Supercomputer Centers and Electricity Service Providers: Europe and the United States

Energy Efficient HPC Working Group

Prepared by Natalie Bates and the Demand Response Team

Google's Relationship

Is Google becoming an energy company?

By Davide Savenije | January 23, 2014

Utility DIVE

Why Google's Future Growth is in Energy

By Travis Hoium |
January 10, 2015

The Motley Fool.
To Educate, Amuse & Enrich™

Will Google be your next electricity provider?

Google- An Energy Company? Some Facts…

- Clean energy
  - US$2B investment worldwide, various technologies
- Google Energy Subsidiary
  - granted the right to sell energy
- Consumer smart-grid products
  - US$3.2B Nest Labs investment in smart thermostat
- Grid infrastructure investment
  - 37% stake in high-voltage direct-current transmission path for 7GW offshore wind power
- Electric utility products
  - General Electric partnership merges Google Maps into electric utility geospatial analytics tools and software

Broad spectrum and substantial investments

Multiple sources 2014-2015

Investing in Energy R&D

- Set ‘game changer’ R&D strategy
  - Combating climate change exclusively with today’s renewable energy technologies simply won’t work
    - Cancelled RE<C, cheap renewable energy R&D program
  - Need something disruptive; "dispatchable" (can be turned on and off), "distributed" (produced near where it's wanted) - at costs well below coal *or* gas
- Hired former head of US DOE ARPA-E Blue Sky
- Hiring electrical power engineers
- Filing related patents

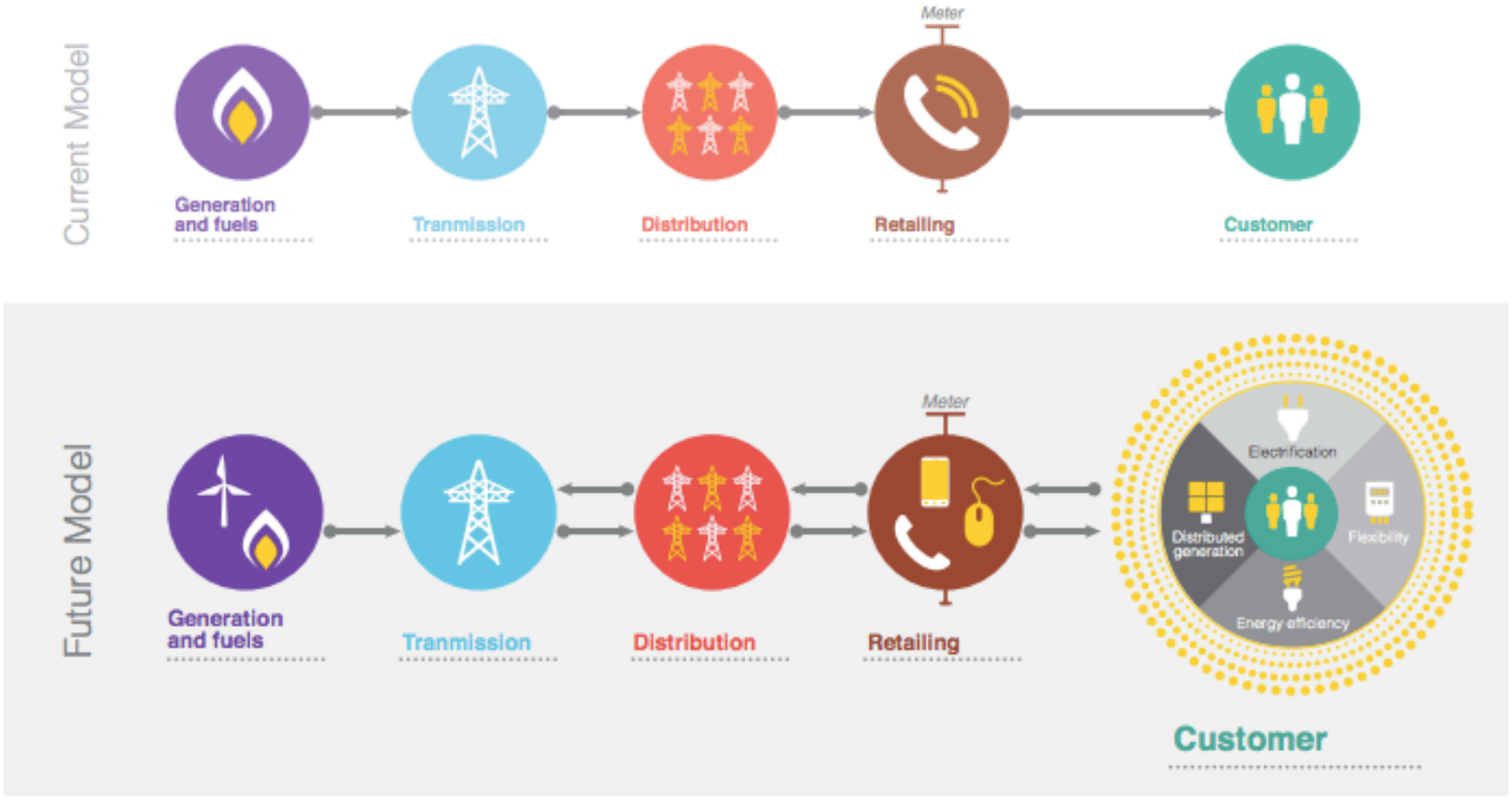
Long-term energy commitment

http://spectrum.ieee.org/energy/renewables/what-it-would-really-take-to-reverse-climate-change

http://www.bloomberg.com/news/articles/2014-06-10/google-said-to-plan-energy-push-with-tools-for-utilities

The Landscape is Changing

Figure 9: New business and investment opportunities are emerging close to the customer



