CERN
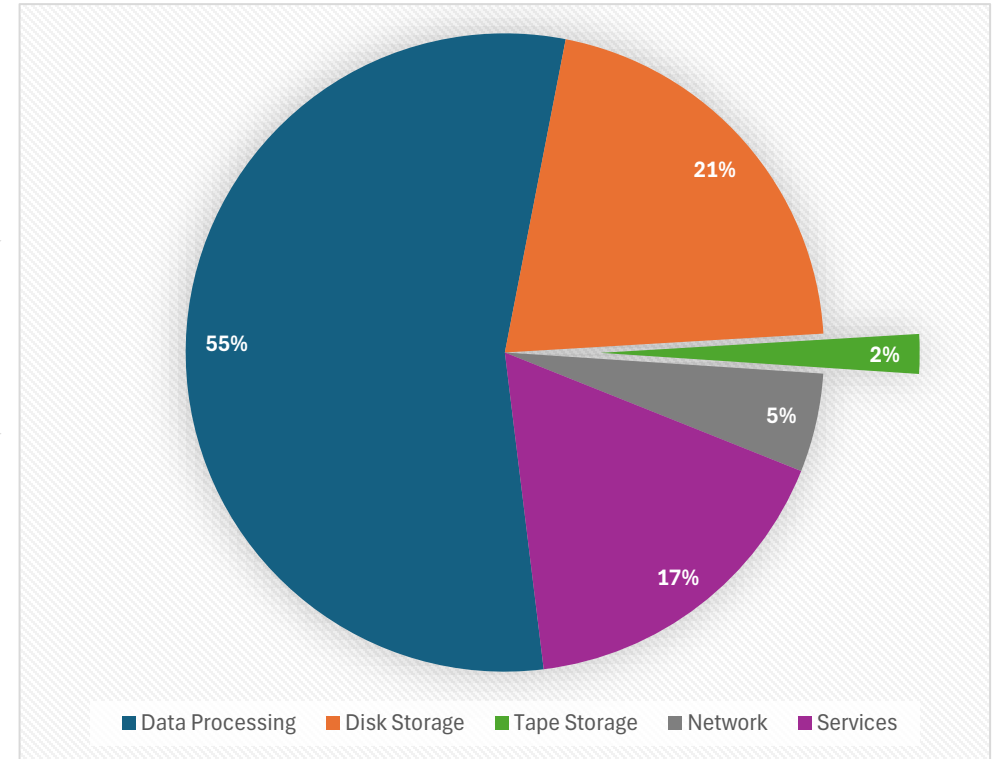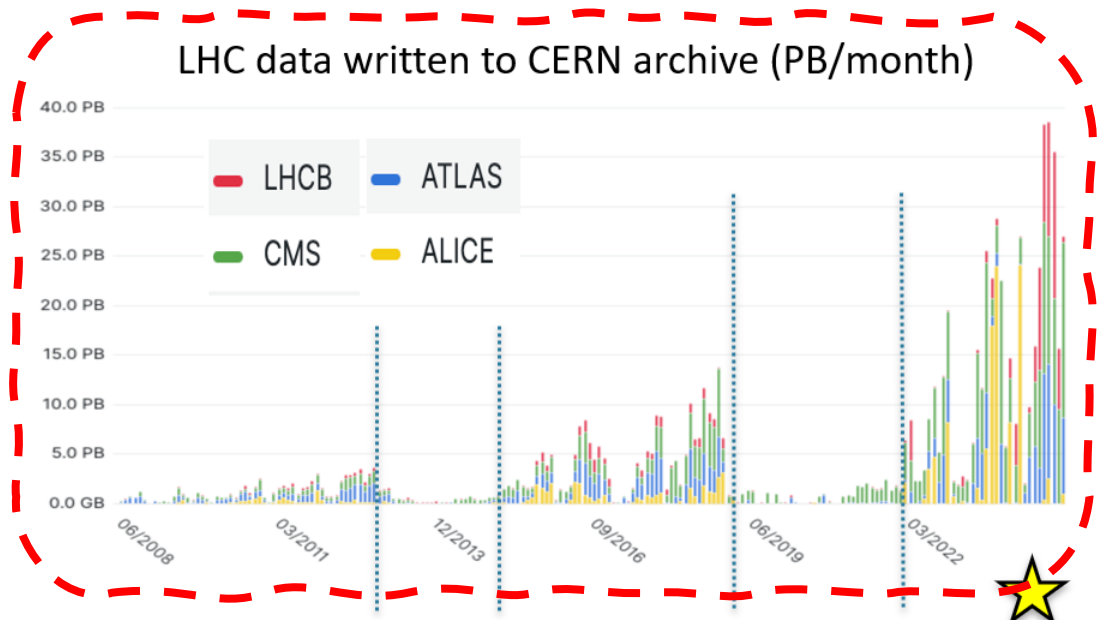## electricity consumption structure

