HA2 Efficient Computing

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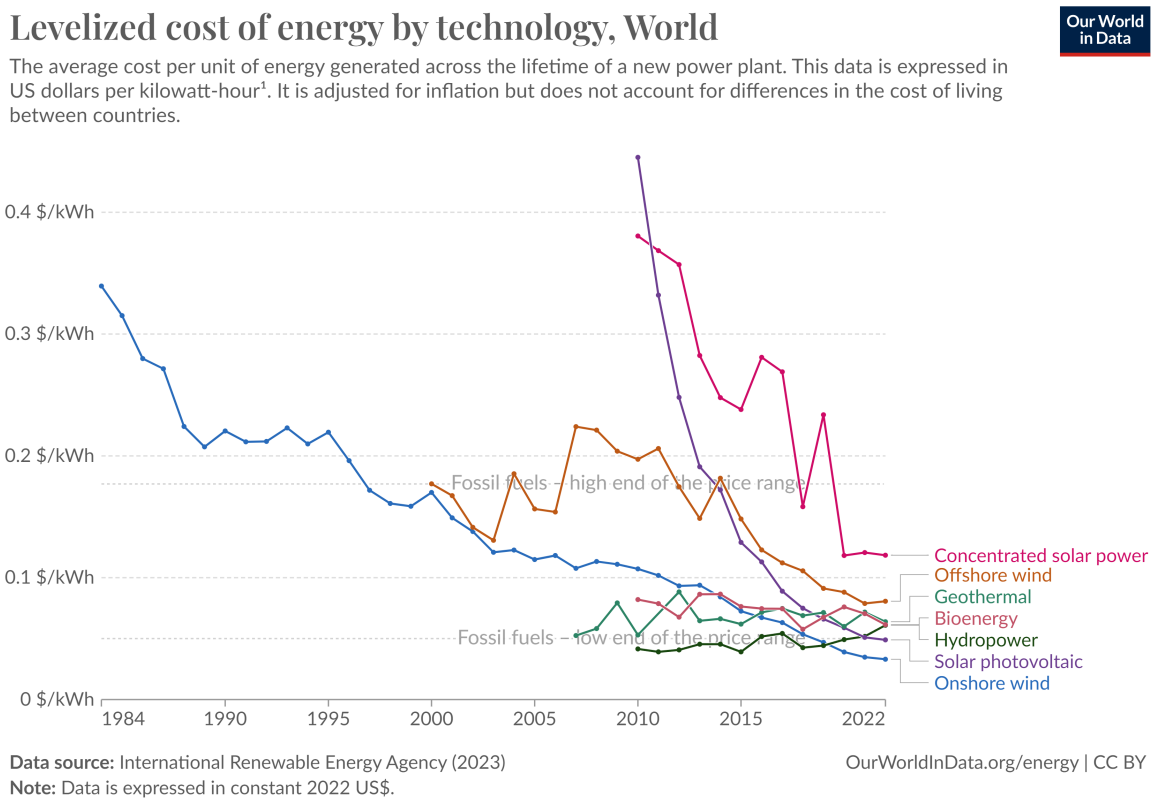
April 14, 2024