New opportunities may open up to innovators

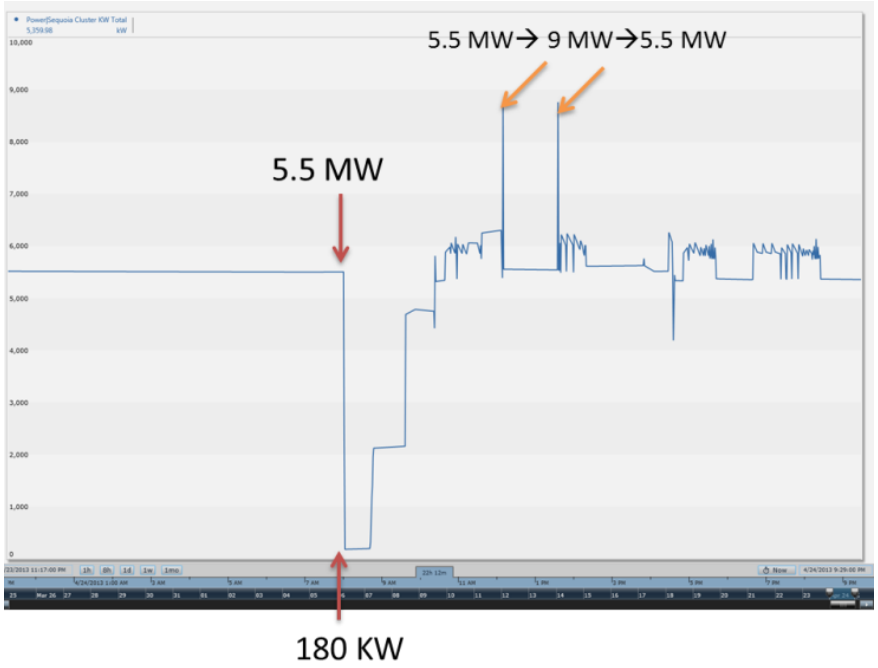
World Economic Forum, Future of Electricity Report 2015

Thank you respondents!

- Europe: LRZ, JSC, HLRS, CEA, EDF, ECMWF, CSCS, KTH, CINECA
  - Germany (3), France (2), United Kingdom, Switzerland, Sweden, Italy
- United States: LLNL, NERSC, SDSC, NCSA, ANL, LANL, Intel, WPAFB, ORNL, NOAA, Purdue
  - California (3), Illinois (2), New Mexico (2), Ohio, Tennessee, West Virginia, Indiana

Investigative Analysis

A snapshot of Sequoia power profile at LLNL



- Increasing power demands as well as instantaneous swings in power may require different relationships with electricity providers
- Changing electricity grid may allow for new and beneficial opportunities
- Energy savings (at least for the electricity grid)

Initial Results and Next Steps

Electrical Grid and Supercomputing Centers: An Investigative Analysis of Emerging Opportunities and Challenges*

- Conclusion: interest is there in the United States, but business case remains to be demonstrated
- Next steps: look at other geographies where electricity is more expensive and subject to more variability with renewables → Europe

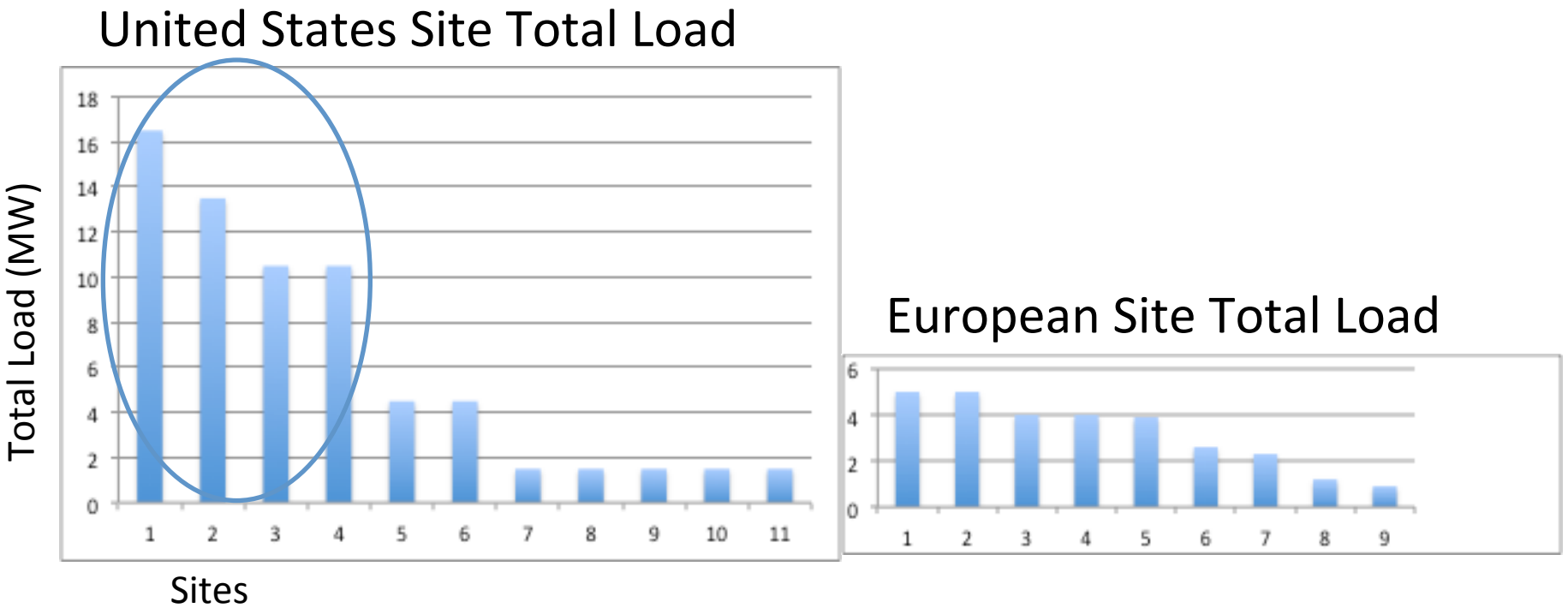
* Bates N, Ghatikar G, Abdulla G, Koenig G, Bhalachandra S, Sheikhalishahi M, Patki T, Rountree B, Poole S, "The Electrical Grid and Supercomputing Centers: An Investigative Analysis of Emerging Opportunities and Challenges". Energiinformatik 2014. Springer Publications. Zurich, Switerland 2014.

