ENERGY CENTER
State Utility Forecasting Group (SUFG)

Methods for Forecasting Energy Supply and Demand

Presented by:
Douglas J. Gotham
State Utility Forecasting Group
Energy Center
Purdue University

Presented to:
Institute of Public Utilities
50th Annual Regulatory Studies Program

August 11, 2008

Outline

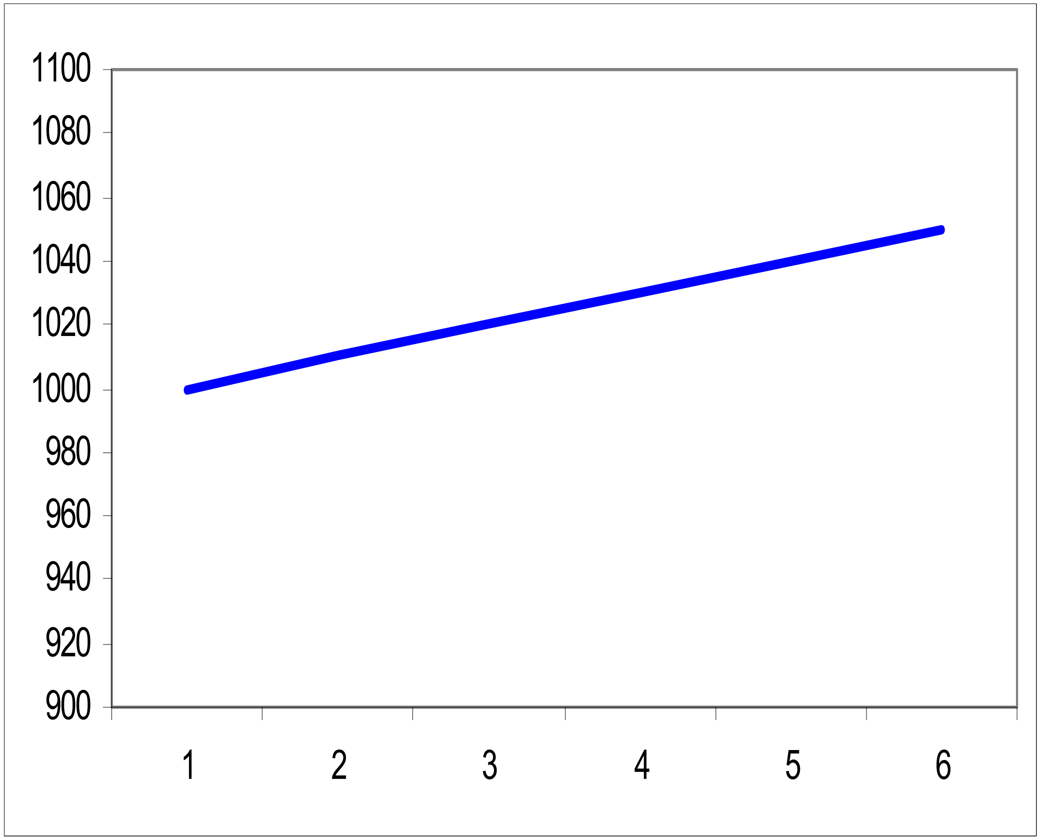
- Modeling techniques
- Projecting peak demand from energy forecasts
- Determining capacity needs from demand forecasts
- Incorporating load management and conservation measures
- Uncertainty

Using the Past to Predict the Future

- What is the next number in the following sequences?
  - 0, 2, 4, 6, 8, 10, 12, 14 ….
  - 0, 1, 4, 9, 16, 25, 36, 49, ...
  - 0, 1, 3, 6, 10, 15, 21, 28, ...
  - 0, 1, 2, 3, 5, 7, 11, 13, ...
  - 0, 1, 1, 2, 3, 5, 8, 13, ...
  - 8, 5, 4, 9, 1, 7, 6, ….

