Environmental Performance of Data Centres - A Case Study of the Swedish National Insurance Administration

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Abstract

There are indications of Data Centres being nodes for environmental impacts in IT solutions, but due to reasons connected to protection of business core assets, few open studies on such centres exist. This LCA case-study of the Swedish National Insurance Agency Data Centre in Sundsvall confirms and quantifies the significance of the environmental load posed by the data centre. The centre increases the IT carbon footprint by more than half (54%) relative to the institutes PC equipment fleet. In the operational phase, climate change contributions are more than double to that of PC use. Environmental impact stemming from embedded emissions in data centre capital infrastructure is significant (33%) given the relative short economic lifetime of the IT hardware. Even within the cold climate geographical zone, about a third (32%) of data centre supplied energy is consumed by air-conditioning thus offering opportunities to further leverage free cooling.

1 Introduction

Data centres are increasingly important parts of business, public sector and society wide IT infrastructures. More and more IT services are delivered through the 'cloud' with physical data centres behind these. Data centre growth over the last decades means these centres alone are estimated to account for more than 1% of global electricity use [1]. Despite indications of data centres being nodes for environmental impacts, little detailed information is publically available on data centre configurations of performances.

The Swedish government operates a Green IT agenda 'ICT for the environment 2010-2015' that departs from the EU energy efficiency and climate change mitigation perspective [2]. The objective is to reduce burdens on the environment by governmental operations. Taking a holistic approach, the initiative centralizes around three ICT related actions: green public procurement, efficiency in IT operations and ICT enabled environmental efficiency. To be able to implement such goals, better knowledge of data centre environmental performance and drivers for environmental impacts is needed.

The magnitude of the environmental burden that IT products and service carry across their life cycle has been reported in several studies (e.g. [3], [4], [5] [6], [7], [8]). The success of strategies that aim to reduce this burden is ultimately measured by the quantified decrease in environmental impact of activities [9]. To support a systematic approach towards performance improvement, a baseline measure of impact is required [10].

This case study carried out at Försäkringskassan, the Swedish National Insurance Agency, investigates environmental performance at the IT infrastructure data centre platform configuration level. IT infrastructure is here defined as the equipment that enables a set of IT services [11]. Data centre is here defined as the conditioned facility that supports and houses centralised IT equipment.

2 Method and Data

Life Cycle Assessment (LCA) methodology is used to estimate the environmental impact of the Försäkringskassan data centre. The functional unit is one year of platform operations in the year 2010. The output parameters studied are electricity use in operations and lifecycle accumulated green house gas emissions indicated as *'Carbon foot-print'* using ReCiPe characterisation factors for climate change impact [12]. A life cycle inventory for 31 IT processes was made with 18 of these representing the data centre domain. The various lifecycle phases are divided up in two elements. The first element is labelled *'Capital'* and represents the procured assets inclusive of activities spanning the production, transport and waste management of each item. The second element called *'Operations'* represents the use stage of the infrastructure item.

The inventory relies on primary data gathered onsite at the data centre with assistance of resident IT infrastructure and facility experts. This information is referred to as the 'foreground inventory' and includes the installed base of equipment, metered energy supply and operational information such as the economic life time of the equipment in use.

2.1 Foreground Inventory description

The studied data centre (~1200 servers, 1.1 PB storage, 1.1MW power, 1750m2 floor-space) hosts central IT infrastructure used by 12 000 staff and web services available to Swedish citizens and various government functions. The centre is operated on a 7x24 basis. For disaster recovery reasons, it is situated at two physically separated locations around Sundsvall in northern Sweden. Each location is equipped with redundant Power Distribution Systems (PDS) fitted out with battery run uninterruptable power supplies (UPS) and diesel fuelled electric generation sets to secure sustained backup power in case of prolonged primary (grid utility) power supply interruptions.

The facilities hosting the IT equipment are kept between certain temperature and humidity thresholds by means of a chilled water based air-conditioning system (HVAC) which is supported by outside air economising roof top fans. In the summer, adiabatic cooling is applied. Within a closed loop system cooled air flows up from the raised floor through the IT racks picking up the heat that is dissipated by IT equipment. Warmer air then leaves the racks through various openings and the Computer Room Air-conditioning Units (CRAC) take the waste heat in. Electricity run chillers recover a level of energy and redistribute this to fulfil two thirds of the demand for office space heating. The combined infrastructure that makes up the power supply system is referred to as the 'electrical plant' whereas the climate control system is referred to as the 'mechanical plant'. Together these two systems form the data centre 'facility' infrastructure.

