# A Truthful Incentive Mechanism for Emergency Demand Response in Colocation Data Centers

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# Demand vs Supply in Power Industry

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Ideal: Supply = Demand

Fact: Supply ≠ Demand

Demand Response

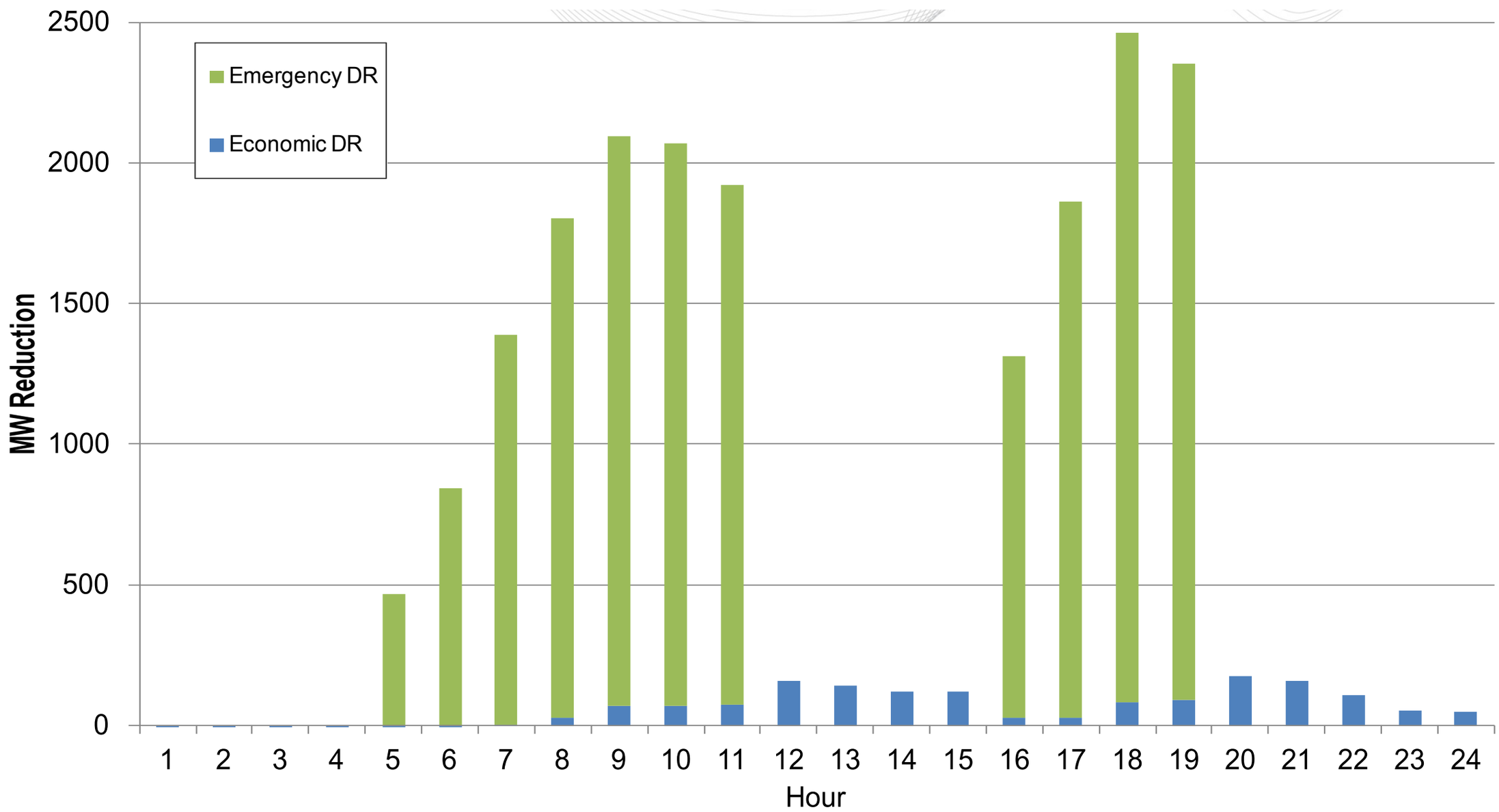
- **Market-based** program to extract flexibility on the demand side, to **reduce peak energy** usage and cost, and to **increase adoption of renewables**, etc.

