

Carbon Models and tools

-- some preliminary discussion

Daohai Li (QMUL)
Alex Owen (QMUL)
Jon Hays (QMUL)
Alex Dibbo (STFC)

Outline

- Slurm/Carbon accounting on the GridPP facility at QMUL
- Dell server CO2 emission

GridPP facility at QMUL


GridPP facility at QMUL

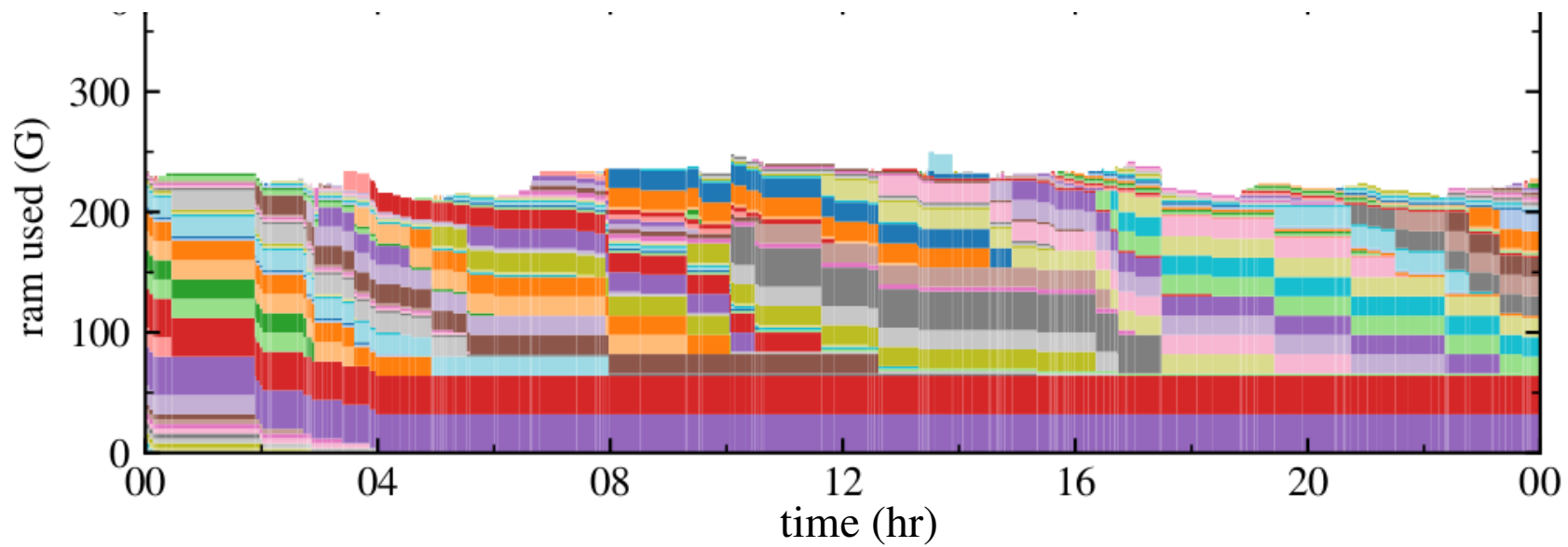
- Compute node: Dell R630/Lenovo SR570 servers (mostly)
 - 96 threads (2*Intel Gold 6248R/6252)
 - 384 GB of RAM
 - Slurm workload manager

