D4.2

Report on energy consumption evaluation

Ondrej Vysocky, Matej Spetko, Filip Vaverka, Lubomir Riha, Laura Bellentani, Kaveh Haghighi Mood

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Authors: Ondrej Vysocky, Matej Spetko, Filip Vaverka, Lubomir Riha (IT4I@VSB), Laura Bellentani (CINECA), Kaveh Haghighi Mood (FZJ)

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0.2	26.4.2024	Matej Spetko, Ondrej Vysocky	Defined target HW platforms and their power monitoring. Results from AMD CPUs and Intel CSL.
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0.4	12.6.2024	Matej Spetko	Added Intel Saphire Rapids w. HBM results
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0.6	14.6.2024	Kaveh Haghighi Mood	Added Fleur Power10 and A64FX results
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Executive Summary

The deliverable's objection is to **evaluate the energy efficiency** of MaX codes on various HW platforms. Energy efficiency is defined as average performance (Floating point operations per second (FLOPs)) per average power consumption (Watt). The FLOPs are measured using performance counters, which are platform-dependent, measured from the complete application execution. The obtained results must be comparable despite each hardware platform providing a different power monitoring solution. For that reason, the energy consumption of the whole compute node is reported. To improve the energy efficiency of the MaX applications, static tuning of hardware power knobs was done on a subset of hardware platforms.

The most energy efficient platform is also the latest HW platform we used for this deliverable that is Intel Saphire Rapids with HBM memory, as can be seen for the following table:

Code	HW platform	Efficiency
BigDFT	SPR+HBM	282 MFLOPs/W
Fleur	SPR+HBM, AMD Zen2	1.82 GFLOPs/W
QE	SPR+HBM	4.56 GFLOPs/W
Siesta	SPR+HBM	2.57 GFLOPs/W
Yambo	SPR+HBM	1,33 GFLOPs/W

We have also shown that a significant portion of the EuroHPC systems, which are based on the AMD Zen2 and Zen3 CPU architectures and Nvidia A100 GPU architecture, can save energy using static tuning, which means that we set a CPU frequency(ies) before application execution. Following table summarizes these findings.

	BigDFT	Fleur	Quantum Espreso	Siesta	Yambo
	Energy consumption reduction[kJ] / Runtime[s] 1st row - resutls with no runtime extension (runtime close to 100% of default) 2nd row - results for maximun energy savings				
AMD Zen2	**-17%** / 101%	**-3%** / 101%	**-2%** / 100%	**-15%** / 100%	**-6%** / 100%

	-26% / 115%	**-9%** / 107%	**-8%** / 112%	**-24%** / 102%	**-23%** / 115%
AMD Zen3	**-12%** / 102% **-23%** / 113%	**-7%** / 101% **-13%** / 112%	**-8%** / 100% **-12%** / 110%	**-15%** / 101% **-24%** / 107%	**-19%** / 100% **-22%** / 109%
Nvidia A100	**-6%** / 102% **-9%** / 109%	**-6%** / 101% **-8%** / 104%	**-7%** / 101% **-10%** / 111%	**-7%** / 101% **-9%** / 102%	**0%** / 100% **-7%** / 111%

Please note that (i) the energy savings are described by the negative number: for instance -26% means that the 26% of energy was saved; (ii) the runtime extension is described by number higher than 100%, where 100% stands for default runtime: for instance 115% means the runtime is extended to 115% of the default runtime.

It is important to note that enabling static tuning on an HPC machine does not require significant effort from the system administrator side. It can be exposed to a user as a scheduler (mostly SLURM) parameter. If such a feature would be enabled, MaX codes have potential to save energy as presented in the table.

Glossary

CPU	Central Processing Unit
GPU	Graphics Processing Unit
AVX	Advanced Vector Extensions
SSE	Streaming SIMD Extensions
CF	CPU core frequency
UCF	CPU uncore frequency
SMF	GPU streaming multiprocessors frequency
TDP	Thermal design power
PDU	power distribution unit
IPMI	Intelligent Platform Management Interface
RAPL	Running Average Power Limit
HDEEM	High Definition Energy Efficient Monitoring
NVML	Nvidia Management Library
DDR	Double Data Rate Synchronous Dynamic Random-Access Memory
HBM	High Bandwidth Memory
CS	IT4Innovations Complementary Systems

Hardware platforms

The MaX applications have been executed on various hardware platforms with a focus on the hardware accommodated in EuroHPC systems (AMD Zen2, AMD Zen3, Intel Sapphire Rapids, Nvidia A100). To evaluate energy efficiency we used a single fully occupied compute node.

On many of the evaluated platforms, it is possible to control power management knobs. The following table lists details of hardware platforms, used power knobs, and available power monitoring solutions.

Power knobs:

- CF = CPU core frequency
- UCF = CPU uncore frequency[1]
- SMF = GPU streaming multiprocessors frequency

In the case of Intel CPUs the maximum available CF depends on the number of active cores (with the increasing number of active cores the peak frequency decreases) and the instruction set of the executed workload (vector instruction set has a lower limit than scalar instruction set, SSE > AVX/AVX2 > AVX-512). Another factor in reducing CPU frequencies is a power capping mechanism, which maintains CPU/GPU power consumption below a specified power limit (in default equals Thermal Design Power (TDP)) by scaling its frequencies.

To improve energy efficiency we scaled the presented power knobs to reduce power consumption. The hardware configuration is set at the beginning of the application execution and persists till the end of the application run. This approach is not optimal, since complex applications have different hardware requirements in time, thus dynamic modification of the hardware configuration may bring higher energy savings without impacting application performance. In this document, we report both configuration that does not impact the application performance and also the configuration that brings the highest energy savings.

[1] Since Nehalem architecture, the Intel company has been using 'uncore' to refer to the frequency of subsystem in the physical processor package that is shared by multiple processor cores e.g., last-level cache, on-chip ring interconnect or the integrated memory controllers, which overall occupies approximately 30 % of a chip area.
D. L. Hill, D. Bachand, S. Bilgin, R. Greiner, P. Hammarlund, T. Huff, S. Kulick, and R. Safranek, "The uncore: A modular approach to feeding the high-performance cores," Intel Technology Journal, vol. 14, no. 2, pp. 30–49, 2010.

$$Energy = power \times time[J]$$

$$Energy = \int_0^t Power(x)\,\mathrm{d}x \approx \frac{\sum_{i=0}^{n} PowerSample_i}{SamplingFrequency}$$

To evaluate energy consumption a variety of power monitoring systems are available. These systems sample power consumption of its specific sampling frequency and specific power domains. Some of these systems monitor compute units (Intel RAPL, AMD RAPL, perf counters, NVML, HDEEM) and only some monitor the entire compute node (HDEEM, PDU, IPMI). We report node energy consumption, to provide comparable results from all the evaluated platforms.

To evaluate node energy consumption on the systems with power monitoring of compute units only, we have evaluated the so-called *Node power baseline* [W]. The baseline represents the power consumption of the on-compute-node components that are not monitored by the used power monitoring system. The baseline power consumption is being evaluated from the Intelligent Platform Management Interface (IPMI) reporting power consumption of the whole node but on a low sampling frequency (less than 1 Hz) which makes this system unsuitable for application execution energy consumption measurement. We execute a unified workload for approximately one minute, which gives us enough confidence to extract the difference in nodes and compute components' power consumption.

In energy consumption measurement and controlling power management knobs, we rely on the **MERIC runtime system** which is developed by IT4Innovations. In the MaX project, we implemented additional support for power monitoring from Raritan PDUs used in the IT4Innovations Complementary Systems (CS), which contains various hardware platforms selected for co-design applications. A virtual machine is running a monitoring server, which, on request, activates a higher frequency of power sampling by the PDU and stores these power samples in the server's database. These samples are exposed to the userspace using a client library running from a monitored server of the CS.

Hardware	Power monitoring	Node power baseline	Tuned power knob
AMD 7h12 CPU (Zen2) - 64 cores - 2.6 GHz nominal frequency - 3.3 GHz turbo frequency - 280 W TDP	AMD RAPL	120 W	CF (3.3 - 1.2 GHz)
AMD 7763 CPU (Zen3) - 64 cores - 2.45 GHz nominal frequency - 3.5 GHz turbo frequency - 280 W TDP	AMD RAPL	120 W	CF (3.5 - 1.2 GHz)
Intel Xeon 6240 CPU (Cascade lake) - 18 cores - 2.6 GHz nominal frequency - 3.9 GHz turbo frequency - 150 W TDP	Intel RAPL	80 W	CF (3.9 - 1.0 GHz), UCF (2.4 - 1.2 GHz)
	HDEEM	n/a	
Intel Xeon Max 9468 CPU (Sapphire Rapids) + HBM - 48 cores - 2.1 GHz nominal frequency - 3.5 GHz turbo frequency - 350 W TDP	Intel RAPL	190 W	CF (3.5 - 0.8 GHz), UCF (2.5 - 0.8 GHz)
Nvidia A100-SXM4 GPU - 400 W TDP	NVML	600 W	SMF (1.41 - 0.21 GHz)
IBM Power 10 (S1022) - 12 cores, 8 threads per core - 2.9 GHz nominal frequency - 4.0 GHz turbo frequency - TDP unknown	PDU	n/a	n/a
Fujitsu A64FX - 48 cores - 2.0 GHz frequency - TDP unknown	Perf counters	10 W	n/a

The following table presents closer details about the systems used to execute the MaX applications.

Hardware	Node hardware	System name
AMD Zen2	2×CPU, 16×DDR4	IT4I Karolina
AMD Zen3	2×CPU, 16×DDR4	IT4I Karolina
Intel Cascade Lake	2×CPU, 12×DDR4	IT4I Barbora
Intel Sapphire Rapids	2×CPU, 2×HBM, 16×DDR5	IT4I CS
Nvidia A100	2×AMD 7763 CPU, 16×DDR4 8×A100 GPU,	IT4I Karolina
A64FX	1×CPU, HBM	IT4I CS
Power10	2×CPU, 16×DDR4	IT4I CS

Energy efficiency measurements and benchmarking setup

This section provides a list of use cases used for measurements of individual applications. For all CPUs measured, the use cases were the same except Yambo, which used use cases generated for each CPU to achieve ideal parallelization efficiency. The GPU tests used use cases with a higher amount of workload than CPUs in order to achieve the highest load. The energy measurements were done only on a single compute node of each platform.

For **BigDFT (version 1.9.4) CPU code** of the application the **H2O-32 benchmark** was used with the iteration count limited to 5. (https://github.com/BigDFT-group/ContainerXP/tree/master/H2O-32/CPU). The **GPU version** of BigDFT was tested with **uo2_2 benchmark** also limited to 5 iterations. (https://gitlab.com/max-centre/benchmarks/-/tree/master/BigDFT/UO2/PBE0/GPU).

As input for running a test case of **Fleur (version MaX-R7.1) on CPU AuAg_108 from benchmark** repository was used (https://gitlab.com/max-centre/JUBE4MaX/-/tree/fleur/max-inputs/workloads/fleur/AuAg_108

/inputfiles). A single iteration of this test case was performed. Karolina Zen2 and Zen3 CPUs used the configuration of 32 MPI processes and 4 OMP threads with proper pinning. On Intel SPR the configuration with 48 MPI processes and 2 OMP threads was used. CSL CPU on Barbora performed the test with 36 MPI processes and no OMP threads. The **GPU version** was measured with **CuAg_256 testcase** by running 8 MPI processes – one per each GPU with 16 OMP threads.
(https://gitlab.com/max-centre/JUBE4MaX/-/tree/fleur/max-inputs/workloads/fleur/CuAg_256/inputfiles)

Quantum ESPRESSO (version 7.2) was measured on all **CPU platforms with AUSURF112**, running 1 MPI process per core and taking 21 iterations to finish the test.
(https://gitlab.com/max-centre/benchmarks/-/tree/master/Quantum_Espresso/PW/Small/AUSURF112). The **GPU version** used the **SiO2 test** with 576 atoms.
(https://gitlab.com/max-centre/benchmarks-max3/-/tree/master/qe/sio2_576/leonardo-booster/7.3.1_2024-02/inputfiles)

Siesta (version 5.1-MaX) used **si-quantum-dot use case** to measure on all **CPU platforms** with supercell size 2-2-2.
(https://gitlab.com/garalb/JUBE4MaX/-/tree/jube-ag/max-inputs/workloads/siesta/si-quantum-dot/inputfiles)

Yambo (version 5.2.0) performed energy measurement on **GrCo test case** with 7 k-points. Yambo internal parallelization parameters were set to fit the core count of each platform.
(https://gitlab.com/max-centre/JUBE4MaX/-/tree/develop/max-inputs/workloads/yambo/grco/inputfiles)

To **evaluate the performance (FLOP/s)** of the MaX application **we implemented a tool to read performance counters related to floating point computation with support for Intel CPUs, AMD CPUs, Fujitsu A64FX, and IBM OpenPOWER.**

Under the MaX project, we have also started implementing another **tool to measure FLOP instructions executed by Nvidia GPU**. This tool is written in C using Nvidia Cupti profiling API. However, we were not successful in using it to analyze the execution of MaX Fortran applications. We will work on transforming the code into a more robust solution (probably into

a library), that will allow us analysis of any C, C++, or Fortran application using Nvidia GPU acceleration.

BigDFT

Following table summarizes the energy consumption measurements for BigDFT on all platforms.

Hardware	Energy efficiency	Node energy consumption	HW configuration	Runtime
AMD Zen2	163 MFLOPs/W	47.56 kJ	default	72 s (100%)
	196 MFLOPs/W	39.65 kJ (**-17%**)	CF 2.8 GHz	101%
	221 MFLOPs/W	35.03 kJ (**-26%**)	CF 1.9 GHz	115%
AMD Zen3	171 MFLOPs/W	45.46 kJ	default	67 s (100%)
	195 MFLOPs/W	39.87 kJ (**-12%**)	CF 2.6 GHz	102%
	221 MFLOPs/W	35.17 kJ (**-23%**)	CF 1.8 GHz	113%
Intel Cascade lake	102 MFLOPs/W	75.71 kJ HDEEM 73.88 kJ RAPL	default	181 s (100%)
	171 MFLOPs/W	71.57 kJ (**-5%**) HDEEM 70.23 kJ (**-5%**) RAPL	CF 2.8 GHz UCF 2.2 GHz	101%
	181 MFLOPs/W	67.59 kJ (**-11%**) HDEEM 67.49 kJ (**-9%**) RAPL	CF 2.3 GHz UCF 1.6 GHz	121%
Intel Sapphire Rapids + HBM	257 MFLOPs/W	61.42 kJ RAPL	default	69 s (100%)
	282 MFLOPs/W	56.84 kJ (**-7%**) RAPL	CF 2.9 GHz UCF 1.4 GHz	97%
	282 MFLOPs/W	56.84 kJ (**-7%**) RAPL	CF 2.9 GHz UCF 1.4 GHz	97%
Intel Sapphire Rapids + DDR	190 MFLOPs/W	82.84 kJ RAPL	default	92 s (100%)
	207 MFLOPs/W	77.68 kJ (**-6%**) RAPL	CF 2.9 GHz UCF 1.6 GHz	101%
	225 MFLOPs/W	75.35 kJ (**-9%**) RAPL	CF 2.1 GHz UCF 1.2 GHz	114%
	n/a	959.40 kJ	default	513 s (100%)

Nvidia A100	n/a	905.94 kJ (**-6%**)	1290 MHz	102%
	n/a	871.30 kJ (**-9%**)	1050 MHz	109%

