Karlsruhe Institute of Technology

A unified Energy Footprint for Simulation Software

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Hartwig Anzt September 12, 2012

ENGINEERING MATHEMATICS AND COMPUTING LAB (EMCL)

Green Computing

- **Hardware developers** aim for **low power devices**
- **Integration** of low-consuming **coprocessors** (GPUs, Cell, MIC, FPGAs. . .)
- **Green500** as counterpart to performance-oriented **TOP500**

THE GREEN 500

Green500 Rank	MFLOPS/W	Site*	Computer*	Total Power (kW)
1	2100.88	DOE/NNSA/LLNL	BlueGene/Q, Power BQC 16C 1.60GHz, Custom	41.10
2	2100.88	IBM Thomas J. Watson Research Center	BlueGene/Q, Power BQC 16C 1.60GHz, Custom	41.10
3	2100.86	DOE/SC/Argonne National Laboratory	BlueGene/Q, Power BQC 16C 1.60GHz, Custom	82.20
4	2100.86	DOE/SC/Argonne National Laboratory	BlueGene/Q, Power BQC 16C 1.60GHz, Custom	82.20
5	2100.86	Rensselaer Polytechnic Institute	BlueGene/Q, Power BQC 16C 1.60GHz, Custom	82.20
6	2100.86	University of Rochester	BlueGene/Q, Power BQC 16C 1.60GHz, Custom	82.20
7	2100.86	IBM Thomas J. Watson Research Center	BlueGene/Q, Power BQC 16C 1.60 GHz, Custom	82.20
8	2099.56	University of Edinburgh	BlueGene/Q, Power BQC 16C 1.60GHz, Custom	493.10
9	2099.50	Science and Technology Facilities Council - Daresbury Laboratory	BlueGene/Q, Power BQC 16C 1.60GHz, Custom	575.30
10	2099.46	Forschungszentrum Juelich (FZJ)	BlueGene/Q, Power BQC 16C 1.60GHz, Custom	657.50

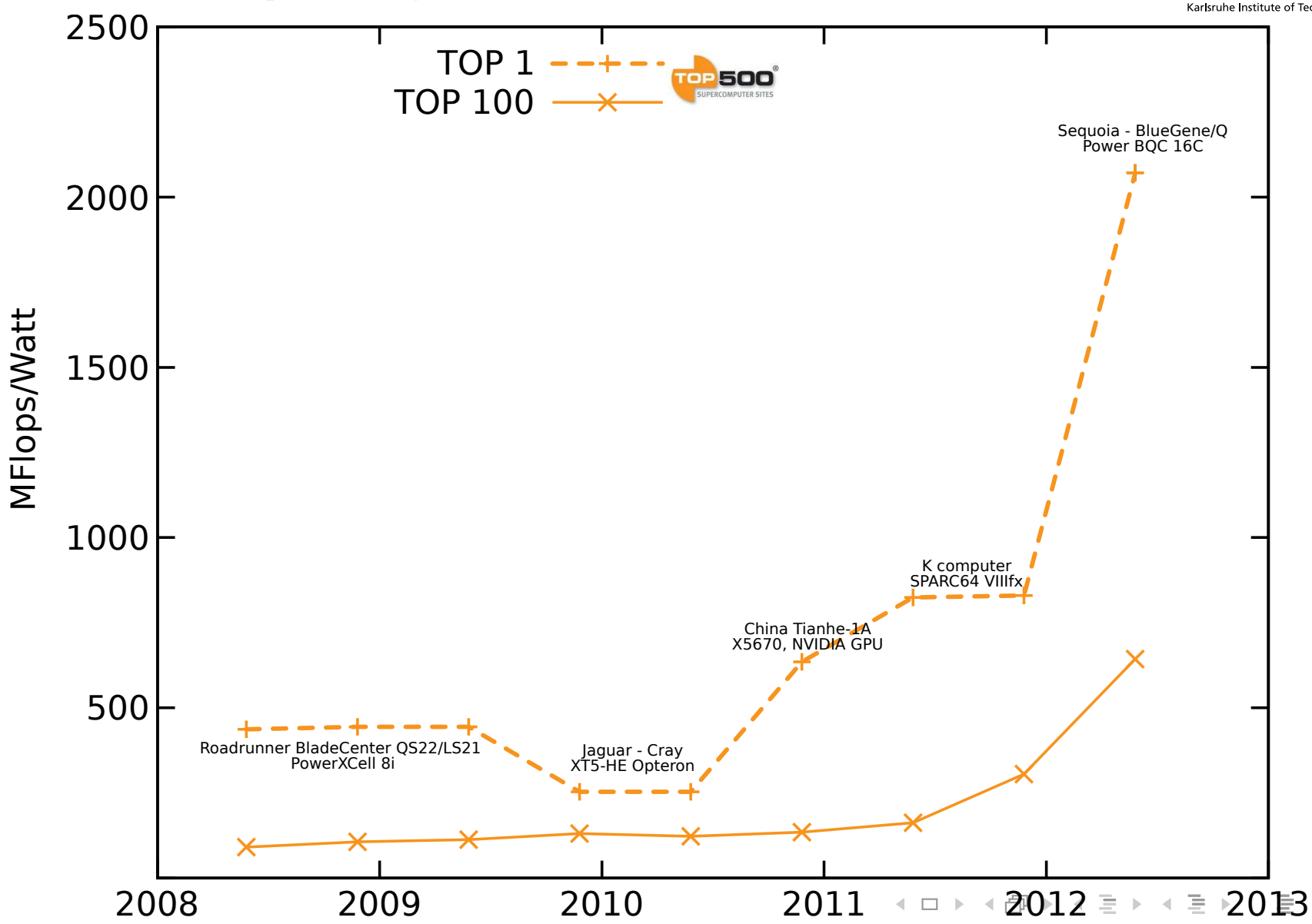
TOP500 JUNE 2012

PRESENTED BY UNIVERSITY OF MANNHEIM · ICL UT INNOVATIVE COMPUTING LABORATORY · BERKELEY LAB Lawrence Berkeley National Laboratory