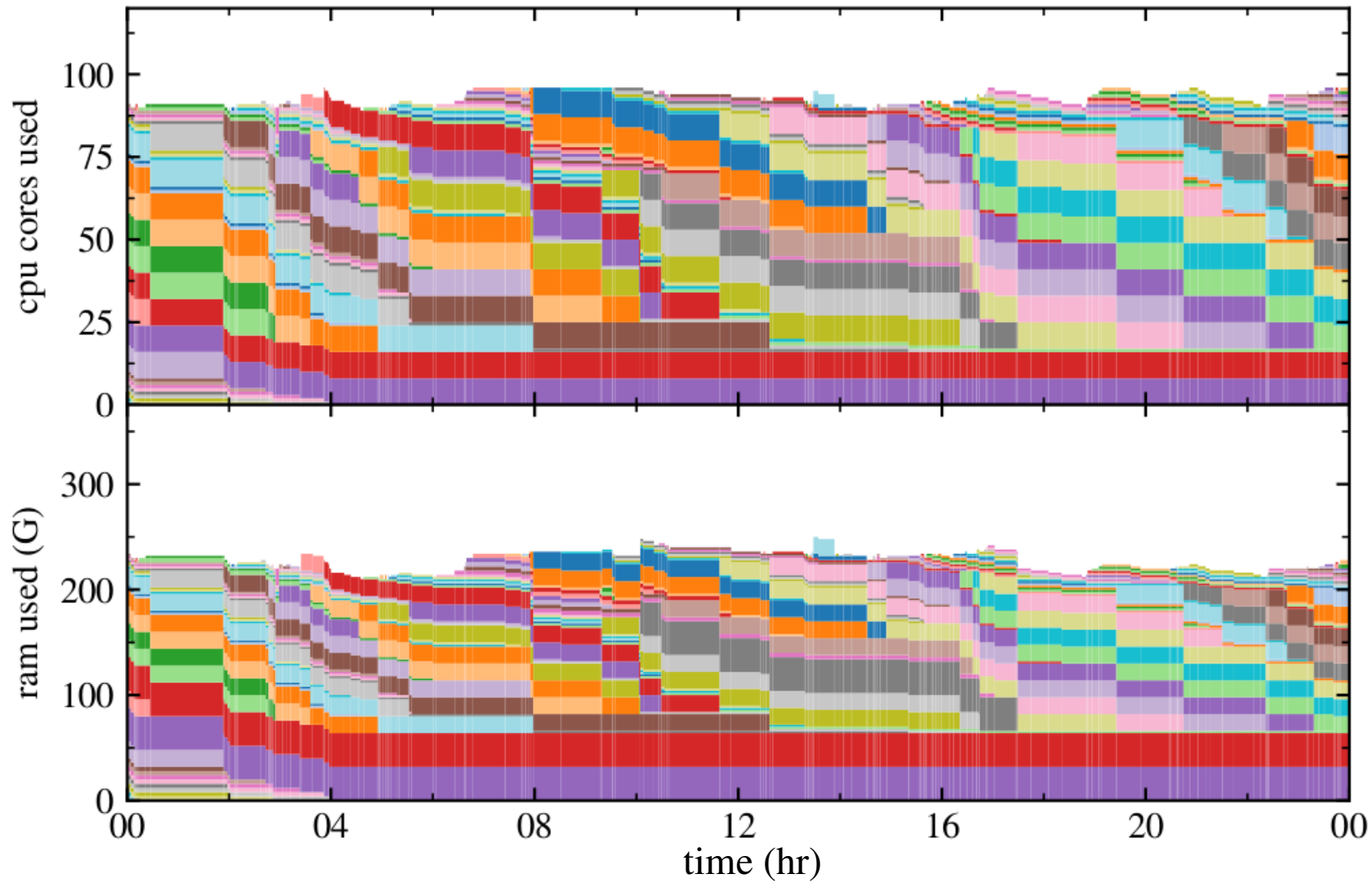
GridPP facility at QMUL

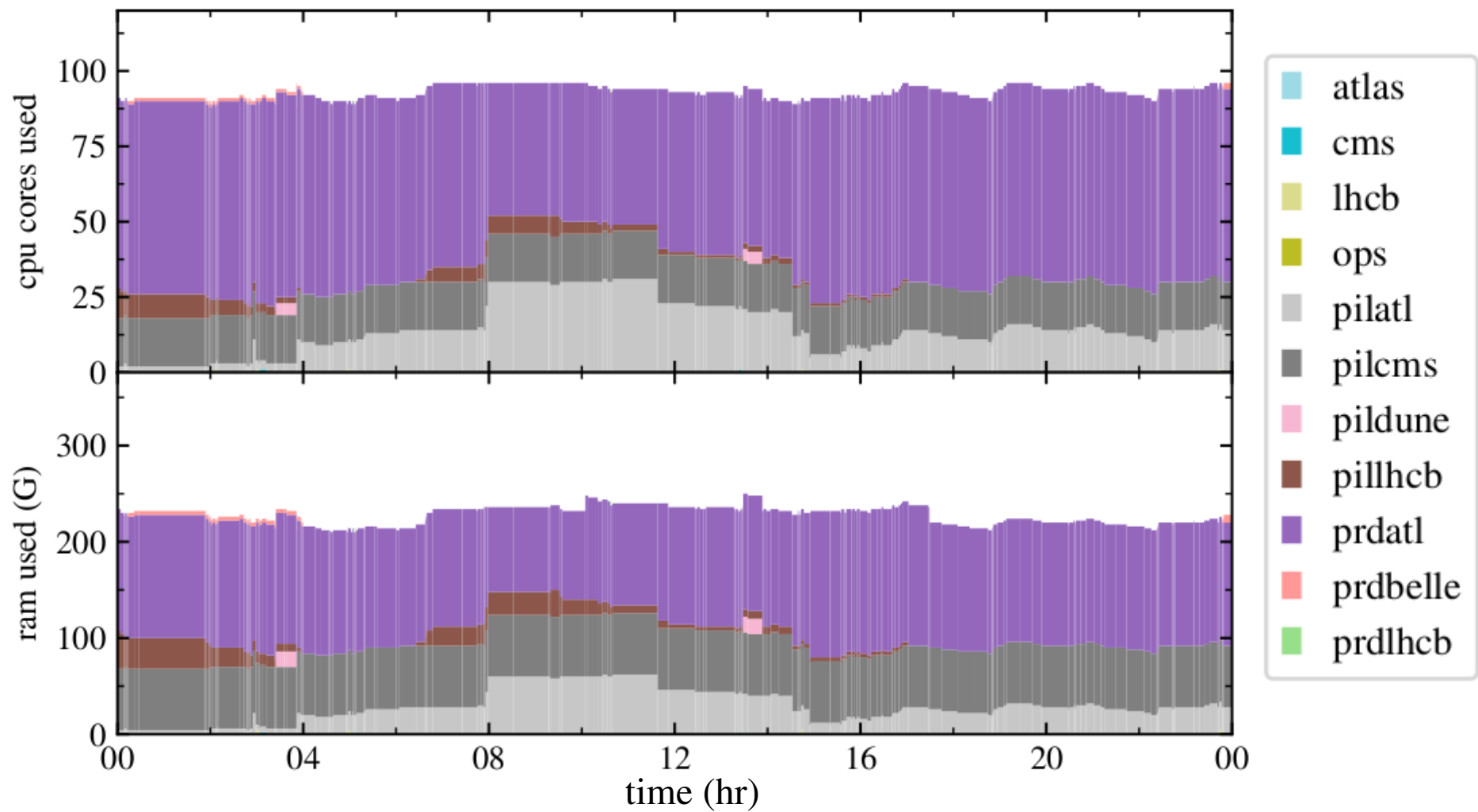
- Compute node: Dell R630/Lenovo SR570 servers (mostly)
 - 96 threads (2*Intel Gold 6248R/6252)
 - 384 GB of RAM
 - Slurm workload manager
- Job accounting (sacct)
 - Number of CPU assigned
 - RAM assigned
 - Start time
 - End time
 - CPU time

