An Evaluation of ICT Smart Systems to Reduce the Carbon Footprint

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Abstract— This research aims to assess and evaluate the impact on sustainability in buildings through implementation of ICT Smart Systems. The setting for this research will be for a large global organisation's headquarters in Germany. The list of objectives are: to audit the ICT infrastructure used and to survey the existing smart systems implemented; to investigate the total energy expenditure and carbon footprint for ICT equipment during a yearly period; and to explore how to best transfer best green ICT practices to other buildings. Based on the findings in this paper, investing in energy-saving ICT equipment, or even a BMS, can be very cost beneficial to a company and reduce the carbon footprint of commercial buildings when implemented correctly.

Keywords—LCA methodology, ICT, Smart Buildings, BMS environmental impact

I. INTRODUCTION

According to the Intergovernmental Panel on Climate Change, the world's buildings account for 32% of global final energy use (Chalmers, 2014) and nearly a third of global GHG emissions (Mardiana and Riffat, 2015). This number is expected to further increase as standards of living increase around the globe. (PBL NEAA, 2016).

A remarkably large part of this energy expenditure comes from Heating, Ventilation and Air-Conditioning (HVAC) systems, a staggering 60% of total consumption (Mardiana and Riffat, 2011). Lighting accounts for roughly 11 to 20% of total building energy demand. The remainder is divided amongst a host of electrical appliances, such as phones, computers and other ICT equipment (EIA, 2017).

Considering these facts, it is crucial to explore developments within this sector to reduce the carbon footprint and energy usage. This study will focus on opportunities within the '*Smart Building*' sector as there are many opportunities to be found here, particularly involving the usage of ICT.

The aim of this research is to assess and analyse the impact on sustainability for ICT smart systems in buildings within a commercial setting for a large, global industrial manufacturing organisation's headquarters in Germany that has such systems implemented already. A set of objectives will support this aim, these are: (i) to audit the current ICT Infrastructure used by the organisation in their building; (ii) to investigate the total energy usage from the ICT Infrastructure; (iii) to survey the existing smart system implementation and how it helps reduce the carbon footprint of ICT; (iv) to explore how to transfer best green ICT practices to other companies.

[1] http://www.oecd.org/site/stitff/45983022.pdf

II. LITERATURE SURVEY

GHG emissions are growing rapidly as a result of the ICT sector, due to the more and more network connected devices being available everywhere, as well the increasing demand for web services. In a BAU scenario, these GHG emissions are expected to triple between 2007 and 2020. However, the ICT sector also contributes to reductions in GHG emissions and energy savings through innovative smart technologies. This is known as the 'enabling effect' of ICT (GeSi, 2010).

ICT is viewed as a crucial part of transitioning to a more sustainable future. While the premise of using ICT smart systems to reduce the carbon footprint sounds very positive, the reality of the situation is that ICT has both significant positive and negative impacts on the environment as laid out in a study by the Organisation for Economic Cooperation and Development (OECD)[1] (see table 1).

Table 1: ICT impacts on the Environment (Berkhout & Hertin, 2001)

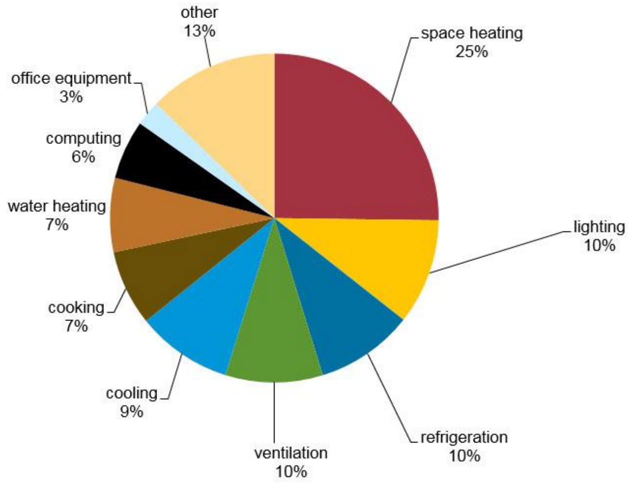
Positive Impacts	Negative Impacts
Dematerialization and online delivery	The production and distribution of ICT Equipment
Reduction in the need for travel	Energy consumption in use (directly and for cooling)
A host of modelling, monitoring and management applications	Short product life-cycles and e-waste
Greater energy efficiency in production, use and recycling	Potentially exploitative applications

Some of these impacts are more pronounced than others, but a big contributor to global emissions is the short product life-cycle sees in most ICT devices. The link between ICT and the broader sustainability goal is tenuous and not always well understood (ibid). A real issue here is "incomplete substitution" of ICT, whereby ICT equipment adds to the overall problem rather than lessening it. OECD identifies this as a very significant issue. The Global e-Sustainability Initiative (GeSI) however, remains positive about the potential of ICT technologies. Through measurement of what is known as the 'mitigation potential' which is used to measure the avoided or reduced GHG emission of ICT, it is believed that the increased use of ICT technologies, such as those in smart building management, will cut overall emissions by 16.5% by 2020 (GeSI, 2008).

