Prosumer Pricing, Incentives and Fairness

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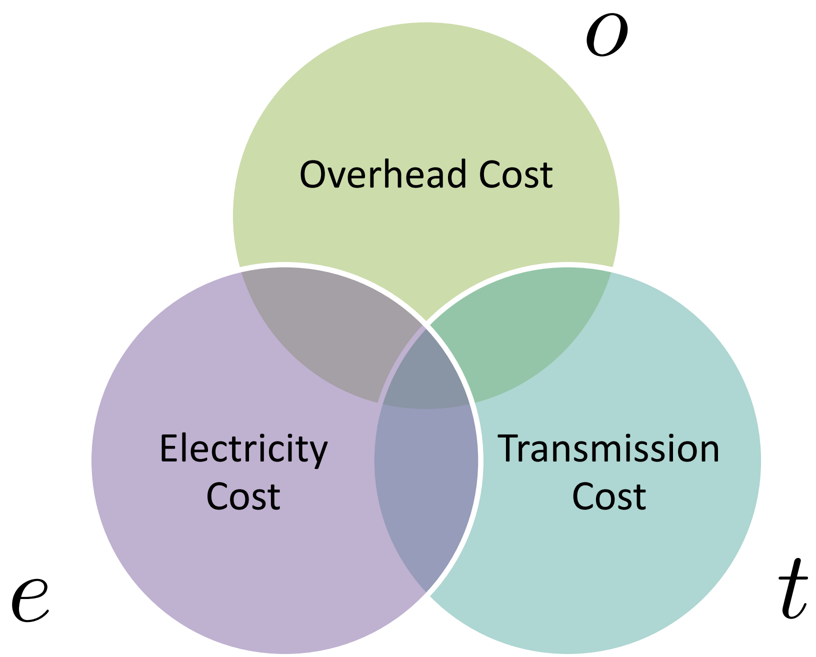
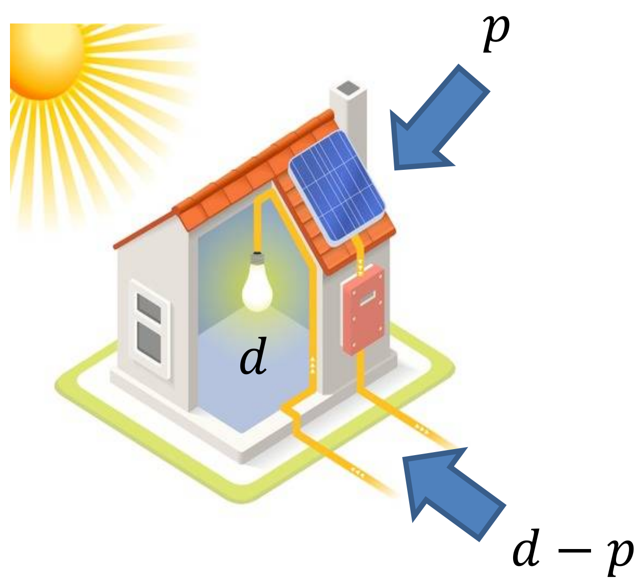
Introduction

Goal: propose a rate structure for electricity customers that

- More fairly divides the utility's overhead cost among customers (consumers or prosumers).
- Provides the utility a mechanism to control the solar penetration.
    - Minimum rate
    - Minimum risk (#connection points)
    - ...

Challenges: Incentives





- Customers pay $e + t + o$ (per unit) to buy energy from the grid.
- Prosumers usually get only e (per unit) for extra energy sold to grid.
- Total overhead cost depends on the capacity of the network.

Challenges: Incentives

Example:

- Assume $e = t = o = 4$ ¢/kWh
- $c =$ solar production cost

$c \geq 12$ ¢/kWh	$12 > c \geq 4$	$c < 4$ ¢/kWh
No investment	Invest up to demand	Invest as much as possible
↓	↓	↓
Consumer	Neutral Prosumer	Positive Prosumer

Challenges: Fairness

Example: Overhead cost

- Proportional to total gross demand
- Split based on net demands

Demand (kWh/month)	600	600
Solar (kWh/month)	0	0
Net demand (kWh/month)	600	600
Overhead	$15	$15

