# Simulation of Auction Mechanism Model for Energy-Efficient High Performance Computing

**Kishwar Ahmed,** Samia Tasnim*, and Kazutomo Yoshii**

University of South Carolina Beaufort

*Florida A&M University

**Argonne National Laboratory



# Outline

- **Background**
- Energy-efficient auction mechanism model
- Mechanism model simulation
- Conclusions

# High Performance Computing (HPC) System


Sierra supercomputer @LLNL in Livermore, CA

# HPC Cloud


Penguin
Computing


NIMBIX


Uber
Cloud


aws


Microsoft
Azure


IBM

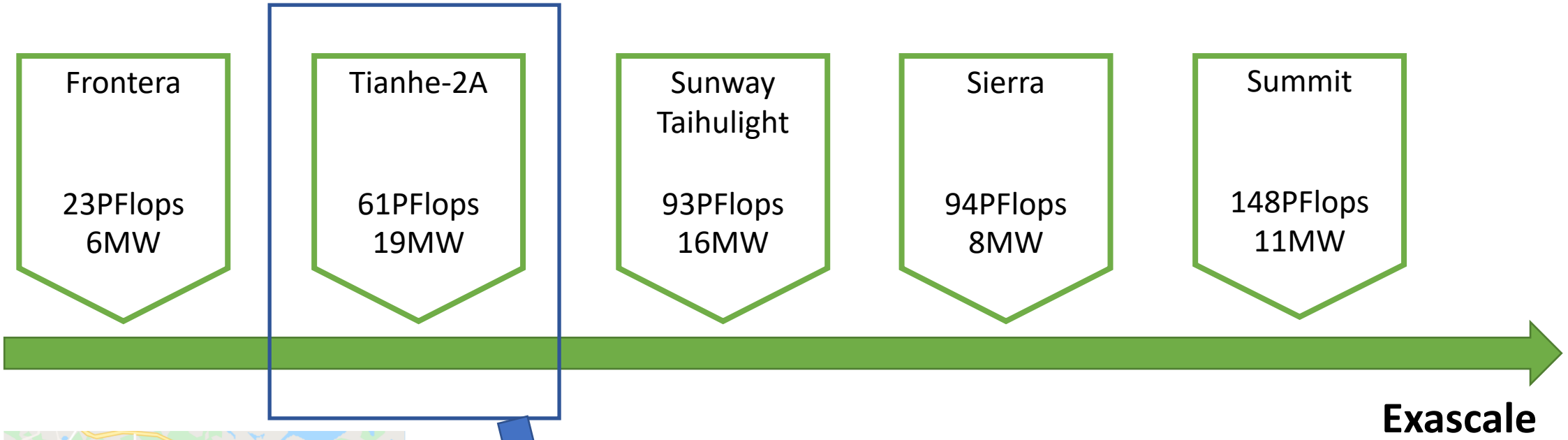

Google
Cloud Platform


Hewlett Packard
Enterprise


NetApp

# HPC is Power-Hungry

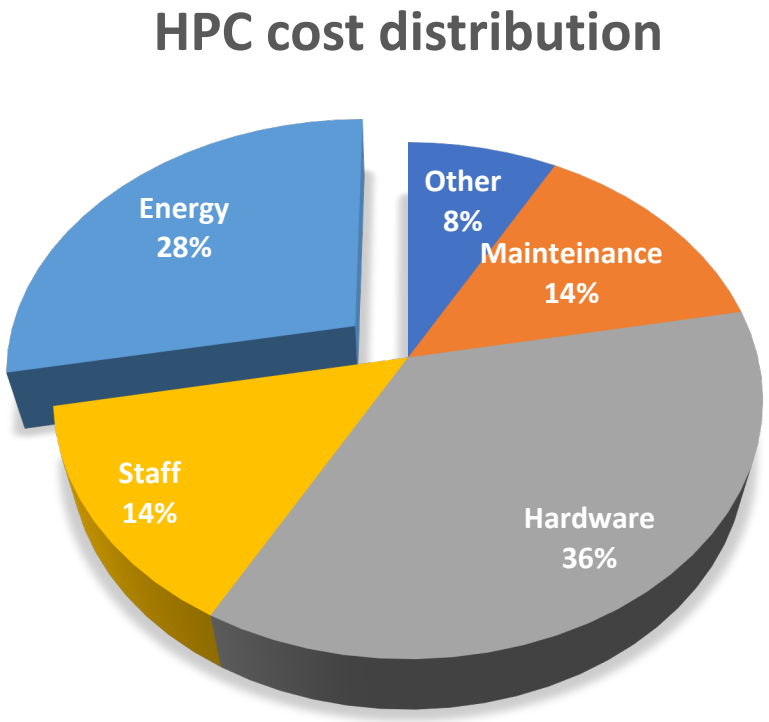
Top supercomputers (November 2019)





Power an entire small city!

# HPC is Energy-Costly




**Lifelong energy cost ≈ investment cost**

Source: “Total Cost of Ownership in High Performance Computing. HPC data center cost considerations: investment, operation and maintenance.” in SoSE 2014

# The Question

How to reduce energy cost of HPC systems, while rewarding HPC users for their participation?

# Our Solution

1 **Energy-efficient auction mechanism model**

- Energy reduction based on DVFS
- Auction mechanism to reward HPC users

2 **Mechanism model simulation**

- Based on parallel discrete-event simulation

# Outline

- Background
- **Energy-efficient auction mechanism model**
- Mechanism model simulation
- Conclusions

# Energy-Efficient Auction Mechanism Model

- Resource allocation model
  - Exploiting dynamic voltage frequency scaling (DVFS)
- Auction mechanism model
  - Bid determination
  - Winning bidder determination
  - Price determination

# Resource Allocation Model

- Reduce energy consumption through DVFS

$$e_i = n_i \cdot p(f_{max}) \cdot t_s \qquad e_i' = n_i \cdot p(f_i') \cdot t_s$$