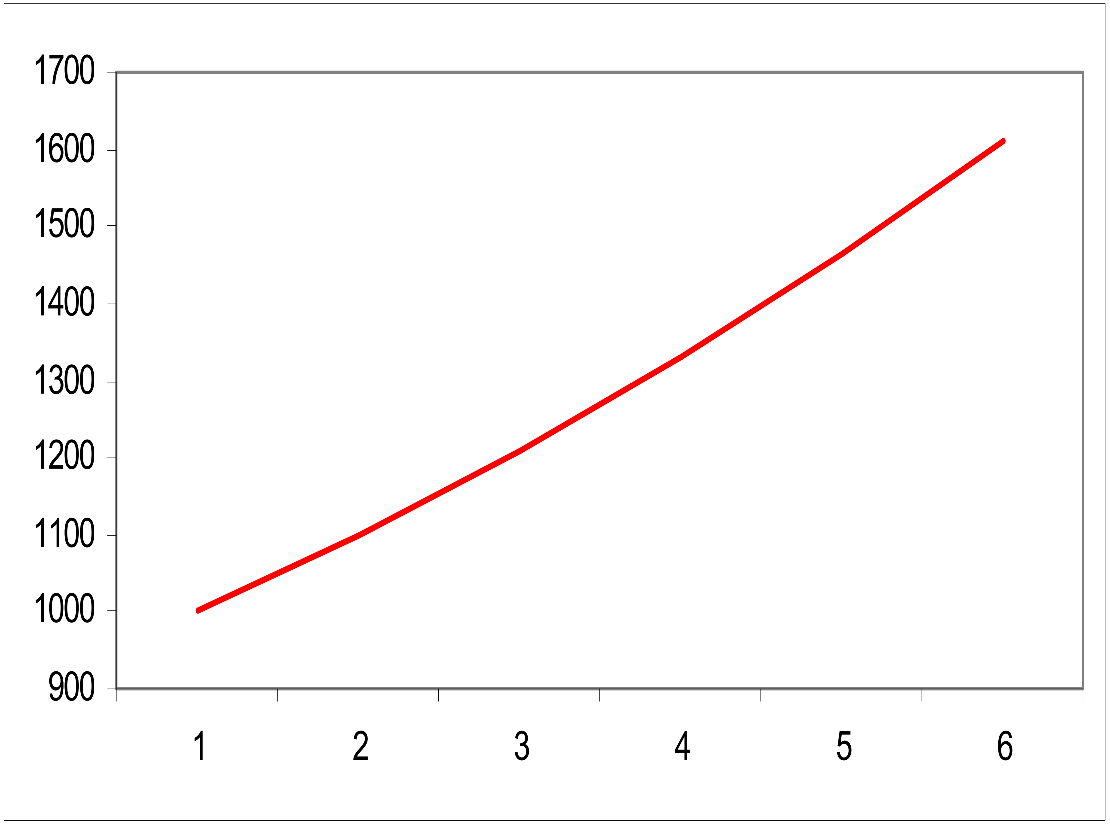
A Simple Example

1000
1010
1020
1030
1040
1050
?
?
?



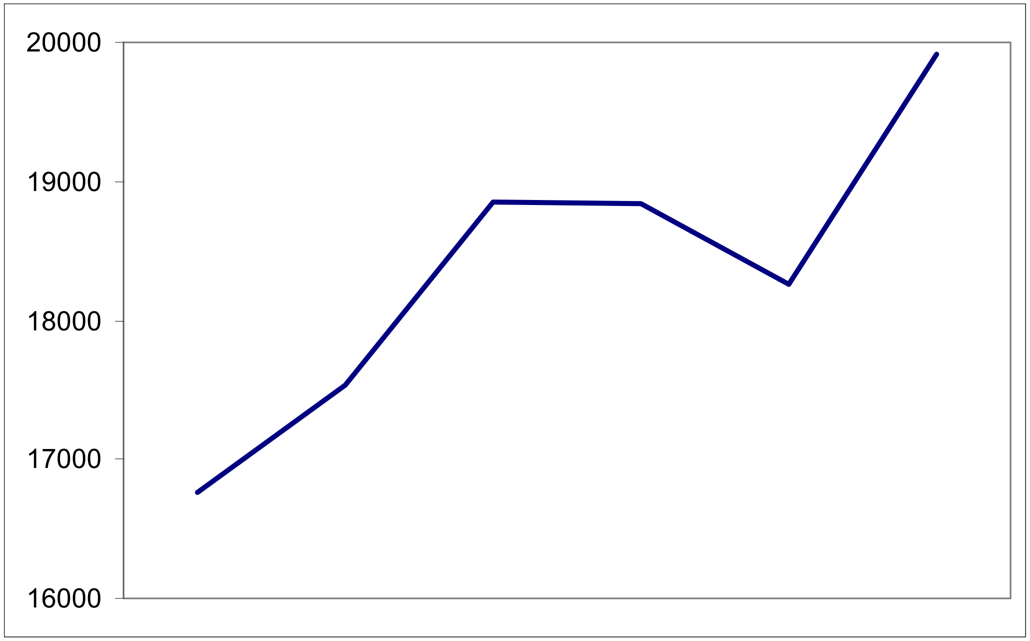
A Little More Difficult

1000
1100
1210
1331
1464
1610
?
?
?



Much More Difficult

16757
17531
18851
18843
18254
19920
?
?
?