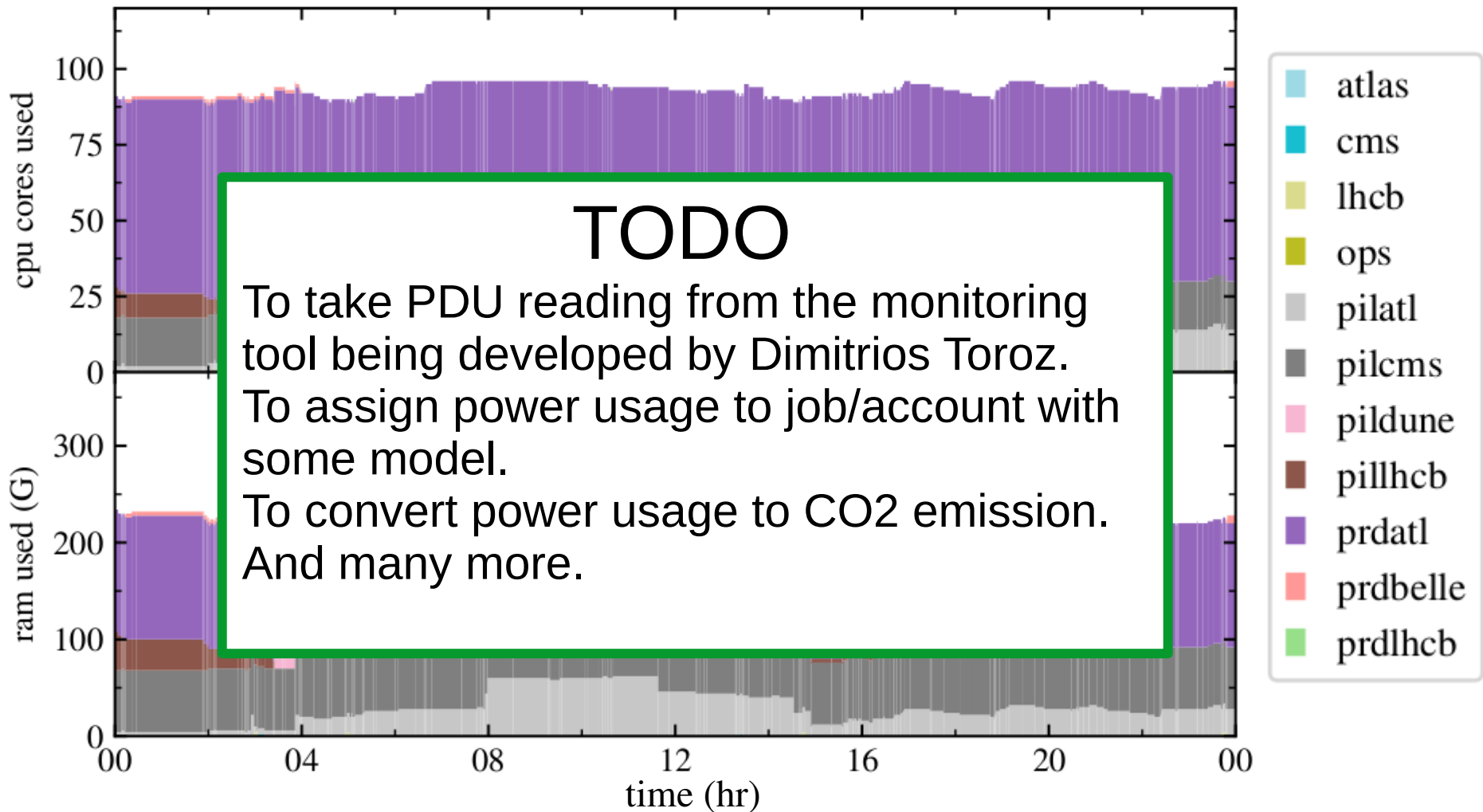
Sample sacct query result

AllocTRES	Start 	End	CPUtime	JobID	Account
billing=1,cpu=1,mem=4G,node=1	2023-12-11T08:01:57	2023-12-12T00:03:18	16:01:21	11865460	pillhcb
billing=1,cpu=1,mem=4G,node=1	2023-12-11T09:19:03	2023-12-12T02:50:30	17:31:27	11866361	pillhcb
billing=1,cpu=1,mem=4G,node=1	2023-12-11T09:30:43	2023-12-12T02:35:10	17:04:27	11866484	pillhcb
billing=1,cpu=1,mem=4G,node=1	2023-12-11T09:30:44	2023-12-12T03:34:59	18:04:15	11866508	pillhcb
billing=8,cpu=8,mem=32000M,node=1	2023-12-11T09:41:34	2023-12-13T09:06:13	15-19:17:12	11866748	pilcms
billing=1,cpu=1,mem=4G,node=1	2023-12-11T09:56:13	2023-12-12T07:45:16	21:49:03	11866723	pillhcb
billing=1,cpu=1,mem=4G,node=1	2023-12-11T10:27:53	2023-12-12T04:21:56	17:54:03	11866986	pillhcb
billing=1,cpu=1,mem=4G,node=1	2023-12-11T11:14:49	2023-12-12T02:16:52	15:02:03	11867323	pillhcb
billing=8,cpu=8,mem=32000M,node=1	2023-12-11T11:25:14	2023-12-13T05:05:45	13-21:24:08	11867394	pilcms
billing=1,cpu=1,mem=4G,node=1	2023-12-11T11:30:41	2023-12-12T04:06:22	16:35:41	11867337	pillhcb
billing=1,cpu=1,mem=4G,node=1	2023-12-11T11:38:56	2023-12-12T03:36:23	15:57:27	11867357	pillhcb
billing=8,cpu=8,mem=32000M,node=1	2023-12-11T13:12:41	2023-12-12T06:52:22	5-21:17:28	11867944	pilcms
billing=1,cpu=1,mem=2000M,node=1	2023-12-11T13:42:02	2023-12-12T09:01:10	19:19:08	11868061	prdatl
billing=8,cpu=8,mem=32000M,node=1	2023-12-11T14:05:54	2023-12-13T09:16:01	14-09:20:56	11868195	pilcms









Dell server carbon footprint

- Dell and many other vendors publish environmental implications for their products.
- Dell:
https://www.dell.com/learn/ag/en/agcorp1/corporate_corp-comm_dellwebpage/environment_carbon_footprint_products



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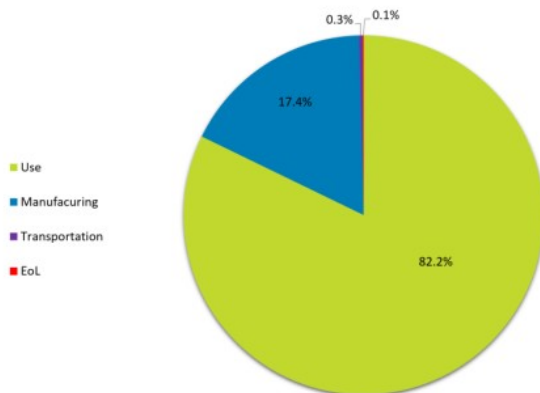


This product's estimated carbon footprint:

7260 kgCO₂e *

Estimated impact by lifecycle stage:

Dell uses PAIA (Product Attribute to Impact Algorithm) to perform product carbon footprints. PAIA is a streamlined LCA tool developed by [MIT's Materials System Laboratory](#). It takes into consideration important attributes of the product which can be correlated to activities in order to calculate the product carbon footprint.

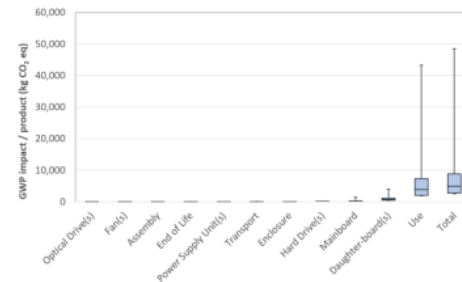


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* This product has an estimated standard deviation of +/- 7580 kgCO₂e

As part of our commitment to transparency, the chart to the right demonstrates the degree of uncertainty that exists within the PAIA model for product carbon footprinting, based on assumptions we have made for select variables.