$$\Delta e_i = e_i - e_i'$$

$$\Delta t_i = 100 \cdot [t(f_{max}) - t(f_i')] \,/\, [t(f_{max})$$

# Enable Users' Participation

## HPC users incur application performance loss

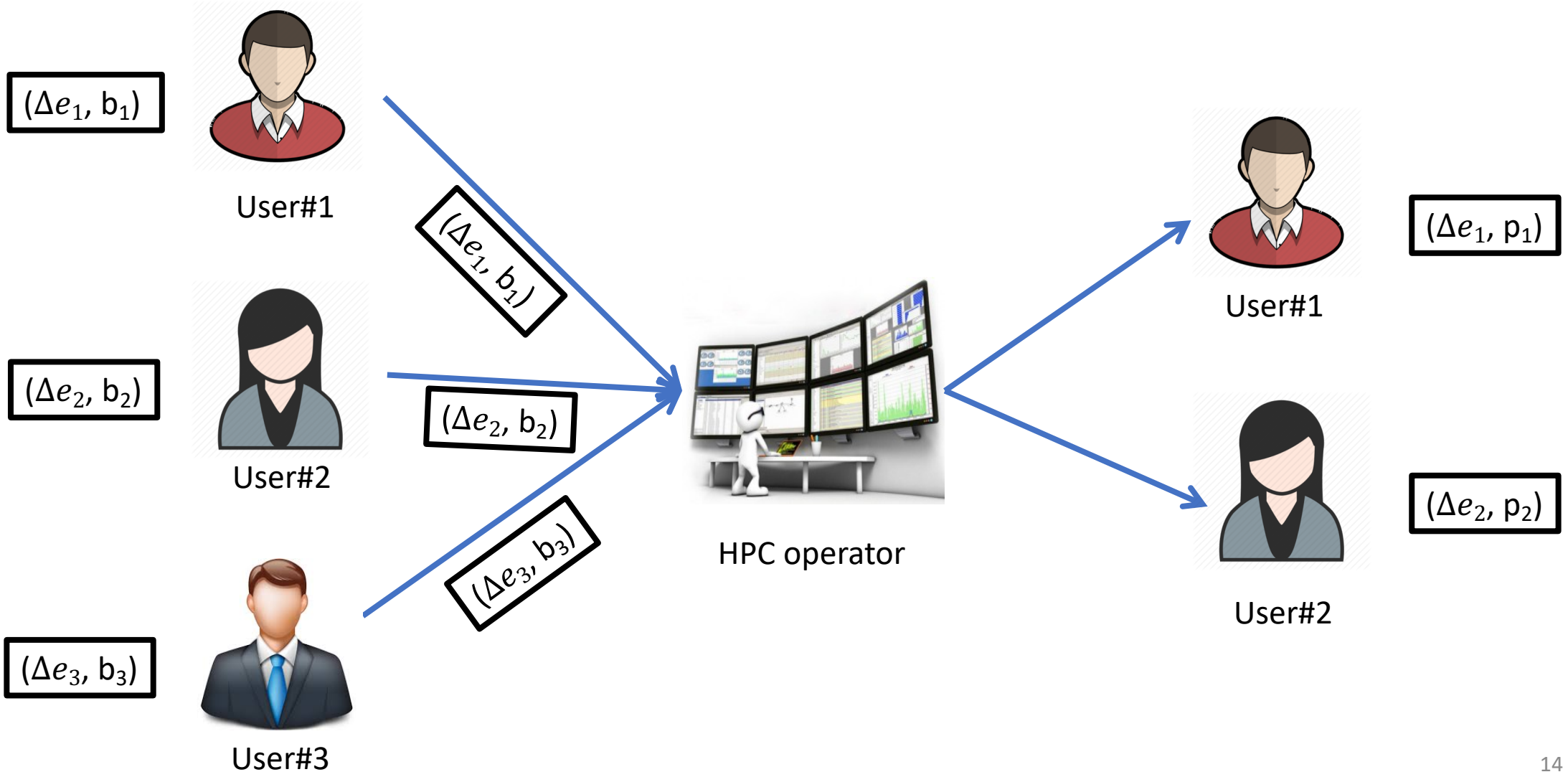
- How to ensure their participation?


HPC users rewarded based on a
**VCG-based auction mechanism** model

# VCG-Based Auction Model

- Vickery-Clarke-Groove (VCG) mechanism
  - A sealed-bid auction mechanism
  - Truth-telling is a dominant strategy
  - Participants are rewarded for truthful participation
- Two stages
  - HPC users submit their energy reduction bid
  - HPC operator determines winning bidders and actual payment

# An Example Scenario



# Determining Bids

- Inconvenience cost

$$c_i = \beta \cdot \Delta t_i$$

  - $\beta$ converts time change to monetary value
  - E.g., 0.0044$/hour at Rice University HPC cluster
- Bid determined by user *i*

$$b_i = \tau_i \cdot c_i$$

  - $\tau_i$ is a truthfulness parameter
  - By default value is 1 (i.e., no cheating)

# Determining Winning Bidders

Operator solves the following optimization to determine the winning bidders

Minimize: $\sum_{i=1}^{N} b_i$

subject to: $\sum_{i=1}^{N} \Delta e_i \geq e_{th}$

# Determining Price

- Payment of bidder *i* ($p_i$) is obtained as
  - Optimal welfare (for the other users) if user *i* was not participating
  - minus welfare of the other players from the chosen outcome
- Mathematically,