Challenges: Fairness

Example: Overhead cost

- Proportional to total gross demand
- Split based on net demands

Demand (kWh/month)	600	600
Solar (kWh/month)	0	300
Net demand (kWh/month)	600	300
Overhead	$20	$10

Proposed Pricing Scheme

$$R(p_i, d_i) = \begin{cases} (d_i - p_i)(e + t) + \frac{d_i - p_i}{\sum_{j=1}^{n}[d_j - p_j]_+} \cdot O, & p_i < d_i \\ 0, & p_i = d_i \\ -(p_i - d_i)e, & p_i > d_i \end{cases}$$

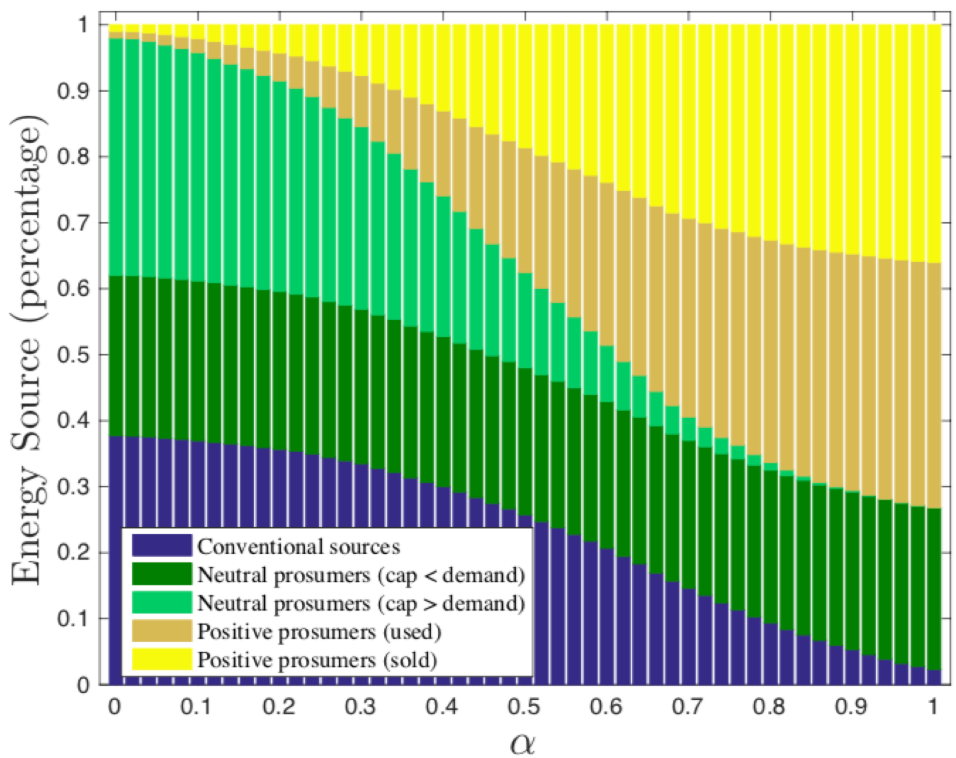
$$R(p_i, d_i) = \begin{cases} \frac{d_i}{\sum_{j=1}^{n} d_j} \cdot O + (d_i - p_i) \cdot r, & p_i < d_i \\ \frac{d_i}{\sum_{j=1}^{n} d_j} \cdot O, & p_i = d_i \\ \frac{d_i}{\sum_{j=1}^{n} d_j} \cdot O - (p_i - d_i)(e + \alpha t), & p_i > d_i \end{cases}$$

$$r = \frac{(e + \alpha t)\sum_{i=1}^{n}[p_i - d_i]_+ + (e + t)\sum_{i=1}^{n}(d_i - p_i)}{\sum_{i=1}^{n}[d_i - p_i]_+}$$

Q: how to obtain gross demands (d_i)?

