ORNL Electric Utility Models

Presented to David Gold

Texas A&M

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ORNL Utility Models

- Models developed to support ongoing analysis
  - Tax treatment of renewable energy
  - DSM
  - IRP
  - Transition costs
  - Market prices
- Two main models now in use
  - ORFIN
  - ORCED

ORFIN Model

- Single utility
- Includes Generation, Transmission, Distribution, Customer Service, and G&A
- Detailed finances
- Multi-year
- Simplified wholesale trading
- Microsoft Excel
- Used in transition cost studies

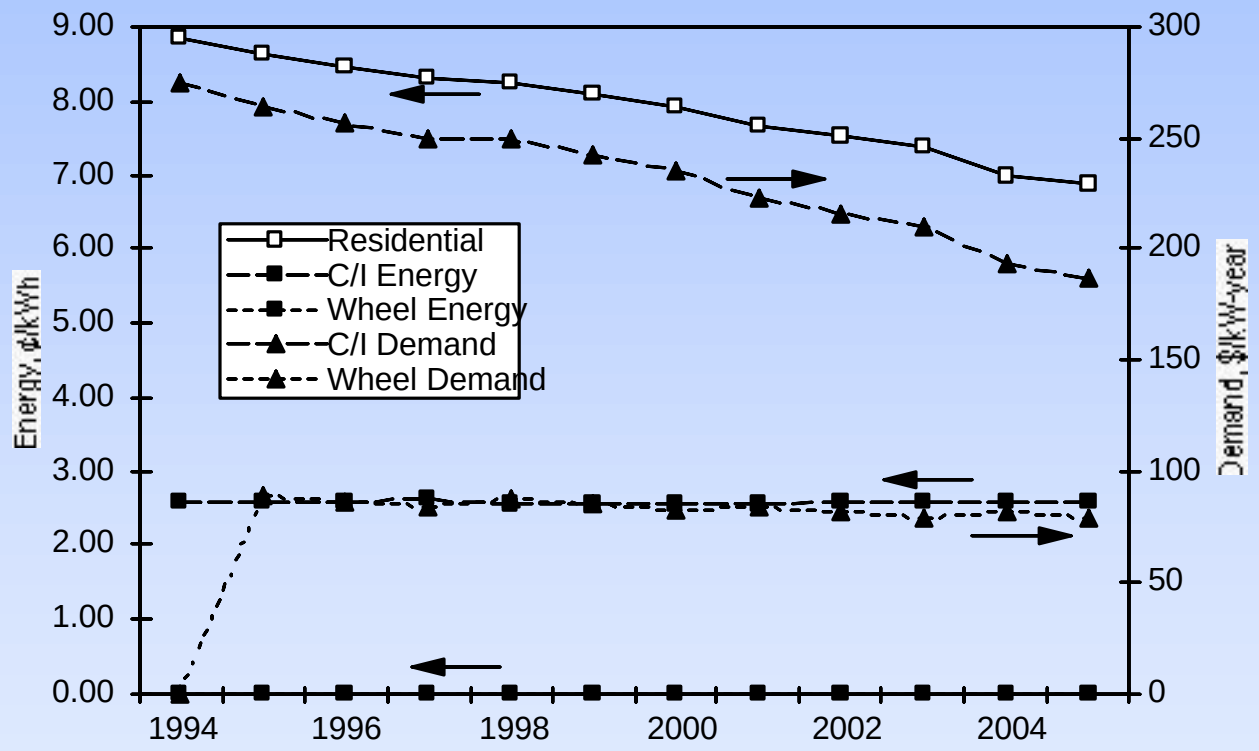
Details of ORFIN

- Full financial reports
  - Income Statement
  - Balance Sheet
  - Sources and Uses of Funds
- Multiple Ratesetting Methods
  - Variable frequency
  - Historical or Future test year
  - Performance based rates
  - Separate Energy, Demand, Customer Service, and Wheeling rates

Details of ORFIN (cont.)

- Three customer types
  - Residential
  - Commercial/Industrial
  - Wheeling (T&D only)

