EDINBURGH NAPIER UNIVERSITY

SCHOOL OF COMPUTING

MSc INITIAL REPORT

1. Student details

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2. Project details

Project title	**Green-sight:** The prototype of a web-based motivational carbon calculator to provide an incentives for sustainable IT
Summary of project (300 words) *(=274 words)* Include a note of its aims, the main research questions, the methods to be deployed, deliverables, and means of evaluating the project work as a whole.	*"In Europe, a survey by IT services firm LogicaCMG stated that more than four in five of the UK, French, German, Dutch, and Swedish companies needed technology that would help them improve their energy efficiency. Some 74% of them said they also needed a way to measure their impact on the environment."* (Garg & Dornfeld, 2008, p. 4) In the context of global warming the challenges we all face are essentials. Our activities and way of life endangered the planet, and our very future. We need to take step to limit this destructive development, and move toward a more sustainable society. As ICT is growing, changing and dynamic, enabling many breakthroughs in all domains it is in a unique position to act as an example and a media to initiate and motivate the behavioural change that is needed to achieve that aim. The purpose of the project is to research sustainability initiatives in ICT, by reviewing current literature in this subject area, and build a framework to develop an information tool able to calculate carbon emissions and

	power consumption of IT devices, in order to give users informative and motivational feedback on how to reduce them. Research, and recent history has proven that web-design application from Web 2.0 have a tremendous impact on the behaviour of their users, and that information tools such as carbon calculators can be of great use to motivate and help decision making toward more sustainable activities. This proof of concept will thus be a web-based application, taking advantage of Web 2.0, and usability and accessibility guidelines, in order to increase user satisfaction and maximize its positive impact among users.

<u>3. Literature review</u> *(>7000 words)*
(Word length depends on the nature of the project. Typically the minimum length at this stage would be 2000 words. Please take supervisor advice on the expected output for your project.)

Please insert a review of the sources of literature consulted to date and a summary of the main findings relevant to your research.

1. Literature Review

In order to define, and understand the state of Sustainability, Sustainable development and Green IT/S, an in-depth literature review has been conducted. Related scholarly articles have been searched in online databases such as ScienceDirect, Emerald, SpringerLink, the Wiley Online Library, IEEE Xplore, ACM Digital Library, and Edinburgh Napier library. Findings of the literature search are that a fair amount of research had been conducted on LCA, and sustainability in general, but there were fewer publications on Green IT/S. The following literature review is organised as follows: the first chapter outline the concept of sustainability and some of the strategies of its application; sustainable practices are discussed as well as Green IT/S. Further literature related to Life Cycle Assessment and Carbon calculators is reviewed to support the definition of the requirements of this project.

1.1. Sustainability

1.1.1. General considerations & Sustainability strategies

"There is unlikely to ever be a single answer to the question, 'what is sustainability'. Instead, definitions should be crafted to serve well in different times and contexts. And, more importantly, the definitions should be practiced, by implementing metrics and indicators of progress along the road to sustainability. It is from practicing sustainability that definitions can best tested and refined." (Vos, 2007)

Sustainability was originally a concept from biology and ecology that moved into economics to explain "the relationship between natural capital and economy" (Vos, 2007, p. 335) (Fuchs, 2008, p. 306). Indeed, in the 1980s, concerns about sustainability and sustainable development have become increasingly important, and the concepts of sustainability really evolved during the 1990s (Vos, 2007) supported by web technologies such as Web 2.0 (Hasan & Kazlauskas, 2009, p. 145).

In 1987, the United Nations defined it as ‘‘[…] development that meets the needs of the present without compromising the ability of future generations to meet their needs’’ (World Commission on Environment and Development., 1987, p. 43); binding it to economic growth and development. In 1994, the triple-bottom line illustrated in Figure 1 appeared and was soon widely adopted for making key strategic (O'Neil, GREEN IT FOR SUSTAINABLE BUSINESS PRACTICE An ISEB Foundation Guide , 2010, p. 5). It is still the most common representation of the concept. It emphasized the link between Economic and Environment, as well as the Social component of that definition.

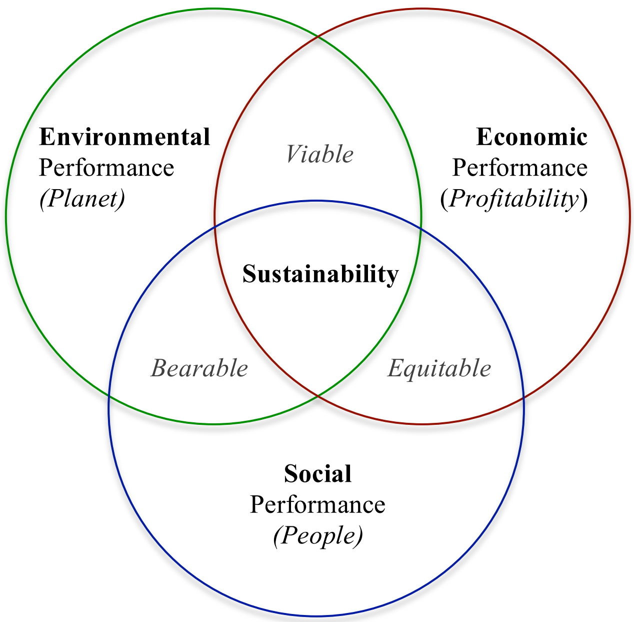

Figure 1: The triple bottom line of sustainable development

Adapted from (Dao, Langella, & Carbo, 2011)

However, several articles discuss the ambiguity and lack of clarity of that definition of 1987 (Jenkin, Webster, & McShane, 2011) (Vos, 2007), some value this fuzziness and some criticize it (Vos, 2007). Robert O. Vos explains that two versions can be distinguished: a “thin” version, which is the most common and a “thick” version that “require deeper transformations from ideas dominant today” (Vos, 2007). For the purpose of this research we won’t use a “thick” version of sustainability, not only because it would imply though choices and drastic change, which is not adapted for this project, but mainly because the aim of the project is to provide motivational feedback, which tends to imply a less drastic approach but more straightforward and feasible initiatives.

Most of the research about sustainable development is focused on corporate and business sustainability, there is much less literature about Universities and higher education sustainability, despite "universities are key stakeholders in achieving a sustainable future" (Ferrer-Balas, et al., 2008) (Stafford, 2011).

