Matching Demand with Supply in the Smart Grid using Agent-Based Multiunit Auction

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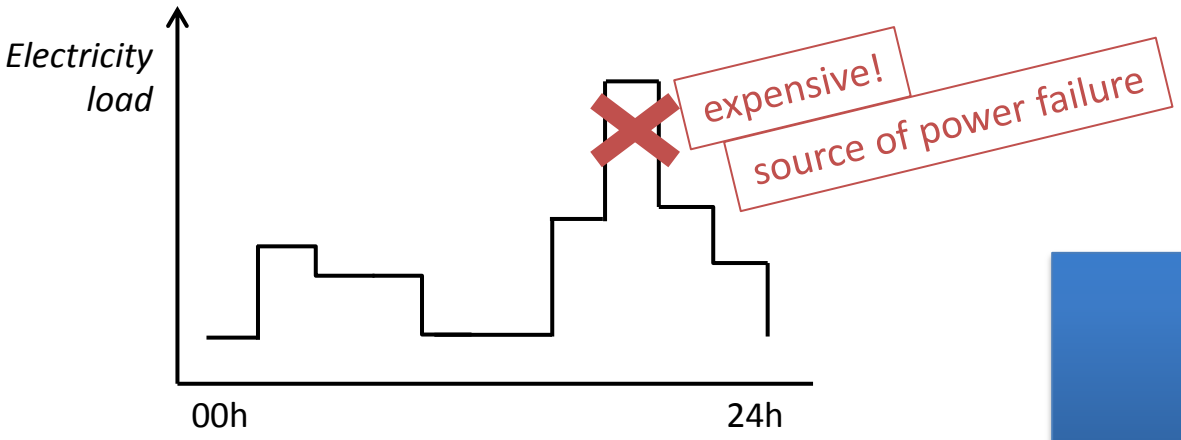
Motivation



Dynamic pricing?