The concept of 'smart buildings' have been around for at least two decades. As the development of technology have progressed, so to have the definition and implementation of the concept of smart buildings. So what is a 'Smart building'? Arkin and Paciuk (1997) suggests that the 'smartness' of a building is not just the technologies utilised within the building (e.g. HVAC or lighting), but that it is also measured by how well these systems are integrated together. Kroner (1997) suggest that smart buildings are simply electronically enhanced buildings. According to a study laid out by CRC Construction Innovation, there are four primary elements that integrate in a smart building: ICT sensors, integrated information management system and performance models, actuators and a backbone or nervous system, which essentially connections the former elements together (CRC Construction Innovation, 2003).

The impact from buildings is very significant. A survey conducted in 2012 by the U.S. Energy Information Administration on Commercial Buildings Energy Consumption shows how HVAC and lighting alone accounts for roughly 78% of a commercial buildings energy usage[2] (see figure 1).

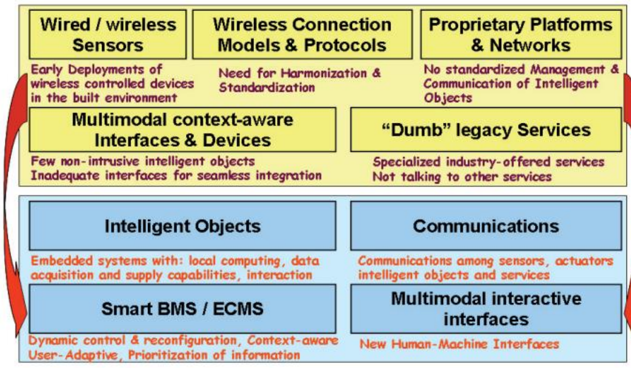
Figure 1: Distribution of energy use in commercial buildings (U.S. Energy Information Administration, 2016)



In another report: Climate Change: Implications for Buildings, it has been underlined that there may be a potential for up to 50-90% energy savings in both new and existing buildings, providing it is done right.[3] One of the key issues with a 'building-as-usual' strategy include is the rise of the global population, and with it, higher demand for energy and higher temperatures as a result of global warming which increases energy demand principally for HVAC systems. (EIA, 2017) The primary mitigation strategies comprise of: Energy efficient technology, such as building envelopes, energy-efficient appliances and improved automation that can respond to changing conditions; Service demand reduction via personal and behavioural changes, which can be moderated through carbon pricing, carbon trading, property CO_2 taxing and absolute consumption limits for a building; System and infrastructure efficiency, which includes retrofitting older buildings and building new buildings with very low energy usage, passive building designs that can alleviate the need for HVAC systems entirely and prioritisation of energy performance and use-factions through building design (Buckman et al, 2014), construction and commissioning; Carbon efficiency, or shifting fuel and energy supply infrastructure to buildings and evolution of the energy provision for those that lack access to modern energy carriers and equipment (estimated 2 billion people)(Chalmers, 2014).

As laid out in a report by the European Commission, it is crucial to reduce energy consumption in buildings when taking into account the targets set for 2020 by the European Council in 2007 in their SET Plan (European Strategic Energy Technology Plan). To achieve this, the one of the most important aims is the mobilisation of ICT to accelerate towards a sustainable and low-carbon economy, and increasing energy efficiency through ICT (European Commission, 2009). Going further, the European Commission has laid out a number of fundamental pillars when it comes to development of smart buildings (see Figure 2).