Still Universities too are undertaking changes to more sustainable activities, through "campus greening", courses on sustainability or collaborative research opportunities (Ferrer-Balas, et al., 2008). However, as for businesses it is hard to rank or grading in sustainability (Mascarelli, 2009) as each case is specific, since all of them are facing different challenges, and thus follow different path (Stafford, 2011, p. 317). Sustainability still seems to be a luxury in higher education (Stafford, 2011, p. 355) and is not often a priority because of financial resources. Among the common barriers IHEs face when trying to change for a more sustainable development, we can count "the lack of an incentive structure for promoting changes" (Ferrer-Balas, et al., 2008, p. 312), the size and wealth of the Universities (Stafford, 2011) (Jenkin, Webster, & McShane, 2011), the absence of common structure-level general will to transform the University or the absence of a "networks of expertise within the universities" (Ferrer-Balas, et al., 2008, p. 312). On the contrary every successful project was backed-up by a "combination of drivers more than based on personal leadership" (Ferrer-Balas, et al., 2008, p. 312) (Jenkin, Webster, & McShane, 2011, p. 22). Those factors are different from the factors that influence corporate sustainability efforts; due to the fact most IHEs are non-profit organizations and for-profit and IHEs have different goals, and motivations (Stafford, 2011). However, although IHEs tend to make long-term investments more likely than for-profits business, financial resources prove to be a major curb (Stafford, 2011).

On the other side, if regulatory pressures generally fail to encourage sustainability efforts, "alumni, faculty, and the community — appear to play a more dominant role in encouraging the adoption of sustainable practices than they do for corporations." (Stafford, 2011, p. 355). Literature (Jenkin, Webster,

& McShane, 2011) (Stafford, 2011, p. 356) also recognizes the influence of media, socio-cultural forces, values, beliefs and trends. Promoting an image of sustainability could be a major incentive just like for business or organizations that advertise their efforts in sustainability to attract customers and/or investors. Such strategies have given birth to "greenwashing" which is part of what (Jenkin, Webster, & McShane, 2011) classified as Image-oriented strategies. They identified "four types of environmental sustainability strategies" according to the impact and amount of change they demand. Table 1 from (Jenkin, Webster, & McShane, 2011, p. 23) shows the classification with examples. This is derived from well-established management literature. This classification will be helpful to decide what strategy to adopt for the case study.

Table 1 Green IT/S strategy types and Green IT/S examples.

Strategy type	Description	Green IT/S strategy	Green IT/S
Type 0: Image-oriented only	Involves portraying an image of caring about the environment by publicly announcing environmental policies (espoused strategy). These policies and practices are not subsequently implemented. Intentions can be "green" (authentic) or "greenwashing" (not authentic).	Announcing a strategy to reduce energy use in the organization's supply chain by using IT/S.	Although intentions are authentic, there are insufficient resources (for example, financial and human resources) to implement the IT/S application.
Type 1: Prevent, control, eco-efficiency	Involves making efficient use of natural and firm resources in order to reduce negative environmental impacts. Focuses on resource efficiency, waste prevention and control.	Introducing an objective to reduce IT/S power consumption across the company.	Implementing energy efficient servers and powering off PC's when not in use
Type 2: Product stewardship, eco-equity	Subsumes type 1 strategy and also involves attempts to achieve eco-equity goals (balancing the firm's and society's short and long term needs for natural resources) by minimizing environmental impacts throughout a product's lifecycle (product stewardship).	Developing a strategy to use IT/S to help reduce the environmental impact of an organization's product(s).	Implementing an IS and associated technology to capture environmental data during product distribution, use and maintenance for product design improvements
Type 3: Sustainable	Subsumes type 1 and 2 strategies; involves infusing	Introducing a goal to substantially	Implementing videoconferencing,

development, eco-effectiveness	environmental sustainability considerations throughout all of the firm's activities and interactions with the goal of stopping environmental degradation altogether.	reduce business travel using IT/S.	telepresence and collaboration tools as substitutes for travel

Table 1: Green IT/S strategy types and Green IT/S examples. Adapted from (Jenkin, Webster, & McShane, 2011, p. 23)

From this classification, Type 1 seems to be the most realistic and adapted strategy for this project. Type 2 and above would require a longer analysis and would likely imply redesigning the IT and IS systems, which is out of the scope of this study. Still there are some lifecycle aspects of the last 2 strategies that could be used in this case. Another problem that could come from the adoption of a strategy of type 2 or 3 is that the drastic changes it would imply could scare as discussed earlier, and that would be counterproductive; the aim being to initiate or consolidate a sustainable initiative, changes have to be done step by step, but must also be on-going.

Rewards have a positive influence on sustainable development, as they act on several factors previously mentioned; starting from the image of the organization, a champion organization attracts more investments and is present in the media (Ferrer-Balas, et al., 2008). The spin-off of such media coverage is often positive as far as finance and reputation are concerned. However until now research can’t establish whether students choose they campus for their sustainability programme (Stafford, 2011, p. 340) although it will probably change in time (Stafford, 2011, p. 345) but this can already enable a university to be part of a network of expertise, which is proven to boost research and progress in sustainable development (Ferrer-Balas, et al., 2008). It can also increase “an institution’s value function directly because sustainable practices are part of the institution’s contribution to the public”, or “attract higher quality students and faculty” thus boosting its research (Stafford, 2011, p. 340).
The effect of a known environmental violation would likely be worse for a University than for a business or a corporation, as the University is a symbol with high expectations from society in general.

Given that financial resources and size are key aspects in the adoption of sustainable practices (Stafford, 2011, p. 356) (Jenkin, Webster, & McShane, 2011, p. 22), developing programme and investing in sustainable development can be seen as a win-win relationship (Vos, 2007) as (Stafford, 2011, p. 345) points out that high levels of research activity are likely to receive more external funding than organizations that are not involved in sustainable development programme.
This conclusion is not so different from the argument that adopting TBL can benefit the growth of firms (Dao, Langella, & Carbo, 2011, p. 65).

In practice, the case of Edinburgh Napier University Carbon Management Plan 2008 – 2013 (Edinburgh Napier University, 2009) (Edinburgh Napier University, 2011) confirms the findings from the literature review so far, as credits and funding have been awarded "from internal ring-fenced capital budgets and Salix with consultancy support from the Carbon Trust." (Edinburgh Napier University, 2011). This helps keeping a holistic approach with on-going efforts.

Following the choice of a strategy of type 1 as described in Table 1, the next chapter examines the links between IT and sustainability, and how IT relate to sustainability.