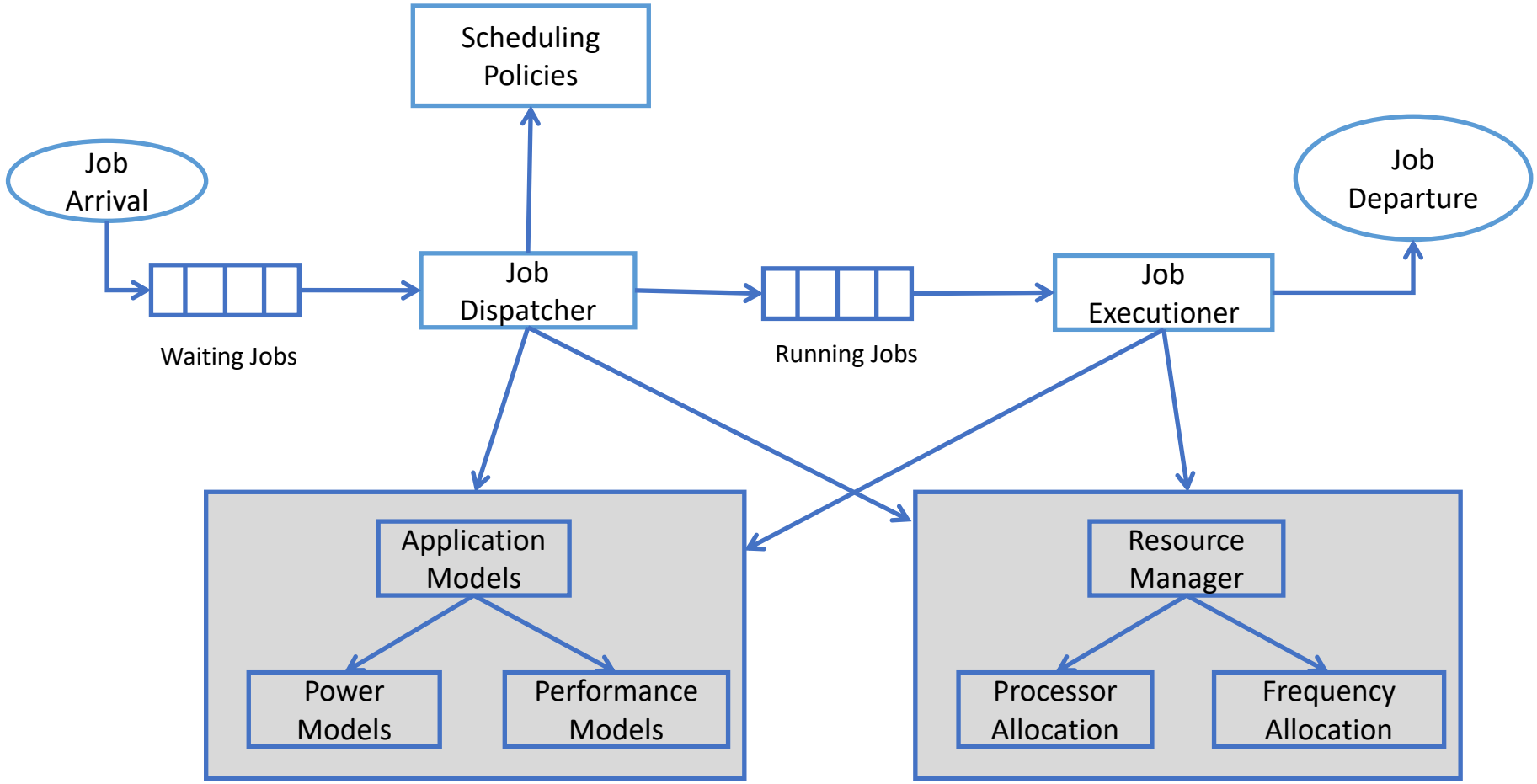
$$p_i = C^*_{B-b_i} - \left[C^*_B - b_i\right]$$
$$= b_i + C^*_{B-b_i} - C^*_B.$$