General Conclusions: US and Europe Comparison

- Neither the US nor European sites are working with their electricity providers to respond to grid requests
- The US sites have had more discussions with their providers about grid integration
- There is no evidence that European sites are more interested in grid integration

Results were not as expected

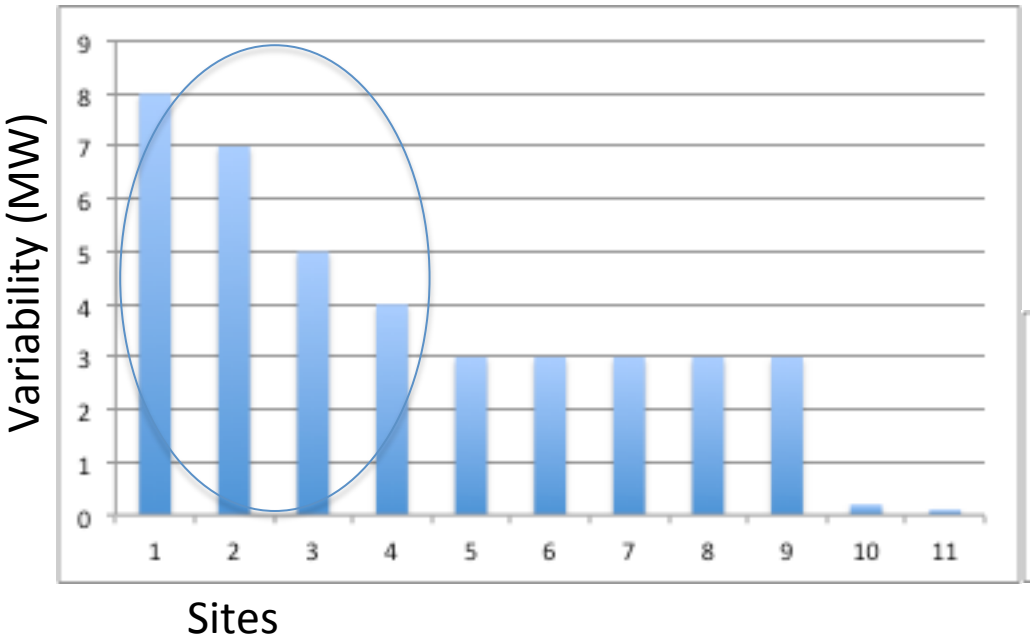
US and European Site Total Load



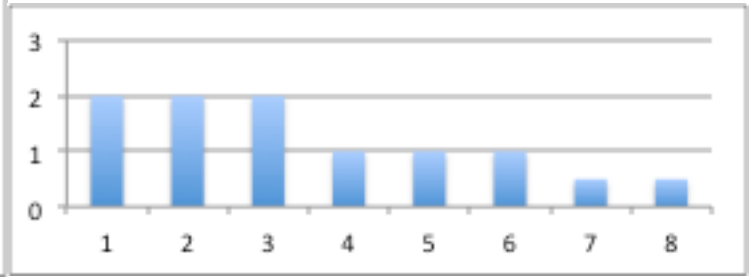
- Most sites in both US and Europe have less than 5MW Total Load (16/20)
- 4 10+MW sites are much larger than all the others

US and European Site Variability

United States Max Variability



Europe Max Variability



- US lowest option = 'Less than 3MW' (unless in comment)
- Most sites in both US and Europe have less than 3MW variability (15/19)
- 4 sites in US much greater than all the others
- Comments: Greatest source of variability is caused by maintenance events

Other questions

- Strategies –what supercomputing centers use to manage power
- Programs- what is offered by electricity providers to motivate their customers to help them balance the grid
- Methods- what is done in transmission and distribution for balancing the grid
- Comments

Power Management Strategies: Grid Response verses Energy Efficiency

Two Examples

- Load migration- a strategy well suited to responding to an electricity provider request, but not likely to improve energy efficiency
- Fine grained power management- more likely to be used for improving overall energy efficiency than for responding to a request from an electricity provider

Power Management Strategies

- Coarse Grain
- Job Scheduling
- Fine Grain
- Lighting
- Air and Liquid Temperatures
- Shut-down
- Load Migration
- Back-up resources (e.g., generator)
- Back-up scheduling
- Cut jobs

Strategy Comparison Summary

- Many sites are using or interested in using energy efficiency strategies
  - fine grained, job scheduling, lighting, temperature
- There is some (low-moderate) interest in strategies for grid integration
  - coarse grain, fine grain, job scheduling, shut-down, back-up resources (e.g., generators)
  - Interest lower in European than US sites
- No sites are already using these strategies for grid integration
- Load migration and cutting jobs is neither used nor interesting

Programs

- PEAK SHEDDING
- PEAK SHIFTING
- DYNAMIC PRICING

Program Comparison Summary

- No engagement
  - Neither European nor US sites are engaged with peak shedding, peak shifting or dynamic pricing programs
- Some communication
  - Many more US than European sites have communicated with their utility providers about these types of programs
- Interest in dynamic pricing
  - Both the European and US sites have some interest in dynamic pricing
- Mixed interest in peak shedding and shifting
  - The Europeans sites are more interested in peak shedding than peak shifting
  - The US sites are opposite: more interested in peak shifting than peak shedding

Motivation:
Europe Only (New Question)

33. Please evaluate as high, medium or low the following motivations for your site's interest in pursuing a stronger relationship with your electric service utility/provider. Create Chart Download

	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

One no-response and one doesn't know

Highest → Lowest: economical, good citizen, adverse consequence, gov't regulation

Methods

- RENEWABLES
- GRID SCALE STORAGE
- FREQUENCY RESPONSE
- REGULATION (Up or Down)
- CONGESTION

Method Comparison Summary

- Strong interest in renewables
  - Both European and US sites are interested in having communication with their providers about renewables
- No discussion about methods
  - Neither European nor US sites have had communication with their electric providers about any of the other methods
- Little interest
  - There is little interest in either European or US sites for communication about the other methods

Comments

- Forecasting demand
- Provider programs
- Swings in power

Forecasting Demand

- Our electricity contract specifies average expected usage and we announce planned changes.
- We've to ensure that our power load neither over- nor undershoots the contracted power band. In any cases of foreseen power abnormalities we've to inform our grid provider at least two days ahead of schedule.
- We project hourly average power at least a day in advance, within +/- 1MW
- Information we're being asked for but can't provide:
  - Multi-year forecast of energy requirements.
  - Additional detailed forecasting and ultimately real time data.
  - Power projections, hour by hour, for at least a day in advance.

Demand forecasting is already required and/or requested

Provider Programs

EUROPE

- 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.
- So far no such option from our suppliers
- We would like to know if we could have time dependent pricing

UNITED STATES

- Our site generates 30-35MW of power yet still imports 5-10MW. as a large generation source the utility providers see the campus as a highly attractive partner for offloading grid stress. automatic load shedding is being explored/deployed today.
- Have talked to provider about the "Voluntary Option" to shed load during peak demand
- We have explored load shed/shift in the past and shown it is do-able. Cultural resistance to impact on HPC productivity.
- Working on load sharing of data with utility to provide better scheduling tools and address potential grid changes.

