Greenhouse Gas Impacts of Hydropower: Analysis using the ORCED Model

Presented to FERC

By Stan Hadley

Oak Ridge National Laboratory

Feb. 1, 2000

GHG and Hydro Power

- Needs for control
  - Physical reasons, CEQ, Executive Order
- CO_2 is main GHG from electricity
  - N_20 is 0.4%, CH_4 is 0.01% compared to CO_2
- National studies on means to reduce emissions
  - 5-Lab, 11-Lab, EIA, Clean Energy Futures, others
- Hydropower Role
  - Usually static
  - Debated
  - Could be large

Valuing GHG Impact of Hydro

- Depends on power displaced
  - What type of production would have been used if the hydro production was not used
  - Multiple plants displaced over any year
- Power displaced depends on
  - Time of displacement
  - Regional power supplies
  - Regional power demands

Calculation Methods

- All methods by necessity simplify reality
- Coefficients
  - Value based on assumption of fuel displaced
- Load Dispatch Models
  - Demands and supplies for region modeled
  - More complex ones take T&D constraints into account
- Capacity Expansion Models
  - Adds new plants and/or retirements over life of plant

ORCED Model

- Expansion of ORFIN Load Dispatch Method
- Bulk power market with marginal cost pricing
- One- and two-region versions
- Up to 52 power plants
- Covers one year only
- Microsoft Excel
- Allows optimization through Excel add-ins
- Used in carbon emission and restructuring studies

ORCED Supply Details

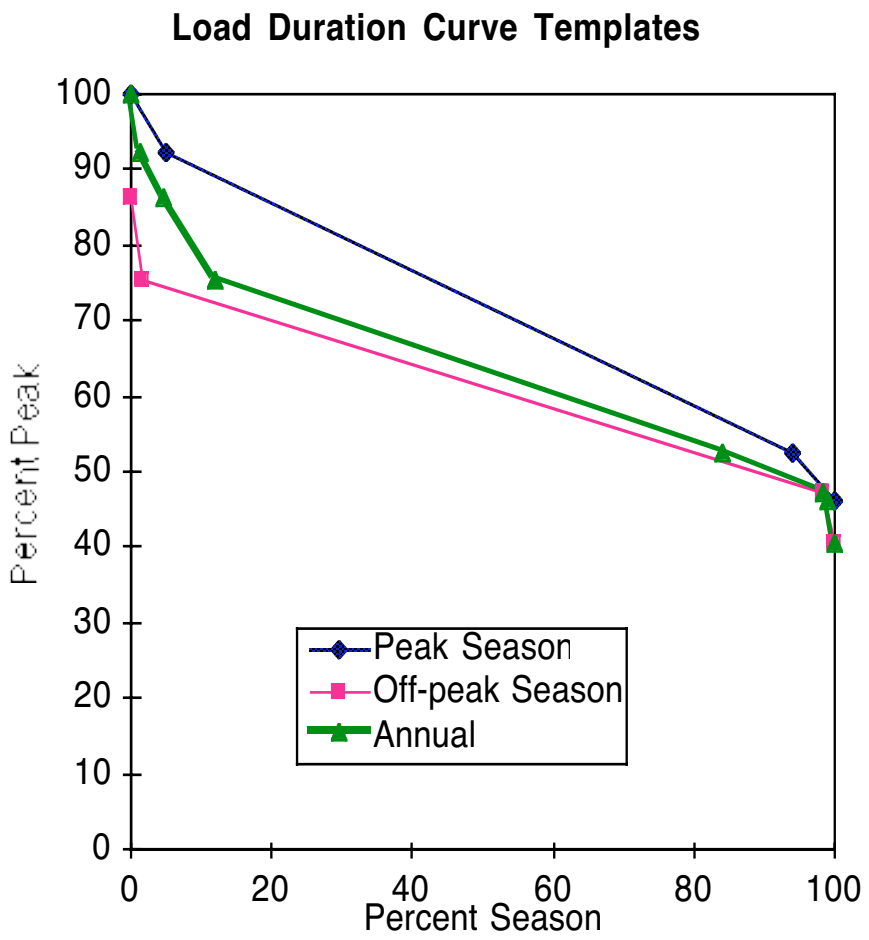
- Plants in region put in 50 “bins”
- Peaking hydro put in 51st and 52nd
- Representative parameters input
  - Capacity
  - Fuel cost
  - Heat rate
  - Fixed and variable O&M
  - Capital cost and year of construction
  - Planned and forced outage rates
- Multiple capital structures allowed