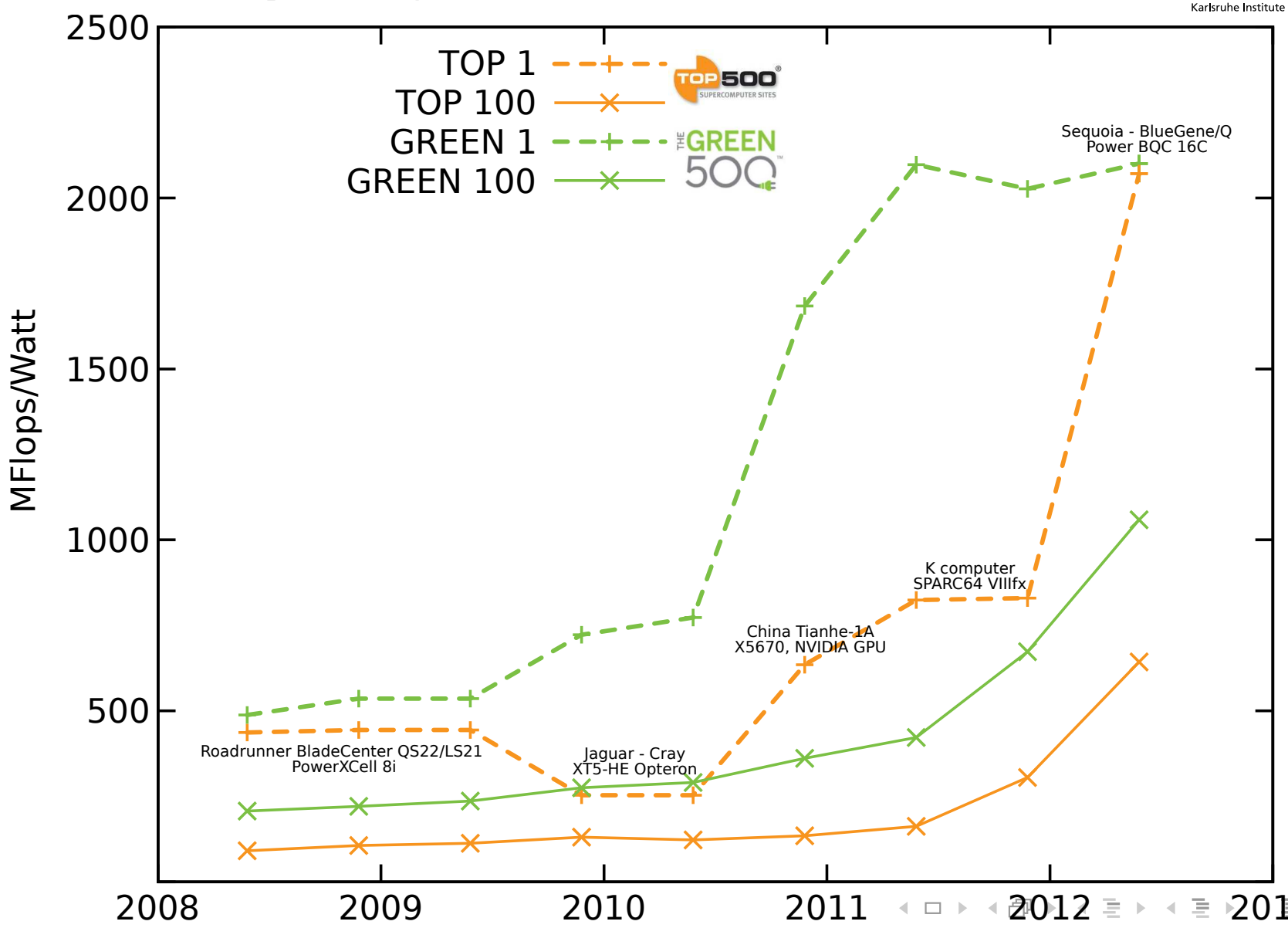
FIND OUT MORE AT www.top500.org

Rank	Site	Computer/Year Vendor	Cores	R_{max}	R_{peak}	Power
1	DOE/NNSA/LLNL United States	**Sequoia** - BlueGene/Q, Power BQC 16C 1.60 GHz, Custom / 2011 IBM	1572864	16324.75	20132.66	7890.0
2	RIKEN Advanced Institute for Computational Science (AICS) Japan	K computer, SPARC64 VIIIfx 2.0GHz, Tofu interconnect / 2011 Fujitsu	705024	10510.00	11280.38	12659.9
3	DOE/SC/Argonne National Laboratory United States	**Mira** - BlueGene/Q, Power BQC 16C 1.60GHz, Custom / 2012 IBM	786432	8162.38	10066.33	3945.0
4	Leibniz Rechenzentrum Germany	**SuperMUC** - iDataPlex DX360M4, Xeon E5-2680 8C 2.70GHz, Infiniband FDR / 2012 IBM	147456	2897.00	3185.05	3422.7
5	National Supercomputing Center in Tianjin China	**Tianhe-1A** - NUDT YH MPP, Xeon X5670 6C 2.93 GHz, NVIDIA 2050 / 2010 NUDT	186368	2566.00	4701.00	4040.0
6	DOE/SC/Oak Ridge National Laboratory United States	**Jaguar** - Cray XK6, Opteron 6274 16C 2.200GHz, Cray Gemini interconnect, NVIDIA 2090 / 2009 Cray Inc.	298592	1941.00	2627.61	5142.0
7	CINECA Italy	**Fermi** - BlueGene/Q, Power BQC 16C 1.60GHz, Custom / 2012 IBM	163840	1725.49	2097.15	821.9
8	Forschungszentrum Juelich (FZJ) Germany	**JuQUEEN** - BlueGene/Q, Power BQC 16C 1.60GHz, Custom / 2012 IBM	131072	1380.39	1677.72	657.5
9	CEA/TGCC-GENCI France	**Curie thin nodes** - Bullx B510, Xeon E5-2680 8C 2.700GHz, Infiniband QDR / 2012 Bull	77184	1359.00	1667.17	2251.0
10	National Supercomputing Centre in Shenzhen (NSCS) China	**Nebulae** - Dawning TC3600 Blade System, Xeon X5650 6C 2.66GHz, Infiniband QDR, NVIDIA 2050 / 2010 Dawning	120640	1271.00	2984.30	2580.0

