Smart Meter Scheduling

Load Balancing with Peak Reduction

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”Optimal Residential Load Control with Price Prediction in Real-Time Electricity Pricing Environments” by Mohsenian-Rad and Leon-Garcia

”SmartCap: Flattening Peak Electricity Demand in Smart Homes” by Barker, Mishra, Irwin, Shenoy and Albrecht

Why bother about scheduling electricity flow?

Background

- Renewable energy sources
- Non-environmental friendly backup generators
- Minimize Peak-to-Average ratio

Why would the consumer bother?

Loads in households

Interactive

Background

Loads in households

Load	Peak	Average	Quantity
Refrigerator	456 W	74 W	1
Freezer	437 W	82 W	1
HRV	1129 W	24 W	1
Dehumidifier	505 W	371 W	1
Main A/C	1046 W	305 W	1
Bedroom A/C 1	571 W	280 W	1
Bedroom A/C 2	571 W	141 W	1
Background	**4715 W**	**1277 W**	7 units
Interactive	**9963 W**	**887 W**	85 units

Why would the consumer bother?

Transparent to householder

Incitement - Economic aspect

How could one solve this?

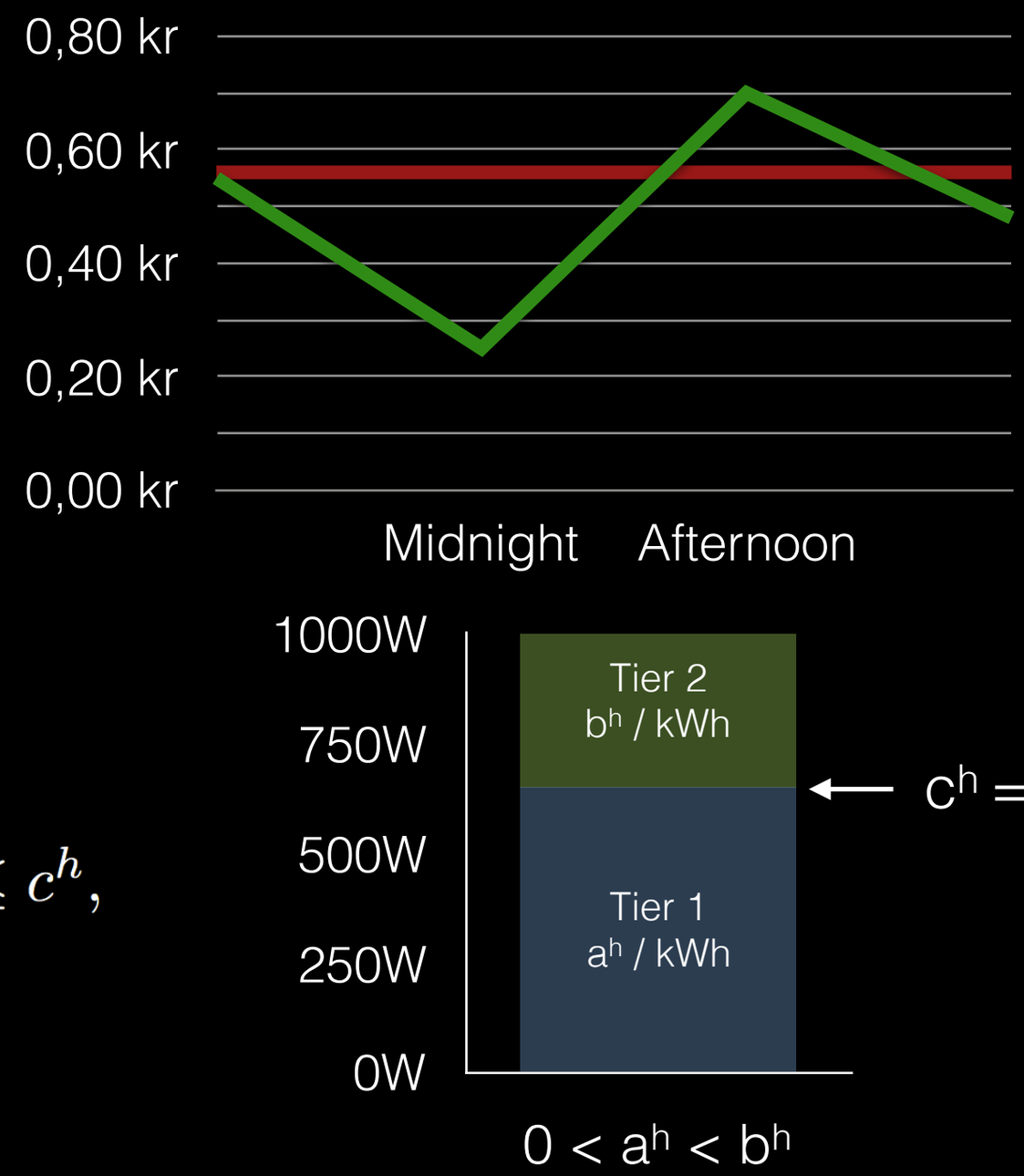
Price Models

Critical-peak

Day-ahead

Inclining block rates

$$p^h(l^h) = \begin{cases} a^h, & \text{if } 0 \leq l^h \leq c^h, \\ b^h, & \text{if } l^h > c^h. \end{cases}$$



Manually Scheduling

Re-evaluate price and load

Consider incoming unpredictable loads

Complex assignment even for consumers that actually want it

Scheduling

Consider Background loads

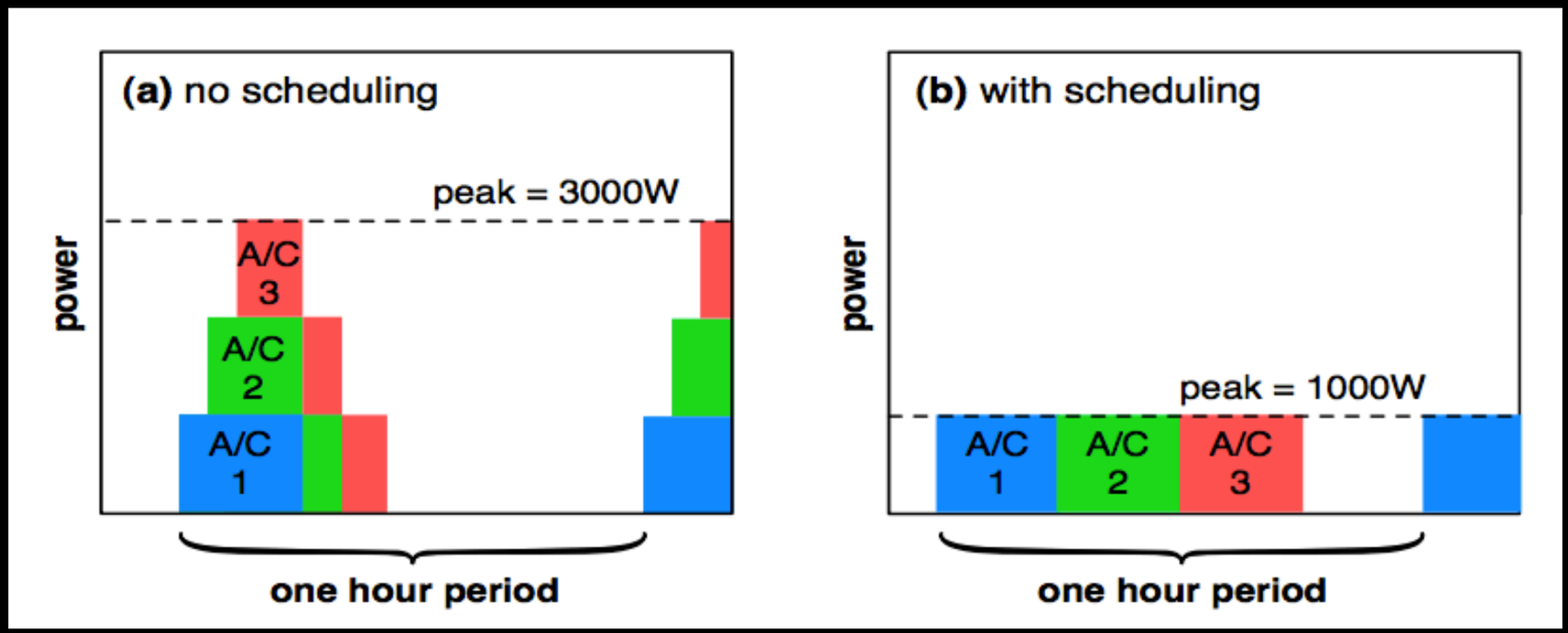
Smart Meter communicate with all sockets

