Systems Level Forecasting

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Outline

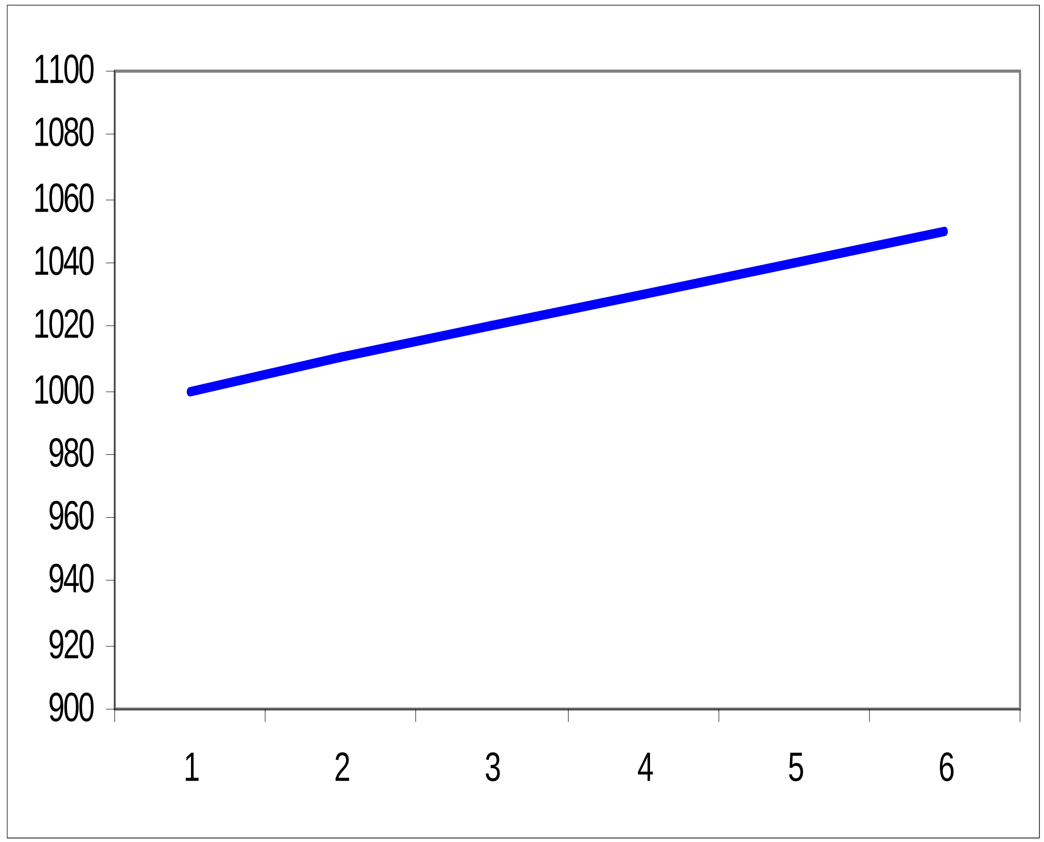
- Forecasting techniques
  - Time series
  - Econometric
  - End use
- Sector level forecasting
  - Residential
  - Commercial
  - Industrial
- Challenges

Using the Past to Predict the Future

- What is the next number in the following sequences?
  - 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, ...
- These types of problems are at the heart of what forecasters do