- Where $C_B^*$ denotes total incentive cost based on the optimization process for the bid set $B = \{b_1, b_2, \ldots, b_N\}$

# Outline

- Background
- Energy-efficient auction mechanism model
- **Mechanism model simulation**
- Conclusions

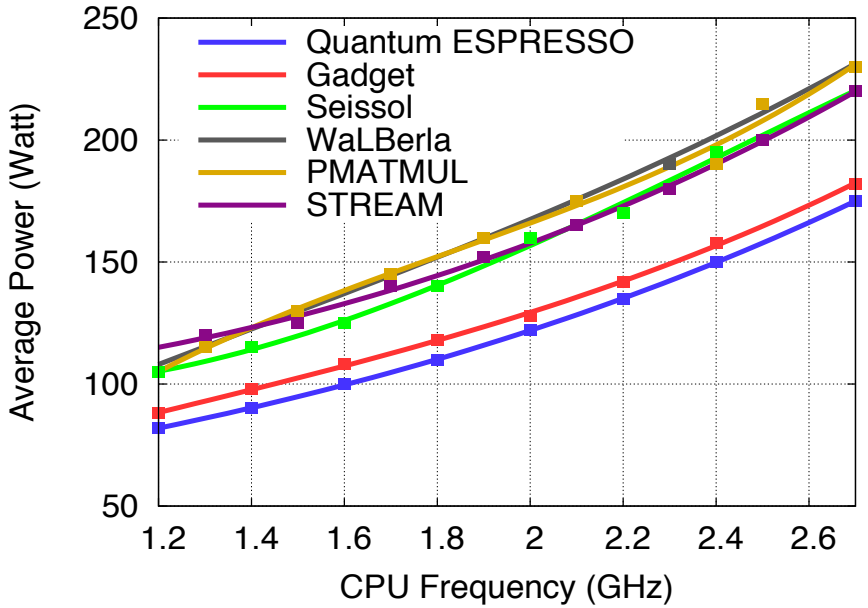
# Scheduling Simulator

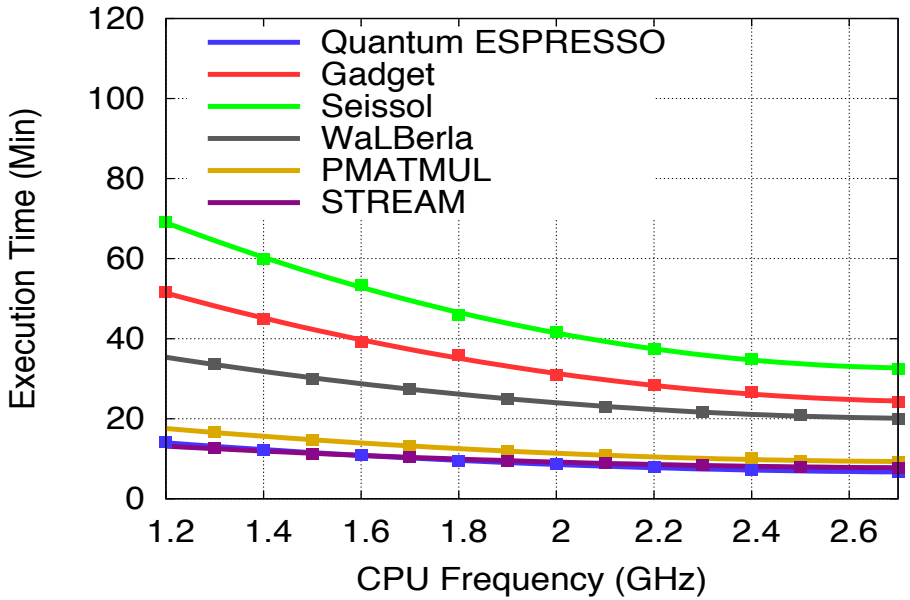


# Simulus: Parallel Discrete Event Simulator

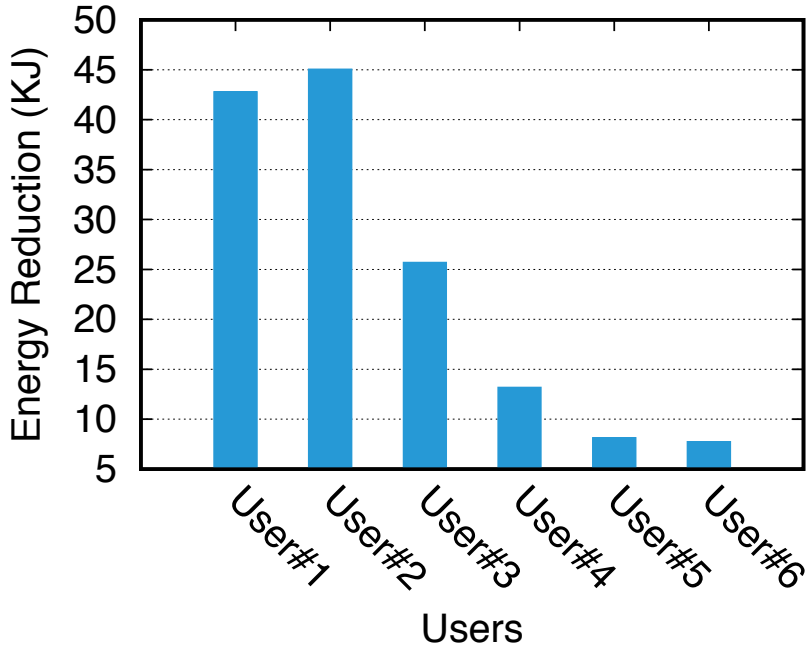
- Discrete-event simulator in Python
- Open-source: https://simulus.readthedocs.io/en/latest/index.html
- Supports parallel and distributed simulation
- Several advanced features to ease modeling and simulation
- Includes documentation and many examples