Figure 2: Technologies for smart buildings (ibid)



There seems to be disagreement as to what sustainable and energy-efficient buildings are and little utilization of ICT-based informed decision-making in the process and use of sustainable and energy-efficient facilities. Some other problem areas that seem to exist surrounding smart buildings are the many standards regulations for such buildings, some of which are in conflict with others, the lack of standardization of environmental systems and their configurations and need for occupancy feedback to interact with behaviour modifications in smart systems (ibid). Beyond this, there are several other barriers, such as lack of incentives for developments in smart building technologies, the buildings sector being slow to adapt new technology; a whole 15 year cycle for commercial buildings on average (ibid), and lack of skilled technicians and operators to handle BMS (Ma et al., 2016). Possibly the most significant problem seems to be the confusion surrounding the enormous quantity of different unknown and often competing vendors that offer different kinds of equipment, components and other systems for smart buildings, most of which often do not work together. With this is mind, many organisations are delaying investments in ICT smart systems for their buildings (Weinschenk, 2017). It is crucial that organisations take time to assess the impact of ICT initiatives in buildings as a greater understanding of the benefits these offer will accelerate their normalization and adoption.

III. METHODOLOGY

There are many different methodologies aiming to assess the balance between direct emissions and enabling effects of ICT. While no one true methodology exists that supports every case scenario, an appropriate methodology is one that is practical, user-friendly and enables the freedom of adapting the method of the methodology to the objectives of the organisation or organisation, while still yielding robust results (Öko-Institut et al, 2013). As this research is aimed towards an organisation which is situated in a smart building with an extensive ICT network for energy efficiency, the following methodology has been chosen due to its adaptability and flexibility of use.

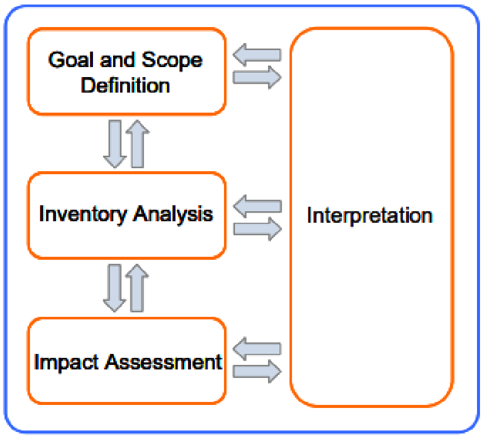
A. Life Cycle Assessment (LCA)

LCA is an approach to evaluating environmental impact that has been around since the 1980s. It is a methodology used to identify and evaluate environmental impacts, especially in relation to a product or material's life cycle. It is considered to be a valuable resource to provide insight and analysis of a product's energy, waste, emissions etc. from a life-cycle perspective, and can provide further examination of any associated issues that might have an effect on the environment (ETSI, 2011). The methodology focuses on analysing and interpreting energy and/or physical requirements for the production and use of a product and any associated waste that may be released into the environment as an effect of the production or use of such a product.
For this research, the ISO 14040 LCA is being adopted. LCA has four basic stages, these are: Goal and scope definition, inventory analysis, impact assessment and interpretation (ATIS Exploratory Group on Green, 2010) (see figure 3).

[2] https://www.eia.gov/consumption/commercial/reports/2012/energyusage/

[3] https://www.cisl.cam.ac.uk/business-action/low-carbon-transformation/ipcc-climate-science-business-briefings/pdfs/briefings/IPCC_AR5__Implications_for_Buildings__Briefing__WEB_EN.pdf

Figure 3: The Methodological Framework for LCA (Lehtinen et al, 2011)



The case study is a global organisation based in Germany. For the purpose of this research, we will be focusing on their headquarters, which is a Leadership in Energy & Environmental Design (LEED) Platinum certified building.[4]
For the purposes of this particular research, the four stages of LCA will be interpreted as such:

1. *Goal and Scope Definition*: Evaluate the environmental impact of the reported ICT equipment used in the organisation's headquarters.
2. *Inventory Analysis*: Provide an overview of the reported ICT inventory, including any ICT equipment that contribute to lower energy usage and by effect lower emissions.
3. *Impact Assessment:* Assess the current carbon footprint of the ICT equipment in the building using SusteIT tool[5].
4. *Interpretation:* Reporting the results, and making recommendations how to apply best green ICT practices to other organisations.

The baseline for this research will be data provided by the organisation. This will include a limited inventory list of ICT equipment in the building and an overview of the ICT smart systems that lower the energy expenditure of the building.

