The Impact of Electricity Pricing Schemes on Storage Adoption In Ontario

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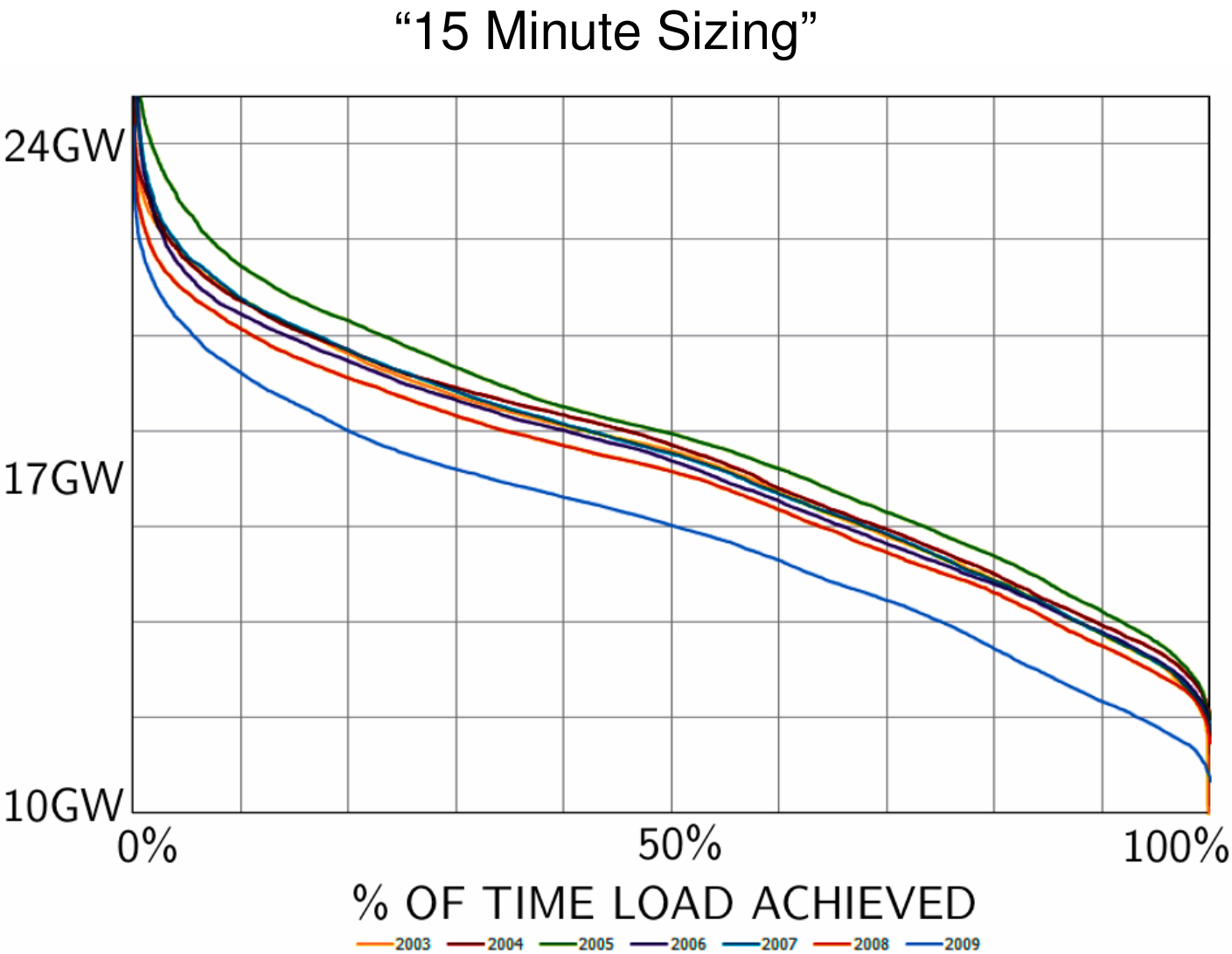
Motivation & Problem

Peak Load Is Expensive

Ontario: $12BN over next 30 years to reduce peak load. 120M/1% reduction.

