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

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June 21, 2016

LLNL-PRES-695291
This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under contract DE-AC52-07NA27344. Lawrence Livermore National Security, LLC

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HPC systems have a high power draw

System (Program)	Processor Architecture	Nodes	Cores	Peak (TFLOP/s)
RZ				
RZCereal (M&IC)	Intel Xeon E5530	21	169	1.6
RZHasGPU	Intel Xeon E5-2667 v3	20	320	8.2
RZMerl (ASC/ M&IC)	Intel Xeon E5-2670	162		
RZSLIC ***	Intel Xeon E5330	3		
RZuSeq (ASC) ****	IBM PowerPC A2	522		
RZZeus (M&IC)	Intel Xeon E5530	267		

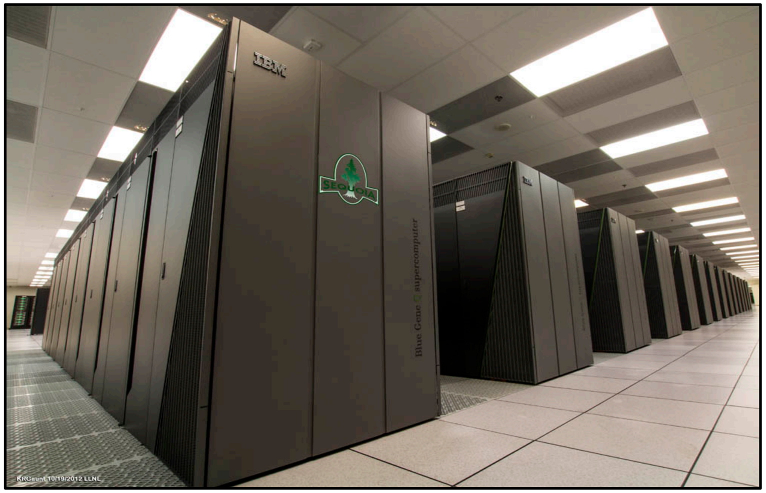
System (Program)	Processor Architecture	Nodes	Cores	Peak (TFLOP/s)
Juno (ASC)	AMD 8354			
Max (ASC)	Intel X… E5-26…			
Muir (ASC)	Intel X… X5660			
Sequoia (ASC) **	IBM PowerPC A2	98,304	1,572,864	20,132
Zin (ASC)	Intel Xeon E5-2670	2,916	46,656	970.4

System (Program)	Processor Architecture	Nodes	Cores	Peak (TFLOP/s)
CZ				
Ansel (M&IC)	Intel Xeon EP X5660	324	3,888	43.5
Aztec (M&IC)	Intel Xeon EP X5660	96	1,152	12.9
Catalyst (ASC/M&IC) ****	Intel Xeon E5-2695 v2	324	7,776	149.3
Cab (ASC/ M&IC)	Intel Xeon E5-2670	1,296	20,736	431.3
			256	1.6
			13,216	112.7
			40	–
			23,328	261.3
			2,592	53.9
	…ntel Xeon …5-2670	324	5,056	107.8
	…BM PowerPC …2	24,576	393,216	5,033