Assumptions for calculating product carbon footprint:

Product Weight	18.6 kg	Server Type	Rack	Assembly Location	EU
Product Lifetime	4 years	Use Location	EU	Energy Demand (Yearly TEC)	1433.574 kWh
HDD/SSD Quantity	x4 1.2TB 2.5" HDD	DRAM Capacity	16GB	CPU Quantity	2

7260 kgCO₂e



1 of these products... has a footprint approx. equivalent to **driving 17,787 miles** in a passenger car.



10 of these products... have a footprint approx. equal to what **85 acres of US forests** can absorb in a year.



100 of these products... have a footprint about the same as the annual average carbon footprint of **145 people**.

To help our customers and other stakeholders contextualize product carbon footprint values, we provide these approximate equivalencies. Please remember these are estimates and should not be used for emission inventory or formal carbon footprinting exercises.

Calculations are based on the following methodologies: 2.45 miles driven per 1 kg CO₂e (source: [U.S. EPA](#)); approx. 850 kg CO₂e absorbed per acre of forests over a year (source: [U.S. EPA](#)); global personal carbon footprint estimated at 5 MT CO₂e per person (source: [World Bank](#)).



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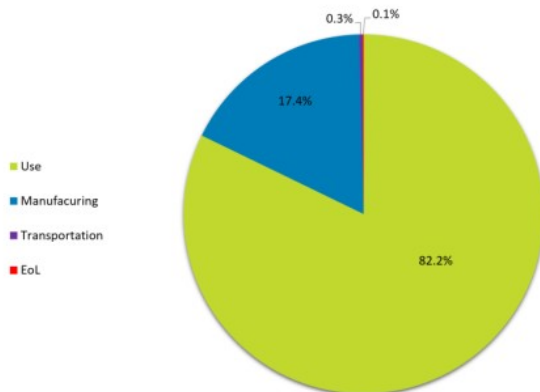


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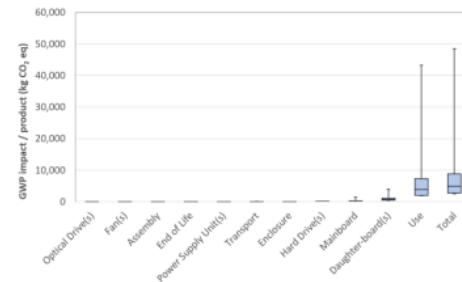


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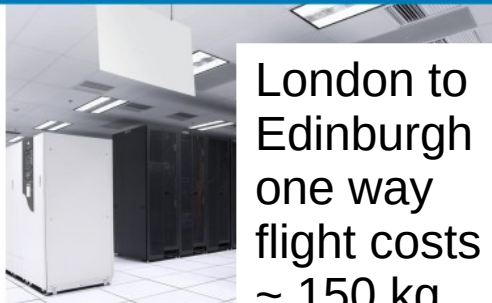
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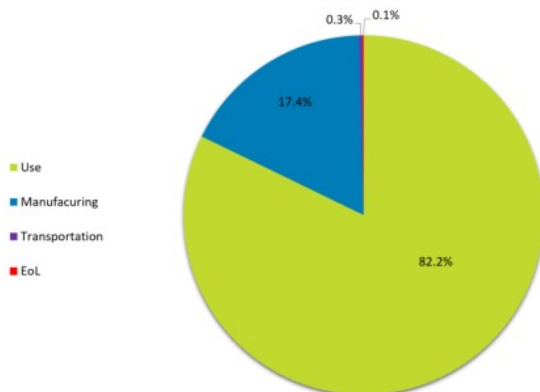
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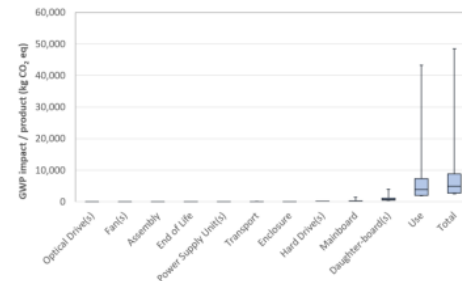


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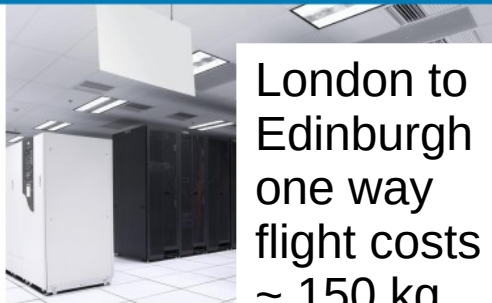
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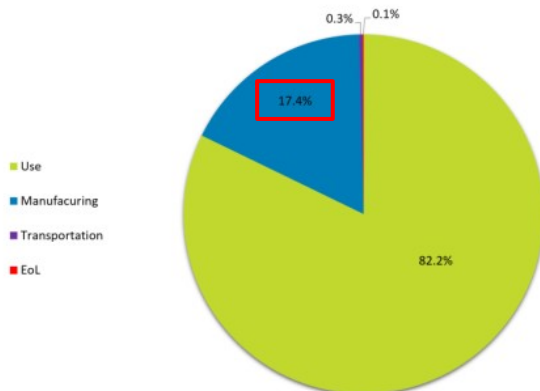
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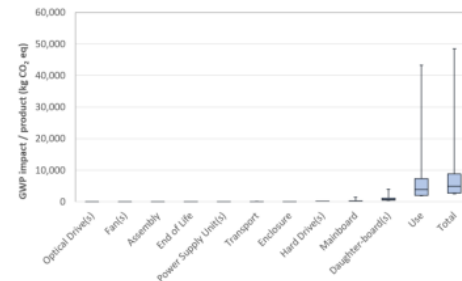


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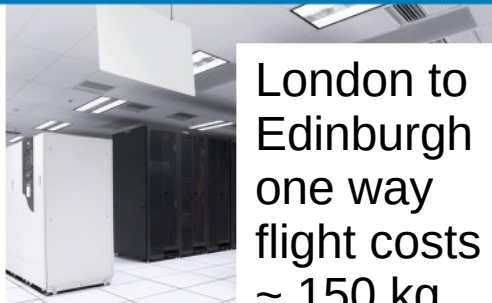
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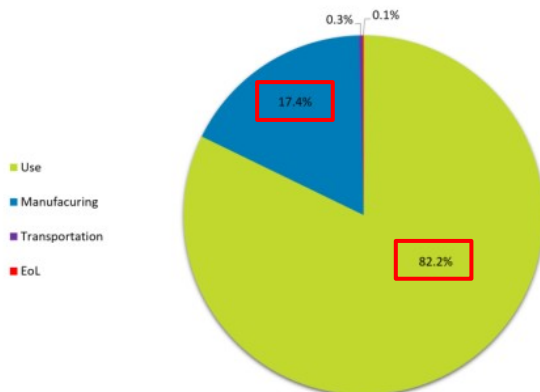
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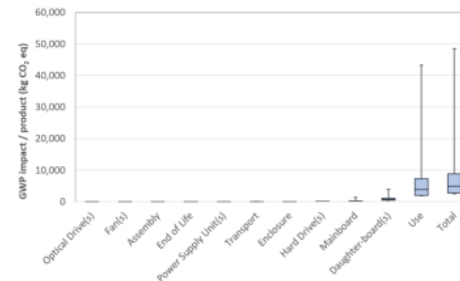