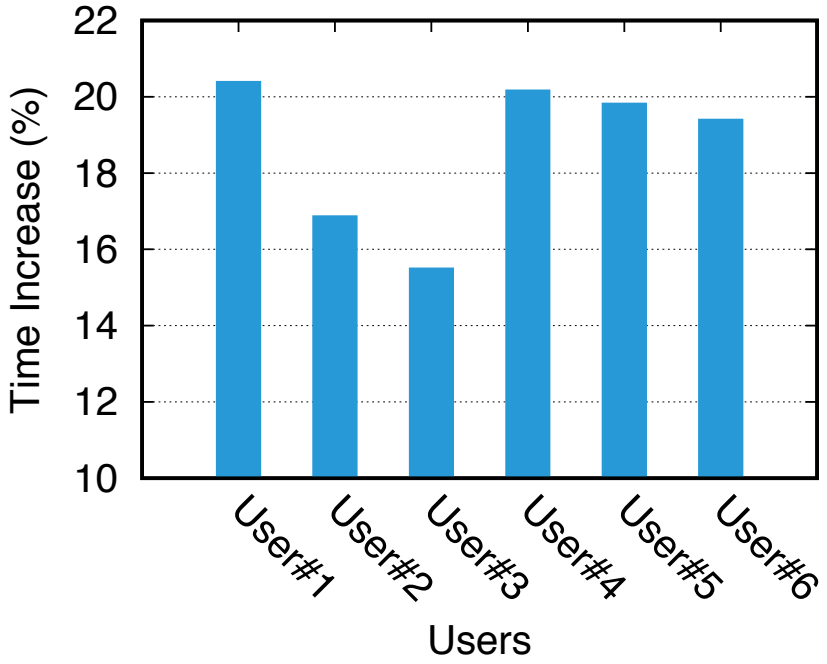
# Model Simulation



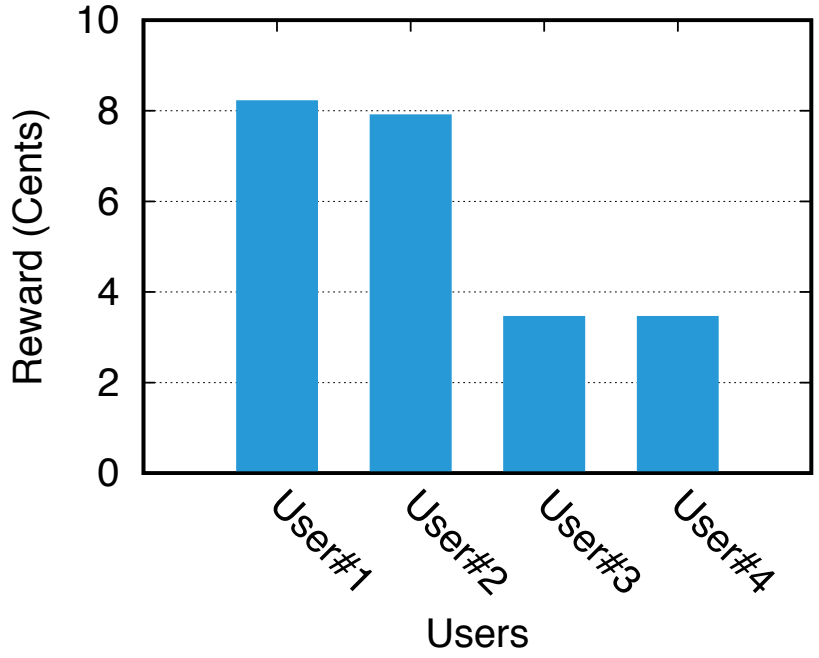
# Energy Reduction and Inconvenience Cost

