RÉPUBLIQUE FRANÇAISE
Liberté Égalité Fraternité

PROGRAMME DE RECHERCHE
NUMÉRIQUE POUR L'EXASCALE

Power capping on heterogeneous platforms

Exa-Soft WP6

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Motivation to improve the energy efficiency of HPC applications

- HPC applications are optimized to run fast.
  1. **Hardware vendors:** multi-core processors, vector units, accelerators, etc.
  2. **Software optimizations:** parallelization at the heart of HPC applications.
- As computing power scales, so does power consumption.

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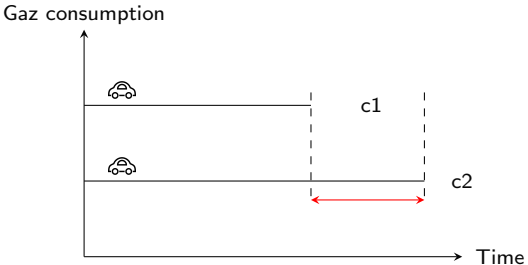
Rank	System	Rmax PFlop/s	Power MW	Green500 Rank
1	El Capitan	1 742	29	18
2	Frontier	1 353	24	22
3	Aurora	1 012	38	64

- 38MW is the equivalent of 70000 french houses.

Metrics of energy aware computing

- $energy(Joule) = power(Watt) \times time(s)$



Energy efficiency

- How well the energy is used (flop/second/Watt)

Energy saving

- We control time execution or power consumption
- Multiple solutions to save power

Hardware

- Dynamic Voltage Frequency Scaling (DVFS)
- Power capping (static or dynamic)

Software

- Energy efficiency aware scheduling

What is Power capping?

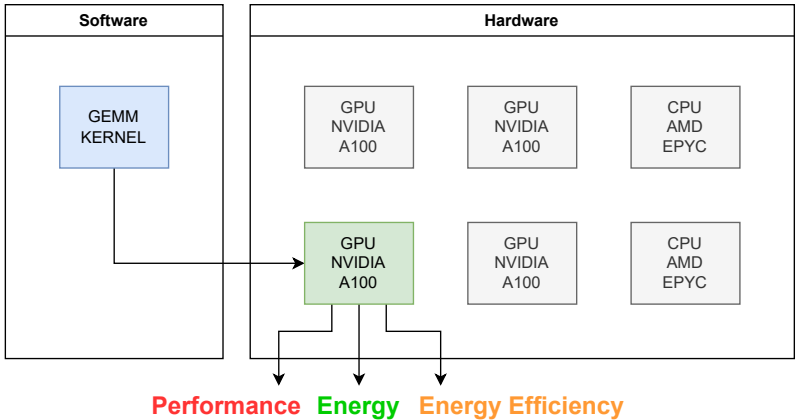
Definition

Power capping is a way of imposing a power consumption limit on a device.

- intel-rapl, nvidia-smi
- static or dynamic
- **MUST BE ROOT!**

Study the energy efficiency under GPU power capping: Profiling

We want to study the impact of static power capping on a single GPU.



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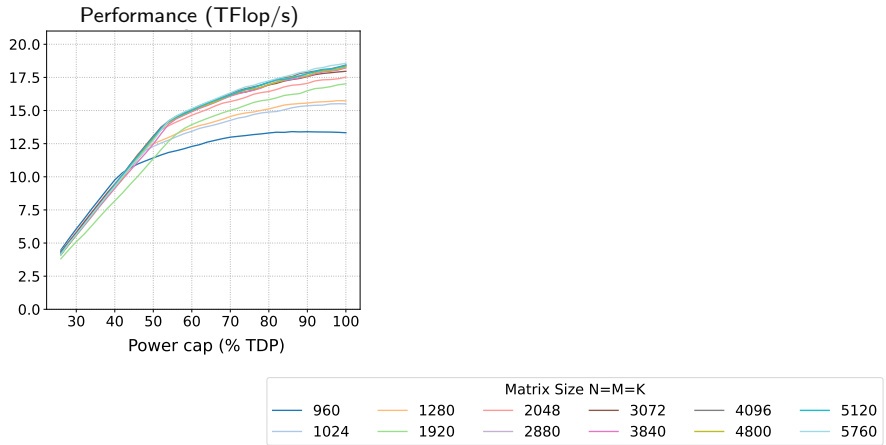