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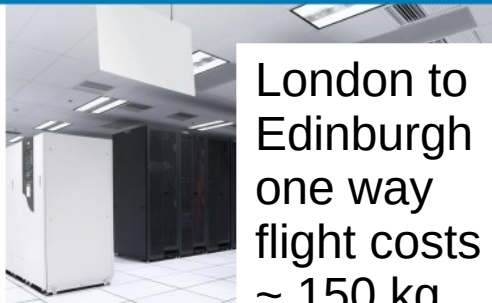
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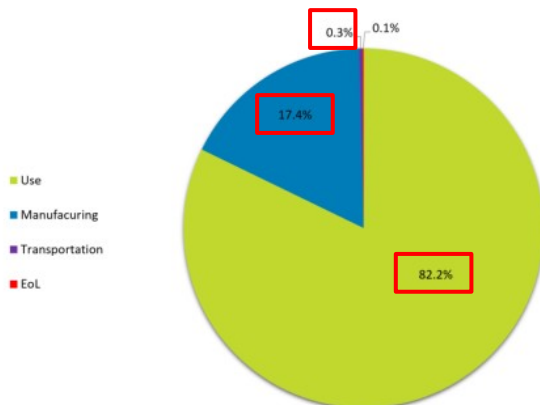
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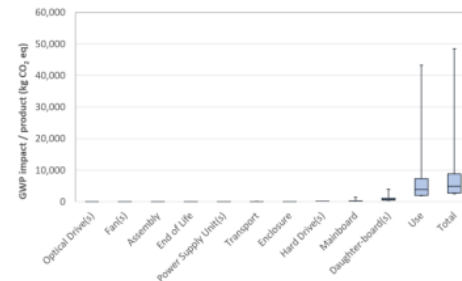


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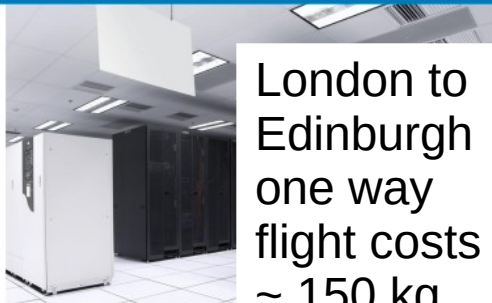
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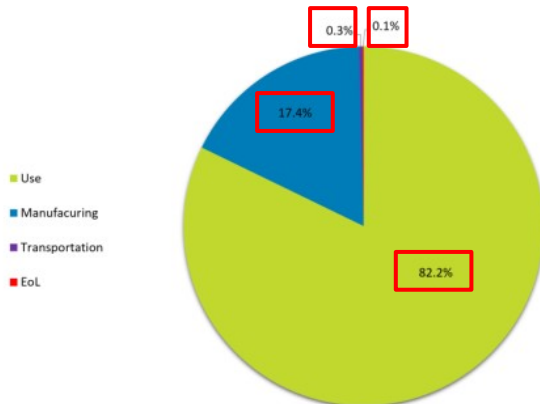
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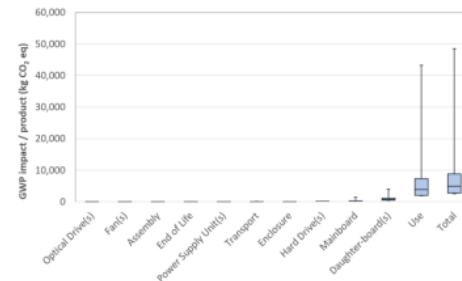


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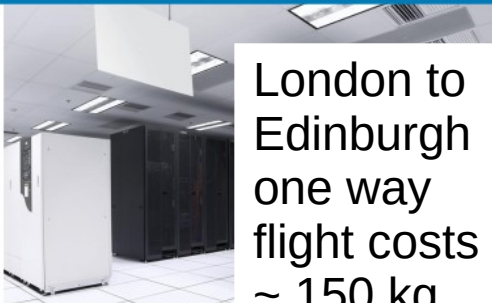
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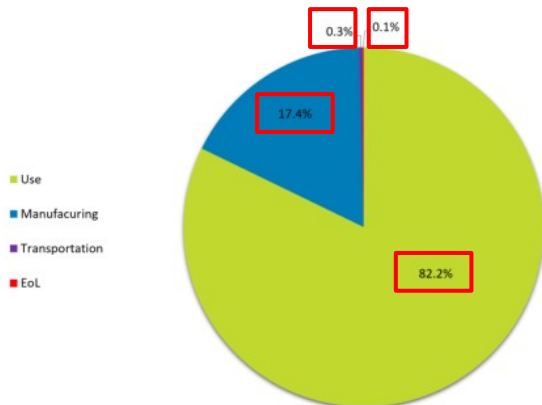
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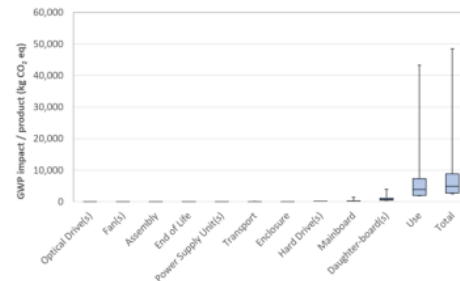
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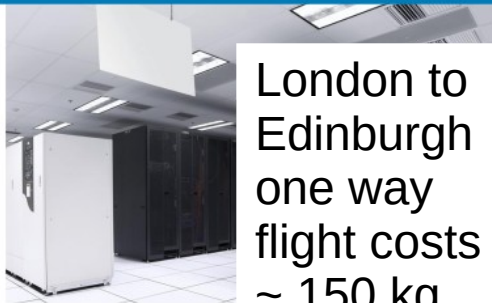
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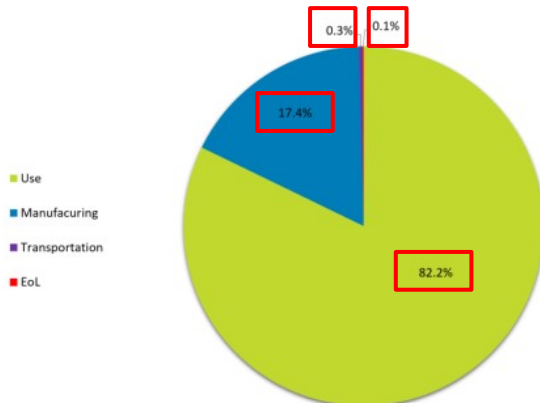
London to Edinburgh one way flight costs ~ 150 kg of CO2.