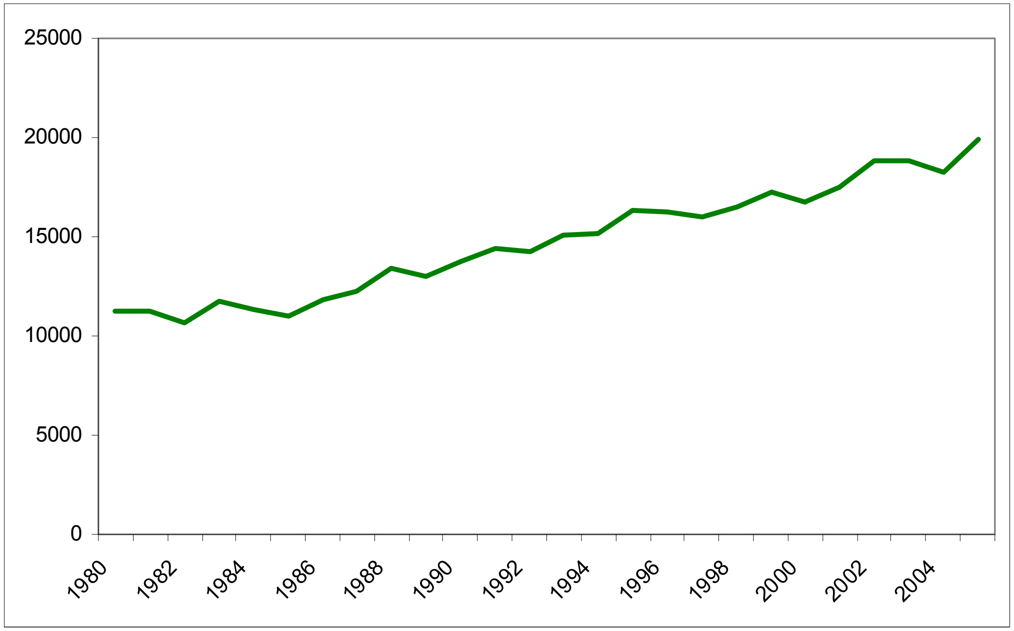


Much More Difficult

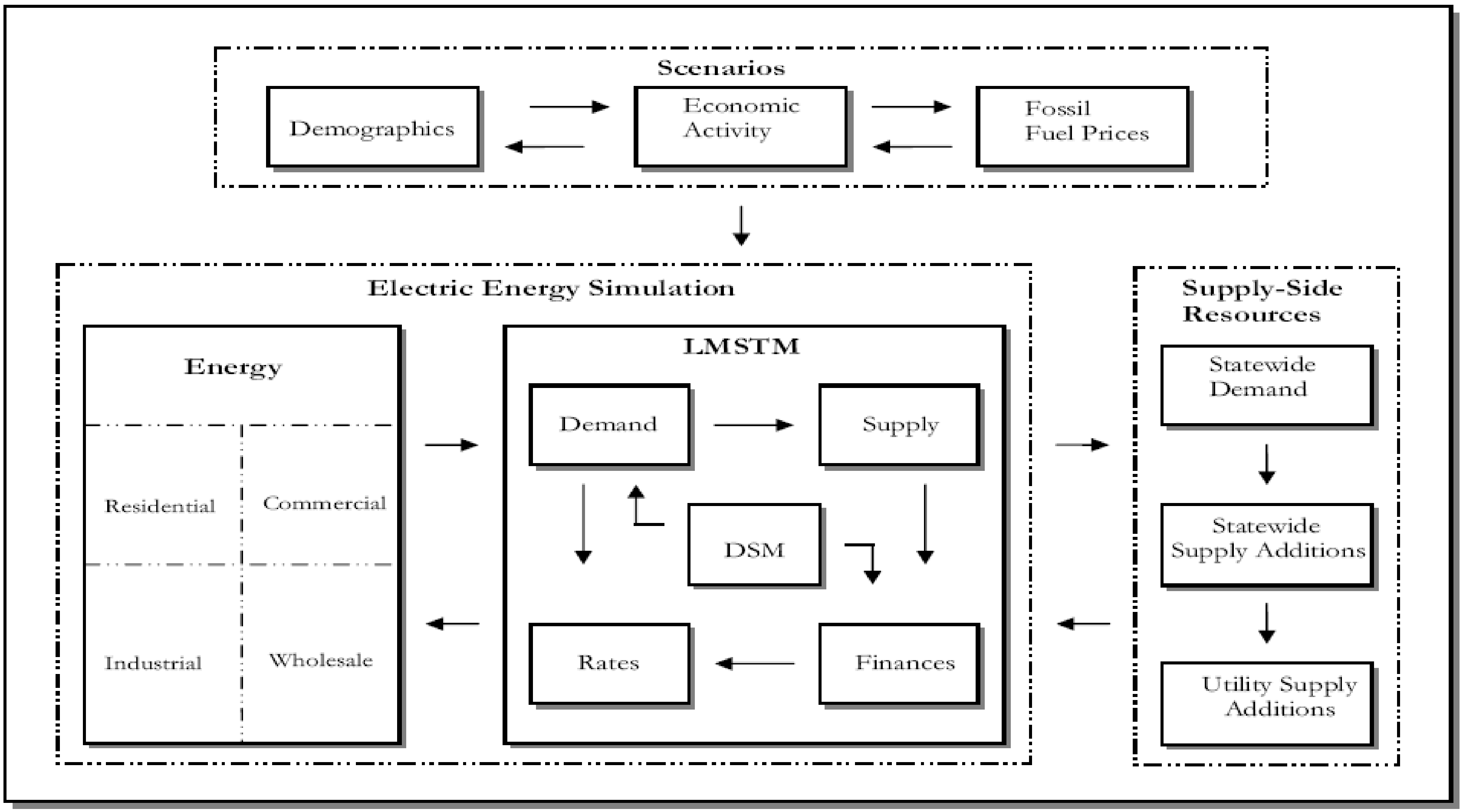
- The numbers on the previous slide were the summer peak demands for Indiana from 2000 to 2005.
- They are affected by a number of factors
  - Weather
  - Economic activity
  - Price
  - Interruptible customers called upon
  - Price of competing fuels