Utility: set dynamic pricing

Customer: voluntarily shift/reduce

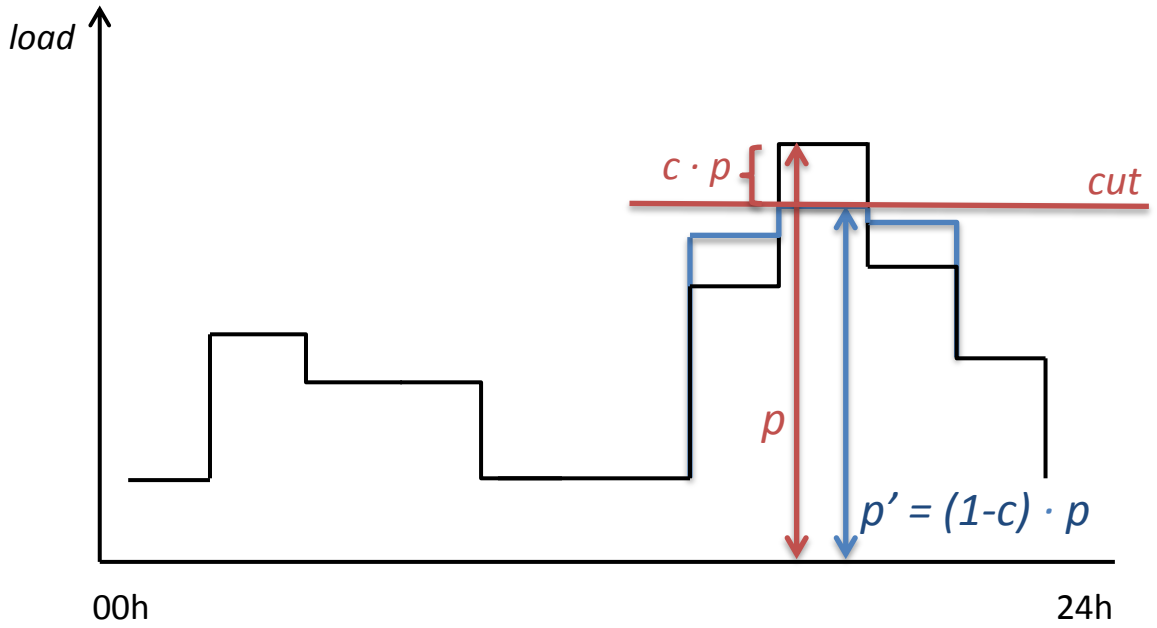
green,
abundant,
but very unpredictable

Our solution

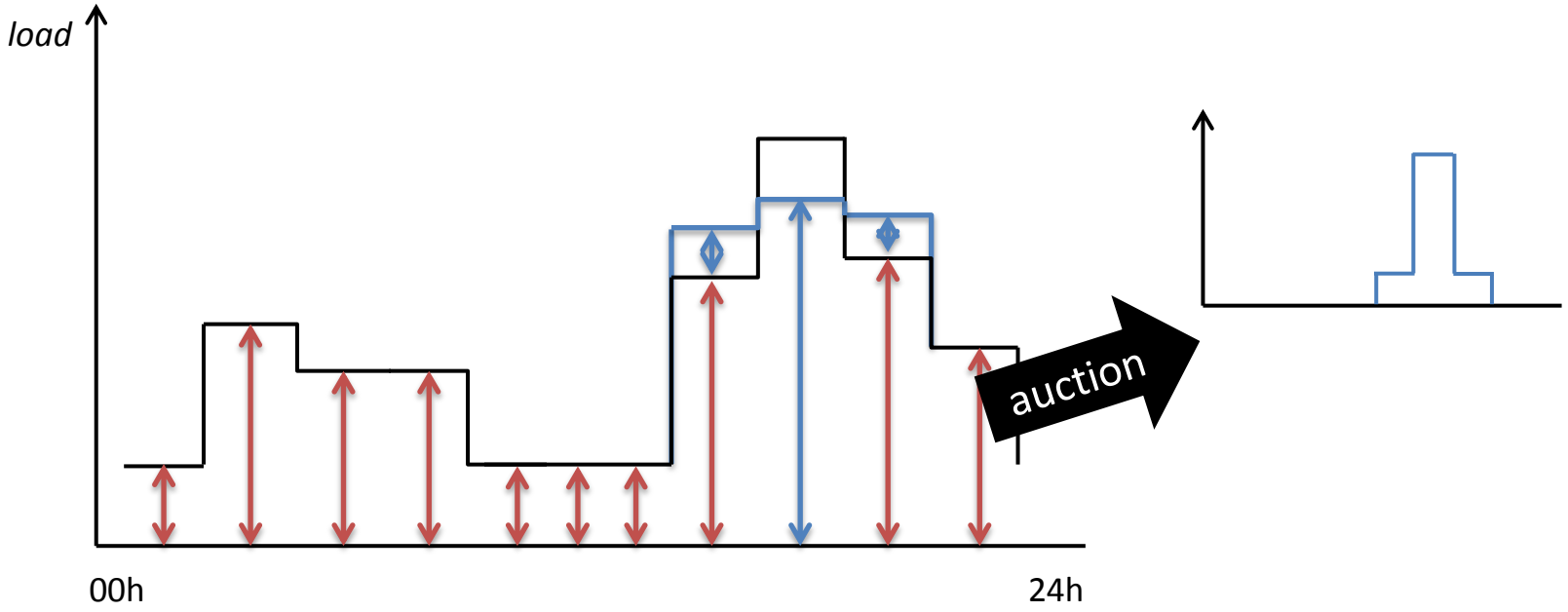
- Matching demand with supply
  - cut PAR (peak to average ratio) explicitly
  - distribute the load using auction
    - provide minimum load guarantee
- Technology advances
  - integration of software agents

PAR-cut (*c*: cut percentage)

- ✓ maintain total load
- ✓ minimize shifting distance



Multiunit Auction [initial condition]