CERN Data Centre
electricity consumption structure

Source: M. Schulz: CERN-IT Sustainability

The HL-LHC challenge – data volume and complexity

LHC data written to CERN archive (PB/month)

2011 Higgs candidate

HL-LHC simulated event

| 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 | 2032 | 2033 | 2034 | 2035 | 2036 | 2037 | (…) |

| LHC Run-1 | LS1 | LHC Run-2 | LS2 | LHC Run-3 | LS3 | HL-LHC Run-4 | LS4 | HL-LHC Run-5 |

L=29 fb-1

L=156 fb-1

L~350 fb-1

L~900 fb-1

L~1200 fb-1
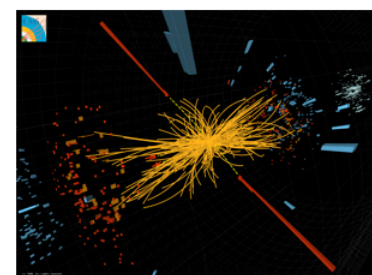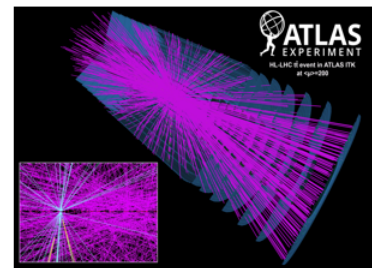
Amount of LHC data stored

Data grouped by VO or experiment ⓘ

ALICE Last: 124 PB   ATLAS Last: 194 PB   CMS Last: 301 PB   LHCb Last: 95.6 PB
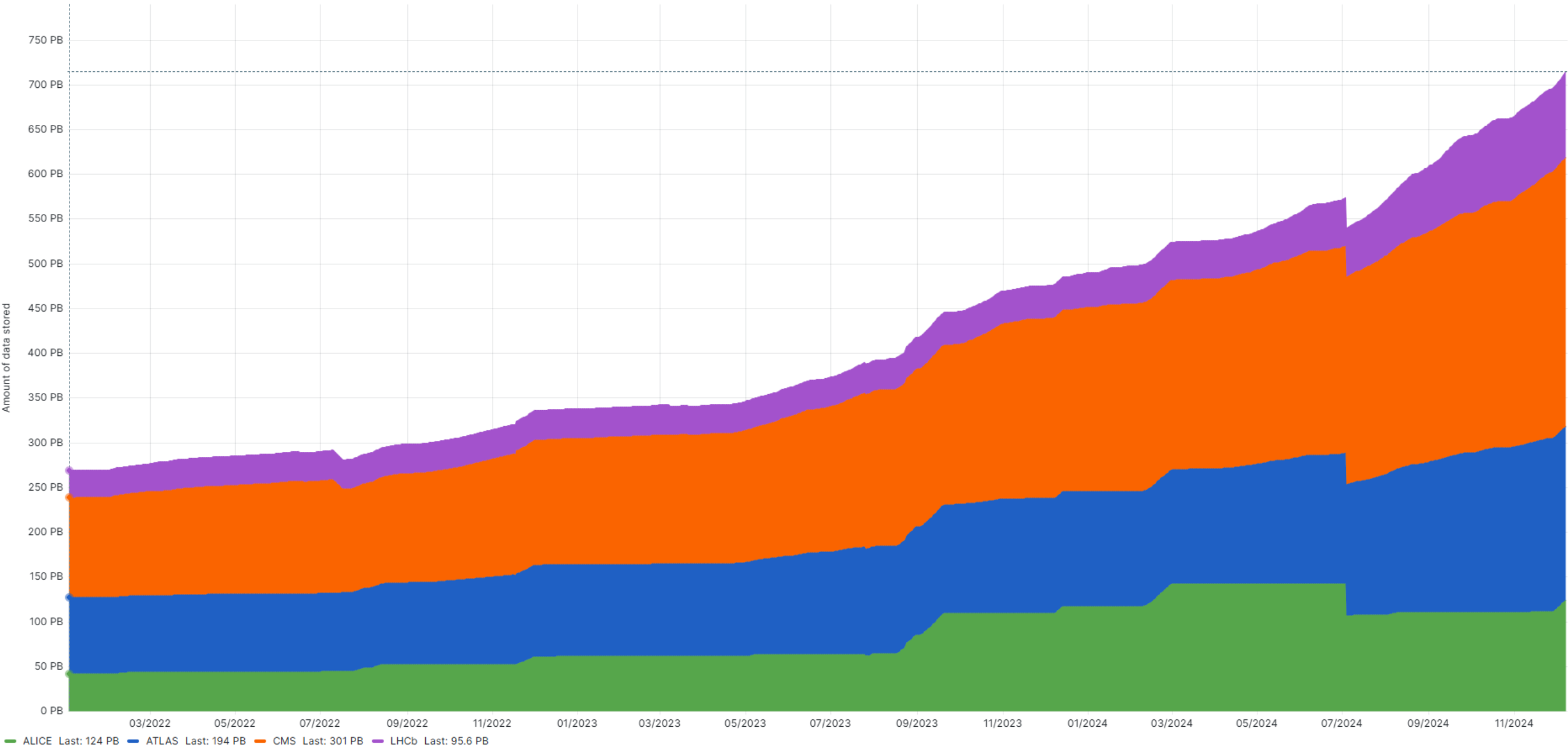
Tape Infrastructure (November 2024)