Evidence of more provider programs in the United States than Europe

Further Evidence: Fewer European Provider Programs

Number who answered "Yes, they had conversations"

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

Swings in Power

- Working directly with provider to ensure that the effects of large load swings are understood. Have funded a simulation that accounts for all loads.
- Our provider has no problem with our load swings. They indicate no concern with our next system either, but we are still looking into possible options in case there actually is a problem.
- Sensitivity of power distribution grid to rapid transients (random daily step changes of 10 MW up or down within a single AC cycle).

US Sites investigating impact of power swings on distribution grid

Next Steps

- Better understand European providers
- Replicate in Japan

Questions, comments, feedback

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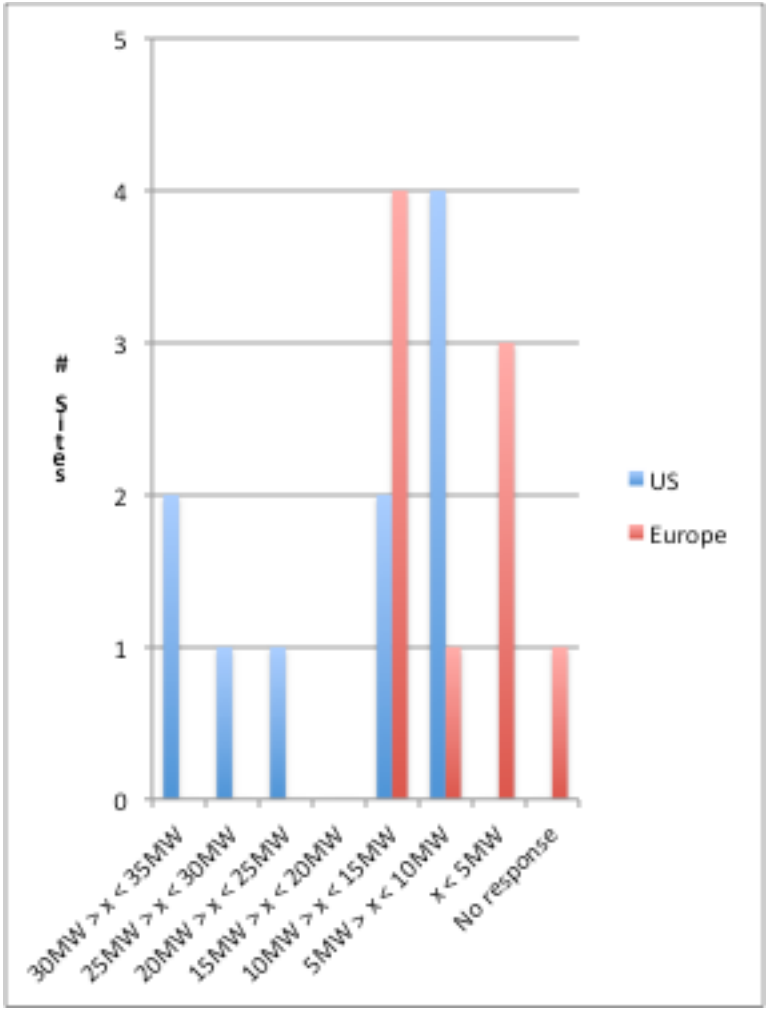
Back-up Detail

Respondent Demographics

- Similar response rate; 9/16 (56%) respondents in Europe and 11/19 (58%) respondents in US
- Top50 sites except for 1 in Europe and 2 in US
- For US and Europe, the sampling was neither random nor anonymous
  - Relied on EE HPC WG membership contacts

US and European Max Site Load



- Again, 4 US sites max load 20+MW
- Half of the sites max load between 5MW-15MW (11/20)
- 3 European and zero US sites less than 5MW max load

US and European PUE

Response Choices	US #	US %	Europe #	Europe %
Not measured	1	9%		0%
Above 1.0 and below 1.25	2	18%	3	33%
Above 1.25 and below 1.5	7	64%	5	56%
Above 1.5	1	9%	1	11%
TOTAL	11	100%	9	100%

- Majority of sites: PUE above 1.25 and below 1.5
- Both US and European Supercomputer Centers much lower PUE than 'average' datacenter

Tweaked Questions: Distinguishing Energy Efficiency and Grid Integration

European questions clearly separated energy efficiency from grid integration

Reminder: this question allows for multiple answers.

- Yes, we do use coarse grained power management for energy efficiency
- Yes, we do use coarse grained power management for responding to grid requests
- No, we do not use coarse grained power management
- We are interested in using coarse grained power management for energy efficiency
- We are interested in using coarse grained power management for responding to grid requests

US questions blurred distinction between energy efficiency and grid integration

- Yes, we do use coarse grained power management as a strategy for responding to grid requests.
- Yes, we do use coarse grained power management as a strategy, but not for grid requests
- No, we do not use a coarse grained power management strategy
- No, but we could and might be interested in using it for grid requests or other purposes

Strategy Comparison Summary

- Both Europe and US are using and/or interested in using some of these strategies for energy efficiency
  - Strategies with greatest use and/or interest: fine grain, job scheduling, lighting
  - US interest in coarse grain, but not Europe
- There are not any sites in either the US or Europe who are using these strategies for grid integration
- There is evidence that there are more US than European sites interested in using these strategies for grid integration
  - Strategies with greatest interest: coarse grain, fine grain, job scheduling, shut-down
  - Strategies with least interest: lighting, air temperature
- Load migration is not interesting for either energy efficiency or grid integration

Coarse Grain

COARSE GRAINED POWER MANAGEMENT: refers to the ability to control SC system power and energy, but contrasts with fine-grained power management in that the resolution is low and it is generally done at a more aggregated level. A typical example is power capping.

Few European, but many US sites interested in coarse-grained power management (2/9 in Europe and 8/11 in US)

Comments: Coarse Grained

Europe

- We manage to utilise our supercomputer to capacity and as such it is unclear to us how we could benefit from power management.
- Slurm has a power capping mechanism - this could be used to block job scheduling beyond a certain level, in case we want to activate power capping

United States

- Nothing is necessary at this time. Our provider has no problem with our load swings. They indicate no concern with our next system either, but we are still looking into possible options in case there actually is a problem.
- We might be interested in the future when operating closer to our design limit and the maximum capacity of our utility feeders.
- We have explored load shed/shift in the past and shown it is do-able. Cultural resistance to impact on HPC productivity.

