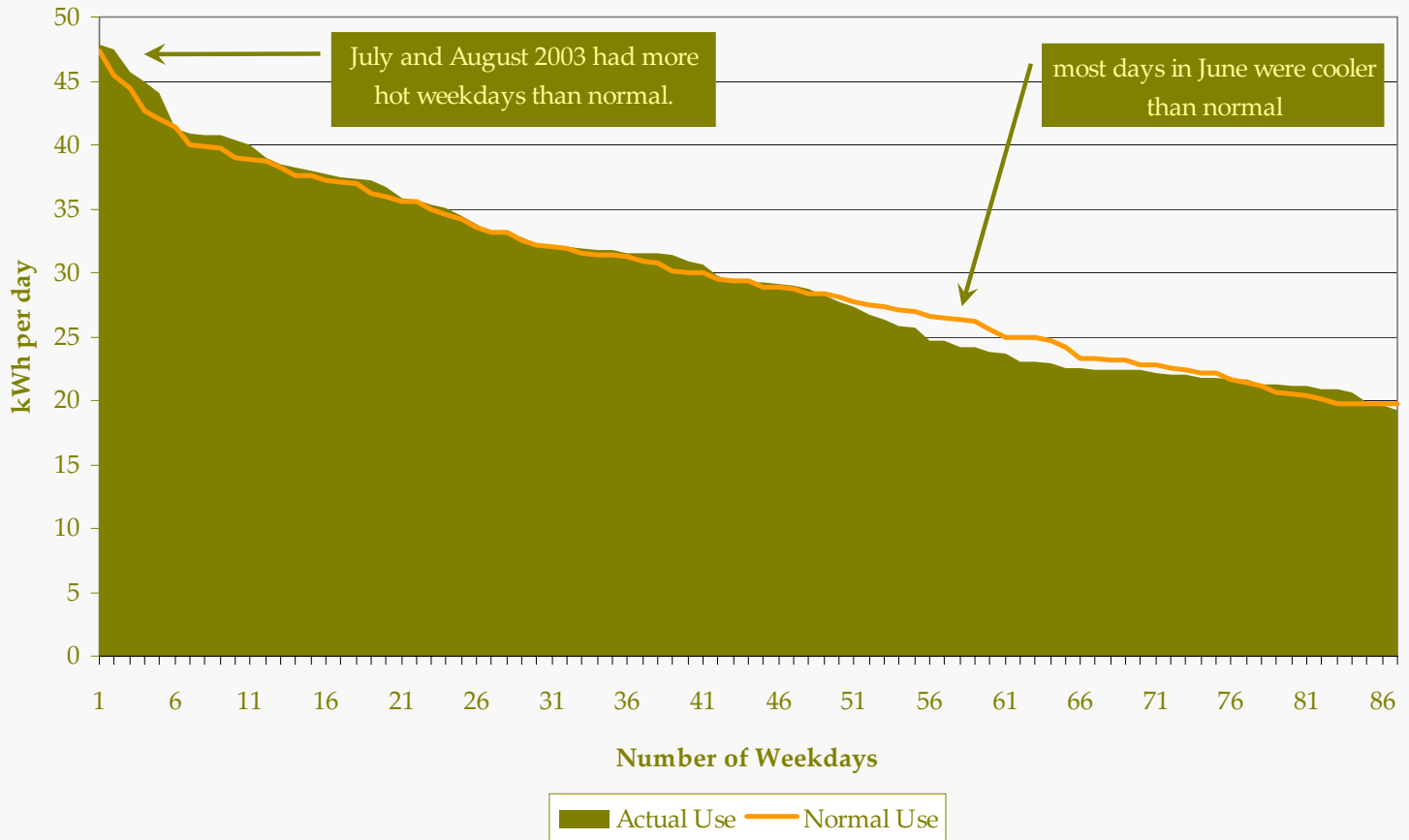
- ✓ Drill Down
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Final Comments

Residential General Usage on Summer Weekdays





Pulling It All Together

Agenda

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Detailed Steps

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Final Comments

- » Normalized Monthly and Annual Load can be built up from daily normalized Load.
- » All rate classes can be added together to create hourly, daily, monthly and annual loads.
- » Normal projections should be “calibrated” to match load forecasts produced by other departments.
- » There will be continual bumps along the road
 - ✓ What is “Normal Weather” for a Weekend?
 - ✓ How much effort can you expend on this analysis?