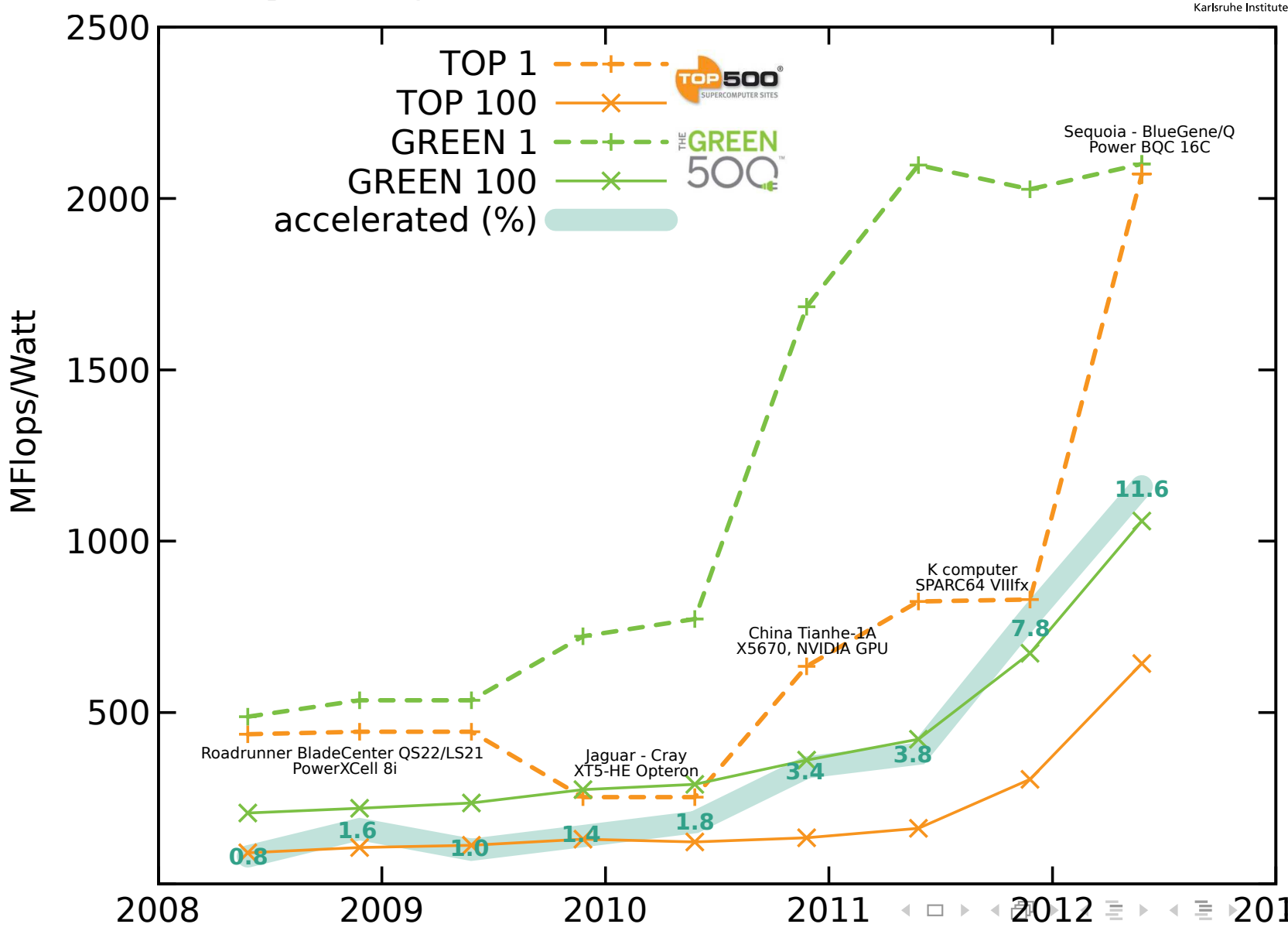
Green Computing



Green Computing



Green Computing



Green Computing

- Increasing focus on **power & energy** (e.g. **Flops/Watt** in Green500)
- Theoretical ratio usually irrelevant
- **Challenge** to transfer the **power efficiency** into the **simulation**
- Energy need in scientific computing depends on software implementation
- **Compare energy & power for different simulation software**

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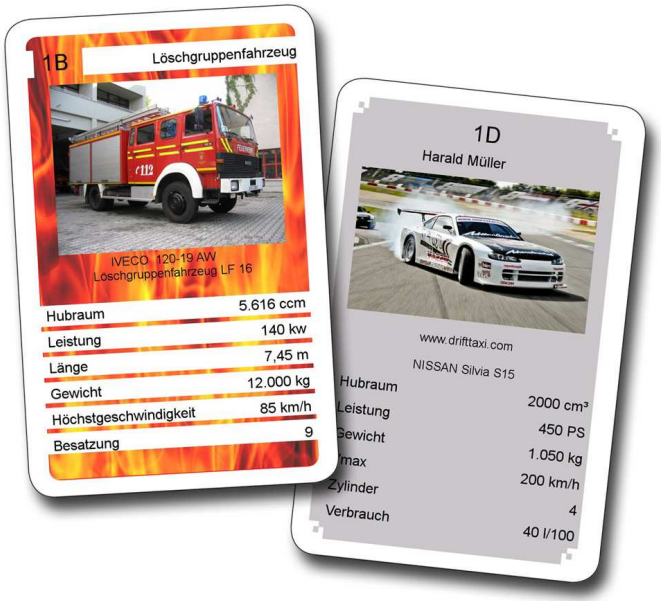
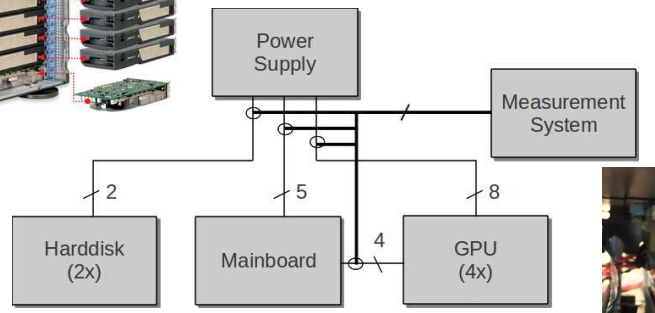
Unified Energy Footprint

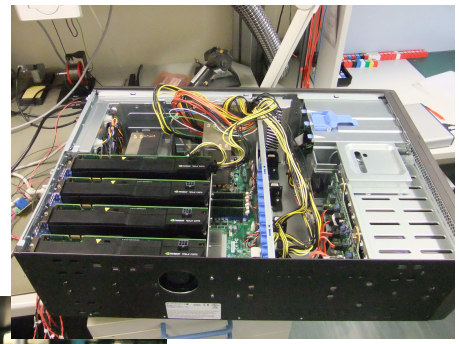
- Introduce **unified energy-footprint** for *simulation software*
- Information about **hardware configuration**, **typical application**, **power** & **energy draft** and **scalability**
- **Compress information** like on ***Autoquartett*** card
- **Easy comparison** for different software packages

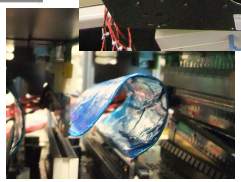


Power measurement

- Supermicro X8DTG-QF GPU-workstation
- 2 $\times$ Intel XEON E5540 @2.53GHz (QPI-connected), 192 GB memory
- 4 $\times$ Fermi C2070 (PCI-Express 16 $\times$)