AMD Zen2 - static tuning results

Set CPU frequency [GHz]	Real CPU frequency [GHz]	Runtime [s]	Runtime extension	Average power consumption of the CPU [W]	CPUs energy consumption [kJ]	Energy savings for CPUs	Node energy consumption [kJ]	Compute node energy savings	GFLOPS /W	Note
3,30	3,23	72	100,0%	269,6	38,9	0,0%	47,6	0,0%	0,16	**Default settings**
3,20	3,17	71	98,7%	260,0	37,0	4,8%	45,6	4,2%	0,17	
3,10	3,08	73	101,6%	245,6	36,0	7,4%	44,8	5,8%	0,17	
3,00	2,99	73	100,6%	232,2	33,7	13,4%	42,4	10,8%	0,18	
2,90	2,90	73	100,6%	220,9	32,1	17,6%	40,8	14,3%	0,19	
2,80	2,80	73	101,4%	211,0	30,9	20,7%	39,6	16,6%	0,20	**No runtime penalty**
2,70	2,70	75	104,2%	202,1	30,4	21,9%	39,4	17,1%	0,20	
2,60	2,60	75	103,9%	195,0	29,2	24,8%	38,2	19,6%	0,20	
2,50	2,50	80	110,5%	187,9	30,0	23,0%	39,5	16,9%	0,20	
2,40	2,40	77	106,1%	180,1	27,6	29,1%	36,8	22,7%	0,21	
2,30	2,30	81	112,9%	172,5	28,1	27,8%	37,9	20,3%	0,20	
2,20	2,20	79	109,0%	166,4	26,2	32,7%	35,6	25,1%	0,22	
2,10	2,10	80	110,6%	160,0	25,6	34,3%	35,1	26,1%	0,22	
2,00	2,00	82	113,7%	155,0	25,4	34,6%	35,3	25,8%	0,22	
1,90	1,90	83	115,3%	150,6	25,1	35,6%	35,0	26,3%	0,22	**Maximum energy savings**
1,80	1,80	85	117,1%	148,4	25,1	35,5%	35,2	25,9%	0,22	
1,70	1,70	87	120,5%	145,6	25,3	34,9%	35,7	24,8%	0,22	
1,60	1,60	93	128,6%	142,7	26,5	31,9%	37,6	20,9%	0,21	
1,50	1,50	92	127,6%	140,4	25,8	33,6%	36,9	22,4%	0,21	
1,40	1,40	95	131,3%	138,1	26,2	32,7%	37,5	21,1%	0,21	
1,30	1,30	99	137,1%	135,3	26,8	31,1%	38,7	18,7%	0,20	
1,20	1,20	103	142,9%	132,5	27,3	29,8%	39,7	16,5%	0,20	

AMD Zen3 - static tuning results

Set CPU frequency [GHz]	Real CPU frequency [GHz]	Runtime [s]	Runtime extension	Average power consumption of the CPU [W]	CPUs energy consumption [kJ]	Energy savings for CPUs	Node energy consumption [kJ]	Compute node energy savings	GFLOPS/W	Note
0,00	3,15	67	100,0%	278,4	37,4	0,0%	45,5	0,0%	0,17	**Default settings**
3,50	3,14	67	100,0%	279,6	37,5	-0,4%	45,6	-0,3%	0,17	
3,40	3,14	67	99,6%	279,8	37,4	0,0%	45,4	0,0%	0,17	
3,30	3,13	68	101,9%	280,1	38,4	-2,6%	46,6	-2,4%	0,17	
3,20	3,12	67	99,7%	278,8	37,3	0,2%	45,4	0,2%	0,17	
3,10	3,07	67	99,5%	274,4	36,7	1,9%	44,7	1,6%	0,17	
3,00	3,00	67	99,5%	266,5	35,6	4,8%	43,6	4,0%	0,18	
2,90	2,90	70	103,9%	254,9	35,6	4,9%	44,0	3,3%	0,18	
2,80	2,80	68	101,2%	248,3	33,8	9,7%	41,9	7,8%	0,19	
2,70	2,70	68	101,1%	239,4	32,5	13,0%	40,7	10,5%	0,19	
2,60	2,60	68	101,9%	231,4	31,7	15,3%	39,9	12,3%	0,19	**No runtime penalty**
2,50	2,50	71	105,6%	222,6	31,6	15,6%	40,1	11,8%	0,19	
2,40	2,40	69	103,4%	214,6	29,8	20,3%	38,1	16,1%	0,20	

2,30	2,30	70	104,7%	206,3	29,0	22,4%	37,5	17,6%	0,21	
2,20	2,20	71	105,5%	199,4	28,3	24,4%	36,8	19,1%	0,21	
2,10	2,10	73	109,2%	192,0	28,2	24,7%	37,0	18,7%	0,21	
2,00	2,00	73	109,2%	185,4	27,2	27,3%	36,0	20,8%	0,22	
1,90	1,90	74	110,2%	179,2	26,5	29,1%	35,4	22,1%	0,22	
1,80	1,80	76	112,5%	172,7	26,1	30,2%	35,2	22,6%	0,22	**Maximum energy savings**
1,70	1,70	78	115,8%	167,2	26,0	30,5%	35,3	22,3%	0,22	
1,60	1,60	79	118,2%	161,8	25,7	31,3%	35,2	22,5%	0,22	
1,50	1,50	82	121,8%	158,0	25,8	30,9%	35,7	21,6%	0,22	
1,40	1,40	86	128,1%	154,5	26,6	28,9%	36,9	18,8%	0,21	
1,30	1,30	87	129,6%	152,1	26,5	29,2%	36,9	18,8%	0,21	
1,20	1,20	90	134,6%	148,7	26,9	28,1%	37,7	17,0%	0,21	

Intel CSL - static tuning results

Runtime [s]

CF/UnCF [MHz]	0	2400	2200	2000	1800	1600	1400	1200
0	181,40	181,63	182,64	184,15	187,67	192,14	202,80	219,17
3300	181,10	181,40	182,08	184,69	187,69	191,62	202,50	219,29
3200	181,38	181,07	182,56	184,70	188,21	192,12	203,10	219,41
3100	180,86	181,24	182,41	184,98	188,43	192,55	203,43	219,82
3000	181,10	180,60	182,48	185,36	188,48	193,05	203,70	219,70
2900	181,25	181,40	183,46	185,50	188,64	192,97	204,43	220,80
2800	181,13	181,00	182,84	185,83	189,46	193,89	204,68	220,76
2700	185,38	185,72	187,68	189,96	193,24	198,08	208,08	224,64
2600	189,94	190,23	192,61	194,55	198,74	202,29	212,55	228,25
2500	197,41	195,33	197,13	199,87	203,14	207,08	216,68	233,97
2300	210,60	206,61	208,88	212,10	215,01	218,96	228,07	243,25
2100	225,29	220,74	222,39	225,02	228,63	232,76	242,44	255,74
1900	243,10	237,98	240,10	241,88	245,05	249,70	258,15	270,90
1700	265,34	259,82	261,25	263,30	265,96	270,31	278,64	289,78
1500	296,18	289,01	289,72	291,12	294,95	298,06	306,84	315,72
1300	334,27	323,14	323,89	328,06	330,14	333,23	340,49	350,46

HDEEM Blade Energy Total [kJ]

CF/UnCF [MHz]	0	2400	2200	2000	1800	1600	1400	1200
0	75,71	75,82	75,08	74,15	73,73	74,19	76,38	80,27
3300	75,59	75,72	74,88	74,32	73,79	74,02	76,21	80,31
3200	75,47	75,38	74,57	73,58	72,80	72,89	75,10	78,81
3100	75,06	75,20	73,97	72,72	71,80	71,94	74,07	77,73
3000	74,74	74,60	73,20	71,82	70,81	71,07	73,05	76,50
2900	74,36	74,42	72,63	70,96	69,94	70,09	72,24	75,72
2800	73,59	73,57	71,57	70,19	69,30	69,51	71,39	74,76
2700	73,08	73,22	71,14	69,47	68,49	68,78	70,42	73,82
2600	72,64	72,73	70,68	68,97	68,22	68,14	69,73	72,76
2500	71,73	72,62	70,43	68,92	67,84	67,79	69,17	72,50
2300	71,74	72,78	70,59	69,06	67,73	67,59	68,72	71,31
2100	71,95	73,56	71,07	69,19	67,89	67,71	68,83	70,77
1900	72,43	74,92	72,28	70,02	68,48	68,28	68,96	70,58
1700	74,29	78,04	75,00	72,59	70,70	70,33	70,85	71,95
1500	78,26	82,78	79,20	76,35	74,50	73,72	74,10	74,66
1300	82,07	87,30	83,37	80,76	78,31	77,30	77,17	77,74

Nvidia A100 - static tuning results

Set GPU frequency [MHz]	Runtime [s]	Runtime extension	Average power consumption of the GPU [W]	Average power consumption of the CPU [W]	CPUs + GPUs energy consumption [kJ]	Energy savings for GPUs + CPUs	Node energy consumption [kJ]	Compute node energy savings	Note
1410	512,8	100,0%	122,7	144,7	651,7	0,0%	959,4	0,0%	**Default settings**
1350	520,9	101,6%	112,5	144,2	618,8	5,1%	931,3	2,9%	
1290	523,4	102,1%	105,3	144,2	591,9	9,2%	905,9	5,6%	**No runtime penalty**
1230	530,3	103,4%	99,4	144,3	574,9	11,8%	893,1	6,9%	
1170	536,8	104,7%	94,5	143,7	560,1	14,1%	882,2	8,0%	
1110	545,6	106,4%	90,3	143,1	550,3	15,6%	877,7	8,5%	
1050	551,6	107,6%	86,7	142,8	540,3	17,1%	871,3	9,2%	**Maximum energy savings**
990	564,1	110,0%	84,7	142,6	543,4	16,6%	881,8	8,1%	
930	576,5	112,4%	83,6	143,1	550,4	15,6%	896,2	6,6%	
870	590,3	115,1%	82,6	142,6	558,3	14,3%	912,5	4,9%	
810	596,9	116,4%	81,7	141,4	558,9	14,3%	917,0	4,4%	

750	617,7	120,5%	80,5	139,8	570,4	12,5%	941,0	1,9%	
690	633,8	123,6%	79,6	139,3	580,3	11,0%	960,5	-0,1%	

Intel SPR HBM - static tuning results

Runtime [s]

CF/UnCF [MHz]	0	2500	2400	2200	2000	1800	1600	1400	1200	1000	800
0	68,76	68,66	68,44	68,26	68,53	68,62	67,74	68,84	71,14	74,70	81,65
3500	68,02	68,74	68,00	67,98	68,76	67,28	67,41	68,80	70,45	74,46	81,48
3300	67,35	68,25	67,67	67,77	68,83	67,17	66,74	69,03	70,33	74,99	80,43
3100	67,94	67,91	67,88	68,23	67,35	67,17	66,33	67,38	70,65	73,60	81,28
2900	66,83	66,98	67,35	66,83	67,15	67,25	66,63	**66,96**	69,45	74,72	79,62
2700	67,32	67,74	68,16	67,25	67,59	66,77	65,85	68,18	70,54	73,77	80,52
2500	67,54	67,71	68,27	68,18	67,46	67,19	68,00	68,68	71,28	74,96	82,97
2300	69,92	70,14	70,05	69,16	69,70	70,67	71,95	73,27	76,25	77,86	86,90
2100	75,79	77,64	77,27	74,11	77,62	76,89	78,49	79,10	81,59	84,80	90,54
1900	84,21	79,72	82,00	80,26	82,07	82,21	83,70	84,12	86,58	91,04	95,27
1700	90,50	88,09	88,04	90,19	88,81	89,65	90,32	91,65	93,38	97,97	103,58
1500	102,66	98,37	99,02	98,41	99,19	101,04	100,26	102,99	103,78	106,64	111,48
1300	116,40	112,09	111,50	112,08	112,41	112,75	113,83	116,23	116,58	118,95	127,78
1100	137,53	130,20	133,94	130,54	133,11	131,50	134,61	133,09	136,67	137,28	148,28
900	163,94	157,56	158,17	158,26	160,44	158,74	160,80	160,75	162,40	167,77	166,49
800	185,16	179,99	180,31	177,90	182,71	180,27	178,60	191,26	192,23	190,89	185,02

RAPL Energy + Baseline [kJ]

CF/UnCF [MHz]	0	2500	2400	2200	2000	1800	1600	1400	1200	1000	800
0	61,42	61,44	61,19	60,88	60,88	60,51	58,85	58,37	58,82	60,40	64,33
3500	60,78	61,51	60,79	60,62	61,08	59,30	58,58	58,35	58,28	60,23	64,19
3300	60,08	61,07	60,50	60,43	61,09	59,20	58,01	58,51	58,18	60,64	63,35
3100	60,61	60,77	60,69	60,84	59,82	59,19	57,63	57,17	58,41	59,53	64,03
2900	59,61	59,94	60,20	59,60	59,66	59,26	57,91	**56,84**	57,44	60,45	62,67
2700	60,14	60,62	60,93	59,97	60,05	58,83	57,21	57,79	58,28	59,59	63,36
2500	60,19	60,55	60,98	60,71	59,72	58,62	57,87	56,95	57,57	59,19	63,78
2300	62,24	62,62	62,42	61,18	60,56	59,31	58,60	58,05	58,85	58,73	63,84
2100	67,24	68,88	68,43	64,39	64,78	61,68	61,01	59,99	60,06	61,24	63,78
1900	68,28	70,58	71,76	67,74	66,16	63,84	62,95	61,55	61,68	63,44	64,80
1700	69,76	77,06	75,50	73,63	69,45	67,33	65,78	64,85	64,30	65,99	67,96
1500	73,79	84,01	82,29	77,82	75,03	73,36	70,56	70,40	69,05	69,40	70,89
1300	78,22	93,02	90,09	85,96	82,25	79,13	77,32	76,72	74,88	74,80	78,33
1100	87,26	104,79	104,78	96,90	94,08	89,24	88,31	84,83	84,64	83,24	87,64
900	95,83	123,08	119,99	113,66	109,82	104,14	101,87	98,75	97,03	97,92	95,26
800	105,69	138,17	134,55	125,57	122,85	116,06	111,16	115,04	112,53	109,34	104,01

Intel SPR DDR - static tuning results

Runtime [s]

CF/UnCF [MHz]	0	2500	2400	2200	2000	1800	1600	1400	1200	1000	800
0	92,39	91,84	91,83	93,18	91,39	92,10	93,40	94,84	97,11	99,88	106,18
3500	91,68	92,49	91,76	91,64	91,70	92,36	93,79	95,33	96,93	100,57	106,19
3300	91,93	91,58	91,38	91,72	91,82	91,97	93,66	94,78	97,26	100,40	106,60
3100	91,65	91,51	91,27	92,42	91,27	92,49	93,46	94,75	96,85	100,66	108,42
2900	92,81	91,84	91,80	91,54	91,73	92,31	93,24	94,91	97,18	100,14	107,11
2700	91,55	91,92	91,31	93,28	91,46	92,18	93,60	94,17	96,56	99,69	107,23
2500	92,72	93,01	92,55	92,98	92,93	92,90	94,92	96,46	98,48	101,64	108,78
2300	96,55	95,78	94,61	95,42	95,90	97,03	97,67	99,97	101,20	105,23	111,50
2100	98,60	98,82	98,50	100,53	99,12	100,98	102,38	104,16	105,21	109,40	114,68
1900	105,30	103,62	104,15	104,86	106,04	106,37	107,47	109,02	111,00	113,95	120,51
1700	111,66	110,95	111,39	111,85	111,41	113,44	114,61	115,25	120,34	121,78	127,25
1500	120,83	119,93	122,10	120,74	120,55	122,18	123,61	124,32	125,37	129,00	135,91
1300	135,83	131,69	131,79	131,63	132,82	134,23	134,35	135,86	137,62	144,17	150,32
1100	151,93	148,98	149,37	148,52	150,60	150,26	151,01	152,29	154,96	157,63	167,75
900	176,12	171,72	176,79	172,08	173,46	173,71	175,39	176,43	178,74	183,77	188,96
800	197,91	189,19	189,04	196,17	190,93	190,92	192,43	194,62	200,52	201,92	207,30

RAPL Energy + Baseline [kJ]

CF/UnCF [MHz]	0	2500	2400	2200	2000	1800	1600	1400	1200	1000	800
0	82,84	82,58	82,47	83,30	80,75	78,92	77,72	76,96	76,87	77,51	80,51
3500	82,32	83,17	82,44	81,93	81,07	79,15	78,06	77,35	76,81	78,10	80,62
3300	82,55	82,37	82,09	81,99	81,18	78,83	77,96	76,88	77,11	77,90	80,87
3100	82,33	82,30	81,99	82,63	80,73	79,24	77,85	76,83	76,79	78,14	82,20
2900	83,34	82,59	82,46	81,83	81,09	79,09	77,68	76,96	77,04	77,74	81,24
2700	82,27	82,67	82,02	83,39	80,85	79,00	77,94	76,44	76,52	77,39	81,31
2500	83,22	83,59	83,04	82,86	80,96	78,16	77,43	76,63	76,40	77,23	80,77
2300	86,40	85,91	84,56	83,58	80,45	78,36	76,51	76,26	75,37	76,66	79,37
2100	87,77	88,21	87,10	85,05	80,27	78,56	77,32	76,47	75,35	76,66	78,56
1900	88,39	91,54	90,03	86,12	83,36	80,37	78,69	77,66	76,97	77,37	79,98
1700	89,92	95,87	93,78	89,40	85,21	83,24	81,57	79,71	80,98	80,24	81,97
1500	92,75	101,00	100,04	93,87	89,61	87,09	85,35	83,38	81,90	82,49	84,97
1300	98,04	107,99	105,11	99,55	95,88	92,84	90,06	88,36	87,14	89,31	91,06
1100	102,97	118,88	115,79	109,17	105,47	100,83	98,07	95,96	95,00	94,57	98,41
900	111,17	133,13	133,13	122,83	117,87	113,07	110,41	107,70	106,00	106,56	107,34
800	119,36	144,58	140,42	137,70	127,78	122,30	119,17	116,73	116,85	115,14	115,72

Fleur

Following table summarizes the energy consumption measurements for Fleur on all platforms.