What if Peak Temperature is on Sunday?

Agenda

Concept

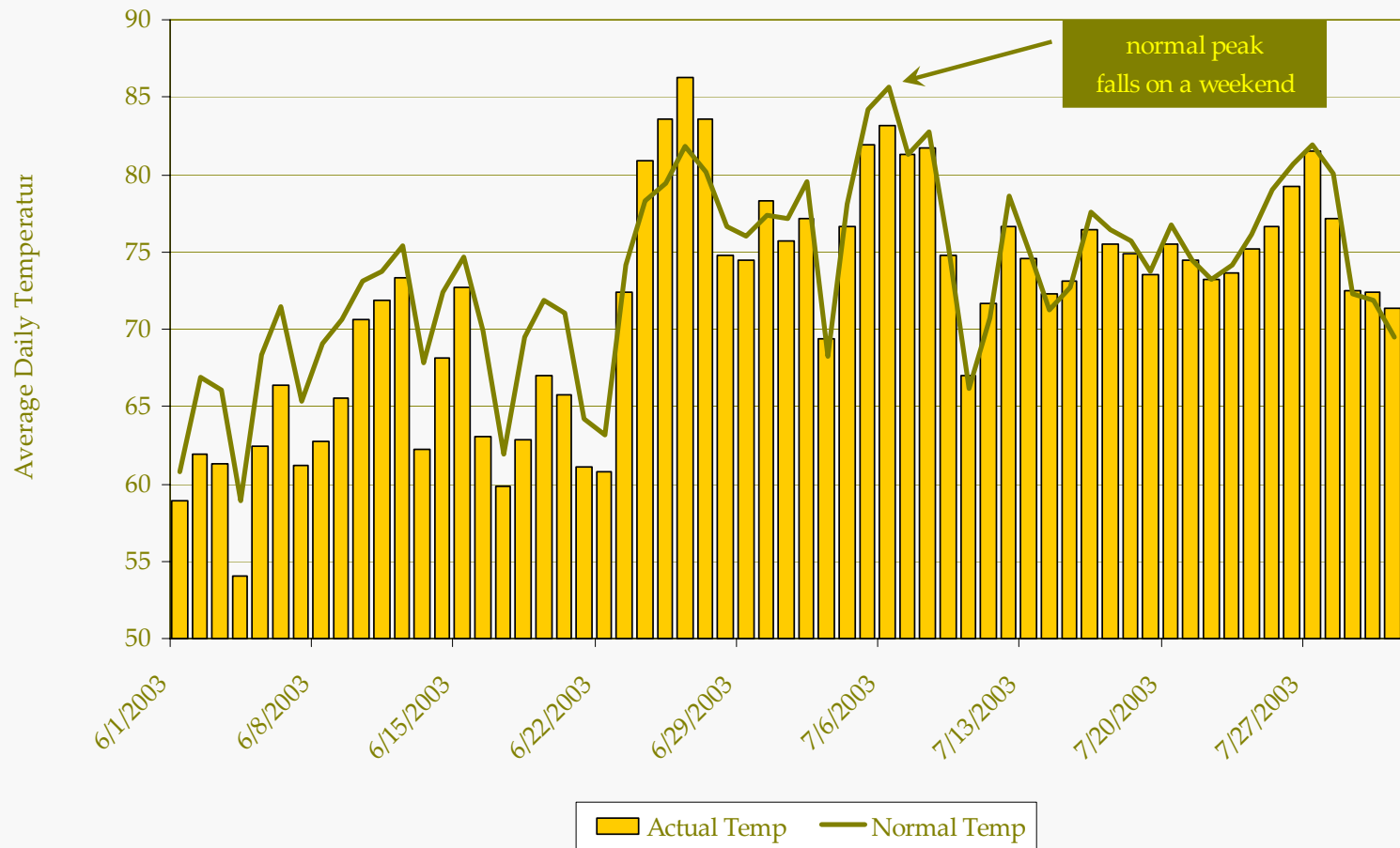
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Final Comments