The hosted IT infrastructure comprises of Servers, Storage and Networking equipment. The server systems include Windows and Unix operated configurations. Each platform is partly consolidated and virtualised on shared hardware. The storage system is tiered across storage area network (SAN) and backup storage configurations. Data centre network links are primarily based on high speed fibre channel technology. For the inventory modelling of this study, the data centre local area network (LAN) category includes both networking and security devices.

For the IT function as a whole, an overall energy saving target is defined but not yet made specific to the different IT areas also because service availability management objectives take priority. Power management software is not actively used.

Table 1 lists the installed capital infrastructure that is the core of the data centre life cycle inventory. In the table component type, installed numbers, weight, economical lifetime and the estimated average power dissipated in operations is specified.

Components in the inventory of the data centre capital infrastructure	*# of units [-]*	*life time [yr]*	*power use [kW]*
Rack [115 kg]	240	12	-
PDS & cabling [796 kg]	32	20	0.1
UPS [2.15 t]	8	20	11.6
Battery [60 kg]	640	8	-
Diesel generator [5.0 t]	9	40	-
Transformer [4.5 t]	3	30	4.7
Casual gains [*]	1	1	4.8
Chiller [2.72 t]	7	20	26.5
CRAC [443 kg]	26	15	6.4
HVAC other [*]	1	1	38.9
Unix server [28 kg]¤	574	5	0.4
Windows server [7 kg]¤	616	5	0.1
LAN device [49 kg]	58	5	2.0
Disk controller # [2.14 t]	8	4	9.3
Hard disk ## [0.9 kg]	6356	4	0.03
Backup disk cabinet [#]	4	4	1.1
Backup hard disk [##]	350	4	0.01
Backup-tape library [#]	2	4	1.4

Table 1: Data centre inventory; installed base 2010 *(Note: * indicates no inventory; ¤ indicates server units are counted as logical instances; # indicates SAN storage capital items are used as proxies for backup storage capital items)*

PC Fleet

For comparison purposes an inventory of the Försäkringskassan Personal Computer (PC) fleet was also made. The installed base is about 14 900 machines, each equipped with a 19" LCD screen, external keyboard and a mouse. The mix of machines is 41% laptops and 59% desktops. A hand full of thin clients was in pre-production. The estimated electricity consumption of the PC fleet is 3.7 GWh per year.

Reporting

For reporting, the inventory processes are summed up in four functional groups:

1. Data centre facility infrastructure
2. Server platform
3. Storage platform
4. Data communication platform

2.1 Background Inventory

The environmental impacts from production and waste handling phases of different equipment as well as of electricity and similar flows needed for the operation, was described using literature data. The foreground dataset was linked to inventory data sets [13]. *'Capital'* Infrastructure components are associated using equipment weight with supplemental material shares and power use estimations stemming from online vendor available product declarations. Electricity production is modelled using the Swedish supply mix of 2005.

2.2 Allocation

Accreditation for avoided emissions as a result of active data centre waste heat recovery and energy reuse, is modelled by system expansion using a heat pump running on the same electricity mix. Credits connected to 0.3 GWh avoided electricity are brought to the account of the data centre facility operations.

3 Results

Table 2 lists the results of one year of Försäkringskassan data centre operation in terms of the direct annual electricity consumption (El.) and carbon footprint. The total amount of electricity consumed is 10.04 GWh for the year 2010. Of the total electricity used, 5.7 GWh is delivered to IT equipment. The remainder 4.3 GWh is consumed by the data centre facility infrastructure. Within the mechanical plant, chillers consume 46%, CRACs 44% and auxiliary HVAC equipment 10% of the supplied electricity.

Including credits to the facility for avoided electricity use due to waste heat reuse, the total data centre electricity use becomes 9.74 GWh. The data centre carbon footprint is estimated at 1.29 kilo-ton CO_2 equivalents.