Fine Grained and Job Scheduling Questions

FINE GRAINED POWER MANAGEMENT: refers to the ability to control SC system power and energy with tools that offer high resolution control and can target specific low level Subsystems. A typical example is CPU voltage and frequency scaling.

JOB SCHEDULING: refers to the ability to control SC system power by understanding the power profile of applications and queuing the applications based on those profiles.

Combining Job Scheduling and Fine Grained Responses

- Fine grained power control mechanisms are being deployed in Job Schedulers
- Same comment for both strategies
  - "We are using an energy-aware scheduling system which is able to automatically select the optimal processing frequency for applications to minimize the system energy needed to run the application to completion."

Response: Job Scheduling/Fine Grained

- Both European and US sites are using and/or interested in job scheduling and fine-grained power management (7/9 in Europe and 8/11 in US)
- Many European and US sites are already using job scheduling and fine-grained power management for energy efficiency (5/9 in Europe and 6/11 in US)
- Less interest in grid integration using fine-grained power management and job scheduling (1/9 in Europe and no more than 4/11 in US*)

  * US Questionnaire asks for interest in "grid integration and other purposes"

Comments: Job Scheduling and Fine Grained Power Management

Europe

- We are using an energy-aware scheduling system which is able to automatically select the optimal processing frequency for applications to minimize the system energy needed to run the application to completion.
- New system end of this year is supposed to allow this
- DVFS on Juropa
- We have studied the impact of frequency tuning, and this can already be used by code developers but it is not fully deployed

United States

- We implement de-clocking to shave up to 30% HPC power load to mitigate plant chiller issues should they occur
- We have trouble with job scheduling for the basic purpose of queuing jobs to optimize the utilization of processors. I'd be interested in using it for energy efficiency, but don't believe the industry can satisfactorily support it. I would not be interested in this to reduce the utility grid demand.

Lighting Control

- LIGHTING CONTROL Question: Data center lights could be turned off or shutdown completely
- Both Europe and US sites are using and/or interested in using lighting control for energy efficiency (8/9 in Europe and 7/11 in US), but not for grid integration (zero in Europe and US)

European Comments

- Our data center is operated as dark center. Hence most of the time the lights in the data center are out.
- We do switch lights off when the room is empty but this is not a recognised strategy within our organisation.

United States Comments

- Our lights automatically shut off 24x7 when there is no motion in the data center. This is so small compared to the HPC demand load that I'd be surprised if the utility is interested.
- All data center lights are controlled by motion sensors.

Tweaked Air Control Question

- European Version

  INCREASING AIR TEMPERATURE: Increasing the temperature of the SC beyond the normal operating limit on a rapid, but temporary basis. For this question, consider the 'normal operating limit' to be set by the SC.

  Note, this rapid and temporary excursion is different from the slow, deliberate and lasting increases in temperature that have been and continue to be a part of a continuous improvement process for energy efficiency purposes.

- US Version

  TEMPERATURE ADJUSTMENT: widen acceptable (ASHRAE Thermal Conditions) temperature set-point ranges and humidity levels for short periods.

Air Temperature Control

- A few European and many US sites are using and/or interested in using air temperature control for energy efficiency (3/9 in Europe and 8/11 in US), but not for grid integration (zero in Europe and 1 in US)

  European Comments

  - Over 90% of our HPC equipment is water cooled and therefore air temperature control would have minimal impact.
  - We did increase normal temperature - but so far we have not done that on a rapid / temporary basis (permanent setting)

  United States Comments

  - Our normal inlet temp is 79F so there is little room for adjustment to save energy.
  - This is a challenge due to contractual obligations. It's easier to never deviate from specific temperature and humidity performance thresholds. We have set ours as high (temps) as possible, according to ASHRAE TC 9.9.
  - We implement de-clocking to shave up to 30% HPC power load to mitigate plant chiller issues should they occur

Liquid Control

- Added a question for European sites about Liquid Cooling Temperature
- 3/9 use liquid cooling temperature control for energy efficiency
- Comments:
  - We try to ensure the maximum water temperature at all times to make best use of our ambient air cooling system. We would not use this in response to demand side requests.
  - Our W4 cooling loop contains no chillers. We use the water temperature as provided by our whet cooling towers to cool the supercomputer.

Shut-down

- SHUTDOWN: Graceful shutdown of idle HPC equipment loads. Usually applies when there is redundancy.
- Only one European, but several US sites using and/or interested in using shut-down for energy efficiency and/or grid integration (1/9 in Europe and 5/11 in US)

COMMENTS:

Europe

- There is nothing idle.
- We had ONE exceptional use of shutdown for energy saving - not a regular practice

United States

- We've had too many instability and equipment failures to utilize this as a strategy.

Load Migration

- LOAD MIGRATION: refers to temporarily shifting computing loads from an SC system in one site to a system in another location that has stable power supply. This strategy can also be used in response to change in electricity prices.
- No interest in load migration for energy efficiency or grid integration (0/9 in Europe and 1/11 in US)

COMMENTS:

Europe

- We do not have a second facility to migrate work to.

United States

- Outside of particular NSF funded systems, there are no distributed homogeneous HPC systems that we operate - preventing load migration.
- We have only one grid available locally.
- Facility is already fed by three diverse 161kV lines, and electrical distribution to the facility uses multiple diverse 13.8kV lines.

Back-up Resources

Using generators and other electrical storage devices.

- Most sites do not use back-up resources (6/9 in Europe and 6/11 in US)
- There is some interest in using back-up resources for energy efficiency, grid integration and other purposes (4/9 in Europe and 5/11 in the US)

COMMENTS:

Europe

- We do not understand how using backup generation can improve energy efficiency. We have started to investigate the opportunities available with our supplier.
- Our highly critical IT systems are backed-up by static UPS systems and a diesel generator. The HPC systems and all other not highly critical IT systems are only backed up by dynamic UPS systems with a maximum autonomy time of 20 s.

United States

- The campus is leveraging parallel electrical distribution to trigger diesel generators and other back-up resources to respond to to grid and non-grid requests.
- The cost of diesel generators is far higher than utility power, so we don't want to pursue this.
- For some systems, we use rotary UPS to "ride through" power interruptions of up to 10-20s.
- Use backup UPS for critical services, such as network, log in nodes, etc.

