Supercomputing Centers and Electricity Service Providers: A Geographically Distributed Perspective on Demand Management in Europe and the United States

ISC High Performance Conference, Frankfurt, Germany

Tapasya Patki, Natalie Bates, Girish Ghatikar, Anders Clausen, Sonja Klingert, Ghaleb Abdulla, Mehdi Sheikhalishahi

June 21, 2016

(EE HPC WG, Demand Response Group)
HPC systems have a high power draw

<table>
<thead>
<tr>
<th>System (Program)</th>
<th>Processor Architecture</th>
<th>Nodes</th>
<th>Cores</th>
<th>Peak (TFLOP/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>RZCereal (M&amp;IC)</td>
<td>Intel Xeon E5530</td>
<td>21</td>
<td>169</td>
<td>1.6</td>
</tr>
<tr>
<td>RZHasGPU</td>
<td>Intel Xeon E5-2667 v3</td>
<td>20</td>
<td>320</td>
<td>8.2</td>
</tr>
<tr>
<td>RZMerl (ASC/M&amp;IC)</td>
<td>Intel Xeon E5-2670</td>
<td>262</td>
<td>2,916</td>
<td>46,656</td>
</tr>
<tr>
<td>RZSLIC ***</td>
<td>Intel Xeon E5330</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RZuSeq (ASC) ****</td>
<td>IBM PowerPC A2</td>
<td>522</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RZZeus (M&amp;IC)</td>
<td>Intel Xeon E5530</td>
<td>267</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Juno (ASC)</td>
<td>Intel Xeon E5-2670</td>
<td>98,304</td>
<td>1,572,864</td>
<td>20,132</td>
</tr>
<tr>
<td>Max (ASC)</td>
<td>Intel Xeon EP X5660</td>
<td>324</td>
<td>3,888</td>
<td>43.5</td>
</tr>
<tr>
<td>Muir (ASC)</td>
<td>Intel Xeon EP X5660</td>
<td>96</td>
<td>1,152</td>
<td>12.9</td>
</tr>
<tr>
<td>Sequoia (ASC) **</td>
<td>Intel Xeon EP X5660</td>
<td>324</td>
<td>7,776</td>
<td>149.3</td>
</tr>
<tr>
<td>Zin (ASC)</td>
<td>Intel Xeon E5-2670</td>
<td>1,296</td>
<td>20,736</td>
<td>431.3</td>
</tr>
<tr>
<td>CSLIC ***</td>
<td>Intel Xeon E5330</td>
<td>40</td>
<td>256</td>
<td>1.6</td>
</tr>
<tr>
<td>RZMerl HasGPU (M&amp;IC)</td>
<td>Intel Xeon E5-2670</td>
<td>262</td>
<td>2,916</td>
<td>46,656</td>
</tr>
<tr>
<td>RZSLIC ***</td>
<td>Intel Xeon E5330</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RZuSeq (ASC) ****</td>
<td>IBM PowerPC A2</td>
<td>522</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RZZeus (M&amp;IC)</td>
<td>Intel Xeon E5530</td>
<td>267</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Juno (ASC)</td>
<td>Intel Xeon E5-2670</td>
<td>98,304</td>
<td>1,572,864</td>
<td>20,132</td>
</tr>
<tr>
<td>Max (ASC)</td>
<td>Intel Xeon EP X5660</td>
<td>324</td>
<td>5,056</td>
<td>107.8</td>
</tr>
<tr>
<td>Muir (ASC)</td>
<td>Intel Xeon EP X5660</td>
<td>96</td>
<td>1,152</td>
<td>12.9</td>
</tr>
<tr>
<td>Sequoia (ASC) **</td>
<td>Intel Xeon EP X5660</td>
<td>324</td>
<td>7,776</td>
<td>149.3</td>
</tr>
<tr>
<td>Zin (ASC)</td>
<td>Intel Xeon E5-2670</td>
<td>1,296</td>
<td>20,736</td>
<td>431.3</td>
</tr>
</tbody>
</table>