Hardware	Energy efficiency	Node energy consumption	HW configuration	Runtime
AMD Zen2	1.78 GFLOPs/W	53.36 kJ	default	109 s (100%)
	1.82 GFLOPs/W	52.00 kJ (**-3%**)	CF 2.9 GHz	101%
	1.94 GFLOPs/W	48.81 kJ (**-9%**)	CF 2.1 GHz	107%
AMD Zen3	1.67 GFLOPs/W	56.96 kJ	default	93 s (100%)
	1.79 GFLOPs/W	53.05 kJ (**-7%**)	CF 2.7 GHz	101%
	1.91 GFLOPs/W	49.73 kJ (**-13%**)	CF 2.0 GHz	112%
Intel Cascade lake	1.00 GFLOPs/W	94.94 kJ HDEEM 87.33 kJ RAPL	default	217 s (100%)
	1.04 GFLOPs/W	91.26 kJ (**-4%**) HDEEM 84.14 kJ (**-4%**) RAPL	CF 2.8 GHz UCF 2.2 GHz	101%
	1.13 GFLOPs/W	84.51 kJ (**-11%**) HDEEM 78.96 kJ (**-10%**) RAPL	CF 1.9 GHz UCF 1.8 GHz	123%
Intel Sapphire Rapids + HBM	1.77 GFLOPs/W	73,31 kJ RAPL	default	82 s (100%)
	1.82 GFLOPs/W	71,83 kJ (**-2%**) RAPL	CF 3.1 GHz UCF 1.8 GHz	101%
	1.82 GFLOPs/W	71.83 kJ (**-2%**) RAPL	CF 3.1 GHz UCF 1.8 GHz	101%
Intel Sapphire Rapids + DDR	1.43 GFLOPs/W	90.22 kJ RAPL	default	100 s (100%)
	1.47 GFLOPs/W	88.48 J (**-2%**) RAPL	CF 2.9 GHz UCF 2.0 GHz	101%
	1.54 GFLOPs/W	86.50 kJ (**-4%**) RAPL	CF 2.3 GHz UCF 1.8 GHz	110%
Nvidia A100	n/a	180.6 kJ	default	111 s (100%)
	n/a	169.3 kJ (**-6%**)	1230 MHz	101%
	n/a	166.3 kJ (**-8%**)	990 MHz	104%
Power10	459 MFLOPs/W	198.6 kJ	default	199 s
A64FX	321 MFLOPs/W	282.5 kJ	default	812 s

AMD Zen2 - static tuning results

Set CPU frequency [GHz]	Real CPU frequency [GHz]	Runtime [s]	Runtime extension	Average power consumption of the CPU [W]	CPUs energy consumption [kJ]	Energy savings for CPUs	Node energy consumption [kJ]	Compute node energy savings	GFLOPS/W	Note
3,30	2,55	109	100,0%	184,4	40,3	0,0%	53,4	0,0%	1,78	**Default settings**
3,20	2,55	109	99,9%	183,2	39,9	0,8%	53,0	0,6%	1,79	
3,10	2,54	109	100,0%	181,4	39,6	1,7%	52,7	1,3%	1,80	
3,00	2,52	109	99,9%	178,9	39,0	3,0%	52,1	2,3%	1,82	
2,90	2,50	110	100,8%	176,2	38,8	3,7%	52,0	2,6%	1,82	**No runtime penalty**
2,80	2,46	111	101,5%	172,8	38,3	4,9%	51,6	3,3%	1,84	
2,70	2,41	111	101,5%	169,9	37,7	6,5%	51,0	4,5%	1,86	
2,60	2,36	112	102,2%	166,9	37,2	7,5%	50,6	5,1%	1,87	
2,50	2,31	112	103,0%	163,6	36,8	8,6%	50,3	5,8%	1,89	
2,40	2,25	113	103,7%	160,5	36,3	9,8%	49,9	6,5%	1,90	
2,30	2,18	115	105,2%	156,0	35,8	11,0%	49,6	7,0%	1,91	
2,20	2,12	116	106,1%	152,4	35,3	12,4%	49,2	7,8%	1,93	
2,10	2,05	117	107,2%	148,6	34,8	13,6%	48,8	8,5%	1,94	**Maximum energy savings**
2,00	1,97	120	109,5%	144,8	34,6	14,0%	49,0	8,2%	1,94	
1,90	1,89	122	111,7%	141,6	34,5	14,3%	49,2	7,9%	1,93	
1,80	1,80	125	114,1%	139,4	34,7	13,7%	49,7	6,9%	1,91	
1,70	1,70	130	118,7%	136,9	35,5	11,9%	51,0	4,4%	1,86	
1,60	1,60	134	123,1%	134,4	36,1	10,3%	52,2	2,1%	1,82	
1,50	1,50	140	127,8%	131,8	36,8	8,6%	53,5	-0,3%	1,77	
1,40	1,40	145	132,6%	129,5	37,5	6,8%	54,9	-2,9%	1,73	
1,30	1,30	152	139,4%	126,5	38,5	4,3%	56,8	-6,4%	1,67	
1,20	1,20	160	147,0%	123,8	39,7	1,3%	59,0	-10,6%	1,61	

AMD Zen3 - static tuning results

Set CPU frequency [GHz]	Real CPU frequency [GHz]	Runtime [s]	Runtime extension	Average power consumption of the CPU [W]	CPUs energy consumption [kJ]	Energy savings for CPUs	Node energy consumption [kJ]	Compute node energy savings	GFLOPS/W	Note
0,00	2,96	93	100,0%	244,6	45,7	0,0%	57,0	0,0%	1,67	**Default settings**
3,50	2,97	93	99,8%	244,7	45,6	0,2%	56,8	0,2%	1,67	
3,40	2,96	93	99,2%	245,2	45,5	0,5%	56,6	0,6%	1,68	
3,30	2,96	93	99,4%	244,8	45,5	0,5%	56,7	0,5%	1,68	
3,20	2,94	93	99,9%	242,8	45,3	0,9%	56,6	0,7%	1,68	
3,10	2,89	94	100,0%	239,2	44,7	2,2%	56,0	1,7%	1,70	
3,00	2,83	94	100,1%	234,7	43,9	3,9%	55,2	3,1%	1,72	
2,90	2,77	94	100,5%	230,0	43,2	5,4%	54,5	4,3%	1,74	
2,80	2,70	94	100,7%	225,2	42,4	7,3%	53,7	5,7%	1,77	
2,70	2,63	95	101,1%	220,5	41,7	8,8%	53,0	6,9%	1,79	**No runtime penalty**
2,60	2,55	95	101,5%	215,6	40,9	10,5%	52,3	8,1%	1,82	
2,50	2,48	96	102,4%	210,6	40,3	11,9%	51,8	9,0%	1,84	
2,40	2,40	97	103,4%	204,8	39,6	13,5%	51,2	10,2%	1,86	
2,30	2,30	98	104,7%	198,0	38,8	15,3%	50,5	11,3%	1,88	
2,20	2,20	100	107,2%	191,0	38,3	16,3%	50,3	11,7%	1,89	
2,10	2,10	102	109,1%	184,5	37,6	17,7%	49,9	12,4%	1,91	
2,00	2,00	104	111,6%	178,2	37,2	18,7%	49,7	12,7%	1,91	**Maximum energy savings**
1,90	1,90	108	115,0%	172,1	37,0	19,1%	49,9	12,3%	1,91	
1,80	1,80	111	118,7%	166,4	36,9	19,3%	50,2	11,8%	1,89	
1,70	1,70	114	122,3%	161,0	36,8	19,5%	50,5	11,3%	1,88	

1,60	1,60	118	126,6%	155,9	36,9	19,3%	51,1	10,3%	1,86	
1,50	1,50	126	135,3%	150,4	38,0	16,8%	53,2	6,6%	1,79	
1,40	1,40	130	138,7%	148,4	38,5	15,8%	54,1	5,1%	1,76	
1,30	1,30	138	147,1%	145,0	39,9	12,8%	56,4	1,0%	1,69	
1,20	1,20	143	152,7%	142,5	40,7	11,1%	57,8	-1,5%	1,65	

Nvidia A100 - static tuning results

Set GPU frequency [MHz]	Runtime [s]	Runtime extension	Average power consumption of the GPU [W]	Average power consumption of the CPU [W]	CPUs + GPUs energy consumption [kJ]	Energy savings for GPUs + CPUs	Node energy consumption [kJ]	Compute node energy savings	Note
1410	110,5	100,0%	96,2	132,1	114,3	0,0%	180,6	0,0%	**Default settings**
1350	111,7	101,1%	90,3	131,7	110,1	3,6%	177,2	1,9%	
1290	111,8	101,1%	85,8	131,7	106,1	7,1%	173,2	4,1%	
1230	111,5	100,9%	81,9	131,7	102,4	10,4%	169,3	6,3%	**No runtime penalty**
1170	112,6	101,9%	79,0	131,6	100,8	11,8%	168,3	6,8%	
1110	114,0	103,1%	76,1	131,8	99,4	13,0%	167,8	7,1%	
1050	115,2	104,2%	73,7	131,4	98,1	14,1%	167,2	7,4%	
990	115,1	104,1%	72,8	131,4	97,2	14,9%	166,3	7,9%	**Maximum energy savings**
930	116,1	105,1%	72,2	131,2	97,5	14,7%	167,2	7,4%	
870	119,3	108,0%	71,3	130,3	99,1	13,2%	170,8	5,4%	
810	119,3	107,9%	71,0	130,4	98,9	13,4%	170,5	5,6%	
750	120,7	109,2%	70,6	130,5	99,6	12,8%	172,0	4,7%	
690	122,2	110,6%	70,1	130,5	100,5	12,1%	173,8	3,8%	

Intel CSL - static tuning results

Runtime [s]								
CF/UnCF [MHz]	0	2400	2200	2000	1800	1600	1400	1200
0	217,15	216,55	219,09	224,66	231,74	244,27	271,19	325,84
3300	216,94	216,25	219,16	224,47	231,79	244,66	270,89	326,23
3200	216,10	215,94	219,42	225,36	231,50	243,41	270,92	326,54
3100	216,61	215,54	218,84	225,48	232,40	243,47	273,50	326,79
3000	215,88	216,95	219,32	224,19	232,85	243,61	273,25	326,94
2900	217,34	216,80	219,39	225,60	233,73	244,58	273,00	328,30
2800	217,14	217,38	219,35	225,55	233,46	244,69	270,86	328,37
2700	218,13	218,49	220,80	226,93	234,73	247,86	273,93	330,19
2600	221,48	219,90	222,88	228,50	235,90	247,79	276,51	332,56
2500	222,81	221,87	224,79	230,23	237,59	249,43	277,51	334,67
2300	229,41	225,79	229,96	234,61	244,28	264,21	284,13	338,24
2100	238,44	235,15	240,68	246,20	254,06	266,42	293,82	348,46
1900	252,03	249,21	252,46	258,20	267,58	278,77	305,59	358,53
1700	270,91	265,66	268,79	275,18	284,18	295,21	321,28	372,33
1500	292,88	287,55	292,17	296,76	305,30	315,84	340,74	393,20
1300	322,93	314,31	317,44	325,80	332,15	343,29	367,42	416,55

HDEEM Blade Energy Total [kJ]								
CF/UnCF [MHz]	0	2400	2200	2000	1800	1600	1400	1200
0	94,94	94,73	94,04	93,98	94,30	97,27	103,91	117,81
3300	94,88	94,58	94,09	94,02	94,42	97,47	103,91	118,08
3200	94,44	94,43	93,89	93,85	93,69	96,31	103,04	117,03
3100	94,40	93,99	93,16	93,20	93,24	95,46	103,04	115,94
3000	93,61	94,08	92,71	91,96	92,61	94,64	101,91	114,84
2900	93,55	93,38	92,00	91,70	92,10	94,13	100,84	114,12
2800	92,80	92,95	91,26	90,90	91,22	93,28	99,21	113,02
2700	91,89	92,07	90,44	89,97	90,26	92,86	98,48	111,30
2600	91,87	91,39	89,89	89,20	89,29	91,34	97,52	109,92
2500	89,81	91,10	89,55	88,71	88,62	90,56	96,29	108,77
2300	88,51	90,03	88,49	86,82	86,77	90,11	93,46	104,58
2100	87,32	89,88	87,93	85,97	85,14	86,62	91,30	102,08
1900	86,49	89,97	87,08	85,23	84,51	85,52	89,78	99,53
1700	87,17	91,20	87,90	86,09	85,09	85,84	89,67	98,69
1500	88,36	93,62	90,50	87,96	86,59	87,09	90,54	99,49
1300	90,72	96,76	92,91	90,94	88,74	89,15	92,04	99,79

Intel SPR HBM - static tuning results

Runtime [s]

CF/UnCF [MHz]	0	2500	2400	2200	2000	1800	1600	1400	1200	1000	800
0	82,45	82,43	83,43	82,82	82,45	84,86	87,45	92,05	100,70	110,67	127,42
3500	81,90	81,95	81,94	82,68	82,90	84,36	88,90	91,98	100,01	109,56	128,86
3300	81,26	82,53	81,74	81,27	83,27	83,37	87,91	94,08	98,74	111,05	127,60
3100	81,12	83,04	81,89	81,68	84,34	**83,22**	86,80	91,68	99,53	111,51	126,82
2900	83,72	82,36	82,50	82,76	82,68	85,37	89,07	91,98	101,36	111,67	126,64
2700	82,82	83,88	83,59	84,01	82,99	85,42	88,42	91,99	100,59	111,00	127,61
2500	84,01	85,53	83,97	85,15	86,57	86,08	90,44	93,62	100,26	112,37	127,72
2300	85,65	85,35	85,10	86,97	85,81	87,29	90,85	96,17	103,40	112,34	131,44
2100	87,45	89,10	88,88	87,27	89,32	91,68	95,07	100,53	107,54	118,00	136,77
1900	111,59	92,12	91,52	93,87	93,46	95,81	100,69	105,00	113,97	122,42	138,42
1700	122,68	99,73	100,14	100,56	101,66	103,94	107,38	111,77	120,44	128,91	144,79
1500	130,52	111,30	111,21	110,61	111,35	113,89	116,36	123,29	125,45	137,60	154,85
1300	144,09	124,34	126,42	124,94	129,65	128,61	135,15	134,60	140,32	147,72	166,96
1100	165,86	145,58	145,74	147,21	148,26	150,03	150,28	155,29	158,30	166,65	179,63
900	197,27	179,21	178,52	183,91	179,48	180,16	181,49	184,94	192,40	192,81	203,84
800	228,65	205,95	205,10	204,70	204,45	205,30	206,30	212,64	214,81	223,00	226,46