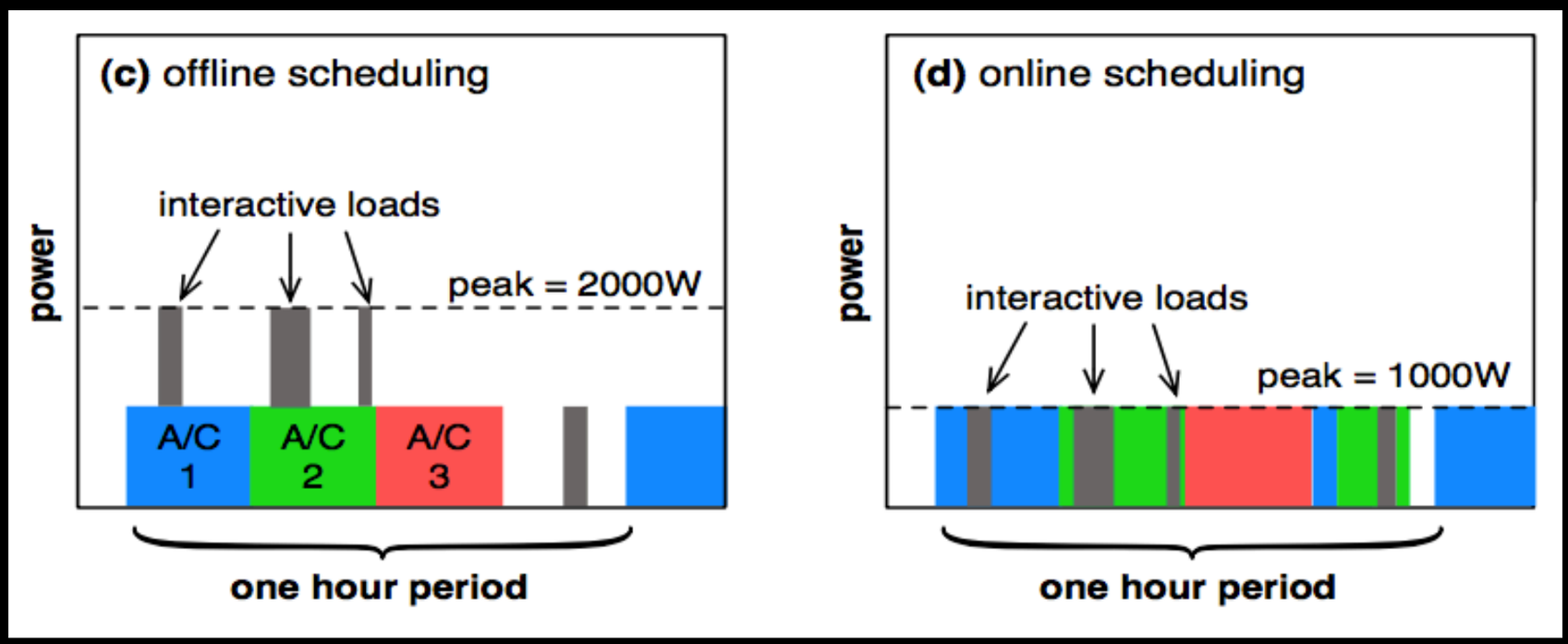
Smooth electricity usage

Scheduling Approach

- Schedule background loads together with interactive loads with Least Slack First (LSF) algorithm
- Schedule tasks with a deadline / waiting time

Least Slack First





Least Slack First

Earliest Deadline First

Loads with a lower slack have a higher priority

Adaptive capacity threshold to determine how many loads to power

Avoid peaks

Scheduling tasks

"How should each user's energy consumption be scheduled in response to time-varying prices?"

Two examples

- Dishwasher
- Plug-in Hybrid Electric Vehicle (PHEV)