Summer Daily Weather





Choosing Normal Weekend Temperatures

Agenda

- Concept
 - ✓ Drill Down
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- Detailed Steps
 - ✓ Daily & Hourly Models
 - ✓ **Bumps Along the Road**
 - ✓ Seasons and Day Types

Final Comments

Date	Actual Temp	Normal Temp	Day of Week
7/6/2003	83.2	85.6	Weekend
7/5/2003	81.9	84.2	Weekend
7/8/2003	81.8	82.7	Weekday
7/27/2003	81.5	81.9	Weekend
7/7/2003	81.3	81.3	Weekday
7/26/2003	79.2	80.7	Weekend
7/28/2003	77.2	80.1	Weekday
7/2/2003	77.1	79.5	Weekday
7/25/2003	76.6	79.0	Weekday
7/12/2003	76.6	78.6	Weekend
7/4/2003	76.6	78.1	Weekday
7/16/2003	76.4	77.6	Weekday
7/1/2003	75.7	77.1	Weekday
7/20/2003	75.5	76.7	Weekend
7/17/2003	75.5	76.4	Weekday

Date	Actual Temp	Normal Temp	Day of Week
7/24/2003	75.2	76.1	Weekday
7/18/2003	74.8	75.7	Weekday
7/9/2003	74.8	75.4	Weekday
7/13/2003	74.5	74.9	Weekend
7/21/2003	74.5	74.5	Weekday
7/23/2003	73.6	74.1	Weekday
7/19/2003	73.5	73.7	Weekend
7/22/2003	73.3	73.2	Weekday
7/15/2003	73.1	72.7	Weekday
7/29/2003	72.5	72.3	Weekday
7/30/2003	72.4	71.9	Weekday
7/14/2003	72.3	71.2	Weekday
7/11/2003	71.7	70.7	Weekday
7/31/2003	71.4	69.5	Weekday
7/3/2003	69.3	68.2	Weekday
7/10/2003	67.0	66.2	Weekday



How many models do you need?

Agenda

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Final Comments

- » How many rate classes are available?
- » What level of accuracy is required?
- » How much time/resources are available for modeling?
- » How much data can you handle?
- » What tools do you have to consolidate the results?

<u>Factors</u>	<u>Simple</u>	<u>Detailed</u>	<u>Considerations</u>
Number of Rate Classes	5	11	smaller classes, end uses?
Number of Seasons	2	3	shoulder season?
Number of Day-Types	<u>2</u>	<u>3</u>	Mon/Fri, Sat/Sun?
Total Number of Models	20	99	



Modeling by Season and Day-Type

Agenda

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Detailed Steps

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Final Comments

- » Make sure your regression tools are easy to manipulate.
 - ✓ Spreadsheets are adequate for performing the analysis.
 - ✓ Consider whether to use “dummy” variables.
 - ✓ Statistics can be misleading. Always look at the picture.
- » Don't Confuse Seasons with Weather
 - ✓ Check whether usage differs at similar temperatures.
 - ✓ Annual model is simpler than multiple seasonal models.
- » Day-types vary by rate class
 - ✓ Commercial customers use less energy on weekends.
 - ✓ Residential customers use more energy on weekends.
 - ✓ Weekday differences may depend on industry.