Plant Definitions from Data Base

- Currently uses data set used by EIA for the Annual Energy Outlook 1999
- Fuel costs based on regional values and plant heat rates
- Separate spreadsheet groups plants into 50 “bins” based on technology, fuel, operations, and cost
- Other data sets available but are not currently used

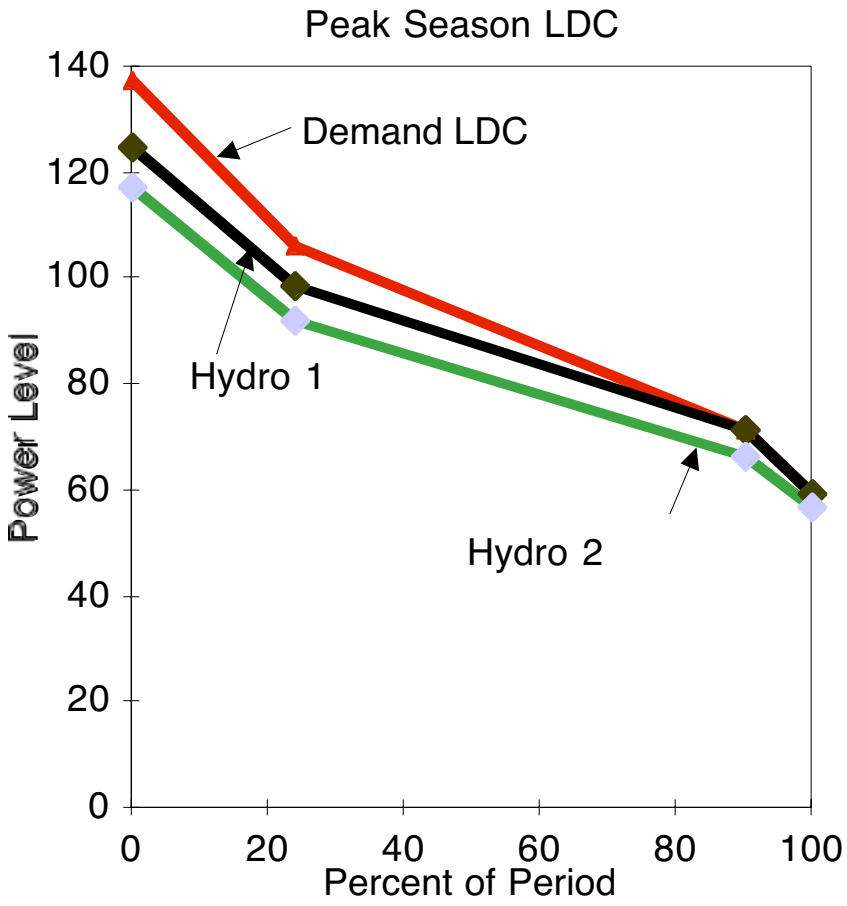
Load Duration Curves Define Demands

- LDC shows % of time demand above power level
- Two seasons modeled
  - Peak and Off-Peak seasons
  - based on hourly load data
- Three-segment LDC calculated for each period