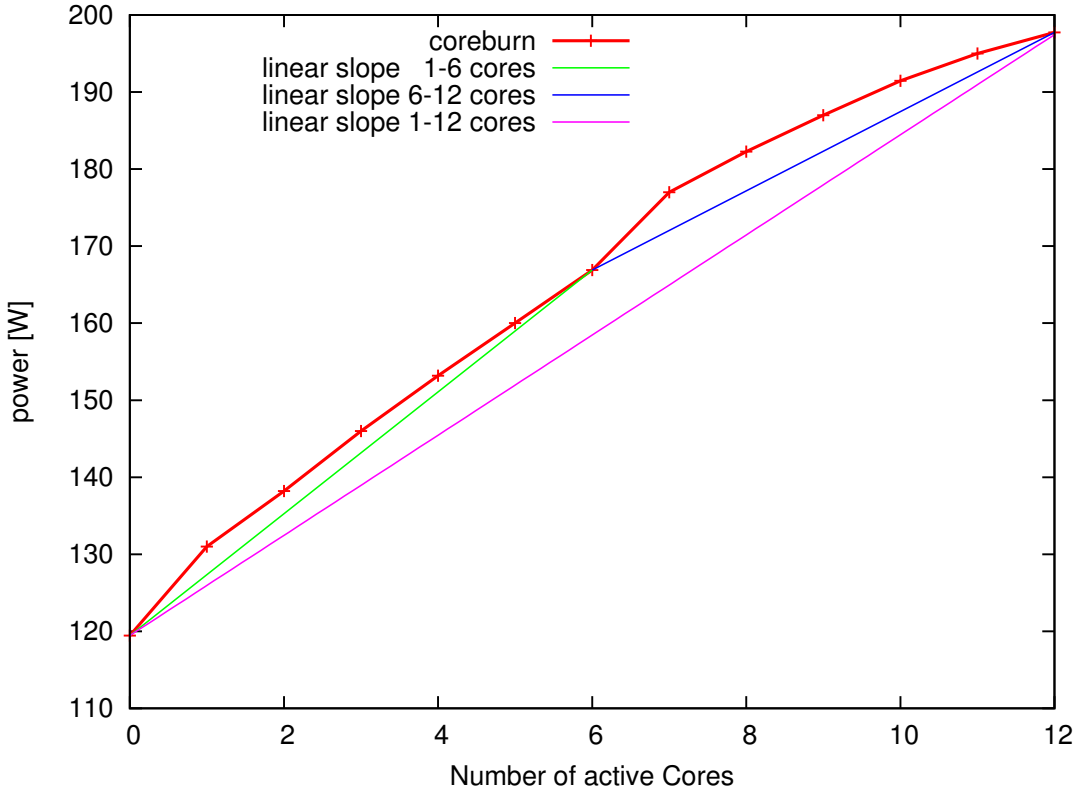




Independent, embedded measurement setup

- Powermeters monitor voltages and currents in lines powering **chipset**, the **hard- disks** and the **GPUs** (including PCI)
- 250 k Samples/second

Hardware evaluation: CPU coreburn

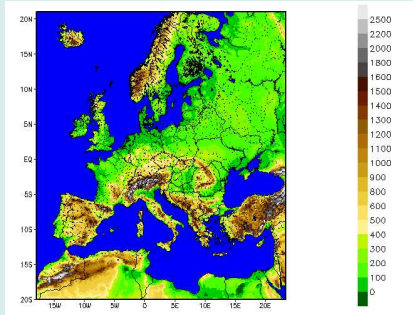


- Evaluate power dissipation of active CPU cores
- almost linear increase ($\approx$ 6.5 Watts/core)
- Pattern when activating cores in 2nd CPU

Energy Footprint: COSMO

COSMO Model (version 4.21)

- Numerical weather simulation
- In operational use by DWD, MeteoSwiss . . .
- $182 \times 170 \times 40$ gridpoints
- resolution of 0.12° and 40 s timestep



Configuration:

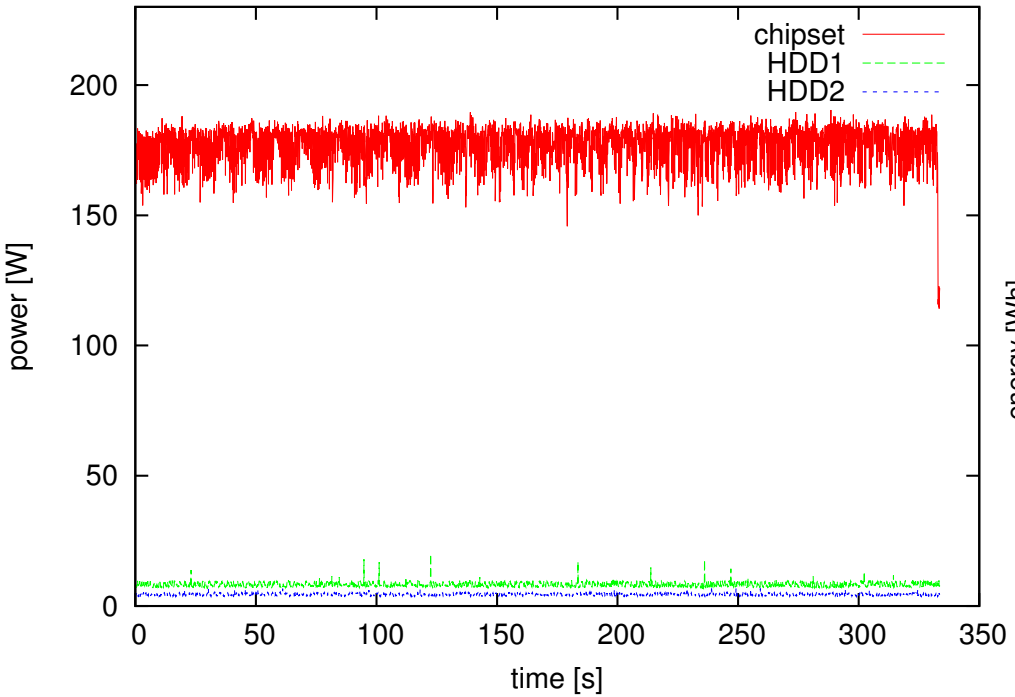
System:	Supermicro X8DTG-QF
CPU:	2 Intel XEON E5540@2.53GHz
Accelerator:	4 Nvidia C2070
Application:	24 h forecast
Resources:	6 cores

Energy summary:

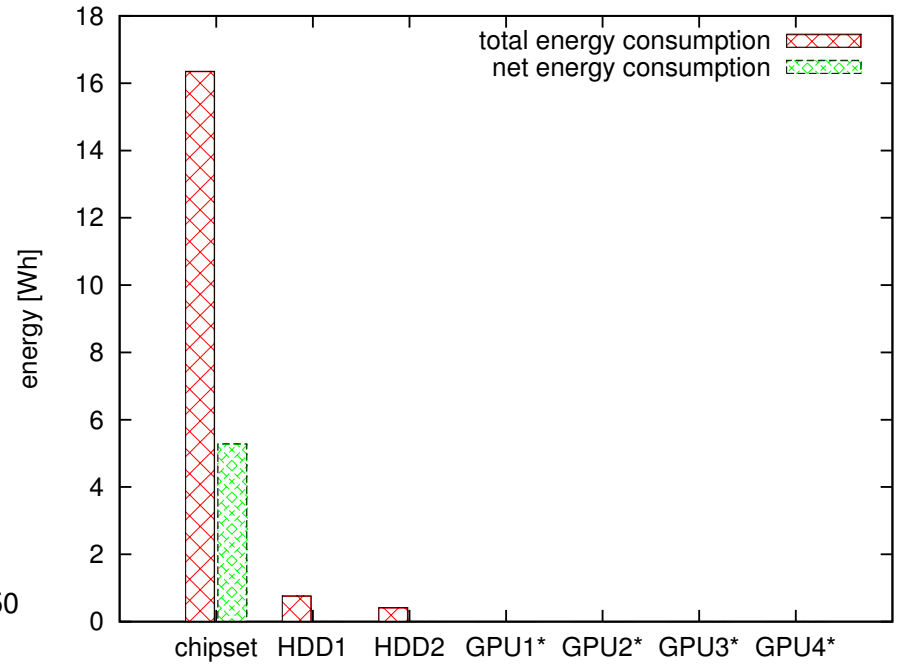
total runtime :	333.65 s
avg. power chipset :	176.45 W
avg. power HDD :	12.69 W
avg. power GPUs* :	0.00 W
total Energy :	17.53 Wh

