The Impact of Electricity Pricing Schemes on Storage Adoption In Ontario

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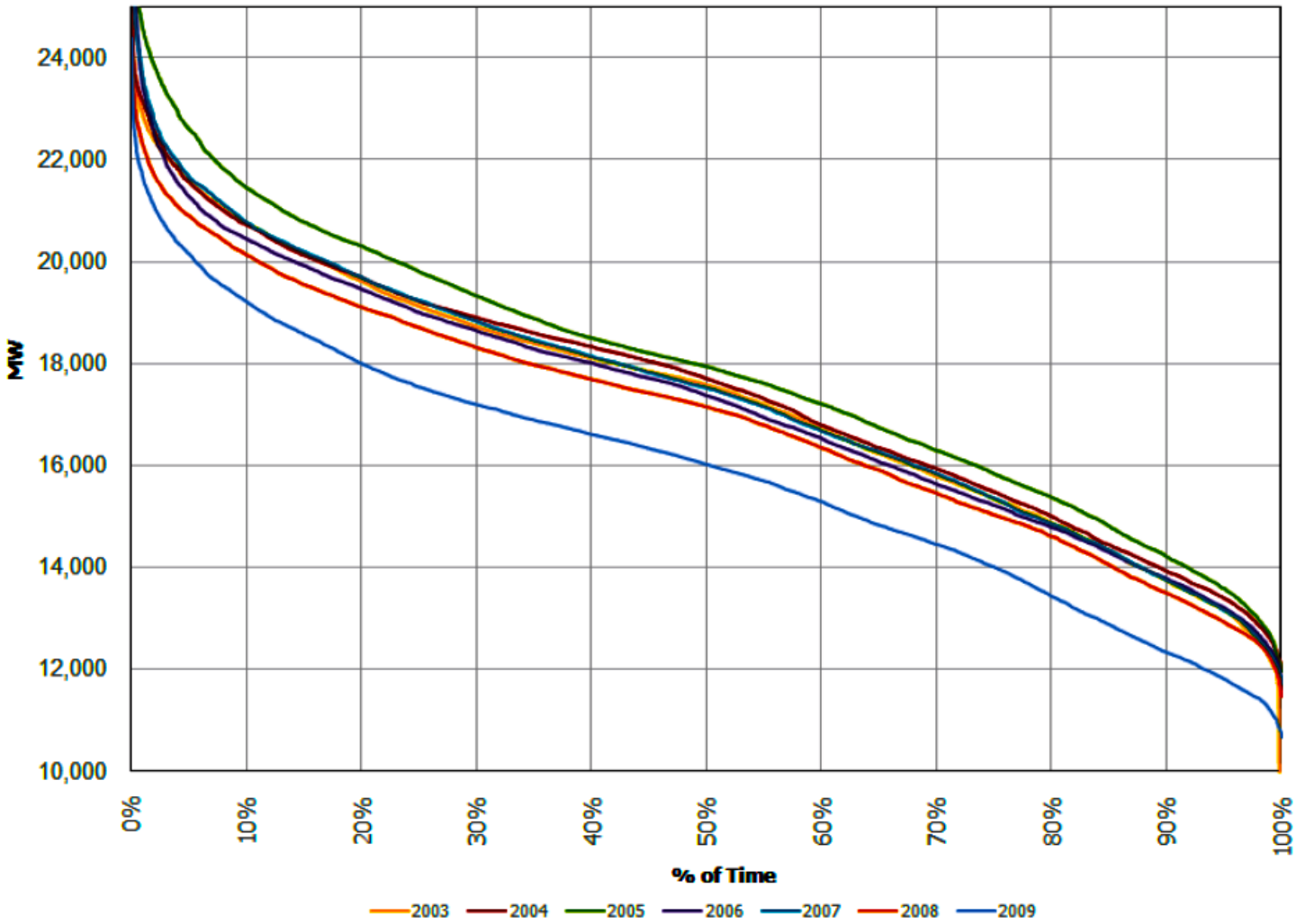
Motivation & Problem

Peak Load Is Expensive

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

"15 Minute Sizing"