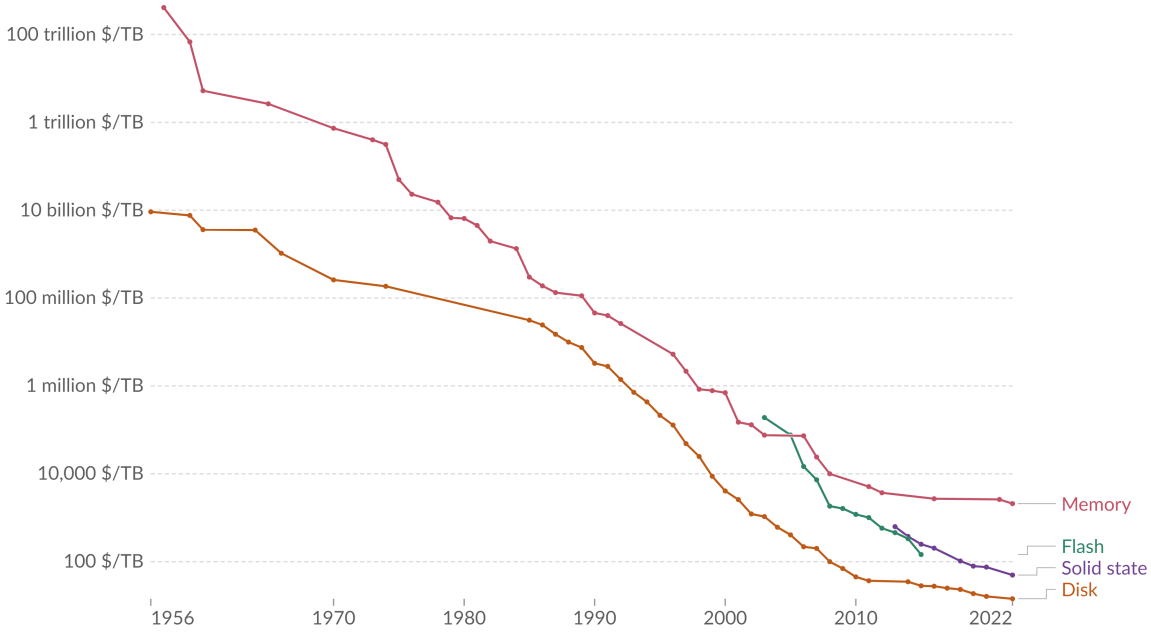
1 Improvement factors for different technologies



1. Watt-hour: A watt-hour is the energy delivered by one watt of power for one hour. Since one watt is equivalent to one Joule per second, a watt-hour is equivalent to 3600 Joules of energy. Metric prefixes are used for multiples of the unit, usually: - kilowatt-hours (kWh), or a thousand watt-hours. - Megawatt-hours (MWh), or a million watt-hours. - Gigawatt-hours (GWh), or a billion watt-hours. - Terawatt-hours (TWh), or a trillion watt-hours.

Historical cost of computer memory and storage

This data is expressed in US dollars per terabyte (TB). It is not adjusted for inflation.

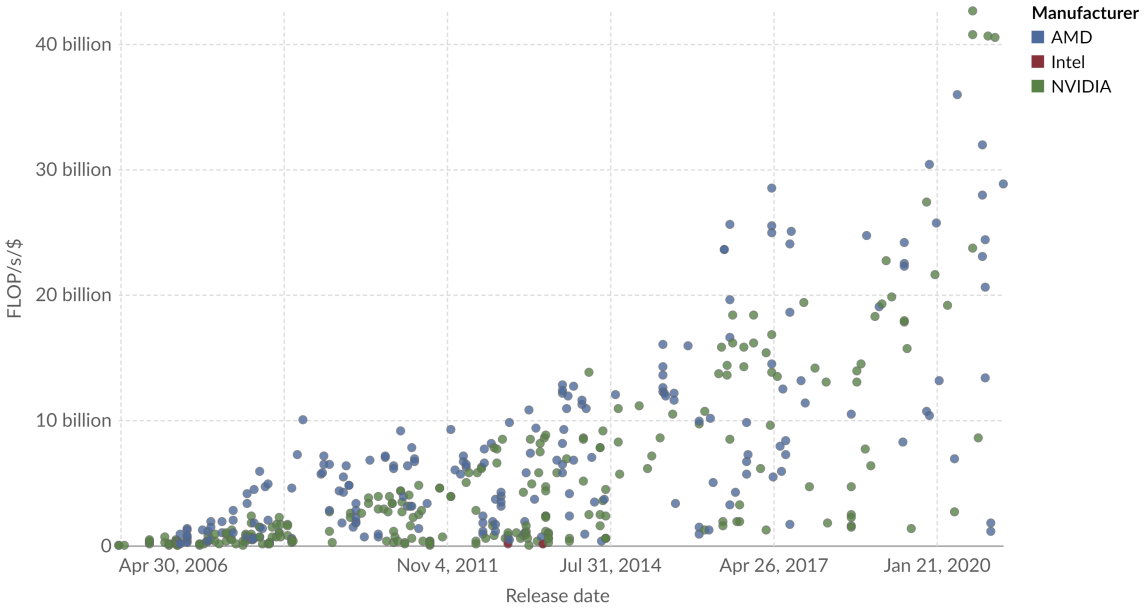


Data source: John C. McCallum (2022) OurWorldInData.org/technological-change | CC BY

Note: For each year, the time series shows the cheapest historical price recorded until that year.