* no GPUs used

Energy Footprint: COSMO Model



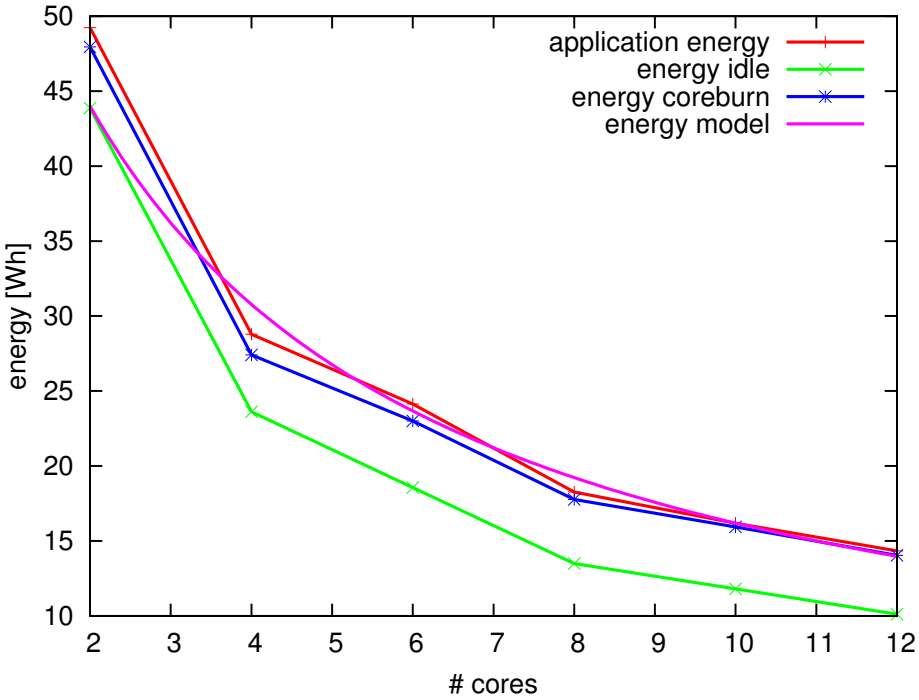
(a) Power profile



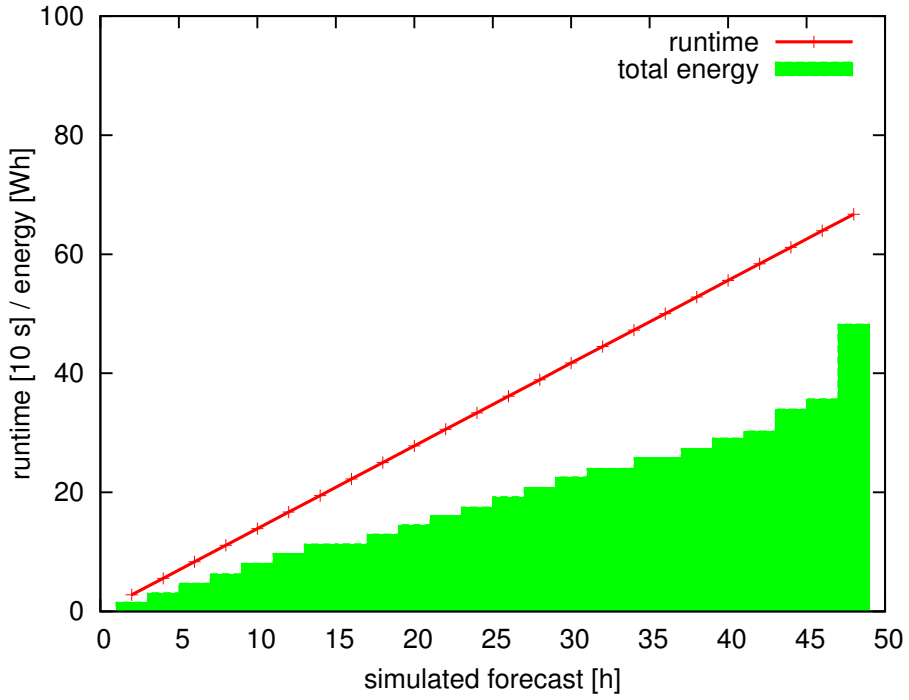
(b) Energy consumption

- Characteristic power draft due to communication
- Very compute-intensive

Energy Footprint: COSMO Model



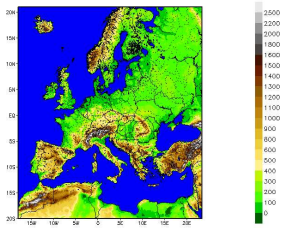
(c) Scaling wrt. hardware

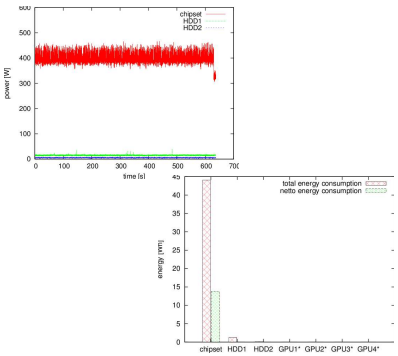


(d) Scaling wrt. simulation parameters

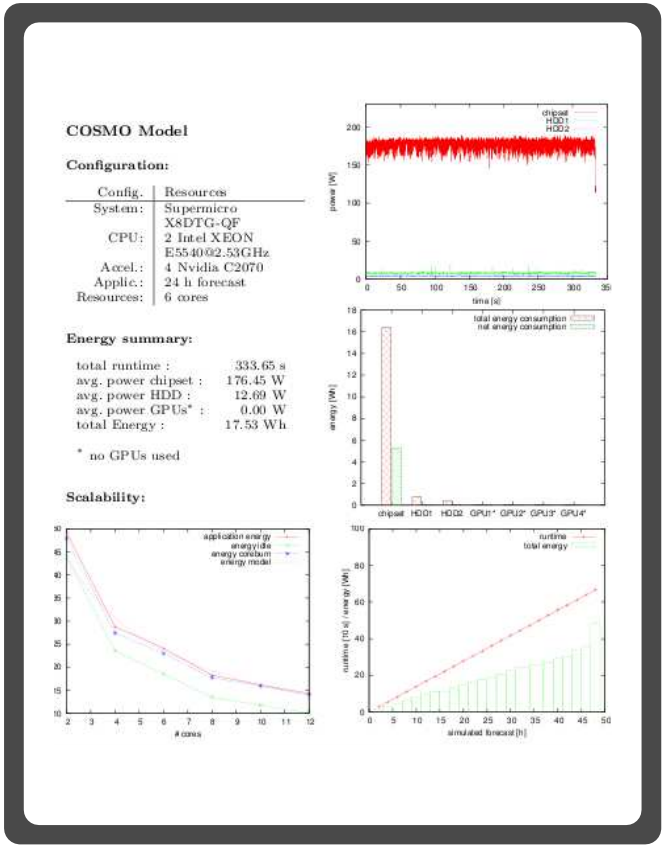
- Excellent scaling wrt. core-numbers
- GPU implementations necessary for higher energy efficiency