Peak Load Is Expensive

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



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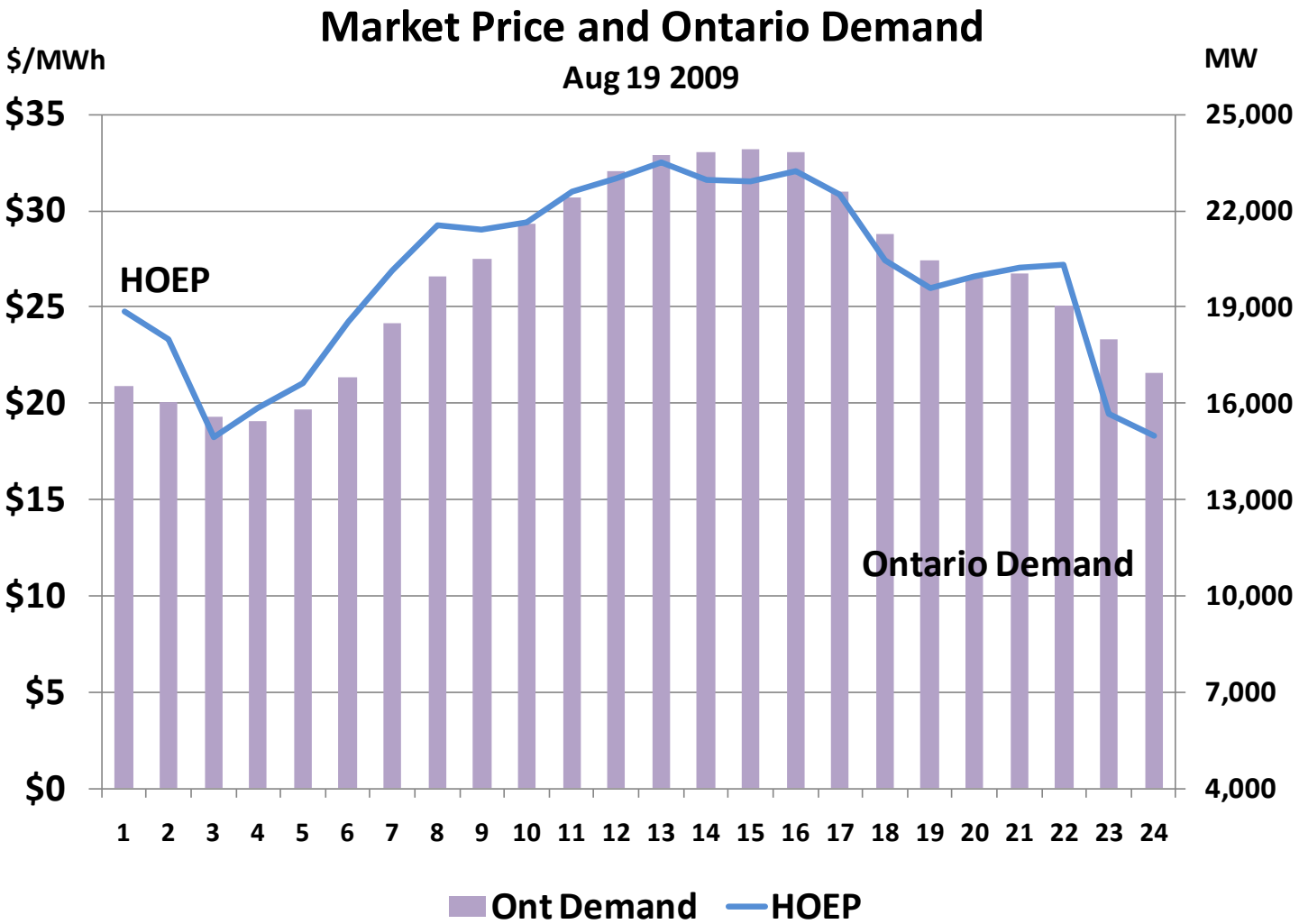
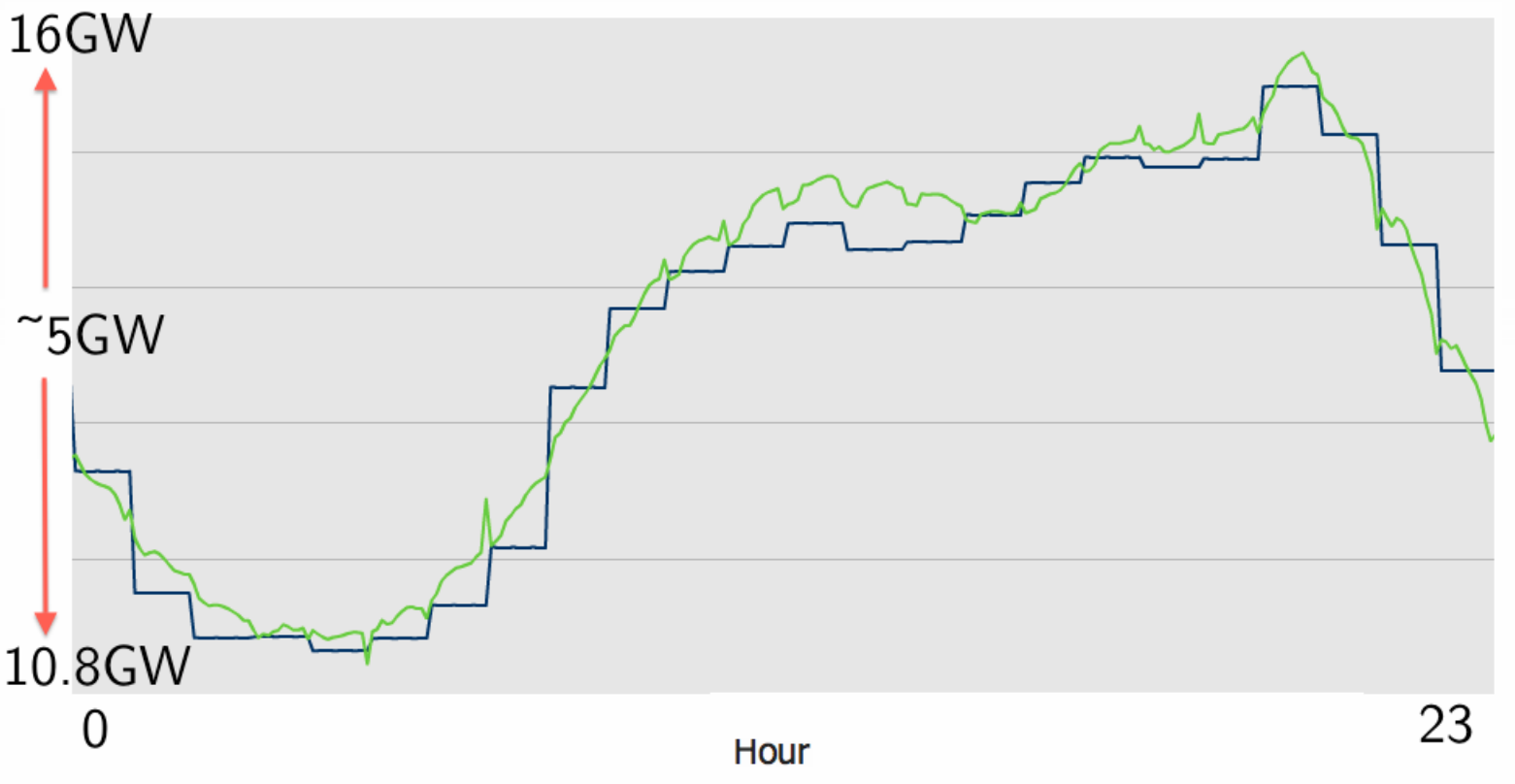