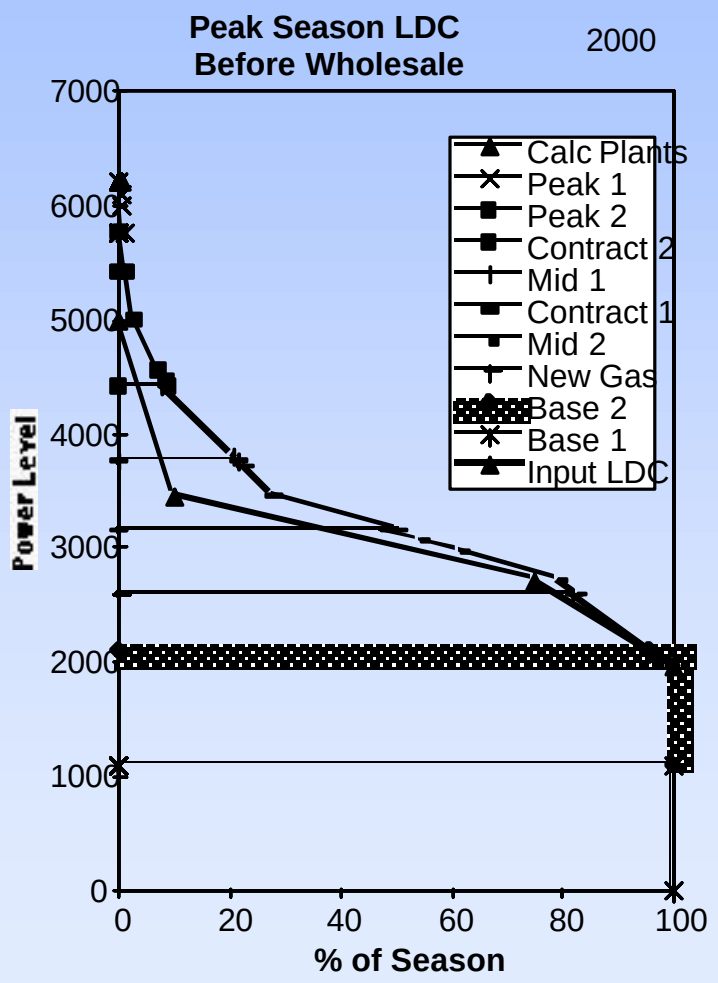
Example of Prices

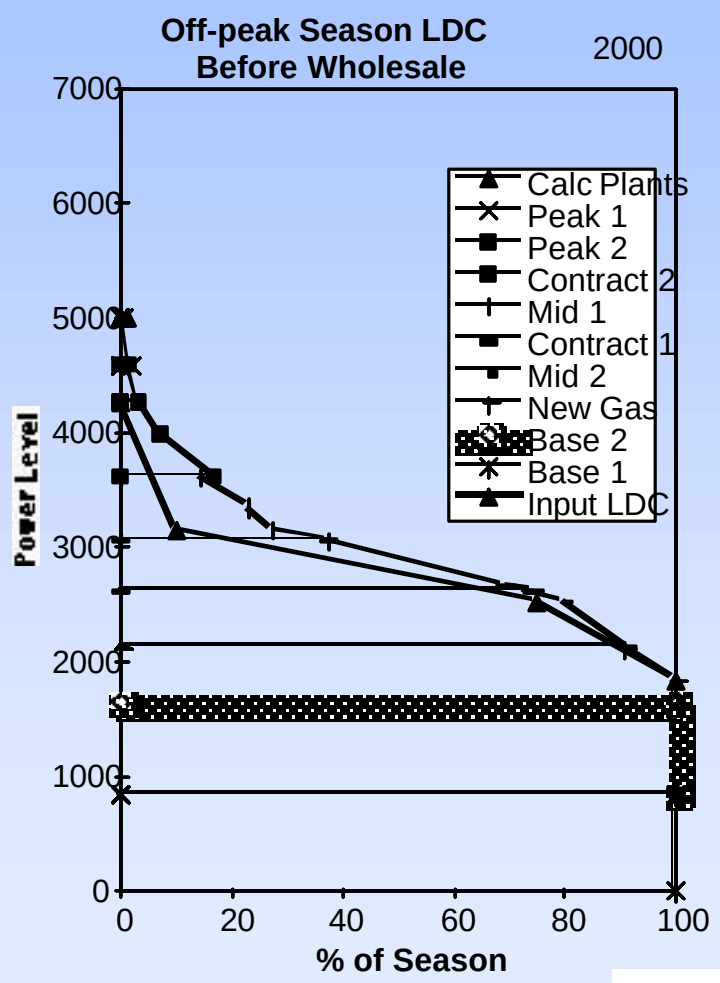


Economic Load Dispatch

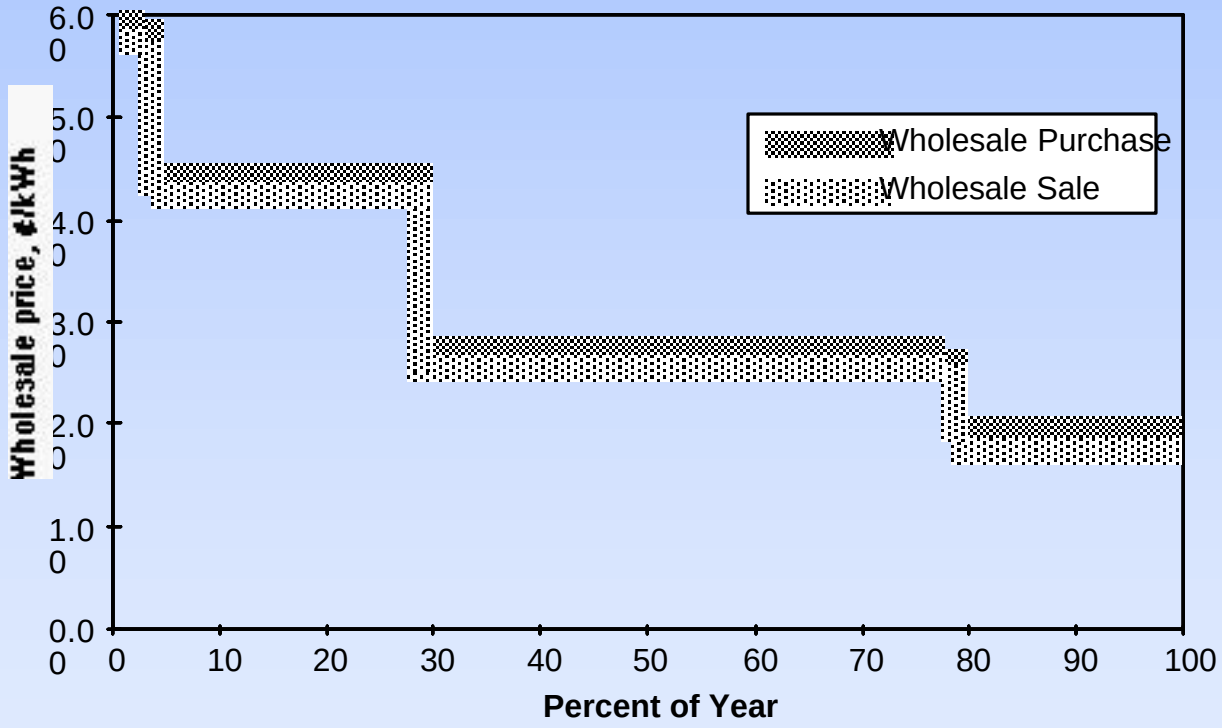
- Load Duration Curves for peak and off-peak seasons
- Ten plants or contracts, treated probabilistically
- Dispatch based on variable cost
- Multi-tiered wholesale market trading
  - Depends on relative price of plants and market
  - Varies over year
  - Influenced by native load