L = load before PAR-cut

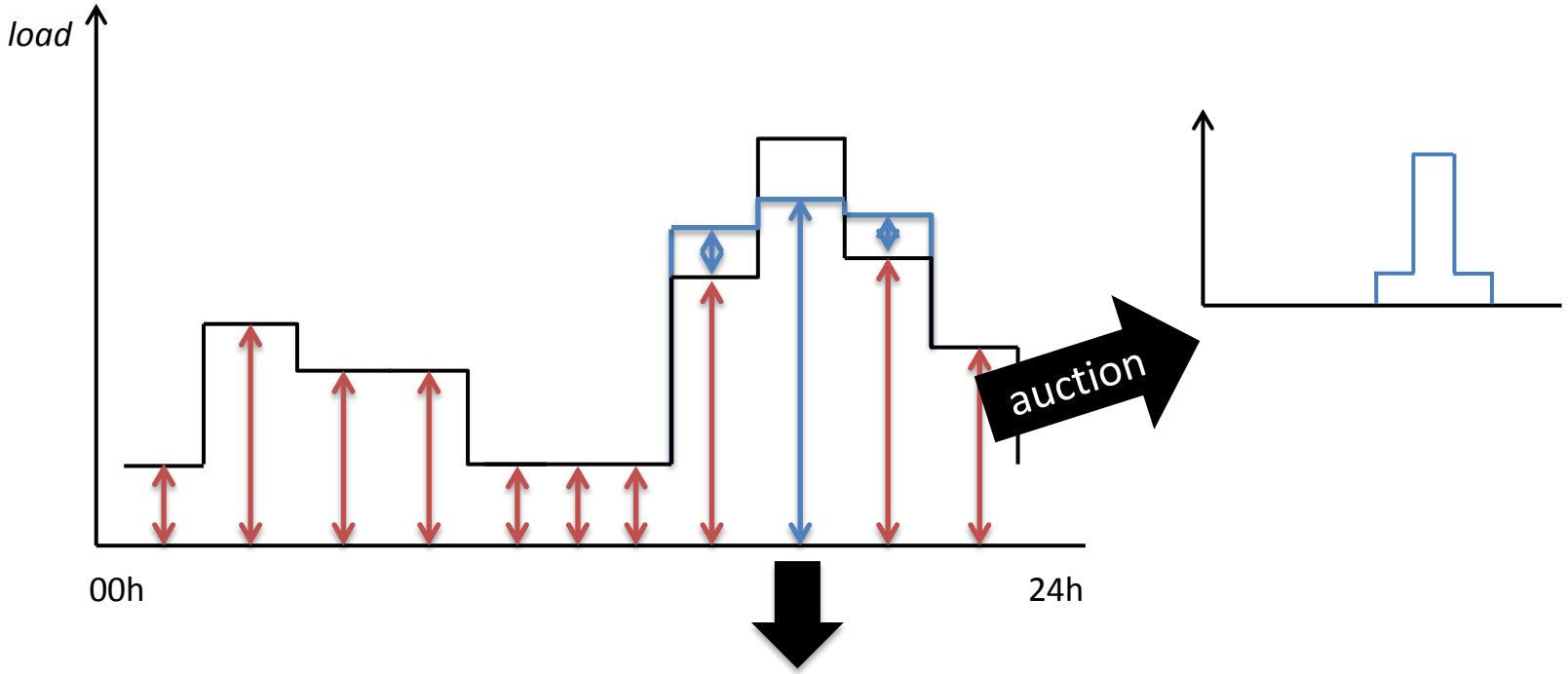
L' = load after PAR-cut

if $L'(t) = L(t)$, we distribute $L(t)$ $\boxed{L_i^0(t) = L_i(t)}$

if $L'(t) > L(t)$, we distribute $L(t)$, auction $L'(t) - L(t)$

if $L'(t) < L(t)$, we auction $L'(t)$

Multiunit Auction [initial condition]



L = load before PAR-cut

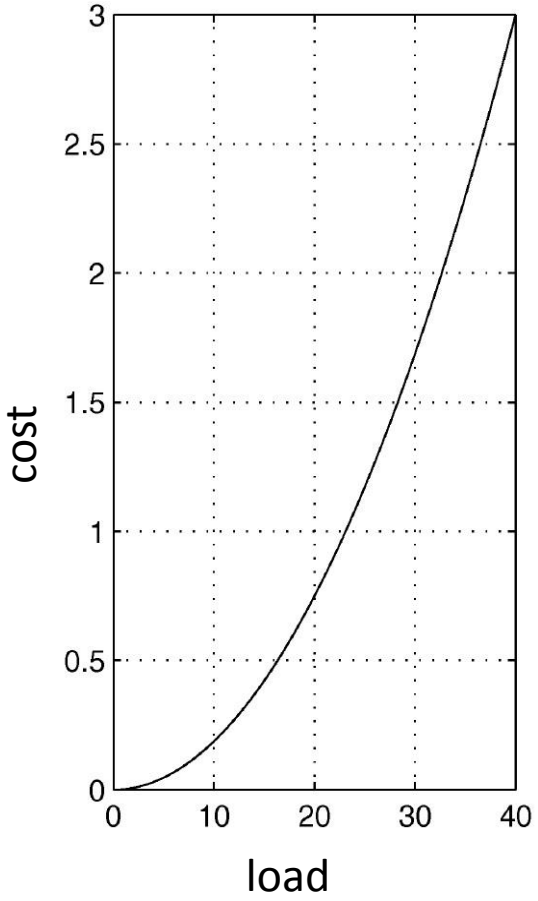
L' = load after PAR-cut

Minimal load guarantee *m*
when L'(t) < L(t), we distribute load *m* to all consumers

Multiunit Auction [bid]

- Cost function *c*:
  - convex and increasing on *L(t)*
- Reserve price:

$$p(t) = \frac{cost(L(t))}{L(t)}$$

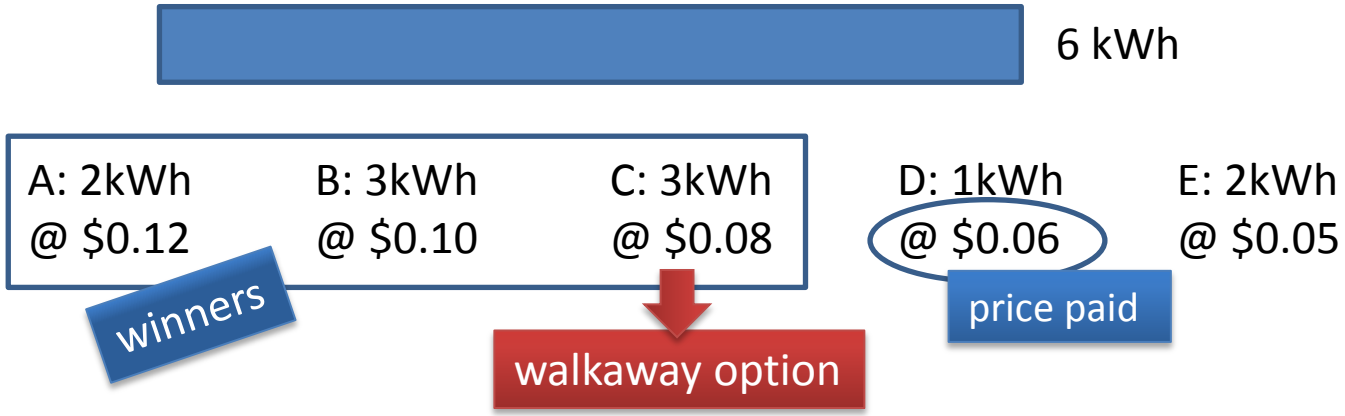


Multiunit Auction [bid]