Choosing Appropriate Seasons

Agenda

Concept

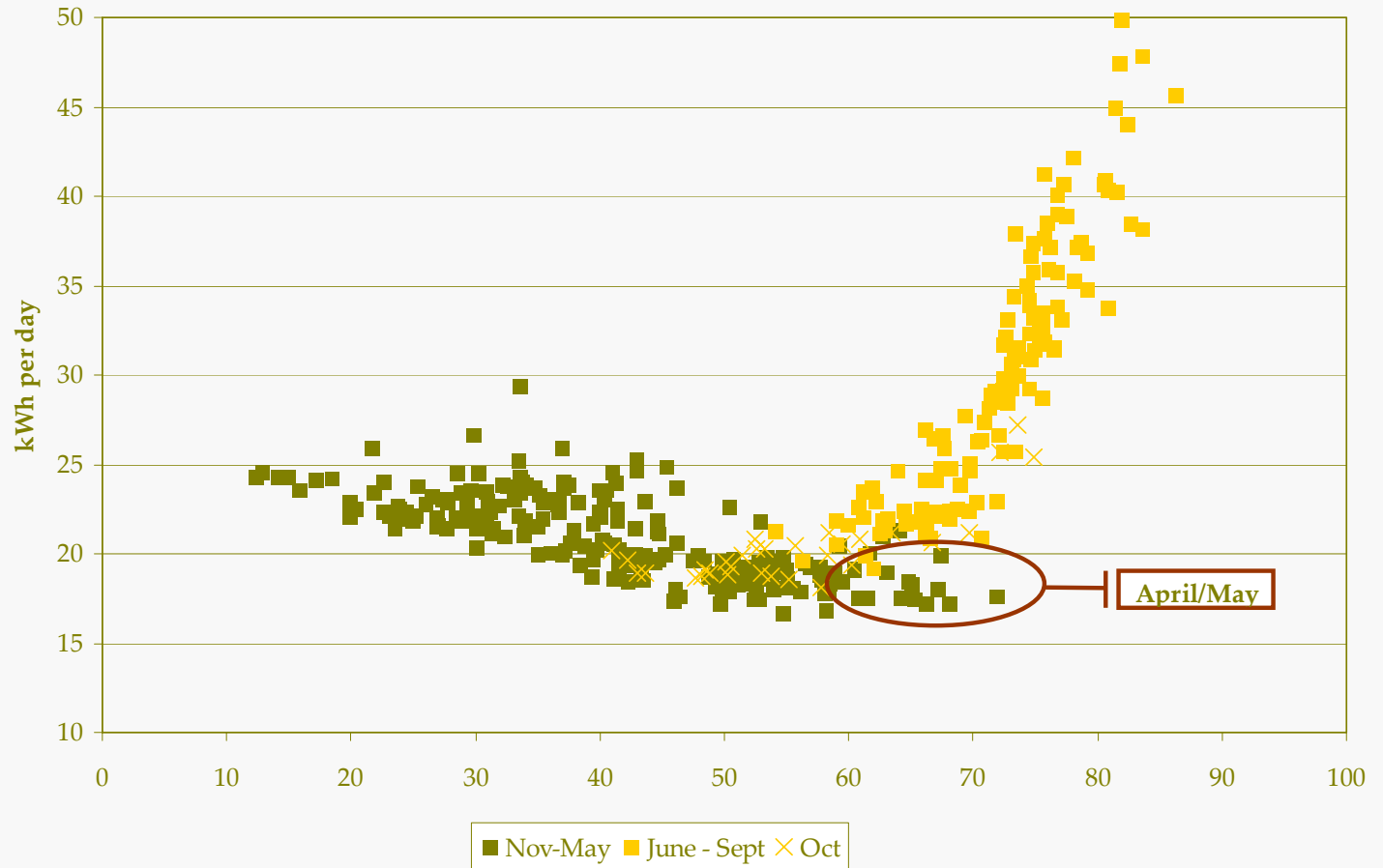
- ✓ Drill Down
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Detailed Steps