Can Storage Adoption Reduce The Load Factor?

- 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



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 ω 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 = Ontario agg. demand at i,

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

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

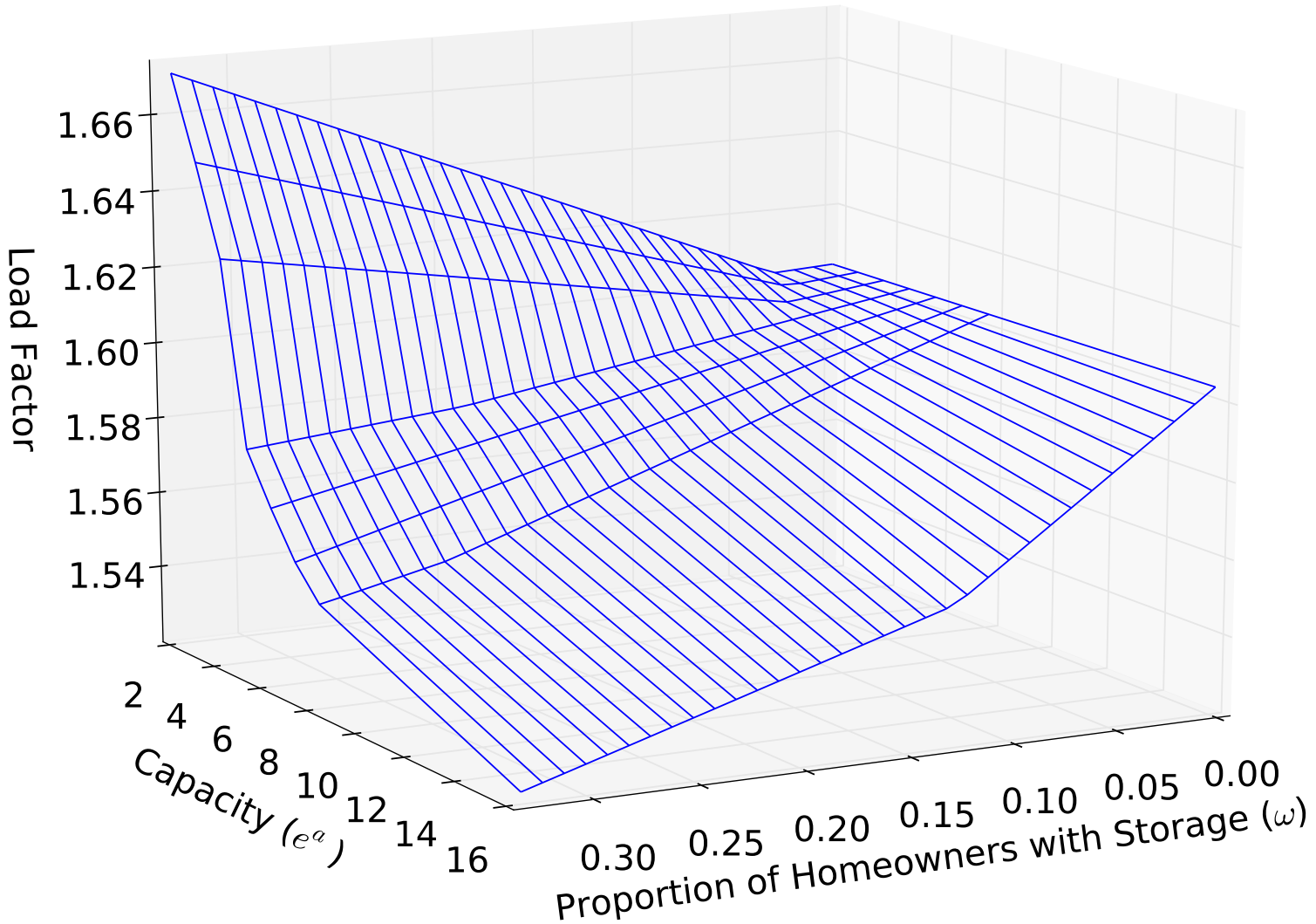
Exact Optimization Is Impossible

We've proven:

- The optimal RTAP, PRTAP, & TUBP optimization windows are infinite
- For TODP, the optimization window is finite only under special conditions