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

Power Generation, Transmission and Distribution

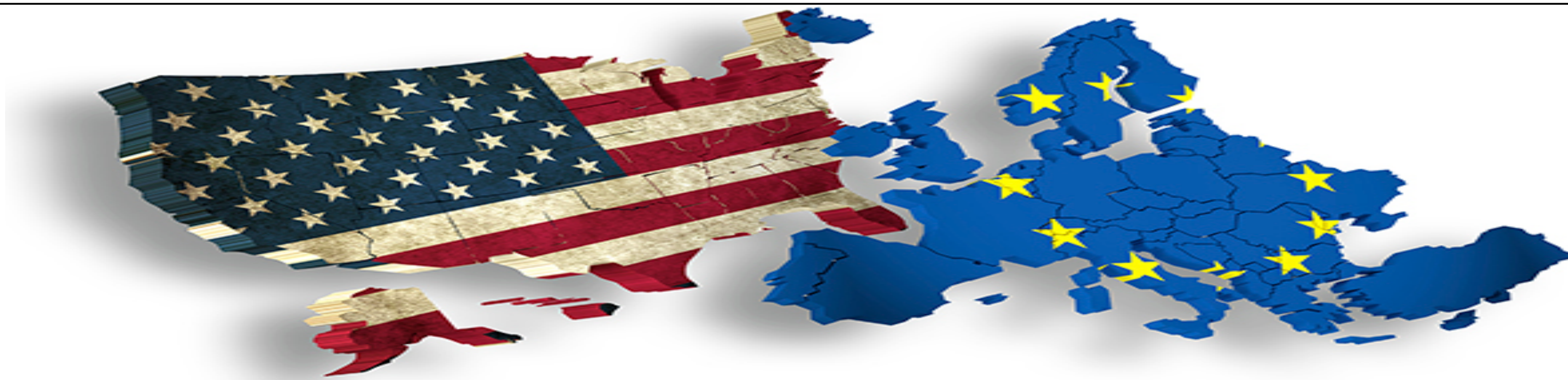


High-performance Computing

<u>Demand Management:</u> Actions taken to establish multi-directional relationships between SCs and ESPs to ensure energy efficiency and grid reliability

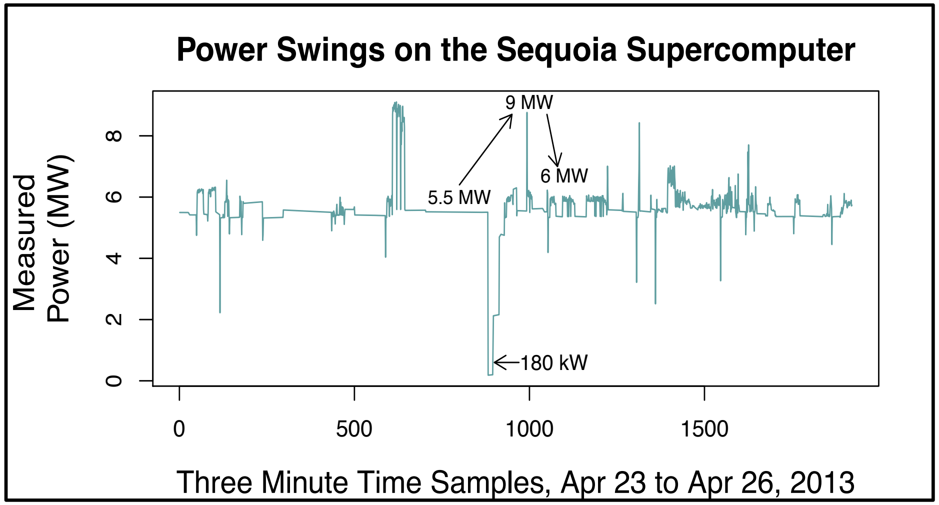
Demand Management: Europe versus United States

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



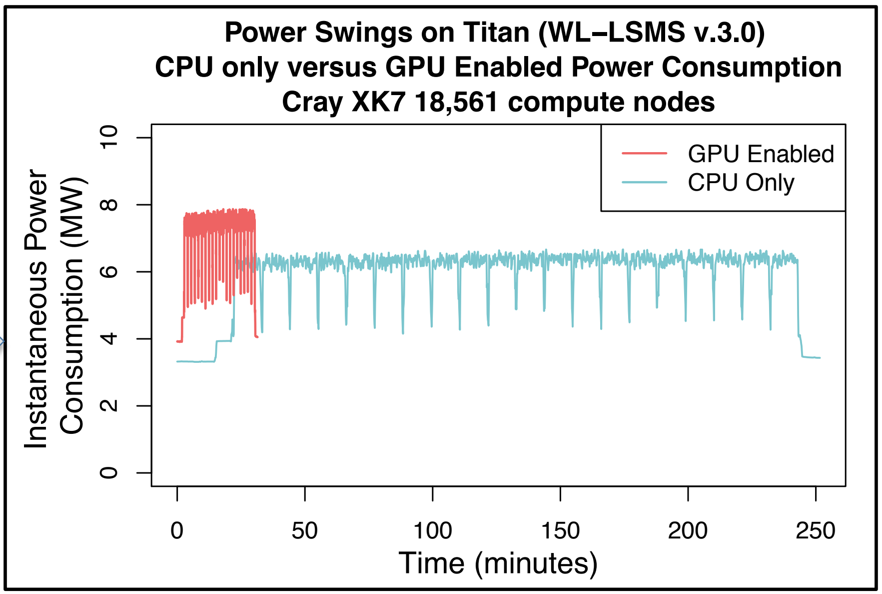
Focus for this paper: understand geographical differences in DM
- Extend study to 9 EU SC sites
- EU has more renewables, thus more variability
- Electricity prices in EU are higher, involve different taxes and peak costs
- Initial Expectation: EU might have a tighter integration between SCs and ESPs

