Estimating the environmental impact of a large Tier 2

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Overview

- The Imperial College Tier 2
- What do we mean by environmental impact?
- Methodology
- Result
- Conclusion
The Imperial College Tier 2

- ~8k worker node cores, hyperthreaded, accommodating ~16k jobs
  - Mainly serving CMS, LHCb and a large number of smaller non-LHC communities
- Memory 2-8 GB/core
- Storage: 85 storage nodes providing ~22 PB
- The Tier 2 is located off campus in a commercial data centre
- Co-located with the Tier 2 are HEP group computing and cloud services
  - These are not included in this survey
- Kit is run until it becomes unreliable rather than operate on a fixed replacement schedule.
  - Typically service life is about 8-10 years
Data centre

- The Tier 2 is hosted at the Virtus [https://virtusdatacentres.com] “London 3” Data Centre in Slough
- 3,000 m² net technical space
- 10 MVA incoming supply from National Grid
- 7.2 MW of total IT load
- **Design power usage effectiveness (PUE) of ~ 1.3**
  - Waste heat reuse in communal parts
- Previously the Tier 2 was hosted on campus in a converted lab space
  - No hot air containment
**Compute**

- **wf**: HP ProLiant SL2x170z G6 (2010)
- **wg**: Dell PowerEdge R410 (2011)
- **wh**: Supermicro X9DRT (2014)
- **wi**: Supermicro X10DRT-P (2016)
- **wj**: Dell PowerEdge R430 (2017)
- **wk**: Dell PowerEdge R440 (2019)
- **wl**: Supermicro H11DSU-iN (2020)
- **wm**: Dell PowerEdge R6525 (2020)

WN distribution by core
Total: ~8000 cores
Storage

**sedsk53-60**: Dell PowerEdge R510 (2012)

**sedsk61-66**: Dell PowerEdge R720xd (2014)

**sedsk68-70**: PowerEdge R730xd (2016)

**sedsk72-77**: Supermicro X10DRi (2018)

**sedsk78-96**: Dell PowerEdge R740xd (2019)

**sedsk00-42**: Dell PowerEdge R740xd2 (2021/22)

**Imperial College London**
What do we mean by environmental impact?

- Carbon footprint:
  - Power consumption
  - Manufacture (limited information)
- Electricity carbon intensity vary by country
  - We use the UK value
- Data centre uses electricity from renewable resources
  - Good, but this does not give us a free pass

Source: [http://calculator.green-algorithms.org/](http://calculator.green-algorithms.org/)
Methodology

● Use DCMI power interface (via ipmitool) to sample the instantaneous power usage of each machine every 5 minutes.
  ○ Very old worker nodes (~15% of cluster) do not have power monitoring available: Estimate power consumption from thermal design power (TDP)
  ○ Older storages nodes with additional chassis for disks do not monitor power to chassis: Estimated values from literature (~15% of cluster)
  ○ Data set for this talk: February 2023 (28 days)
  ○ Investigated PDU monitoring, however this is aggregated by phase, which tends to be shared by different types of machines.
  ○ Where the node type is homogeneous across a single phase, the PDU measurement is used as a cross-check.

● Use vendor provided information on carbon footprint where available.
  ○ Information is limited and difficult to validate against our actual setup.

● Electricity carbon intensities are country specific: UK 231.12 gCO₂e/kWh (2019)
CVMFS issues? Multicore jobs in single core slots?

Overall load and power usage are fairly constant.
Little difference in the distribution in newer nodes wrt previous generation.

Load15 and cpu_user vs power usage: Dell PowerEdge R430 (2017)

Lines are an artefact of the power measurement resolution (~15 W)
load15 and cpu_user vs power usage: Dell PowerEdge R6525 (2020)

Possibly an architecture feature artifact (Turbo Core)?
Worker nodes

Power usage/core suggest that our policy of running nodes until they die might keep our capacity up, but might not be the best for the environment.