COSMO's scorecard





compress information on scorecard



COSMO Model

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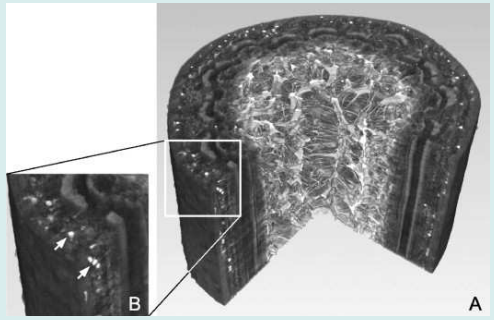
Scalability:

- Hardware & software configuration
- Compact summary of power & energy analysis for easy comparison

Energy Footprint: PyHST CPU-version

PyHST CPU-version

- X-ray tomography reconstruction (3D)
- Filtered Back Projection (FBP)
- Using CPU for reconstruction



Configuration:

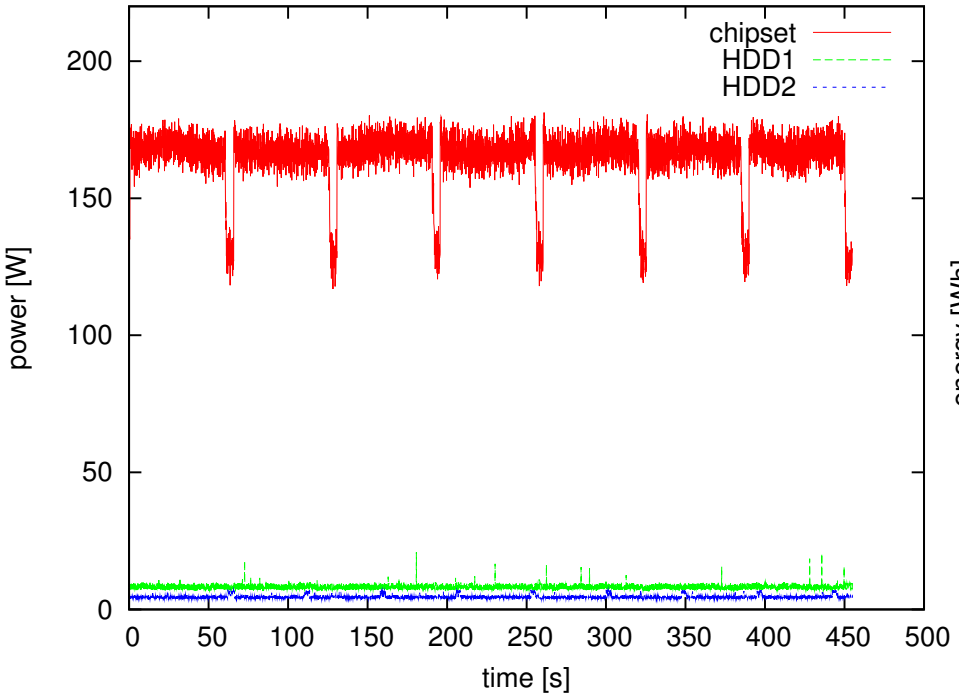
System:	Supermicro X8DTG-QF
CPU:	2 Intel XEON E5540@2.53GHz
Accelerator:	4 Nvidia C2070
Application:	400 frames (1776x1707)
Resources:	6 cores

Energy summary:

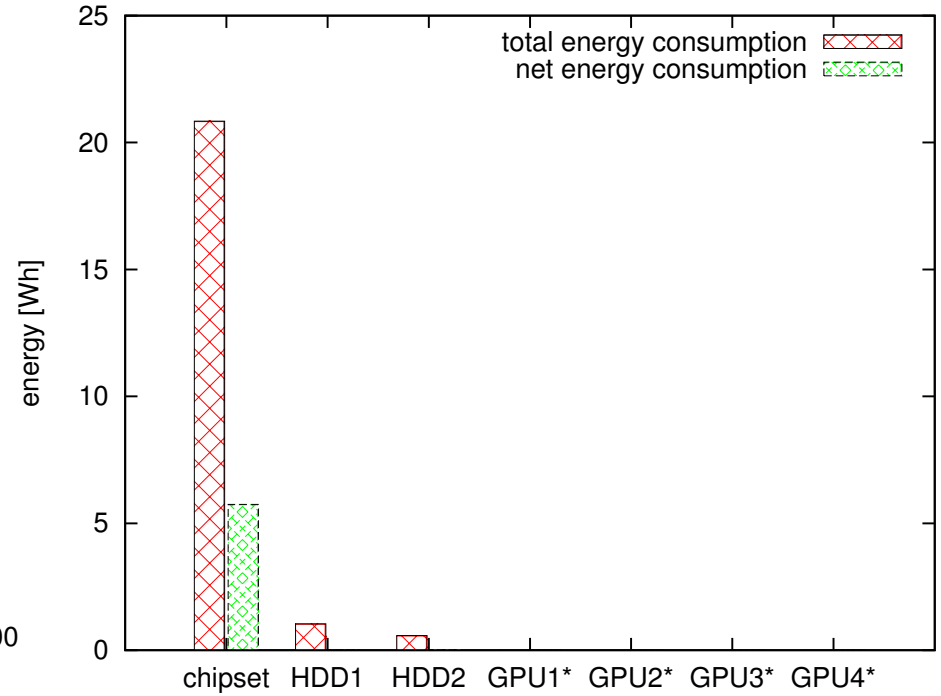
total runtime :	455.07 s
avg. power chipset :	164.87 W
avg. power HDD :	12.76 W
avg. power GPUs* :	0.00 W
total Energy :	22.45 Wh