CERN Tape Archive

- Archive of the physics data
- Provisioned capacity: ~1.2 EB

- Libraries:
  - 4 x IBM TS4500
  - 3 x Spectra Logic TFinity
- Drives:
  - 40 x IBM TS1170, 46 x IBM TS1160
  - 80 x LTO-9, 10 x LTO-8
- Media:
  - 250 PB on 3592JF, 150 PB on 3592JE, 227 PB on 3592JD
  - 551 PB on LTO-9, 17 PB on LTO-8, 59 PB on LTO-7M

IBM Spectrum Protect

- Backup of the business data
- Licensed capacity: ~15 PB

- Libraries:
  - 1 x IBM TS4500 (partitioned)
  - 1 x Spectra Logic TFinity (partitioned)
- Drives:
  - 10 x LTO-9
  - 10 x LTO-8
- Media:
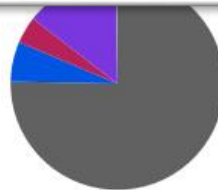 - 12 PB on LTO-8
  - 11 PB on LTO-7M

IBM CO2e Report

Physical **Tape**
CO₂e Report

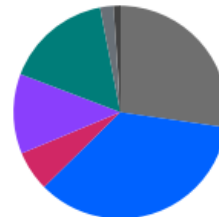**Breakdown of the CO₂e and Other Positive Sustainability Impacts of IBM Physical Tape Produ...**
The Product Life Cycle

Shawn O. Brume Sc.D.
IBM Report Analyst
Shawn.Brume@ibm.com
January 2022

50.0 metric tons CO₂e

1.4 metric tons CO₂e

Weight	2.9kg
Recycle Offset	3.2kg
Energy Usage (Average)	.031 kWh
Life Cycle	6.85Yrs
Production	41.3kg
MFG Distribution	.4kg
Operational Energy	836.4kg
Cooling Energy	347.1kg
End-of-Life	4.94kg

Automation Frame: Life Cycle Climate change Contribution

- End of Life 3%
- Raw materials, collection, reprocessing 11%
- Usage 73%
- Production 8%
- Distribution 5%

*T4500 frame average, small automation not included. 16.4 Year Lifecycle

Tape Drive: Life Cycle Climate change Contribution

- End of Life 3%
- Raw materials, collection, reprocessing 2%
- Usage 93%
- Production 1%
- Distribution 1%