IV. RESULTS & DISCUSSION

A. Inventory Audit

The organisation has provided an inventory list of the ICT equipment used in the building as well the sensors and systems that control usage and output of energy. The office hours are 8-9 hours per day, 5-6 days a week with an average number of working months of about 11 months. So as to better estimate energy usage and carbon footprint, it will be assumed a working day is 9 hours, 6 days a week. This equates to 288 days/year where the office is open. Outside of office hours, all ICT equipment is switched off by the BMS. Certain equipment, such as routers, sensors and other control modules are left active throughout the year, equating to 8760 hours/year. For company mobile phones, the power consumption has been averaged from that of charging a phone and the number of hours spent charging on average in a year.[6] Based on the data gathered and provided by the organisation, SusteIT will be used to calculate the energy usage, CO_2 emissions and energy cost of the ICT equipment.

The total kWh can be calculated into kWh/year by the formula, as is done in the SusteIT tool:

$$E_{(\mathrm{kWh})} \ = \ P_{(\mathrm{W})} \ \times \frac{t_{(\mathrm{hr})}}{1000} \times 288\ (\mathrm{days})$$

Table 2: Inventory List

Device	Quantity	Brand - Model	Watts (Active)	Watts (Powersaving mode)	Hours (Active, idle) per Year	Hours (Powersaving mode) per year	kWh/y per unit	kWh/y per unit (Powersaving)	Total kWh/y
Standard PCs	200	Fujitsu Esprimo	80	20	1728	864	138.2	17.28	31,096
Laptops	1,000	Fujitsu Lifebook	65	15	2016	576	131	8.64	139,640
LED Monitors w. power saver functions	1,600	DELL	28	3	2016	576	56.4	1.8	93,120
Conference room and other screens	180	Samsung LED TV Monitors	50	20	1440	1152	72	23	17,100
								PCs & Monitors Sub-Total:	280,956
Wireless Access Points	320	ASUS BRT-AC828	8	1	4380	4380	27.6	4.4	10,240
								Networking Sub-Total:	10,240
PBX Connected Phones	650	Siemens OptiPoint	5	--	2592	--	13	--	8,450
Regular VOIP Phones	200	Siemens Gigaset	2	--	2592	--	5.2	--	1,040
Business use mobile phones (charging)	1,000	Varies (Samsung or iPhone mainly)	8	--	864	--	6.9	--	6,900
								Phones Sub-Total:	16,390
Small networked office printer/scanner	250	HP LaserJet Pro	470	3	576	2016	270.7	7.7	69,600
Networked Office printer/scanner/fax machines	40	HP LaserJet Enterprise	620	6	1008	1584	625	19.71	27,944
								Printers Sub-Total:	97,544
Building Sensors for energy saving and optimization	30,000	Varied	1	--	8760	--	8.8	--	264,000
RoomOptiControl modules	200	Siemens	2	--	8760	--	17.5	--	3,500
								Sensors & Control Sub-Total:	267,500
Photovoltaic Array	800 Solar Panels	Siemens	--	--	--	--	--	--	221,967*
								* Power Generation Sub-Total:	
								Total:	450,633

Table 2 shows the ICT inventory list calculated in SusteIT. This includes estimated power consumption of single unit, both active and in power-saving/standby mode. This has been divided into four categories with their calculated total power consumption: PCs & Monitors (280,956 kWh/year), Networking (10,240 kWh/year), Phones (16,390 kWh/year), Printers (97,544 kWh/year) and Sensors & Control (267,500 kWh/year). Furthermore, the organisation has a large photovoltaic system consisting of 800 solar panels covering more than 13,900ft^2 of the building's roof. According to the client, this system provides roughly a third of the energy required to run the building, this has therefore been subtracted from the overall power usage and emissions of the ICT inventory.

Table 3 shows the data as it would be further inputted into SusteIT. To calculate the Energy Cost and CO_2 emissions per year, a country electricity price and country emissions number is required. This data has been retrieved from Eurostat, the statistical office of the European Union and from the European Environment Agency respectively.[7,8] As the office is based in Germany, all prices are displayed in Euro (€).

Table 3: Overview of Energy Use and CO_2 emissions for ICT equipment

Germany electricity price (€/kWh)	**0.15**
Germany CO_2 emission (kg CO_2/kWh	**0.425**

Category	Energy Use (kWh/y)	%	Energy Cost (€/y)	CO_2 emissions (kg/y)
PCs & Monitors	280,956	34%	42,143	119,406
Networking	4,351	1%	1,536	4,352
Phones	6,964	1%	2,459	6,966
Printers	41,446	5%	14,632	41,456
Sensors & Control	267,500	32%	40,125	113,688
Power Generation	-221,967	-27%	-33,295	-94,336
TOTAL	**379,250**	**100%**	**67,600**	**191,532**

Figure 4 shows the distribution of kWh/y in percentage for the inventory. This shows that the biggest source of energy usage is from PCs & Monitors (34%), closely followed by Sensors & Controls. Networking, Phones and Printers do no contribute a large part to the energy usage. At the same time, the photovoltaic array that generates energy does indeed generate about a third of the energy used, thus subtracting from the overall usage.

