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International Sustainable Ecological Engineering Design for Society (SEEDS) Conference 2015

Conference proceedings

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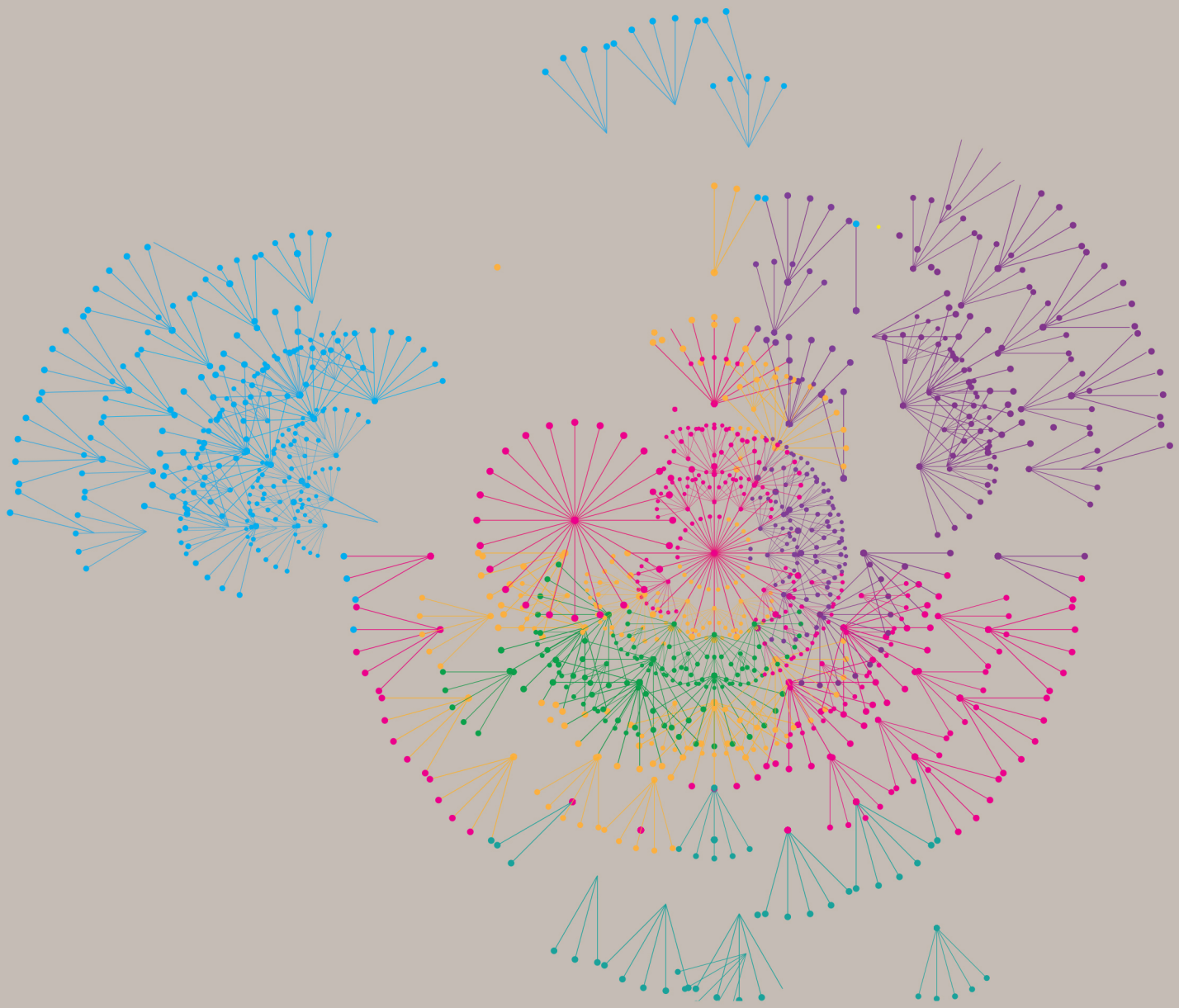

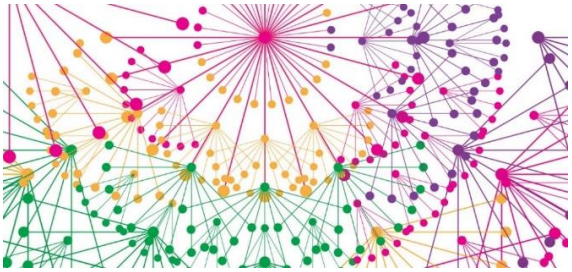

Sustainable Ecological Engineering Design for Society (SEEDS)

Selected Papers from the First International Conference a companion to:

'Sustainable Ecological Engineering Design – Selected Proceedings from the International Conference of Sustainable Ecological Engineering Design for Society (SEEDS)'

Conference Chairs

Professor Mohammad Dastbaz
Professor Chris Gorse

17 & 18 September 2015

Leeds Beckett University

Published by LSIPublishing

ISBN Number 978-0-9955690-0-3

Leeds Sustainability Institute

The Leeds Sustainability Institute at Leeds Beckett University have hosted and supported this conference. Support has also been received from industrial partners, including, **Saint-Gobain, ARC, and the Chartered Institute of Building**, we are grateful for this support.
The Leeds Sustainability Institute is a centre of research, informed and supported by business leaders, professional associations and community groups. Our research addresses the challenges of creating more sustainable places, communities and economies. Through the Institute a wealth of experience and skill is captured, with the potential to influence and shape the future via its networks and partners.