# Emergency Demand Response

- Reduce energy consumption to a certain level during emergencies;

- The **last line of defence** for power grids before cascading blackouts take place;

# Emergency Demand Response




Demand Response in PJM: January 7, 2014

# Data Centers are Power-Hungry

In 2013, U.S. data centers power consumption

**91 billion** kWh of electricity;
**34** large (**500-MW**) power plants;

roughly **140 billion** kWh annually by 2020,
**50** large power plants,
**$13 billion** annually in electricity bills
**100 million metric tons** of carbon pollution per year.

# Data Centers in EDR

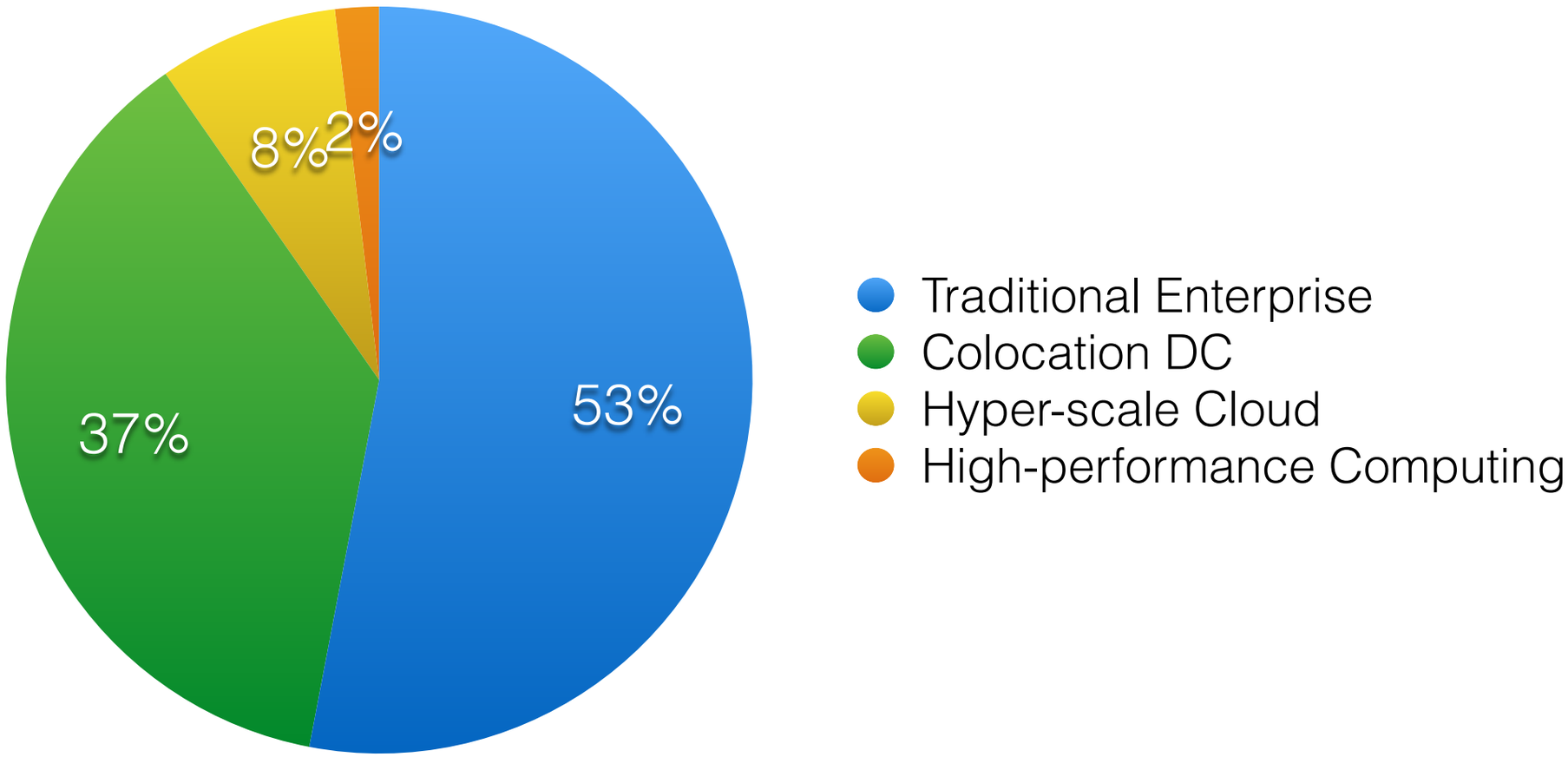
- Data centers are promising participants in emergency demand response;
- For example, On July 22, 2011, **hundreds of data centers** participated in emergency demand response and contributed by cutting their electricity usage before a nation-wide blackout occurred in the U.S. and Canada.