1.1.2. Sustainable practices & Green IT/S

"Green information technologies and systems refer to initiatives and programs that directly or indirectly address environmental sustainability in organizations." (Jenkin, Webster, & McShane, 2011, p. 17)

Why is IT so important when an organisation is developing a sustainable programme? IT have been adopted everywhere and is now part of everyone's job. In organisation IS often making the difference between organisations because a well design, adapted system gives an organisation a competitive advantage over another (Dao, Langella, & Carbo, 2011, p. 65). We have discussed it earlier; few organizations are engaged in sustainability efforts

(Dao, Langella, & Carbo, 2011, p. 65) mainly because of the investments that they imply, but also because of the fact people tend to think IT is not a major sector to put efforts in (Jenkin, Webster, & McShane, 2011, p. 34). However, legislation related to reduction of carbon emission is coming, and soon organizations will have no choice but to adhere and abide by the law (O'Neil, GREEN IT FOR SUSTAINABLE BUSINESS PRACTICE An ISEB Foundation Guide , 2010, p. 2)

The ICT industry would be responsible for “approximately 2 per cent of worldwide carbon emissions” (O'Neil, GREEN IT FOR SUSTAINABLE BUSINESS PRACTICE An ISEB Foundation Guide , 2010, p. 1) (Intel Corporation, 2009) (Fuchs, 2008), which seems little compared to other sectors such as transportation. But the growth of IT is a factor to be considered, and eventually, “IT is quickly surpassing air transportation in terms of its carbon footprint” (Jenkin, Webster, & McShane, 2011, p. 18) as the use of information technologies is exploding. In fact, IT could contribute way more than other sector to globally reduce carbon emissions (O'Neil, GREEN IT FOR SUSTAINABLE BUSINESS PRACTICE An ISEB Foundation Guide , 2010, p. 1) it could have the potential to reduce global emissions by 15% (Jenkin, Webster, & McShane, 2011, p. 18). “IT contributions to the sustainability go beyond reducing IT’s energy consumption through green IT initiatives” (Dao, Langella, & Carbo, 2011, p. 76).

Indeed changing to a sustainable IT can contribute to changing people routines and affect their cognition and awareness about sustainability (Dao, Langella, & Carbo, 2011, p. 26). “The relationship of ICTs and sustainability is not only a question of ethical consumerism, but also one of corporate social and ecological responsibility.” (Fuchs, 2008, p. 298)

This is where Green IT/S come from, and what it is aiming at. Not only “Green IT is a collection of strategic and tactical initiatives that directly reduces the carbon footprint of an organization’s computing operation” (O'Neil, GREEN IT FOR SUSTAINABLE BUSINESS PRACTICE An ISEB Foundation Guide , 2010, p. 4); but it can also “enable the development of sustainability capabilities that address all three factors of the TBL” shown on Figure 1 [economic, social and environmental] (Dao, Langella, & Carbo, 2011, p. 76)

Green IT/S is made of two components that have different roles and impacts. (Hasan & Kazlauskas, 2009, p. 147) The most common and well know is *Green IT,* which *“addresses energy consumption and waste associated with the use of hardware and software, tends to have a direct and positive impact.”* (Jenkin, Webster, & McShane, 2011, p. 18) (O'Neil, GREEN IT FOR SUSTAINABLE BUSINESS PRACTICE An ISEB Foundation Guide , 2010, p. 4) (Hasan & Kazlauskas, 2009, p. 147).

But there is also *Green IS*, which is related to the *“development and use of information systems to support or enable environmental sustainability initiatives and, thus, tends to have an indirect and positive impact.”* (Jenkin, Webster, & McShane, 2011, p. 18) (Hasan & Kazlauskas, 2009, p. 147). Some see more potential in Green IS than Green IT because it “tackles a much larger problem by recognizing the context of an information systems as an ecosystem” (Hasan & Kazlauskas, 2009, p. 147)

Still, the two are meant to help reducing “the organisation’s overall carbon footprint, regardless of the type, shape or size of the organisation.” (O'Neil, GREEN IT FOR SUSTAINABLE BUSINESS PRACTICE An ISEB Foundation Guide , 2010, p. 4)

However, despite Green IT/S has been well defined, little research on information systems has focused on sustainability (Dao, Langella, & Carbo, 2011, p. 76) and “limited research has examined the contribution of IT resources to sustainability beyond reducing energy consumption of corporate IT infrastructure” (Dao, Langella, & Carbo, 2011, p. 76) an acknowledgement generally found in other documents; (Jenkin, Webster, & McShane, 2011, p. 27), (Hasan & Kazlauskas, 2009, p. 147). The next sections bring more light and details on them.

“An appropriate mantra for any organisation committed to Green IT should be ‘ Reduce, Reuse, Recycle’” (O'Neil, GREEN IT FOR SUSTAINABLE BUSINESS PRACTICE An ISEB Foundation Guide , 2010)

As far as reducing energy consumption is concerned, much experimentation has been conducted. The relative success of Green IT compared to Green IS is due to the fact it is less difficult to setup energy efficient products than it is to redesign a whole system, and there is an real urge for a drastic reduction of IT computers and super computers. For instance, western European electricity consumption of data centres has been estimated at 56 TWh/year in 2007 and is projected to increase to 104 TWh/year by 2020 (O'Neil, Green IT for Sustainable Business Practice - Sustainable Working Practices, 2010) and this poses problem to the EU energy and environmental policies, as well as it represent a considerable cost of energy, that corporations and organizations would like to reduce.

Many recommendations are going in that direction. For instance CRT monitors must be replaced, as they use 60% more power than a LCD on average or using networked laser printers rather than inkjet printers that waist more ink. (O'Neil, GREEN IT FOR SUSTAINABLE BUSINESS PRACTICE An ISEB Foundation Guide , 2010)
Replacing older PCs with Energy efficient (Gold EPEAT rating) PCs, since their actual use over their lifecycle is the most emitting proportion in terms of carbon emissions, along with the energy needed for their production (Intel Corporation, 2009). This replacement policy has its limits tough.
Indeed, Moore’s Law states that the computing power of computers doubles every 18 months and so far his law has proven true. It gives computers a short lifespan of 2 to 3 years. The problem is that people frequently buy new computers in order to participate in technological progress, because their computer gets deprecated (Fuchs, 2008, p. 299), which is obviously this is against sustainability gaols.
However, sustainable development does not imply that technological progress should slow down, but “the ways hardware is manufactured and diffused

surely have to change because the low life span of computers is detrimental to reaching ecological goals.” (Fuchs, 2008, p. 299)
“What is needed are reusable, recyclable, and upgradeable computer hardware and periphery” (Fuchs, 2008, p. 299) (O'Neil, GREEN IT FOR SUSTAINABLE BUSINESS PRACTICE An ISEB Foundation Guide , 2010, p. 49) or a green information systems that can run on older machines and limit the need to renew infrastructure every 2-3 years, “but this would require some steps away from the logic of profitability towards the logic of ecological sustainability” (Fuchs, 2008, p. 299), or in other words, towards sustainable development as descripted in the TBL in Figure 1. “If corporate social responsibility shall not only be an ideology, corporations must be ready to go beyond and to question to a certain extent capitalist logic.” (Fuchs, 2008, p. 299)