- Bid: an agent(on behalf of a consumer) submit $\{b_1, \ldots, b_{|T|}\}$
- Our agents apply myopic best response
  - an agent bid on time slot *t* if there is a requirement for *t*
  - if there is not enough load available on *t*, she bids on the closest available time slot

Multiunit Auction [winners]

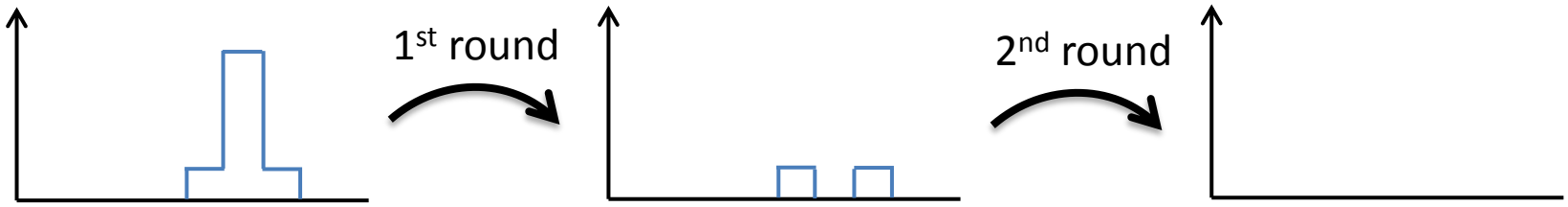
- For each time slot,
  - winners: highest bidders
    - smallest set of winners
    - allocate, tentatively, maximum number of resources
  - price paid: highest non-winning bid



Multiunit Auction [multiple round]

! There is a possibility that not all loads are not distributed in one round

multiple round auction



Multiunit Auction [truthful bidding]

✓Truthful bidding is a myopic best response

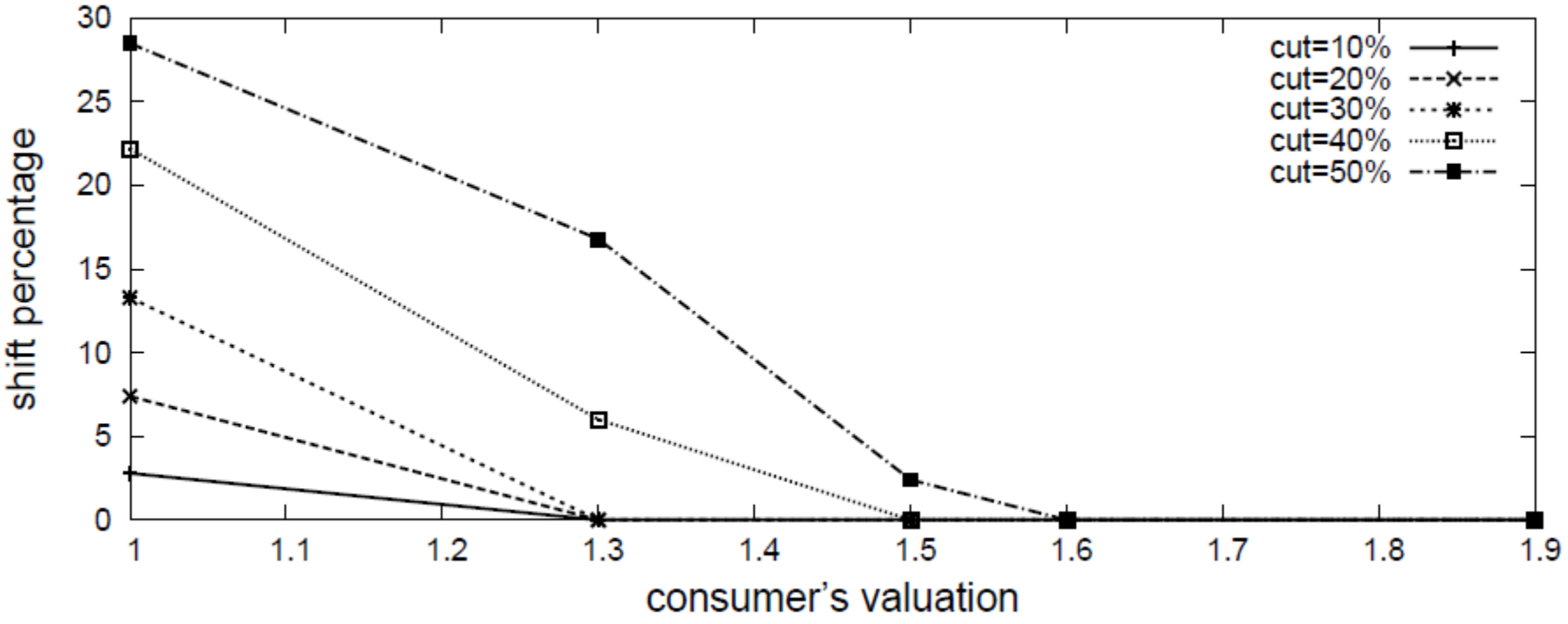
(no incentive for agents to lie about their valuations)