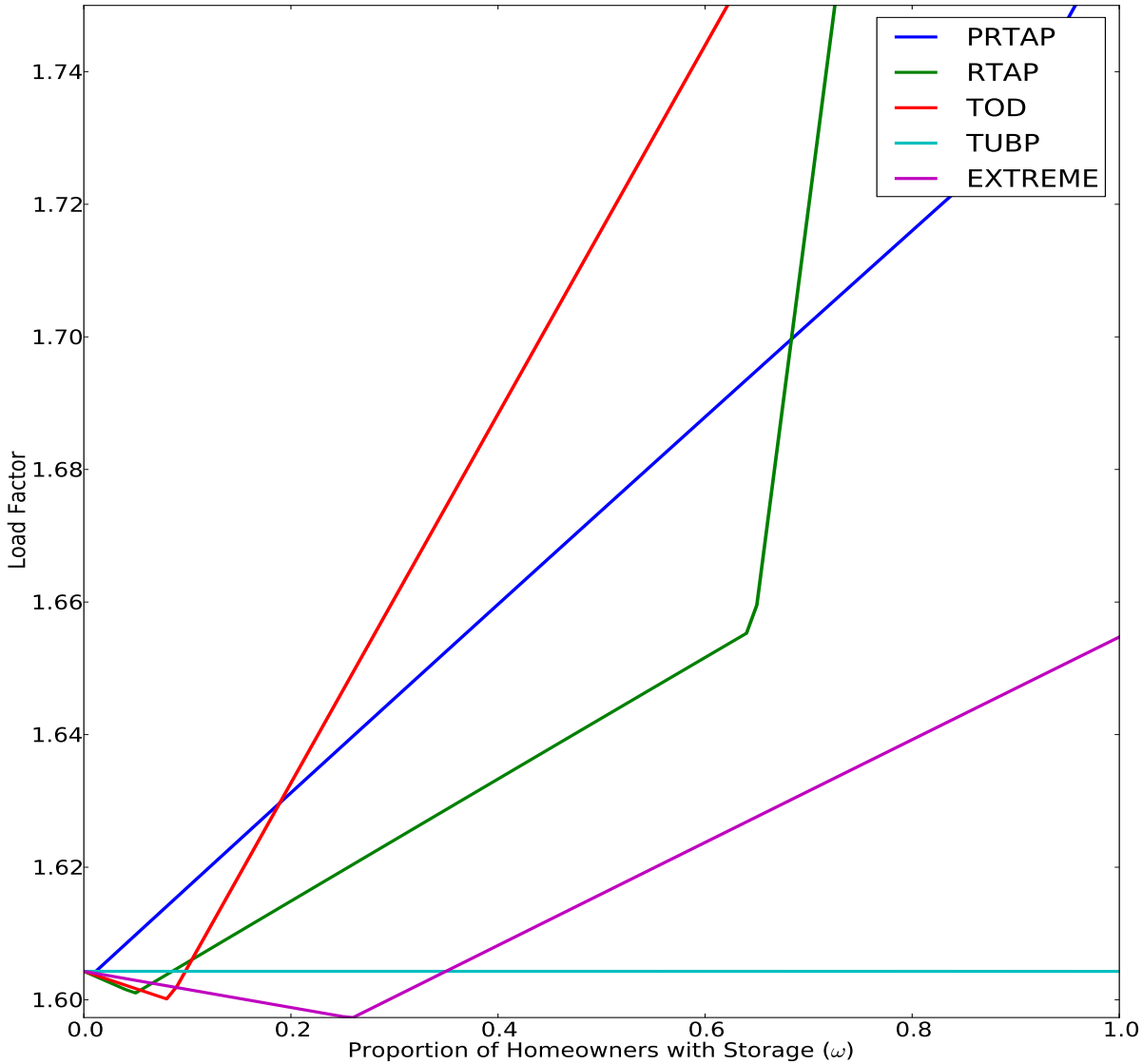
Results

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



The LF for varying levels of ω and storage capacity under RTAP.

Then Things Go Wrong!