Another very efficient initiative is to reduce the number of PCs on site to provide not more than one PC per user unless necessary (O'Neil, Green IT for Sustainable Business Practice - Sustainable Working Practices, 2010) was effectively done in Napier and produced positive results (Edinburgh Napier University, 2011).
A further step could be to implement a PC sharing scheme to reduce the number of units to less than one par user. However this implies a tight secure management of users privacy, and require steps to be taken to ensure that personal data is not stored nor accessible once the user has logged off for instance (O'Neil, Green IT for Sustainable Business Practice - Sustainable Working Practices, 2010).

Still unused or unwanted infrastructure need to be recycled, or reused and must not end up in a landfill (O'Neil, GREEN IT FOR SUSTAINABLE BUSINESS PRACTICE An ISEB Foundation Guide , 2010, p. 49). Best practice and CM (Configuration Management) help organization to identify, reuse or reassign assets. In many cases rather than sending a working infrastructure to recycle it can be given to a school, or a charitable organization to be reused. (O'Neil, Green IT for Sustainable Business Practice - Sustainable Working Practices, 2010).

However, this implies security measures to ensure no data goes out of the organisation. Measures must also be taken when an infrastructure than cannot be reused. It must then be recycled. To ease this process, organisations should only buy flexible products that can be disassembled to be recycled, and contract licenced organisations that commit to recycle products properly, and make sure they don’t end up in a landfill (O'Neil, Green IT for Sustainable Business Practice - Sustainable Working Practices, 2010) (Dao, Langella, & Carbo, 2011, p. 47) or worse.

Green IT is focussed on reducing consumption, but the contributions of IT to sustainability should go beyond that, “to the contribution of IT in a broader sustainability framework.” (Dao, Langella, & Carbo, 2011, p. 76).

“IT/S fits within and contributes to corporate environmental agendas” (Jenkin, Webster, & McShane, 2011, p. 35) but it can also contribute to changing people’s habits and raise awareness (Jenkin, Webster, & McShane, 2011) (Dao, Langella, & Carbo, 2011) (Fuchs, 2008) (Bottrill, 2007). But “achieving the organization's espoused Green IT/S strategy depends on the actual behaviours of the employees and the organization.” (Jenkin, Webster, & McShane, 2011, p. 26)

Sustainability initiatives must be accompanied with cultural change and vice versa. Easy initiatives must be implemented to drive through “a collective focus of sustainability across the whole organisation.” (O'Neil, GREEN IT FOR SUSTAINABLE BUSINESS PRACTICE An ISEB Foundation Guide , 2010, p. 5) Such initiatives have a positive impact at employee-level, which is valuable for both the organisation carbon footprint, its personnel, as it affects the employee cognitions and “could result in organizational routines, […] an organizational culture that becomes more environmentally-focused” (Jenkin, Webster, & McShane, 2011, p. 26).

‘The overall ownership of sustainability initiatives” (Jenkin, Webster, & McShane, 2011, p. 34) is also a key stakeholder in the success of sustainability programmes such as Green IS. In most cases the IT department manages implementation of technologies and systems whereas the provision of power, cooling and overall management of energy costs is managed by the Facilities Management team. Although they are interdependent in such situation, the independence of departments may result in “misalignment with organizational goals” (Jenkin, Webster, & McShane, 2011, p. 35); hence there is a need to align the two on common policies and goals. Having a coordinating office is very helpful in that case. Edinburgh Napier University followed that path and planned an on-going and holistic initiative, coordinated by a Sustainability Office (Edinburgh Napier University, 2011)

As discussed earlier limiting the renewal of PC units and using infrastructure with remote, virtualized systems that can run on older computers is a cost effective and efficient solution. Cloud computing, Platform as a Service (PaaS) or Software as a Service (SaaS) are part of the virtualization initiatives meant to limit that need to change PC, and ensure a longer lifespan “running multiple virtual computers on a single physical computer. This reduces operational expenses by decreasing power consumption and hardware acquisition costs. Virtualization strategies can be applied at the desktop level by replacing personal computers with thin clients or by consolidating servers in data centres.” (Jain, Benbunan-Fich, & Mohan, 2011, p. 28) (O'Neil, GREEN IT FOR SUSTAINABLE BUSINESS PRACTICE An ISEB Foundation Guide , 2010). Such solution belong to both Green IT and Green IS, and reflect the tight link between the two, and the room for optimization and progress. (Hasan & Kazlauskas, 2009, p. 147)

Other easier steps can be taken in corporations and universities, such as encouraging “more use of digital document readers, digital editing capability (eg use tracking and commenting facilities in word processors), and online data collection, store, manipulation and display (eg online surveys).” (Hasan & Kazlauskas, 2009, p. 147). Following the example of banks that have used information systems since the 1960s (Hasan & Kazlauskas, 2009, p. 144), and are now switching to greener systems, that for instance use online transactions which “replace the need for paper documents and the energy needed to move people to the shop-front” (Hasan & Kazlauskas, 2009, p. 147), IHEs tend to use more and more similar systems, such as Web Course Tools, Turnitin, and other internal information systems that limit the use of paper documents, as well as they provide efficiency gains (Berkhout & Hertin, 2001, p. 10).

This chapter has described sustainability from its first conceptual definitions to the Green IT/S strategies, and applications. The reasons why adopting sustainable initiatives in and with IT is important, and efficient have been explored. Green IT/S has been defined and the distinction between the term Green IT, which sees ICT as a contributor of carbon emission throughout the lifespan of a IT hardware and Green IS which “looks positively to ICT as a provider of solutions” (Hasan & Kazlauskas, 2009, p. 147) has been explained. Green IT/S interest and coverage has increased recently because of the increase of energy cost and the growing interest in sustainability. Literature in this area is very sparse, but some research is and has been conducted providing interesting tools for further work, and improvement. Recently a conceptual framework has been designed and the “recent calls by MIS journals for special issues focusing on Green IT/S” (Jenkin, Webster, & McShane, 2011, p. 34). Initiatives such as SMART 2020 (The Climate Group, 2008) will also contribute to the coverage of this area. But Green IT/S face another challenge, which concerns “how to accurately measure environmental impacts” (Jenkin, Webster, & McShane, 2011, p. 35), and that introduces the next chapters of this review: life cycle assessment and carbon calculators.