Numerical Results

- $n = 10{,}000$ customers
- $e = t = 4$ ¢/kWh
- $c \sim$ Normal distribution (mean=6 ¢/kWh, variance=1)
- $d \sim$ Uniform distribution (between 400 and 1600 kWh/month)



Numerical Results

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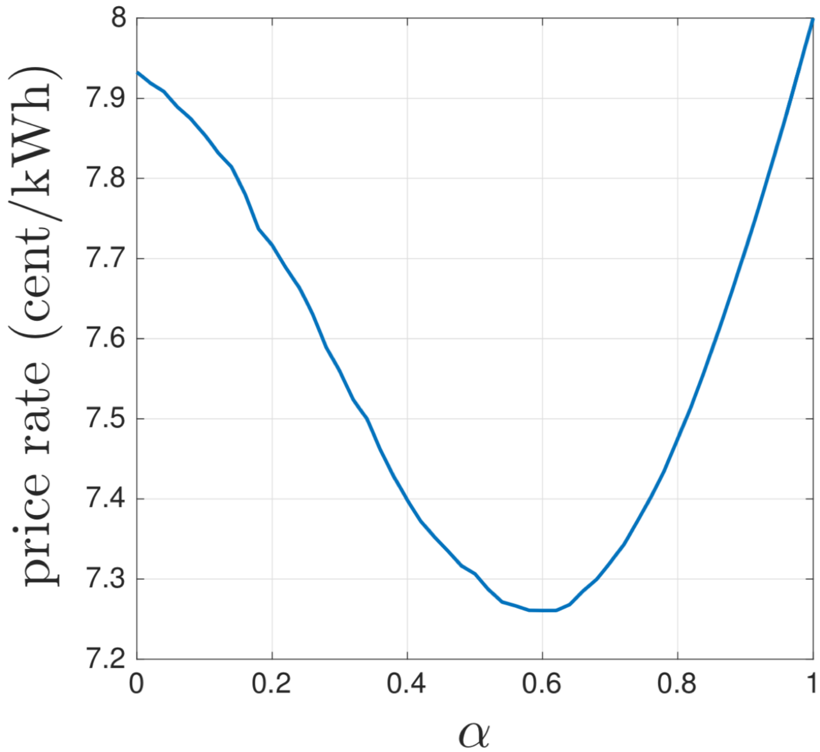
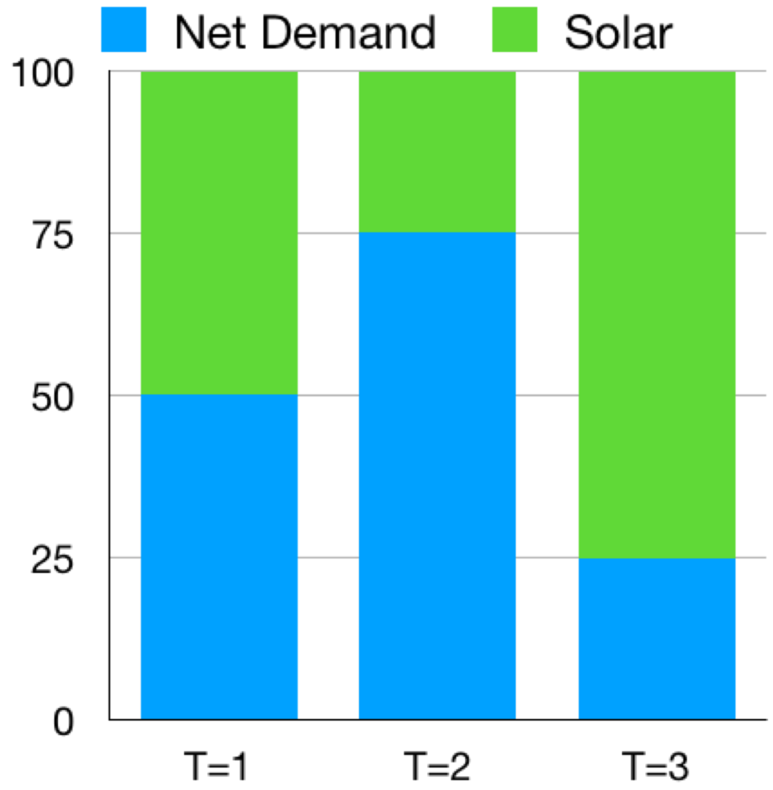


Inducing Truthfulness

- How do we obtain gross demands (d_i's)?
  - Let customers report their gross demand
  - Introduce penalty for inconsistent reports
  - At time t pay additional amount of $\gamma\left|d_i^t - d_i^{t-1}\right|$



Inducing Truthfulness

- Two factors that limit the cheating level
  - Higher penalty rate (γ)
  - More uncertainty (e.g. more rounds)