Two fold problem! Price optimization vs. less waiting time

Price vs. Waiting time

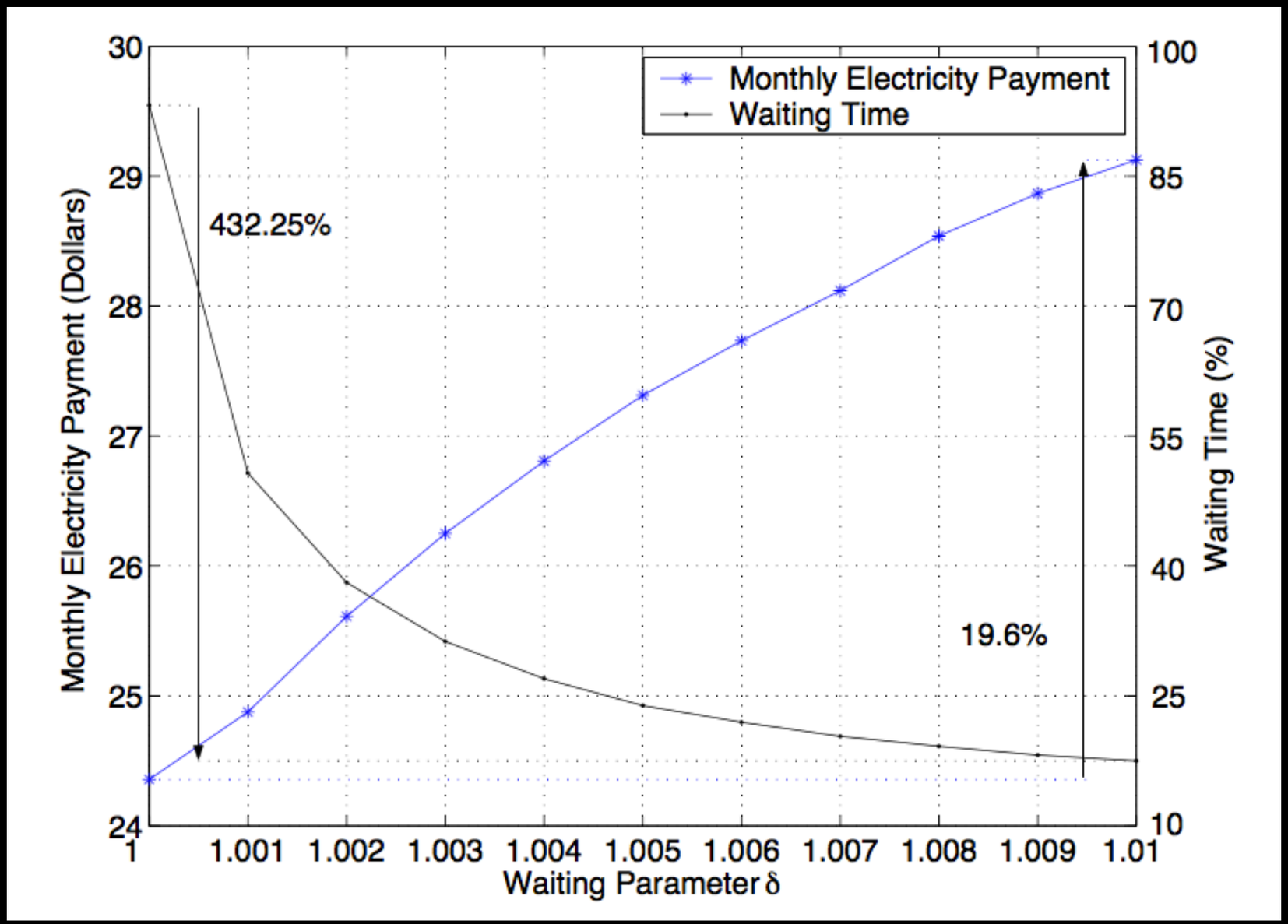
Consider price and waiting time for all appliances

Comfortable with low waiting time, beneficial to save money

Proposed formula

$$\underset{x\in\mathcal{X}}{\textbf{minimize}} \quad \sum_{h=1}^{H} p^h \left(\sum_{a\in\mathcal{A}} x_a^h \right) \left(\sum_{a\in\mathcal{A}} x_a^h \right) + \lambda_{\text{wait}} \sum_{h=1}^{H} \sum_{a\in\mathcal{A}} \frac{(\delta_a)^{\beta_a - h}\, x_a^h}{E_a},$$