Example of LDC and Dispatch

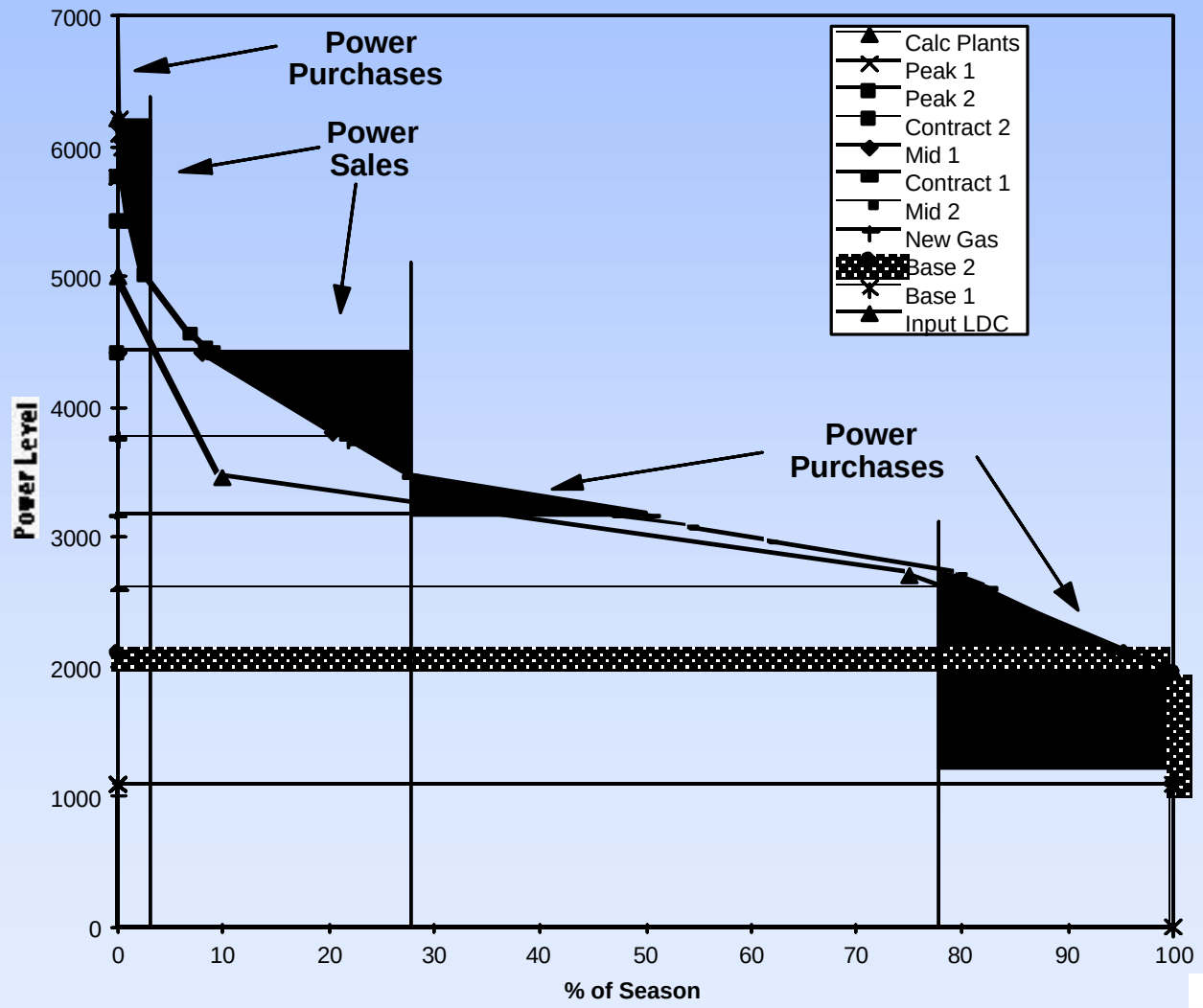




Wholesale Price Definition

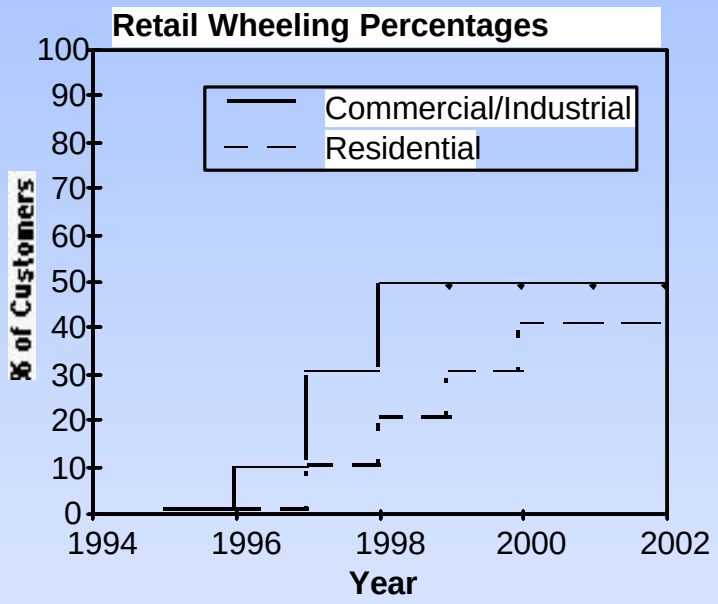


Example of Wholesale trading



Details of ORFIN (cont.)

- Retail wheeling
  - User input percentage of customers
  - Separate rates of change by customer type
  - Amounts change by year
  - Customers still pay wheeling charge



ORCED Model

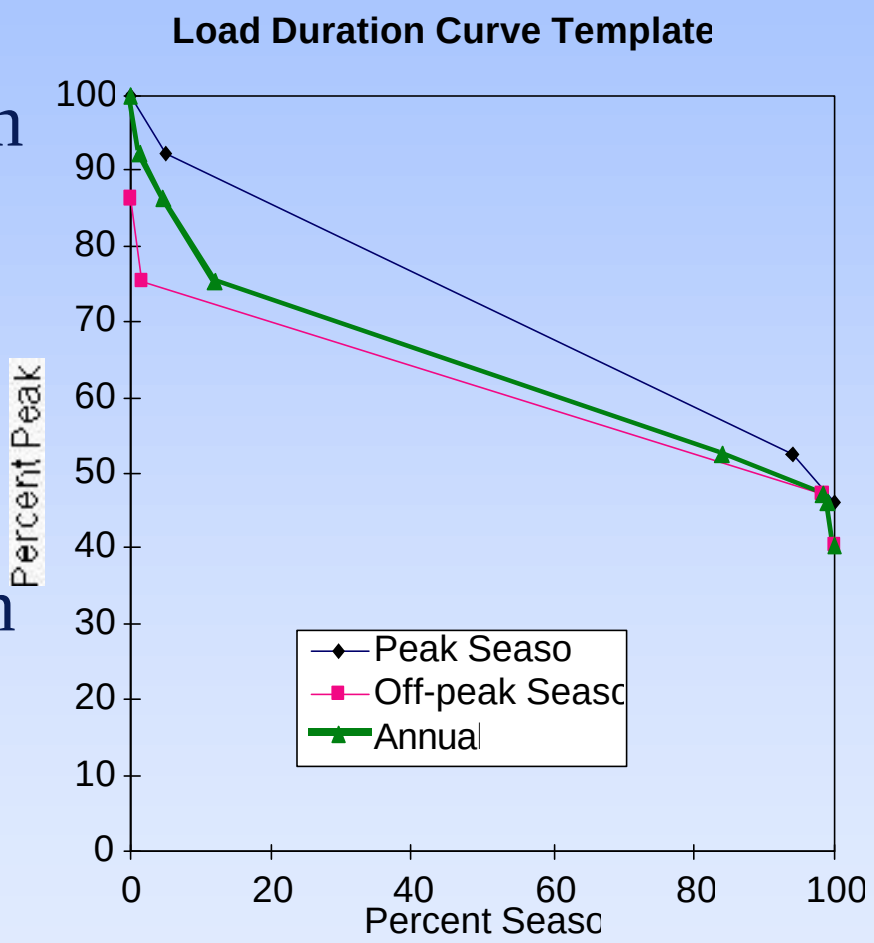
- Expansion of ORFIN Load Dispatch Method
- Bulk power market with marginal cost pricing
- One- and two-region versions
- Up to 51 power plants
- Covers one year only
- Microsoft Excel
- Allows optimization through Excel add-ins
- Used in carbon emission and restructuring studies

ORCED Single Region Details

- Plants in region put in 25 bins (or 50)
- All hydro put in 26th (or 51st)
- Representative parameters input
  - Capacity
  - Fuel cost
  - Heat rate
  - Fixed and variable O&M
  - Capital cost and year of construction
  - Planned and forced outage rates
- Multiple capital structures allowed