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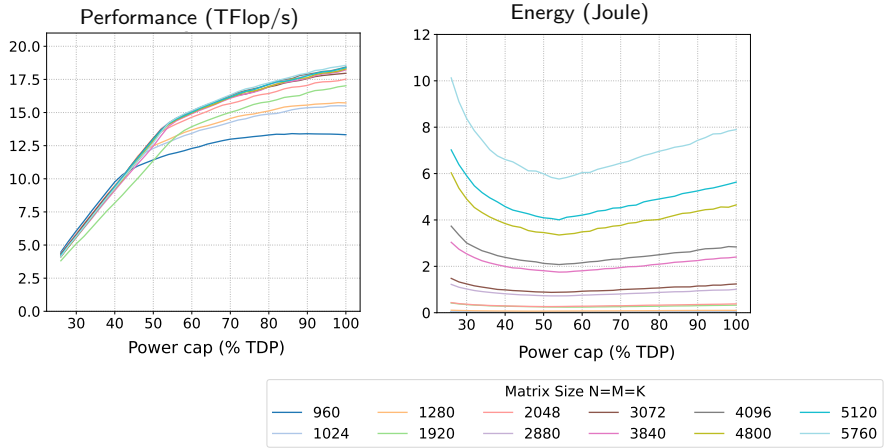

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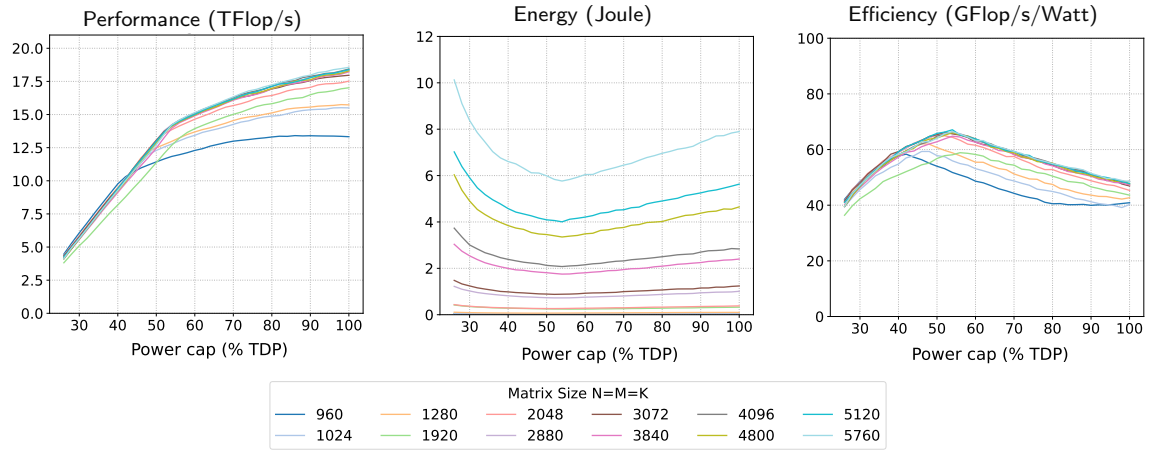