Scheduling Control Parameter, δ



Price prediction

$1 \leq P \ll H$

Estimate the price based on previous prices

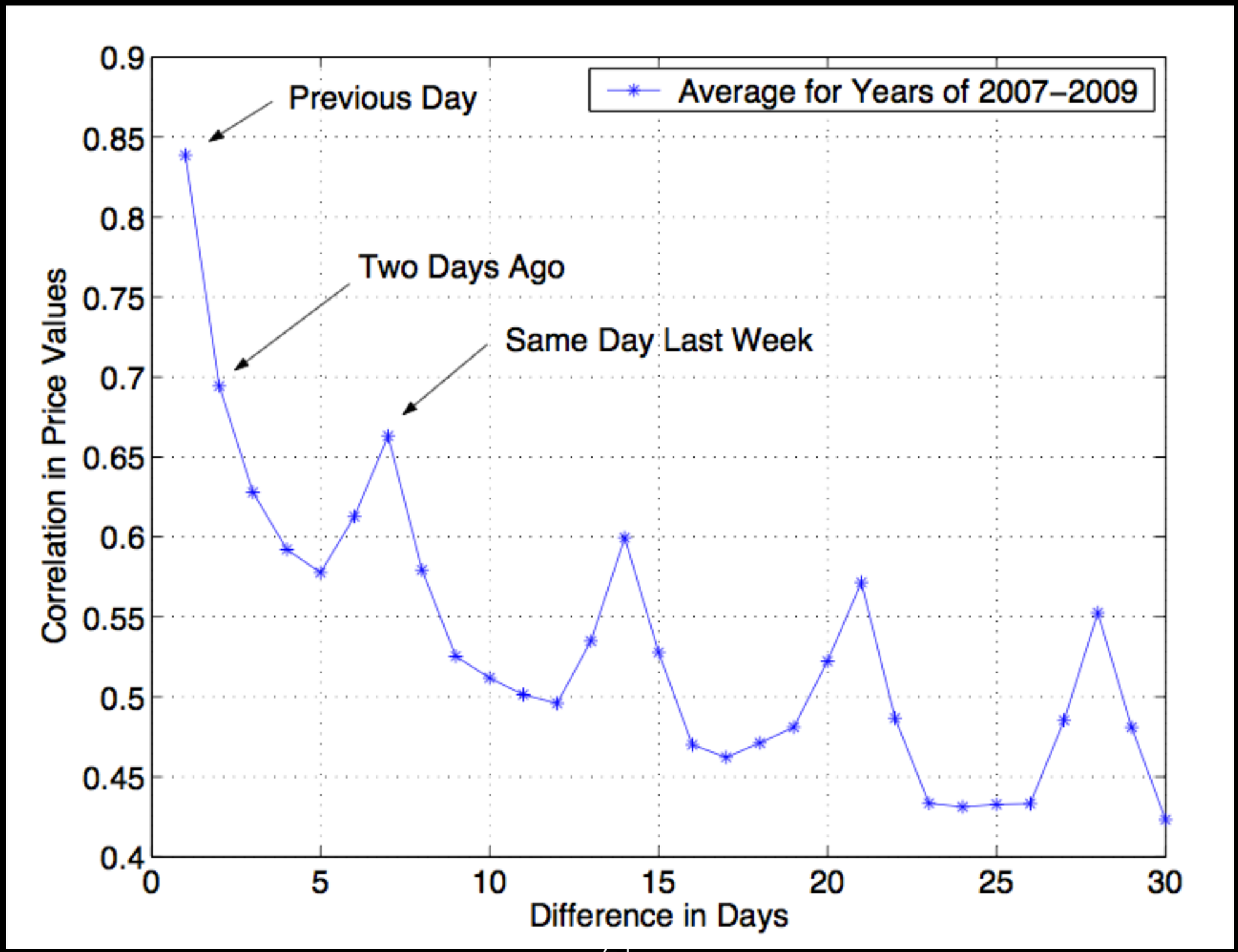
Low computational operations that can reside in the Smart Meter

Price prediction

Yesterday, the day before yesterday and the same day last week

Weighted Average Price

Price prediction



Calculate the price

$$\hat{a}^h[t] = k_1\, a^h[t-1] + k_2\, a^h[t-2] + k_7\, a^h[t-7], \quad \forall\, h \in \mathcal{H}.$$

$$\hat{p}^h(l^h) = \begin{cases} \hat{a}^h, & \text{if } 0 \leq l^h \leq \hat{c}^h, \\ \hat{b}^h, & \text{if } l^h > \hat{c}^h. \end{cases}$$