- **wf**: HP ProLiant SL2x170z G6 (2010) 17.0 W/core
- **wg**: Dell PowerEdge R410 (2011) 14.2 W/core
- **wh**: Supermicro X9DRT (2014) 12.3 W/core
- **wi**: Supermicro X10DRT-P (2016) 10.2 W/core
- **wj**: Dell PowerEdge R430 (2017) 10.1 W/core
- **wk**: Dell PowerEdge R440 (2019) 10.9 W/core
- **wl**: Supermicro H11DSU-iN (2020) 5.4 W/core
- **wm**: Dell PowerEdge R6525 (2020) 6.1 W/core
## Storage

<table>
<thead>
<tr>
<th>Group</th>
<th>Manufacturer</th>
<th>Year of Purchase</th>
<th>All disks/active disks</th>
<th>Disk Size (TB)</th>
<th>Storage per server (TB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>00-42</td>
<td>Dell</td>
<td>2020/21</td>
<td>26/22</td>
<td>16</td>
<td>352</td>
</tr>
<tr>
<td>53-60*</td>
<td>Dell</td>
<td>2012</td>
<td>36/30</td>
<td>3</td>
<td>90</td>
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<tr>
<td>61-66**</td>
<td>Dell</td>
<td>2014</td>
<td>36/30</td>
<td>4</td>
<td>120</td>
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<tr>
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<td>2016</td>
<td>28/24</td>
<td>8</td>
<td>192</td>
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*estimate
**measured + estimate for extra chassis

Number of disks alone is not the whole picture.
Storage

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*estimate
**measured + estimate for extra chassis

However, newer storage servers use less energy per usable TB. Phew!
### Results: Power consumption: Worker nodes

<table>
<thead>
<tr>
<th>Node group</th>
<th>Power measurement in Watts</th>
<th>Power per node group in Watts</th>
<th>Power per core in Watts</th>
<th>Energy per year (kWh) per node</th>
<th>Energy per year per node group (kWh)</th>
<th>Energy per year per core (kWh)</th>
<th>kg CO2e/year</th>
<th>PUE = 1 total kg CO2e/year</th>
<th>actual PUE = 1.3 total kg CO2e/year</th>
</tr>
</thead>
<tbody>
<tr>
<td>wf (2010)</td>
<td>136</td>
<td>4896</td>
<td>17.0</td>
<td>1191</td>
<td>42889</td>
<td>17.0</td>
<td>382</td>
<td>13,767</td>
<td>17,898</td>
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<tr>
<td>wg (2011)</td>
<td>171</td>
<td>11970</td>
<td>14.2</td>
<td>1498</td>
<td>104857</td>
<td>14.2</td>
<td>481</td>
<td>33,659</td>
<td>43,757</td>
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<tr>
<td>wh (2014)</td>
<td>197</td>
<td>4728</td>
<td>12.3</td>
<td>1726</td>
<td>41417</td>
<td>12.3</td>
<td>554</td>
<td>13,295</td>
<td>17,283</td>
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<tr>
<td>wi (2016)</td>
<td>204</td>
<td>2448</td>
<td>10.2</td>
<td>1787</td>
<td>21444</td>
<td>10.2</td>
<td>574</td>
<td>6,884</td>
<td>8,949</td>
</tr>
<tr>
<td>wj (2017)</td>
<td>162</td>
<td>9720</td>
<td>10.1</td>
<td>1419</td>
<td>85147</td>
<td>10.1</td>
<td>456</td>
<td>27,332</td>
<td>35,532</td>
</tr>
<tr>
<td>wk (2019)</td>
<td>351</td>
<td>5265</td>
<td>10.9</td>
<td>3075</td>
<td>46121</td>
<td>10.9</td>
<td>987</td>
<td>14,805</td>
<td>19,246</td>
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<tr>
<td>wl (2020)</td>
<td>693</td>
<td>5544</td>
<td>5.4</td>
<td>6071</td>
<td>48565</td>
<td>5.4</td>
<td>1,949</td>
<td>15,590</td>
<td>20,266</td>
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<tr>
<td>wm (2020)</td>
<td>784</td>
<td>21952</td>
<td>6.1</td>
<td>6868</td>
<td>192300</td>
<td>6.1</td>
<td>2,205</td>
<td>61,728</td>
<td>80,247</td>
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<tr>
<td>SUM</td>
<td></td>
<td>66,523 W</td>
<td></td>
<td>582,741 kWh</td>
<td></td>
<td></td>
<td></td>
<td>187,060 kg CO₂e</td>
<td>243,178 kg CO₂e</td>
</tr>
</tbody>
</table>