# Co-location Data Centers

- Most large data centers are colocations; (1,200 colocations in the U.S.)
- Many colocations are in metropolitan areas, where demand response is most wanted;
- Highly "**Uncoordinated**". Unlike owner-operated data centers, colocations have no control of the servers which are managed by the tenants;
- "**No incentive** to save energy". Typical pricing approach is based on the tenants' subscribed power at fixed rates, regardless of their power usage.

A photo of a colocation data center

Estimated % of Electricity Usage by U.S. Data Center Segment in 2011




The now U.S.**$25** billion global colocation market is expected to grow to U.S.**$43** billion by 2018 with a projected annual compound growth rate of **11%.**

**Current Trend**: many enterprise in-house data centers are moving to colocations!

# How do colocations help in EDR?

# Goals of Auction Approach

- Provide incentive to tenants in colocations;
- Eliminate falsified bids from strategic tenants;
- Try to minimize the colocation-wide cost;

# Colocation-Wide Cost Minimization

cost of backup energy storage

energy reduction cost

$$\textbf{MinCost}\text{: minimize}_{\boldsymbol{x},y} \quad \alpha y + \sum_{i \in \mathcal{N}} b_i x_i \tag{1}$$

energy reduction by winning tenants

EDR target

subject to:

$$y + \gamma \sum_{i \in \mathcal{N}} e_i x_i \geq \delta, \tag{1a}$$

$$x_i \in \{0, 1\}, \quad \forall i \in \mathcal{N}, \tag{1b}$$

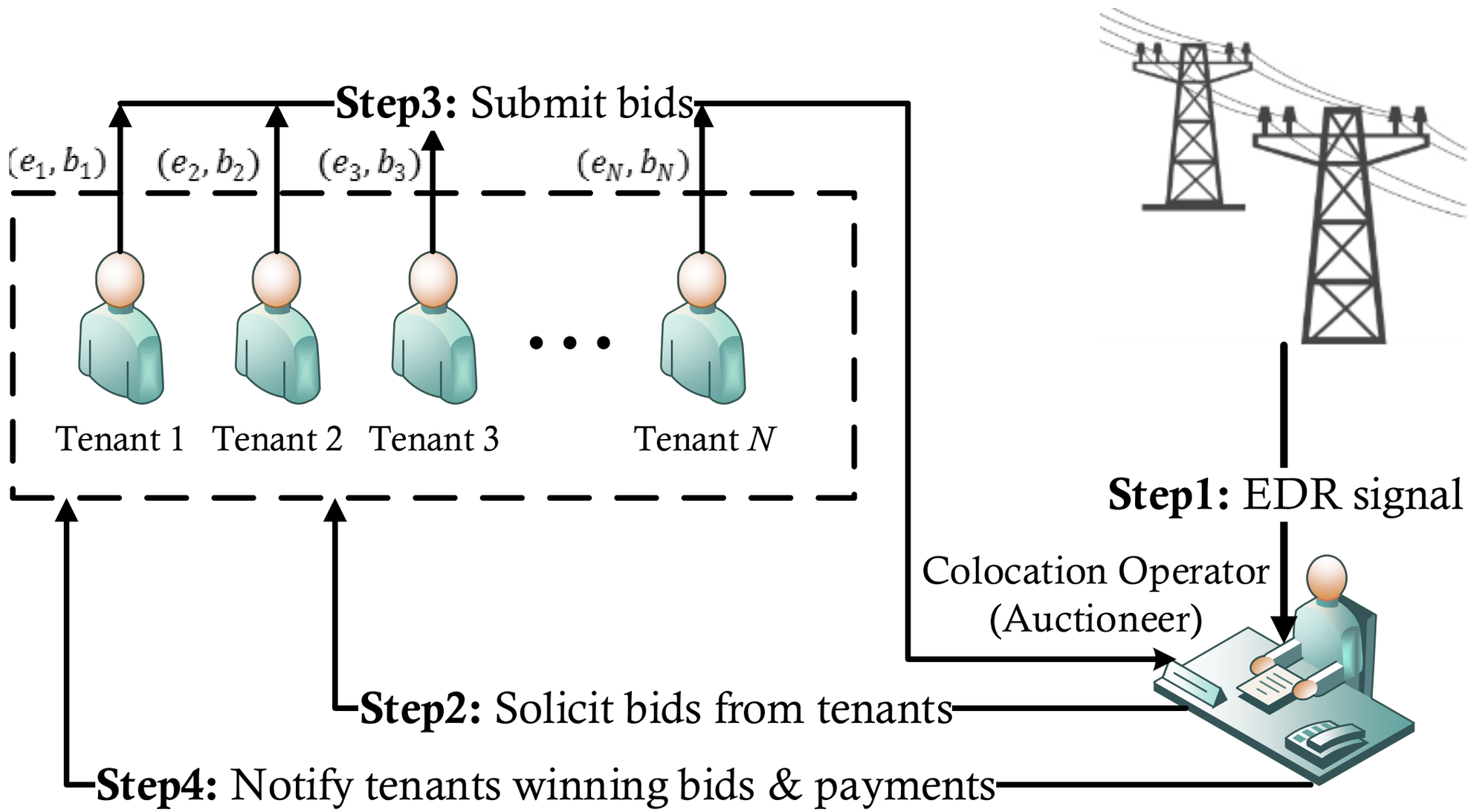
$$y \geq 0. \tag{1c}$$

# Can VCG Auction Help?

- The underlying problem is **NP-complete**;
- Optimally solving the cost minimization problem is **computationally infeasible**;
- **NO!** VCG auction cannot help in an efficient way!

# Truth-DR

- We propose a reverse auction named **Truth-DR**,



# Truth-DR

- Properties:
  - **truthful** in expectation
  - **computationally efficient;**
  - **individually rational**
  - **2-approximation** in colocation-wide social cost, compared with the optimal solution.