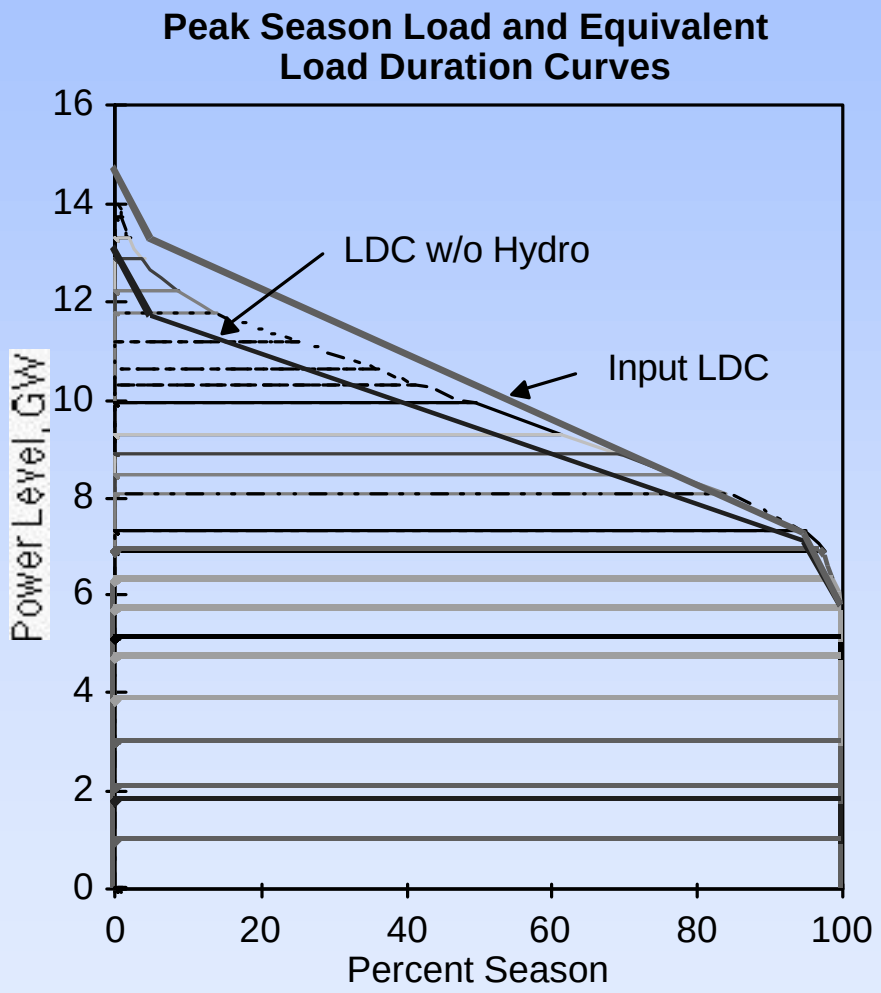
Load Duration Curves Define Demands

- Two seasons based on hourly load data
- Three-segment LDC calculated for each period
- LDC's for sectors can be calculated and combined
- Load factors can be changed to alter LDC's



Hydro Lowers Peak of LDC

- LDC points lowered starting with highest points
- Points lowered until energy reduction matches energy available from Hydro

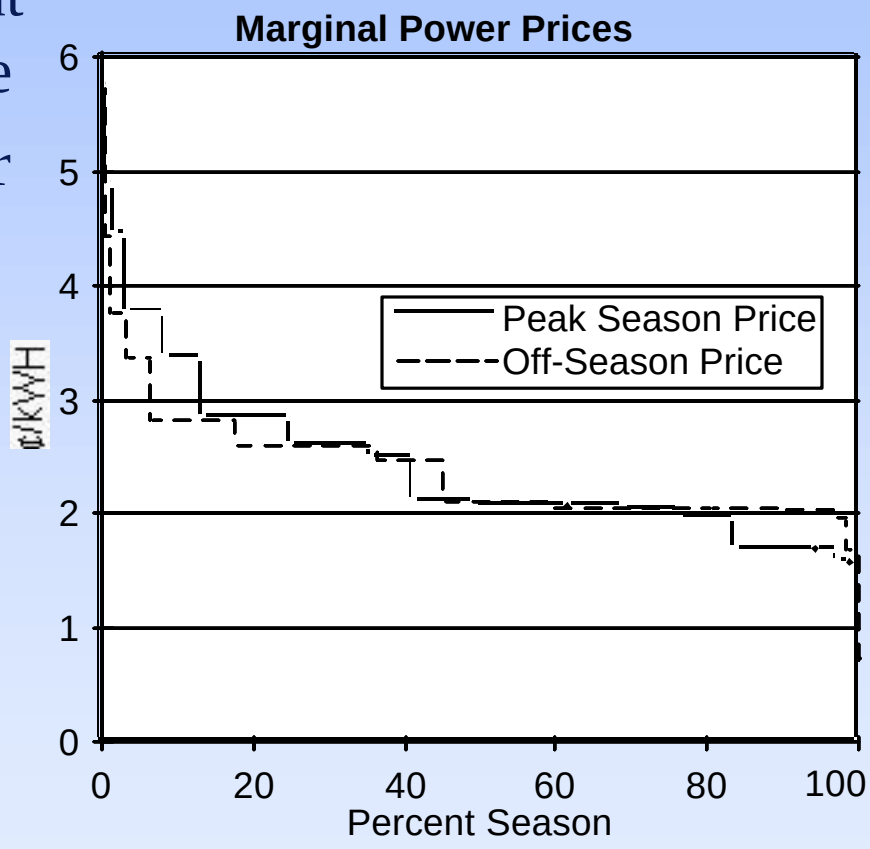


Economic Dispatch Matches Supply and Demand

- Lowest price plants loaded first
- Probabilistic forced outages and deratings increase use of high cost plants
- Cost of Unserved Energy can be predefined or calculated based on input elasticity of demand
- Percent of time when all plants fully loaded represents the Loss of Load Probability