1.2. The Life Cycle Approach

“Just like living organisms, products have a life cycle as well.”
(UNEP/ SETAC Life Cycle Initiative, 2005)

This brief chapter focuses on Life cycle assessment (LCA) and explains the reasons why taking a life cycle approach to grasp sustainability issues is crucial. Some applications of LCA is similar context to this project are mentioned, and the reasons why it cannot be fully applied to it are explained.

LCA is a quantitative tool for chain analysis, contributing to rational decision-making; its aim is to quantify potential environmental impacts of products over

their full life cycle (Heijungs & Udo de Haes, Life-cycle assessment for energy analysis and management, 2007). It appeared in the early 1970s at the same time in four countries, the UK, Switzerland, Sweden and the US (Heijungs & Udo de Haes, Life-cycle assessment for energy analysis and management, 2007). The first versions were rather simple, focussing on energy usage, mainly of the final product, from which it was calculating its “embodied energy” (Heijungs & Udo de Haes, Life-cycle assessment for energy analysis and management, 2007).
However its image was quite stained by the fact the methodological basis was not rationalised enough at the time, leading to conflicting results between studies. (Heijungs & Udo de Haes, Life-cycle assessment for energy analysis and management, 2007).

In 1989, SETAC, The Society of Environmental Toxicology and Chemistry created an LCA Advisory Group (SETAC). Few years after in 1994, ISO (ISO, 2011) undertook to standardize LCA, but did not imposed one standardized methodology. Different viewpoints emerged from this attempt to standardize LCA, on one hand LCA as support for decision-making, and on the other hand, LCA as a source of scientifically proven results (Heijungs & Udo de Haes, Life-cycle assessment for energy analysis and management, 2007) but despite those difference of view points, interest in LCA has increased a lot since then. (UNEP/ SETAC Life Cycle Initiative, 2005) (UNEP/ SETAC Life Cycle Initiative, 2009)
From 2002 the United Nations’ Environment Programme became active in the field of LCA and launched the UNEP SETAC Life-Cycle Initiative, (in cooperation with SETAC) to promote LCA and bring it into practice through 3 programmes (LCI, LCIA and LCM) aiming at the development of more simple methods and publicly available databases (UNEP/ SETAC Life-Cycle Initiative, 2011).

While the main applications of LCA where related to product design this has changed. LCA is now applied to large products and services, such as the management of municipal solid-waste, waste-water treatment, electricity production, the use of building materials, the production of automobiles and of

ICT (Heijungs & Udo de Haes, Life-cycle assessment for energy analysis and management, 2007) few carbon calculators make use of life cycle assessment, to produce more a comprehensive and accurate results (Garg & Dornfeld, 2008). The major advantage of this approach is that the carbon footprint results produced includes embodied footprint of each components. As a consequence, some products that have a "green" image but have a large embodied footprint can be identified. Such precise results enable organizations to take steps to reduce their footprint and plan their sustainability programme more efficiently.

However they are some drawback to LCA. Although it can easily include impacts with an input-output character (extraction from, and emission to the environment), it cannot include impacts related to land use for instance (Heijungs & Udo de Haes, Life-cycle assessment for energy analysis and management, 2007). They are also problem of special and temporal resolutions. LCA performs at global level, without distinction, and omit potential catastrophes, meaning it is not usable for a precautionary approach (Heijungs & Udo de Haes, Life-cycle assessment for energy analysis and management, 2007). But more importantly in the context of this project, LCA implies a long rigorous process of analysis, which is not compatible with the time constraints of this project. However, examples of carbon calculators such as the one developed to calculate the carbon footprint of The University of Berkley library systems (Garg & Dornfeld, 2008) point out that this method is relevant in the context of sustainability and carbon calculation, and thus, should be used in a further evolution of the project.

This chapter has described LCA history and progress from its first conceptual definitions. They are two major approaches to LCA, the decision-making, or the source of results. In the case of this project, both would be applicable. Some of its applications have been discussed, as well as its drawbacks. The reasons why it cannot be fully adopted for this project are discussed although the values of this method in the context of carbon calculation, the next chapter, are recognized. LCA would be of great benefit for such project on a longer time frame. In the context of this project with limited time to perform an in depth analysis suitable to perform comprehensive life cycle assessments, the use of another approach is more suitable. The next chapter explains alternative approach, and balance it with LCA.

1.3. Carbon Footprinting

1.3.1. General considerations

“The carbon footprint is a measure of the exclusive global amount of carbon dioxide (CO2) and other greenhouse gases emitted by a human activity or accumulated over the full life cycle of a product or service”.
(Wiedmann, Minx, Barrett, & Wackernagel, 2006)

As seen is the previous chapters, since the end of the 90s, with the Kyoto Protocol of 1998, there has been a growing demand for solutions to limit carbon emissions, and a real need to provide tools to accurately measure environmental impacts, in order to provide efficient recommendations to reduce them. Among the existing specific software, carbon calculators have become popular as they can be used to “forecast and monitor the carbon emission from all we do” (Hasan & Kazlauskas, 2009, p. 147). Their success is also partly due to their commercial application. This chapter examines them from every angle.

Reducing carbon footprints has become a necessary step in combating climate change on the global and on the individual level. Research from UK’s Economic and Social Research Council has identified that since the Stern Review on the Economics of Climate Change was published (The Office of Climate Change, 2006) ‘Carbon footprint’ has become a buzz phrase in the medias (Nerlich & Koteyko, 2009) (Padgett, Steinemann, Clarke, & Vandenbergh, 2007) (Finkbeiner, Carbon footprinting—opportunities and threats, 2009).
However, carbon footprint is not something new, “it has been around for decades—just being called differently, i.e. the result of the life cycle impact category indicator global warming potential (GWP)” (Finkbeiner, Carbon

footprinting—opportunities and threats, 2009, p. 91). Many researchers in LCA and sustainability tend to look down on Carbon footprinting (CFP), they are concerned that some applications of CFP would be oversimplified, and thus lead to counterproductive results. (Finkbeiner, Carbon footprinting—opportunities and threats, 2009) (UNEP/ SETAC Life Cycle Initiative, 2009) (Heijungs, Huppes, & Guinée, Life cycle assessment and sustainability analysis of products, materials and technologies. Toward a scientific framework for sustainability life cycle analysis, 2010) (Garg & Dornfeld, 2008, p. 5).