RAPL Energy + Baseline [kJ]

CF/UnCF [MHz]	0	2500	2400	2200	2000	1800	1600	1400	1200	1000	800
0	73,31	73,79	74,55	73,58	72,52	73,35	73,87	75,47	79,87	85,29	94,78
3500	72,81	73,35	73,23	73,44	72,96	72,99	74,91	75,38	79,44	84,52	95,78
3300	72,22	73,87	72,99	72,16	73,15	72,07	74,09	76,69	78,31	85,38	94,78
3100	72,04	74,28	73,04	72,38	73,84	**71,83**	73,13	74,92	78,73	85,55	94,03
2900	74,17	73,50	73,42	73,14	72,22	73,31	74,49	74,83	79,72	85,27	93,63
2700	73,10	74,64	74,11	73,87	72,23	73,01	73,72	74,51	78,77	84,40	93,65
2500	73,85	75,79	74,11	74,48	74,48	72,84	74,32	74,77	77,56	84,24	92,43
2300	74,61	75,25	74,62	75,03	72,91	72,30	72,96	74,71	77,63	81,83	92,05
2100	75,68	77,75	77,18	74,65	74,57	73,88	74,27	75,82	78,25	83,15	92,83
1900	80,69	80,15	79,06	79,28	76,70	75,62	76,46	77,03	80,49	83,94	91,79
1700	85,38	86,15	85,67	83,73	81,31	79,46	79,18	79,62	82,65	86,01	93,42
1500	88,30	95,15	93,86	90,01	86,35	84,42	83,24	84,99	83,95	89,29	97,18
1300	93,41	105,19	104,95	98,53	96,89	92,19	93,04	90,02	90,80	93,16	101,81
1100	103,18	120,58	117,42	112,00	107,27	103,70	100,39	100,17	99,14	101,64	106,59
900	116,03	143,44	138,65	134,60	125,31	120,10	116,79	115,17	115,98	113,69	117,21
800	130,15	161,62	156,29	147,40	139,98	134,38	130,25	129,59	126,96	128,51	127,79

Intel SPR DDR - static tuning results

Runtime [s]

CF/UnCF [MHz]	0	2500	2400	2200	2000	1800	1600	1400	1200	1000	800
0	100,45	100,54	100,27	101,59	100,83	103,51	106,46	111,26	122,43	135,50	159,68
3500	100,57	100,09	100,37	100,44	101,85	103,73	106,92	112,57	122,10	135,57	160,41
3300	100,74	101,41	99,98	100,80	100,84	103,46	106,88	111,65	122,23	136,87	158,76
3100	99,80	100,69	103,26	100,53	102,51	103,03	106,55	113,28	120,70	135,23	158,62
2900	100,57	100,17	100,24	100,69	100,99	103,11	106,57	111,80	122,26	137,19	161,75
2700	101,33	100,72	100,93	101,51	101,99	104,58	107,61	112,67	121,31	136,41	160,67
2500	102,09	101,64	102,11	102,11	103,05	106,21	110,04	113,78	123,25	138,10	162,79
2300	103,25	104,08	103,42	102,99	104,89	106,68	110,35	115,69	126,32	138,96	162,49
2100	105,34	105,60	105,96	106,63	108,70	109,57	113,57	118,43	128,35	141,99	164,40
1900	126,35	109,96	110,86	111,26	112,44	115,47	118,16	122,45	132,51	146,19	167,96
1700	132,29	115,37	115,84	116,64	118,85	120,82	125,36	129,51	137,86	151,45	173,67
1500	140,22	124,36	125,67	124,88	127,12	129,27	132,14	136,47	146,91	159,58	181,35
1300	151,94	135,35	136,29	136,61	138,31	141,30	144,72	147,48	159,88	169,47	190,36
1100	170,17	152,78	152,80	153,26	155,23	156,21	160,88	164,72	170,41	185,48	206,05
900	195,29	175,76	178,33	178,00	178,41	184,81	186,90	186,80	194,32	207,14	226,94
800	213,82	194,49	194,25	198,49	199,64	200,72	203,57	203,87	213,99	224,60	241,09

RAPL Energy + Baseline [kJ]

CF/UnCF [MHz]	0	2500	2400	2200	2000	1800	1600	1400	1200	1000	800
0	90,22	90,65	90,28	90,87	88,87	88,12	87,99	89,11	94,72	101,55	115,29
3500	90,38	90,23	90,36	89,85	89,71	88,33	88,42	90,12	94,41	101,56	115,84
3300	90,47	91,41	89,97	90,02	88,72	87,88	88,13	89,21	94,31	102,23	114,60
3100	89,58	90,70	92,68	89,66	89,94	**87,44**	87,71	90,24	92,97	100,91	114,20
2900	90,08	90,07	89,90	89,55	88,48	87,22	87,45	88,81	93,78	101,87	115,89
2700	90,46	90,30	90,20	89,90	88,93	87,93	87,76	89,04	92,68	100,84	114,59
2500	90,83	90,83	90,93	89,99	88,79	88,14	88,47	88,62	92,74	100,49	114,22
2300	91,20	92,49	91,50	89,71	88,32	86,50	86,50	87,57	92,08	98,20	110,60
2100	92,50	93,39	93,04	91,41	89,36	86,57	86,54	87,17	91,02	97,50	108,85
1900	95,97	96,67	96,52	93,66	90,57	88,79	87,73	87,90	91,65	97,88	108,48
1700	97,51	100,61	99,85	96,35	93,32	90,68	90,56	90,46	92,96	99,00	109,60
1500	99,86	107,32	106,64	100,51	97,26	94,45	93,04	92,86	96,41	101,67	111,71
1300	104,41	115,13	112,84	106,89	102,86	100,30	98,96	97,54	101,92	105,19	114,32
1100	112,08	126,46	123,01	116,43	112,01	107,69	106,74	105,76	105,92	111,97	120,44
900	122,22	141,30	138,97	130,93	124,80	122,98	119,95	116,24	117,00	121,25	129,21
800	129,64	153,81	148,97	143,35	136,97	131,50	128,54	124,66	126,49	129,40	135,22

Quantum ESPRESSO

Following table summarizes the energy cosumption measurements for Quantum ESPRESO on all platforms.

Hardware	Energy efficiency	Node energy consumption	HW configuration	Runtime
AMD Zen2 (RAPL + Baseline)	2.88 GFLOPs/W	243.21 kJ	default	442 s (100%)
	2.95 GFLOPs/W	237.53 kJ (**-2%**)	CF 2.7 GHz	100%
	3.11 GFLOPs/W	224.92 kJ (**-8%**)	CF 2.1 GHz	112%
AMD Zen3 (RAPL + Baseline)	3.02 GFLOPs/W	232.00 kJ	default	356 s (100%)
	3.28 GFLOPs/W	213.12 kJ (**-8%**)	CF 2.5 GHz	100%
	3.41 GFLOPs/W	204.98 kJ (**-12%**)	CF 2.1 GHz	110%
Intel Cascade lake	2.53 GFLOPs/W (HDEEM Blade)	279.76 kJ HDEEM 259.29 kJ RAPL	default	656 s (100%)
	2.60 GFLOPs/W (HDEEM Blade)	272.66 kJ (**-3%**) HDEEM 253.30 kJ (**-2%**) RAPL	CF 2.7 GHz UCF 2.2 GHz	101%
	2.72 GFLOPs/W (HDEEM Blade)	260.04 kJ (**-7%**) HDEEM 243.73 kJ (**-6%**) RAPL	CF 1.9 GHz UCF 1.8 GHz	116%
Intel Sapphire Rapids + HBM	4.46 GFLOPs/W	204.43 kJ RAPL	default	229 s (100%)
	4.56 GFLOPs/W	202.05 kJ (**-1%**) RAPL	CF default UCF 1.2 GHz	103%
	4.56 GFLOPs/W	202.05 kJ (**-1%**) RAPL	CF default UCF 1.2 GHz	103%
Intel Sapphire Rapids + DDR	4.00 FLOPs/W	227.07 kJ RAPL	default	253 s (100%)
	4.17 FLOPs/W	220.09 J (**-3%**) RAPL	CF 2.5 GHz UCF 1.6 GHz	100%
	4.25 FLOPs/W	218.07 J (**-4%**) RAPL	CF 2.3 GHz UCF 1.4 GHz	103%
Nvidia A100	n/a	239.67 kJ	default 1410 MHz	112 s (100%)
	n/a	222.16 kJ (**-7%**)	1290 MHz	101%
	n/a	214.57 kJ (**-10%**)	1050 MHz	111%
Power10	1.15 GFLOPs/W	610 kJ	default	628 s (100%)

AMD Zen2 - static tuning results

Set CPU frequency [GHz]	Real CPU frequency [GHz]	Runtime [s]	Runtime extension	Average power consumption of the CPU [W]	CPUs energy consumption [kJ]	Energy savings for CPUs	Node energy consumption [kJ]	Compute node energy savings	GFLOPS /W	Note
3,30	2,62	447	100,0%	212,1	189,6	0,0%	243,2	0,0%	2,88	Default settings
3,20	2,62	446	99,9%	211,9	189,2	0,2%	242,7	0,2%	2,88	
3,10	2,61	447	99,9%	211,4	188,9	0,4%	242,5	0,3%	2,89	
3,00	2,62	446	99,8%	211,6	188,8	0,4%	242,3	0,4%	2,89	
2,90	2,60	446	99,8%	209,5	186,9	1,4%	240,4	1,2%	2,91	
2,80	2,58	448	100,2%	206,9	185,3	2,3%	239,0	1,7%	2,93	
2,70	2,55	449	100,5%	204,4	183,6	3,1%	237,5	2,3%	2,95	No runtime penalty
2,60	2,51	453	101,3%	200,5	181,6	4,2%	235,9	3,0%	2,97	
2,50	2,45	457	102,3%	195,3	178,5	5,8%	233,4	4,1%	3,00	
2,40	2,37	465	104,0%	188,4	175,2	7,6%	231,0	5,0%	3,03	
2,30	2,29	474	106,1%	180,7	171,4	9,6%	228,4	6,1%	3,06	
2,20	2,20	488	109,1%	172,0	167,7	11,5%	226,2	7,0%	3,09	
2,10	2,10	502	112,3%	164,1	164,7	13,1%	224,9	7,5%	3,11	Maximum energy savings
2,00	2,00	518	115,9%	157,0	162,7	14,2%	224,9	7,5%	3,11	
1,90	1,90	535	119,7%	151,9	162,6	14,2%	226,8	6,7%	3,09	
1,80	1,80	557	124,6%	148,5	165,5	12,7%	232,3	4,5%	3,01	
1,70	1,70	581	130,1%	144,9	168,5	11,1%	238,3	2,0%	2,94	
1,60	1,60	606	135,6%	141,7	171,7	9,4%	244,5	-0,5%	2,86	
1,50	1,50	634	141,8%	138,4	175,5	7,4%	251,5	-3,4%	2,78	
1,40	1,40	668	149,4%	135,1	180,4	4,8%	260,6	-7,1%	2,69	
1,30	1,30	703	157,2%	131,8	185,1	2,3%	269,5	-10,8%	2,60	
1,20	1,20	748	167,4%	128,3	191,9	-1,2%	281,7	-15,8%	2,48	

AMD Zen3 - static tuning results

Set CPU frequency [GHz]	Real CPU frequency [GHz]	Runtime [s]	Runtime extension	Average power consumption of the CPU [W]	CPUs energy consumption [kJ]	Energy savings for CPUs	Node energy consumption [kJ]	Compute node energy savings	GFLOPS /W	Note
0,00	2,82	356	100,0%	265,9	189,3	0,0%	232,0	0,0%	3,02	Default settings
3,50	2,81	357	100,2%	267,4	190,7	-0,8%	233,6	-0,7%	3,00	
3,40	2,80	355	99,9%	267,6	190,2	-0,5%	232,9	-0,4%	3,00	
3,30	2,80	354	99,4%	267,8	189,5	-0,1%	232,0	0,0%	3,02	
3,20	2,80	354	99,5%	267,4	189,5	-0,1%	232,0	0,0%	3,02	
3,10	2,78	355	99,7%	265,5	188,5	0,4%	231,1	0,4%	3,03	
3,00	2,75	353	99,2%	263,2	185,8	1,9%	228,1	1,7%	3,07	
2,90	2,72	351	98,7%	260,4	182,9	3,4%	225,0	3,0%	3,11	
2,80	2,67	350	98,3%	257,0	179,8	5,0%	221,8	4,4%	3,16	
2,70	2,62	349	98,1%	252,8	176,5	6,8%	218,4	5,9%	3,20	
2,60	2,56	356	100,1%	245,8	175,2	7,5%	217,9	6,1%	3,21	
2,50	2,48	356	99,9%	239,7	170,5	9,9%	213,1	8,1%	3,28	No runtime penalty
2,40	2,40	362	101,8%	230,8	167,2	11,7%	210,7	9,2%	3,32	
2,30	2,30	372	104,5%	220,9	164,3	13,2%	208,9	9,9%	3,35	
2,20	2,20	382	107,3%	210,9	161,0	14,9%	206,9	10,8%	3,38	
2,10	2,10	390	109,7%	202,5	158,1	16,5%	205,0	11,6%	3,41	Maximum energy savings
2,00	2,00	407	114,3%	193,3	157,2	16,9%	206,0	11,2%	3,40	
1,90	1,90	420	117,9%	185,7	155,8	17,7%	206,2	11,1%	3,39	
1,80	1,80	439	123,2%	177,6	155,8	17,7%	208,4	10,2%	3,36	
1,70	1,70	452	127,0%	171,2	154,8	18,2%	209,0	9,9%	3,35	

1,60	1,60	477	133,9%	164,2	156,5	17,3%	213,6	7,9%	3,28	
1,50	1,50	501	140,7%	158,8	159,0	16,0%	219,1	5,6%	3,19	
1,40	1,40	523	147,0%	155,5	162,6	14,1%	225,4	2,8%	3,10	
1,30	1,30	556	156,2%	151,7	168,7	10,9%	235,4	-1,5%	2,97	
1,20	1,20	593	166,7%	148,0	175,6	7,2%	246,8	-6,4%	2,84	

Intel CSL - static tuning results

Runtime [s]								
CF/UnCF [MHz]	0	2400	2200	2000	1800	1600	1400	1200
0	656,87	655,78	657,56	668,26	680,82	701,04	750,81	847,91
3300	654,51	655,58	659,69	666,27	680,41	701,27	750,31	851,66
3200	655,25	656,66	659,36	668,27	679,79	699,95	748,33	853,62
3100	655,62	654,30	660,39	669,89	681,85	700,47	750,30	848,54
3000	654,86	654,42	660,18	668,38	681,76	700,18	749,85	850,65
2900	656,29	655,41	659,64	667,78	681,47	700,57	751,43	851,77
2800	654,30	655,44	660,12	668,67	680,27	700,49	750,15	851,81
2700	657,89	656,63	661,69	669,57	683,38	703,62	755,20	854,39
2600	658,73	658,39	663,88	672,73	685,29	705,27	752,29	853,12
2500	668,17	660,97	665,93	673,92	687,11	708,20	754,73	852,65
2300	674,57	669,00	675,14	683,41	698,13	717,82	770,80	870,21
2100	697,07	690,06	693,57	702,89	718,94	743,06	793,94	893,58
1900	744,26	729,82	735,11	747,04	763,31	789,73	834,85	933,00
1700	807,47	789,66	795,48	807,97	822,40	841,03	894,37	980,55
1500	896,48	867,04	874,36	883,41	899,48	920,47	970,17	1047,71
1300	1004,85	973,43	977,68	989,82	1002,45	1020,32	1065,18	1138,27