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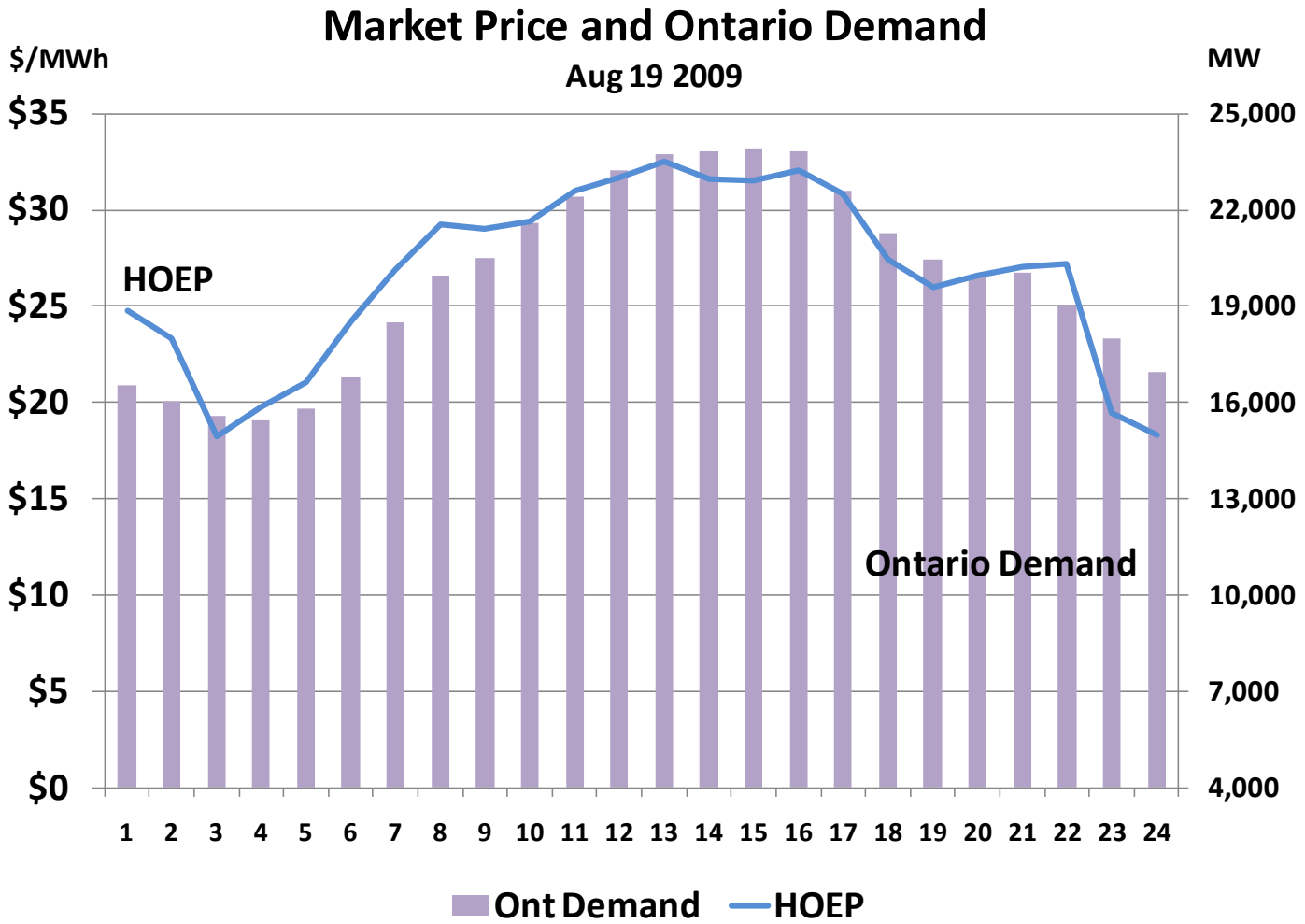
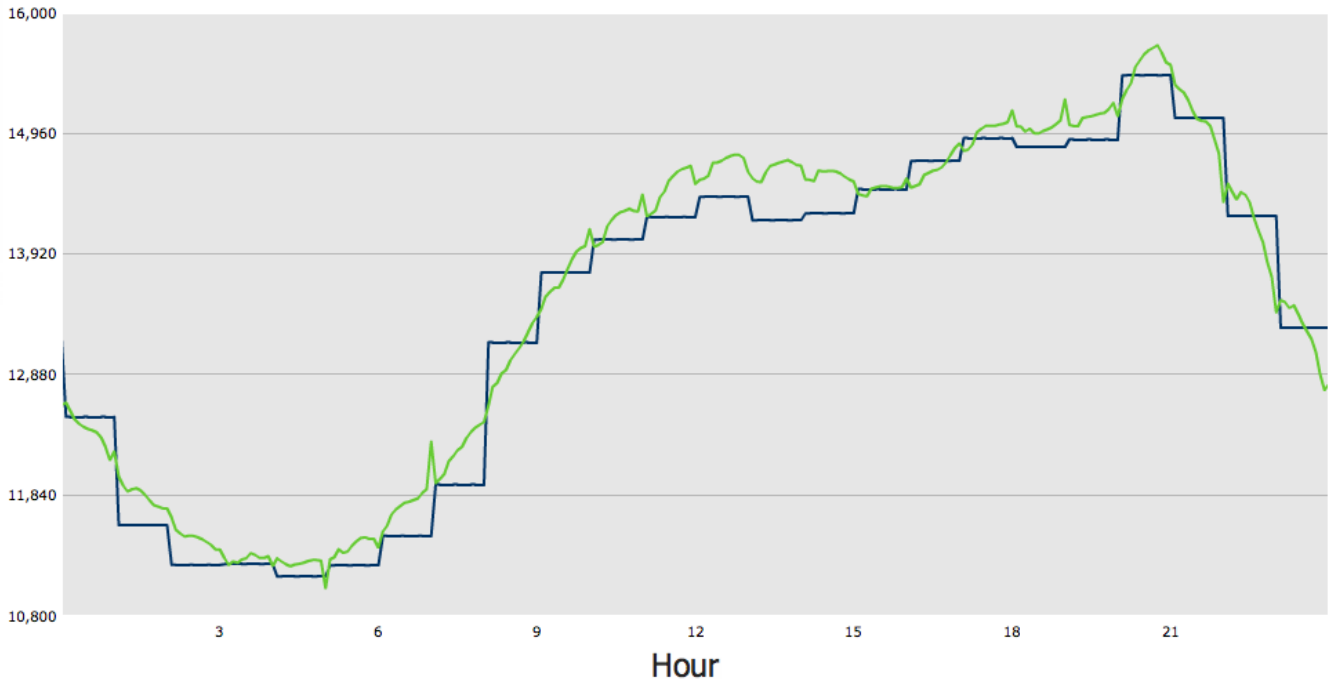