Data centre infrastructure item	*El. use*	*Carbon footprint*		
		Tot.	Cap.	Ops.
	GWh	kt	%	%
FACILITY				
Electric. plant	*0.96*	*0.19*	*57%*	*43%*
Mech. Plant	*3.35*	*0.32*	*5%*	*95%*
Waste heat Recovery credit	-0.30	-0.03		
Facility total	**4.01**	**0.48**	26%	74%
IT PLATFORM				
Windows Servers	*0.49*	*0.07*	*35%*	*65%*
Unix Servers	*2.06*	*0.27*	*33%*	*67%*
Servers total	2.56	0.34	33%	67%
SAN storage	*2.08*	*0.30*	*38%*	*62%*
Backup storage	*0.08*	*0.07*	*90%*	*10%*
Storage total	2.16	0.37	48%	52%
Data-comm. tot.	1.01	0.10	14%	86%
IT total	**5.73**	**0.81**	38%	62%
TOTAL DATA CENTRE	**9.74**	**1.29**	33%	67%

Table 2: Data centre operational energy consumption and carbon footprint.

An energy efficiency indicator common to the industry is the data centre infrastructure-efficiency metric (*DCiE*) that divides the IT equipment energy demand by the total energy consumed. The inverse ratio is called the power use effectiveness ratio (*PUE*) [14]. In our analysis these metrics show: DCiE = 57%, PUE = 1.75. When incorporating the electricity credit, the adjusted metrics equate to 59% and 1.70 respectively.

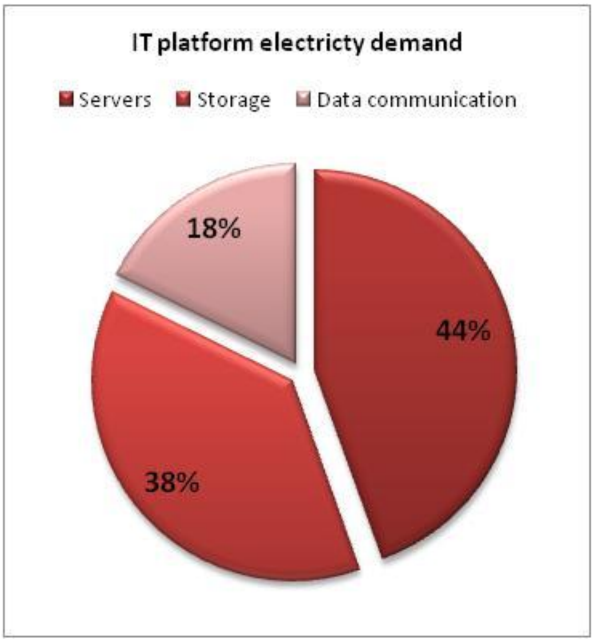

Figure 1: IT platform electricity demand fractions

Figure 1 shows the share of electricity used by IT platform. Within the group of servers, Unix servers account for 81% whereas Windows servers account for 19% of server electricity consumed.

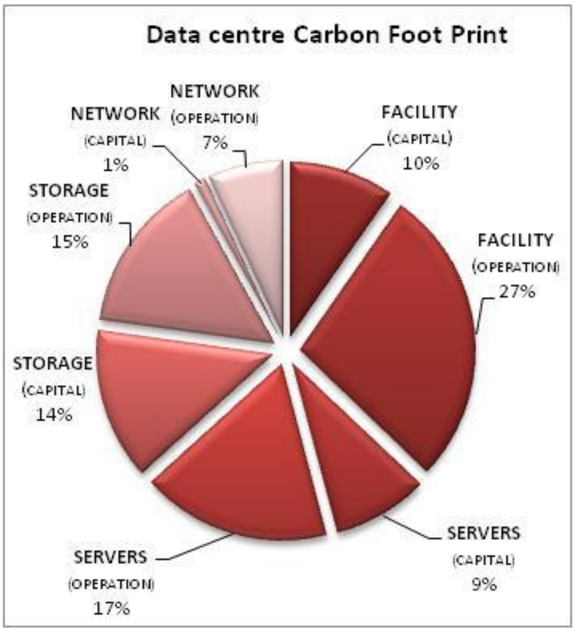

Figure 2:Data centre Carbon Footprint fractions

Figure 2 illustrates the carbon footprint share of capital and operational elements for the different platforms. Of the green house gas emissions that make up the total data centre carbon footprint, 33% are embodied in capital infrastructure. In the carbon footprint of IT platform (thus excluding the facility overhead), the capital contributions are higher at 38%.