Back-up Scheduling

Refers to deferring data storage processes to off-peak periods.

- Most sites do not use back-up scheduling (8/9 in Europe and 11/11 in US)
- Interest in back-up scheduling for energy efficiency, grid integration or other purposes in US only (1/9 in Europe and 5/11 in US)

COMMENTS:

Europe

- A significant degree of our storage utilises asyncronous IO techniques to overlay compute and IO in an efficient way.

United States

Cut Jobs

- New question added to European questionnaire.
- No interest in cutting jobs for either energy efficiency or grid integration (8/9 respondents)
- Comment: we do not exactly cut jobs, we do have a 'time limit' setting mechanisms that can be considered more or less similar (gracefully terminates application) - moderate interest for potential other features

Other Strategies?

United States

- Working on load sharing of data with utility to provide better scheduling tools and address potential grid changes.
- Nothing is necessary at this time. Our provider has no problem with our load swings. They indicate no concern with our next system either, but we are still looking into possible options in case there actually is a problem.
- We use water-side economizing via dry coolers. We could manually switch the sequence to use all the dry coolers and pre-cool or turn off a chiller. Our sequence of operations tries to do this automatically all the time based on an energy calculation. We can shut off N+1 equipment, taking the risk of start up time if the primary fails.
- Working directly with provider to ensure that the effects of large load swings are understood. Have funded a simulation that accounts for all loads; the results of that simulation have been made available to provider.
- Conduct preventative maintenance on HPC systems at end of summer months when peak power usage may be highest and used to set the month's power bill.
- Controlled power reduction on request, by shutting down equipment, in cases of major power-related emergencies (very rare)

Europe

- We've to ensure that our power load neither over- nor undershoots the contracted power band. In any cases of foreseen power abnormalities we've to inform our grid provider at least two days ahead of schedule.

What you'd like to know

Is there information you would like from your provider that you are not getting?

Europe

- We would like to know if we could have time dependent price.
- We are open to new features our provider(s) might offer
- Not at present but we have not engaged sufficiently with our supplier as yet.

United States

- Yes, we are working on obtaining additional data from them and a means of sharing data between them and us.
- Sensitivity of power distribution grid to rapid transients (random daily step changes of 10 MW up or down within a single AC cycle).
- I'd like detailed information about disruptions and power quality from their perspective. Occasionally, we'll experience a brown out that automatically transfers us to generator power, but the utility provides no information on the root cause or what actually happened.

What you're being asked for

Is your provider asking for information from you that you are not able to provide?

Europe

- Multi-year forecast of energy requirements.

United States

- Additional detailed forecasting and ultimately real time data.
- Power projections, hour by hour, for at least a day in advance.

Electricity Provider Introduction

- Help us to understand the nature of the relationship you have, if any, between your HPC facility and your site's electric utility/ provider.
- Have had any communication about the following programs and methods with your site's electric utility/provider.
- Please describe the nature of that communication in the comments.

Programs

- PEAK SHEDDING
- PEAK SHIFTING
- DYNAMIC PRICING

Program Comparison Summary

- Neither European nor US sites are engaged with peak shedding, peak shifting or dynamic pricing programs
- There are more US than European sites who have communicated with their utility providers about these types of programs
- The Europeans sites are not interested in peak shifting, although there is some interest in peak shedding and dynamic pricing
- The US sites are slightly more interested in peak shifting than peak shedding and dynamic pricing

Peak Shedding

Utility provider arrangements used to reduce peak load, where the reduced load is not shifted to another time.

	Europe		US	
Yes, we have had conversations with our electric utility/provider about peak shedding.	1	11%	6	55%
No and we are not interested	4	44%	3	27%
We have not had conversations, but we are interested	3	33%	2	18%
Don't know	1	11%	0	0%
	9	100%	11	100%

- Only one European but many US sites have had conversations about peak shedding with their utility provider
- Of those who have not had conversations, there are slightly more who are NOT interested than those who are interested in both Europe and US

Comments: Peak Shedding

Europe

- Currently not an issue for us.
- We are starting to consider the implications of this type of strategy and are fully aware that it needs to be carefully evaluated.
- So far no such option from our suppliers

United States

- UCSD generates 30-35MW of power yet still imports 5-10MW. as a large generation source the utility providers see the campus as a highly attractive partner for offloading grid stress. automatic load shedding is being explored/ deployed today.
- Have talked to PG&E subcontractor about he "Voluntary Option" to shed load during peak demand days.
- Our load is typically very steady daily and monthly, so this doesn't make sense. We would be sacrificing compute cycles.
- Not currently necessary.
- Technical feasibility has yet to be developed. Business case has yet to be developed.

Peak Shifting

Utility provider arrangements where the load during peak times is moved, typically to non-peak hours.

	Europe		US	
Yes, we have had communication with our electric utility/provider about peak shifting.	0	0%	4	36%
No and we are not interested	6	67%	3	27%
We have not had conversations, but we are interested	2	22%	4	36%
Don't know	1	11%	0	0%
	9	100%	11	100%

- Europe predominately NOT interested in peak shifting and have not had communication with their utility provider, but several US sites have had discussions and/or are interested

Comments: Peak Shifting

Europe

- Currently not an issue for us.
- The reason we have a high HPC utilisation is that it is the only mechanism to accommodate our workload, we lack spare capacity to move work to "off peak" periods.
- So far no such option from our suppliers

United States

- Not to move to non-peak hours. We have one rate, we do not have off-peak and on-peak rates.
- Our load is typically very steady due to job scheduling, so this doesn't make sense in most 24 hour cycles.
- Not currently necessary.
- Have talked to PG&E subcontractor about he "Voluntary Option" to shed load during peak demand days.
- Technical feasibility has yet to be developed. Business case has yet to be developed.

Dynamic Pricing

Time varying pricing arrangements used to increase, shed or shift electricity consumption. There are two types of pricing, peak and real-time. Peak pricing is pre-scheduled; however, the consumer does not know if a certain day will be a peak or a non-peak day until day-ahead or day-of. Real-time pricing is not pre-scheduled; prices can be set day-ahead or day-of.