Can Storage Adoption Reduce The Load Factor?

- A better metric: *load factor (LF)*—peak/average.
- The grid is underutilized much of the day
- Goal: off-peak ↑ peak ↓ (ideal = flat)
- Homeowners (≈30% of aggregate load) can help via electricity arbitrage using storage



Problem Formulation

Given...

1. the “grid” sets the electricity pricing scheme p for Ontario
2. people are selfish
3. everyone (grid + Ontarians) benefits if the LF is reduced

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Project Goals:

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

Methodology

Methodology

We...

1. Measured the power usage of 16 homes every 6s for 5-9 months
2. Scale these to some portion ω of Ontario homeowners assumed to have storage (*agents*)
3. Simulate the impact of agents' actions on the LF for $\omega : 0 \rightarrow 1$ and for different pricing schemes

$$\underbrace{o_i'(\omega)}_{\text{new agg. approx}} \approx \underbrace{(1-\beta)o_i}_{\text{industry \& comm.}} + \underbrace{(1-\omega)\,\beta o_i}_{\text{homeowners w/out storage}} + \underbrace{\beta\omega o_i \frac{q_i}{l_i}}_{\text{agents}}$$

Simulations

Agents...

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

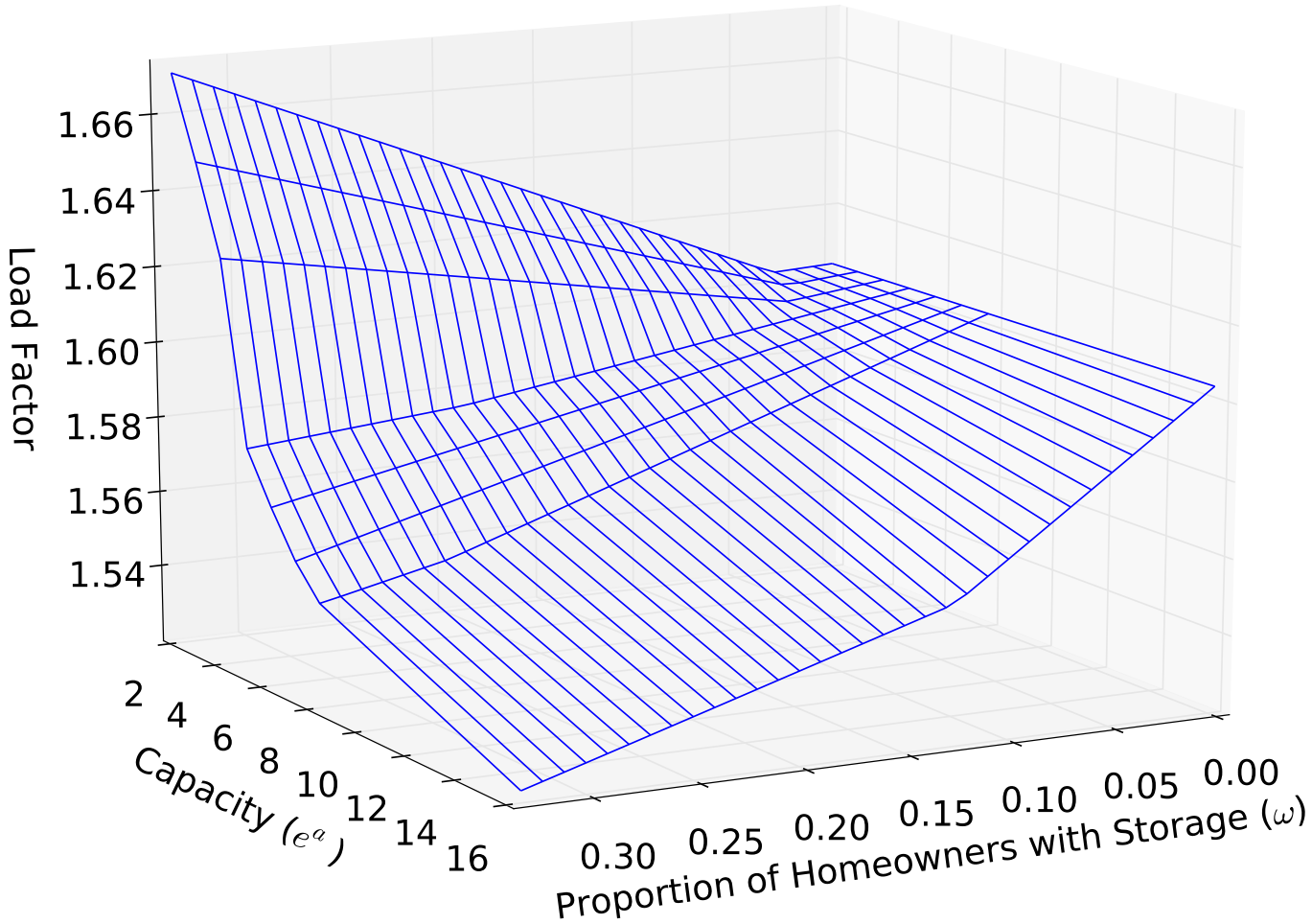
*details skipped here due to time

Pricing Strategies

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

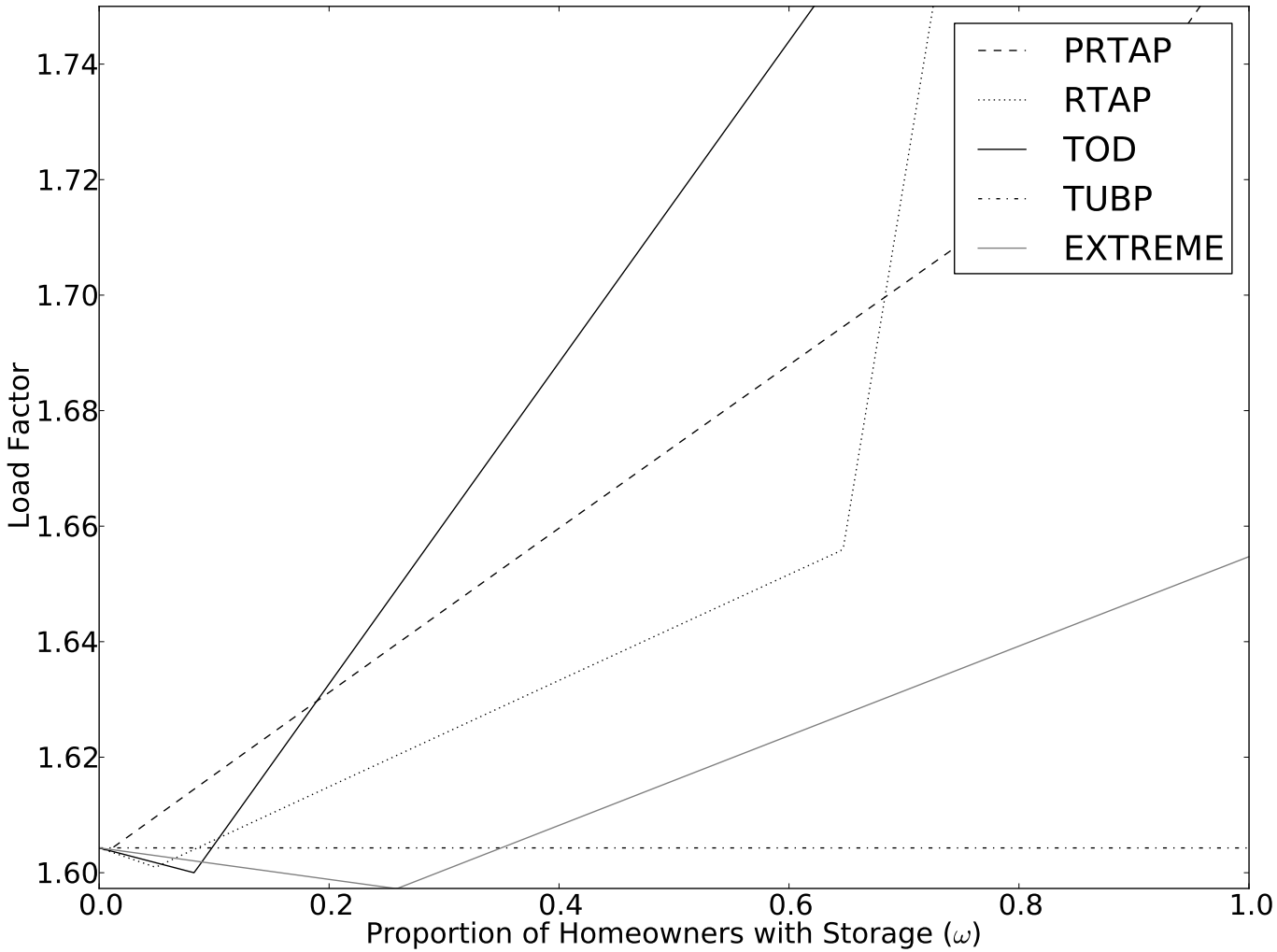
Results

It's All Fun And Games While ω Is Low...