Stats

Max: 98,304 nodes in one system (Sequoia)

25 systems across open and closed zones

~40MW of total power onsite

Various processor architectures
Relationships between Electricity Service Providers and SC Centers are unidirectional at present

Demand Management: Actions taken to establish multi-directional relationships between SCs and ESPs to ensure energy efficiency and grid reliability
Demand Management: Europe versus United States

Prior Work:
• Study DM in the US
• Surveyed 11 SC sites – 4 of these had HPC workloads of 10 MW or more
• None of the SCs were actively communicating with their ESPs
• Conclusion: Interest in tighter integration, but business case not demonstrated

Focus for this paper: understand geographical differences in DM
• Extend study to 9 EU SC sites
• EU has more renewables, thus more variability
• Electricity prices in EU are higher, involve different taxes and peak costs
• Initial Expectation: EU might have a tighter integration between SCs and ESPs
The Need for Demand Management: Power swings may not be predictable

**Sequoia (LLNL):**
1.57 million cores
Rating: 7.9 MW
Power swings of 3-6 MW

**Titan (ORNL):**
299K CPU cores, 18 688 GPUs
Rating: 8.2 MW
Power swings of a few MW in both CPU-only and GPU-enabled runs
Demand Management Overview: Strategies, Programs, Methods, Forecasting

**Strategies:**
- Used by SCs to manage power and provide load flexibility
- May or may not improve energy efficiency
- **Example:** job scheduling, power capping

**Programs:**
- Incentives offered by ESPs to SCs to motivate them to balance the grid and perform power management
- **Example:** peak shedding, peak shifting, and dynamic pricing

**Methods:**
- Used by ESPs to balance the grid in transmission and distribution phases
- **Example:** grid scale storage

**Forecasting:**
- Predicting the amount of power required by an SC for a certain period of time
Quantitative and Qualitative Analysis

Quantitative Survey:
• 11 US SCs, 9 EU SCs
• 31 Survey Questions,
  • Examples include facility energy, PUE, HPC load details; variability details and usage of strategies, programs and methods

Qualitative Analysis:
• Three sites: ORNL, LLNL, LRZ
• Understand the details of the electricity pricing structure
Quantitative Study: HPC Load Results

**Europe:**
- All SCs have HPC load under 5 MW

**United States:**
- 4 SCs have a load of more than 10 MW, others under 5 MW
Quantitative Study: Maximum Variability Results

Europe:
- Variability of 0.5 to 2 MW

United States:
- 3 sites had variability of more than 5 MW
- Minimal option was “less than 3 MW”

All Sites:
- Typically, variability is due to maintenance
- Can be scheduled *day-ahead*
Quantitative Study: Motivation for stronger relationship with your ESP

Ques: Please evaluate as high, medium or low the following motivations for your site’s interest in pursuing a stronger relationship with your electricity service provider

<table>
<thead>
<tr>
<th>Motivation</th>
<th>Low</th>
<th>Medium</th>
<th>High</th>
<th>Rating Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Economically justified</td>
<td>14.3%</td>
<td>28.6%</td>
<td>57.1%</td>
<td>7</td>
</tr>
<tr>
<td>Good citizen</td>
<td>14.3%</td>
<td>71.4%</td>
<td>14.3%</td>
<td>7</td>
</tr>
<tr>
<td>Adverse consequences</td>
<td>66.7%</td>
<td>16.7%</td>
<td>16.7%</td>
<td>6</td>
</tr>
<tr>
<td>Government regulation</td>
<td>71.4%</td>
<td>28.6%</td>
<td>0.0%</td>
<td>7</td>
</tr>
</tbody>
</table>

- Key motivation for a stronger relationship with ESP is to be a good citizen
Quantitative Study: Strategies and Programs

**Strategies:**
- Most SCs in the US were *moderately interested* in coarse-grained power management, fine-grained power management and temperature control.
- SCs in EU had *low interest*.

**Programs:**
- No SCs were actively engaged in programs.
- SCs in US have communicated, as opposed to SCs in EU.
- More interest in peak shedding and dynamic pricing.
- More interest in discussion about renewables.