	Europe		US	
Yes, we have had communication with our electric utility/provider about dynamic pricing.	0	0%	5	45%
No and we are not interested	5	56%	4	36%
We have not had conversations, but we are interested	3	33%	2	18%
Don't know	1	11%	0	0%
	9	100%	11	100%

- Europe predominately NOT interested in dynamic pricing and have not had communication with their utility provider
- Many US sites have had discussions
- Of the US sites who have not had communication, there are many who are not interested

Comments: Dynamic Pricing

Europe

- Currently not an issue for us.
- So far no such option from our suppliers

United States

- Mis forecasts could lead to sale of power at higher than purchase price and can be an issue for profit to the National Treasury.
- Pricing based on our generation/consumption to the best of my knowledge is generally fixed.
- Our Utilities group is negotiating prices on a continuing basis, daily, I believe.
- Not currently implemented.
- The pricing arrangement is done at the base level where we are located and not by our organization.
- Project hourly average power for at least a day in advance, within +/- 1MW

Methods

- RENEWABLES
- GRID SCALE STORAGE
- FREQUENCY RESPONSE
- REGULATION (Up or Down)
- CONGESTION

Method Comparison Summary

- Both European and US sites are interested in having communication with their providers about renewables
- Neither European nor US sites have had communication with their electric providers about any of the other methods
- There is little interest in either European or US sites for communication about the other methods

Renewables

- Variability in the electric power generation from renewable resources and the methods used to respond to that variability

	Europe		US	
Yes, we have had communication with our electric utility/provider about renewables.	1	11%	4	36%
No and we are not interested	3	33%	2	18%
We have not had conversations but we are interested	4	44%	5	45%
Don't know	1	11%	0	0%
	9	100%	11	100%

- Many more US than European sites have had communication with their electric utility/provider about renewables
- Both European and US sites are interested in having this discussion

Comments: Renewables

Europe

- We've signed a power contract for 100% renewable energy (mainly electricity from hydroelectric power stations).
- So far no such option from our suppliers.
- Currently not an issue for us.

United States

- At the Institutional level not just for HPC.
- The campus has a large fuel cell (2.5+ MW) and works with the utility with renewables.
- We looked for green power sources as part of LEED certification. The cost was unsustainable.
- Provider already uses multiple sources (hydroelectric, nuclear, natural gas, coal, wind). Further use of renewables would be of interest.
- Variability in power generation is beyond our control or visibility. Utilities and power grid operators see this, we don't.

Grid Scale Storage

- Methods used to store electricity on a large scale. Pumped-storage hydroelectricity is the largest-capacity form of grid energy storage.

	Europe		US	
Yes, we have had communication with our electric utility/provider about grid scale storage.	0	0%	1	9%
No and we are not interested	7	78%	4	36%
We have not had conversations but we are interested	1	11%	6	55%
Don't know	1	11%	0	0%
	9	100%	11	100%

- Neither US nor European sites have had communication with their electric utility/providers about grid scale storage
- Many more US than European sites are interested in having this discussion

Comments: Grid Scale Storage

Europe

- Currently not an issue for us.

United States

- At the Institutional level not just for HPC.
- We are interested in technical options for energy storage on time scales of a single AC cycle to several hours, at 10 MW+ scale. We are less concerned about energy storage at time scales of hours to days.

Frequency Response

- Methods used to keep grid frequency constant and in-balance. Generators are typically used for frequency response, but any appliance that operates to a duty cycle (such as air conditioners and heat pumps) could be used to provide a constant and reliable grid balancing service by timing their duty cycles in response to system load.

	Europe		US	
Yes, we have had communication with our electric utility/provider about frequency response.	0	0%	2	18%
No	8	89%	9	82%
Don't know	1	11%	0	0%
	9	100%	11	100%

- Neither US nor European sites have had communication with their electric utility/provider about frequency response.

Comments: Frequency Response

Europe

- We are not large enough to have an impact on the local grid by using such mechanisms. The only option for us is to run on local generation which would not be particularly responsive to frequency shifts. As a consequence of utilizing diesel rotary UPS machines on our site we do have automatic on-site generation that operates when frequency fluctuations of more than 0.5Hz occur.
- So far no such option from our suppliers.
- Currently not an issue for us.

United States

- Again, this isn't visible to us nor controllable by us; this is a power grid regulation problem.
- Not sure.

Regulation

- **(Up or Down): Methods used to maintain that portion of electricity generation reserves that are needed to balance generation and demand at all times. Raising supply is up regulation and lowering supply is down regulation. There are many types of reserves (e.g., operating, congestion), distinguished by who controls them and what they are used for.**

	Europe		US	
Yes, we have had communication with our electric utility/provider about regulation.	1	11%	2	18%
No	7	78%	9	82%
Don't know	1	11%	0	0%
	9	100%	11	100%

- Similar to frequency response, very few US or European sites have had communication with their electric utility/provider about regulation.

Comments: Regulation

Europe

- We've to ensure that our power load neither over- nor undershoots the contracted power band. In any cases of foreseen power abnormalities we've to inform our grid provider at least two days ahead of schedule.
- Currently not an issue for us.

United States

- Learning about the process outside of our visibility or control.
- Not sure.

Congestion

- **Methods used to resolve congestion that occurs when there is not enough transmission capability to support all requests for transmission services. Transmission system operators must re-dispatch generation or, in the limit, deny some of these requests to prevent transmission lines from becoming overloaded. Or, methods used to resolve congestion that occurs when the distribution control system is overloaded. It generally results in deliveries that are held up or delayed.**

	Europe		US	
Yes, we have had communication with our electric utility/provider about congestion.	0	0%	2	18%
No	8	89%	9	82%
No answer	1	11%	0	0%
	9	100%	11	100%

- Identical to frequency response, very few US or European sites have had communication with their electric utility/ provider about congestion.

Comments: Congestion

Europe

- Not an issue for us - big line, dedicated
- Currently not an issue for us.

United States

- Learning about the process outside of our visibility or control.
- Not sure.

Motivation:
Europe Only (New Question)

33. Please evaluate as high, medium or low the following motivations for your site's interest in pursuing a stronger relationship with your electric service utility/provider. Create Chart Download

	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

One no-response and one don't know

Power Quality Issues

Do you experience any power quality issues at your HPC facility?

Europe

- Occasional brown-outs due to strong thunder storm activity. Within expected and acceptable range for us.
- We never have a problem with our HPC facility.
- Yes, we observed several lightning induced brown outs during 2013
- Very good quality of power we thus dismissed most of UPSs, having instead compute blades with ultracapacitors to handle subt-second power outages Only some critical equipment is protected with UPSs (<20%) observed short outages (~300 ms), handled by UltraCapas, are ~5 Times a year

United States.