Question

- How do we find a pattern in these peak demand numbers to predict the future?



The Short Answer



Methods of Forecasting

- Time Series
  - trend analysis
- Econometric
  - structural analysis
- End Use
  - engineering analysis

Time Series Forecasting

- Linear Trend
  - Fit the best straight line to the historical data and assume that the future will follow that line
    - works perfectly in the 1st example
  - Many methods exist for finding the best fitting line; the most common is the least squares method
- Polynomial Trend
  - Fit the polynomial curve to the historical data and assume that the future will follow that line
  - Can be done to any order of polynomial (square, cube, etc.) but higher orders are usually needlessly complex
- Logarithmic Trend
  - Fit an exponential curve to the historical data and assume that the future will follow that line
    - works perfectly for the 2nd example

Good News and Bad News

- The statistical functions in most commercial spreadsheet software packages will calculate many of these for you.
- These may not work well when there is a lot of variability in the historical data.
- If the time series curve does not perfectly fit the historical data, there is model error.
  - There is normally model error when trying to forecast a complex system.

Methods Used to Account for Variability

- Modeling seasonality/cyclicality
- Smoothing techniques
  - Moving averages
  - Weighted moving averages
  - Exponentially weighted moving averages
- Filtering techniques
- Box-Jenkins

Econometric Forecasting

- Econometric models attempt to quantify the relationship between the parameter of interest (output variable) and a number of factors that affect the output variable.
- Example
  - Output variable
  - Explanatory variable
    - Economic activity
    - Weather (HDD/CDD)
    - Electricity price
    - Natural gas price
    - Fuel oil price

Estimating Relationships

- Each explanatory variable affects the output variable in different ways. The relationships can be calculated via any of the methods used in time series forecasting.
  - Can be linear, polynomial, logarithmic, moving averages, …
- Relationships are determined simultaneously to find overall best fit.
- Relationships are commonly known as sensitivities.

Example Sensitivities for State of Mississippi

A 10 percent increase in:	Results in this increase in electricity sales
Electricity price	-3.0 percent
Cooling degree days	+0.7 percent
Real personal income	+7.8 percent

End Use Forecasting

- End use forecasting looks at individual devices, aka end uses (e.g., refrigerators)
- How many refrigerators are out there?
- How much electricity does a refrigerator use?
- How will the number of refrigerators change in the future?
- How will the amount of use per refrigerator change in the future?
- Repeat for other end uses

The Good News

- Account for changes in efficiency levels (new refrigerators tend to be more efficient than older ones) both for new uses and for replacement of old equipment
- Allow for impact of competing fuels (natural gas vs. electricity for heating) or for competing technologies (electric resistance heating vs. heat pump)
- Incorporate and evaluate the impact of demand-side management/conservation programs

The Bad News

- Tremendously data intensive
- Primarily limited to forecasting energy usage, unlike other forecasting methods
  - Most long-term planning electricity forecasting models forecast energy and then derive peak demand from the energy forecast