Two main causes:

- pricing mechanism
- agents' myopic best response

Experiments [load shifting]US distribution

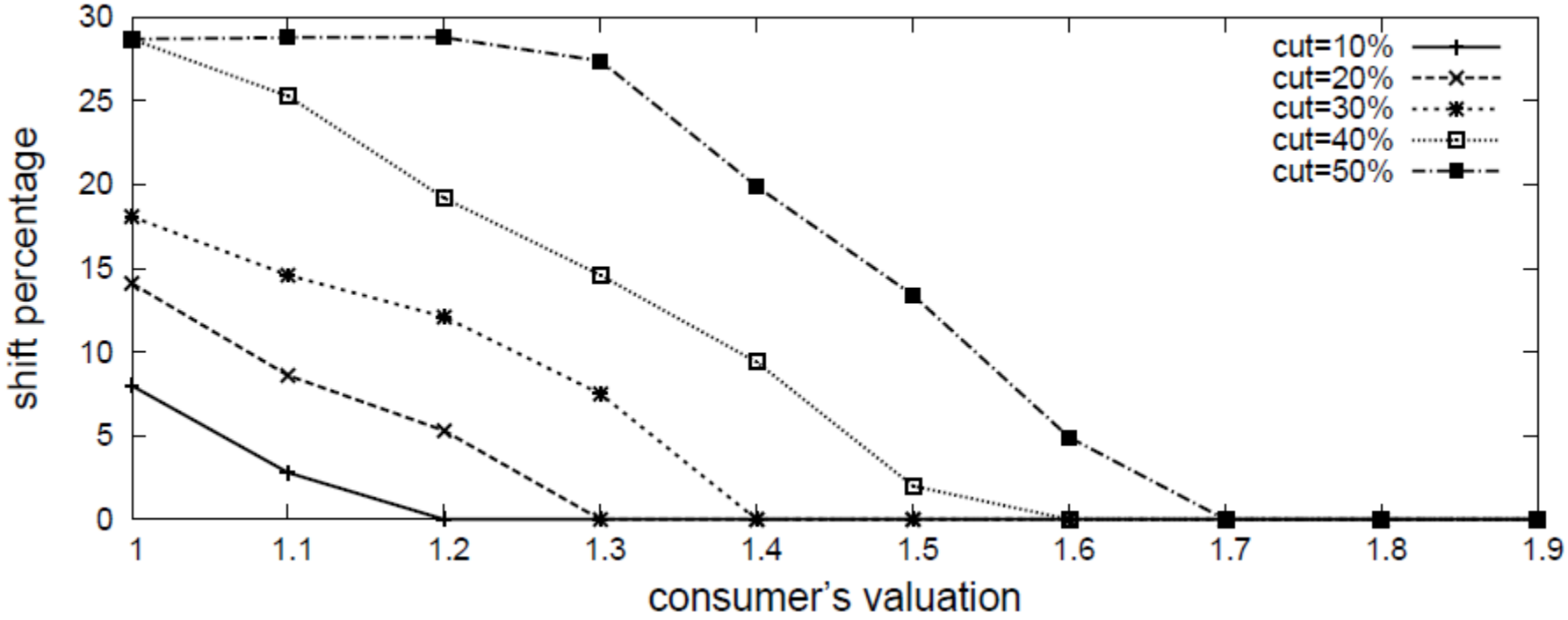
Consumer's bid = consumer's valuation · *p(t)*



consumers' valuation distribution: 1.0=0.4, 1.3=0.2, 1.5=0.2, 1.6=0.1, 1.9=0.1
(inspired by the 2004 **US** households wealth distribution)