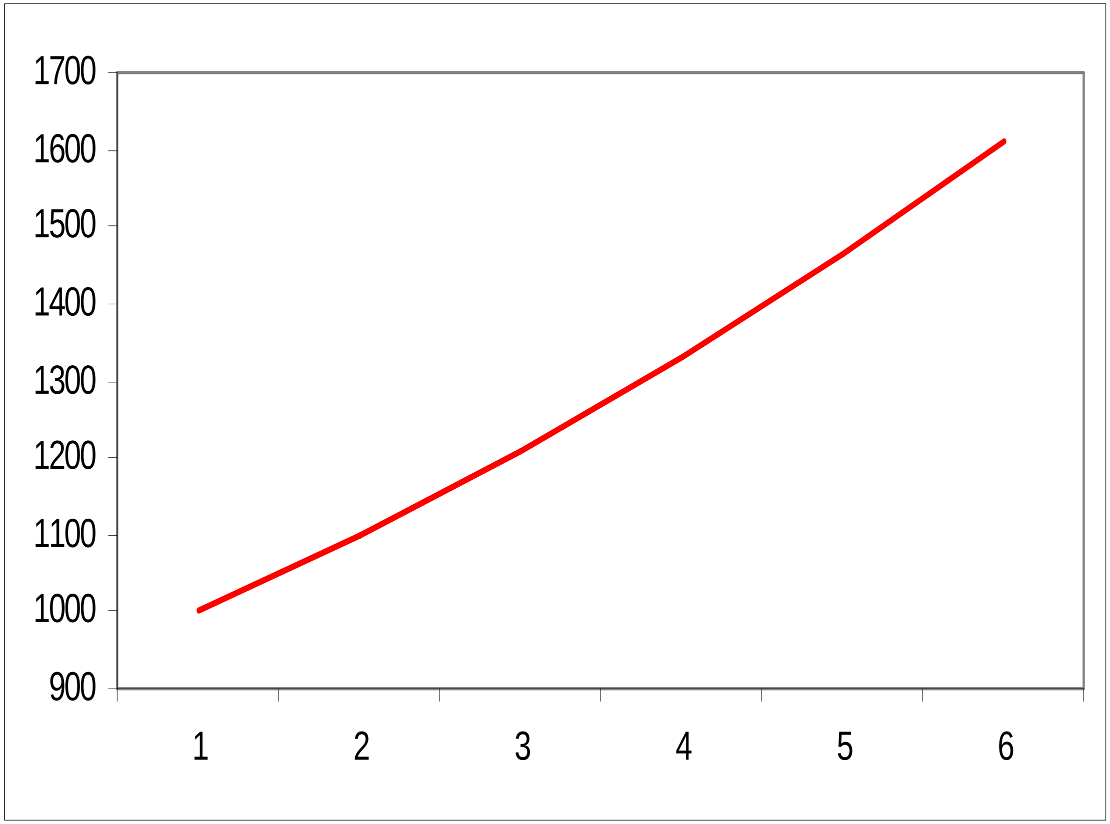
A Simple Example

1000
1010
1020
1030
1040
1050
?
?
?