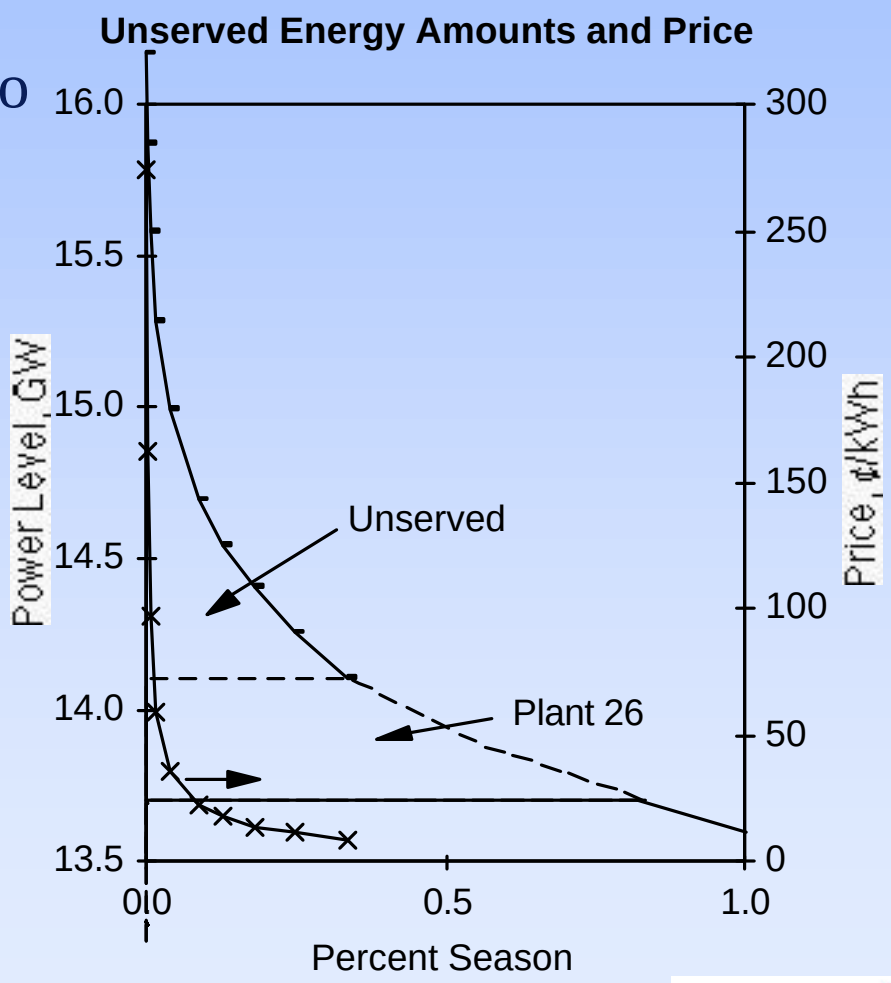
Marginal Prices Defined for Each Segment

- Based on bid price of plant on the margin at each time
- Costs and prices raised for low capacity factor plants to recover start-up costs
- Costs and prices can be raised to include a CO2 tax (or allowance trade)
- Prices can also include an uplift charge and/or capacity charge



Unserved Energy Price Variations

- Calculate prices needed to reduce demand by unserved energy amount assuming elasticity
- Low elasticity means higher prices
- These prices paid to all suppliers during time of unserved energy
- Price of unserved energy can be set by user