GPU computational performance per dollar

Graphics processing units (GPUs) are the dominant computing hardware for artificial intelligence systems. GPU performance is shown in floating-point operations[1]/second (FLOP/s) per US dollar, adjusted for inflation.



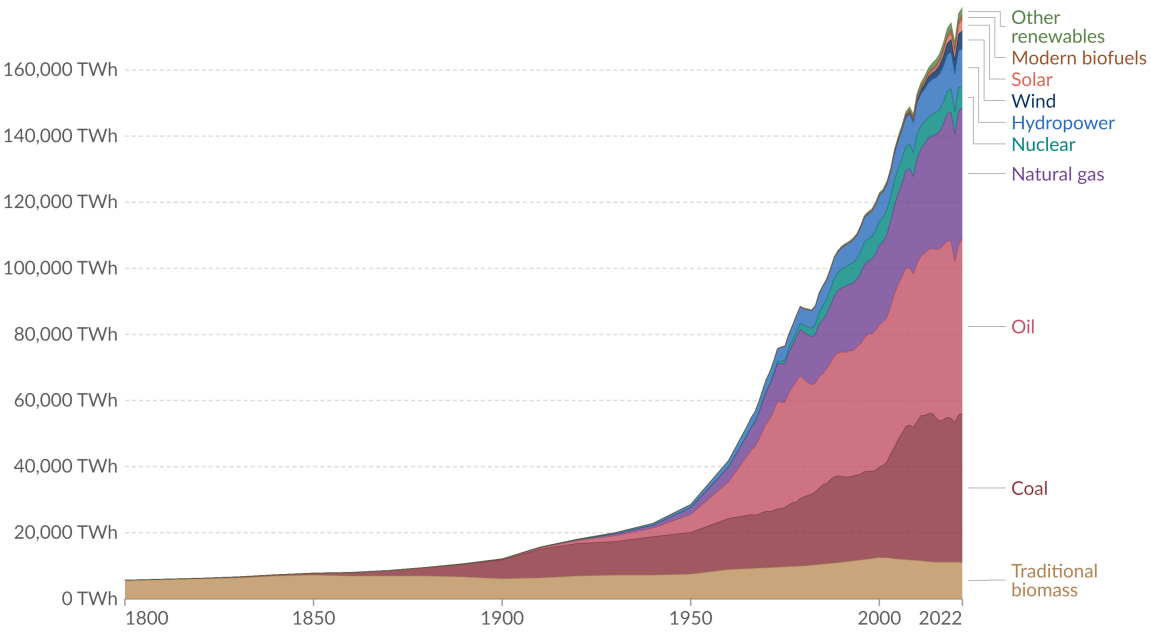
Data source: Sun et al., Median Group via Epoch (2022) OurWorldInData.org/artificial-intelligence | CC BY

Note: FLOP/s values refer to 32-bit (full) precision.

1. Floating-point operation: A floating-point operation (FLOP) is a type of computer operation. One FLOP represents a single arithmetic operation involving floating-point numbers, such as addition, subtraction, multiplication, or division.

Global primary energy consumption by source

Primary energy[1] is based on the substitution method[2] and measured in terawatt-hours[3].



Data source: Energy Institute - Statistical Review of World Energy (2023); Smil (2017) OurWorldInData.org/energy | CC BY

Note: In the absence of more recent data, traditional biomass is assumed constant since 2015.