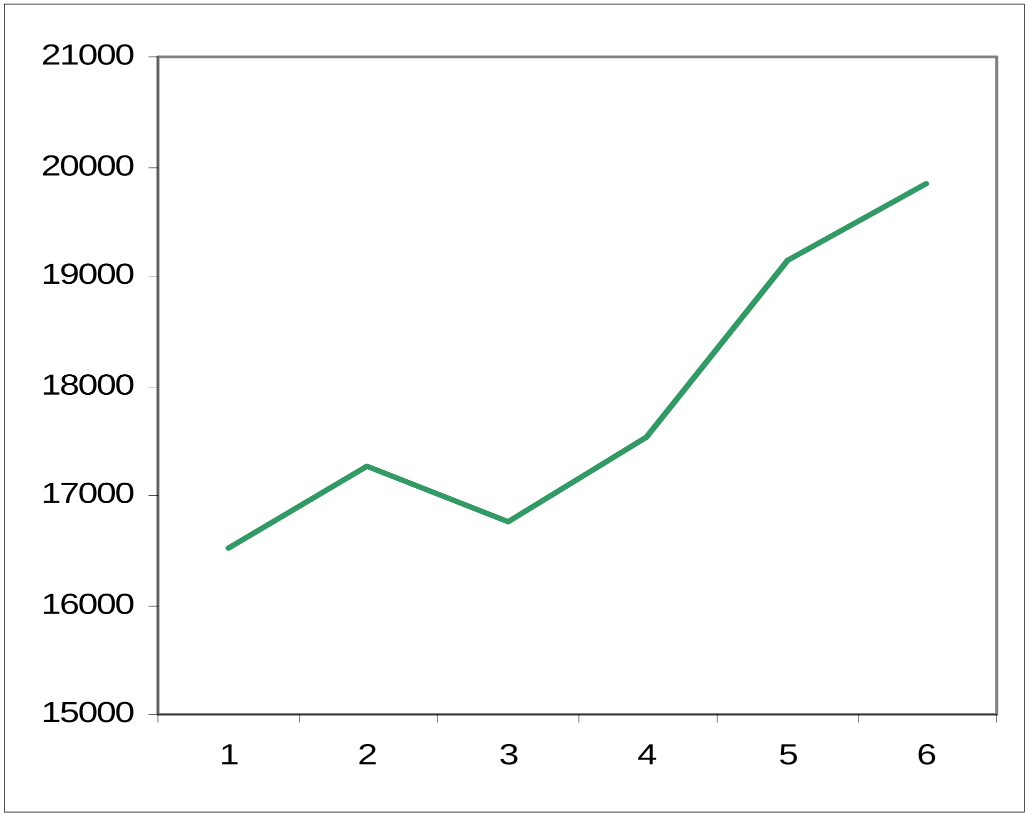
A Little More Difficult

1000
1100
1210
1331
1464
1610
?
?
?



Much More Difficult

16527
17266
16757
17531
19137
19839
?
?
?