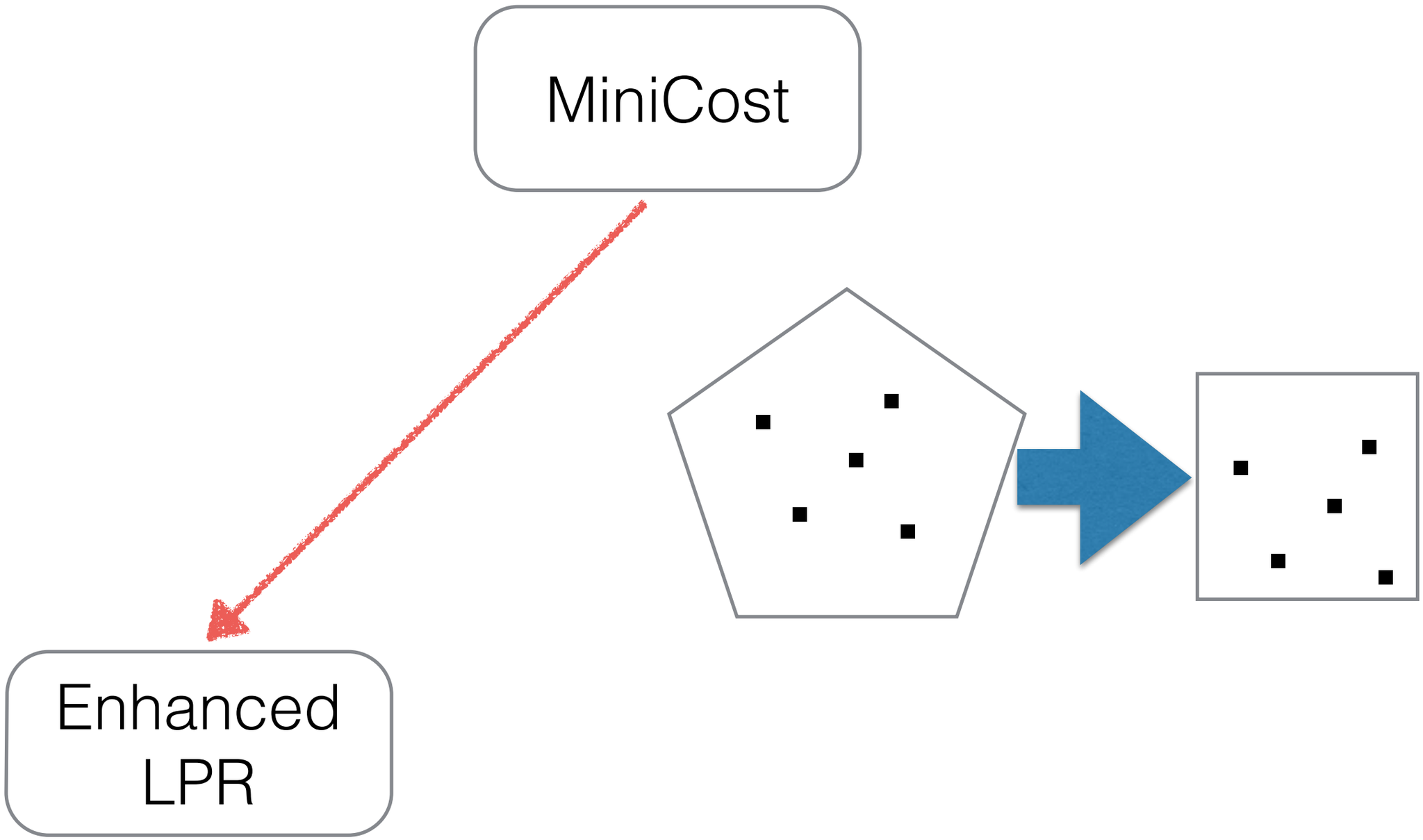
# Details about Truth-DR

Design a 2-approximation algorithm

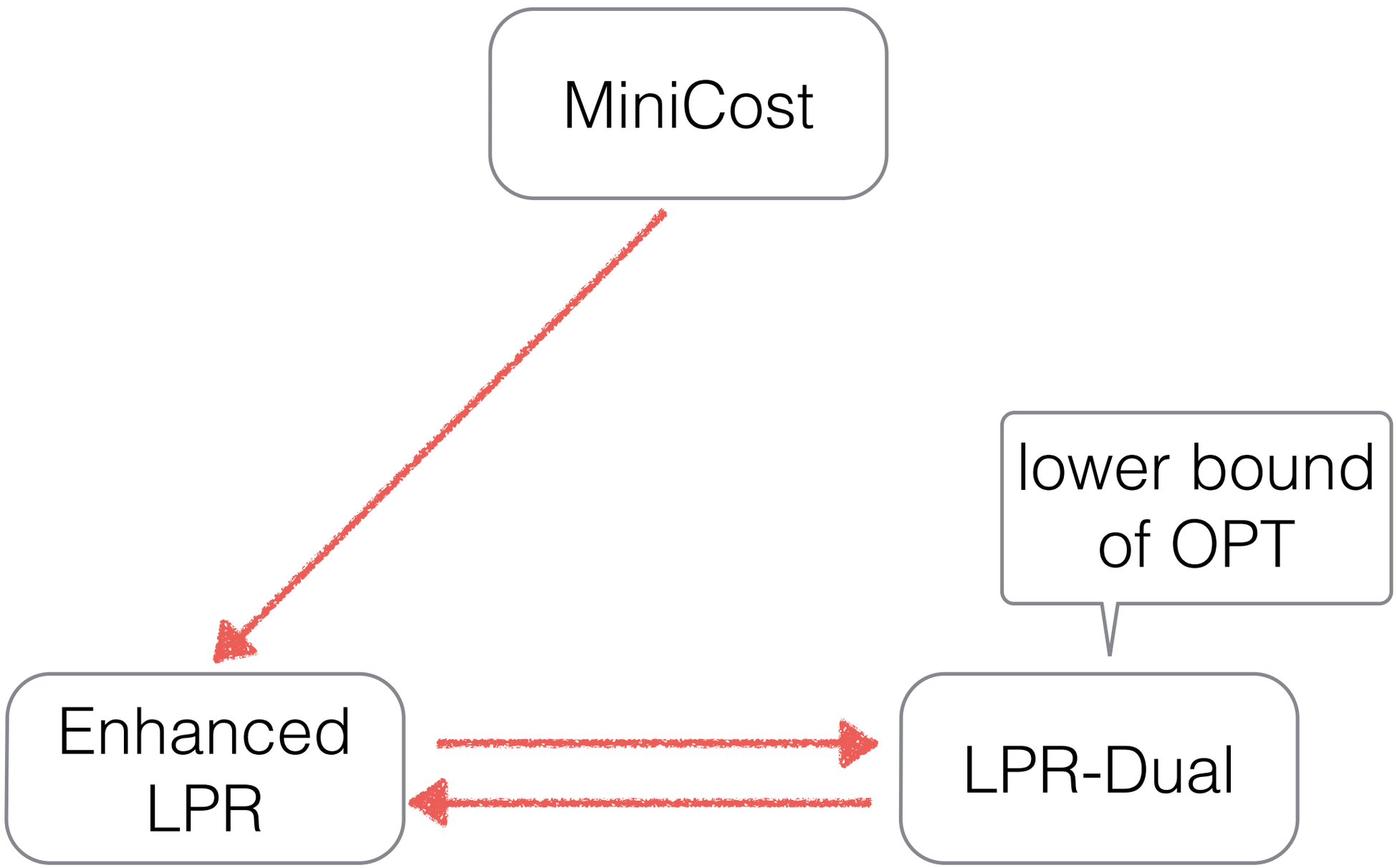
→

a randomized auction framework

# 2-Approximation Algorithm



# 2-Approximation Algorithm



# Randomized Auction Framework

1: Optimal Fractional Solution

- Solve LPR (2), obtaining optimal BES usage $y^*$ and optimal fractional winner decisions $\boldsymbol{x}^*$.

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3: Winner Determination and Payment

- Select a mixed integer solution $(\boldsymbol{x}^l, y^l)$ from set $\mathcal{I}$ randomly, using weights of the solutions in the decomposition as probabilities
- Calculate the payment of tenant $i$ as

$$f_i = \begin{cases} 0 & \text{if } x_i = 0 \\ b_i + \frac{\int_{b_i}^{\alpha\gamma e_i} \min\{2x_i^*(b, b_{-i}), 1\} db}{\min\{2x_i^*(b_i, b_{-i}), 1\}} & \text{otherwise} \end{cases}$$

# Conclusion

- This work studied how to enable **colocation EDR** at the minimum colocation-wide cost.
- To address the challenges of **uncoordinated** power management and tenants' lack of incentives for EDR, we proposed a first-of-its-kind auction based incentive mechanism, called Truth-DR, which is **computationally efficient**, **truthful in expectation** and guarantees a **2-approximation** in colocation-wide social cost

Thanks!

Questions?