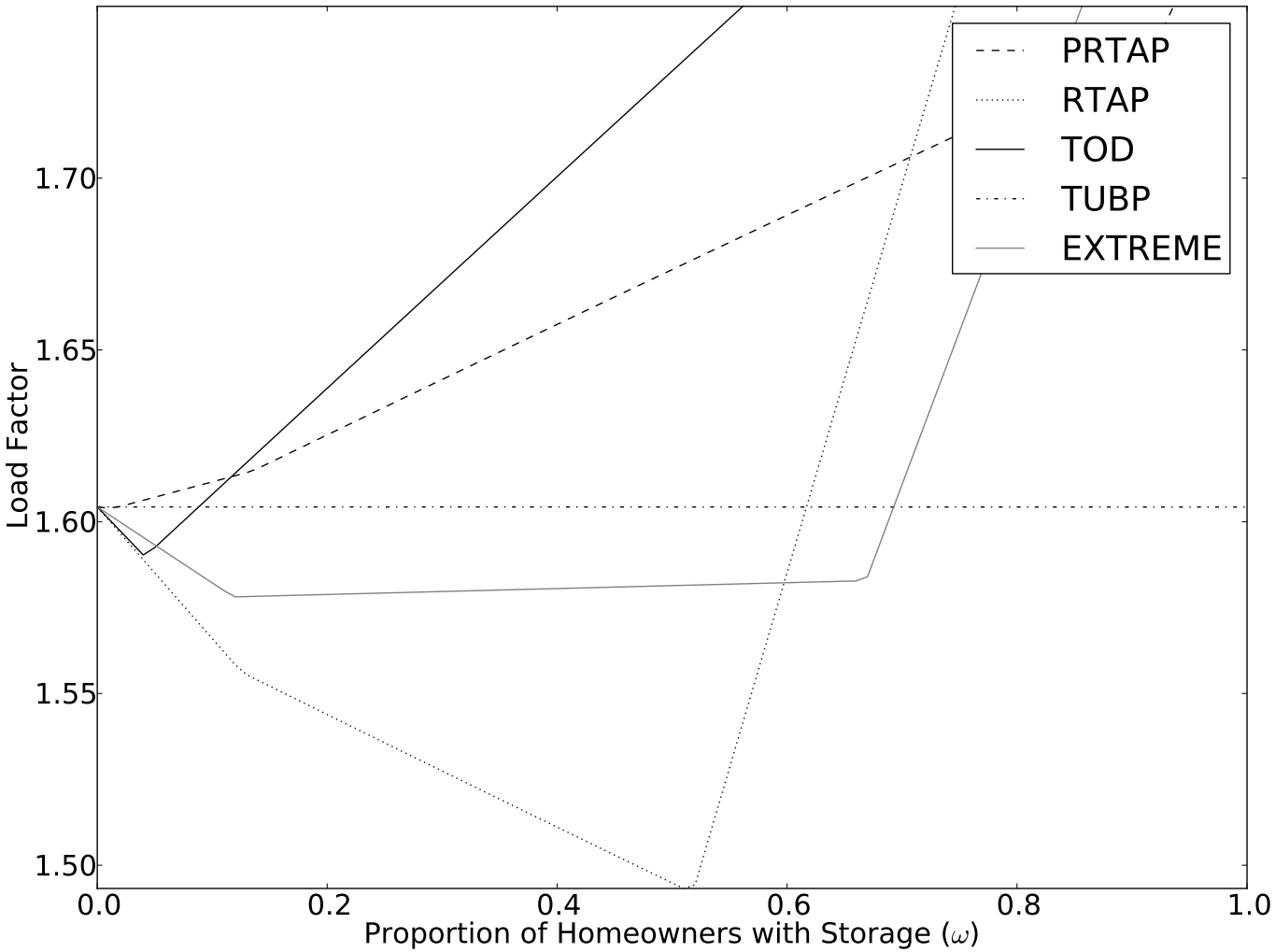
The LF for varying levels of ω and storage capacity under RTAP. The LF decreases for sufficient storage capacities and small values of ω

Then Things Go Wrong!



Capacity = 4kWh

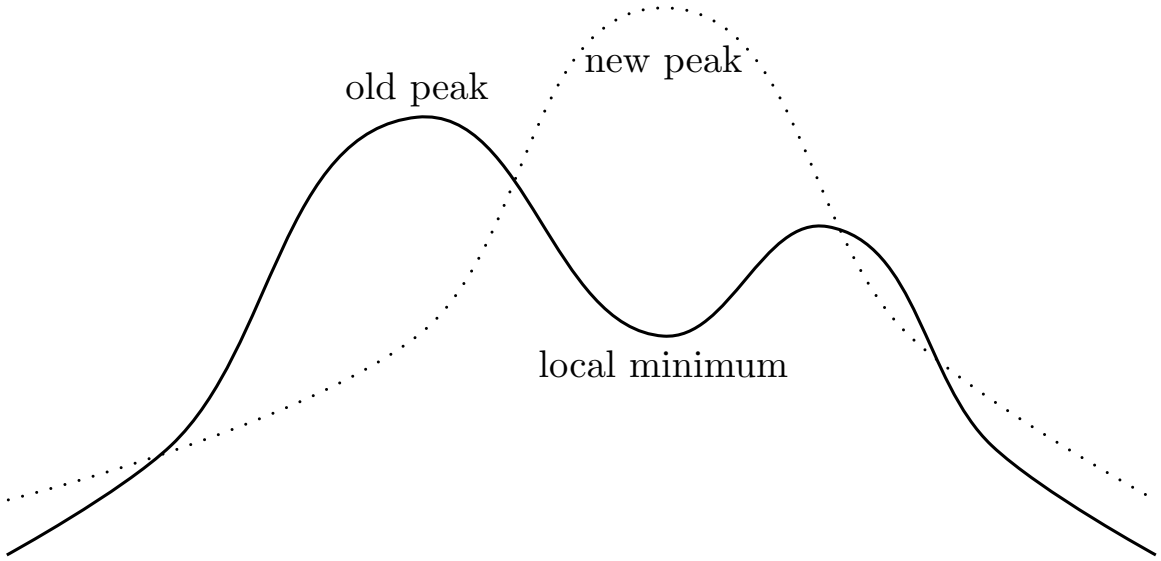
Then Things Go Wrong!