*7-year lifecycle assumed for percentage calculations

- Aluminum
- CU
- Plastics
- Silicon Card
- Silicon Processor
- Tin

- FE
- Aluminum
- CU
- Plastics
- Silicon Card
- Silicon Processor
- Tin

Environmental footprint of 1.2 EB – best case

- Could comfortably fit into two IBM TS4500 tape libraries, each with 15000 slots (IBM TS1170 drives and 3592JF cartridges)

Disclaimer: First version of the sustainability calculator tool

Tape solution being chosen:	TS4500
Geographic region of deployment:	Europe
TS4500 Library frame	1
Number of TS4500 Drive frames:	2
Number of TS4500 S-frames:	15
Number of TS1100 tape drives:	48
Number of LTO Full High tape drives:	0
Enter number of Cartridges:	15000
Enter type of media:	3592 Media
The total CO2e contribution for a TS4500 configuration as listed, with all shipping to Europe is:	530 mt
Based on the TS4500 having a 9-year life cycle.	

2 x 530 mt = 1060 mt / 9 years = 118 mt per year

118 mt / 1200 PB = ~0.1 mt of CO_2e per PB per year

118 mt of CO_2e = ~30 petrol cars driving 15000 km per year
Source: https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator

- Reality – more hardware is needed:
  - Throughput requirement – at least 40 GB/s
  - Cost optimisation = using cheaper media
  - Multiple generations of tape drive technologies
  - Protection against library failures / outages
  - Avoiding vendor lock-in
  - Configuration not constant / Variable growth

Environmental footprint of 1.2 EB – reality – 1/2

IBMLIB1		IBMLIB2		IBMLIB3		IBMLIB4	
Tape solution being chosen:	TS4500	Tape solution being chosen:	TS4500	Tape solution being chosen:	TS4500	Tape solution being chosen:	TS4500
Geographic region of deployment:	Europe	Geographic region of deployment:	Europe	Geographic region of deployment:	Europe	Geographic region of deployment:	Europe
TS4500 Library frame	1	TS4500 Library frame	1	TS4500 Library frame	1	TS4500 Library frame	1
Number of TS4500 Drive frames:	2	Number of TS4500 Drive frames:	3	Number of TS4500 Drive frames:	2	Number of TS4500 Drive frames:	2
Number of TS4500 S-frames:	15	Number of TS4500 S-frames:	14	Number of TS4500 S-frames:	15	Number of TS4500 S-frames:	15
Number of TS1100 tape drives:	0	Number of TS1100 tape drives:	0	Number of TS1100 tape drives:	48	Number of TS1100 tape drives:	48
Number of LTO Full High tape drives:	38	Number of LTO Full High tape drives:	10	Number of LTO Full High tape drives:	0	Number of LTO Full High tape drives:	0
Enter number of Cartridges:	17500	Enter number of Cartridges:	1014	Enter number of Cartridges:	15394	Enter number of Cartridges:	13639
Enter type of media:	LTO Media	Enter type of media:	LTO Media	Enter type of media:	3592 Media	Enter type of media:	3592 Media
The total CO_2E contribution for a TS4500 configuration as listed, with all shipping to Europe is:	450 mt	The total CO_2E contribution for a TS4500 configuration as listed, with all shipping to Europe is:	296 mt	The total CO_2E contribution for a TS4500 configuration as listed, with all shipping to Europe is:	534 mt	The total CO_2E contribution for a TS4500 configuration as listed, with all shipping to Europe is:	520 mt
Based on the TS4500 having a 9 year life cycle.		Based on the TS4500 having a 9 year life cycle.		Based on the TS4500 having a 9 year life cycle.		Based on the TS4500 having a 9 year life cycle.	