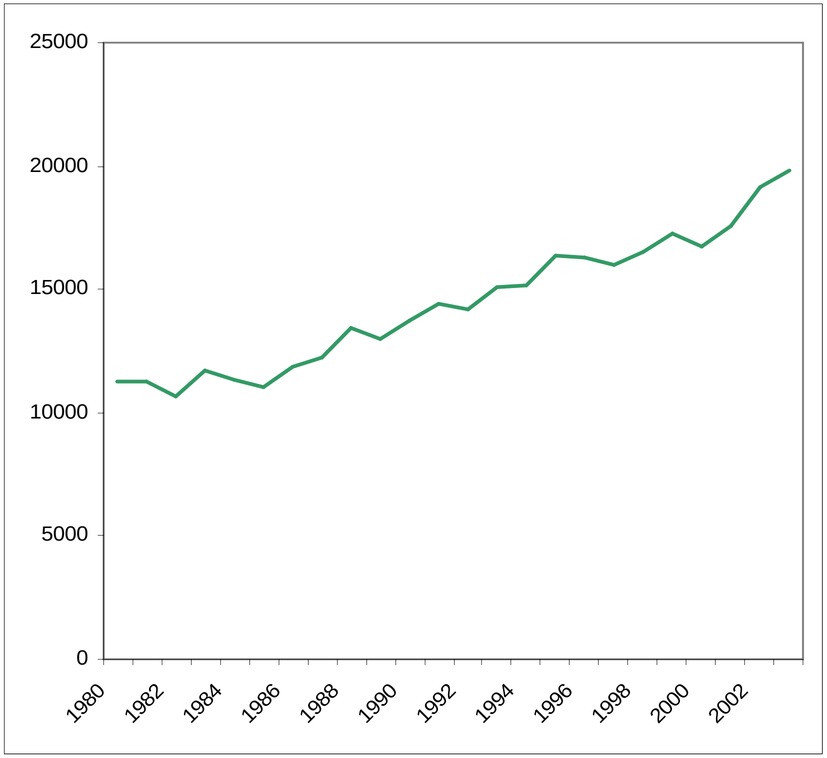


Much More Difficult

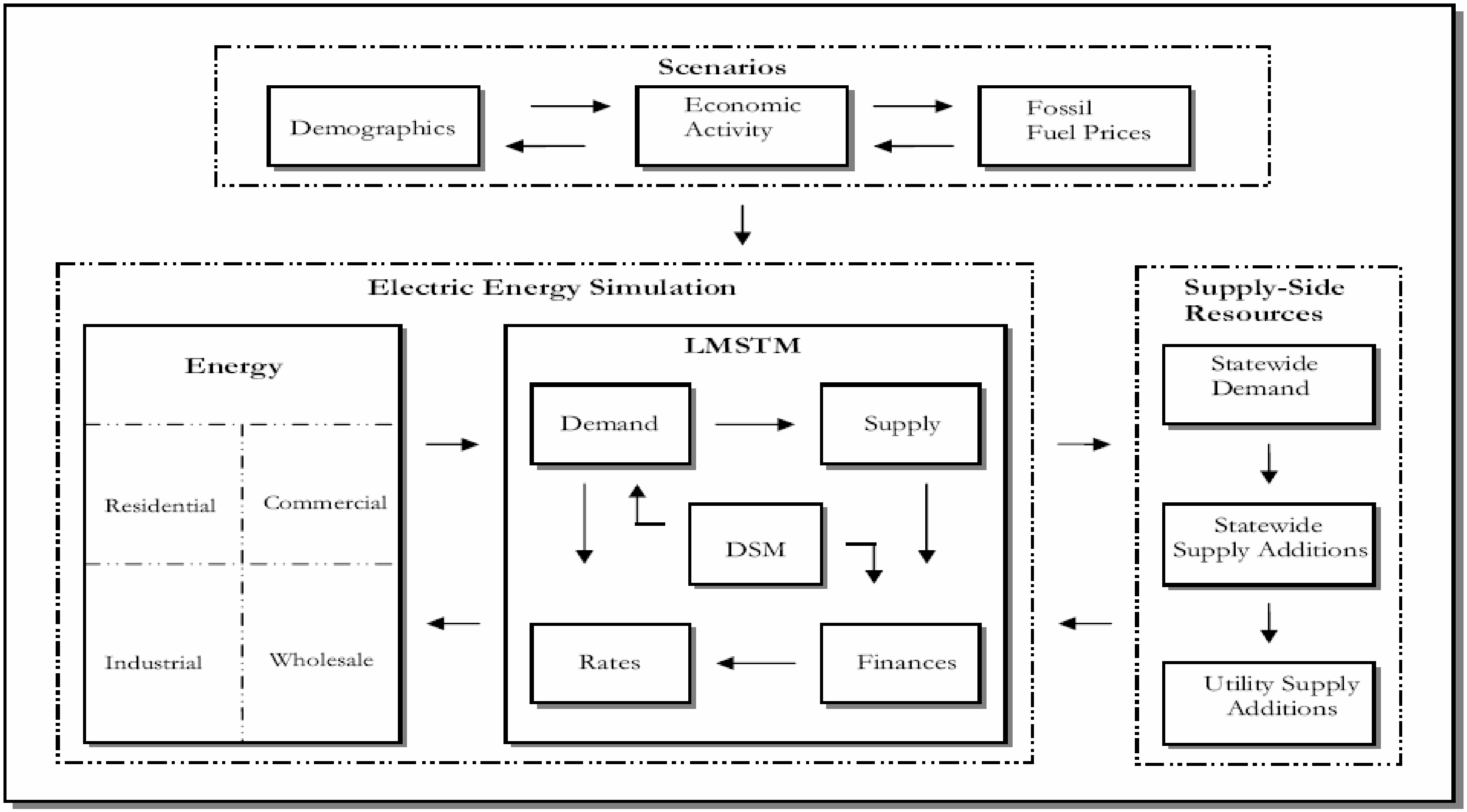
- The numbers on the previous slide were the summer peak demands for Indiana from 1998 to 2003.
- They are affected by a number of factors
  - Weather
  - Economic activity
  - Price
  - Interruptible customers called upon
  - Price of competing fuels

Question

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



The Short Answer



Methods of Forecasting

- Palm reading
- Tea leaves
- Tarot cards
- Ouija board
- Crystal ball
- Astrology
- Dart board
- Hire a consultant
- Wishful thinking

Alternative 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 ordinary least squares method

    - Ordinary least squares: find the line that minimizes the sum of the squares of the differences between the historical observations and the line

Time Series Forecasting

- 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 out put 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…
- Relationships are determined simultaneously to find overall best fit.
- Relationships are commonly known as sensitivities.
- A number of techniques have been developed to find a good fit (ordinary least squares, generalized least squares, etc.).