1. Primary energy: Primary energy is the energy available as resources – such as the fuels burnt in power plants – before it has been transformed. This relates to the coal before it has been burned, the uranium, or the barrels of oil. Primary energy includes energy that the end user needs, in the form of electricity, transport and heating, plus inefficiencies and energy that is lost when raw resources are transformed into a usable form. You can read more on the different ways of measuring energy in our article.

2. Substitution method: The 'substitution method' is used by researchers to correct primary energy consumption for efficiency losses experienced by fossil fuels. It tries to adjust non-fossil energy sources to the inputs that would be needed if it was generated from fossil fuels. It assumes that wind and solar electricity is as inefficient as coal or gas. To do this, energy generation from non-fossil sources are divided by a standard 'thermal efficiency factor' – typically around 0.4 Nuclear power is also adjusted despite it also experiencing thermal losses in a power plant. Since it's reported in terms of electricity output, we need to do this adjustment to calculate its equivalent input value. You can read more about this adjustment in our article.

3. Watt-hour: A watt-hour is the energy delivered by one watt of power for one hour. Since one watt is equivalent to one Joule per second, a watt-hour is equivalent to 3600 Joules of energy. Metric prefixes are used for multiples of the unit, usually: - kilowatt-hours (kWh), or a thousand watt-hours. - Megawatt-hours (MWh), or a million watt-hours. - Gigawatt-hours (GWh), or a billion watt-hours. - Terawatt-hours (TWh), or a trillion watt-hours.

2 Hyperscale Data Center Campus in the district "Rhein-Erfurt-Kreis"

$\Rightarrow \frac{200\ \text{MegaWatt}}{2} = 100 \times 10^6\ \text{Watt für Laptops}$

$\Rightarrow \text{Anzahl Laptops} = \frac{100 \times 10^6\ \text{Watt}}{60\ \text{Watt pro Laptop}} = 1.67 \times 10^6$

$\Rightarrow \text{Rechenleistung insgesamt} = 1.67 \times 10^6 \times 100 \times 10^6\ \text{FLOP/s} = 1.67 \times 10^{14}\ \text{FLOP/s}$

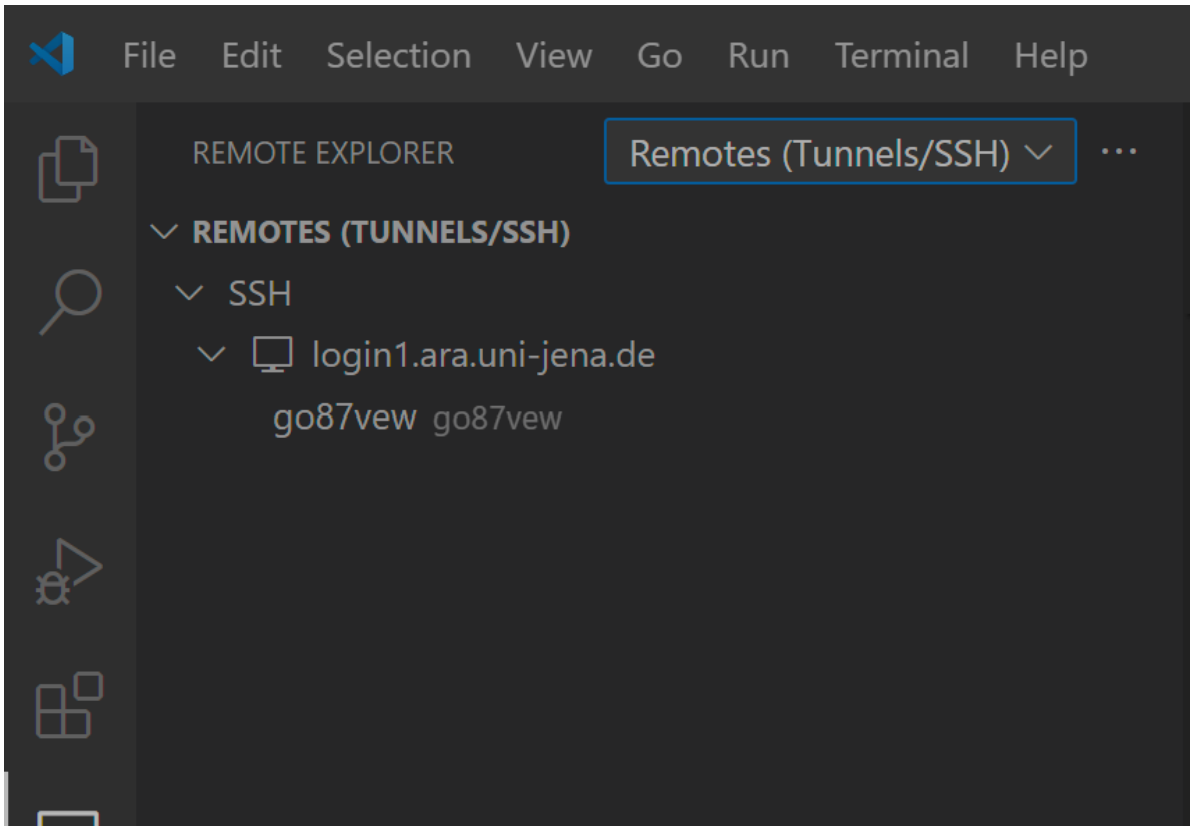
$\Rightarrow \text{Pro Minute} = 1.67 \times 10^{14}\ \text{FLOP/s} \times 60\ \text{s} = 1.0 \times 10^{16}\ \text{FLOP}$