Proposed formula

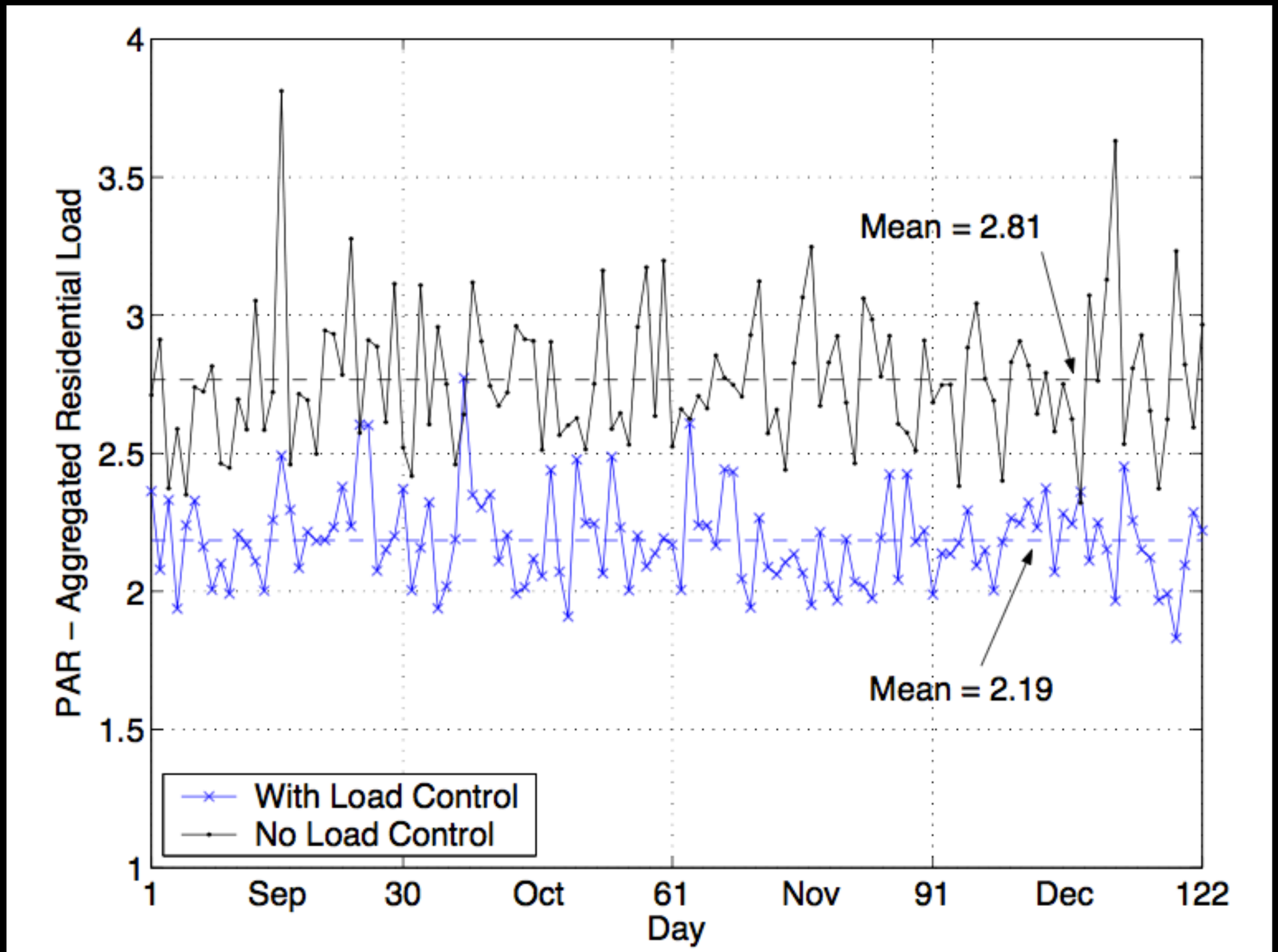
$$\underset{x\in\mathcal{X}}{\textbf{minimize}} \sum_{h=1}^{P} p^h \left(\sum_{a\in\mathcal{A}} x_a^h \right) \left(\sum_{a\in\mathcal{A}} x_a^h \right)$$

$$+ \sum_{h=P+1}^{H} \hat{p}^h \left(\sum_{a\in\mathcal{A}} x_a^h \right) \left(\sum_{a\in\mathcal{A}} x_a^h \right)$$