HDEEM Blade Energy Total [kJ]								
CF/UnCF [MHz]	0	2400	2200	2000	1800	1600	1400	1200
0	279,76	279,73	276,42	276,01	275,88	279,67	291,69	316,96
3300	279,10	279,54	277,18	275,25	275,75	279,74	291,51	318,16
3200	278,69	279,26	276,21	275,06	274,55	278,15	289,49	317,28
3100	278,12	277,76	275,79	274,65	274,16	277,19	288,75	313,81
3000	277,04	277,08	274,83	273,24	273,25	276,11	287,51	313,08
2900	277,02	276,56	273,76	272,14	272,28	275,31	286,96	311,75
2800	275,52	275,98	273,36	271,67	270,92	274,32	285,58	310,67
2700	275,72	275,31	272,66	270,75	270,78	273,97	285,56	309,27
2600	274,89	275,00	272,29	270,61	270,00	273,08	283,01	307,36
2500	274,40	274,82	271,79	269,88	269,44	272,82	282,52	306,03
2300	268,69	270,58	267,37	264,96	264,27	266,64	276,46	297,08
2100	268,07	272,14	267,35	263,87	261,71	263,38	270,45	288,06
1900	267,17	278,18	270,38	264,19	260,04	261,70	266,95	283,21
1700	267,05	282,57	273,16	266,68	261,68	261,19	267,56	280,81
1500	272,51	290,71	280,89	272,93	267,44	266,80	271,93	282,54
1300	282,18	307,17	295,42	287,27	280,09	278,35	281,55	290,43

Nvidia A100 - static tuning results

Set GPU frequency [MHz]	Runtime [s]	Runtime extension	Average power consumption of the GPU [W]	Average power consumption of the CPU [W]	CPUs + GPUs energy consumption [kJ]	Energy savings for GPUs + CPUs	Node energy consumption [kJ]	Compute node energy savings	Note
1410	112,1	100,0%	163,2	116,5	172,4	0,0%	239,7	0,0%	**Default settings**
1350	112,1	100,0%	153,4	116,5	163,7	5,1%	230,9	3,7%	
1290	112,9	100,7%	141,8	116,6	154,4	10,4%	222,2	7,3%	**No runtime penalty**
1230	117,1	104,5%	131,7	116,7	150,6	12,7%	220,8	7,9%	
1170	119,5	106,7%	123,7	117,9	146,4	15,1%	218,2	9,0%	
1110	124,7	111,3%	114,9	117,7	144,0	16,5%	218,8	8,7%	
1050	124,9	111,5%	110,3	117,9	139,6	19,0%	214,6	10,5%	**Maximum energy savings**
990	128,7	114,9%	107,2	118,0	140,8	18,4%	218,0	9,0%	
930	133,2	118,9%	105,1	117,8	143,3	16,9%	223,2	6,9%	
870	137,1	122,3%	103,4	118,4	145,9	15,4%	228,1	4,8%	
810	144,3	128,8%	100,6	118,4	150,2	12,9%	236,8	1,2%	
750	147,3	131,5%	99,4	116,3	151,4	12,2%	239,8	-0,1%	
690	155,3	138,6%	96,8	117,0	156,5	9,2%	249,7	-4,2%	

Intel SPR HBM - static tuning results

Runtime [s]

CF/UnCF [MHz]	0	2500	2400	2200	2000	1800	1600	1400	1200	1000	800
0	229,59	235,37	235,08	235,01	234,83	235,03	234,44	234,49	236,96	245,63	263,56
3500	229,56	235,01	235,00	234,86	234,86	234,67	235,44	235,06	238,19	246,08	263,91
3300	229,76	236,19	236,53	236,07	235,61	235,59	236,70	236,72	238,72	248,27	264,95
3100	231,22	237,11	237,21	237,16	236,08	237,36	238,20	238,29	239,84	249,40	268,22
2900	232,28	238,11	239,87	237,50	238,98	238,73	238,95	239,11	242,74	252,74	271,85
2700	234,29	240,66	241,51	241,63	240,57	241,15	242,19	241,06	245,25	256,18	276,62
2500	236,55	243,15	242,98	243,41	244,39	243,61	243,57	245,14	249,61	260,55	280,34
2300	244,64	253,44	249,95	252,81	250,56	250,72	254,78	251,29	260,48	271,54	293,88
2100	257,28	260,12	260,28	260,52	261,99	264,05	265,58	269,32	281,90	302,30	331,29
1900	316,39	284,93	285,91	290,97	292,45	294,04	298,02	304,27	310,29	333,40	371,00
1700	350,57	322,17	324,36	325,14	326,01	329,76	338,38	341,68	349,28	359,47	382,49
1500	418,46	401,02	405,59	406,46	405,55	408,79	414,47	417,73	422,79	433,83	406,65
1300	454,31	476,03	444,40	438,32	438,98	436,16	429,50	432,62	433,80	443,95	455,90
1100	545,31	537,44	534,32	535,11	537,81	542,13	544,83	548,15	560,26	564,43	587,89
900	733,92	746,16	756,92	747,11	752,42	739,06	719,35	697,62	673,14	661,13	660,78
800	772,98	778,35	753,32	774,73	764,98	783,86	765,46	756,49	767,34	766,42	769,10

RAPL Energy + Baseline [kJ]

CF/UnCF [MHz]	0	2500	2400	2200	2000	1800	1600	1400	1200	1000	800
0	204,43	210,64	210,31	209,93	208,73	207,34	205,09	202,78	202,05	205,69	214,80
3500	204,43	210,31	210,26	209,83	208,78	207,05	205,92	203,18	202,86	206,07	215,00
3300	204,82	211,36	211,60	210,87	209,42	207,76	206,77	204,34	203,24	207,40	215,67
3100	206,14	212,17	212,16	211,79	209,78	209,20	207,96	205,40	204,01	208,15	217,72
2900	207,09	213,04	214,43	212,10	212,14	210,20	208,43	205,97	205,88	210,37	220,03
2700	208,89	215,23	215,83	215,48	213,36	212,09	210,80	207,38	207,62	212,59	223,09
2500	210,76	217,35	217,03	216,82	216,10	213,45	211,46	209,68	210,04	214,65	224,60
2300	217,17	225,98	222,74	223,37	219,09	216,52	216,54	211,02	213,65	217,84	228,58
2100	227,68	231,43	230,44	227,70	225,56	223,26	220,83	218,97	222,34	231,17	245,02
1900	248,27	251,34	250,10	249,65	245,80	241,44	237,93	236,03	234,64	244,50	262,45
1700	268,51	280,98	279,88	274,07	267,19	260,13	258,24	253,87	252,42	254,04	262,99
1500	284,16	342,42	340,87	328,95	314,69	304,79	299,63	293,77	289,54	290,66	270,71
1300	294,38	397,95	366,84	345,14	330,71	316,23	302,86	296,38	289,82	290,23	291,92
1100	334,07	438,58	424,79	404,05	387,79	374,71	364,80	356,61	354,09	349,90	356,20
900	433,88	581,54	573,04	536,68	515,22	486,05	458,75	433,39	408,85	394,40	386,82
800	444,80	600,96	566,05	550,34	518,51	508,53	481,00	462,41	455,94	445,88	439,06

Intel SPR DDR - static tuning results

Runtime [s]

CF/UnCF [MHz]	0	2500	2400	2200	2000	1800	1600	1400	1200	1000	800
0	253,14	255,10	254,49	256,28	255,59	254,24	255,43	258,53	265,65	278,40	304,41
3500	252,15	254,58	253,82	255,02	254,93	253,54	256,36	258,88	264,53	278,88	304,89
3300	251,53	253,59	253,65	254,15	253,65	253,09	254,92	256,40	263,00	278,46	303,13
3100	250,52	253,03	254,75	251,65	252,70	253,14	254,41	255,67	263,29	276,31	302,78
2900	250,30	251,59	251,93	251,95	252,23	253,04	253,89	256,03	262,45	275,61	301,16
2700	250,03	251,33	251,66	251,76	252,35	252,44	253,62	255,08	261,57	275,81	299,58
2500	249,08	251,64	251,82	252,05	251,81	251,89	253,53	255,53	262,01	275,53	299,38
2300	252,63	255,42	255,22	255,20	255,38	256,39	257,51	260,33	267,75	280,77	307,05
2100	260,07	262,29	262,72	261,62	262,30	263,07	265,51	270,35	277,43	291,47	315,86
1900	312,78	276,83	275,66	277,05	277,96	280,86	284,77	290,54	297,76	310,93	333,18
1700	340,75	298,56	298,33	300,08	304,03	305,25	309,18	315,30	324,64	335,65	355,97
1500	374,37	329,00	332,12	331,15	332,56	337,11	339,39	343,38	354,50	364,47	388,24
1300	415,77	370,50	372,00	371,83	376,20	376,69	381,59	384,43	396,30	404,38	428,03
1100	475,79	429,79	430,12	427,94	433,29	436,82	439,32	440,38	452,28	462,96	484,21
900	560,23	515,06	516,29	517,78	519,24	519,55	524,22	528,76	536,93	546,97	565,99
800	622,05	574,63	580,32	575,45	577,15	580,44	587,33	588,01	598,34	607,05	623,98

RAPL Energy + Baseline [kJ]

CF/UnCF [MHz]	0	2500	2400	2200	2000	1800	1600	1400	1200	1000	800
0	227,07	229,41	228,82	229,88	227,70	224,17	222,16	221,05	222,25	227,16	240,51
3500	226,22	228,95	228,23	228,87	227,15	223,53	222,84	221,31	221,38	227,49	240,90
3300	225,78	228,08	228,08	228,17	226,15	223,25	221,66	219,59	220,35	227,09	239,67
3100	224,92	227,58	229,02	226,01	225,40	223,29	221,42	219,07	220,56	225,71	239,36
2900	224,81	226,37	226,61	226,24	224,94	223,19	220,89	219,29	220,04	225,24	238,40
2700	224,62	226,11	226,37	226,11	225,08	222,75	220,74	218,65	219,45	225,35	237,33
2500	223,74	226,37	226,45	226,21	224,29	221,77	220,09	218,30	218,88	224,33	236,30
2300	226,70	229,69	229,28	227,61	225,10	222,59	220,12	218,07	218,82	223,57	236,44
2100	232,72	235,33	234,82	231,10	227,94	224,45	221,70	219,82	219,56	224,59	235,80
1900	235,18	247,07	244,58	241,83	237,66	233,20	229,43	227,40	226,87	230,97	240,27
1700	244,75	264,71	262,45	258,18	252,57	244,29	239,83	237,49	237,68	239,93	247,62
1500	256,67	289,07	288,19	277,01	266,45	259,38	253,31	249,22	249,79	251,11	260,10
1300	272,38	320,62	315,33	299,75	289,93	279,04	273,75	268,02	268,31	267,86	276,28
1100	297,36	360,23	351,00	332,10	320,69	310,38	302,26	294,59	293,61	294,16	300,14
900	335,03	415,65	405,32	385,43	368,95	354,30	345,68	338,49	334,16	332,86	336,55
800	363,34	455,00	446,43	419,96	401,82	387,19	378,90	368,17	364,01	361,26	363,42

Siesta

Following table summarizes the energy cosumption measurements for Siesta on all platforms.

Hardware	Energy efficiency	Node energy consumption	HW configuration	Runtime
AMD Zen2 (RAPL + Baseline)	0.97 GFLOPs/W	224.54 kJ	default	436 s (100%)
	1.16 GFLOPs/W	187.60 kJ (**-15%**)	CF 2.3 GHz	100%
	1.23 GFLOPs/W	178.09 kJ (**-24%**)	CF 1.9 GHz	102%
AMD Zen3 (RAPL + Baseline)	0.98 GFLOPs/W	224.71 kJ	default	380 s (100%)
	1.15 GFLOPs/W	190.00 kJ (**-15%**)	CF 2.4 GHz	101%
	1.28 GFLOPs/W	171,15 J (**-24%**)	CF 1,5 GHz	107%
Intel Cascade lake	1.01 GFLOPs/W (HDEEM Blade)	212,43 kJ HDEEM 201,90 kJ RAPL	default	524 s (100%)
	1.03 GFLOPs/W (HDEEM Blade)	210,42 J (**-1%**) HDEEM 200,26 kJ (**-1%**) RAPL	CF 2,5 GHz UCF 2,4 GHz	101%
	1.16 GFLOPs/W (HDEEM Blade)	185,44 kJ (**-13%**) HDEEM 179,25 kJ (**-11%**) RAPL	CF 1,7 GHz UCF 2,0 GHz	114%
Intel Sapphire Rapids + HBM (RAPL + Baseline)	2.53 GFLOPs/W	109.96 kJ RAPL	default	123 s (100%)
	2.57 GFLOPs/W	108.53 kJ (**-1%**) RAPL	CF 2.9 GHz UCF 1.8 GHz	99%
	2.57 GFLOPs/W	108.53 kJ (**-1%**) RAPL	CF 2.9 GHz UCF 1.8 GHz	99%
Intel Sapphire Rapids + DDR	1.38 GFLOPs/W	201.20 kJ RAPL	default	222 s (100%)
	1.54 GFLOPs/W	185.67 kJ (**-8%**) RAPL	CF 2.3 GHz UCF 1.8 GHz	101%
	1.73 GFLOPs/W	174.41 kJ (**-13%**) RAPL	CF 1.5 GHz UCF 1.4 GHz	112%
Nvidia A100	n/a	471.86 kJ	1410 MHz	292 s (100%)
	n/a	439.11 kJ (**-7%**)	1170 MHz	101%
	n/a	429.94 kJ (**-9%**)	930 MHz	102%

AMD Zen2 - static tuning results

Set CPU frequency [GHz]	Real CPU frequency [GHz]	Runtime [s]	Runtime extension	Average power consumption of the CPU [W]	CPUs energy consumption [kJ]	Energy savings for CPUs	Node energy consumption [kJ]	Compute node energy savings	GFLOPS/W	Note
3,30	3,00	436	100,0%	197,5	172,2	0,0%	224,5	0,0%	0,98	Default settings
3,20	2,95	434	99,7%	192,2	167,0	3,0%	219,1	2,4%	1,00	
3,10	2,89	435	99,8%	186,3	162,2	5,8%	214,4	4,5%	1,02	
3,00	2,83	435	99,9%	181,4	158,0	8,3%	210,2	6,4%	1,04	
2,90	2,76	435	99,8%	176,9	154,0	10,6%	206,3	8,1%	1,06	
2,80	2,68	436	100,0%	172,5	150,4	12,7%	202,7	9,7%	1,08	
2,70	2,60	436	100,1%	168,9	147,4	14,4%	199,8	11,0%	1,10	
2,60	2,53	437	100,2%	165,2	144,3	16,2%	196,7	12,4%	1,11	
2,50	2,45	438	100,4%	161,8	141,6	17,8%	194,1	13,6%	1,13	
2,40	2,37	438	100,5%	158,0	138,4	19,7%	190,9	15,0%	1,15	
2,30	2,28	438	100,5%	154,2	135,1	21,6%	187,6	16,4%	1,17	No runtime penalty
2,20	2,19	439	100,8%	150,1	131,9	23,4%	184,6	17,8%	1,19	
2,10	2,09	441	101,2%	146,0	128,9	25,2%	181,8	19,0%	1,21	
2,00	2,00	442	101,4%	142,7	126,3	26,7%	179,3	20,1%	1,22	
1,90	1,90	444	101,8%	140,7	124,8	27,5%	178,1	20,7%	1,23	Maximum energy savings
1,80	1,80	447	102,6%	139,3	124,5	27,7%	178,2	20,6%	1,23	
1,70	1,70	453	103,9%	138,0	125,0	27,4%	179,4	20,1%	1,22	
1,60	1,60	458	104,9%	136,8	125,2	27,3%	180,1	19,8%	1,22	
1,50	1,50	461	105,8%	135,7	125,1	27,3%	180,5	19,6%	1,21	
1,40	1,40	463	106,2%	134,5	124,6	27,6%	180,2	19,8%	1,22	
1,30	1,30	469	107,5%	133,1	124,8	27,5%	181,0	19,4%	1,21	
1,20	1,20	476	109,1%	131,7	125,3	27,2%	182,4	18,8%	1,20	