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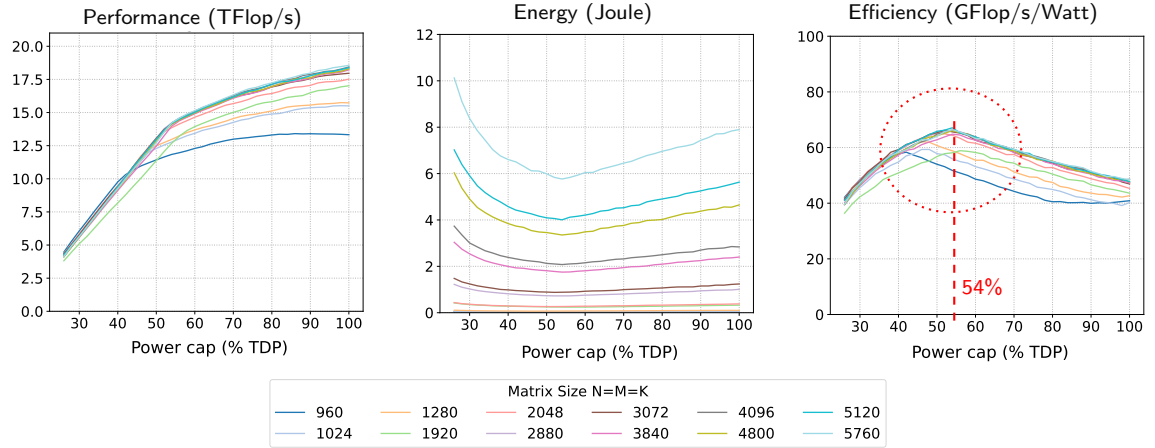
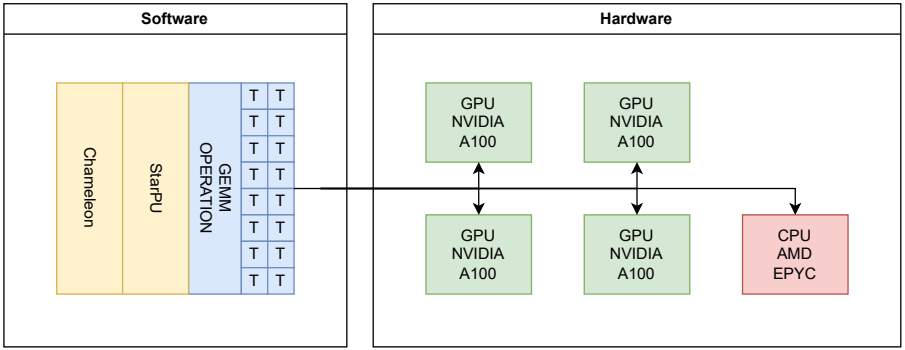


- **Faster is not equivalent to being energy efficient.**

Study the energy efficiency under GPU power capping

We want to study the impact of power capping on a heterogeneous compute node.



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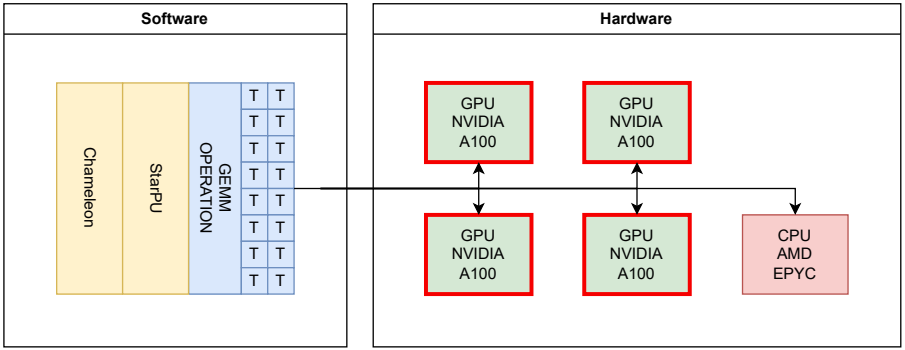

Study the energy efficiency under GPU power capping

Platform hardware

- 1x CPU AMD Zen3 EPYC 7513
- 4x GPU Nvidia A100-SXM4-40GB

Power settings for a GPU

	Config.	Power (W)	Percent.
P_{low}	L	100	25%
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P_{high}	H	400	100%

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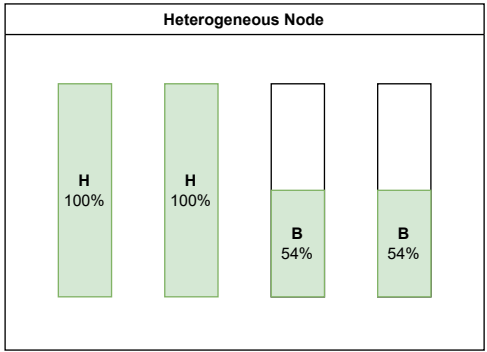

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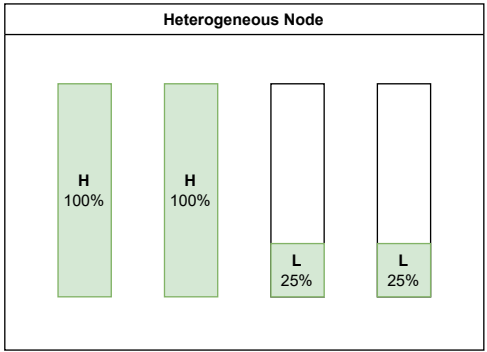