Capacity = 4kWh

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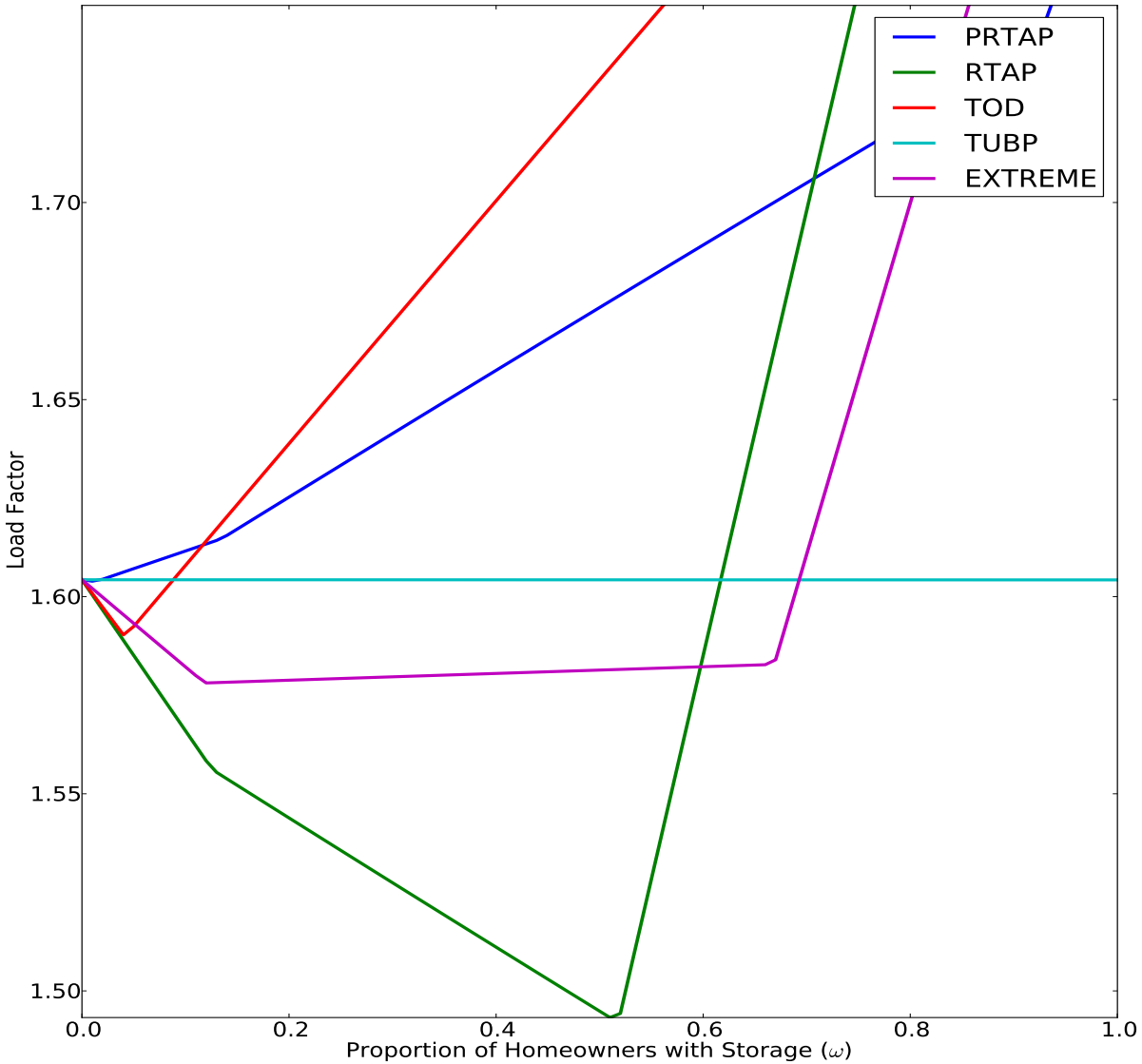
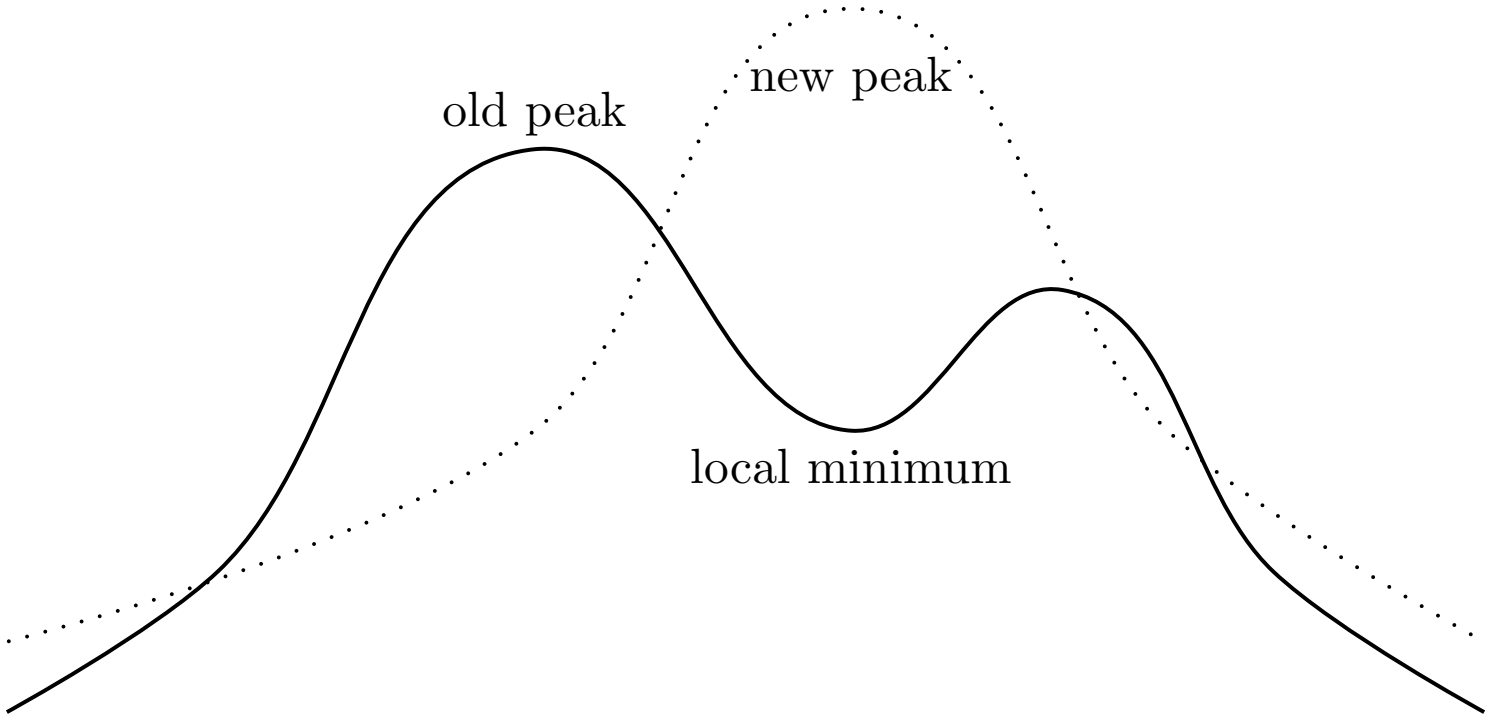