<table>
<thead>
<tr>
<th>Program</th>
<th>Europe</th>
<th>United States</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak Shedding</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>Peak Shifting</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>Dynamic Pricing</td>
<td>0</td>
<td>5</td>
</tr>
</tbody>
</table>

Table 1. Motivation for communicating with ESP (European Respondents)

We also asked our European respondents to indicate what might motivate them to communicate with their ESPs. The results are shown in Table 1. As can be noted from this table, the main motivators are the financial incentives and the desire to be “good citizens.” Thus, SC motivations are driven by market-based mechanisms that justify economics and social responsibility, even under the absence of regulatory support.

Table 2. Communications with ESPs regarding available programs

We noted that none of the European SCs communicated about grid integration potential, demand management and available flexibility with their associated ESPs. Additionally, there was little interest in a tighter integration with the ESPs. In general, the SCs in the United States seem to have a closer relationship with their ESPs than the ones in Europe. This can also be verified from Table 2, which shows that only 1 of the 9 respondents in Europe have had a discussion with their ESP.

4.1 Comments from Survey Respondents

From the comments section in our questionnaire, we noted that all SCs are already using demand forecasting to communicate their upcoming programs.

- No SCs were actively engaged in programs.
- SCs in US have communicated, as opposed to SCs in EU.
- More interest in peak shedding and dynamic pricing.
- More interest in discussion about renewables.
Quantitative Study: Comments

- All SCs use demand forecasting to notify ESPs about maintenance cycles
- SCs in US showed more interest overall for ESP programs
- SCs in EU had little knowledge about ESP programs

“There are not so many related options and features offered by providers. We are open to further and pro-active efforts as long as providers have other kinds of programs to propose”

“With many of your questions I am wondering about the kind of contracts other centers might have and about the quality of some electricity providers.”
Qualitative Analysis: Key Questions

Goal: Understand the details that were not captured in the quantitative survey

- Responsibility for negotiating the contract between SC and ESP
- Details of electricity pricing structure
- Future relationship with ESP
## Qualitative Analysis

<table>
<thead>
<tr>
<th>Site</th>
<th>Negotiation</th>
<th>Provider/Pricing</th>
</tr>
</thead>
<tbody>
<tr>
<td>ORNL</td>
<td>DOE negotiates with TVA (Tennessee Valley Authority) (35 MW – 75 MW)</td>
<td>Demand charge: based on the peak power usage for the month Energy charge: based on actual power consumption</td>
</tr>
<tr>
<td>LLNL</td>
<td>DOE negotiates with Exeter (100 MW)</td>
<td>No demand charge Energy charge: 4.5 cents per kWh</td>
</tr>
<tr>
<td>LRZ</td>
<td>Stadtwerke Munchen (4 – 6 MW)</td>
<td>Charges for power grid, renewable energy, concession levy and other taxes. Depends on season, peak usage, etc. 16 euro-cents per kWh</td>
</tr>
</tbody>
</table>
Qualitative Analysis: Similarities and Differences

**Similarities:**
- Power purchase negotiations were done by a third party annually
- Peak power capacity was negotiated
- In LRZ and ORNL, a lower power bound was also negotiated
- These were site-level negotiations, not just HPC center negotiations

**Differences:**
- Pricing structure was very different
  - LLNL: flat rate
  - ORNL: variable rate, but less sensitive to pricing
  - LRZ: high and variable rate, sensitive to pricing and power swings
- In US, reliability was not a major concern (LLNL and ORNL)
- US mostly thermal generation, EU mostly renewable
Conclusions and Future Work

- Demand management is critical for energy efficiency in the future
- SCs in EU and US are not actively engaged, need for tighter integration
- Higher interest, and more awareness in US than EU

- SEDC (Smart Energy Demand Coalition) in EU drew similar conclusions
- What about China/Japan?

[https://eehpcwg.llnl.gov/](https://eehpcwg.llnl.gov/)