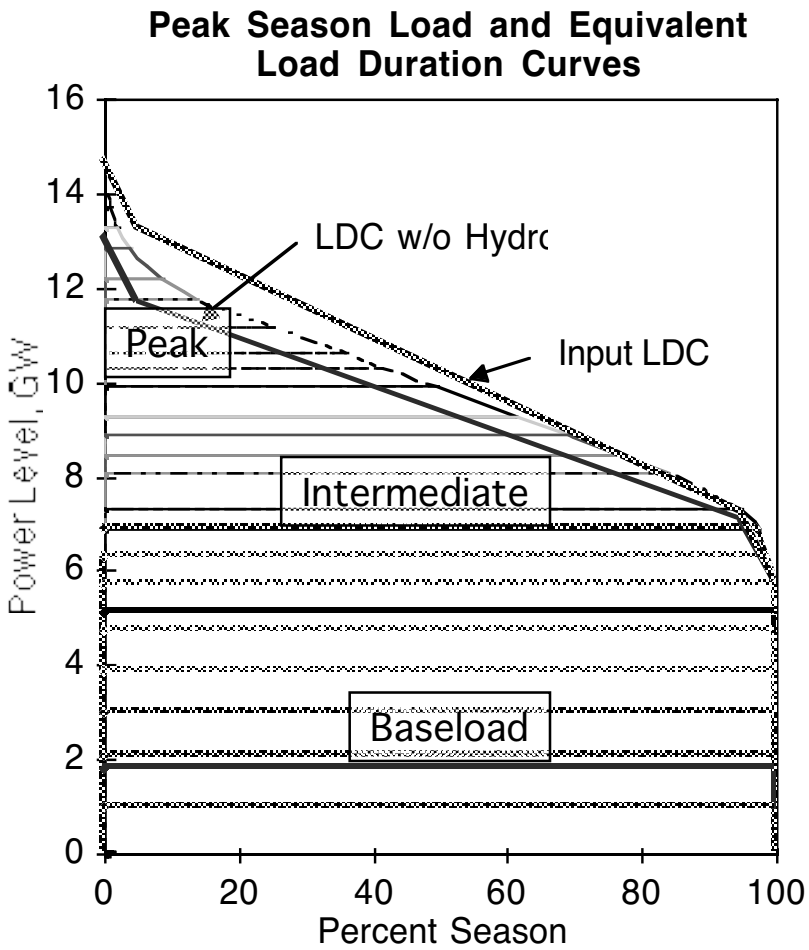
Demands and Supplies Modeled with Load Duration Curve

- LDC points lowered for hydro starting with highest points
- Points lowered until energy reduction matches energy available from Hydro
- Second hydro treated similarly



Economic Dispatch Matches Supply and Demand

- Lowest price plants loaded first
- Probabilistic forced outages and deratings increase use of high cost plants
- Unserved Energy during time demand exceeds capacity



Additional Issues

- Pricing and financial information provided
- Carbon, SO_2, and NOx emissions reported
- T&D constraints not included
- Ancillary Services not included
- Pumped storage can be modeled but not tested yet
- Model expansion to 200 plants underway

Hydropower Impact depend on Region

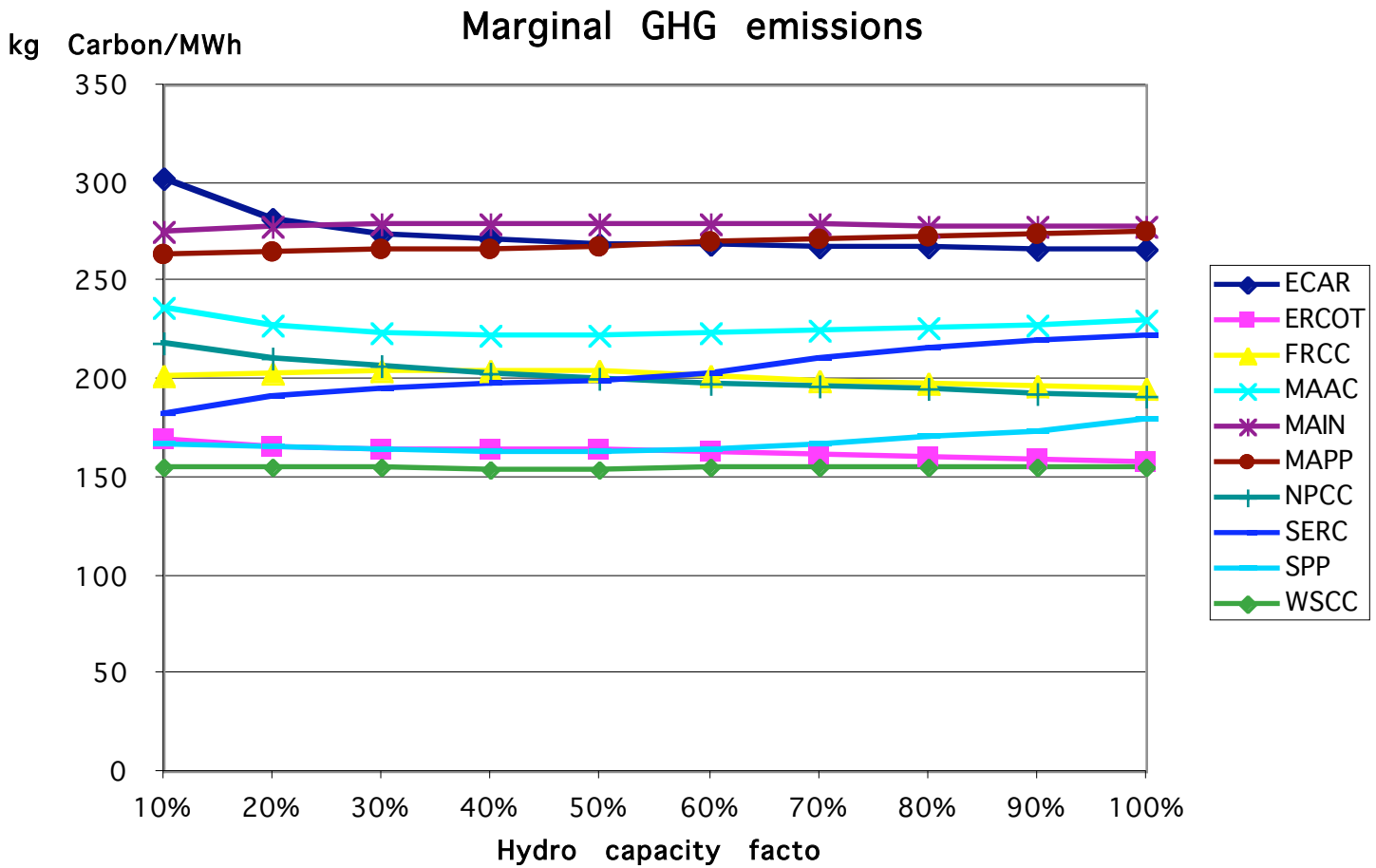
- NERC regions have different mix of capacities
  - Coal
  - Gas
  - Nuclear
  - Hydro
  - Oil
  - Other

