# Decision Making in Combined Capacity Expansion and Energy Markets

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## Research Question

Can a GAMS model be created to more accurately depict decision making for a firm in combined capacity expansion and energy markets?

## Motivation

- Electric markets are generally considered natural monopolies
- Natural monopolies are inefficient and can be assuaged by regulation
- Past regulation in power markets has led to other inefficiencies such as violent price spikes and underinvestment in capacity
- Capacity markets and energy markets individually fail to fully adjust the market
- No model currently combines the two regulation methods for more accurate predictions

## Capacity Markets

- Operate by paying producers for built capacity
- Help to provide incentive to invest in capacity for future production and high peak hours
- Do not provide incentive for production to be useful, leads to unnecessary production

## Energy Markets

- Operate with an ISO choosing production based on bids placed by firms
- Help pricing approach marginal cost
- Do not provide incentive to invest in capacity for future production

## General Format

$$MAX \quad Profit = G_1 * P + G_1 * MC_1 + CC_1 + CG_1$$

s.t.

$$MIN \quad Total\ Cost = \sum_0^i G_i * MC_i$$

s.t.

$$KKT\ conditions\ for\ equilibrium$$

## Decision Variables

| | |
|---|---|
| $G_i$ | Production level for firm $i$ |
| $B$ | Additional build capacity for firm 1 |
| $\lambda$ | Price for the market, determined by ISO |

## Constants

| | |
|---|---|
| $MC_i$ | Marginal cost of production for firm i |
| $H_i$ | Current capacity for firm $i$ |
| $D$ | Demand of the market |
| $\sigma$ | Capital payoff constant |
| $\tau$ | Capital payoff multiple |
| $\iota$ | Capital cost constant |
| $\kappa$ | Capital cost multiple |

## Parameters

| | |
|---|---|
| $CC_i(H_i,\mathrm{B})$ | Capital costs for firm $i$ |
| $CG_i(H_i,\mathrm{B})$ | Additional build capacity for firm 1 |

## Parameter Equations

$$CC_1 = \iota + [\kappa * (H_1 + B)]$$
$$CC_{2-i} = \iota + (\kappa * H_i)$$
$$CG_1 = \sigma + [\tau * (H_1 + B)]$$
$$CG_{2-i} = \sigma + (\tau * H_i)$$

## Implementation

The model assumes fixed capacity for the other firms and excludes uncertainty. The model solves for the amount of extra capacity firm 1 should build now given the expected future profits from the capacity market (the capital gains and costs) and the energy market (the price set by the ISO based on minimizing costs). While the model lacks a bid price for the energy market to determine production, it is assumed a second highest bid model is used to reveal the true marginal cost of production, information currently constant in the model. Solving to maximize profit using MPEC reveals the optimal extra capacity firm 1 should build now to maximize profits.

## Extensions

The model has potential to be modified to include uncertainty of other firms' additional build capacity, a strategic bid level for each firm, and to include the decision models for all $i$ firms, rather than a single firm. Ideally, the profit function can be modified to incorporate hyperbolic time discounted values for more optimal results.

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