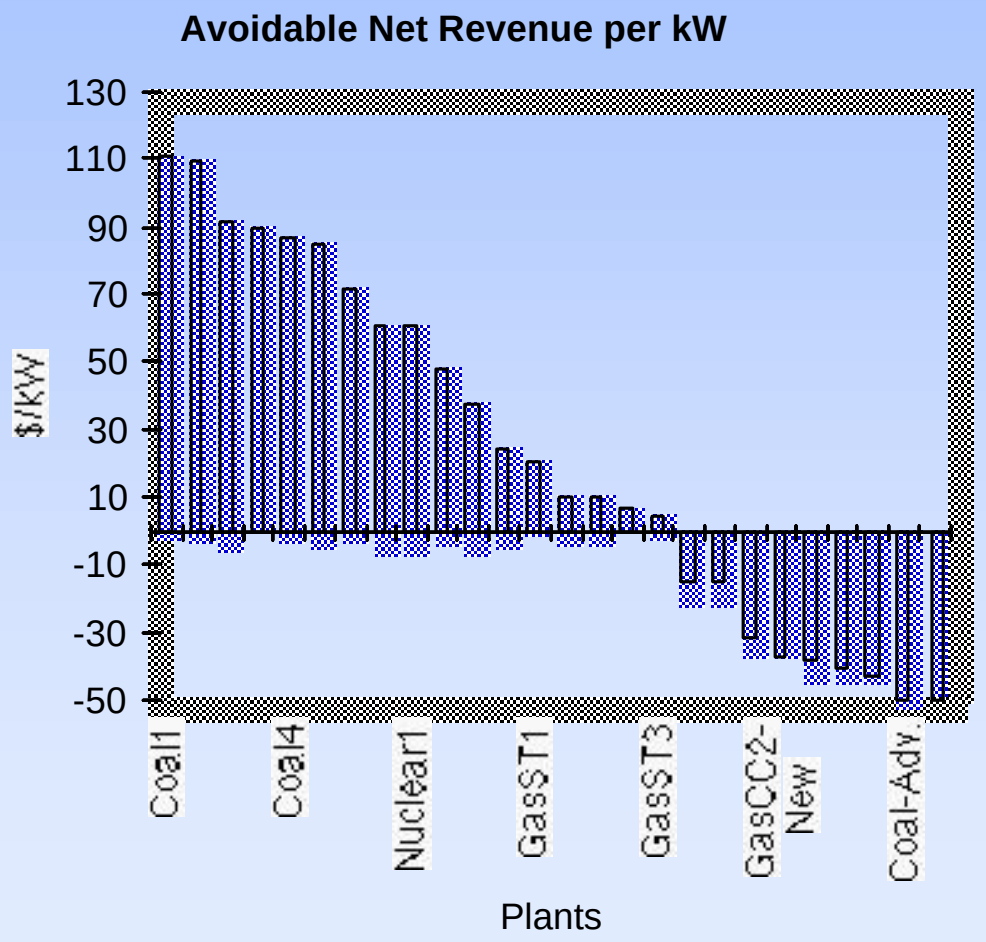


Plant Finances From Prices And Costs

- Revenues based on production under each segment of price curve
- Costs defined as variable, avoidable fixed, and unavoidable
- Capital may be avoidable or unavoidable
- Profit made when plant operates and is not the marginal plant
- Profits can be high during unserved energy

Losses can determine capacity charge

- Loss per KW adjusted for availability
- Cut off at required reserve margin

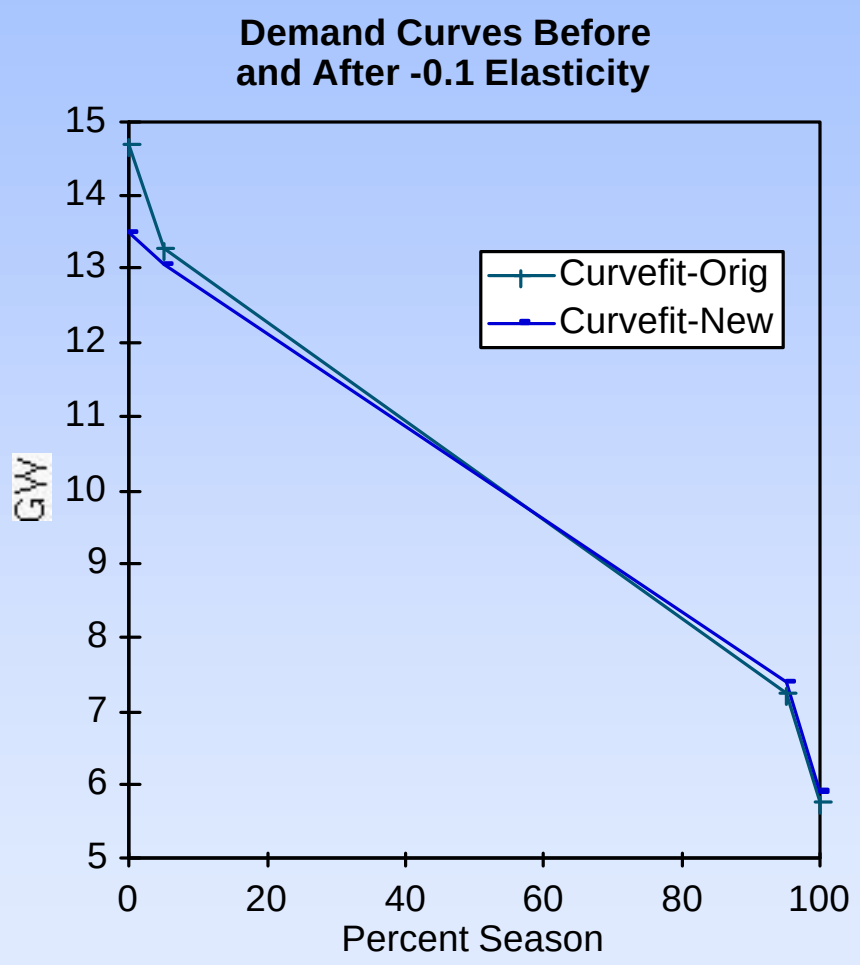


Adjust Inputs to Optimize Results

- Objective function must be decided upon:
  - Minimize avoided costs?
  - Minimize total costs?
  - Minimize price?
  - Maximize net revenues?
  - Other?
- Variables and constraints must be set:
  - Which plant capacities are allowed to vary?
  - What limits on plant capacities?
  - Can bid prices change?
  - Constraints on reserve margin or LOLP?
  - CO2 or other constraints?
- Use Solver or genetic algorithm to solve