Example

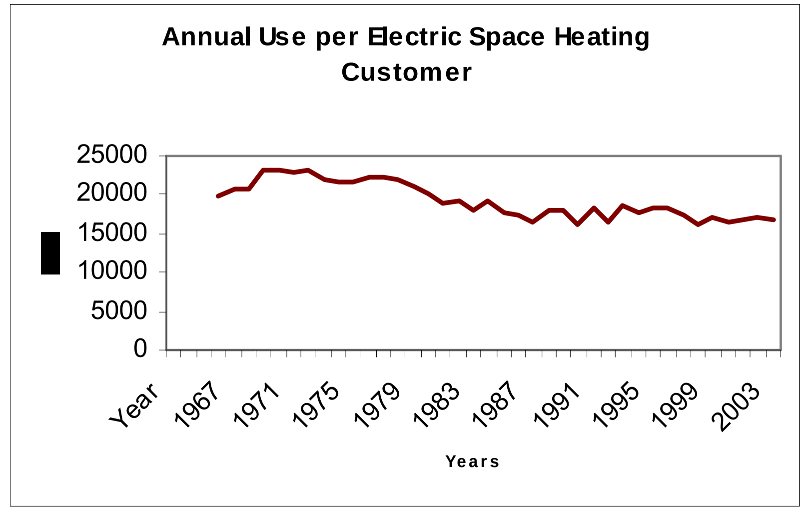
- State Utility Forecasting Group (SUFG) has electrical energy models for each of 8 utilities in Indiana
- Utility energy forecasts are built up from sectoral forecasting models
  - residential (econometric)
  - commercial (end use)
  - industrial (econometric)

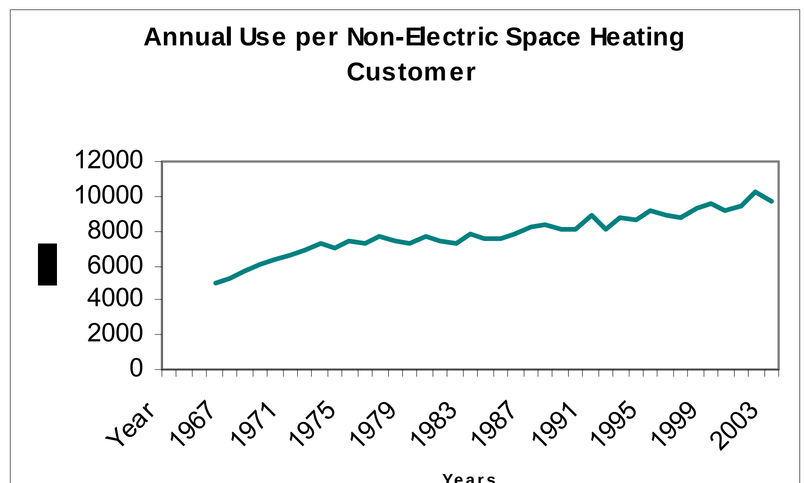
Another Example

- The Energy Information Administration's National Energy Modeling System (NEMS) projects energy and fuel prices for 9 census regions
- Energy demand
  - residential
  - commercial
  - industrial
  - transportation

SUFG Residential Sector Model

- Residential sector split according to space heating source
  - electric
  - non-electric
- Major forecast drivers
  - demographics
  - households
  - household income
  - energy prices





Residential Model Sensitivities

10 Percent Increase In	Causes This Percent Change in Electric Use
Number of Customers	11.1
Electric Rates	-2.4
Natural Gas Price	1.0
Distillate Oil Prices	0.0
Appliance Price	-1.8
Household Income	2.0

Source: SUFG 2007 Forecast

NEMS Residential Module

- Sixteen end-use services
  - i.e., space heating
- Three housing types
  - single family, multi-family, mobile home
- 34 end-use technologies
  - i.e., electric air-source heat pump
- Nine census divisions

SUFG Commercial Sector Model

- Major forecast drivers
  - floor space inventory
  - end use intensity
  - employment growth
  - energy prices
- 10 building types modeled
  - offices, restaurants, retail, groceries, warehouses, schools, colleges, health care, hotel/motel, miscellaneous
- 14 end uses per building type
  - space heating, air conditioning, ventilation, water heating, cooking, refrigeration, lighting, mainframe computers, mini-computers, personal computers, office equipment, outdoor lighting, elevators and escalators, other

Commercial Model Sensitivities

10 Percent Increase In	Causes This Percent Change in Electric Use
Electric Rates	-2.5
Natural Gas Price	0.2
Distillate Oil Prices	0.0
Coal Prices	0.0
Electric Energy-weighted Floor Space	12.0

Source: SUFG 2005 Forecast

NEMS Commercial Module

- Ten end-use services
  - i.e., cooking
- Eleven building types
  - i.e., food service
- 64 end-use technologies
  - i.e., natural gas range
- Ten distributed generation technologies
  - i.e., photovoltaic solar systems
- Nine census divisions