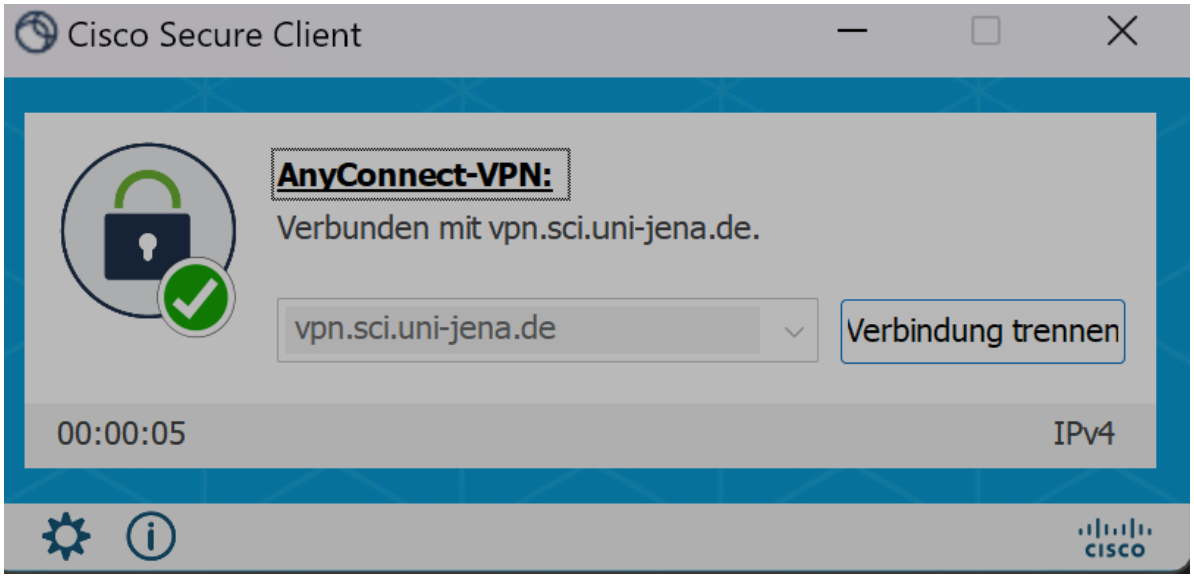
$\Rightarrow 1.0 \times 10^{16} = \frac{2}{3}n^3$

$\Rightarrow n = \sqrt[3]{\frac{3}{2} \times 1.0 \times 10^{16}} = 246621.20743304683$