Finkbeiner stresses that if everything were to be blindly assessed on their carbon footprint, many valuable steps towards sustainability, such as renewable energy would have to be abandoned, and we would also stop recycling things such as paper. This is obviously not the way to go, but this must be kept in mind.
This brings back LCA, and the need for a global understanding and approach to sustainability. And just like for LCA, the ISO working group is working on the standardisation of CFP. The list of methodological issues they raise, including the scope of emissions, the life cycle stages, the system boundaries etc. (Finkbeiner, Inaba, Tan, Christiansen, & Klüppel, 2006) assert the value of CFP and the need for further discussion and standardization (Finkbeiner, Carbon footprinting—opportunities and threats, 2009) and just like LCA is an interactive technique (Finkbeiner, Inaba, Tan, Christiansen, & Klüppel, 2006) that, as seen earlier, took years to evolve (Finnveden, et al., 2009), CFP will need several iteration of research and development to reach maturity.

LCA specialists tend to consider CFP as a way to “get life cycle approaches into organisations and decision making contexts which pure LCA did not reach yet.” (Finkbeiner, Carbon footprinting—opportunities and threats, 2009). In other words, just like “sustainability must be viewed as a journey, not a fixed destination” (Vos, 2007, p. 336) (UNEP/ SETAC Life Cycle Initiative, 2007, p. 5) CFP must not be considered as a destination, but a mean or a first step to promote sustainability. The call for publication on the relation between LCA and carbon footprinting (Finkbeiner, Carbon footprinting—opportunities and threats, 2009, p. 93) is a sign that it might become a valuable asset to LCA as soon as it has been fully standardized. Examples of successful methodological use of LCA in a CFP context (Garg & Dornfeld, 2008) validate the importance, and great potential of both.

In this section the danger caused by carbon footprinting popularity have been discussed. Literature in this area stresses the link discussed in the previous chapter between LCA and CFP, and points out the risk of oversimplified use of CFP, as well as the positive opportunities it provides for sustainability. Bearing that in mind the next section gives more details into the carbon calculation tools.

1.3.2. Carbon calculation

“Carbon calculators hope to raise awareness about climate change and to give people an insight into how their behaviour contributes to the problem by enabling them to calculate the carbon emissions they are directly responsible for.”

(Bottrill, 2007, p. 11)

The success of carbon footprinting discussed earlier brought plenty of carbon calculators that have been developed by all sorts of organizations, such as “non-government organisations, commercial companies, government agencies, universities and media groups.” (Bottrill, 2007, p. 1) (Nerlich & Koteyko, 2009)
(Padgett, Steinemann, Clarke, & Vandenbergh, 2007, p. 106) This section explains their purpose, target, and how they work. Their limitations are discussed and at the end, recommendations from the literature review are summarised.

Among the literature reviewed, the unanimous opinion is that carbon calculators are meant to be information tools to increase awareness about CO2 emissions, and promote carbon emission reductions (Padgett, Steinemann, Clarke, & Vandenbergh, 2007, p. 107) (Padgett, Steinemann, Clarke, & Vandenbergh, 2007, p. 114) (Bottrill, 2007, p. 1) (Mascarelli, 2009) (Garg & Dornfeld, 2008).

To achieve that, not only they should be able to “identify, quantify and monitor greenhouse gas emissions as well as to access meaningful feedback on opportunities to reduce those emissions” (Bottrill, 2007, p. 1). But they also have to be fit for purpose, “to meet the specific needs of energy end-users, be they government, organisations, companies, or citizens” (Bottrill, 2007, p. 1). And they must be consistent and clear to provide better benefit (Padgett, Steinemann, Clarke, & Vandenbergh, 2007, p. 114). This last aspect is often discussed in the literature, as it is poses problem, even more since carbon calculation has become a business with the creation of carbon offsetting companies.

Selling offset or enabling people to people to “invest in carbon saving projects to offset their emissions” (Bottrill, 2007, p. 2) is the arguable second function of carbon calculators. Carbon offsets are used to compensate emissions by funding a carbon dioxide saving elsewhere (Garg & Dornfeld, 2008, p. 3). This practice was introduced after the Kyoto Protocol, for large organizations to “buy carbon offsets in order to comply with caps on the total amount of carbon dioxide they are allowed to emit” but it could also be used to voluntarily contribute to carbon saving projects (Garg & Dornfeld, 2008, p. 3). However “buying offsets is still a fairly new and unregulated practice” (Mascarelli, 2009, p. 155) (Finkbeiner, Carbon footprinting—opportunities and threats, 2009, p. 91) and many are concerned that it could replace real efforts and initiatives toward emissions reductions (Mascarelli, 2009) and lead to an “overdependence on these several new carbon offsetting business” (Garg & Dornfeld, 2008, p. 5). Part of the concerns from LCA specialists discussed above come from that, and also from the general acknowledgment that many calculators lack transparency regarding the calculation methods (Padgett, Steinemann, Clarke, & Vandenbergh, 2007) (Finkbeiner, Carbon footprinting—opportunities and threats, 2009) (Bottrill, 2007) (Garg & Dornfeld, 2008). Many reviews comparing carbon calculators reported discrepancy between results from the same input (Padgett, Steinemann, Clarke, & Vandenbergh, 2007) (Bottrill, 2007).

The inconsistency of performance and results is due to the lack of efficient regulation and standardized methods for calculation, as discussed earlier. They are many different practices as of today. Among them two approaches can be distinguished: the first, and potentially most accurate is based on a life cycle approach, discussed in the previous chapter, and the other one is restricted to "immediately attributable emissions from energy use of fossil fuels." (Garg & Dornfeld, 2008, p. 3) Although "a general understanding is that CFP should relate to the life cycle using process-based data, the inclusion of the use phase might be controversial between business-to-business and business-to-consumer perspectives" (Finkbeiner, Carbon footprinting—opportunities and threats, 2009, p. 92).

Another reason of inconsistencies is the type of data input. "There are three types of data that calculators will commonly use to calculate the carbon emissions of an individual or household – 1) building fabric- and technology-based, 2) expenditure-based and 3) quantity-based." (Bottrill, 2007, p. 2) The first is used to calculate building energy use, which is out of scope. The second is quite commonly used, although it is unlikely to produce accurate results, since it coverts a cost into a quantity and is not always aware of the tariff rate charged to the end-user of the calculator (Bottrill, 2007, p. 16) (Padgett, Steinemann, Clarke, & Vandenbergh, 2007). The third type, - quantity based - inputs is acknowledged to be the most accurate (Bottrill, 2007) (Padgett, Steinemann, Clarke, & Vandenbergh, 2007) (Garg & Dornfeld, 2008).