SUFG Industrial Sector Model

- Major forecast drivers
  - industrial activity
  - energy prices
- 15 industries modeled
  - classified by Standard Industrial Classification (SIC) system
  - some industries are very energy intensive while others are not

Indiana's Industrial Sector

SIC	Name	Current Share of GSP	Current Share of Electricity Use	Forecast Growth in GSP Originating by Sector	Forecast Growth in Electricity by Intensity by Sector	Forecast Growth in Electricity Use by Sector
20	Food & Kindred Products	3.51	5.61	0.96	-0.79	0.17
24	Lumber & Wood Products	1.95	0.70	0.96	-0.42	0.54
25	Furniture & Fixtures	1.60	0.46	0.62	-0.64	-0.02
26	Paper & Allied Products	1.36	2.96	0.96	-0.56	0.40
27	Printing & Publishing	2.55	1.30	0.96	-0.96	0.00
28	Chemicals & Allied Products	14.25	17.10	3.49	-0.80	2.70
30	Rubber & Misc. Plastic Products	4.77	6.25	4.52	-0.67	3.85
32	Stone, Clay, & Glass Products	1.76	5.30	0.96	-0.67	0.29
33	Primary Metal Products	8.55	31.34	1.02	1.76	2.77
34	Fabricated Metal Products	6.25	5.29	2.51	-0.76	1.75
35	Industrial Machinery & Equipment	6.73	4.44	1.05	-0.68	0.37
36	Electronic & Electric Equipment	16.19	5.54	5.33	-0.56	4.77
37	Transportation Equipment	22.89	9.38	3.87	-0.68	3.19
38	Instruments And Related Products	4.98	0.77	5.33	-0.86	4.47
39	Miscellaneous Manufacturing	1.63	1.06	4.19	-5.24	-1.05
Total	Manufacturing	100.00	100.00	3.48	-0.81	2.67

Source: SUFG 2007 Forecast

Industrial Model Sensitivities

10 Percent Increase In	Causes This Percent Change in Electric Use
Real Manufacturing Product	10.0
Electric Rates	-4.8
Natural Gas Price	1.4
Oil Prices	0.9
Coal Prices	0.2

Source: SUFG 2007 Forecast

NEMS Industrial Module

- Seven energy-intensive industries
  - i.e., bulk chemicals
- Eight non-energy-intensive industries
  - i.e., construction
- Cogeneration
- Four census regions, shared to nine census divisions

Energy → Peak Demand

- Constant load factor / load shape
  - Peak demand and energy grow at same rate
- Constant load factor / load shape for each sector
  - Calculate sectoral contribution to peak demand and sum
  - If low load factor (residential) grows fastest, peak demand grows faster than energy
  - If high load factor (industrial) grows fastest, peak demand grows slower than energy

Energy → Peak Demand

- Day types
  - Break overall load shapes into typical day types
    - low, medium, high
    - weekday, weekend, peak day
  - Adjust day type for load management and conservation programs
  - Can be done on a total system level or a sectoral level

Load Diversity

- Each utility does not see its peak demand at the same time as the others
- 2005 peak demands occurred at:
  - Hoosier Energy – 7/25, 6PM
  - Indiana Michigan - 8/3, 2PM
  - Indiana Municipal Power Agency – 7/25, 3PM
  - Indianapolis Power & Light - 7/25, 3PM
  - NIPSCO – 6/24, 1PM
  - PSI Energy – 7/25, 4PM
  - SIGECO – 7/25, 4PM
  - Wabash Valley – 7/24, 5PM

Load Diversity

- Thus, the statewide peak demand is less than the sum of the individual peaks
- Actual statewide peak demand can be calculated by summing up the load levels of all utilities for each hour of the year
- Diversity factor is an indication of the level of load diversity
- Historically, Indiana’s diversity factor has been about 96 – 97 percent
  - that is, statewide peak demand is usually about 96 percent of the sum of the individual utility peak demands

Peak Demand → Capacity Needs

- Target reserve margin
- Loss of load probability (LOLP)
- Expected unserved energy (EUE)
- Assigning capacity needs to type
  - peaking
  - baseload
  - intermediate
- Optimization

Reserve Margin vs. Capacity Margin

$$RM = \frac{capacity - demand}{demand} x100\% \qquad CM = \frac{capacity - demand}{capacity} x100\%$$

- Both reserve margin (RM) and capacity margin (CM) are the same when expressed in megawatts
  - difference between available capacity and demand
- Normally expressed as percentages