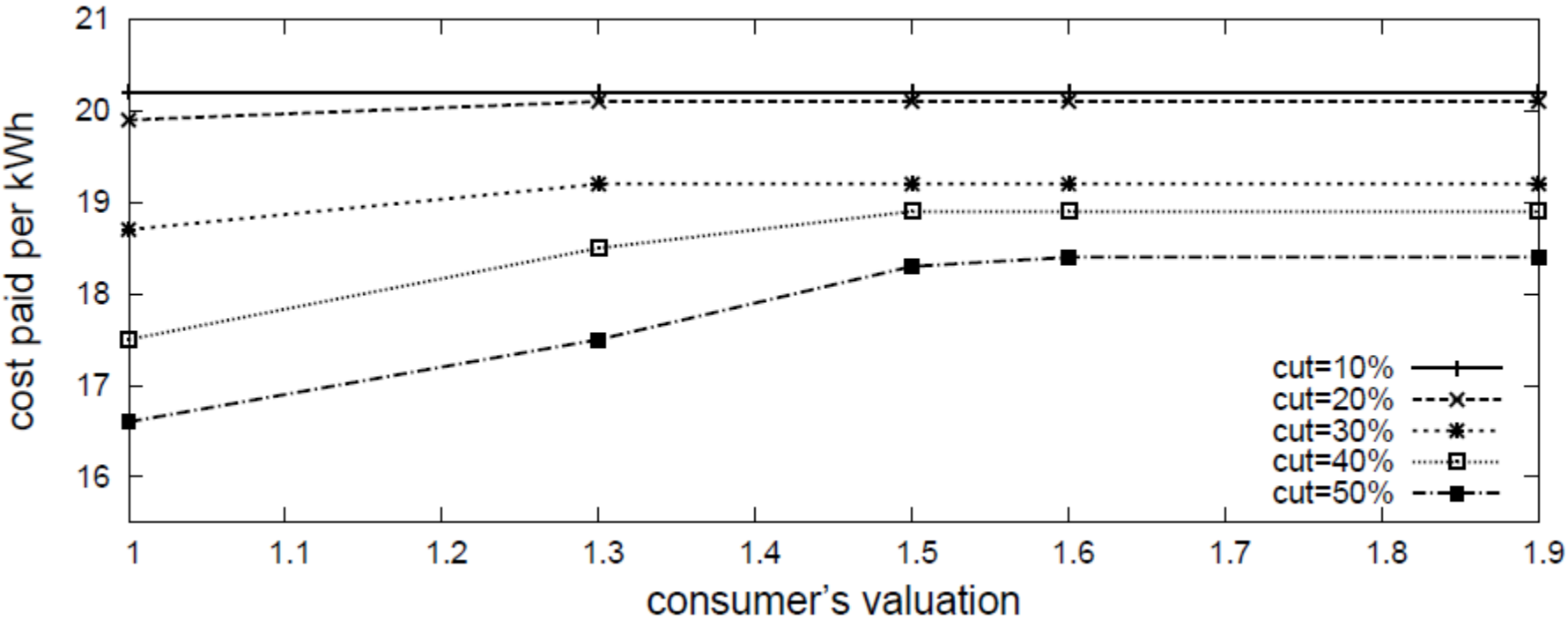
Experiments [load shifting] Uniform distribution