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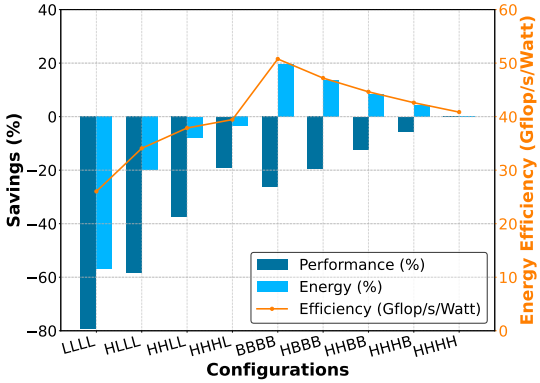

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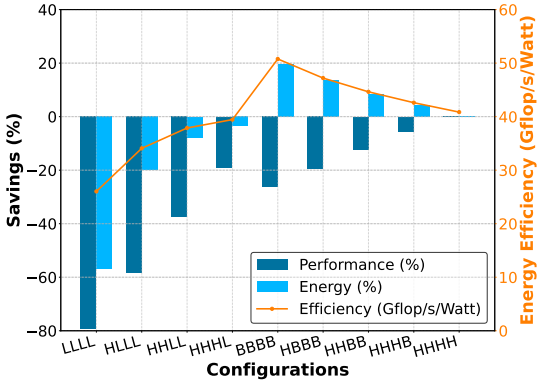

- Excessive slowdown → higher energy consumption

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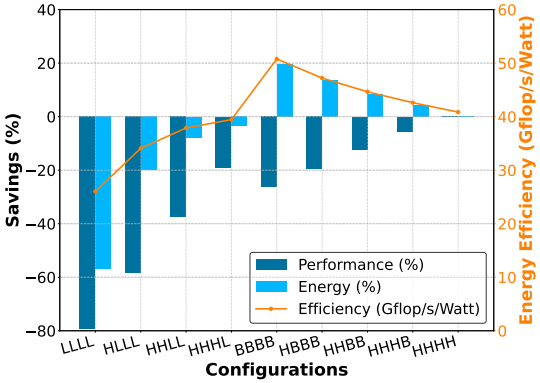
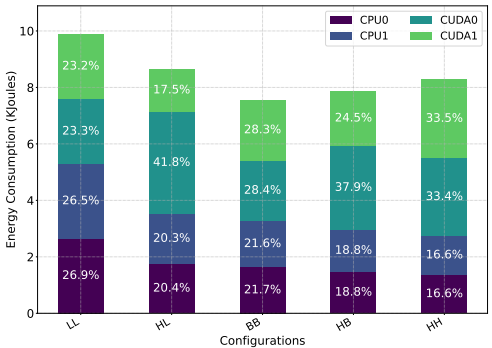


- Excessive slowdown → higher energy consumption
- **20% energy efficiency improvements** when power capping 4 GPUs to 54%

Power cap on CPU

What is the CPU's energy consumption ?



Platform hardware

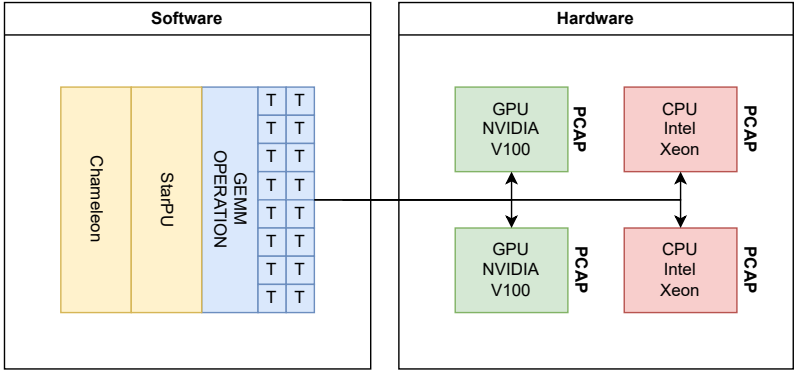
- 2x CPU Intel Xeon Gold 6126
- 2x GPU Nvidia V100-PCIE-16GB

We want to power cap CPUs:

- CPUs take 24 % of the total workload.
- They consume from 33 % to 53 % of the total energy consumption depending on the configuration.

Power cap on CPU

We want to study the impact of power capping on 2 GPUs and 2 CPUs.