AMD Zen3 - static tuning results

Set CPU frequency [GHz]	Real CPU frequency [GHz]	Runtime [s]	Runtime extension	Average power consumption of the CPU [W]	CPUs energy consumption [kJ]	Energy savings for CPUs	Node energy consumption [kJ]	Compute node energy savings	GFLOPS/W	Note
0,00	3,15	380	100,0%	235,9	179,1	0,0%	224,7	0,0%	0,98	Default settings
3,50	3,15	380	100,1%	237,8	180,7	-0,9%	226,3	-0,7%	0,97	
3,40	3,15	380	100,0%	237,7	180,6	-0,8%	226,2	-0,6%	0,97	
3,30	3,15	380	100,1%	237,5	180,5	-0,8%	226,1	-0,6%	0,97	
3,20	3,11	381	100,3%	234,9	178,9	0,2%	224,6	0,1%	0,98	
3,10	3,04	380	100,2%	228,6	174,0	2,9%	219,6	2,3%	1,00	
3,00	2,95	380	100,1%	222,7	169,3	5,5%	215,0	4,3%	1,02	
2,90	2,86	380	100,2%	215,9	164,3	8,3%	209,9	6,6%	1,04	
2,80	2,77	381	100,2%	210,1	159,9	10,7%	205,6	8,5%	1,07	
2,70	2,68	381	100,3%	203,9	155,4	13,3%	201,1	10,5%	1,09	
2,60	2,58	382	100,6%	198,8	151,9	15,2%	197,7	12,0%	1,11	
2,50	2,49	382	100,6%	194,0	148,1	17,3%	194,0	13,7%	1,13	
2,40	2,39	382	100,7%	188,5	144,1	19,6%	190,0	15,4%	1,15	No runtime penalty
2,30	2,30	384	101,1%	183,5	140,8	21,4%	186,9	16,8%	1,17	
2,20	2,20	387	101,8%	178,4	138,0	23,0%	184,4	18,0%	1,19	
2,10	2,10	386	101,6%	174,0	134,3	25,1%	180,6	19,7%	1,21	
2,00	2,00	388	102,1%	169,4	131,3	26,7%	177,8	20,9%	1,23	
1,90	1,90	394	103,9%	165,0	130,1	27,4%	177,4	21,0%	1,24	
1,80	1,80	394	103,7%	161,0	126,8	29,2%	174,0	22,6%	1,26	
1,70	1,70	397	104,5%	157,4	124,9	30,3%	172,5	23,3%	1,27	
1,60	1,60	405	106,6%	153,5	124,3	30,6%	172,9	23,1%	1,27	

1,50	1,50	406	106,9%	150,8	122,4	31,7%	171,2	23,8%	1,28	**Maximum energy savings**
1,40	1,40	411	108,4%	149,2	122,7	31,5%	172,1	23,4%	1,27	
1,30	1,30	420	110,5%	147,5	123,9	30,9%	174,2	22,5%	1,26	
1,20	1,20	424	111,7%	146,3	124,1	30,7%	175,0	22,1%	1,25	

Intel CSL - static tuning results

Info Time [s]

CF/UnCF [MHz]	0	2400	2200	2000	1800	1600	1400	1200
0	524,00	523,35	529,36	549,97	577,71	614,33	736,53	987,04
3300	523,19	522,66	529,98	549,18	577,70	614,68	736,69	986,60
3200	523,42	523,10	530,00	550,24	578,23	614,55	738,16	985,80
3100	523,87	523,16	532,26	550,23	577,79	615,56	737,84	987,16
3000	524,26	524,12	530,82	550,64	579,97	616,53	738,51	987,28
2900	524,77	525,31	531,99	551,68	579,14	616,63	740,59	987,48
2800	525,14	525,26	532,02	552,31	579,81	618,24	739,17	988,89
2700	525,83	526,42	533,54	553,21	581,63	618,81	740,47	990,50
2600	527,48	527,21	533,82	554,38	582,07	619,44	743,13	990,98
2500	529,07	528,12	534,98	555,59	583,04	620,70	742,34	992,53
2300	535,75	537,38	542,41	562,77	590,04	627,21	748,31	998,61
2100	545,84	544,97	552,37	571,14	598,70	636,93	755,41	1002,82
1900	558,24	556,84	563,49	583,59	609,81	646,75	765,81	1010,64
1700	574,19	572,93	579,21	599,06	624,68	661,12	778,77	1023,47
1500	596,55	594,04	600,81	620,10	645,72	681,06	795,67	1037,61
1300	626,19	623,63	631,35	648,58	672,94	709,16	820,49	1060,01

HDEEM Blade Energy Total [kJ]

CF/UnCF [MHz]	0	2400	2200	2000	1800	1600	1400	1200
0	212,43	212,32	207,06	206,72	208,86	215,44	243,68	303,37
3300	212,25	212,15	207,24	206,46	208,89	215,59	243,73	303,15
3200	211,95	211,90	206,73	206,08	208,19	214,65	243,36	301,91
3100	211,61	211,50	207,00	205,60	207,55	214,48	242,61	301,57
3000	211,33	211,33	205,95	205,16	207,67	214,16	242,05	300,78
2900	210,95	211,23	205,79	204,90	206,77	213,53	242,05	300,02
2800	210,59	210,66	205,24	204,54	206,37	213,42	240,91	299,65
2700	210,39	210,68	205,28	204,38	206,44	213,10	240,78	299,54
2600	210,52	210,53	204,95	204,30	206,13	212,80	241,01	299,07
2500	209,96	210,42	204,91	204,22	205,96	212,71	240,26	298,92
2300	199,06	200,27	194,07	192,99	193,68	199,80	224,25	278,02
2100	195,64	196,56	190,94	189,15	189,86	195,37	218,54	269,54
1900	193,40	194,55	188,37	186,71	186,56	191,80	214,35	263,33
1700	191,93	193,69	187,35	185,44	184,88	189,45	211,02	258,95
1500	191,13	193,27	187,09	184,03	183,43	187,61	207,29	251,83
1300	193,70	196,61	190,16	186,49	185,37	189,13	207,35	250,27

Nvidia A100 - static tuning results

Set GPU frequency [MHz]	Runtime [s]	Runtime extension	Average power consumption of the GPU [W]	Average power consumption of the CPU [W]	CPUs + GPUs energy consumption [kJ]	Energy savings for GPUs + CPUs	Node energy consumption [kJ]	Compute node energy savings	Note
1410	292,3	100,0%	91,7	140,3	296,5	0,0%	471,9	0,0%	**Default settings**
1350	293,4	100,4%	86,4	139,9	284,9	3,9%	461,0	2,3%	
1290	294,8	100,9%	82,3	139,9	276,6	6,7%	453,5	3,9%	
1230	295,2	101,0%	78,8	140,2	268,9	9,3%	446,0	5,5%	
1170	295,2	101,0%	75,8	140,4	262,0	11,6%	439,1	6,9%	**No runtime penalty**
1110	295,9	101,2%	73,4	139,8	256,5	13,5%	434,0	8,0%	
1050	297,2	101,7%	71,2	139,9	252,4	14,9%	430,8	8,7%	
990	298,8	102,2%	70,4	139,5	251,8	15,1%	431,1	8,6%	
930	298,7	102,2%	70,0	139,5	250,7	15,4%	429,9	8,9%	**Maximum energy savings**
870	302,2	103,4%	69,6	139,3	252,3	14,9%	433,7	8,1%	
810	305,1	104,4%	69,0	138,9	253,3	14,6%	436,3	7,5%	
750	308,3	105,5%	68,7	138,7	254,9	14,0%	439,9	6,8%	
690	317,1	108,5%	68,1	138,0	260,4	12,2%	450,7	4,5%	

Intel SPR HBM - static tuning results

Runtime [s]

CF/UnCF [MHz]	0	2500	2400	2200	2000	1800	1600	1400	1200	1000	800
0	122,92	123,95	123,07	125,27	123,64	123,39	123,09	130,55	139,09	159,91	186,87
3500	121,85	123,84	122,49	124,64	122,87	122,91	122,57	129,49	139,11	157,83	186,97
3300	121,81	122,09	123,01	122,94	124,57	121,86	124,29	128,31	140,58	157,96	187,17
3100	123,70	122,36	124,12	123,04	125,04	121,80	125,03	128,47	140,21	156,50	188,76
2900	123,95	122,12	124,45	123,35	124,65	**121,71**	124,79	128,54	140,65	156,39	186,96
2700	123,84	122,44	124,58	123,31	125,59	122,13	124,17	128,53	140,88	156,40	187,41
2500	123,76	123,08	123,80	124,06	124,85	122,35	123,40	130,47	142,09	157,36	187,91
2300	124,62	126,39	124,61	127,00	125,40	125,78	125,20	133,52	143,87	159,04	189,57
2100	127,82	128,49	126,79	129,89	128,28	127,82	130,15	138,20	147,10	165,88	193,68
1900	139,57	133,72	135,92	133,53	135,21	134,63	140,44	145,21	157,28	173,66	204,50
1700	152,91	146,90	148,38	146,23	145,28	145,32	149,69	156,04	165,02	183,25	216,89
1500	169,32	160,38	162,50	162,48	161,81	162,39	169,70	170,25	178,35	215,61	267,49
1300	196,29	193,27	192,98	189,33	190,54	192,47	197,88	199,80	208,79	220,92	256,74
1100	227,62	227,13	219,69	221,75	221,75	220,45	221,86	228,33	234,32	248,87	263,87
900	271,04	262,71	272,96	267,15	261,50	257,21	267,44	268,19	272,77	283,65	313,26
800	318,38	296,43	306,38	296,40	299,59	302,85	302,98	304,78	304,79	308,83	317,60

RAPL Energy + Baseline [kJ]

CF/UnCF [MHz]	0	2500	2400	2200	2000	1800	1600	1400	1200	1000	800
0	109,96	110,96	110,15	112,05	110,42	110,01	109,05	113,46	116,50	128,85	144,96
3500	109,02	110,87	109,63	111,48	109,80	109,45	108,64	112,60	116,49	127,32	145,14
3300	109,00	109,30	110,10	109,97	111,32	108,61	110,02	111,68	117,65	127,42	145,14
3100	110,71	109,55	111,09	110,05	111,73	108,62	110,72	111,84	117,39	126,30	146,25
2900	110,93	109,33	111,39	110,33	111,38	**108,53**	110,50	111,89	117,72	126,19	145,05
2700	110,84	109,61	111,49	110,28	112,22	108,88	110,10	111,86	117,82	126,23	145,31
2500	110,71	110,17	110,76	110,91	111,49	108,98	109,13	113,02	118,35	126,19	144,15
2300	111,47	113,08	111,42	113,42	111,79	111,42	109,71	112,60	116,75	124,48	141,69
2100	114,24	114,87	113,26	115,82	113,88	112,17	110,86	113,15	116,03	125,78	140,65
1900	118,83	119,37	121,23	118,69	118,82	114,83	115,06	114,89	119,50	127,25	143,34
1700	128,30	130,85	131,91	128,82	125,01	120,09	119,12	119,76	122,00	130,59	147,95
1500	139,80	142,56	143,89	141,04	134,83	129,34	129,79	126,33	127,70	147,59	175,13
1300	156,60	170,13	168,53	158,62	152,04	146,56	145,16	141,90	143,32	147,48	164,85
1100	169,61	196,74	186,40	178,69	170,13	161,68	157,17	156,05	155,06	160,23	165,15
900	182,22	221,51	222,89	206,62	192,75	181,52	181,28	176,17	173,66	175,77	188,59
800	199,95	245,27	245,14	224,73	215,48	207,72	200,38	195,01	189,88	187,73	188,59

Intel SPR DDR - static tuning results

Runtime [s]

CF/UnCF [MHz]	0	2500	2400	2200	2000	1800	1600	1400	1200	1000	800
0	222,06	221,90	222,04	222,45	222,80	224,95	226,32	234,88	265,28	309,98	378,52
3500	222,01	222,68	222,44	222,57	221,97	223,23	226,71	234,50	265,78	309,56	377,46
3300	222,79	221,35	222,63	221,55	222,92	223,56	227,22	234,36	266,36	311,49	379,07
3100	221,84	222,20	221,11	222,11	222,66	224,61	225,28	234,68	266,69	311,17	379,03
2900	221,34	222,26	222,09	223,15	222,79	223,92	227,03	235,53	266,97	311,45	378,27
2700	222,17	222,43	222,08	221,88	222,83	224,26	226,84	236,58	266,86	310,41	378,65
2500	222,21	222,13	222,04	222,32	223,01	224,35	226,57	234,08	267,08	310,69	380,05
2300	222,82	222,85	222,85	223,31	224,52	225,48	227,57	234,92	269,16	314,35	384,23
2100	224,13	223,90	224,40	225,13	226,16	227,52	229,58	237,45	271,28	314,77	384,39
1900	228,84	226,94	227,00	228,35	228,43	231,16	232,60	241,05	276,27	318,55	387,94
1700	232,65	230,10	231,34	230,30	233,12	234,49	236,13	244,34	280,25	323,83	391,74
1500	239,29	235,49	236,60	236,34	239,94	240,07	241,56	249,26	286,34	333,54	400,89
1300	247,34	242,65	244,29	244,11	246,74	247,34	249,81	256,94	297,56	340,64	408,06
1100	259,08	254,29	255,69	255,83	259,12	258,57	260,41	269,20	314,51	357,67	428,42
900	276,95	271,74	273,61	274,75	287,90	276,54	277,54	290,82	338,42	385,39	453,69
800	290,76	286,45	286,56	295,38	312,61	288,99	291,30	299,87	363,30	407,37	477,10

RAPL Energy + Baseline [kJ]

CF/UnCF [MHz]	0	2500	2400	2200	2000	1800	1600	1400	1200	1000	800
0	201,20	201,10	201,17	200,63	197,88	190,96	185,86	186,71	202,93	228,96	267,31
3500	201,14	201,80	201,54	200,78	197,09	189,79	186,09	186,30	202,98	228,09	266,16
3300	201,84	200,60	201,71	199,84	197,93	190,03	186,50	186,19	203,60	229,50	267,47
3100	200,99	201,30	200,35	200,34	197,63	190,85	184,86	186,42	203,82	229,20	267,51
2900	200,57	201,40	201,23	201,24	197,54	190,34	186,22	187,13	204,16	229,51	266,80
2700	201,30	201,57	201,21	200,13	197,77	190,49	186,14	187,94	204,10	228,77	267,34
2500	201,33	201,28	201,14	200,31	196,18	188,97	184,10	183,98	201,77	226,12	264,77
2300	201,77	201,87	201,54	200,42	193,40	185,67	180,92	180,54	198,44	223,06	260,92
2100	202,67	202,53	202,24	199,49	190,60	183,20	178,29	178,15	194,99	217,68	254,29
1900	202,45	204,59	203,82	197,58	187,32	180,63	175,34	175,52	192,38	213,64	248,82
1700	204,10	206,92	207,04	195,97	187,68	179,96	174,67	174,57	191,33	212,84	246,27
1500	207,09	211,06	209,74	197,32	189,57	180,82	175,37	174,41	191,56	214,63	247,01
1300	209,73	215,92	212,78	199,77	191,18	182,57	177,39	176,12	194,90	214,72	246,55
1100	213,76	223,35	217,75	204,93	196,07	186,65	180,89	180,35	201,20	220,34	253,15
900	219,64	232,94	226,92	214,21	211,54	194,62	187,90	189,79	210,79	231,55	262,26
800	224,75	241,40	234,22	226,20	225,64	200,36	194,25	193,15	222,81	241,21	272,26

Yambo

Following table summarizes the energy cosumption measurements for Yambo on all platforms.