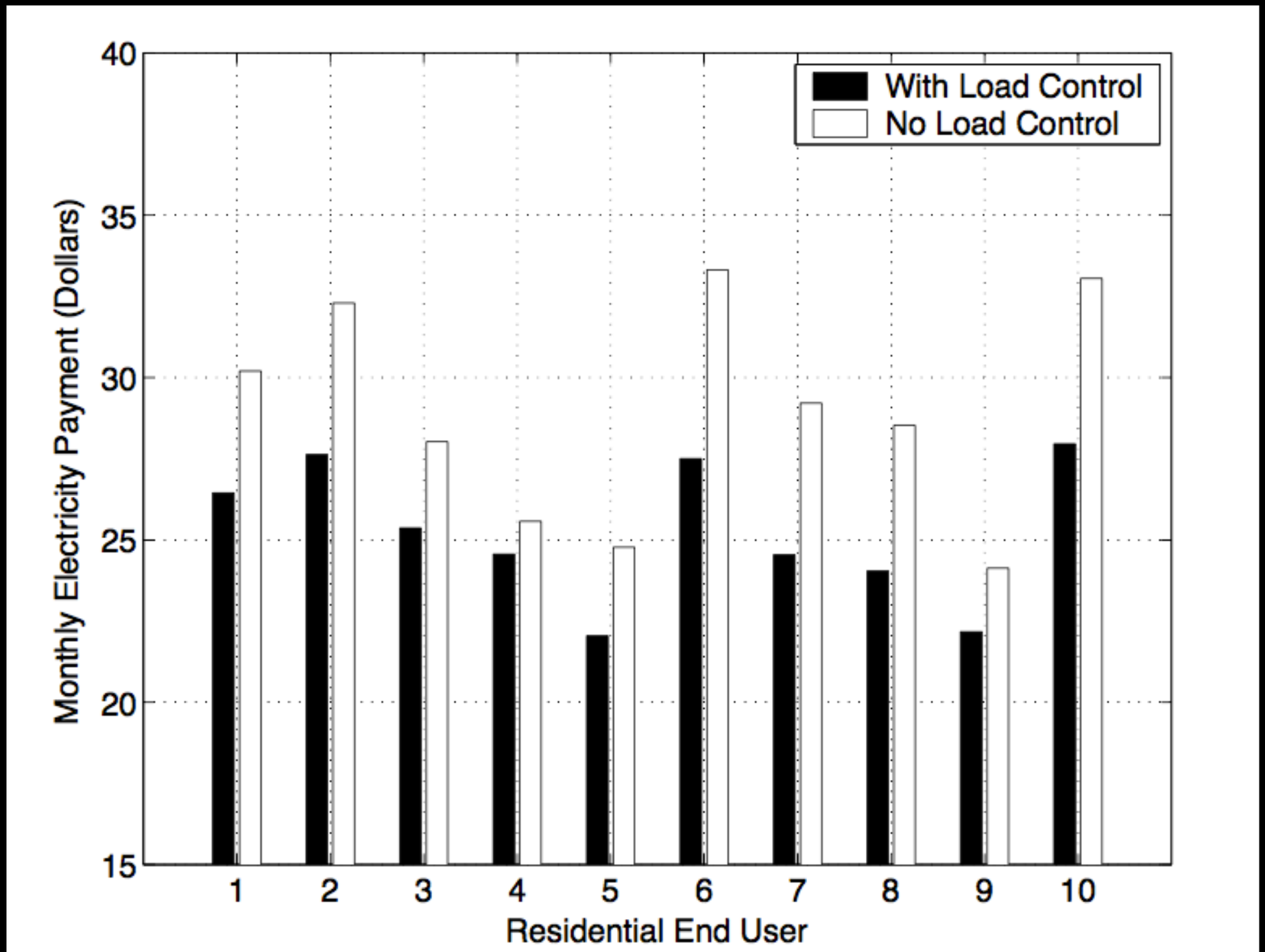
$$+ \lambda_{\text{wait}} \sum_{h=1}^{H} \sum_{a\in\mathcal{A}} \frac{(\delta_a)^{\beta_a - h}\, x_a^h}{E_a},$$