Reserve Margins

- Reserve/capacity margins are relatively easy to use and understand, but the numbers are easy to manipulate
  - Contractual off-system sale can be treated as a reduction in capacity or increase in demand
    - does not change the MW margin, but will change the percentage
  - Similarly, interruptible loads and direct load control is sometimes shown as an increase in capacity

LOLP and EUE

- Probabilistic methods that account for the reliability of the various sources of supply
- Loss of load probability
  - given an expected demand for electricity and a given set of supply resources with assumed outage rates, what is the likelihood that the supply will not be able to meet the demand?
- Expected unserved energy
  - similar calculation to find the expected amount of energy that would go unmet
- Both are used in resource planning to ensure that sufficient capacity is available for LOLP and/or EUE to be less than a minimum allowable level

Capacity Types

- Once the amount of capacity needed in a given year is determined, the next step is to determine what type of capacity is needed
  - peaking (high operating cost, low capital cost)
  - baseload (low operating cost, high capital cost)
  - intermediate or cycling (operating and capital costs between peaking and baseload)
    - some planners only use peaking and baseload

Assigning Demand to Type

- SUFG uses historical load shape analysis for each of the utilities to assign a percentage of their peak demand to each load type
- Percentages vary from utility to utility according to the characteristics of their customers
  - utilities with a large industrial base tend to have a higher percentage of baseload demand
  - those with a large residential base tend to have a higher percentage of peaking demand
- Rough breakdown:
  - baseload 65%, intermediate 15%, peaking 20%

Assigning Existing Resources

- SUFG then assigns existing generation to the three types according to age, size, fuel type, and historical usage patterns
- Purchased power contracts are assigned to type according to time period (annual or summer only) and capacity factor
- Power sales contracts are also assigned to type

Assigning Capacity Needs to Type

- Future resource needs by type are determined by comparing existing capacity to projected demand, while accounting for interruptible and buy through loads, as well as firm purchases and sales and retirement of existing units
- Breakdown of demand by type is not projected to change across the forecast horizon

NEMS Electricity Market Module

- Eleven fossil generation technologies
  - i.e., advanced clean coal with sequestration
- Two distributed generation technologies
  - baseload and peak
- Seven renewable generation technologies
  - i.e., geothermal
- Conventional and advanced nuclear
- Fifteen supply regions based on NERC regions and sub-regions

Load Management and Conservation Measures

- Direct load control and interruptible loads generally affect peak demand but not energy forecasts
  – delay consumption from peak time to off-peak time
  – usually subtract from peak demand projections
- Efficiency and conservation programs generally affect both peak demand and energy forecasts
  – consumption is reduced instead of delayed
  – usually subtract from energy forecast before peak demand calculations

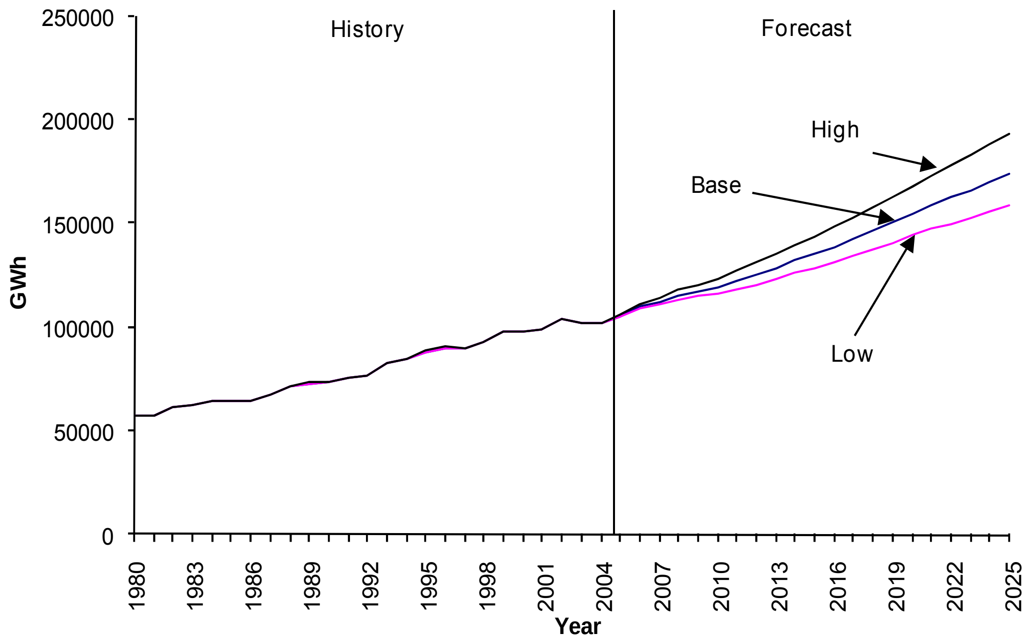
Sources of Uncertainty

- Exogenous assumptions
  - forecast is driven by a number of assumptions (e.g., economic activity) about the future
- Stochastic model error
  - it is usually impossible to perfectly estimate the relationship between all possible factors and the output
- Non-stochastic model error
  - bad input data (measurement/estimation error)