Capacity on Margin

- **Marginal capacity is different than Average**
- **Values below based on no transmission constraints**

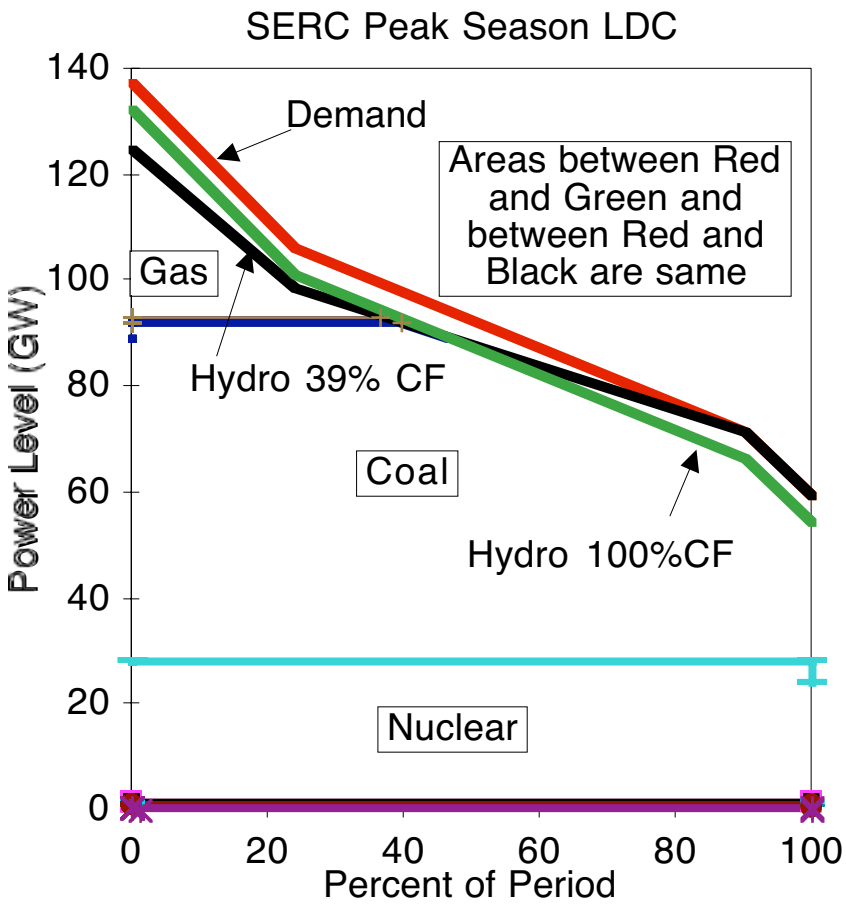
Fuel	ECAR	ERCOT	FRCC	MAAC	MAIN	MAPP	NPCC	SERC	SPP	WSCC
Gas	8	97	57	48	6	22	59	41	79	96
Coal	88	0	2	38	91	69	3	55	21	4
Oil	2	2	38	14	2	8	38	3	0	0
Uranium	0	0	0	0	0	0	0	0	0	0
Water	0	0	0	0	0	0	0	0	0	0
Other	1	0	0	0	0	1	0	0	0	0