This product's estimated carbon footprint:

7260 kgCO2e *

Estimated impact by lifecycle stage:

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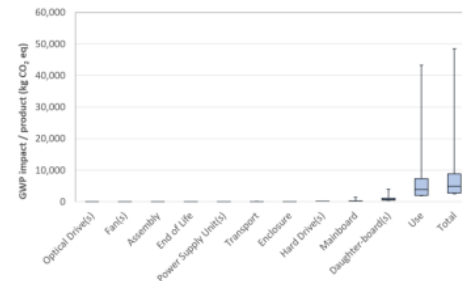


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Assumptions for calculating product carbon footprint:

Product Weight	18.6 kg	Server Type	Rack	Assembly Location	EU
Product Lifetime	4 years	Use Location	EU	Energy Demand (Yearly TEC)	1433.574 kWh
HDD/SSD Quantity	x4 1.2TB 2.5" HDD	DRAM Capacity	16GB	CPU Quantity	2

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1 of these products... has a footprint approx. equivalent to **driving 17,787 miles** in a passenger car.



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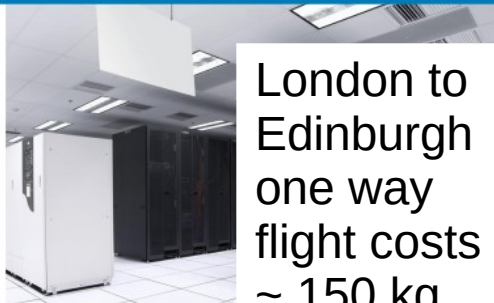
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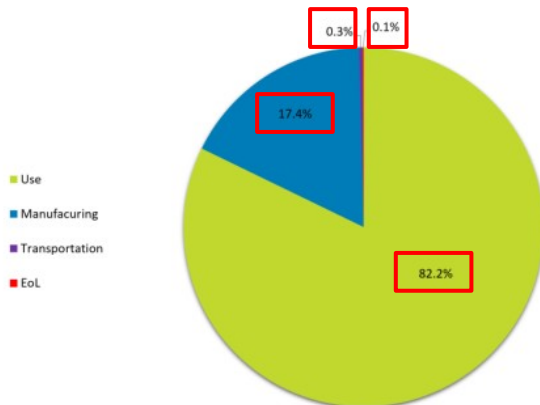
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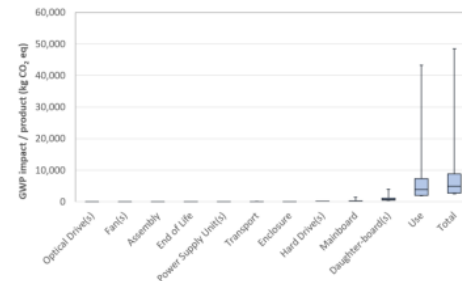


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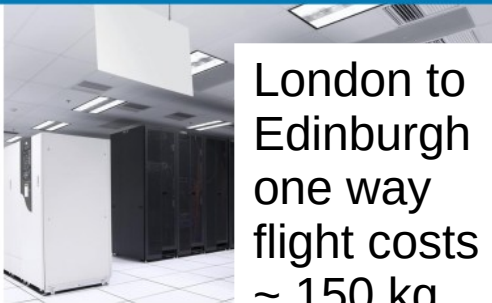
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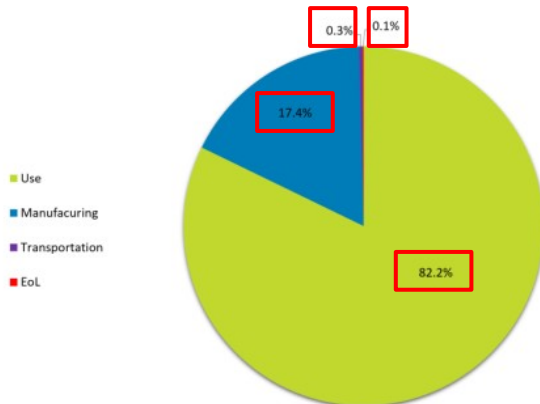
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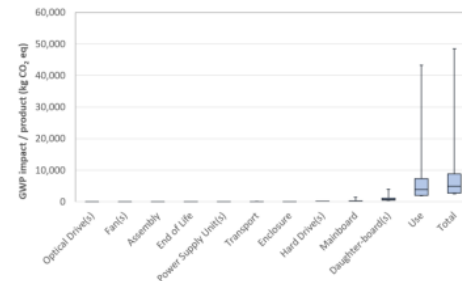


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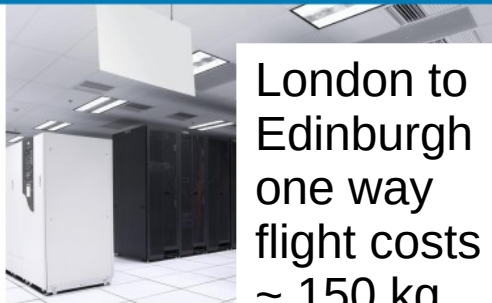
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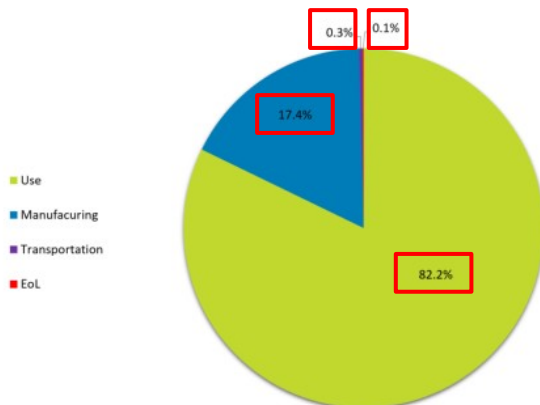
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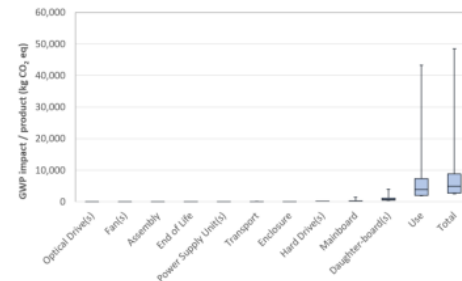