In the context of this project, the choice of the AMEE platform (AMEE UK Ltd., 2011) limits the risks of miscalculation, and discrepancy, and will allow spending time on other key aspects of carbon calculators such as their content, guidance, and usability; the latter being a known key factor of success of an information tool (Bottrill, 2007, p. 7) (O'Reilly, 2005) (Davis, 1989).

Another limitation comes from the fact that most existing carbon calculators only focus on the emissions from home energy and travel use. (Bottrill, 2007) (Padgett, Steinemann, Clarke, & Vandenbergh, 2007) Not to mention that only

few calculators try to estimate the embodied emissions, as “this is limited because of the difficulty in calculating these sources of emissions with any accuracy” (Bottrill, 2007, p. 2). Embodied emissions require LCA, which is time consuming and difficult for many reasons discussed earlier, but as a consequence can produce results that are not accurate. This lack of accuracy can also results in the discrepancy between conversions factors. Most calculators use the same conversion factors, than the national government, (Digest of United Kingdom Energy Statistics in the case of the UK) but some use different ones, providing different results. The delta can be very important some time. See (Padgett, Steinemann, Clarke, & Vandenbergh, 2007) & (Bottrill, 2007) for details.
This poses problem since “the accuracy with which carbon emissions are measured is important if people are to be able to benchmark and monitor the changes in their carbon emission profiles over time.” (Bottrill, 2007, p. 2) And this brings another problem: the fact that carbon calculators give results per annum while taking input from a shorter period such as week, month, quarter. This limitation prevents them from taking into consideration seasonal fluctuations and variations in lifestyle (Bottrill, 2007, p. 2) (Padgett, Steinemann, Clarke, & Vandenbergh, 2007, p. 114) (Finkbeiner, Carbon footprinting—opportunities and threats, 2009).

Having reviewed the role, target, principles and limitations of carbon calculators, the last part of this review provides some recommendations based on reviews of existing carbon calculators. The Paper presented at European Council for Energy Efficient Economies (ECEEE) Summer Study 2007 by Catherine Bottrill (Bottrill, 2007) introduces some acknowledged useful guidelines that should be used for this project. Another evaluation of a Carbon Credit Information System (Smart, Armstrong, & Vanclay, 2007) confirmed the importance of providing meaningful feedback to satisfy the user, and all articles reviewed stressed the need to provide clear and transparent information regarding the calculation methods, which could prove to be a problem with the AMEE platform. However, the review of both CFP and LCA literature stressed the importance of accuracy of the results to allow monitoring carbon emission over time, and thus evaluating efforts. This is just as important as the quality of usability and accessibility. Further discussion on AMEE will be provided in the platform review, to see if it acts as a workaround or as a proper alternative.

1.4. Findings & future research

With the exponential increase of use of information technologies, taking actions to reduce their carbon emission has become crucial and critical to mitigating the global warming. The literature review conducted revealed that Green Information Technologies and Green Information Systems are getting attention and there are very promising initiatives and research conducted in sustainability. Green IT/S should contribute to reducing the carbon footprint of the ICT sector, but could and should also contribute to greater change, through behavioural change. IT has great potential to help and the increase of coverage, call for articles and multidisciplinary research projects in this domain are very positive indicators of increased concerned and interest. The sustainable practices and strategies reviewed will prove useful when producing feedback from the carbon calculator's results, and will help focussing on how to provide motivational feedback and recommendations.

The review of LCA and carbon calculation related articles introduced some very useful recommendations, and emphasized the potential tremendous impact of such tools with regard to behavioural change if designed the right way. It also drew the intrinsic link between IT and sustainability. The review provided some insights regarding the mistakes to avoid, which will contribute to the design phase of the prototype. Evaluation methodologies such as the Technology Acceptance Model and the User Information Satisfaction Model have also been found, and they will underpin the design and evaluation of the prototype. Incidentally, this review helped drawing boundaries to the project and contributed to define its scoped. Choices had to be made in order to maintain the feasibility of this project within its time constrains, and that explains why the research project won't be focused on or analyse very interesting aspects such as LCA and Green IS are would deserve more attention and research in further research. The societal impact of ICT and relationship between this and sustainability should also be part of further work, as it is also crucial to understand it to propose and provide efficient solutions.

4. Annotated contents list for the dissertation

Please show the proposed structure for the final version of the dissertation. This should give a brief indication of what each section will contain.

1. **Introduction** *(What I'm going to do and why)*

   (General introduction to the project, revealing its origins, aims, objectives and motivations)

   a. Structure of the paper *(this will introduce the structure of the dissertation)*

   b. Project Plan & phases *(overview of the timeframe; stages and phases)*

   c. Deliverables *(what are the outcomes)*

2. **Literate Review** *(What do I need to know to do it well)*

   a. Sustainability

   b. Life Cycle Approaches

   c. Carbon footprinting

   d. Findings *(what I learnt from this review and how it underpins my work)*

3. **Methodology** *(How will I do it, what process)*

   a. Research Methodology (qualitative, action research? ...)

   b. Development Methodology (agile, UML…)

   c. Evaluation Methods (TAM, UIS…)

   d. Data collection

4. **Analysis and Design** *(What will I do, what product)*

   a. System requirement analysis

   b. Features Definition

   c. Usability and User Experience

   d. Platform review

5. **Results** *(What I have achieved)*

   a. Prototype development

   b. Research achievements

6. **Evaluation** *(How I have achieved it – self appraisal)*

7. **Conclusion** *(Where does it go from here)*

8. **References**

5. References

Please list all references as relevant to your literature review. Please use a standardised format for your references. (APA)

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6. Work plan

Please indicate the work that remains to be completed for your project. This should include completion dates for each stage. You may like to present this in chart format.

In order to plan and organise the workload, an Apple Numbers document see has been designed to plan and keep track of time spent on each tasks.

