The Impact of Electricity Pricing Schemes on Storage Adoption In Ontario

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Motivation & Problem
Ontario: $12BN over next 30 years to reduce peak load. 120M/1% reduction.
Peak Load Is Expensive

For two reasons: **sizing** and generation:

“15 Minute Sizing”

![Graph showing % of time load achieved over different years (2003 to 2009).](image-url)
Peak Load Is Expensive

For two reasons: sizing and generation:

![Graph showing Market Price and Ontario Demand on Aug 19 2009]

HOEP reflects marginal cost of supply in each hour.
Can Storage Adoption Reduce The Load Factor?

- A better metric: load factor (LF)—peak/average.
- Goal: utilization. Off-peak ↑ peak ↓ (ideal = flat)
- Homeowners (∼30% of aggregate load) can help via electricity arbitrage using storage

![Graph showing load factor over time](image_url)
Problem Formulation

Given...

- the “grid” sets the electricity pricing scheme $p$ for Ontario
- people are perfectly rational*
- everyone (grid + Ontarians) benefits if the LF is reduced
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Project Goals:

- Is electricity arbitrage under $p$ profitable for homeowners?
- What should the grid make $p$ to reduce the LF the most given the above and have (1) hold?
Methodology
Methodology

We...

- Measure 16 homes consumption every 6s for 5-9 months
- Scale these to \( \omega \) of Ontario homeowners assumed to have storage (agents)
- Simulate the impact of agents’ actions on the LF for \( \omega : 0 \rightarrow 1 \) and for different \( p \)
- Approximation: given \( o_i = \text{Ontario agg. demand at } i \),

\[
\begin{align*}
o_i'(\omega) &\approx (1 - \beta) o_i + (1 - \omega) \beta o_i + \omega \beta o_i h_i \\
\text{new agg. approx} &\quad \text{industry & comm.} & \text{homeowners w/out storage} &\quad \text{agents}
\end{align*}
\]
Simulations

Agents...
- are given some storage
- know past hourly \{prices, Ontario agg. load, own load\} but must predict future values*
- optimize their storage profile over a window of size $w$ each hour
- update their predictions and re-optimize every hour

* details skipped here
Pricing Strategies

- Real Time Aggregate Pricing (RTAP)
- Proportional RTAP (PRTAP)
- Time of day pricing (TODP)
- Tiered base usage pricing (TUBP)*
- “Extreme” pricing (EP)

*acts as flat here
Exact Optimization Is Impossible

We’ve proven:

- The optimal RTAP, PRTAP, & TUBP optimization windows are infinite
- For TODP, the optimization window is finite only under special conditions
Results
It’s All Fun And Games While $\omega$ Is Low...

The LF for varying levels of $\omega$ and storage capacity under RTAP.
Then Things Go Wrong!

Capacity = 4kWh
Then Things Go Wrong!

Proportion of Homeowners with Storage ($\omega$)

Load Factor

PRTAP
RTAP
TOD
TUBP
EXTREME

Capacity = 16kWh
What is Going On?

- All non-flat pricing schemes where agents’ all view the same price* leads to the correlation of otherwise uncorrelated load

*PRTAP wasn’t a good scheme for different mathematical reasons
Unstable System

peaky system
→ storage adoption
→ new peak
→ convergence to flat pricing
→ storage useless
→ peaky system
→ pricing plan changes
→ storage usage
→ ...???

We don’t know the best solution yet to this problem.

Two Ideas: Randomness (can’t enforce), Subregional Pricing...
Electricity is Too Cheap To Buy Storage

Posed a realistic storage cost model, but LP became an IP. Under optimistic cost model ($20/kWh every 500 cycles), storage still isn’t profitable.
Conclusions

- We asked whether storage is profitable and whether its adoption can reduce the LF
- As the penetration rate increases, the system doesn’t converge
- For proposed/in use pricing schemes, storage is not profitable