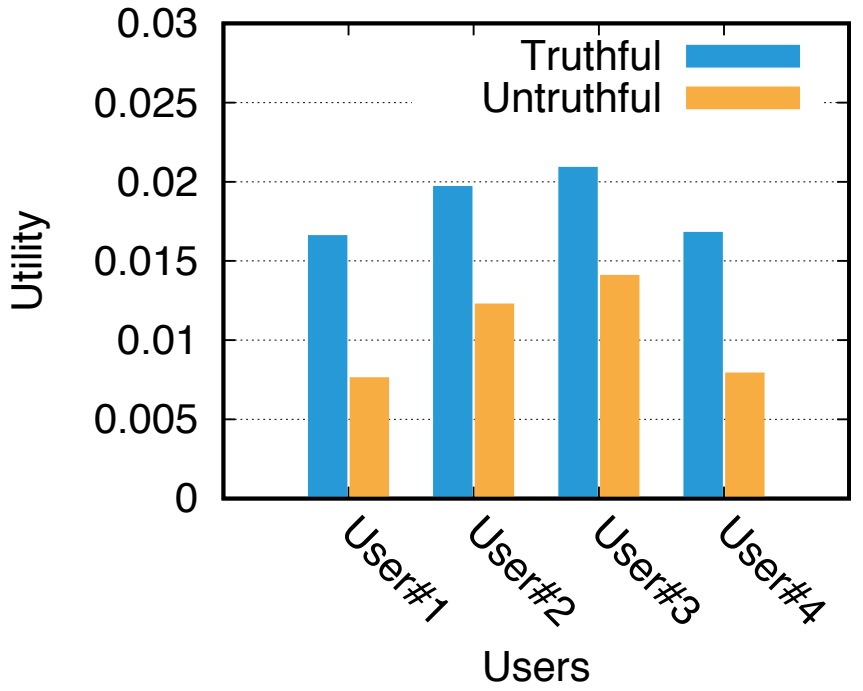



**Various energy reduction amount, at increased time in execution**

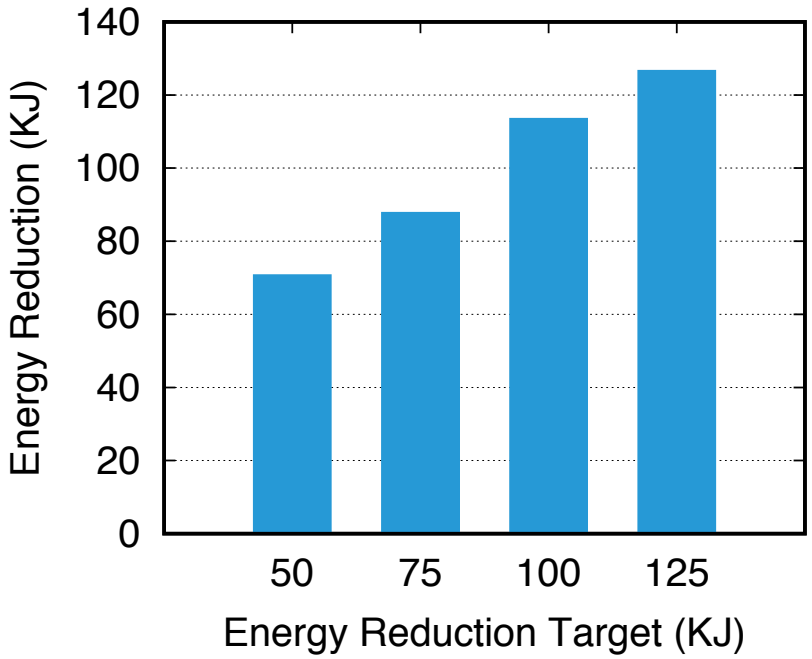
# User Reward and Utility

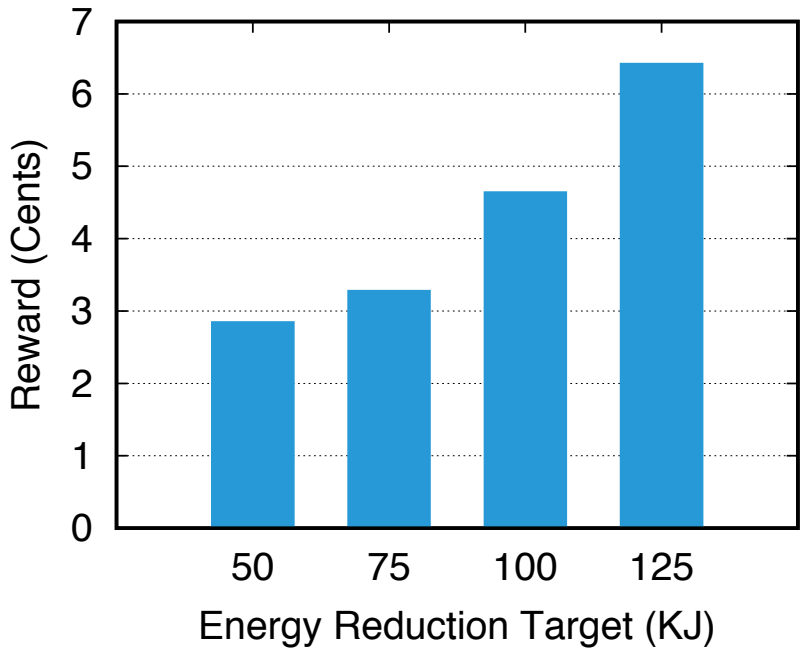



**Users achieve higher utility when they submit truthful valuation**

# Impact of Energy Reduction Target




**Increased energy reduction and reward for higher energy reduction target**

# Conclusions

- HPC systems are power-hungry and energy-costly
- We proposed
  - VCG-based auction mechanism model
  - Truthful participation from HPC users
- We developed
  - A job scheduling simulator
  - Includes resource allocation and auction mechanism model

# Thank You!
# Questions?

**Acknowledgements:**