Simulation Results

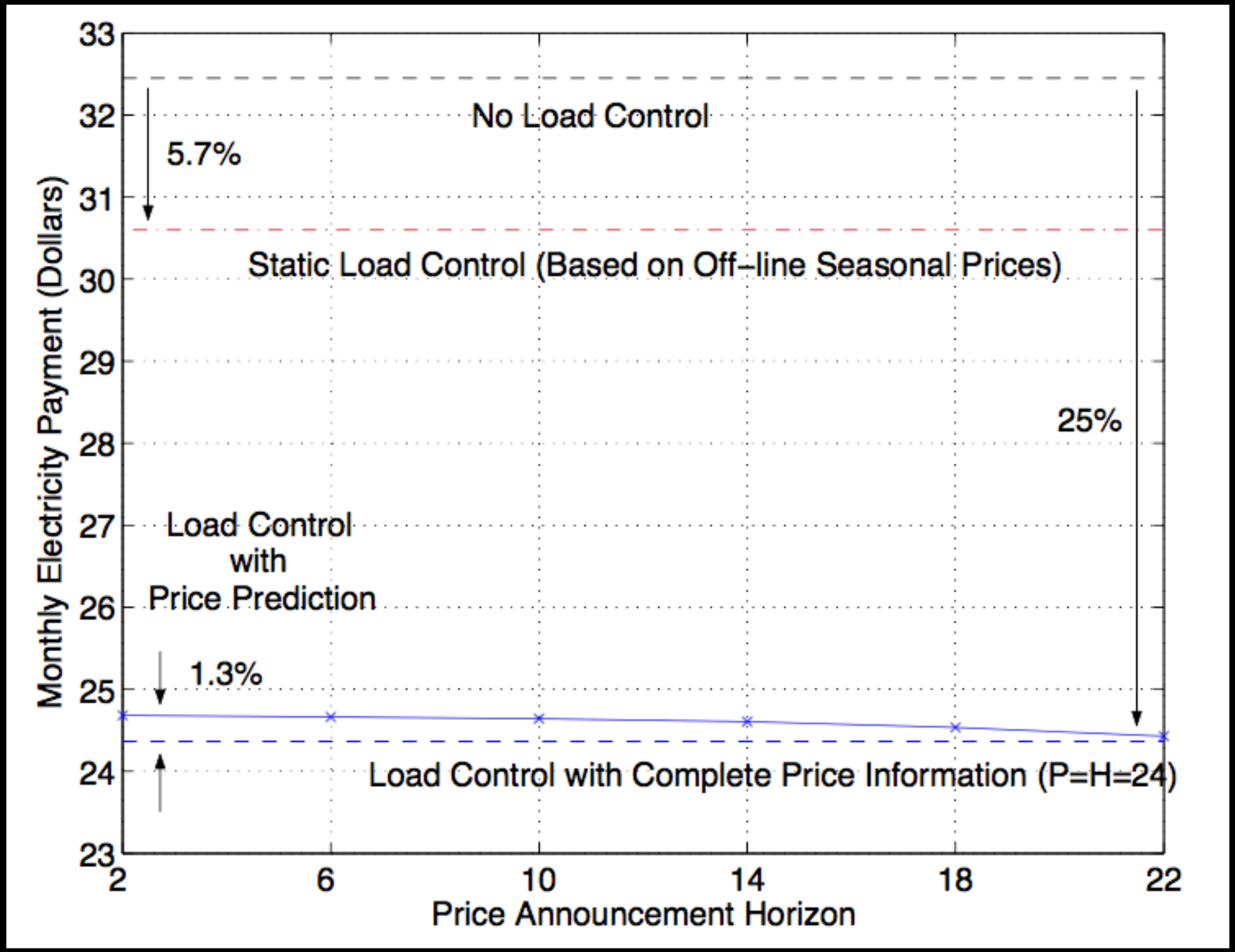
Results


PAR – Aggregated Residential Load
4
3.5
3
2.5
2
1.5
1
Mean = 2.81
Mean = 2.19
With Load Control
No Load Control
1
Sep
30
Oct
61
Nov
91
Dec
122
Day

Results


With Load Control
No Load Control
Monthly Electricity Payment (Dollars)
40
35
30
25
20
15
1
2
3
4
5
6
7
8
9
10
Residential End User

Results


No Load Control
5.7%
Static Load Control (Based on Off–line Seasonal Prices)
25%
Load Control
with
Price Prediction
1.3%
Load Control with Complete Price Information (P=H=24)
Monthly Electricity Payment (Dollars)
Price Announcement Horizon
33
32
31
30
29
28
27
26
25
24
23
2
6
10
14
18
22

Conclusion

Aiming for a consistent and stable electricity flow

Two algorithms presented: Least Slack First and task Scheduling with waiting time / deadline

Successfully reduce Peak to average ratio in households

”The easiest way to save money is to waste less energy.”

–Barack Obama

References

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Quote by Barack Obama, https://www.ase.org/resources/president-obama-embraces-energy-efficiency-2012-state-union