$n \approx 246621 \Rightarrow \text{Dauer für einen Laptop} = \frac{1.0 \times 10^{16}\ \text{FLOP}}{100 \times 10^6\ \text{FLOP/s}} = 1.0 \times 10^8\ \text{s} \approx 27777.78\ \text{h} = 1157.\overline{407}\ \text{Tage}$

3 connect to the cluster





```
PROBLEMS  OUTPUT  DEBUG CONSOLE  TERMINAL  PORTS

[go87vew@login1 ~]$ sinfo
PARTITION   AVAIL  TIMELIMIT  NODES  STATE NODELIST
b_test         up    3:00:00      2   idle node[001-002]
b_standard*    up 8-08:00:00      1  inval node115
b_standard*    up 8-08:00:00     79  alloc node[003-005,007-013,015-017,019,021-039,044-057,066-076,085-095,103-105,112,114,116-117,121-12
b_standard*    up 8-08:00:00     45   idle node[006,014,018,020,040-043,058-065,077-084,096-102,106-111,113,118-120,124-126,136]
gpu_test       up    1:00:00      1   idle node127
gpu_p100       up 8-08:00:00      2   idle node[128-129]
gpu_v100       up 8-08:00:00      1   idle node130
gpu_a100       up 8-08:00:00      1  drain node131
gpu_a100       up 8-08:00:00      3    mix node[132-134]
b_fat          up 8-08:00:00      1  inval node137
b_fat          up 8-08:00:00      1  down* node139
b_fat          up 8-08:00:00      1    mix node140
b_fat          up 8-08:00:00      1  alloc node138
s_test         up    3:00:00      1   idle node141
s_standard     up 8-08:00:00      1  down* node217
s_standard     up 8-08:00:00      9    mix node[161,176,178,180,187,209,218,225,283]
s_standard     up 8-08:00:00     99  alloc node[162-168,170-175,177,179,181-184,186,188-201,203,206-208,210-216,219-224,226-234,237,239-24
s_standard     up 8-08:00:00     10   idle node[169,185,204-205,235-236,238,249,251,268]
s_standard     up 8-08:00:00      1   down node202
s_fat          up 8-08:00:00      2  alloc node[271-272]
s_fat          up 8-08:00:00      2   idle node[269-270]
s_hadoop       up 8-08:00:00      4   idle node[286-289]
s_parallel     up 2-00:00:00      4  down* node[150,293,309,314]
s_parallel     up 2-00:00:00      4  alloc node[310-313]
s_parallel     up 2-00:00:00     35   idle node[142-149,151-160,294-308,315-316]
[go87vew@login1 ~]$ sacct --version
slurm 23.11.5
[go87vew@login1 ~]$ squeue -u go87vew
             JOBID PARTITION     NAME     USER ST       TIME  NODES NODELIST(REASON)
[go87vew@login1 ~]$
```

Mein altes sbatch Script für das Tsunami Lab.

```
#!/bin/bash
#SBATCH --job-name=tsunami
#SBATCH --output=tsunami_output.txt
#SBATCH --error=tsunami_error.txt
#SBATCH --partition=s_hadoop
#SBATCH --nodes=1
#SBATCH --ntasks=1
#SBATCH --time=180:00
#SBATCH --cpus-per-task=72


# Set the email address where notifications should be sent.
#SBATCH --mail-user=daniel.schicker@uni-jena.de

# Specify the types of email notifications you want to receive.
#SBATCH --mail-type=BEGIN,END,FAIL

# Load modules
module load tools/python/3.8
module load compiler/gcc/11.2.0
module load compiler/intel/2020-Update2
module load libs/hdf5/1.10.8-gcc-10.2.0
module load libs/zlib/1.2.11-intel-2018
module load libs/netcdf/4.6.1-intel-2018
python3.8 -m pip install --user scons

date
cd /beegfs/go87vew/tsunami_lab
scons
OMP_NUM_THREADS=32 ./build/tsunami_lab
OMP_NUM_THREADS=34 ./build/tsunami_lab
OMP_NUM_THREADS=36 ./build/tsunami_lab
```