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

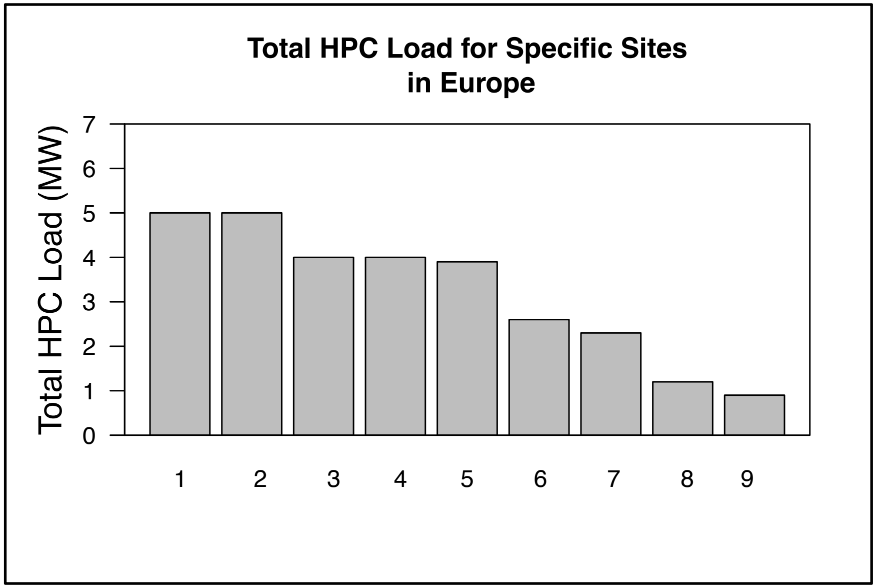
Quantitative Survey:

- 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:

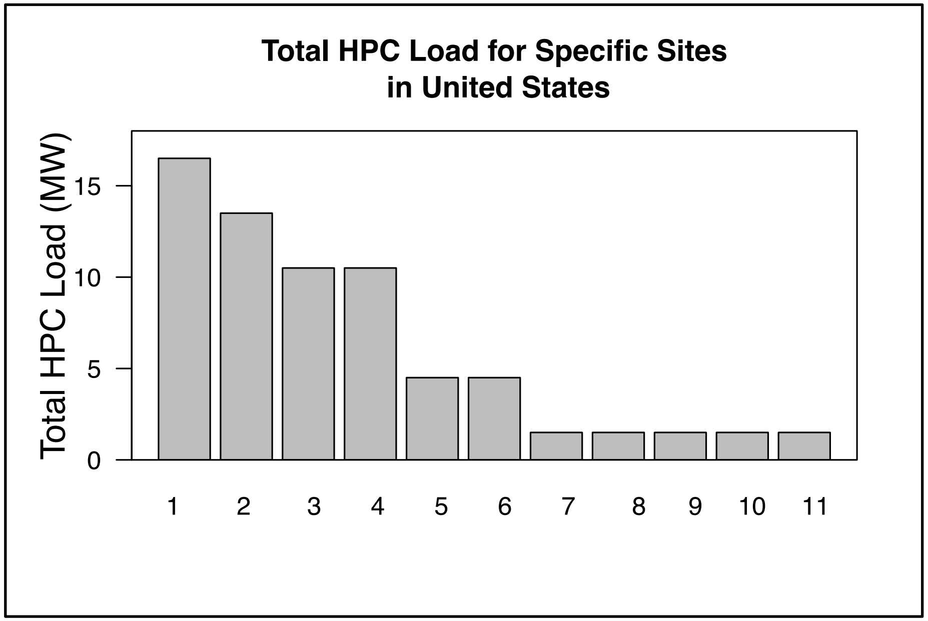
- Three sites: ORNL, LLNL, LRZ
- Understand the details of the electricity pricing structure

Quantitative Study: HPC Load Results



Europe:

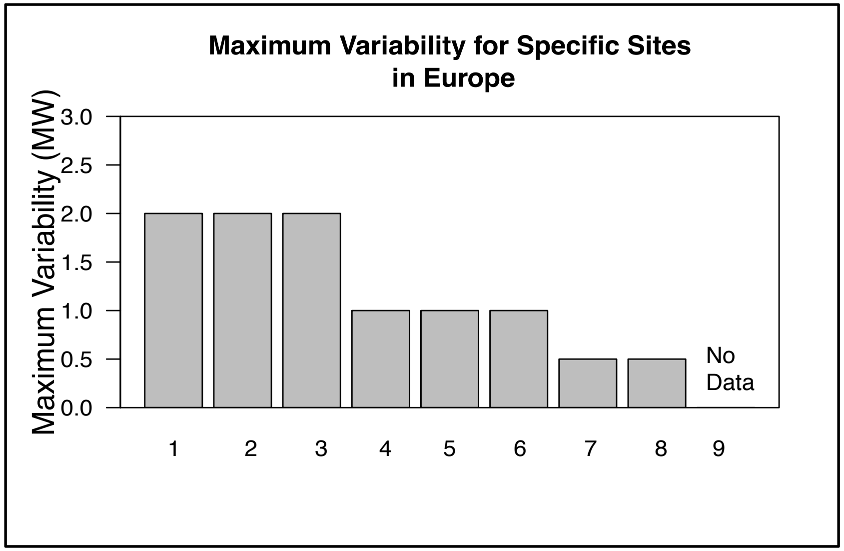
- All SCs have HPC load under 5 MW



United States:

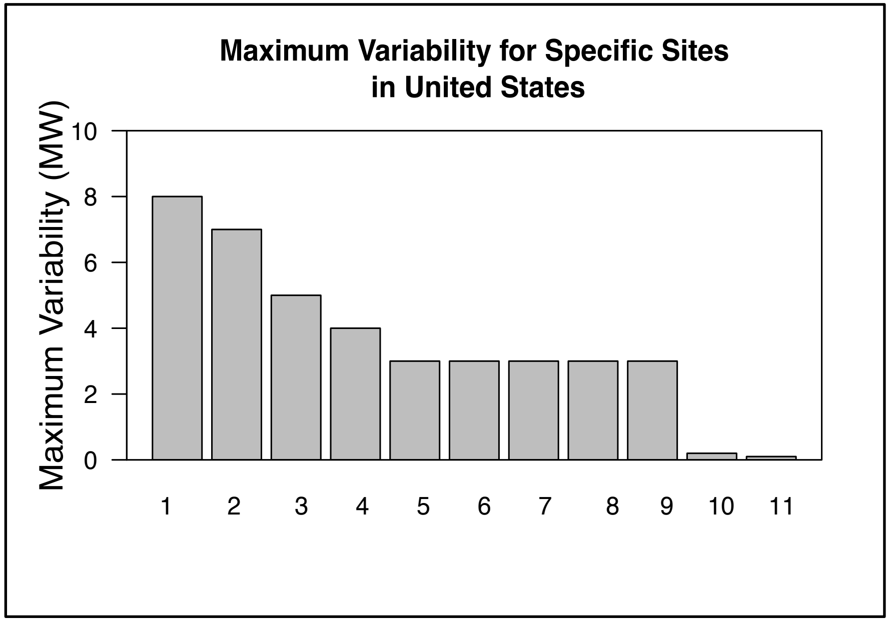
- 4 SCs have a load of more than 10 MW, others under 5 MW

Quantitative Study: Maximum Variability Results



All Sites:

- Typically, variability is due to maintenance
- Can be scheduled *day-ahead*



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"

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				
	Low	Medium	High	Rating Count
Economically justified	14.3% (1)	28.6% (2)	57.1% (4)	7
Good citizen	14.3% (1)	71.4% (5)	14.3% (1)	7
Adverse consequences	66.7% (4)	16.7% (1)	16.7% (1)	6
Government regulation	71.4% (5)	28.6% (2)	0.0% (0)	7

- Key motivation for a stronger relationship with ESP is to be a *good citizen*

Quantitative Study: Strategies and Programs

Program	Europe	United States
Peak Shedding	1	6
Peak Shifting	0	4
Dynamic Pricing	0	5

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

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

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

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

Qualitative Analysis

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

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/

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