Consumer's bid = consumer's valuation · *p(t)*

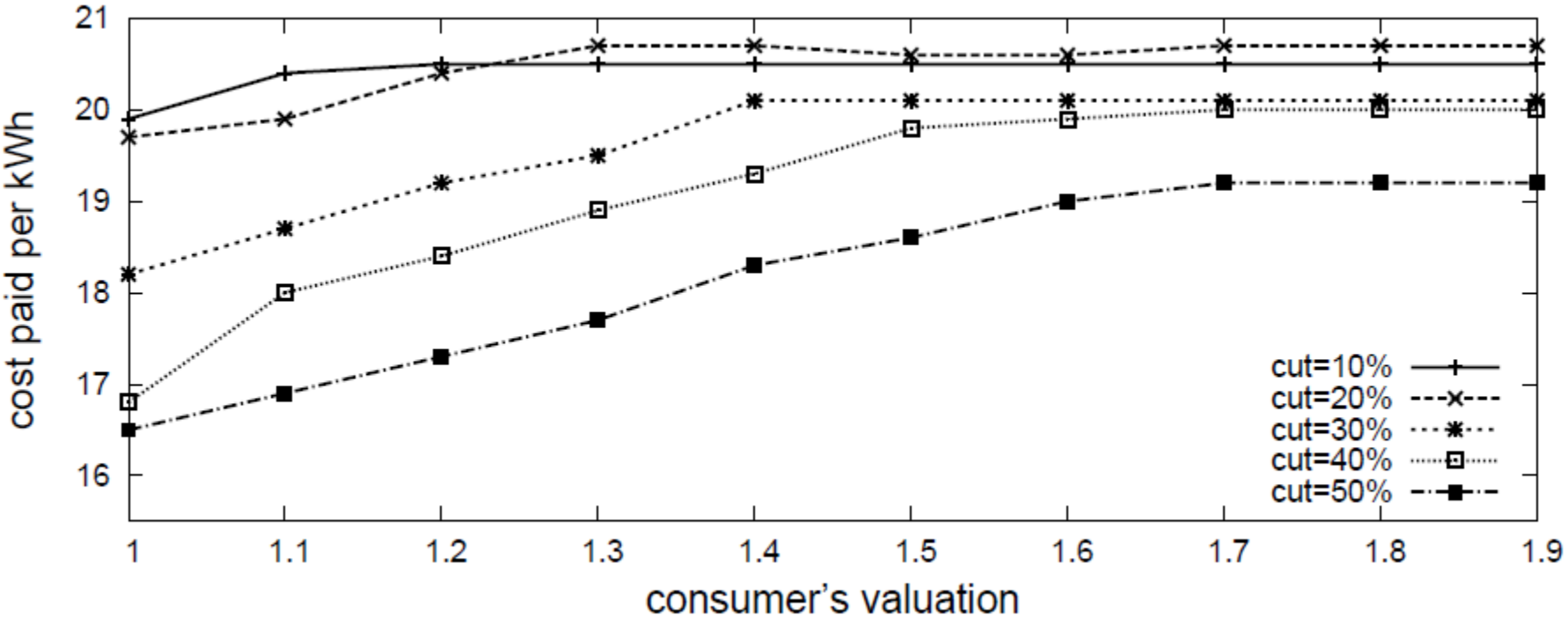


uniform consumers' valuation distribution: 1.0=0.1, 1.1=0.1, …, 1.9=0.1

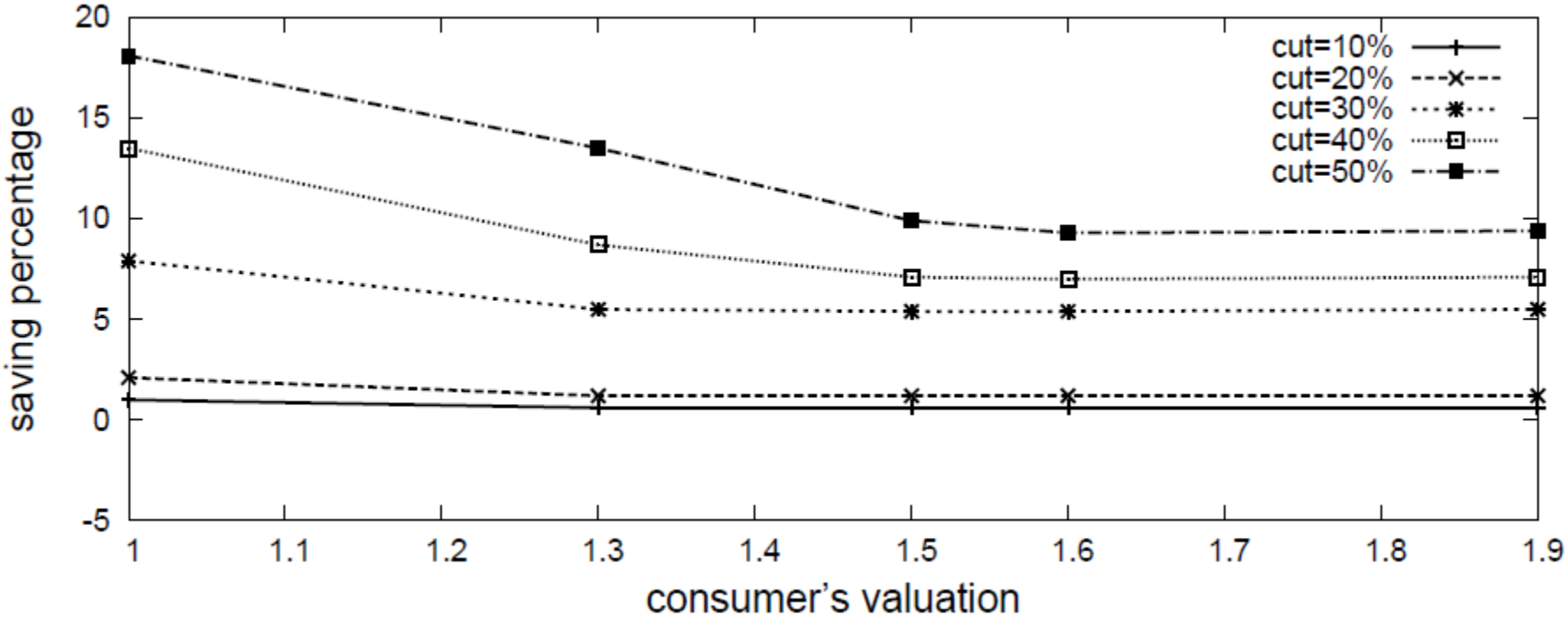
Experiments [price paid]US distribution



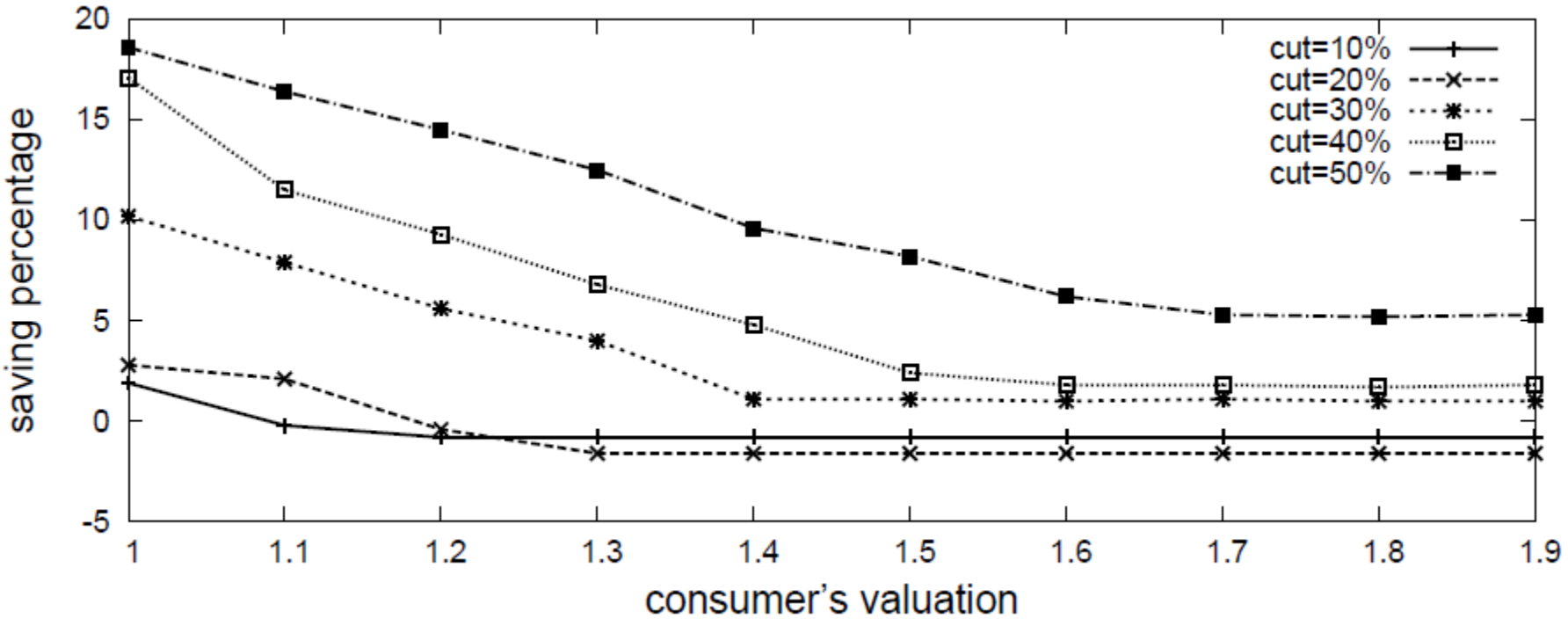
Experiments [price paid] Uniform distribution