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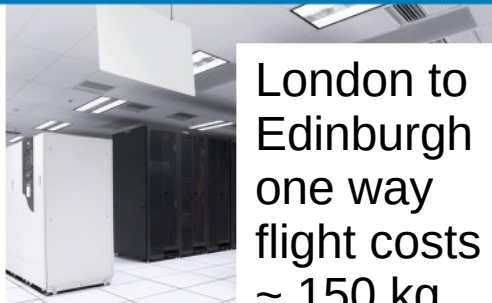
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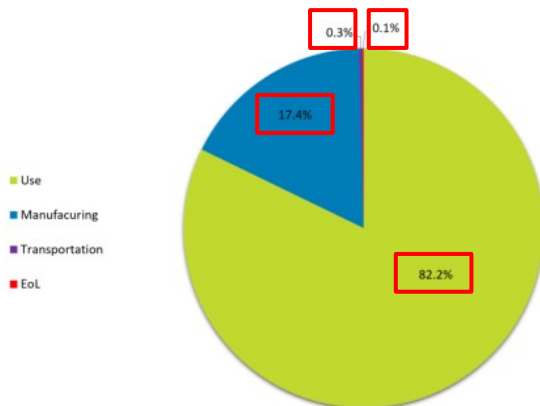
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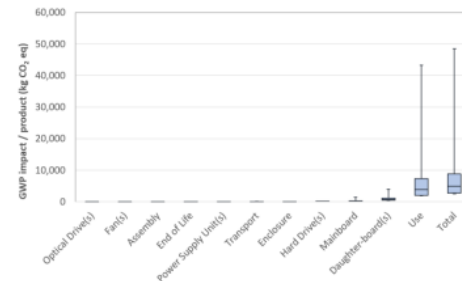


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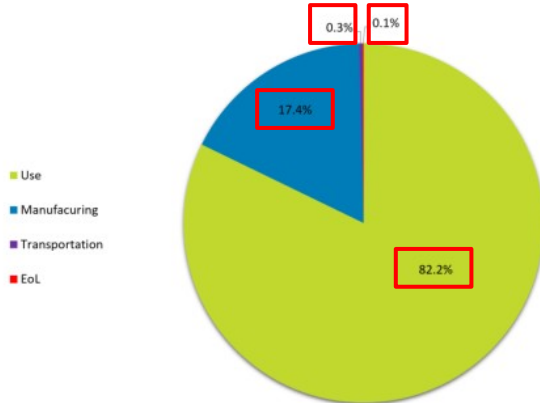
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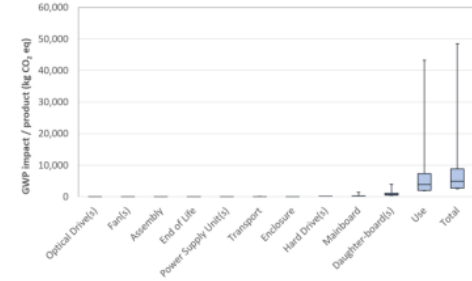


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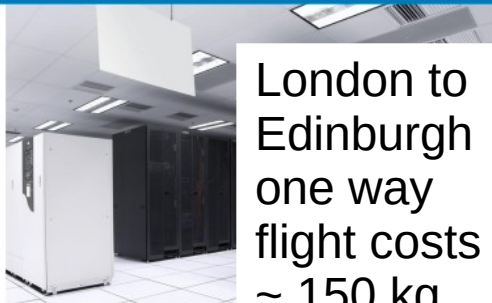
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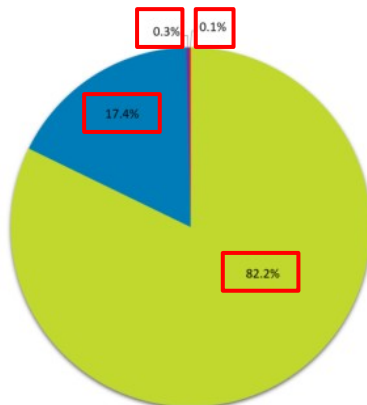
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- Use
- Manufacturing
- Transportation
- EoL

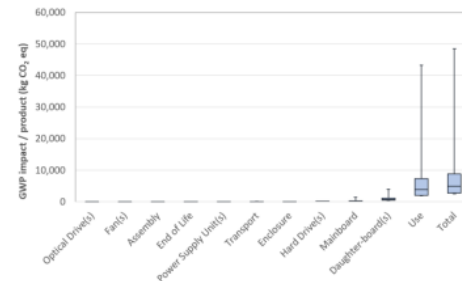


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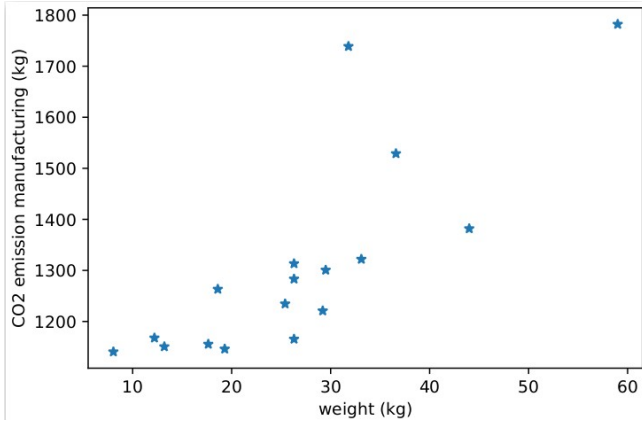
More Dell servers