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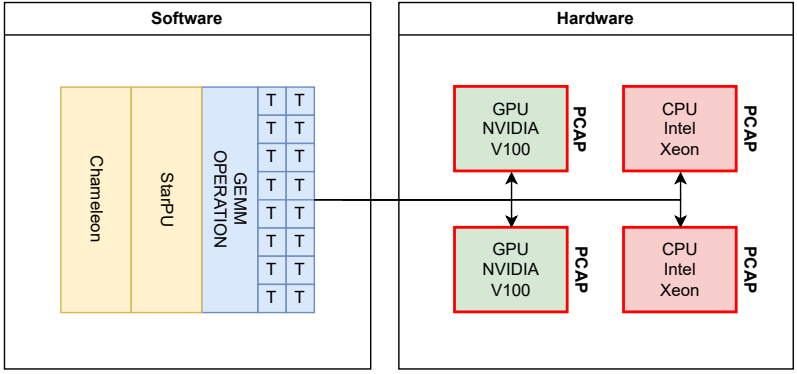


Results with CPU power capping

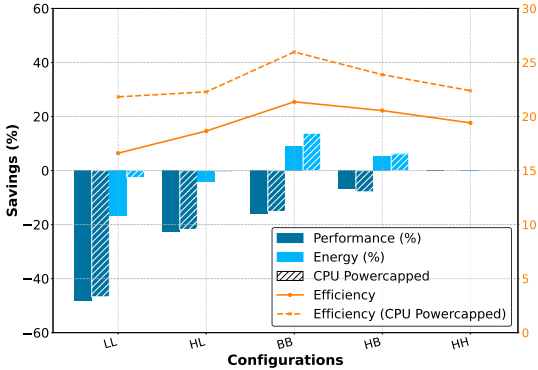
Platform hardware

- 2x CPU Intel Xeon Gold 6126
- 2x GPU Nvidia V100-PCIE-16GB

Power settings for a GPU

	Config.	Power (W)	Percent.
P_{low}	L	100	40%
P_{best}	B	155	62%
P_{high}	H	250	100%

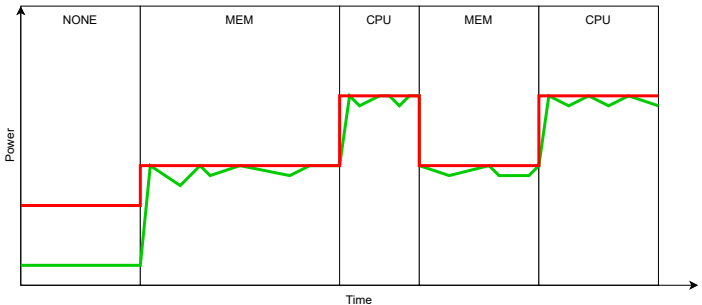
Default configuration is HH



- **26% energy efficiency improvements** when power capping both CPUs.

From static to dynamic power capping

How dynamic power capping behaves compared to static power capping?



- Adapt power capping on the go with the detected **phases** and measured **metrics**
- We can introduce a user tolerated **slowdown**

The aim is to have a better power management with a power cap defined by the user.

DUFP

DUFP (Dynamic Uncore Frequency and Power capping)

- Uncore frequency scaling and dynamic power capping tool.
- Separated process that runs beside main applications.
- Only on one CPU.

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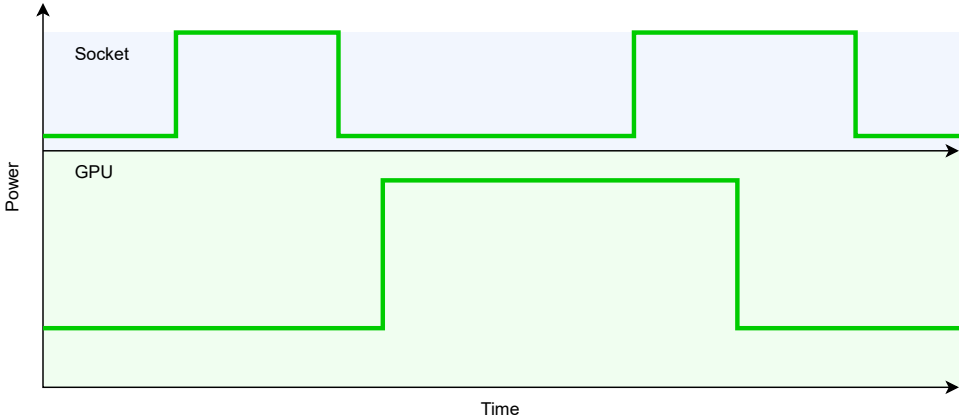
Contribution: make DUFP a heterogeneous power balancing tool

