Prosumer Pricing, Incentives and Fairness

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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 (number of connection points)
  - ...

Introduction

Ali Khodabakhsh (UT Austin)
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.
Example:
- Assume $e = t = o = 4 \, \text{¢/kWh}$
- $c = \text{solar production cost}$

- $c \geq 12 \, \text{¢/kWh}$: **No investment**
- $12 > c \geq 4$:
  - **Consumer**
  - **Neutral Prosumer**
- $c < 4 \, \text{¢/kWh}$:
  - **Invest as much as possible**
  - **Positive Prosumer**
Example: Overhead cost

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

<table>
<thead>
<tr>
<th></th>
<th>House 1</th>
<th>House 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demand (kWh/month)</td>
<td>600</td>
<td>600</td>
</tr>
<tr>
<td>Solar (kWh/month)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Net demand (kWh/month)</td>
<td>600</td>
<td>600</td>
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<td>Overhead</td>
<td>$15</td>
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<td>$10</td>
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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
- $e = t = 4 \, \text{¢/kWh}$
- $c \sim \text{Normal distribution (mean=6 \, \text{¢/kWh, variance=1)}$
- $d \sim \text{Uniform distribution (between 400 and 1600 kWh/month)}$
Numerical Results

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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 $\gamma |d_i^t - d_i^{t-1}|$
Two factors that limit the cheating level

- Higher penalty rate ($\gamma$)
- More uncertainty (e.g. more rounds)