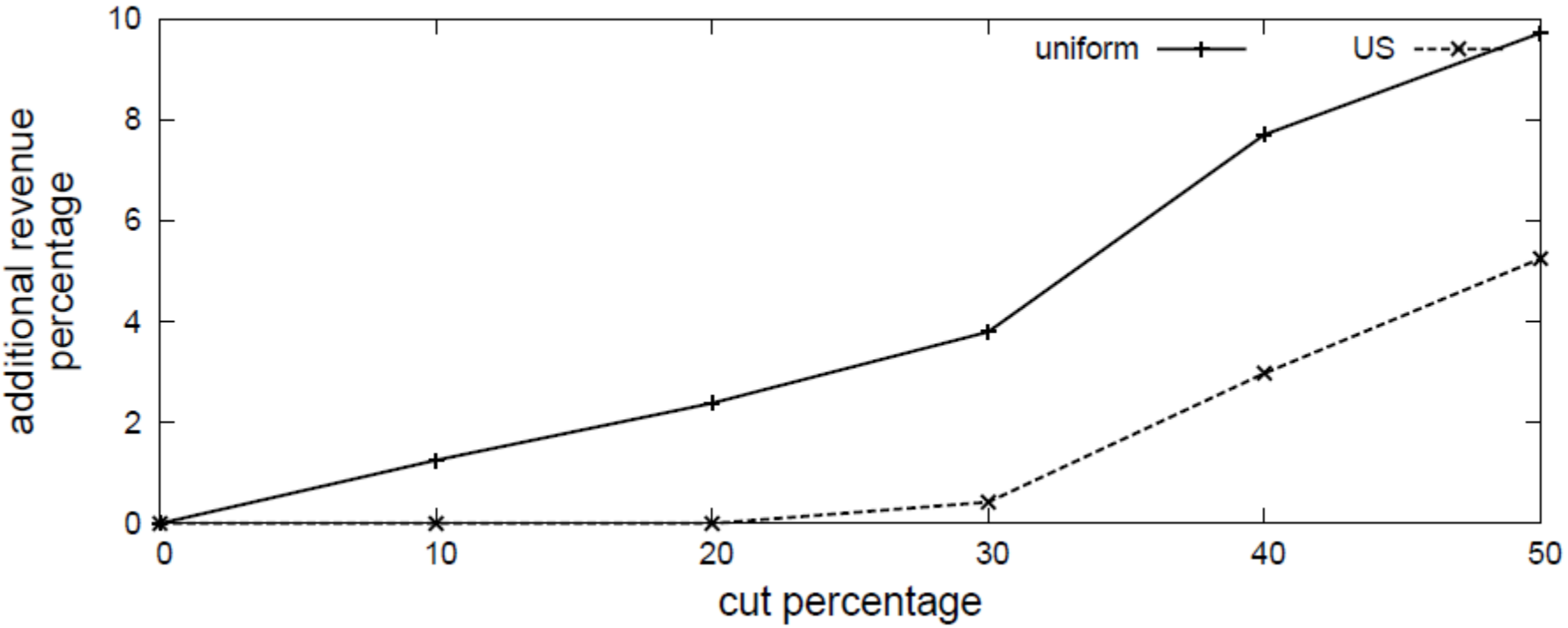
Experiments [cost saving]US distribution



Experiments [cost saving] Uniform distribution



Experiments [company's additional benefit]



Conclusions

- Matching demand with supply
  - we cut PAR explicitly
  - distribute the loads using multiunit auction
    - provide minimum load guarantee
- Trade-off between convenience and cost
  - load shifting vs price paid
- Cost saving also for consumers without load shifting
- Additional benefit for the utility company

Discussions / Future Work

- Weak consumers may benefit from considering non-myopic strategies and reasoning over multiple steps at once
- Policy implications of the approach
- Taking time distance into account in measuring customer's load shifting

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