Example

- Project annual electricity requirements for Indiana using an Excel spreadsheet

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
- 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

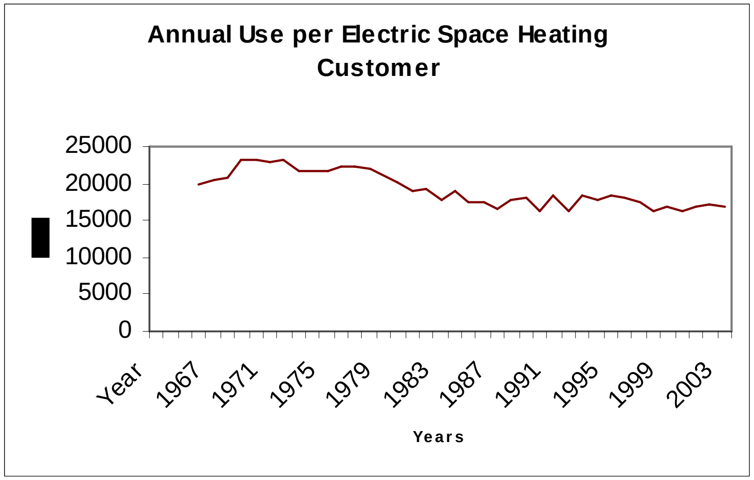
- The Energy Information Administration's National Energy Modeling System (NEMS) projects energy and fuel prices for 9 census regions
- Energy demand
  - residential
  - commercial
  - industrial
  - transportation

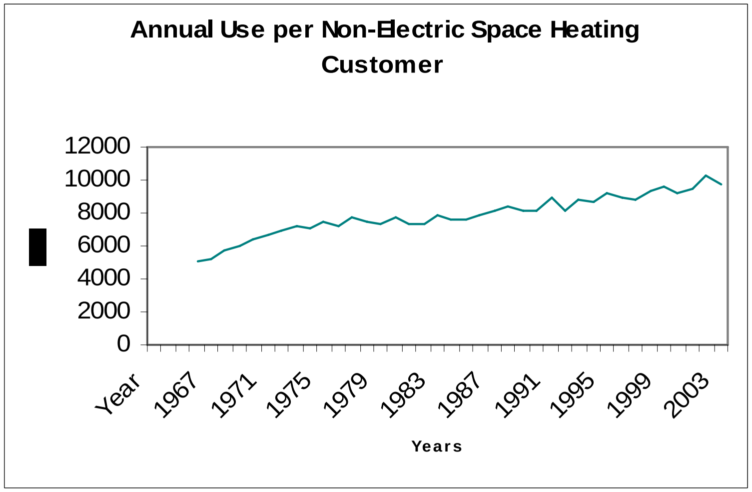
Residential Sector Model

Drivers?