Hardware	Energy efficiency	Node energy consumption	HW configuration	Runtime
AMD Zen2 (RAPL + Baseline)	0.69 GFLOPs/W	215.90 kJ	default	337 s (100%)
	0.73 GFLOPs/W	203.98 kJ (**-6%**)	CF 3.0 GHz	100%
	0.89 GFLOPs/W	166.78 kJ (**-23%**)	CF 2.0 GHz	115%
AMD Zen3 (RAPL + Baseline)	0.76 GFLOPs/W	195.90 kJ	default	290 s (100%)
	0.94 GFLOPs/W	157.91 kJ (**-19%**)	CF 2.4 GHz	100%
	0.96 GFLOPs/W	153.62 kJ (**-22%**)	CF 2.0 GHz	109%
Intel Cascade lake	0.55 GFLOPs/W (HDEEM Blade)	322.13 kJ HDEEM 303,30 kJ RAPL	default	747 s (100%)
	0.57 GFLOPs/W (HDEEM Blade)	311.58 kJ (**-3%**) HDEEM 294.36 J (**-3%**) RAPL	CF 2,7 GHz UCF 2,2 GHz	101%
	0.63 GFLOPs/W (HDEEM Blade)	278.54 J (**-14%**) HDEEM 267.45 J (**-12%**) RAPL	CF 1,9 GHz UCF 1,8 GHz	116%
Intel Sapphire Rapids + HBM	1.20 GFLOPs/W	207.67 kJ RAPL	default	235 s (100%)
	1.33 GFLOPs/W	191.27 J (**-8%**) RAPL	CF default UCF 1.4 GHz	97%
	1.33 GFLOPs/W	191.27 kJ (**-8%**) RAPL	CF default UCF 1.4 GHz	97%
Intel Sapphire Rapids + DDR	1.16 GFLOPs/W	214.11 kJ RAPL	default	240 s (100%)
	1.20 GFLOPs/W	209.90 kJ (**-2%**) RAPL	CF 3.1 GHz UCF 1.8 GHz	101%
	1.26 GFLOPs/W	204.02 J (**-5%**) RAPL	CF 2.3 GHz UCF 1.4 GHz	107%
Nvidia A100	n/a	1246.50 kJ	default	623 s (100%)
	n/a	n/a	n/a	100%
	n/a	1154.98 kJ (**-7%**)	1170 MHz	111%

AMD Zen2 - static tuning results

Set CPU frequency [GHz]	Real CPU frequency [GHz]	Runtime [s]	Runtime extension	Average power consumption of the CPU [W]	CPUs energy consumption [kJ]	Energy savings for CPUs	Node energy consumption [kJ]	Compute node energy savings	GFLOPS /W	Note
3,30	3,11	337	100,0%	260,1	175,4	0,0%	215,9	0,0%	0,69	Default settings
3,20	3,10	336	99,7%	257,2	173,0	1,4%	213,4	1,2%	0,69	
3,10	3,06	336	99,5%	251,9	169,0	3,6%	209,3	3,1%	0,71	
3,00	2,99	336	99,7%	243,3	163,6	6,7%	204,0	5,5%	0,73	No runtime penalty
2,90	2,90	341	101,0%	229,9	156,6	10,7%	197,5	8,5%	0,75	
2,80	2,80	343	101,8%	218,7	150,2	14,4%	191,4	11,4%	0,77	
2,70	2,70	348	103,2%	209,3	145,6	17,0%	187,4	13,2%	0,79	
2,60	2,60	351	104,1%	201,0	141,2	19,5%	183,3	15,1%	0,81	
2,50	2,50	357	106,0%	192,8	137,8	21,5%	180,7	16,3%	0,82	
2,40	2,40	363	107,6%	184,7	134,0	23,6%	177,6	17,7%	0,83	
2,30	2,30	367	108,7%	176,2	129,2	26,4%	173,2	19,8%	0,86	
2,20	2,20	373	110,7%	168,9	126,1	28,1%	170,9	20,8%	0,87	
2,10	2,10	380	112,6%	162,1	123,1	29,8%	168,7	21,9%	0,88	
2,00	2,00	386	114,5%	156,0	120,4	31,3%	166,8	22,8%	0,89	Maximum energy savings
1,90	1,90	395	117,1%	151,5	119,7	31,8%	167,1	22,6%	0,89	
1,80	1,80	403	119,7%	148,9	120,2	31,5%	168,6	21,9%	0,88	
1,70	1,70	416	123,2%	146,3	121,6	30,7%	171,5	20,6%	0,86	
1,60	1,60	430	127,5%	143,5	123,5	29,6%	175,1	18,9%	0,85	
1,50	1,50	447	132,6%	140,6	125,7	28,3%	179,4	16,9%	0,83	
1,40	1,40	465	137,9%	137,9	128,3	26,9%	184,1	14,7%	0,80	
1,30	1,30	489	145,1%	135,0	132,0	24,7%	190,7	11,7%	0,78	
1,20	1,20	514	152,5%	131,9	135,7	22,7%	197,4	8,6%	0,75	

AMD Zen3 - static tuning results

Set CPU frequency [GHz]	Real CPU frequency [GHz]	Runtime [s]	Runtime extension	Average power consumption of the CPU [W]	CPUs energy consumption [kJ]	Energy savings for CPUs	Node energy consumption [kJ]	Compute node energy savings	GFLOPS /W	Note
0,00	3,14	290	100,0%	278,3	161,2	0,0%	195,9	0,0%	0,76	Default settings
3,50	3,13	280	96,7%	279,5	156,5	2,9%	190,1	3,0%	0,78	
3,40	3,13	273	94,3%	280,0	153,0	5,1%	185,8	5,2%	0,80	
3,30	3,13	277	95,8%	279,7	155,2	3,7%	188,4	3,8%	0,79	
3,20	3,11	274	94,6%	278,2	152,4	5,4%	185,3	5,4%	0,80	
3,10	3,06	272	94,1%	273,2	148,9	7,6%	181,6	7,3%	0,82	
3,00	2,99	272	93,8%	267,3	145,2	9,9%	177,9	9,2%	0,83	
2,90	2,90	270	93,3%	265,3	143,3	11,1%	175,7	10,3%	0,84	
2,80	2,80	275	94,9%	250,3	137,5	14,7%	170,5	13,0%	0,87	
2,70	2,70	278	96,0%	241,0	134,0	16,9%	167,3	14,6%	0,89	
2,60	2,60	282	97,2%	230,5	129,8	19,5%	163,6	16,5%	0,91	
2,50	2,50	290	100,1%	221,6	128,5	20,2%	163,3	16,6%	0,91	
2,40	2,40	290	100,1%	212,4	123,1	23,6%	157,9	19,4%	0,94	No runtime penalty
2,30	2,30	297	102,6%	204,3	121,3	24,7%	157,0	19,9%	0,94	
2,20	2,20	302	104,4%	196,8	119,1	26,1%	155,4	20,7%	0,95	
2,10	2,10	311	107,4%	189,4	117,8	26,9%	155,1	20,8%	0,96	
2,00	2,00	317	109,4%	182,5	115,6	28,3%	153,6	21,6%	0,96	Maximum energy savings
1,90	1,90	328	113,4%	175,8	115,5	28,4%	154,9	20,9%	0,96	
1,80	1,80	341	117,7%	169,4	115,5	28,3%	156,4	20,2%	0,95	
1,70	1,70	357	123,2%	163,4	116,6	27,6%	159,5	18,6%	0,93	

1,60	1,60	366	126,3%	157,9	115,5	28,3%	159,4	18,6%	0,93	
1,50	1,50	381	131,6%	152,6	116,3	27,8%	162,1	17,3%	0,91	
1,40	1,40	401	138,4%	149,6	119,9	25,6%	167,9	14,3%	0,88	
1,30	1,30	421	145,4%	146,3	123,2	23,5%	173,7	11,3%	0,85	
1,20	1,20	450	155,6%	142,8	128,7	20,1%	182,7	6,7%	0,81	

Intel CSL - static tuning results

Runtime [s]

CF/UnCF [MHz]	0	2400	2200	2000	1800	1600	1400	1200
0	747,26	747,20	746,67	773,51	785,35	824,05	915,94	1071,97
3300	745,66	746,57	749,84	762,77	789,82	815,09	915,45	1072,74
3200	744,51	746,46	749,26	764,13	786,45	815,81	913,44	1070,90
3100	757,74	743,80	749,11	772,83	790,38	815,88	937,23	1073,47
3000	744,97	746,21	747,14	763,67	811,15	816,70	935,47	1072,33
2900	744,04	742,98	748,33	765,48	789,30	818,94	919,14	1098,65
2800	745,10	745,94	751,02	767,89	789,81	820,66	917,45	1075,99
2700	747,99	750,08	753,62	799,71	793,83	841,96	926,20	1081,54
2600	750,81	752,00	759,49	778,02	798,36	829,85	941,27	1082,48
2500	757,77	757,63	789,31	777,93	801,32	832,79	948,36	1089,01
2300	777,12	777,65	778,51	798,17	818,91	850,19	953,53	1113,92
2100	799,85	797,19	801,85	818,31	845,49	871,42	970,18	1141,58
1900	832,15	829,92	835,99	849,39	868,20	897,66	1008,50	1166,99
1700	880,53	878,15	883,07	896,00	911,46	933,95	1073,70	1194,38
1500	1005,78	942,78	948,91	960,25	973,21	993,43	1064,29	1220,63
1300	1038,30	1038,47	1042,86	1057,28	1064,23	1083,86	1155,15	1260,61

HDEEM Blade Energy Total [kJ]

CF/UnCF [MHz]	0	2400	2200	2000	1800	1600	1400	1200
0	322,13	322,28	316,91	318,92	314,23	321,47	342,06	379,82
3300	321,62	321,95	317,96	315,54	315,69	318,74	341,91	380,06
3200	320,63	321,37	317,04	314,42	312,88	316,83	338,33	375,41
3100	324,24	319,83	316,25	315,45	312,00	314,46	342,17	372,52
3000	319,59	319,96	314,23	310,84	315,83	312,59	338,99	368,65
2900	317,96	317,70	313,11	309,59	307,31	310,48	330,94	371,44
2800	317,18	317,44	312,56	308,23	304,93	308,32	327,63	362,05
2700	317,01	317,77	311,58	314,73	304,08	311,70	327,57	360,76
2600	316,52	316,87	311,58	307,16	303,35	306,67	329,00	358,25
2500	311,07	316,99	317,89	305,42	302,41	305,61	328,60	357,48
2300	304,62	311,26	299,95	294,58	290,60	293,22	312,01	343,53
2100	297,01	303,82	292,49	285,60	283,04	283,94	300,82	332,91
1900	294,25	302,11	291,05	283,40	278,54	280,26	298,51	327,02
1700	296,45	305,22	293,41	285,53	279,33	279,03	302,25	322,60
1500	313,21	312,06	300,17	291,19	283,95	282,44	291,22	317,01
1300	314,17	326,70	313,45	303,87	294,05	292,16	300,51	315,19

Nvidia A100 - static tuning results

Set GPU frequency [GHz]	Runtime [s]	Runtime extension	Average power consumption of the GPU [W]	Average power consumption of the CPU [W]	CPUs + GPUs energy consumption [kJ]	Energy savings for GPUs + CPUs	Node energy consumption [kJ]	Compute node energy savings	Note
1410	622,7	100,0%	146,5	114,8	872,9	0,0%	1246,5	0,0%	**Default settings, No runtime penalty**
1350	654,8	105,2%	130,7	114,9	834,9	4,3%	1227,8	1,5%	
1290	685,6	110,1%	117,7	114,2	802,4	8,1%	1213,8	2,6%	
1230	698,0	112,1%	110,2	114,0	774,4	11,3%	1193,1	4,3%	
1170	691,8	111,1%	105,1	114,5	739,9	15,2%	1155,0	7,3%	**Maximum energy savings**
1110	716,9	115,1%	98,8	114,6	731,0	16,3%	1161,2	6,8%	
1050	770,7	123,8%	92,1	114,1	744,0	14,8%	1206,4	3,2%	
990	755,9	121,4%	91,3	114,2	724,7	17,0%	1178,2	5,5%	
930	797,0	128,0%	88,9	114,1	748,5	14,2%	1226,7	1,6%	
870	825,4	132,6%	87,4	114,1	765,1	12,3%	1260,4	-1,1%	
810	864,2	138,8%	85,4	113,8	787,0	9,8%	1305,5	-4,7%	
750	915,2	147,0%	83,4	113,8	819,2	6,1%	1368,4	-9,8%	
690	960,6	154,3%	81,8	113,7	846,8	3,0%	1423,1	-14,2%	

SPR HBM - static tuning results

Runtime [s]

CF/UnCF [MHz]	0	2500	2400	2200	2000	1800	1600	1400	1200	1000	800
0	235,15	235,22	227,99	232,18	262,20	232,75	227,56	228,83	237,61	247,41	264,08
3500	237,70	240,08	239,24	245,62	247,65	245,77	241,09	240,22	248,79	264,55	293,29
3300	268,34	272,29	275,84	257,88	242,89	236,98	234,14	236,55	244,95	264,31	305,73
3100	235,59	245,09	239,63	236,71	264,63	260,11	272,71	262,14	269,45	286,69	318,79
2900	251,16	256,66	265,12	250,21	256,02	250,02	253,78	250,90	257,54	275,58	304,33
2700	242,93	250,39	245,22	233,36	233,17	229,85	225,55	229,66	238,92	248,78	294,70
2500	239,53	245,57	240,64	243,49	244,56	241,12	237,28	240,38	258,56	262,05	284,54
2300	255,75	242,20	243,17	242,26	240,21	248,64	239,09	244,06	263,81	259,95	281,54
2100	246,46	268,76	246,12	245,88	250,46	245,07	248,13	251,14	261,83	279,43	285,67
1900	295,55	263,65	259,61	260,64	265,29	263,01	268,67	273,10	272,10	278,21	293,18
1700	302,40	281,90	300,33	303,41	287,60	300,92	284,23	305,29	296,83	328,64	314,80
1500	333,87	315,44	309,85	324,60	322,52	312,53	313,00	318,97	324,17	331,32	385,99
1300	396,43	356,50	352,35	354,32	358,31	356,64	360,89	360,31	367,34	411,93	383,28
1100	431,24	412,69	428,12	406,01	413,78	476,44	409,47	419,51	492,40	464,71	433,28
900	517,97	497,03	494,16	496,62	504,40	495,06	536,20	523,59	506,63	508,10	512,83
800	567,70	556,81	563,40	554,03	552,59	554,72	573,64	558,04	599,31	617,85	616,62

RAPL Energy + Baseline [kJ]