SPECTRALIB1		SPECTRALIB2		SPECTRALIB3	
Tape solution being chosen:	TS4500	Tape solution being chosen:	TS4500	Tape solution being chosen:	TS4500
Geographic region of deployment:	Europe	Geographic region of deployment:	Europe	Geographic region of deployment:	Europe
TS4500 Library frame	1	TS4500 Library frame	1	TS4500 Library frame	1
Number of TS4500 Drive frames:		Number of TS4500 Drive frames:		Number of TS4500 Drive frames:	1
Number of TS4500 S-frames:	12	Number of TS4500 S-frames:	12	Number of TS4500 S-frames:	12
Number of LTO Full High tape drives:	8	Number of LTO Full High tape drives:		Number of LTO Full High tape drives:	6
Enter number of Cartridges:	10571	Enter number of Cartridges:	11295	Enter number of Cartridges:	810
Enter type of media:	LTO Media	Enter type of media:	LTO Media	Enter type of media:	LTO Media
The total CO_2E contribution for a TS4500 configuration as listed, with all shipping to Europe is:	332	The total CO_2E contribution for a TS4500 configuration as listed, with all shipping to Europe is:	334 mt	The total CO_2E contribution for a TS4500 configuration as listed, with all shipping to Europe is:	232
Based on the TS4500 having a 9 year life cycle.		Based on the TS4500 having a 9 year life cycle.		Based on the TS4500 having a 9 year life cycle.	

**Disclaimer:
Extrapolated calculation, using IBM methodology on Spectra Logic Tfinity product**

Environmental footprint of 1.2 EB – reality – 2/2

- Summary:
  - IBM: 250 + 296 + 534 + 520 = 1800 mt / 9 years
  - Spectra Logic: 332 + 334 + 232 = 898 mt / 9 years
  - Total: 2698 mt / 9 years = 300 mt / year

- 300 mt / 1200 PB = 0.25 mt of CO_2e per PB per year

- 300 mt of CO_2e = ~80 petrol cars driving 15000 km per year
  Source: https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator

- Comparison: *The Dirty Secret of SSDs: Embodied Carbon* (https://arxiv.org/pdf/2207.10793)
  - Table 1 – 1 TB HDD generates 100 Kg of CO_2e per 5 years = 20 Kg per year
    - This includes server hardware
  - With ~100000 HDDs at CERN, that would be around 2000 tons of CO_2e per year

Energy consumption of 1.2 EB tape archive – 1/2

- IBM
  - Considering maxiumum values from: https://www.ibm.com/docs/en/ts4500-tape-library?topic=planning-power-consumption-cooling-requirements

  - IBMLIB1 : 1925 W
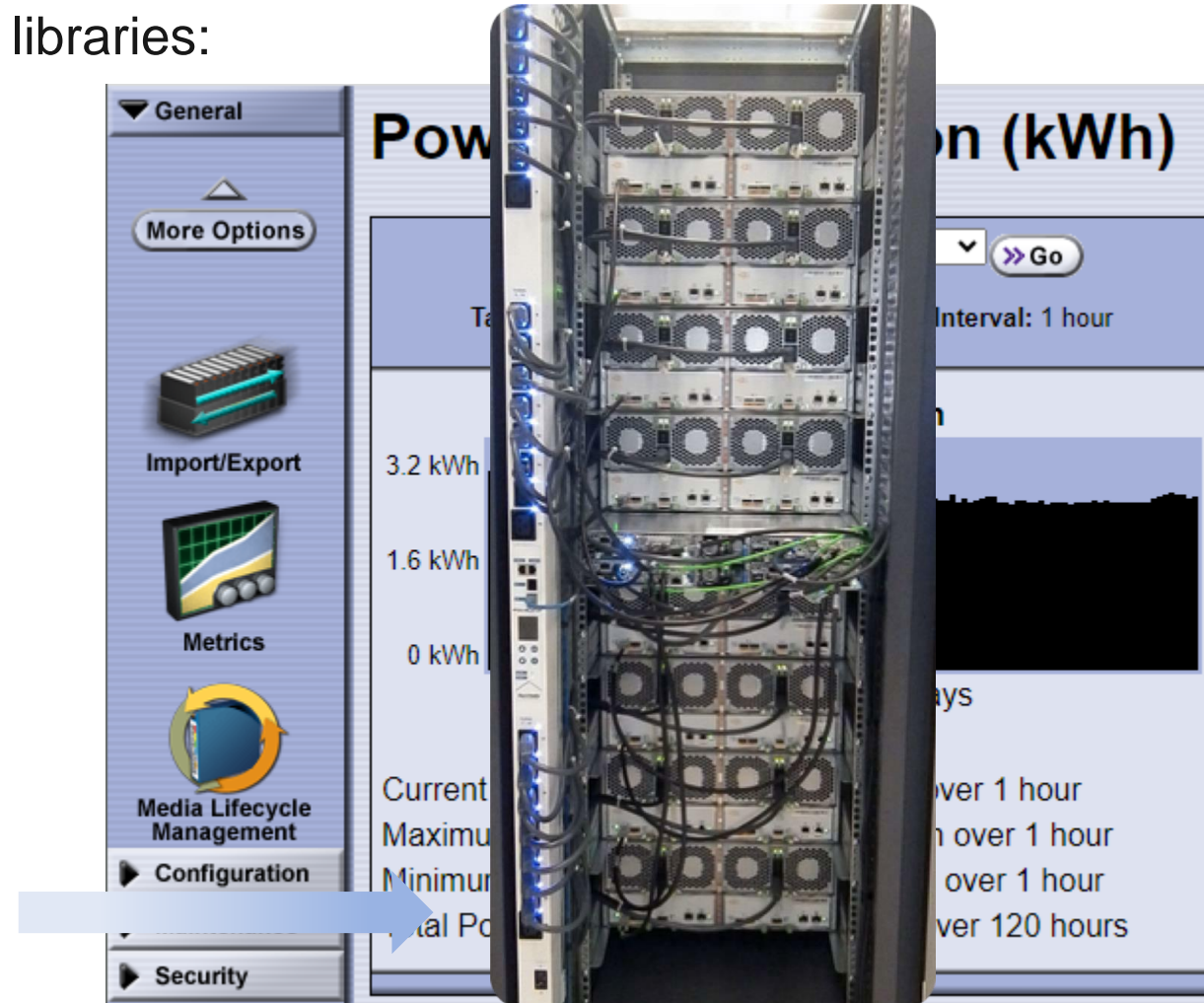 - IBMLIB2 :   939 W
  - IBMLIB3 : 3543 W
  - IBMLIB4 : 3543 W