- Multi socket, multi GPU
- Global node power management
- Power balancing between sockets and GPUs

Example of heterogeneous dynamic power capping



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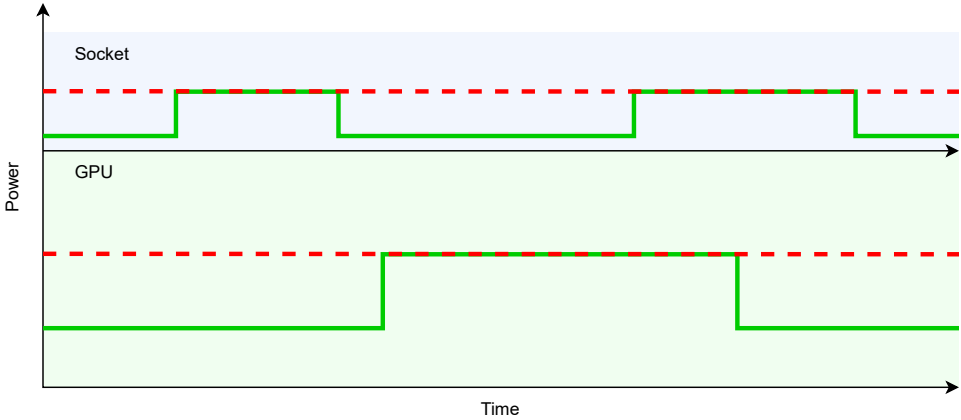

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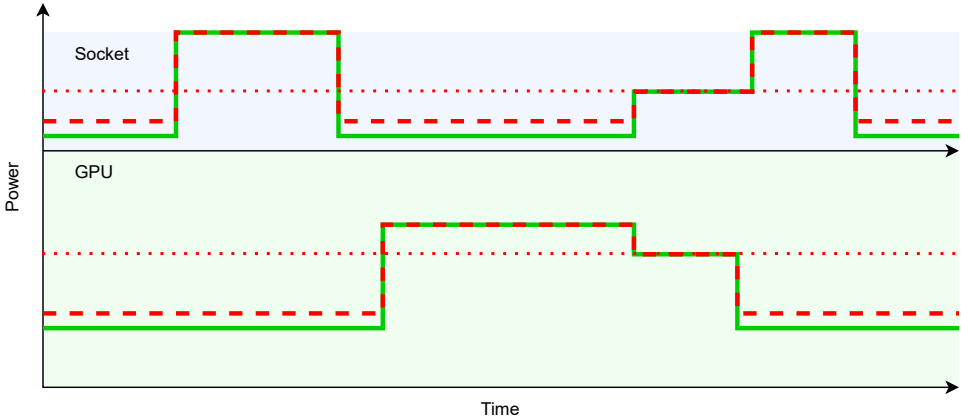
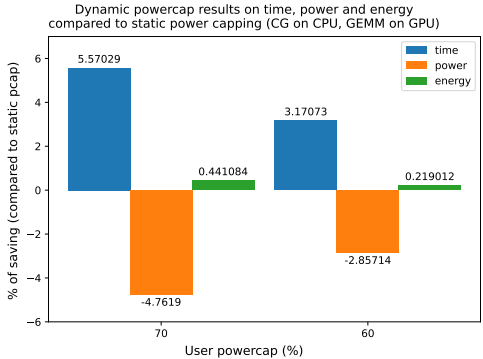


First results

First results with one CPU and one GPU

- 1 Intel CPU
- 1 NVIDIA V100 GPU
- CG (NAS Parallel Benchmark) on CPU
- DGEMM (MAGMA) on GPU



Conclusion

Static power capping

- Applying power capping on a single GPU **improve energy efficiency**.
- On multiple GPUs, applying the best power cap on all GPUs provide a **20 % energy efficiency improvement**.
- With CPU power capping, we can reach 26 % of energy efficiency improvement.

Dynamic power capping

- Adapted DUFP for multi-socket usage.
- Added heterogeneous balancing for power capping.
- New algorithm proposed and first promising results.

Future work

- Test power capping with more complex HPC applications.
- Mix **energy efficiency aware** scheduler and power capping (Jules Risse).