PC Fleet

The carbon footprint of the PC fleet amount to 2,4 kilo-ton CO2 eq. with 84% attributed to the load by embedded emissions in capital and 16% originating from operations.

4 Discussion

The carbon footprint of the data centre implies an overhead factor of 1.5 over the PC carbon footprint. Study results reveal several areas for attention when aiming to improve the environmental performance of the data centre.

Capital Infrastructure

The relatively high contribution of material elements to the overall carbon footprint of the data centre provided services is emphasized. A reduced material intensity of data centre services is a significant lever for a lowered carbon footprint. In comparison to the facility infrastructure, IT capital related impact stands out in particular. A key driver here is the relatively shorter life time of IT equipment. The importance of capital contributions is especially relevant in the context of a low fossil content and high share of renewable sources in the electricity mix as applicable with the Swedish production mix. The insight related to the importance of data centre capital is also relevant when considering reducing the significant carbon footprint of the PC fleet. In relative terms, data centre capital currently implies a factor 1.2 overhead to the PC capital share in the PC carbon footprint. In a life-cycle perspective solutions that imply a problems shift towards the data centre should be avoided [15], [16] including considerations of capital contributions. When reviewing the servers, it must be noted that different applications have different hardware resource requirements. Never the less, modular configurations as deployed in the virtualized Windows area overall show less material overhead, lower power consumption and relative longer economical lifetime of capital in comparison to their standalone counterparts. The combination of modular hardware, server consolidation and virtualization, reduces the carbon footprint for the server platform. On a side note, a potential rebound effect associated to the flexibility offered by virtualization may be applicable. Deployment of virtual machines takes generally takes less effort then procurement of dedicated hardware. To further investigate this, system expansion into the application domain and service management practices would be required.

Within the storage platform significant overall contributions to the carbon footprint are connected to the SAN. The impact stemming from SAN capital closely matches that of SAN operations. Besides reduced demand for data storage, infrastructure measures can reduce SAN related impacts. Solutions that, while providing similar functionality, limit the amount of hard disk units deployed, lower overall SAN power consumption and within the lifecycle only marginally increase upstream environmental impacts can contribute to a significant reduction of the environmental load of the data centre overall. Further research into this area is recommended.

Data centre cooling

As indicated by the DCiE, 43% of electricity supplied to the data enter is considered overhead. The energy use in mechanical plant operations dominates the carbon footprint of the facility infrastructure. This is despite the use of free cooling by indirect integration of outside air and waste heat reuse in the (mainstream) data centre facility technology setup. By retrofit, technology options could be considered that are better attuned to the cold climate geographic zone. Various data centres are specifically situated in the north of Sweden for benefits in direct air side free cooling [17]. Alternative localised clean tech innovations to consider are for example snow cooling [18] or tapping in to low temperature river water [19] all of which may reduce the need of electricity based artificial cooling.

Within the constraints of the current facility setup, certain improvements can also be made. Best practice examples are shared by the voluntary EU Code of Conduct. In this forum benchmarks of data centres are available that show the Försäkringskassan reported DCiE is only slightly above the European average of 56% despite its favourable geographical location. [20]. In particular the potential for decreased chiller use stands out when compared to indicators for higher temperature regions (notably the Stockholm area). To better leverage free cooling and minimise chiller-hours, pre-requisite actions that avoid the mixing of cold and hot air within the data centre rooms take priority. After such air flow containment, further tuning of humidity controls and temperature levels can then be planned [21] [22] [23].

5 Conclusion

A life cycle inventory and assessment of the data centre of the Swedish Insurance Authority was performed. The environmental load associated to the capital infrastructure of the data centre is significant and to a large extent dependent on the relatively short economic lifespan and specific configuration of IT equipment. Opportunities to further leverage free cooling are identified. Supported by an effective Green IT policy, environmental performance of the IT data centre can be improved through infrastructure architecture and design.

6 Acknowledgments

We recognise Försäkringskassan IT Infrastructure and facility teams for their contributions and especially thank Rickard Edebrandt for his continued support.

7 Literature

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