machine name ▲	cpu number	dram capacity (G)	HDD/SSD quantity	product weight (kg)	carbon footprint (kgCO2e)	manufacturing	use	energy demand (yearly tec in kwh)
PowerEdge R230	1	16	2*1T(2.5 HDD)	8.05	5380	21.2	78.4	1011.34
PowerEdge R240	1	16	2*1T(3.5 HDD)	12.2	5260	22.2	77.3	980.7
PowerEdge R330	2	16	2*1T(3.5 HDD)	19.3	5510	20.8	78.7	1014.8
PowerEdge R340	1	16	2*1T(3.5 HDD)	13.2	5230	22	77.6	987.3
PowerEdge R430	2	16	2*1T(3.5 HDD)	26.3	8150	14.3	85.3	1760.3
PowerEdge R440	2	16	2*1.2T(2.5 HDD)	17.64	7360	15.7	83.9	1480
PowerEdge R540	2	32	4*2T(3.5 HDD)	25.4	8230	15	84.6	1636.37
PowerEdge R630	2	16	4*1.2T(2.5 HDD)	18.6	7260	17.4	82.2	1433.57
PowerEdge R640	2	32	4*300G(2.5 HDD)	26.3	7730	16.6	83	1760.3
PowerEdge R730	2	16	4*300G(2.5 HDD)	29.2	7490	16.3	83.2	1473.5
PowerEdge R730XD	2	32	2*300G(2.5 HDD)+6*1T(2.5 HDD)	29.5	8970	14.5	85.1	1813.32
PowerEdge R740	2	32	2*300G(2.5 HDD)+1*1T(2.5 HDD)	26.3	8640	15.2	84.3	1760.3
PowerEdge R740XD	2	32	4*1T(2.5 HDD)+2*120G(2.5 HDD)	33.1	9180	14.4	85.2	1858.87
PowerEdge R830	2	256	4*1T(2.5 HDD)+2*300G(2.5 HDD)	31.8	12600	13.8	85.9	2622.31
PowerEdge R840	4	128	4*1T(2.5 HDD)+2*300G (2.5 HDD)	36.6	15600	9.8	89.9	3325.7
PowerEdge R930	4	256	2*300G(2.5 HDD)+4*2T(2.5 HDD)	59	13300	13.4	85.9	2764.22
PowerEdge R940	2	64	2*300G(2.5 HDD)+4*2T(2.5 HDD)	44	14100	9.8	89.6	3012.13

Some interesting trends

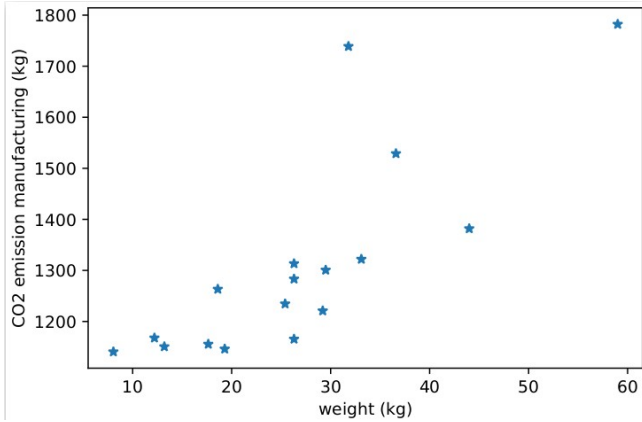
Some interesting trends

Heavier machines
cost more CO2 to
manufacture

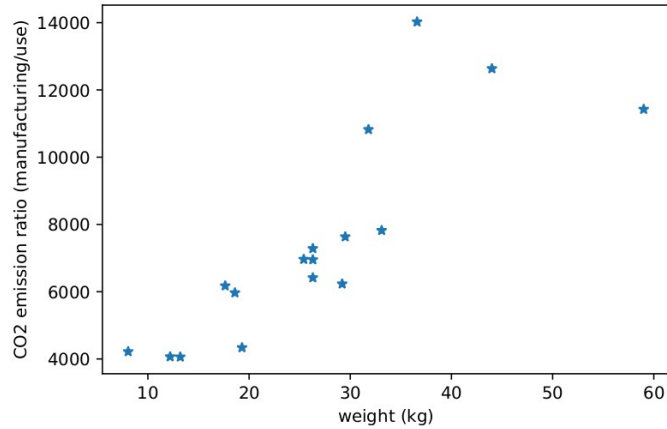


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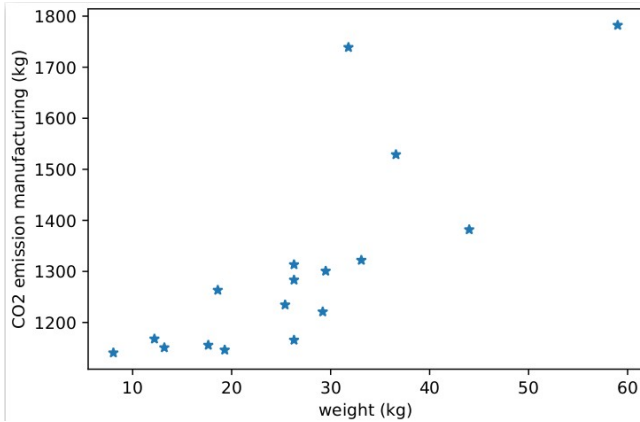


Heavier machines
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run

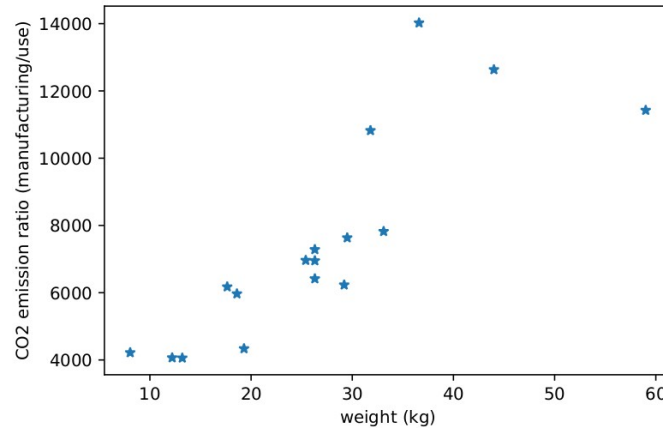


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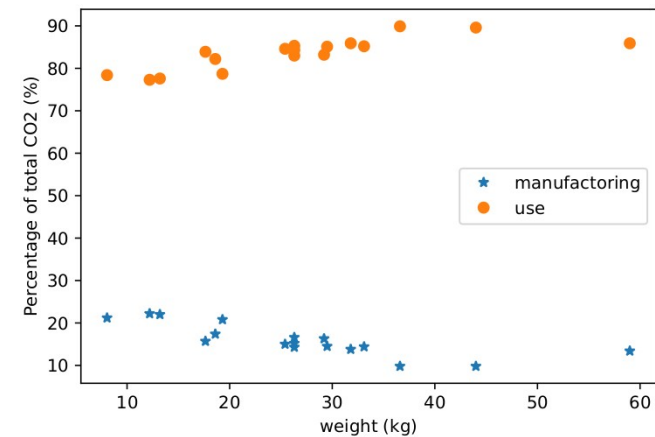
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Heavier machines cost more CO2 to run



Heavier machines cost more to run than to manufacture



To be continued

PCF Dependency on Configuration, Location, and Use Phase

Ex: R750 Server