Adjust LDC based on price and elasticity

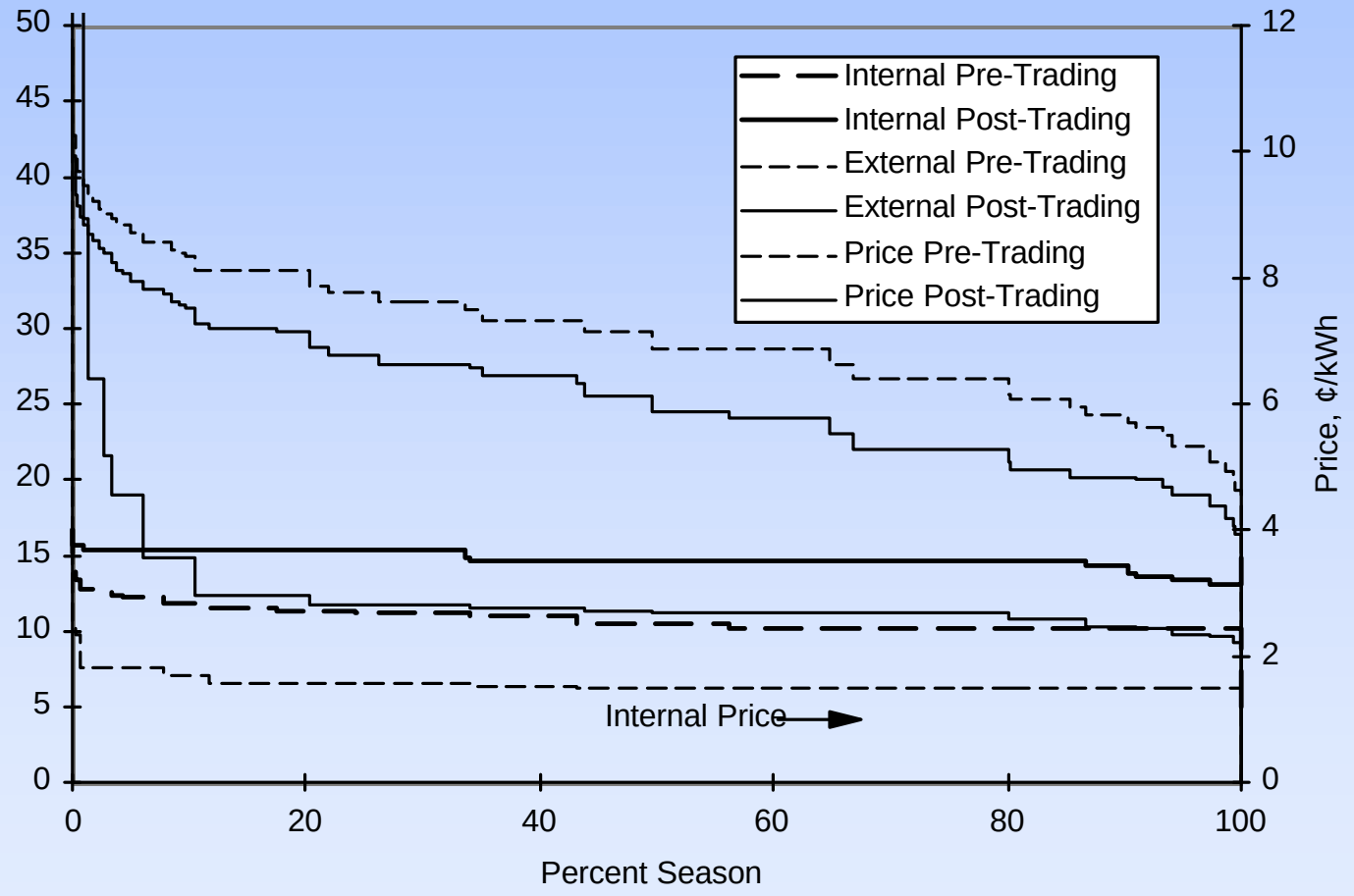
- Price impacts can raise or lower demand in each segment.
- A separate elasticity based on the average price can raise or lower the whole LDC
- Separate elasticities for each customer class can be used
- Demand changes will change plant loads and thereby prices, which can require iteration

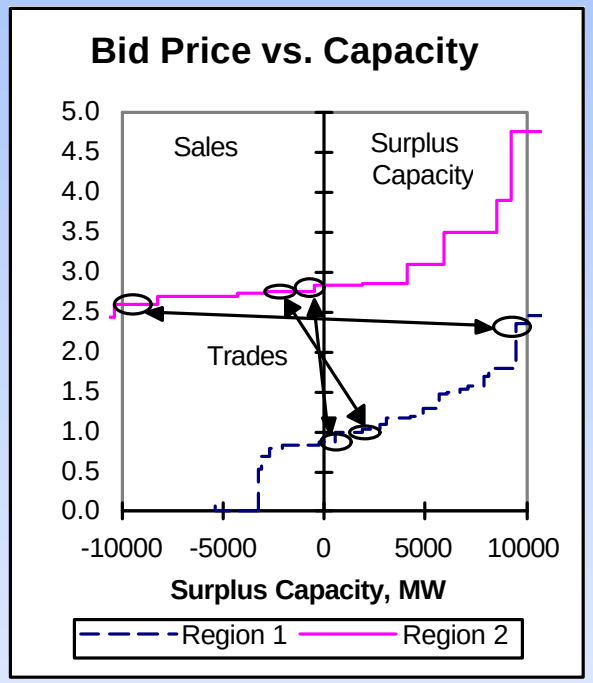


Two-Region ORCED

- Define two single-region ORCED sets
- Define transmission link between two
  - Capacity
  - Losses
  - Cost
- Allow trading in each time period based on costs of surplus and operating plants.
- Prices based on plant left on margin

Sales and Price Changes from Trading



Trading in Market

- Market set by internal demands
- Trades at each time between low and high-cost producers
- Trading ends when:
  - no more profitable trades, or
  - Transmission capacity reached
- Price set by last plant on margin