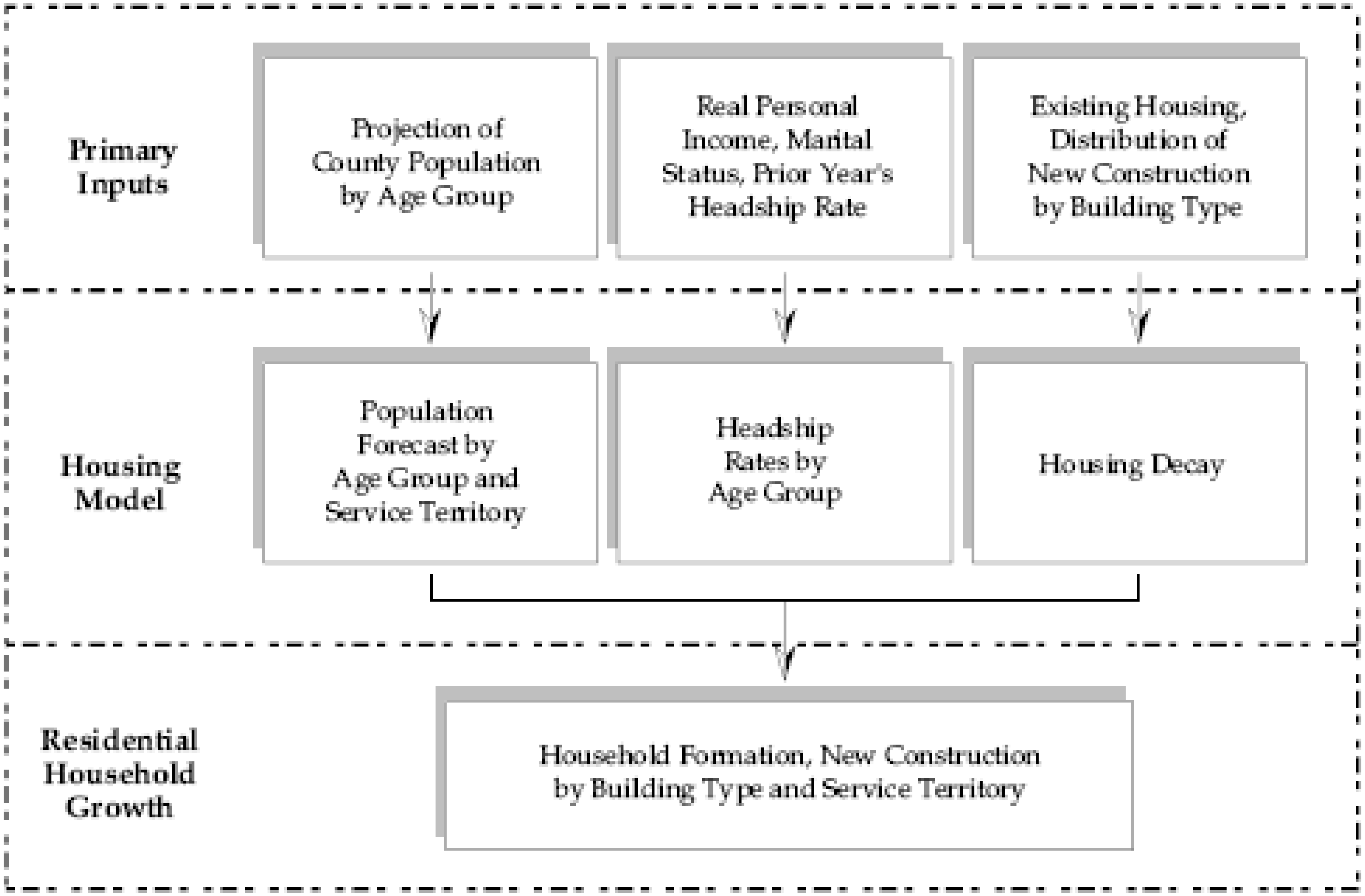
SUFG Residential Sector Model

- Residential sector split according to space heating source
  - electric
  - non-electric





Housing Formation Model



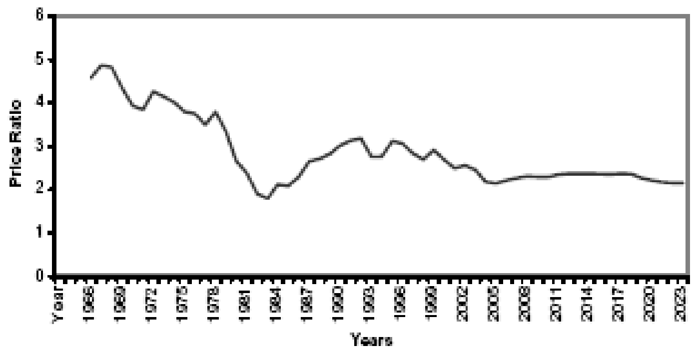
Expenditure Share Model

- SUFG uses the expenditure share model to project average electricity consumption by non-electric heating customers
- Relates the fraction of a household's total income that is spent on the commodity
- Log-log functional form
- Explanatory variables include: multi-period prices, real income per household, appliance price index, and heating/cooling degree days

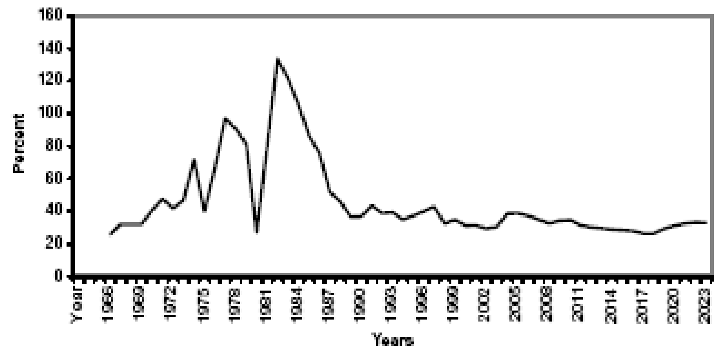
SUFG Residential Sector Model

- Major forecast drivers
  - demographics
  - households
  - household income
  - energy prices