Alternate Scenarios

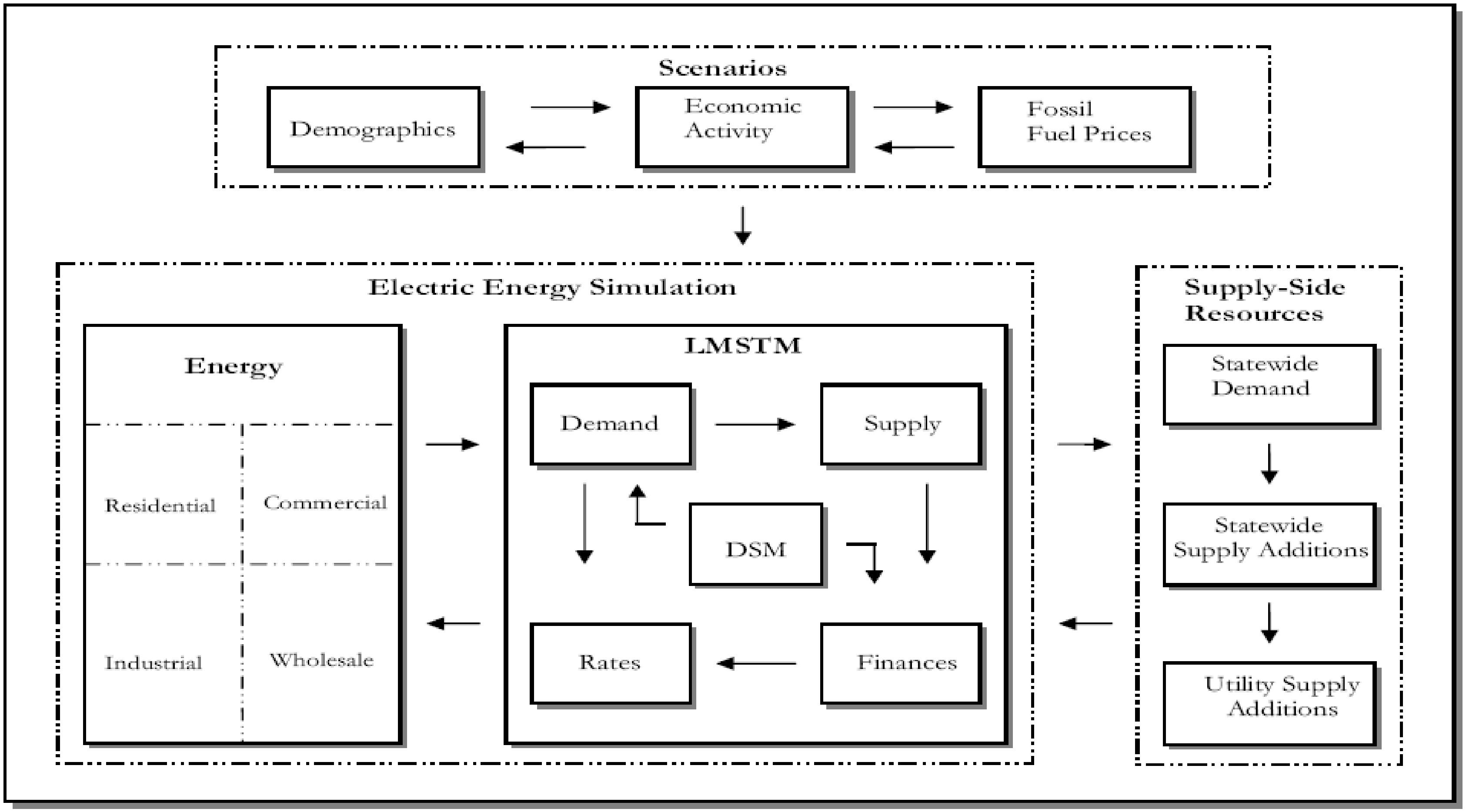
- Given the uncertainty surrounding long-term forecasts, it is inadvisable to follow one single forecast

- SUFG develops alternative scenarios by varying the input assumptions



Source: SUFG 2007 Forecast

Back to the Short Answer



Further Information

- State Utility Forecasting Group
  - http://www.purdue.edu/dp/energy/SUFG/
- Energy Information Administration
  - http://www.eia.doe.gov/index.html