Marginal GHG emissions by Region



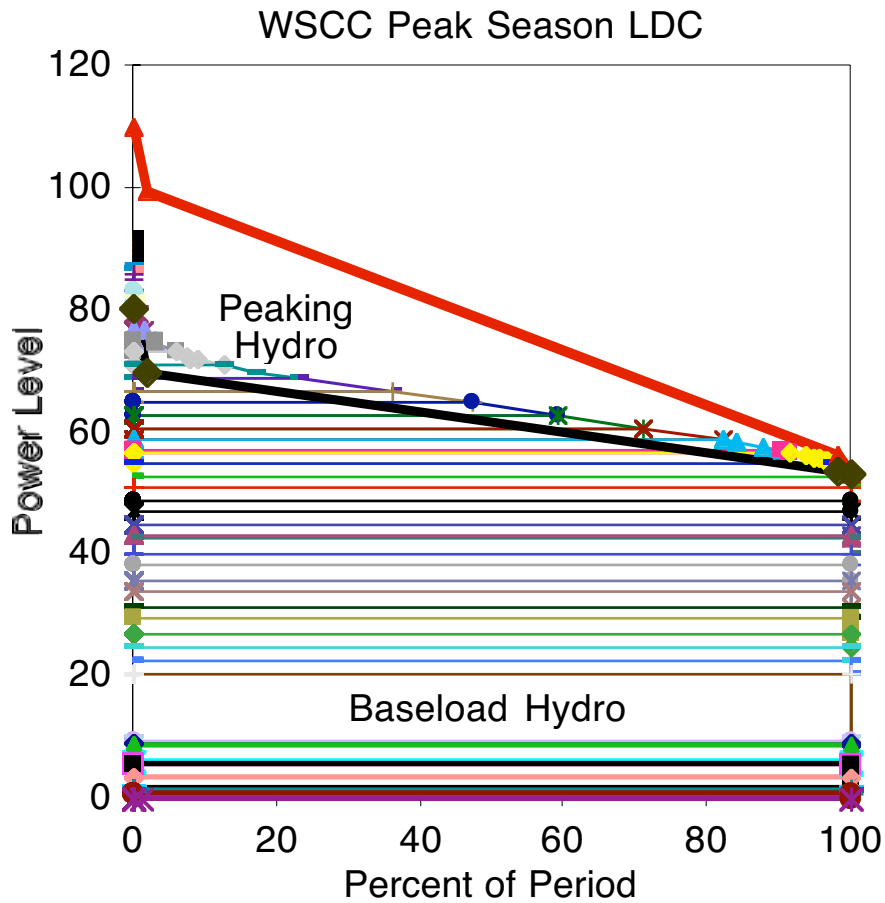
Peaking versus Run of River

- Peaking displaces highest cost plants, typically gas-fired
- Run of river displaces whatever is on margin throughout year, more like baseload
-