- No, only when there is a glitch.
- We have had brown outs and a few other things. We condition our power to our systems now, so the major issue is if we have a power outage.
- We have clean, relatively reliable power to the area with an additional feed from campus power plant available.
- Under voltage incidents (brown outs) have been rare, but had significant impact. We've had only one complete loss of power in 13 months since moving onto a dedicated, buried feeder line from a new substation that is dedicated to this industrial park.

Final Open-ended Questions

Please help us understand the economic aspects of power saving strategies. This is an open ended question and we encourage any feedback. For instance, what might it take to induce your site to participate in programs offered by your electric service provider? What are the trade-offs between savings and loss of scientific productivity and equipment depreciation.	Other Comments, feedback, etc.
We have an electricity contract. We specify average expected usage and we announce planned changes. We have electricity delivered as contracted. No questions asked. Power saving strategy so far is on the procurement level and with cooling optimization. In the future we hope to apply voltage/frequency changes to save energy. However, we expect that to be in the low percentage range. We justify our energy usage by the results of the research done on our systems. We plan to do a semi-quantitative study on that.	With many of your questions I am wondering about the kind of contracts other centers might have and about the quality of some elecrticity providers.
not so many related options and features offered by providers so far we have a European Code of Conduct approach, we also participate in 'CEE' programmes that gives us credits and money saving in exchange of energy optimisations, which we re-invest in equipment - so we are open to further and pro-active efforts as long as providers have other kinds of programmes to propose	
No response	
LRZ has considered both energy to solution and the energy delay product in its energy saving strategy. For the SuperMUC system the energy to solution for applications would be minimal when running the system at 1.8 GHz processing frequency. However running all applications with this processor frequency would reduce the productivity of the system drastically. We've therefore also considered the energy delay product to account for the loss in productivity when trying to optimize the energy consumption of SuperMUC Between 2.7 GHz (the nominal frequency of the processors) and 2.5 GHz the energy delay product curve is very flat and the energy to solution curve decreases sharply between 2.7 and 2.2 GHz. As a compromise between minimal energy consumption and maximal system productivity we've selected 2.3 GHz as default processing frequency. While this setting is well justified for the majority of the applications running on SuperMUC, a small number of heavily optimized application would show significant performance penalties when running at default frequency of 2.3 GHz. In order to enhance the productivity of the system for well optimized applications, these applications will run at · 2.5 GHz, when the LoadLeveler runtime prediction mechanism predicts that the application will run 5% faster at this frequency · 2.7 GHz , when the LoadLeveleer untime prediction mechanism predicts that the application will run 12% faster at this frequency Using this approach, we ensure that our approach does not cause penalties on applications which benefit from running at higher processor frequencies. In addition we create an incentive for application developers to optimize their codes for the target architecture.	
No response	
We would need to understand the full impact of any possible strategy on our operational performance and evaluate this against potential cost savings.	
Currently we have not evaluated such trade-offs.	
No response	
No response	

US and European Facility Detail

Total Load	HPC Load	Max	Variability
US Sites			
16-17MW	13-14MW	30-35MW	5MW
13-14MW	10-11MW	30-35MW	8MW
10-11MW	7-8MW	25-30MW	Less than 3MW
10-11MW	10-11MW	20-25MW	7MW
4-5MW	4-5MW	11MW	Less than 3MW
4-5MW	3.7MW	5-10MW	4MW
1-2MW	1-2MW	5-10MW	Less than 3MW
1-2MW	1-2MW	6.8MW	140kW
1-2MW	1-2MW	5MW	Less than 3MW
1-2MW	1-2MW	10-15MW	200kW or less
1-2MW	Less than 1	5MW	Less than 3MW

Total Load	HPC Load	Max	Variability
European Sites			
5 MW	4 MW	10 MW	Less than 1MW
5 MW	3 MW	5-10 MW	2 MW
4 MW	3 MW	10-15 MW	Don't know
4 MW	3 MW	10-15 MW	2 MW
3.9 MW	3 MW	No response	1 MW
2.6 MW	2.16 MW	10-15 MW	1 MW
2.3 MW	1.9 MW	4.5 MW	2 MW
1.2 MW	0.7 MW	Less than 5 MW	1 MW
0.9 MW	0.8 MW	Less than 5 MW	Less than 1MW

Intra-hour Variability Comment Detail

US Sites
No comment
7.8MW for Maintenance- not scheduled. Typical maintenance that may cause system drain to idle state occurs approximately once every four weeks. HPC systems are taken off line once annually, with a full variation above 10MW.
There is a 2MW drop for a few hours every few weeks for preventive maintenance
No comment
Mostly due to PMs, user workload or other center-wide outages.
Right now we have weekly maintenance periods, so once a week for 6-8 hours depending.
There is a 2MW drop monthly for a 48 hour period during Preventative Maintenance periods. Also, our HPC system has a peak load of 1.70MW when near 100% utilization and 0.55MW when idle. This swing can happen for 1 hour a week.
Normal load while processing may vary +/- 5 %. We maintain a job queue that insures there will be jobs waiting for available nodes so processor utilization rates are maximized. During Preventative Maintenance periods (up to 3 times each year) HPC load may be zero for up to 8 hours.
Approximately 1.0 MW when we shut down HPC system completely for facilities maintenance. This is a rare event required for electrical maintenance. Only for intermittent construction projects.
load is usually very constant based on configured utilization rates. fluctuation is usually 200 kW or less.
No comment
European Sites
In normal operation we have a small intra-hour fluctuation of load, significantly less than 1MW. We do not have a regular scheduled (ie at least monthly) intra-hour variation of load.
The idle power of our supercomputer is 0.8 MW. The power consumption of the system, fully loaded with one highly optimized application is up 2.8 MW. Hence the power draw of our system can vary by a magnitude of up to 2 MW after system or application crashes or unscheduled maintenance periods. System maintenance periods in a 6 to 8 weeks time slot.
Don't know
No comment
system load variation, max. 500 kW variation
No comment
maybe once a year unscheduled 1MW intra-hour power variation. scheduled complete down (fire alarm test) every other year
No comment
No comment

Please evaluate as high, medium or low the MW impact of each of these strategies as a response to a grid request.