  - Total IBM (maximum continuous): 9950 W
  Maximum continuous power is consumed when the drives are actively reading or writing to the tape and the cooling fan rotates at normal speed.
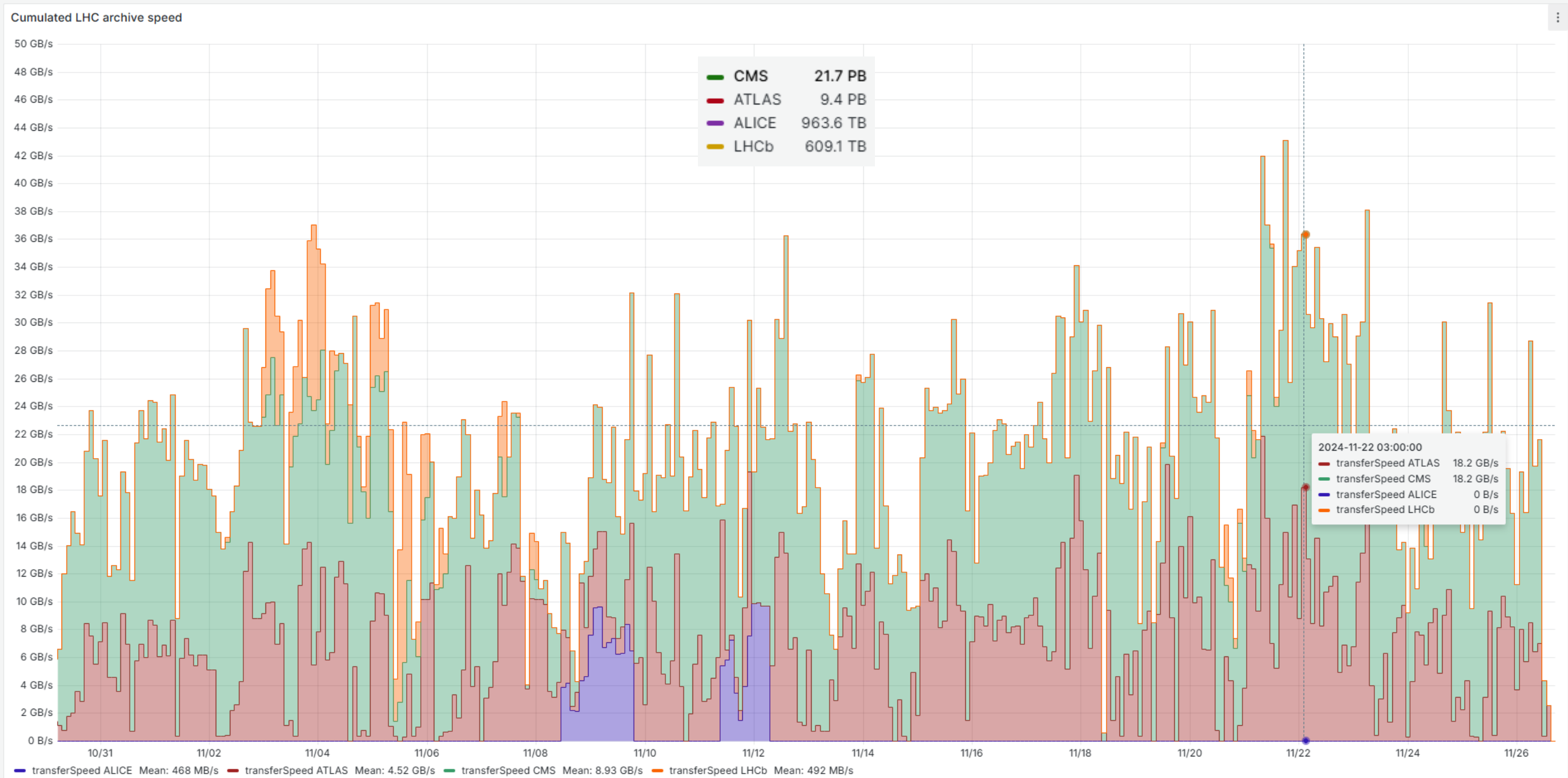
Frame model, feature codes, and drives	IBMLIB3		
	Quantity	Per unit	Max total
L25	1,00	130,00	130,00
FC 1460 (redundant accessor power/network)	1,00	5,00	5,00
FC 1531, 1532, 1533, and 1534 (one of each FC per frame with drives)	12,00	3,00	36,00
D25	2,00	11,00	22,00
FC 1450 (TS4500 FCA including one LCC and two ac/dc power supplies)	2,00	38,00	76,00
S25	15,00	11,00	165,00
FC 1442 (HA kit with second accessor; for Dx5 or Sx5)	1,00	85,00	85,00
LTO drives	0,00	37,00	0,00
TS1160 drives	48,00	63,00	3024,00
Total library power consumption (watts)			3543,00