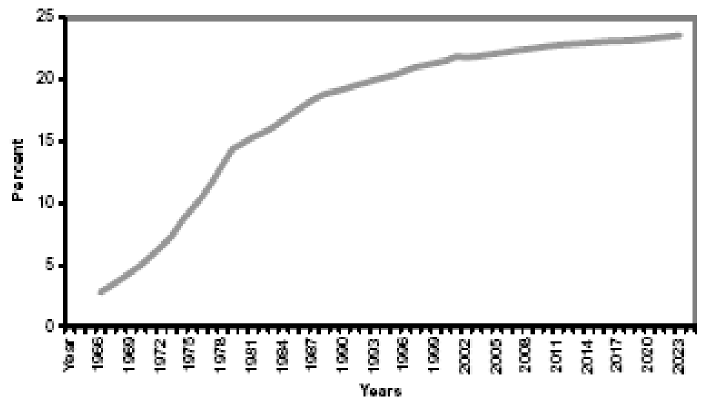
Panel A. Electric/Gas Price Ratio



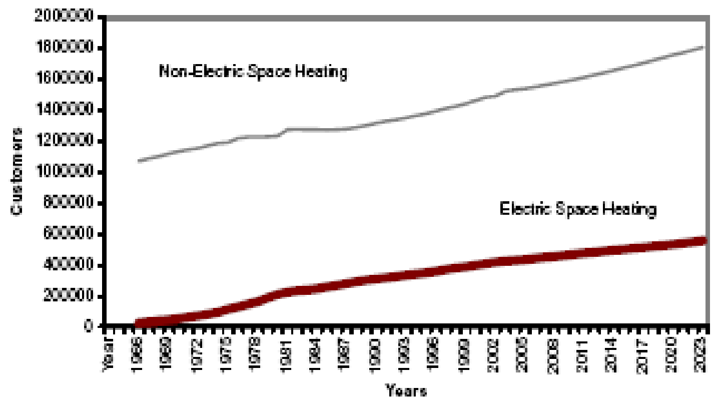
Panel B. Electric Space Heating Penetration



Panel C. Electric Space Heating Saturation



Panel D. Electric Customers



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

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

Commercial Sector Model

Drivers?

SUFG Commercial Sector Model

- 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

SUFG Commercial Model

- For each end use/building type combination there is an initial stock of equipment
- Initial stock is separated by age (vintage) and efficiency
- Additional stock for next year is determined by economic drivers
- Some existing stock will be replaced due to failure or early replacement
- Older vintages are more likely to be replaced

Major Commercial Drivers

- Floor space inventory
- End use intensity
- Employment growth
- Population (schools and colleges)
- Energy prices