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

$\rightarrow$ storage adoption

$\rightarrow$ new peak

$\rightarrow$ convergence to flat pricing

$\rightarrow$ storage useless

$\rightarrow$ peaky system

$\rightarrow$ pricing plan changes

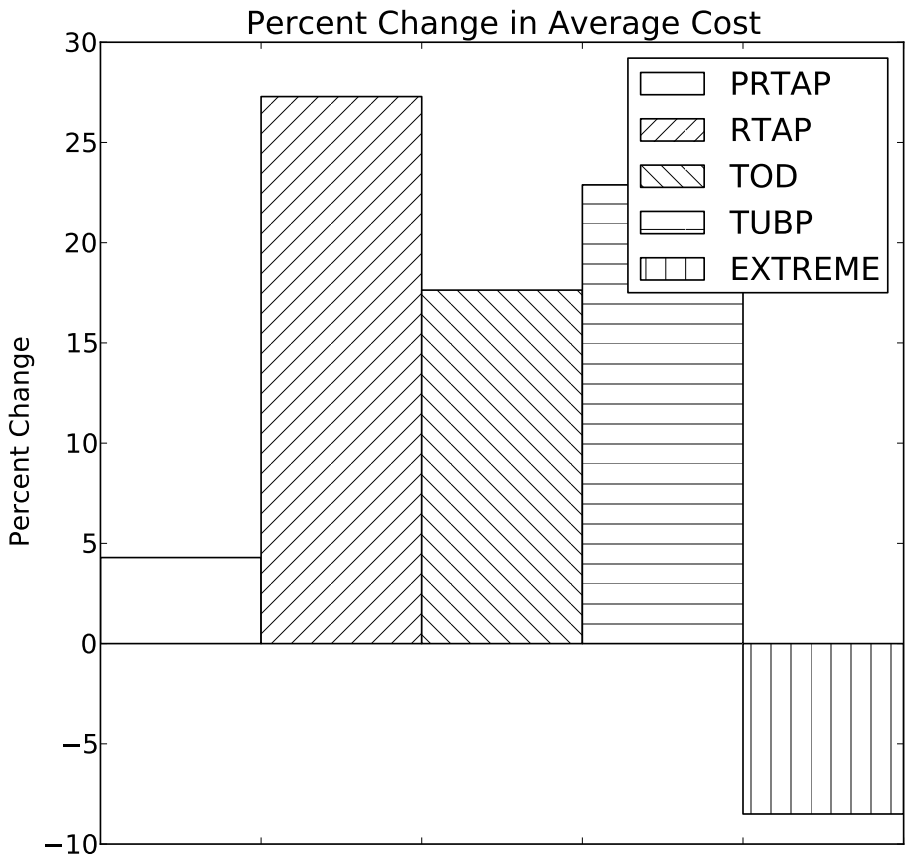
$\rightarrow$ storage usage

$\rightarrow$ ...???

There is no apparent solution (yet) to this problem.

Electricity is Too Cheap To Buy Storage

- Posed a realistic storage cost model, but LP became an IP
- Currently resorted to an optimistic cost model ($20/kWh every 500 cycles), and 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