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Final Comments

Residential General





Distinguishing Weekends from Weekdays

Agenda

Concept

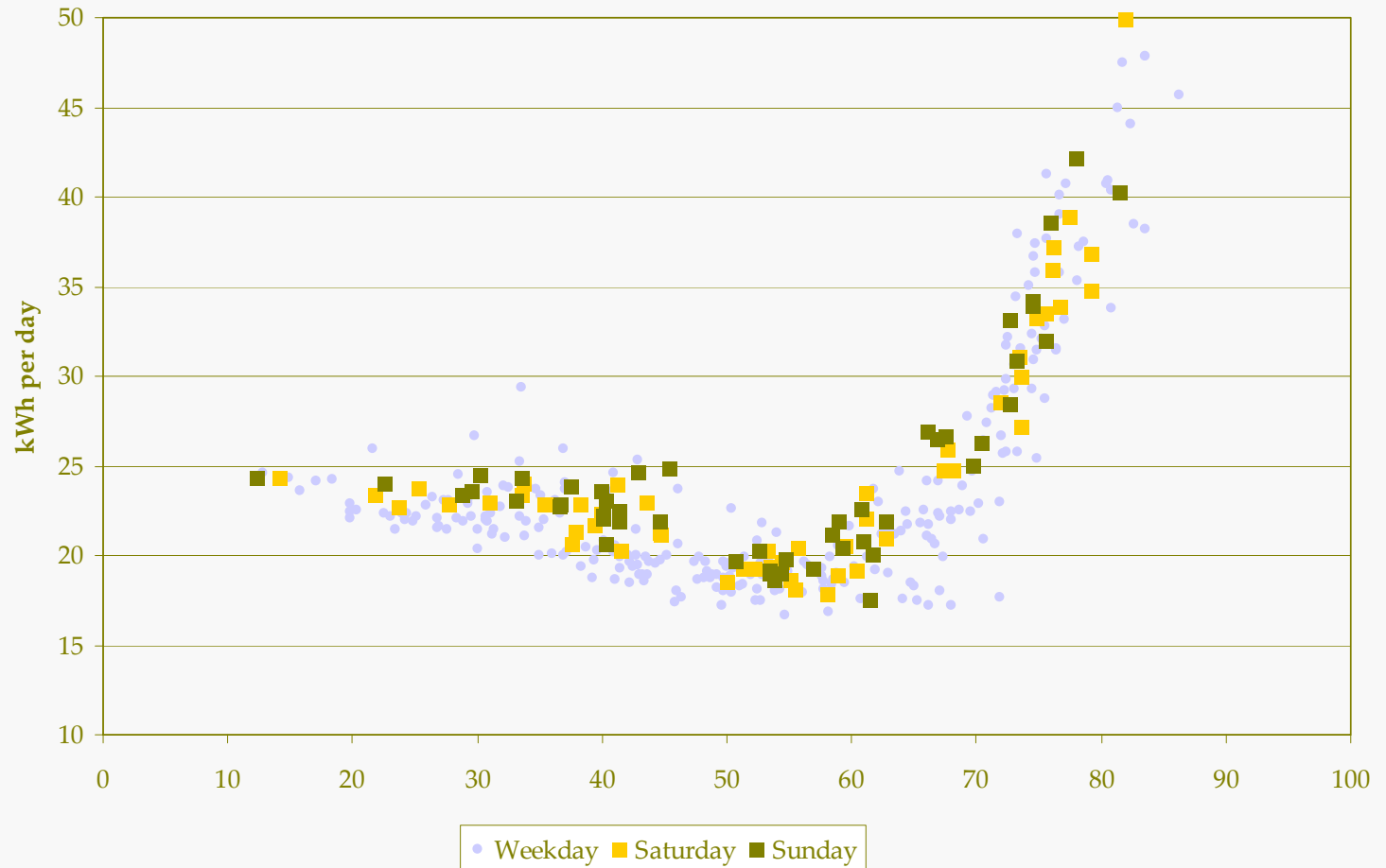
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Final Comments