		Week 0													
		Prepare dissertation proposal Literature searching Submission of preliminary proposal to supervisor													
		A													
		29/8		30/8		31/8		1/9		2/9		3/9		4/9	
A	Clarify Objectives and Plan Project	5	5					5	5	5	7	5	4	2	2
B	Literature Search												1	2	2
C	Literature Review														
D	Initial report														
E	Design & requirements specification														
F	Prototype and Testing														
G	Implementation														
H	Evaluation														
I	Outline dissertation														
J	Draft/Final Submission and Viva														
	TOTAL DAY / DAY PLAN	5	5	0	0	0	0	5	5	5	7	5	5	4	4
	TOTAL WEEK / WEEK PLAN							24							26

		Week 1													
		Revision of proposal Submission of Literature searching to supervisor Literature review **Submission of proposal to module leader**													
		A, B													
		5/9		6/9		7/9		8/9		9/9		10/9		11/9	
A	Clarify Objectives and Plan Project		5												
B	Literature Search	3		4	5	2	2	2	6	2	3	3	3	2	2
C	Literature Review	2		1	1	2	2	4		2	2	2	2	2	2
D	Initial report														
E	Design & requirements specification														
F	Prototype and Testing														
G	Implementation														
H	Evaluation														
I	Outline dissertation														
J	Draft/Final Submission and Viva														
	TOTAL DAY / DAY PLAN	5	5	5	6	4	4	6	6	4	5	5	5	4	4
	TOTAL WEEK / WEEK PLAN							33							35

		Week 2													
		Submission of literature review draft 1 to supervisor Reading on sustainability													
		C													
		12/9		13/9		14/9		15/9		16/9		17/9		18/9	
A	Clarify Objectives and Plan Project			1	1										
B	Literature Search	2	2	3	3			3	3	1					
C	Literature Review	2	2	2	2	2	5	3	3	3	7	3	5	6	5
D	Initial report													2	2
E	Design & requirements specification														
F	Prototype and Testing														
G	Implementation														
H	Evaluation														
I	Outline dissertation														
J	Draft/Final Submission and Viva														
	TOTAL DAY / DAY PLAN	4	4	6	6	2	5	6	6	4	7	3	5	8	7
	TOTAL WEEK / WEEK PLAN							33							40

		Week 3													
		Reading on methodology Reading on usability Reading on carbon calculators													
		C, D													
		19/9		20/9		21/9		22/9		23/9		24/9		25/9	
A	Clarify Objectives and Plan Project														
B	Literature Search														
C	Literature Review	6	6	4	6										
D	Initial report					6	6	4	6	1	6	2	5	3	5
E	Design & requirements specification														
F	Prototype and Testing														
G	Implementation														
H	Evaluation														
I	Outline dissertation														
J	Draft/Final Submission and Viva														
	TOTAL DAY / DAY PLAN	6	6	4	6	6	6	4	6	1	6	2	5	3	5
	TOTAL WEEK / WEEK PLAN							26							40

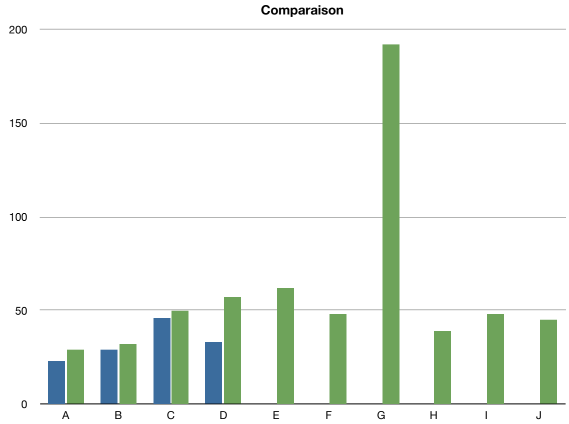
Figure 2: Screenshot of the first 4 weeks of the project

The spreadsheet in Figure 2 includes the deliverables and outcomes for each week, they are organised by tasks. The meeting with the supervisor are visible, in orange. Pink indicates a low availability and red is a major difficulty, in this case, sickness.

This view allows comparing the time initially allocated to each day against the time spent as well as the time spent at the end of the week, against the initial planning. This eases both organisation and decision-making and enables to reallocate tasks if necessary.

The screenshot below in Figure 3 represents the dashboard, which provides a more global view of the project progress. All charts are dynamic based on the week timetable. The charts displayed at the bottom are likely to change when the analysis and design phase are complete, and the software specification finished. Until then the only provide a rough indication of the time planned on each phase. During the dissertation it acts as a guideline, and on the completion of the later it will help evaluation the time management and choices made.

		Spent	Planned	Remaining	Recommended
A	*Clarify Objectives and Plan Project*	23	29	6	30
B	*Literature Search*	29	32	3	50
C	*Literature Review*	46	50	4	80
D	*Initial report*	33	57	24	50
E	*Design & requirements specification*	0	62	62	50
F	*Prototype and testing*	0	48	48	80
G	*Implementation*	0	192	192	120
H	*Evaluation*	0	39	39	40
I	*Outline dissertation*	0	48	48	50
J	*Draft/Final Submission and Viva*	0	45	45	50
		131	602	471	600



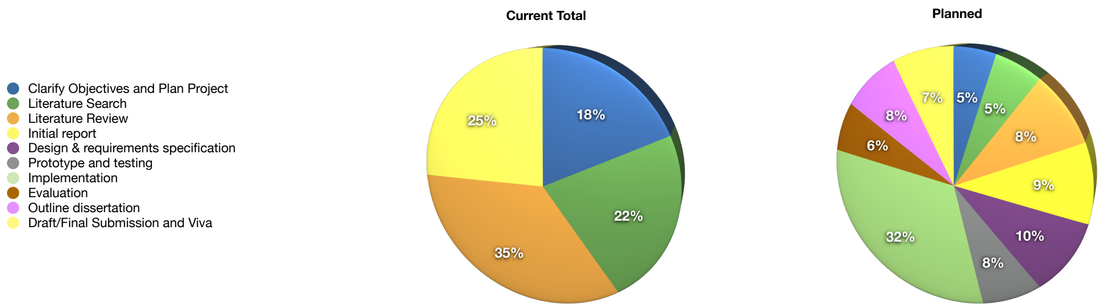


Figure 3: Screenshot of the Project Plan dashboard as of the 27th of September

Using this programme, and taking in consideration the submission of the initial report on the 28th of September, the design and specification should be completed by the start of week 6, as it has been allocated a week and a half work. The implementation phase would then start with weekly builds of prototypes using agile methods, until the end of week 9 when a reasonably sophisticated version of the prototype it should be tested by potential end users. Week 10 and 11 are currently kept as a safeguard against risks, for testing and evaluation with end users, and for fixing. In the meantime, the feedback provided by the testing will be included in the dissertation and enrich the evaluation of the project. Week 12 to 14 will be used to finish the dissertation, including the results chapter, the evaluation, and the conclusion, and prepare the viva.