CF/UnCF [MHz]	0	2500	2400	2200	2000	1800	1600	1400	1200	1000	800
0	207,67	208,58	202,54	204,38	223,49	200,48	194,84	191,27	192,68	195,62	202,77
3500	209,52	212,54	211,25	214,32	213,43	209,51	203,78	198,54	199,59	206,06	220,19
3300	233,90	238,24	239,66	224,43	210,29	203,53	199,15	196,20	197,12	205,86	227,82
3100	208,24	216,77	211,91	207,93	225,30	219,11	224,28	212,29	212,23	219,53	235,24
2900	220,50	225,53	231,22	217,39	219,13	212,15	211,79	205,13	204,70	212,50	226,72
2700	213,92	220,56	215,59	205,37	203,05	198,53	193,29	191,56	193,35	196,21	220,87
2500	210,95	216,46	211,95	212,06	210,51	205,62	200,45	197,70	204,61	203,48	213,84
2300	223,50	213,66	213,66	210,61	206,78	208,57	198,35	196,52	204,10	198,49	208,07
2100	217,07	234,33	216,14	213,13	212,02	203,79	199,96	196,75	198,55	205,40	205,88
1900	212,57	231,85	227,36	223,20	220,82	211,25	208,60	205,79	200,53	200,48	205,55
1700	211,57	246,92	257,17	252,57	231,86	231,30	214,42	221,00	210,91	224,78	213,58
1500	222,61	272,38	264,88	263,77	250,80	234,91	228,13	225,43	222,60	222,39	247,77
1300	251,76	303,51	293,40	279,90	269,88	258,07	252,50	245,20	242,73	262,09	242,30
1100	264,24	341,04	342,35	310,14	300,95	325,63	276,94	274,51	306,55	286,10	264,40
900	304,06	396,28	383,45	364,73	352,51	332,44	344,86	327,77	309,84	304,11	300,62
800	326,76	436,32	428,35	399,42	379,59	364,65	363,41	344,03	356,45	358,74	350,54

SPR DDR - static tuning results

Runtime [s]

CF/UnCF [MHz]	0	2500	2400	2200	2000	1800	1600	1400	1200	1000	800
0	239,70	244,30	240,37	240,53	238,01	243,78	246,72	254,18	264,21	279,64	299,24
3500	239,68	238,82	240,52	239,30	238,93	244,41	245,01	273,68	259,86	276,32	306,01
3300	237,89	239,72	238,31	238,59	240,16	249,81	244,08	250,82	263,55	275,64	299,01
3100	239,28	239,58	239,25	252,72	239,91	242,85	258,71	252,99	263,22	291,51	300,38
2900	238,61	242,24	272,20	238,57	254,62	263,64	250,92	275,03	263,53	286,12	300,37
2700	237,07	237,97	254,35	240,57	249,74	246,00	246,87	251,97	261,08	274,90	326,28
2500	236,54	237,84	238,57	238,28	238,77	254,39	245,00	252,64	262,04	275,23	299,37
2300	244,60	264,25	243,69	242,19	249,15	248,45	251,43	255,82	266,84	279,66	323,00
2100	263,68	254,06	253,07	254,34	255,44	257,71	261,65	277,31	278,69	292,31	315,58
1900	291,09	283,07	268,68	294,83	299,00	279,75	284,46	302,03	299,12	312,73	348,53
1700	326,05	295,34	292,09	304,31	294,01	299,46	304,44	310,54	321,47	330,79	355,18
1500	354,73	318,63	322,23	321,48	343,86	328,74	334,78	338,67	372,25	364,87	386,73
1300	402,79	363,77	362,89	369,24	368,14	374,86	396,91	384,45	388,55	403,19	446,80
1100	459,95	420,49	426,16	420,55	425,25	438,60	429,57	433,49	447,41	461,08	475,24
900	547,89	522,56	528,23	504,23	504,83	508,51	504,92	520,30	531,21	531,53	550,68
800	598,45	556,75	555,75	562,58	569,59	598,19	568,06	572,34	584,43	584,16	694,41

RAPL Energy + Baseline [kJ]

CF/UnCF [MHz]	0	2500	2400	2200	2000	1800	1600	1400	1200	1000	800
0	214,11	218,72	215,38	214,11	210,36	210,54	207,57	207,09	208,65	214,82	223,08
3500	214,30	214,34	215,45	213,16	211,06	210,97	206,24	219,54	205,95	212,78	227,26
3300	212,85	215,07	213,73	212,63	211,84	214,64	205,63	204,88	208,34	212,29	222,83
3100	214,12	214,94	214,44	222,99	211,74	209,90	215,15	206,30	208,13	221,85	223,82
2900	213,63	217,06	239,84	212,63	222,08	224,00	210,16	220,33	208,41	218,62	223,78
2700	212,55	213,67	226,14	214,07	218,59	212,06	207,47	205,65	206,65	211,87	239,31
2500	212,06	213,48	213,82	212,11	210,62	217,20	205,75	205,50	206,76	211,35	222,45
2300	218,68	234,04	217,74	214,80	217,39	210,28	206,44	204,02	205,98	210,24	231,84
2100	233,88	226,97	225,20	223,23	218,70	212,19	208,50	212,77	208,74	213,06	222,76
1900	215,41	249,87	237,78	250,58	243,32	222,05	218,36	223,14	216,19	220,15	236,16
1700	225,75	260,22	254,79	254,07	236,40	230,74	226,89	224,56	225,17	226,14	235,65
1500	236,78	277,79	275,95	261,98	264,65	245,03	241,21	236,79	249,77	240,92	248,44
1300	257,20	309,84	300,98	290,02	276,30	269,17	273,80	259,25	254,74	257,68	275,96
1100	281,60	346,81	341,19	319,72	308,31	303,15	288,66	282,45	282,24	284,16	285,96
900	322,40	414,74	406,84	370,05	353,10	340,68	327,44	326,11	323,07	316,78	320,18
800	344,90	436,75	423,56	405,07	390,25	390,68	360,63	352,38	348,88	341,57	390,19

JUBE continuous monitoring

The requirement of streamlining benchmarking and profiling MaX applications on different platforms led to the implementation of an ecosystem of JUBE script, JUBE4MaX, described in D3.1. The tool, developed at Julich Supercomputing Center provides a script-based framework to easily create benchmark sets, run them on different computer systems, and evaluate the results. For each benchmark application, the benchmark data is written in a certain format that allows JUBE to obtain the desired information. The data analysis can be automated by pre- and post-processing scripts extracting information and storing it, so it can be easily retrieved for postprocessing and visualization.

The possibility to automatize benchmarks/profiling with JUBE and the standardization of the outputs, is an important aspect to ensure the reproducibility and hence comparability of the results. In this respect, JUBE can help in performing and analyzing benchmarks in a systematic way, and it allows custom workflows to be able to adapt to new architectures. One key advantage of using JUBE, as opposed to manually running an application in different configurations in a job script, is that individual run configurations are automatically separated into different work packages with individual run directories, while common files and directories (like input files, preprocessing, etc.) can easily be integrated into the workflow.

Further, JUBE's commands can cover all actions common to a benchmarking/profiling session:

- *jube run* executes a number of commands populating the work packages and submitting the job scripts,
- *jube analyze* parses the log files and collects the result of the benchmark, while
- j*ube result* organizes the data parsed across work packages in tables.

JUBE4MaX

The implementation of the JUBE4MaX repository follows a building-block approach, where the different parameters of a benchmark/profiling session are combined from separated xml scripts. These are organized into a structure of folders related to 4 different aspects, involved in a benchmark:

- Applications: containing the application parameters such as the name of the executable, the definition of the arguments, the regex patterns to parse in the application logfile (energy, time of inner clocks, etc.);

- Platforms: containing the cluster parameters such as the number of sockets, cores per node, gpus per node, Slurm options, for example in order to derive a given mapping of the mpi task over the node;
- Workloads: containing the input files of selected benchmarks for an application and the related parameters
- Scripts: containing parameter definition and wrappers needed to measure the application with external tool (nvidia-smi, Score-P, HDEEM for example)

These scripts can be included from a common profiling/benchmarking interface, which is the only file to be actually exposed/modified by the user running the benchmark with JUBE. Here, benchmark-related parameters such as the actual number of nodes, tasks per node, install to be used for the benchmarks are defined; all the operations such as the generation of the directories for the different parameters in the benchmark, copy of the files needed for each benchmark (jobscripts, wrappers) and job submission is automatically managed with the command jube run. Once the outputs of the benchmark are ready, our scripts also cover the parsing of the logfiles to extract how specific metrics vary for the different executions of the benchmark (e.g. the energy used, the GPU memory, etc.).

To monitor energy consumption of MaX codes executed on Barbora cluster, the JUBE4MaX ecosystem has been extended to support Atos High Definition Energy Efficient Monitoring (HDEEM), which provides fine-grain power monitoring of the compute node and on-node subunits.

The JUBE configuration file scripts/hdeem/scripts.xml contains three main tags:

1. Parameterset for profiling “profilingset”, containing the strings to start and stop the profiling demons on the nodes before and after the application execution, the command to check the HDEEM report and the name of the file to parse to collect selected metrics from the various workpackages of the benchmark

```
<parameterset name="profilingset">
    <parameter name="daemon" >checkHdeem</parameter>
    <parameter name="profout">stats.hdeem.*.out</parameter>
    <parameter name="startstr">srun -N $SLURM_NNODES --ntasks-per-node=1 starter.sh</parameter>
    <parameter name="stopstr">srun -N $SLURM_NNODES --ntasks-per-node=1 stopper.sh</parameter>
</parameterset>
```

2. Dos needed after the job execution to modify the checkHdeem utility output and enable parsing selected metrics

```
<dos>
  <do>echo "postprocessing reports..."</do>
  <do>for file in hdeem.*.out ; do awk '/HDEEM_VERSION/ {flag=1;next} /HDEEM statistics total/
{flag=0} flag { print }' $file > stats.$file ; done </do>
  <do>echo "... done. Files are ready to be analyzed"</do>
</dos>
```

3. The copy command, which defines the action and the path of the wrappers to start/stop HDEEM;

```
<fileset name="profilingfiles">
  <copy>./wrappers/*</copy>
</fileset>
```

Postprocessing is instead managed by an analyze.xml script, specific for the HDEEM output and the platform where the application is measured. The output of hdeem contains indeed energy-related metrics for every sensor detected on the node, and the available sensors depend on the platform where the benchmark is run. Currently, it is not possible to define patterns to parse a posteriori of the benchmark, once HDEEM has reported the available sensors; this would require using an additional application as a "source code" generator. Coherently with the building-block approach depicted above, we implement different xml files for the platforms supported. For example, for Barbora, we have:

`/scripts/hdeem/analyze/it4i/barbora/analyze.xml`

```
<?xml version="1.0" encoding="UTF-8"?>
<jube>

    <patternset name="pattern">
      <pattern name="duration" type="float">Polling duration\s+\(s\) : ${jube_pat_fp}</pattern>
      <pattern name="blade_w" type="float">BLADE\s+${jube_pat_fp}\s+${jube_pat_nfp}</pattern>
      <pattern name="blade_e" type="float">BLADE\s+${jube_pat_nfp}\s+${jube_pat_fp}</pattern>
      <pattern name="cpu0_w" type="float">CPU0\s+${jube_pat_fp}\s+${jube_pat_nfp}</pattern>
      <pattern name="cpu1_w" type="float">CPU1\s+${jube_pat_fp}\s+${jube_pat_nfp}</pattern>
                                                    <pattern          name="cpu0_e"
type="float">CPU0${jube_pat_nint}\s+${jube_pat_nfp}\s+${jube_pat_fp}</pattern>
                                                    <pattern          name="cpu1_e"
type="float">CPU1${jube_pat_nint}\s+${jube_pat_nfp}\s+${jube_pat_fp}</pattern>
```

```
                                                                    <pattern           name="ddr_w"
type="float">DDR\_${jube_pat_nwrd}\s+${jube_pat_fp}\s+${jube_pat_nfp}</pattern>
                                                                    <pattern           name="ddr_e"
type="float">DDR\_${jube_pat_nwrd}\s+${jube_pat_nfp}\s+${jube_pat_fp}</pattern>
    </patternset>

   <table name="result" style="csv" sort="nodes" >
      <column title="Nodes">nodes</column>
      <column title="Tasks">tasks</column>
      <column format=".3f" title="duration (s)">duration_max</column>
      <column format=".3f" title="blade_av_power (W)">blade_w_avg</column>
      <column format=".3f" title="blade_av_energy (J)">blade_e_avg</column>
      <column format=".3f" title="cpu0_av_power (W)">cpu0_w_avg</column>
      <column format=".3f" title="cpu0_av_energy (J)">cpu0_e_avg</column>
      <column format=".3f" title="cpu1_av_power (W)">cpu1_w_avg</column>
      <column format=".3f" title="cpu1_av_energy (J)">cpu1_e_avg</column>
      <column format=".3f" title="ddr_av_power (W)">ddr_w_avg</column>
      <column format=".3f" title="ddr_av_energy (J)">ddr_e_avg</column>
   </table>

</jube>
```

This approach can be extended to any platform supporting hdeem.

The following is an example of energy and power measured by the HDEEM and parsed by the JUBE. Here the values over available DDR power sensors are averaged, but it is possible to print them all separately, if needed, also after the benchmark has run (configuration.xml file should be modified).

Example output of a JUBE result:

```
Nodes,Tasks,duration(s),blade_av_power(W),blade_av_energy(J),cpu0_av_power(W),cpu0_av_energy
(J),cpu1_av_power(W),cpu1_av_energy(J),ddr_av_power(W),ddr_av_energy(J)

1,36,16.066,369.099,5929.577,137.009,2201.740,136.424,2192.337,9.971,160.229
2,72,12.616,367.979,4641.316,136.620,1722.779,140.150,1767.293,8.848,111.570
```

This approach can be eventually extended to provide also dynamical values, in addition to summarized ones as done in this example.

Applications energy efficiency analysis summary

Out of the CPU architecture used in this deliverable, the most efficient one in terms of FLOPS per Watt is the Sapphire Rapids generation from Intel. It is understandable as this is the most recent CPU architecture we have used. The following table contains results for optimal configurations which did not extended the runtime.

Code	HW platform	Efficiency
BigDFT	SPR+HBM	282 MFLOPs/W
Fleur	SPR+HBM, AMD Zen2	1.82 GFLOPs/W
QE	SPR+HBM	4.56 GFLOPs/W
Siesta	SPR+HBM	2.57 GFLOPs/W
Yambo	SPR+HBM	1,33 GFLOPs/W

Currently a significant portion of the EuroHPC systems is based on the AMD Zen2 and Zen3 CPU architecture and Nvidia A100 GPU architecture. In the deliverable we have presented the results for the individual application for energy optimization using static tuning. Following table summarizes these findings. Please note that (i) the energy savings are described by the negative number: for instance -26% means that the 26% of energy was saved; (ii) the runtime extension is described by number higher than 100%, where 100% stands for default runtime: for instance 115% means the runtime is extended to 115% of the default runtime.

	BigDFT	Fleur	Quantum Espreso	Siesta	Yambo
	Energy consumption reduction[kJ] / Runtime[s] 1st row - resutls with no runtime extension (runtime close to 100% of default) 2nd row - results for maximun energy savings				
AMD Zen2	**-17%** / 101% **-26%** / 115%	**-3%** / 101% **-9%** / 107%	**-2%** / 100% **-8%** / 112%	**-15%** / 100% **-24%** / 102%	**-6%** / 100% **-23%** / 115%
AMD Zen3	**-12%** / 102% **-23%** / 113%	**-7%** / 101% **-13%** / 112%	**-8%** / 100% **-12%** / 110%	**-15%** / 101% **-24%** / 107%	**-19%** / 100% **-22%** / 109%
Nvidia A100	**-6%** / 102%	**-6%** / 101%	**-7%** / 101%	**-7%** / 101%	**0%** / 100%

	-9% / 109%	**-8%** / 104%	**-10%** / 111%	**-9%** / 102%	**-7%** / 111%

It is important to note that enabling static tuning on HPC machine does not require significant effort from the system administrator side. It can be exposed to a user as a scheduler (mostly SLURM) parameter. If such a feature would be enabled MaX codes have potential to save energy as presented in the table.