Residential General





Distinguishing Between Weekdays

Agenda

Concept

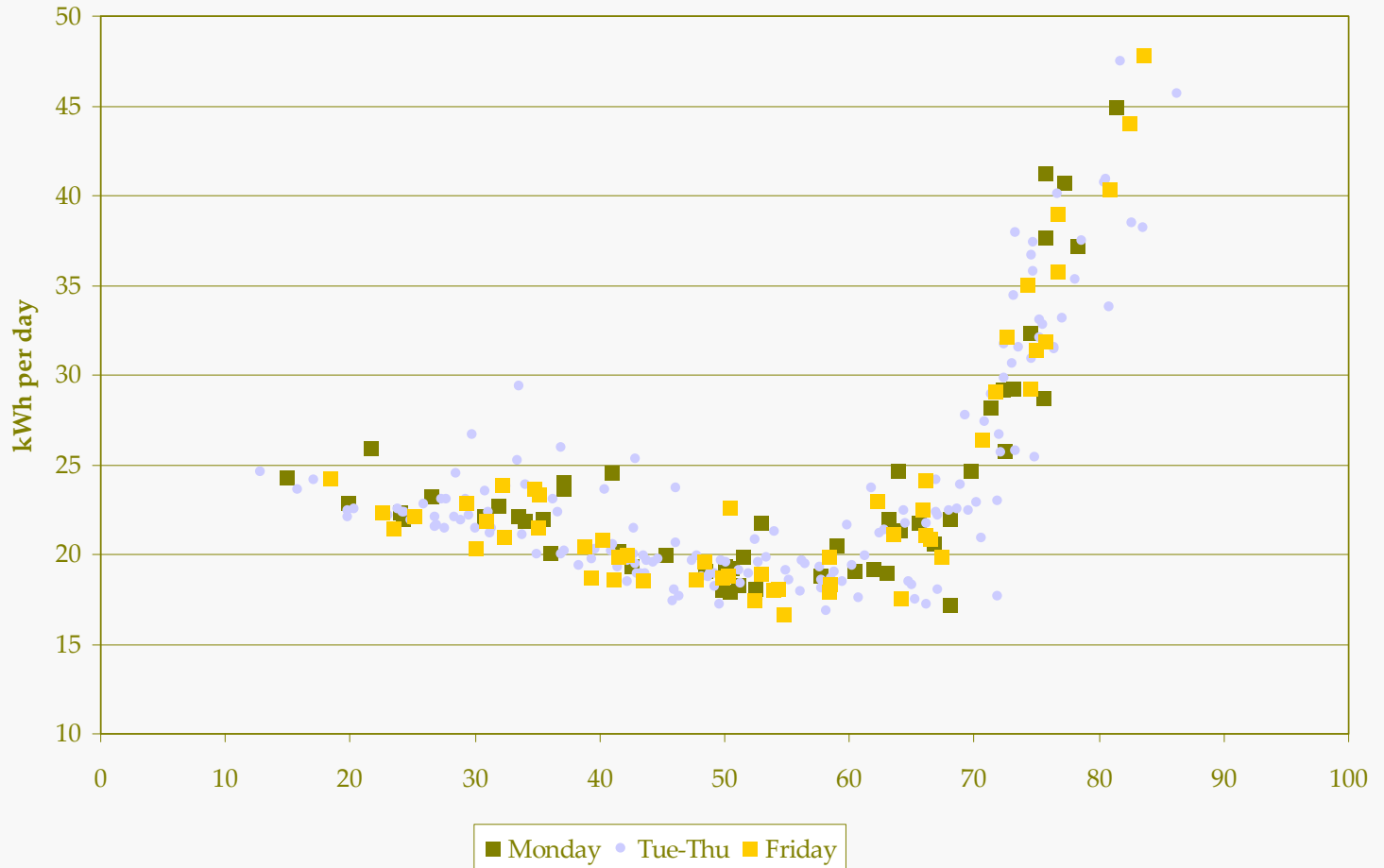
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Final Comments

Residential General





Recommended Seasons and Day Types

Agenda

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Final Comments

Based on the data presented today:

- » Two seasons are recommended for Residential General
 - ✓ Summer includes June through October.
 - ✓ Winter includes November through May.
- » Two day types are recommended for Residential General
 - ✓ Weekdays include Monday through Friday.
 - ✓ Weekends include Saturday and Sunday.



Final Comments – You Can Do This!

Agenda

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Final Comments

- » You have the skills.
 - ✓ Load analysis is part of load research skill set.
 - ✓ Forecasters can always assist with regression skills.
- » You have the tools.
 - ✓ Many companies have HELM, Load Vision, etc.
 - ✓ You can always do this on a spreadsheet.
- » You have the data.
 - ✓ Use as much load research as you have.
 - ✓ Estimate or “proxy” any missing rate classes.
 - ✓ If you don’t have normalized results for the system, then you can start the process here and now.
- » You can get the results.
 - ✓ System load requirements are improved by the application of load research results.
 - ✓ Fuel cost budgets and system planning will be improved.