Hydro split between peak and baseload

- Split hydro to model minimum flow level
- Changes which plants are on margin



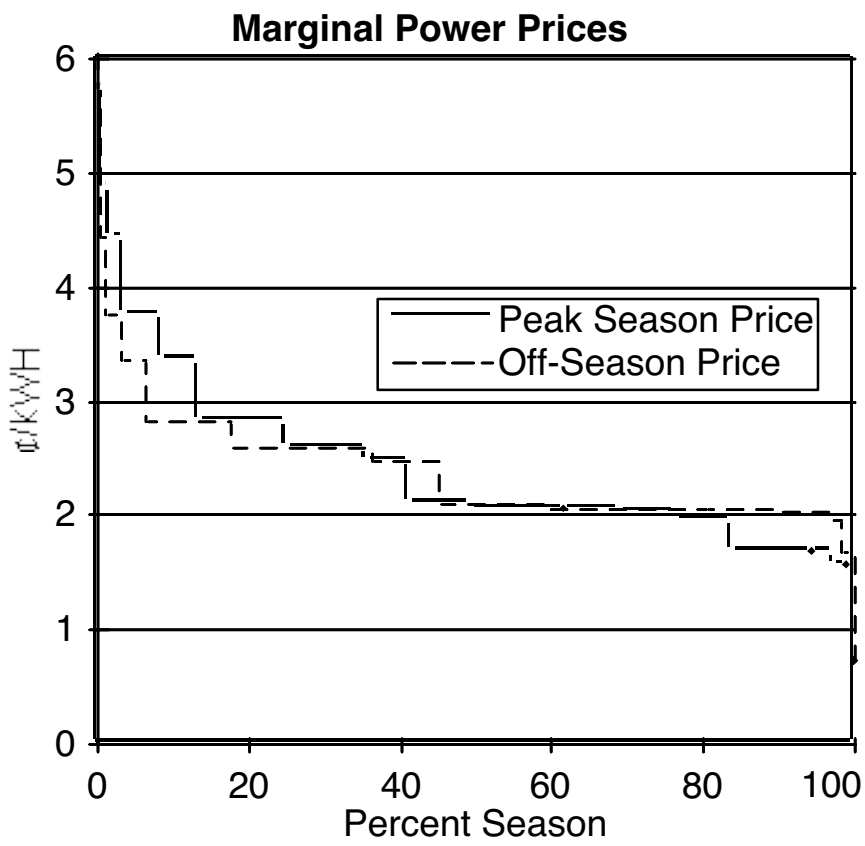
Conclusions

- GHG impact of hydropower very dependent on:
  - Regional demands
  - Regional supplies
  - Marginal capacity of region
  - Flow characteristics of hydro facility
- ORCED allows simplified modeling of hydropower interactions in bulk power markets
- Resulting GHG impacts give indication of hydropower value

Extra Slides

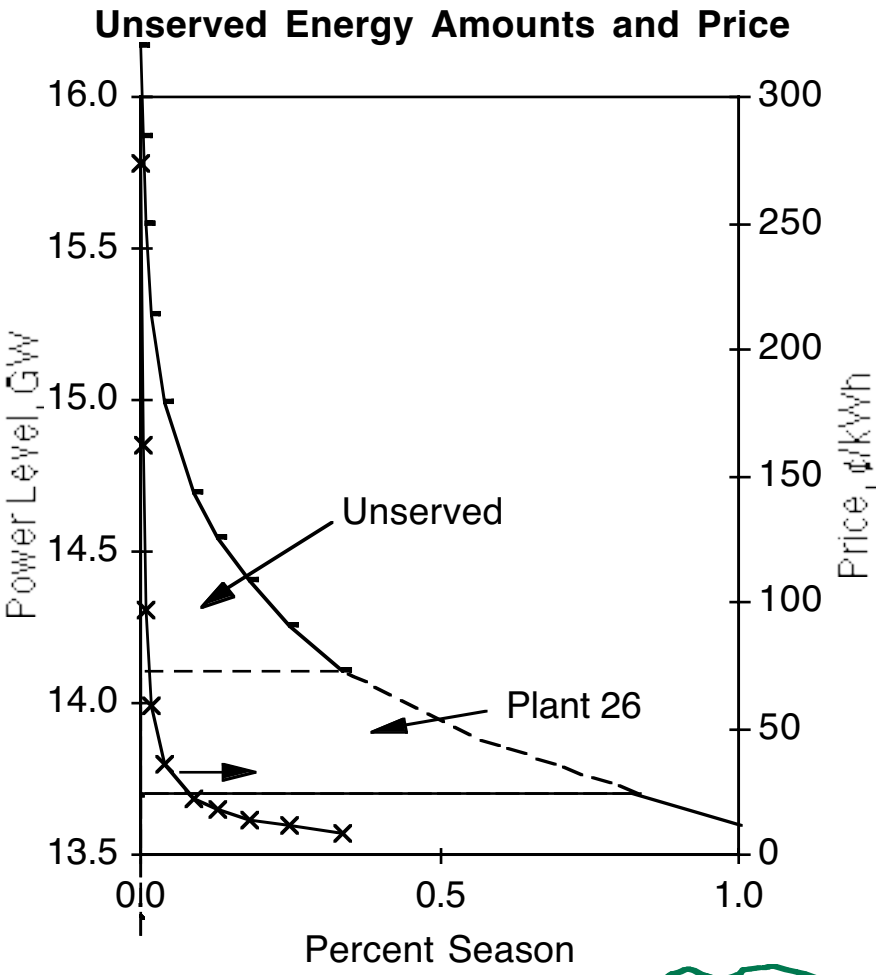
Marginal Prices Defined for Each Segment

- 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