[4] http://leed.usgbc.org/leed.html

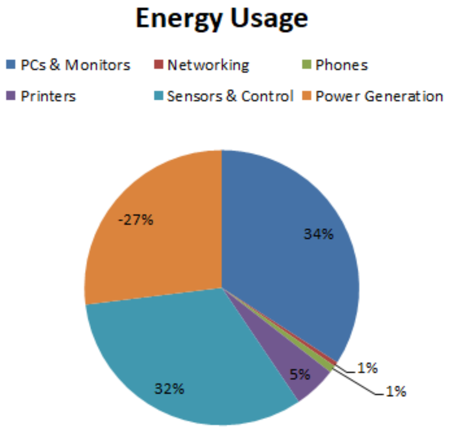
[5] http://www.susteit.org.uk/files/

[6] https://www.techadvisor.co.uk/how-to/gadget/how-much-does-it-cost-charge-phone-tablet-or-laptop-3632210/

[7] http://ec.europa.eu/eurostat/statistics-explained/index.php/Electricity_price_statistics

[8] https://www.eea.europa.eu/data-and-maps/indicators/overview-of-the-electricity-production-2/assessment

Figure 4: Distribution of the Energy Usage for ICT equipment



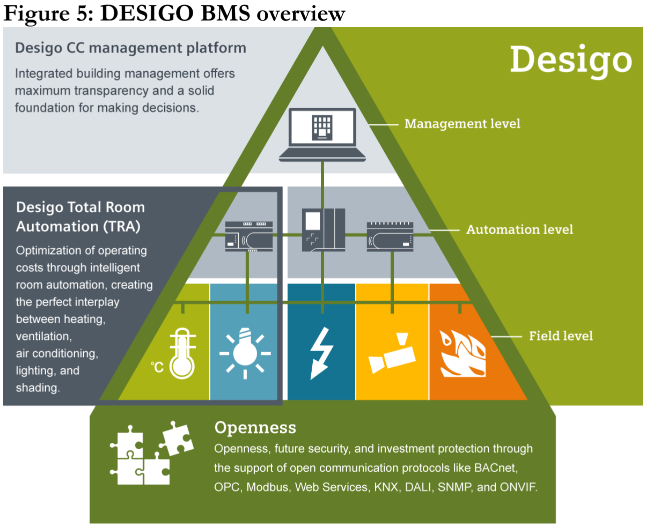
B. *Building Management System - Desigo*

The 30,000 sensors and control modules utilized in the building is connected to a Desigo[9] system from Siemens which is an advanced BMS that links up all subsystems in the building (light, HVAC, energy, video management, fire protection and access). The sensors in the building continually analyses and adjusts the subsystems for the BMS to effectively reduce the energy usage of the building. To save energy, the company has heavily invested in ICT equipment that use as little power as possible, or equipment that has good power-saving modes to conserve energy when it is not being used.

RoomOptiControl, a part of the Desigo system, has been installed in every room of the building. These modules provide continuous feedback to users and will detect unnecessary energy consumption and alert users. At management level, the Desigo BMS is connected to Desigo CC; a management software platform. This allows personnel to continually monitor, respond to alarms and to make changes where needed, this software is used both on company smartphones as well as personal computers and is connected to the cloud, meaning operators do not have to be on site to monitor the BMS.

Through this advanced BMS implementation and the use of their photovoltaic array, the company's headquarters use 90% less energy and have a 90% smaller carbon footprint compared to their old headquarters.

Figure 5: DESIGO BMS overview



V. CONCLUSION

ICT Smart Systems such as BMS can be very beneficial in reducing energy usage, costs and emissions when implemented correctly. Buildings currently account for 32% of global energy use and 19% of GHG emissions from energy, and energy use of buildings could double or even triple by 2050 as standards of living and commerce increases (Chalmers, 2014). Furthermore, many initiatives and policies are being put in place, such as the one the European Union in the Climate Action policy.[10] It is clear that new strategies for ICT smart systems must be considered to accelerate the adoption and normalization of such systems on a global scale.