**Headline figure:**
HEPSPEC06 hours delivered (12 months) 1,498,292,348 -> 0.162 g/HEPSPEC06/hour
## Results: Power consumption: Storage nodes

<table>
<thead>
<tr>
<th>Group</th>
<th>Average power usage (W)</th>
<th>power per node group (W)</th>
<th>energy per node group/year (kWh)</th>
<th>energy per TB/year (kWh)</th>
<th>kg CO2e/year/TB</th>
<th>PUE = 1 total kg CO2e/year</th>
<th>actual PUE = 1.3 total kg CO2e/year</th>
</tr>
</thead>
<tbody>
<tr>
<td>00-42</td>
<td>340</td>
<td>14,620</td>
<td>128,071</td>
<td>8.5</td>
<td>2.0</td>
<td>29,584</td>
<td>38,460</td>
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<tr>
<td>(2020/21)</td>
<td></td>
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<tr>
<td>53-60</td>
<td>330</td>
<td>2,640</td>
<td>23,126</td>
<td>32.1</td>
<td>7.4</td>
<td>5,342</td>
<td>6,945</td>
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<tr>
<td>(2012)</td>
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<td></td>
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<td></td>
</tr>
<tr>
<td>61-66</td>
<td>306</td>
<td>1,530</td>
<td>13,403</td>
<td>22.3</td>
<td>5.2</td>
<td>3,096</td>
<td>4,025</td>
</tr>
<tr>
<td>(2014)</td>
<td></td>
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</tr>
<tr>
<td>68-70</td>
<td>331</td>
<td>993</td>
<td>8,699</td>
<td>15.1</td>
<td>3.5</td>
<td>2,009</td>
<td>2,612</td>
</tr>
<tr>
<td>(2016)</td>
<td></td>
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<tr>
<td>72-77</td>
<td>451</td>
<td>2,706</td>
<td>23,705</td>
<td>16.5</td>
<td>3.8</td>
<td>5,476</td>
<td>7,118</td>
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<tr>
<td>(2018)</td>
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<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>78-96</td>
<td>268</td>
<td>5,092</td>
<td>44,606</td>
<td>12.2</td>
<td>2.8</td>
<td>10,304</td>
<td>13,395</td>
</tr>
<tr>
<td>(2019)</td>
<td></td>
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<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>SUM</td>
<td>27,581 W</td>
<td>241,610 kWh</td>
<td></td>
<td></td>
<td></td>
<td>55,812 kg CO2e/year</td>
<td>72,555 kg CO2e/year</td>
</tr>
</tbody>
</table>

**Headline figure:** 3.3 kg CO2/year/TB
New servers (Dell-R6525 in this example) have started being sold with catchy “lifetime” carbon footprint.

Manufacture carbon footprint retrieved by squinting.

No (public) information available for older nodes.

Carbon footprint due to usage depends heavily on local factors, but we can measure it - unlike for manufacture.

5440 kgCO2e +/-*

*The product carbon footprint data generated in this report was created using the GaBi 10 Software system for life cycle engineering, developed by Sphera Solutions Inc.

To view the full Life Cycle Analysis report click here.

Documentation for all GaBi datasets can be found online (Sphera Solutions Inc., 2020).
That’s not quite our server.
If you are a vendor reading this slide, can our kit please come with manufacturing carbon footprint of the actual server we have just bought?

Total number of machines: 84 storage servers and 253 worker nodes.
1600 kg CO$_2$e per node assuming 8 year lifetime: 200 kg per node per year: Total for site: 67,400 kg CO$_2$e.

What follows is a back of the envelope calculation....
Summary: kg CO$_2$e per year per Tier 2

PUE = 1.3: 383,000 kg = 445 sysadmins crossing the Atlantic in a plane*

*One sysadmin going from LHR to JFK: 860 kg CO$_2$ e
Conclusion

- Full carbon equivalent impact not easy to estimate accurately.
- Highly dependent on manufacturer for information that we can’t measure, e.g. embodied carbon cost.
- In-built server power monitoring good, but could be improved:
  - Careful PDU bank to Server mapping would allow better cross-checking of results.
  - Servers could contain more power sensors for specific components.
- Things are improving:
  - Greener energy supplies.
  - Heat reclamation becoming more commonplace.
  - Increasing communication with vendors around embodied carbon.
Backup: References


https://accounting.egi.eu/egi/