Energy consumption of 1.2 EB tape archive – 2/2

- Spectra Logic
  - Considering maximum values as reported by the libraries:

  - SPECTRALIB1: 2900 W
  - SPECTRALIB2: 3200 W
  - SPECTRALIB3: not implemented

  - Total Spectra Logic (estimation): 8000 W

- TOTAL: ~18 kW per 1.2 EB = ~15 W per PB

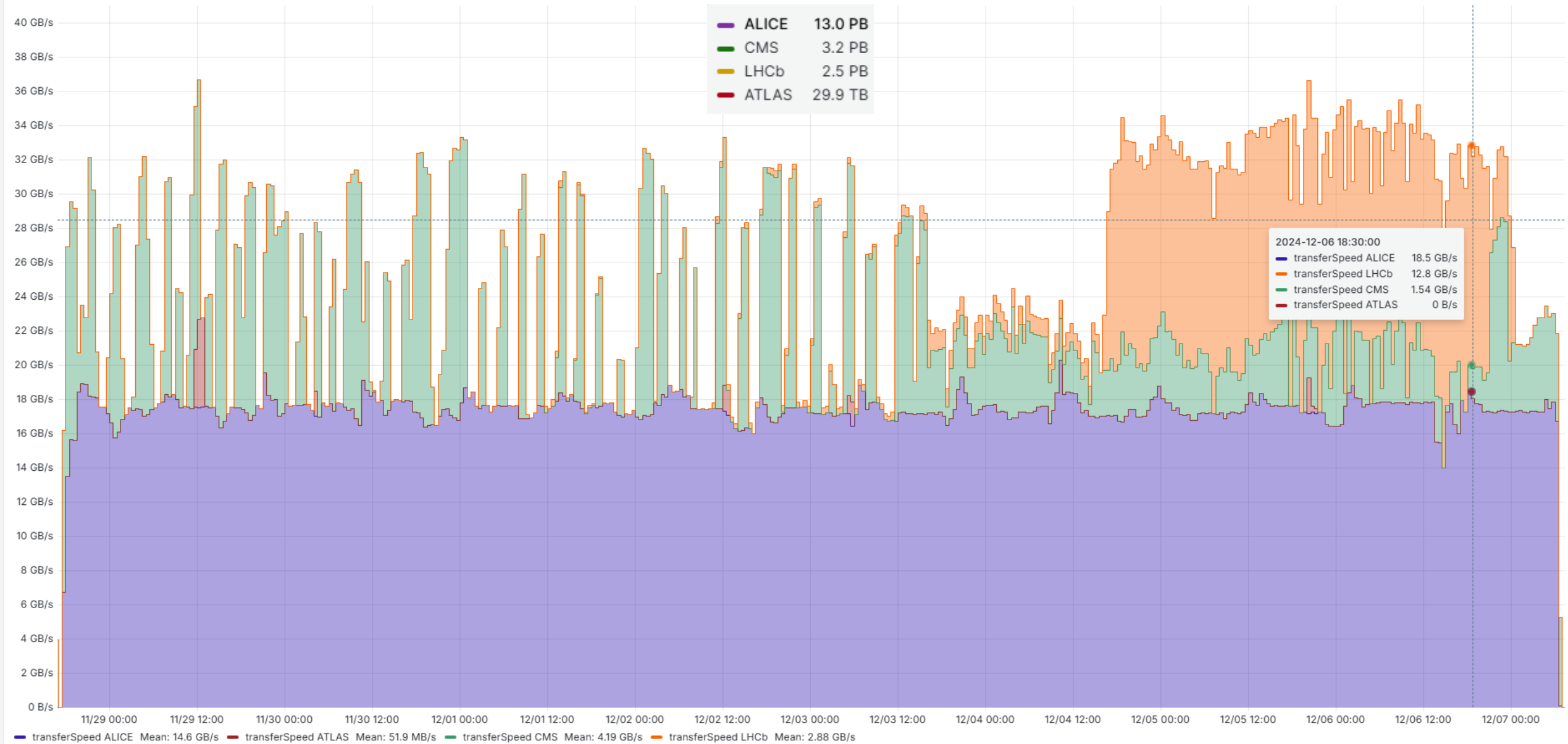- Comparison: According to PDU monitoring, one rack at CERN usually consumes ~3 kW (example PDU-SJ06-01)

33 PB in 4 weeks = ~1 PB/day

18 PB in 9 days = ~2 PB/day

Cumulated LHC archive speed

ALICE	13.0 PB
CMS	3.2 PB
LHCb	2.5 PB
ATLAS	29.9 TB

2024-12-06 18:30:00

transferSpeed ALICE	18.5 GB/s
transferSpeed LHCb	12.8 GB/s
transferSpeed CMS	1.54 GB/s
transferSpeed ATLAS	0 B/s

transferSpeed ALICE Mean: 14.6 GB/s transferSpeed ATLAS Mean: 51.9 MB/s transferSpeed CMS Mean: 4.19 GB/s transferSpeed LHCb Mean: 2.88 GB/s

Conclusion

- Quantify environmental and sustainability impact of any (IT) equipment is a complex excercise

- The carbon footprint is dominated by the usage pattern and the capacity (number of tape cartridges)

- Calculations are based on IBM report (Spectra Logic not (yet) contacted (shortage of time))

- CERN Tape Archive:
  - Generates around 300 mt CO_2e per year (80 petrol cars driving 15000 km per year)
  - Consumes around 18 kW (around 15 W per PB)

- Spikey usage demands larger configuration and has bigger environmental footprint

- Adding more:
  - Capacity will generate more CO_2e, but will not increase power consumption
  - Throughput (assuming same drive generations) will generate more CO_2e as well as increase power consumption

- Future work:
  - Include server hardware
  - Improved IBM tool (allow for different energy sources; consider growth of the archive)