As the research has demonstrated, there are many benefits to a fully implemented BMS. Converging from field level into a centralized management system to constantly being able to monitor building metrics can be extremely cost effective. With these considerations in mind, why then is ICT smart systems not seen more commonly in buildings?

Most likely, this is due to the many obstacles to implementing ICT smart systems into buildings, such as lack of incentives for smart buildings and the need for new business models where there are plenty of money for well-developed existing projects (Fawkes, 2015). Another factor holding back the smart building revolution back seems to be a lack of advice and knowledge on the subject and the huge market full of equipment, systems, interfaces and components that often do not function together. A convergence of these systems is needed, for a simpler and cheaper overall solution. In turn companies should then be able to see more immediate benefits of introducing a ICT smart systems into a new or existing building.

Recommendations

- Switch to ICT equipment with power-saving functions, so when it is not being used, it will go to standby mode or similar. For portable equipment, not only will this conserve battery life, but tremendously decrease the overall energy usage as shown in table 2.
- Switch off all non-essential equipment outside of office hours. Even with power-saving functions, the energy use for equipment is still significant for extended periods of time and can be costly.
- Install energy-saving kits for power-outlets that can be programmed to turn off when not in use.
- Invest in a BMS. Even a simple implementation could potentially be very cost-effective and help accelerate towards a more sustainable future.
- Invest in and install in-house energy generation such as a photovoltaic array, which are currently at an all-time low cost (Wesoff, 2017). Combining this with an advanced, fully connected BMS could reduce energy use by up to 90% while reducing the carbon footprint.

9 http://www.buildingtechnologies.siemens.com/bt/global/en/buildingautomation-hvac/building-automation/building-automation-and-control-system-europe-desigo/pages/desigo.aspx

10 https://ec.europa.eu/clima/policies/strategies_en

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PBL Netherlands Environmental Assessment Agency (NEAA). 2016. *Trends in Global CO_2 Emissions – 2016 Report*. Available from: http://edgar.jrc.ec.europa.eu/news_docs/jrc-2016-trends-in-global-co2-emissions-2016-report-103425.pdf . [5 January 2018]

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APPENDIX

Inventory List

	Quantity	Power usage pr. Unit in W (Normal/Powersaving)	Daily hours used on average (Normal/Powersaving)
Fujitsu Esprimo Desktop PCs	200	80 (20)	6 (3)
Fujitsu LifeBook Laptops	1,000	65 (15)	7 (2)
DELL 24' Monitors	1,600	28 (3)	7 (2)
Samsung 50' LED TVs	180	50 (20)	5 (4)
HP LaserJet Pro Printers	250	470 (3)	2(7)
HP LaserJet Enterprise Printers	40	620 (6)	3.5(5.5)
Siemens OptiPoint Office Phones	650	5	9
Siemens GigaSet Phones	200	2	9
Company Mobile phones (Samsung/iPhone)	1,000	--	--
ASUS BRT-AC828 Wireless Routers	320	8 (1)	24
DESIGO Sensors	30,000	1	24
RoomOptiControl Modules	200	2	24

Re: Project Work - Data Gathering Indbakke x

[redacted]
til mig

Dear Andreas,

Here is the data we have been able to share with you. Apologies if it is in a slightly different format than requested.

The building project has been running since 2010 and finished in 2016 and the building has a Platinum Leader in Energy and Environmental Design (LEED) certification. We have reduced our energy usage and carbon footprint by around 90 percent compared to our old headquarters.

The whole building has incorporated a Siemens DESIGO BMS, which is a state-of-the-art building automation system. For more information on this, please visit this address:
Siemens DESIGO Building Management System

Desigo is connected to 30,000 data points/sensors that continually provide us with valuable data on the building, and it is all managed in Desigo CC. We also have RoomOptiControl modules linked up to Desigo in every room of the office which lets our employees control things such as lighting and climate, you can also read more about this in the link I sent you.

On the roof of the building we have installed a photovoltaic system consisting of over 800 solar panels, which produces around a third of the energy that the building needs.

Our average office hours are between 8-9 hours, 5-6 days a week. The office is open around 11 months. Desigo switches off anything non-essential outside of office hours as long as it is not being used. Sensors, routers and control modules are left on throughout the whole year (24/7/365).

I have compiled and inventory list of our office IT equipment and the sensors/RoomOptiControl. This includes their hours of use and power usage. Please see the embedded file for more information.

If you have any further questions, feel free to get back to me.

With best regards,
[redacted]