* no GPUs used

Energy Footprint: PyHST CPU-version



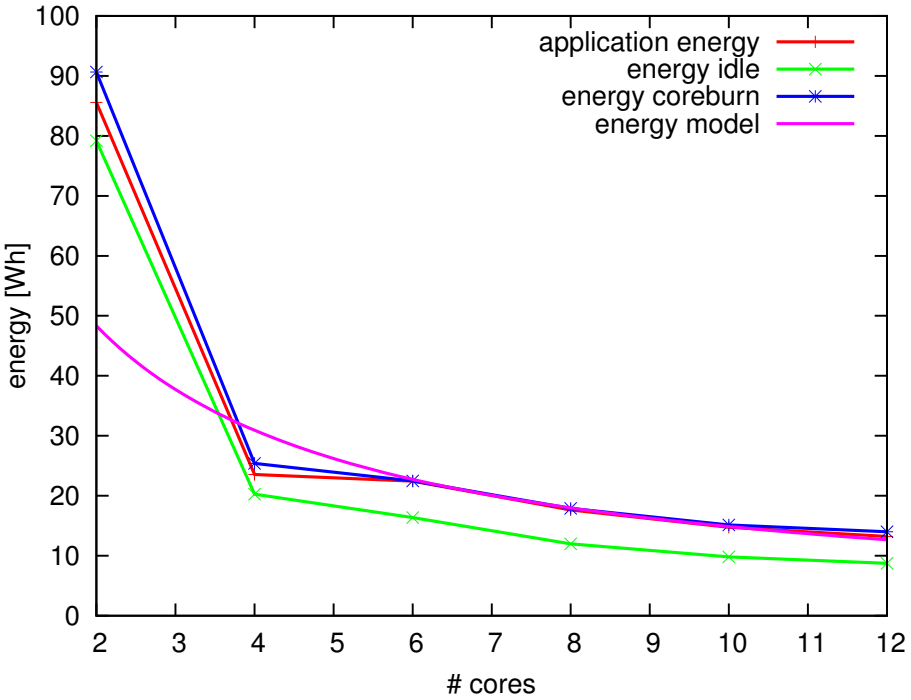
(e) Power profile



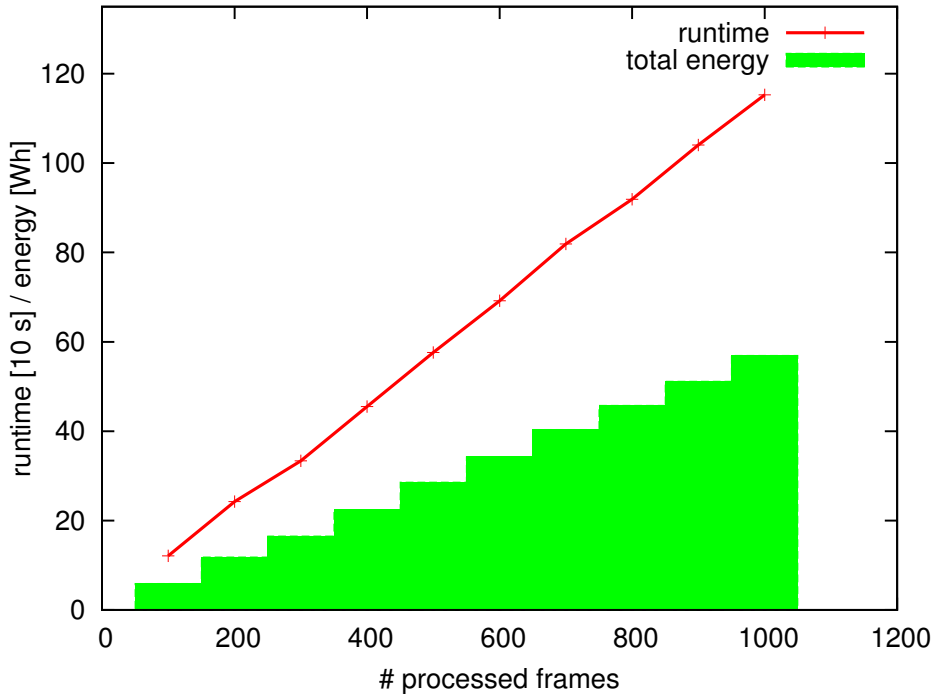
(f) Energy consumption

- I/O should be handled asynchronously to computation

Energy Footprint: PyHST CPU-version



(g) Scaling wrt. hardware



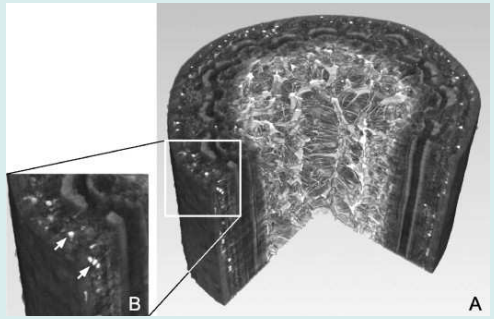
(h) Scaling wrt. simulation parameters

- Poor core-scaling due to sequential I/O
- Linear runtime & energy increase for higher frame counts

Energy Footprint: PyHST GPU-version

PyHST GPU-version

- X-ray tomography reconstruction (3D)
- Filtered Back Projection (FBP)
- Using GPU / multiple GPUs for reconstruction



Configuration:

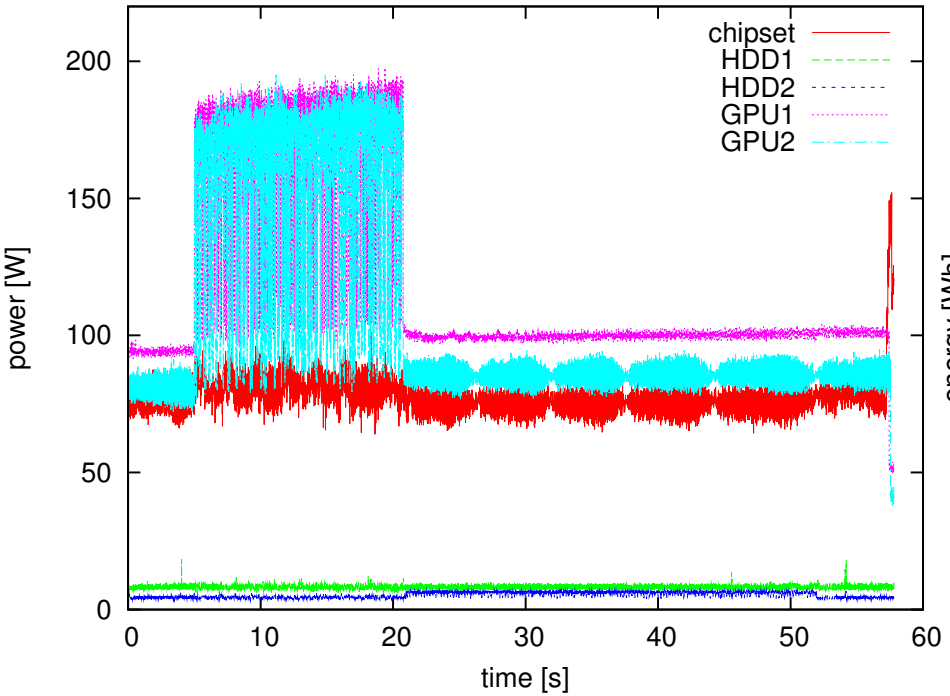
System:	Supermicro X8DTG-QF
CPU:	2 Intel XEON E5540@2.53GHz
Accelerator:	4 Nvidia C2070
Application:	400 frames (1776x1707)
Resources:	2 cores + 2 GPUs

Energy summary:

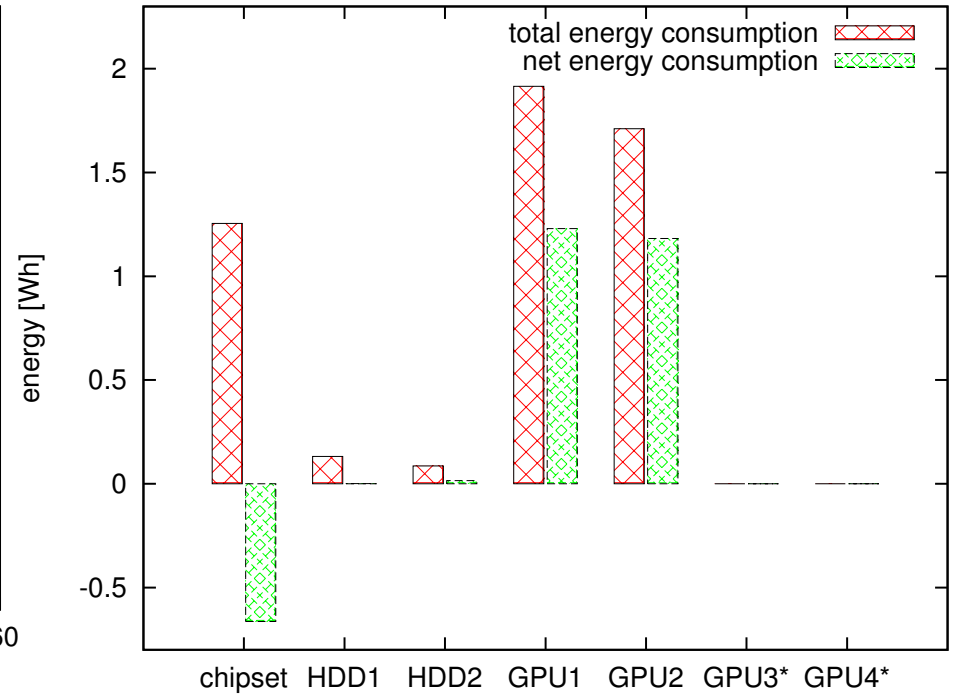
total runtime :	57.82 s
avg. power chipset :	78.11 W
avg. power HDD :	13.25 W
avg. power GPUs* :	225.82 W
total Energy :	5.09 Wh

* 2 GPUs used

Energy Footprint: PyHST GPU-version



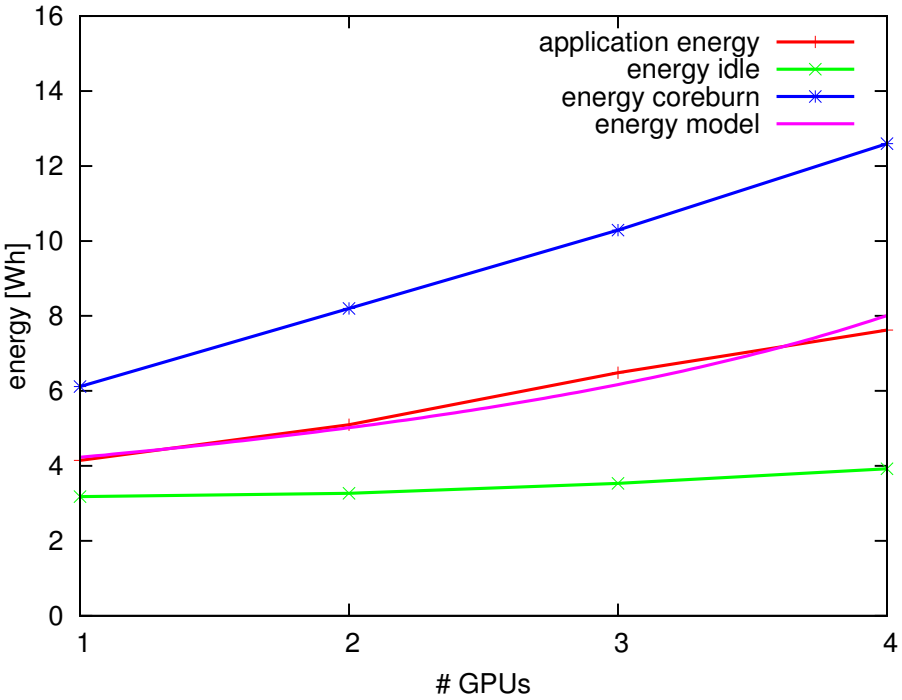
(i) Power profile



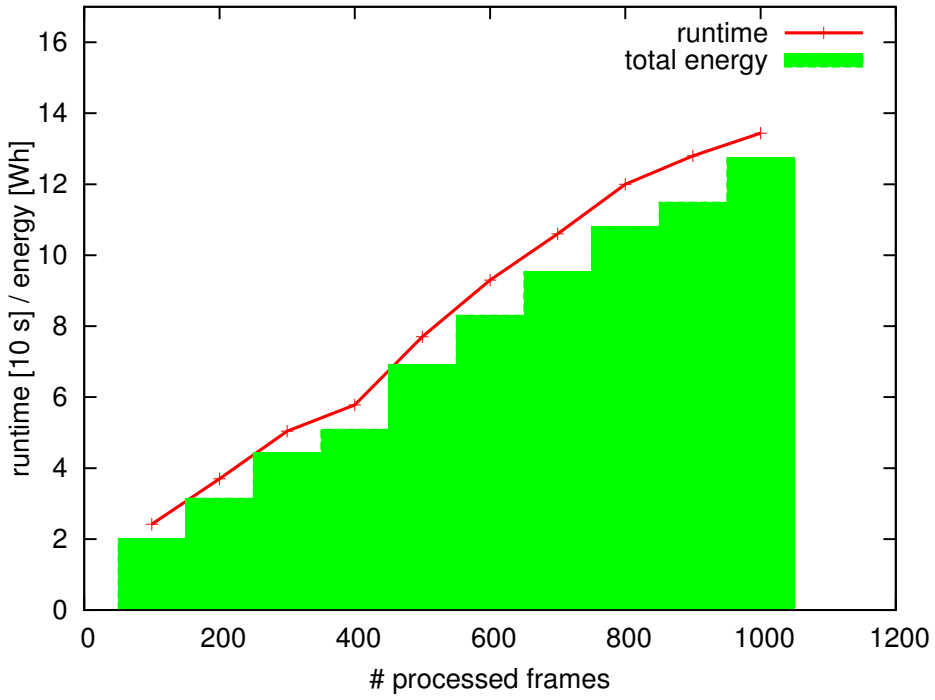
(j) Energy consumption

- runtime for I/O phase exceeds reconstruction phase

Energy Footprint: PyHST GPU-version



(k) Scaling wrt. hardware



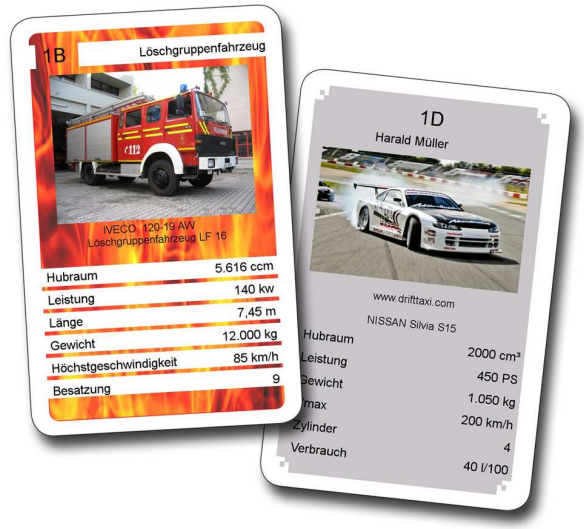
(l) Scaling wrt. simulation parameters

- No gain for multiple GPUs (CPU I/O, additional power dissipation)
- Initialization overhead for small frame counts

Summary & Outlook

Information about **power & energy draft** and **scaling** simplifies

- **comparison of software implementations**
- **identification of energy bottlenecks & optimization**
- **decisions when acquiring hardware**



Unified Energy Footprint

Standard for creating a comprehensive **database** for **software implementations**.