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

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

Industrial Sector Model

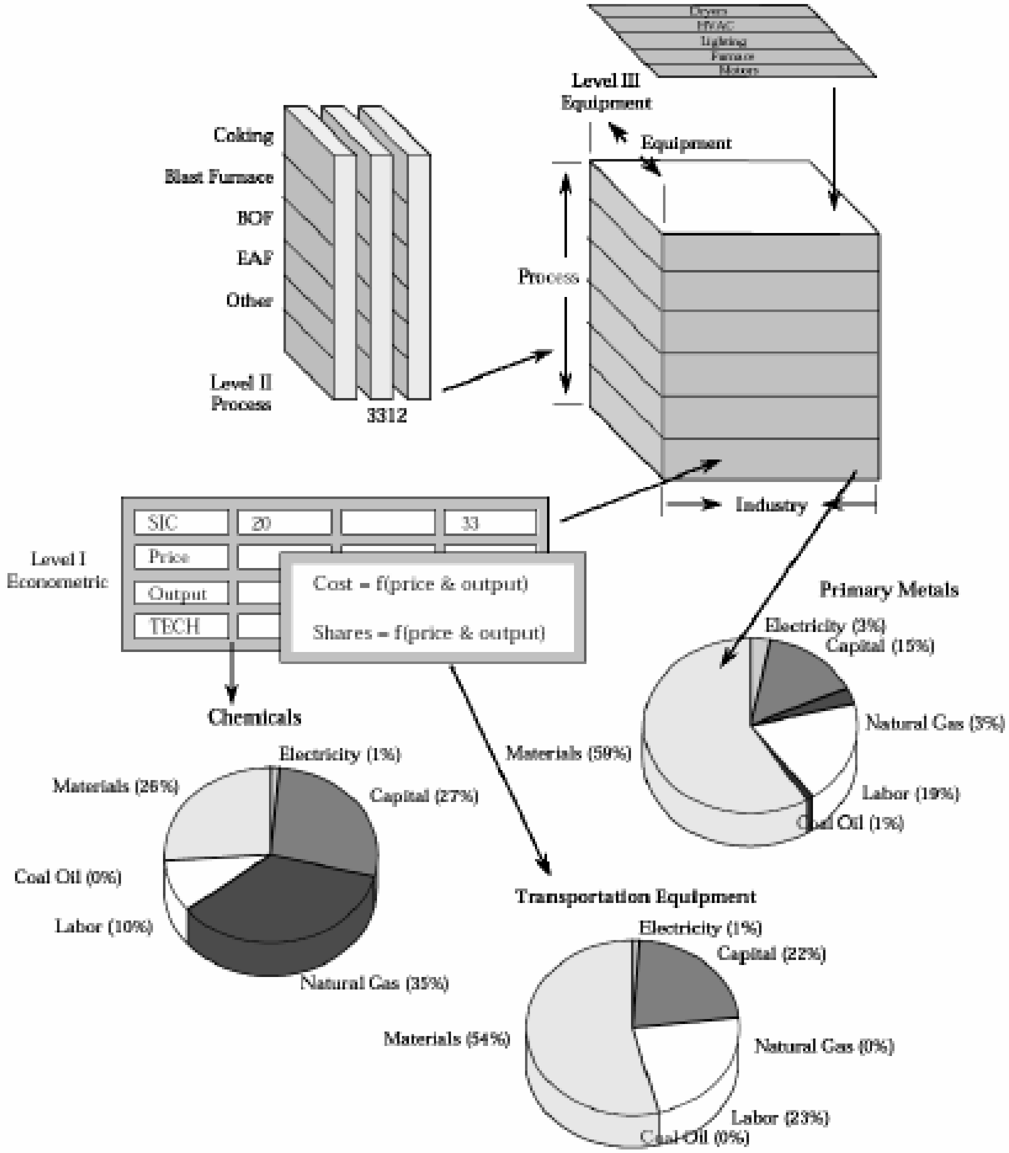
Drivers?

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

SUFG looks at industrial energy use from three perspectives:

- LEVEL I Econometric at 2-digit SIC level
- LEVEL II Process model of iron and steel industry
- LEVEL III Motor model to evaluate technologies and standards



Indiana's Industrial Sector

SIC	Name	Current Share of GSP	Current Share of Electricity Use
20	Food & Kindred Products	3.64	5.73
24	Lumber & Wood Products	2.42	0.71
25	Furniture & Fixtures	2.15	0.57
26	Paper & Allied Products	1.40	2.92
27	Printing & Publishing	2.65	1.32
28	Chemicals & Allied Products	14.28	17.46
30	Rubber & Misc. Plastic Products	4.10	6.21
32	Stone, Clay, & Glass Products	1.83	5.36
33	Primary Metal Products	8.99	30.05
34	Fabricated Metal Products	6.64	5.23
35	Industrial Machinery & Equipment	9.18	4.47
36	Electronic & Electric Equipment	15.21	5.61
37	Transportation Equipment	21.36	9.87
38	Instruments And Related Products	4.26	0.80
39	Miscellaneous Manufacturing	1.88	1.11
Total	Manufacturing	100.00	100.00

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 Prices	1.4
Oil Prices	0.9
Coal Prices	0.2

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

Challenges

- Data availability
- Determining the appropriate calibration period
- Error/uncertainty

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)

Further Information

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