Capacity = 16kWh

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

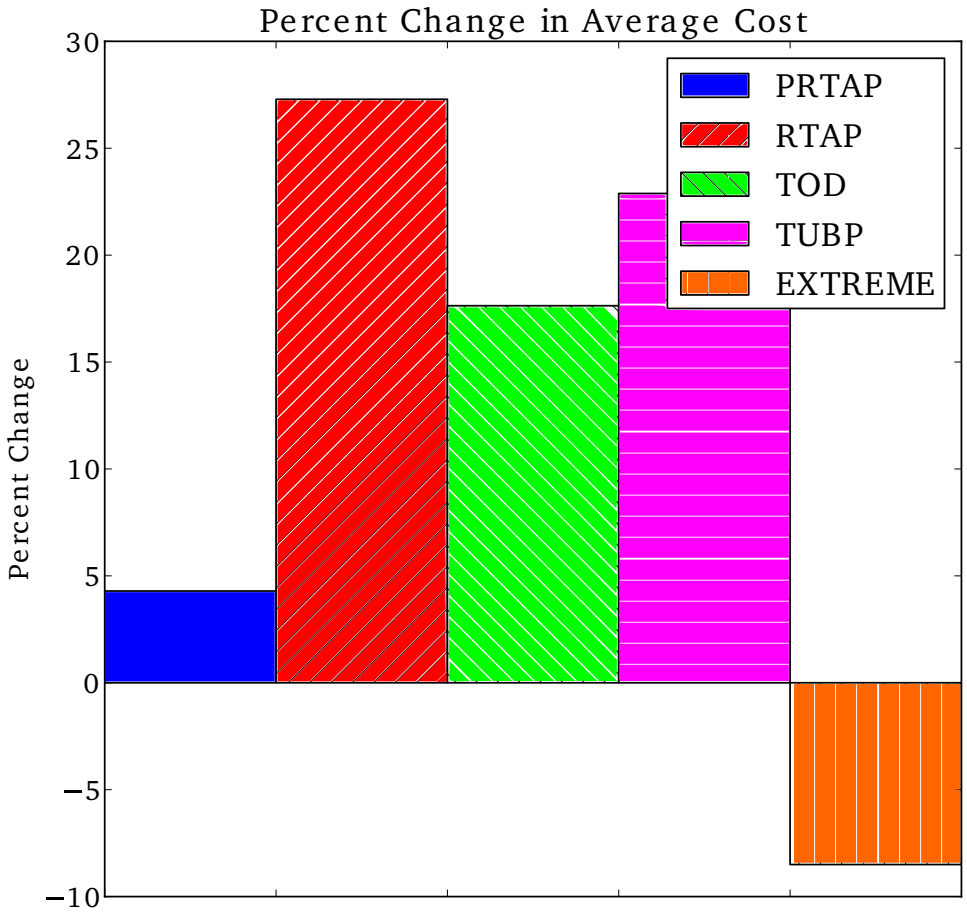
$\rightarrow$ ...???

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