Welcome from Chris Gorse

Welcome to the Inaugural Sustainable Ecological, Engineering Design for Society Conference. It is a privilege to have seen the contributions from across the globe and the expert led knowledge that is now contained in our SEEDS-2015 conference proceedings. The work is varied and rich, bringing a multifaceted approach to addressing the challenges of sustainability. From the small to large research projects that have been reported, all bring valuable contributions to improve sustainability and reduce negative impacts; all are essential in tackling the immediate and foreseeable challenges.
It has been encouraging to see the interest from well establish experts and those embarking on new research journeys. The established bringing their authoritative knowledge and proven methods and the new, with unhindered imagination and open minds, contributing a different approach to innovation and research. By bringing the different perspectives together we should generate new avenues of research that could and hopefully will secure the positive change needed. The energy of the new and the chartered knowledge of the experienced are both required to achieve the change to address sustainability and ensure future generations benefit from the ecosystem that currently supports us. It is a pleasure that both those at the top and start of their careers have come together as part of the SEEDS community.
We are very honoured by the high quality of professionals and academics that have joined our International Scientific Committee. The Committee was drawn from leading experts across the globe with eminent figures from Australia, USA, China, South Africa, Russia and Europe; all are to be commended on their contributions to the reviewing process. The time for submission was demanding for both the authors and reviewers and we're grateful for all of the contributions.
This year's SEEDS conference focused its attention on key sustainability topics, particularly exposing applied research, technology and innovation that are having a positive impact on society and the built environment. From the work presented, knowledge gained and shared we believe this will help to take the whole sustainability agenda forward. It's also very encouraging that so many industrial partners are interested in the conference. The examples of research being led by industry show how serious the concerns are and how important and immediate the sustainability concerns have become for the whole community. The engagement between academics, industry and the broader community is essential if we are to embrace the level of change needed.

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With special thanks to the International SEEDS Conference Specialist Review Committee

All based at Leeds Beckett University

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2015 Conference Theme

Healthy, Energy Efficient Buildings and Spaces

The built environment has a greater impact on natural resources and produces more waste than any other industry. However, beyond the green rhetoric research is being applied on the ground to address the balance between the built and natural environment. The International SEEDS Conference brings together experts from around the world focussing on the changes that are taking place and the benefits or consequences that are being predicted and measured regarding the built environment's impacts. As well as addressing technical issues, measuring energy efficiency and modelling energy performance, emphasis is placed on the health and wellbeing of the users of spaces occupied and enclosed. Understanding how buildings and spaces are designed and nurtured to obtain the optimal outcome is the focus of discussion and debate. This holistic approach draws together the research themes of energy, building performance and physics while placing health, wellbeing and ecology at the heart of the conference.

Through research and proven practice, the aim of the SEEDS conference is to foster ideas on how to reduce negative impacts on the environment while providing for the health and wellbeing of the society. The professions and fields of research required to ensure buildings meet user demands and provide healthy enclosures are many and diverse. The SEEDS conference addresses the interdependence of people, the built and natural environments, and recognises the interdisciplinary and international themes required to assemble the knowledge required for positive change.

The themes and topics covered by the papers include:

Building and environment design
Energy efficient modelling, simulation and BIM
Integrating urban and natural environment
Building performance, analysis and evaluation
Thermal comfort, air quality and overheating
Green spaces, enclosures and buildings
Green technologies and IT
Renewable energy
Energy flexible buildings
Energy behaviour and lifestyle
Dampness, water damage and flooding
Building surveys, thermography, building pathology
Water quality
Air quality
Planning and sculpturing positive change
Reducing consumption and waste
Sustainability, ethics and responsibility
Occupant behavioural change
Community building and masterplanning
Health benefits of alternative and natural materials
Urban heat island and mitigation
Building resilience
Sustainable cities
Zero energy and energy plus buildings
Local producers and urban environments, edible
Trees and green city landscape
Designing edible urban landscapes

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Green IT

Policy Change and Energy

Energy

Change

The SEEDS 2015 Conference Papers that have been published by Springer in a separate book entitled, 'Sustainable Ecological Engineering Design' edited by Mohammad Dastbaz and Chris Gorse are listed in Appendix A.

Development, Impact and Change

AN EFFECTIVE APPROACH FOR THE MANAGEMENT OF WASTE COFFEE GROUNDS

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Keywords: Resource Recovery, Sustainable Waste Management, Coffee, and Earthworms.

ABSTRACT

In recent years the disposal of organic wastes from domestic, commercial, agricultural and industrial sources have caused concerns due to the environmental and economic problems associated with waste. The waste produced particularly in urban areas represents a huge cost for cities and a burden to the environment but, at the same time, represents an opportunity to take stock of valuable resources, which can be exploited. By boosting solutions to reduce waste and promoting its use as a resource the natural and living environment in urban areas can be enhanced. Cities are complex systems similar to living organisms that use energy, air, water and nutrients and need to dispose of waste in a sustainable way. By adopting an urban metabolism perspective cities can open the way for innovative and systematic approaches, which involve the analysis and use of resource-flows. Waste coffee grounds represent an under-utilised high nutrient material with potential to be exploited. Coffee is regarded as the highest consumed beverage in the developed world, and is the second most traded commodity in the world after oil. This paper will present research findings for an effective approach for the management of waste coffee grounds. This is achieved through examining an alternative approach of resource recovery and sustainable waste management practices for waste coffee grounds. It will also use a case study to examine the potential for waste coffee grounds to promote an ecological rethinking of nutrient flows.

Fletcher, I. (2015) **An effective approach for the management of waste coffee grounds** *In;* Gorse, C and Dastbaz, M (Eds) *International SEEDS Conference,* 17 – 18 September 2015, Leeds Beckett University UK, Sustainable Ecological Engineering Design for Society.

1. INTRODUCTION

Since the Industrial Revolution, industrial production and urbanisation have constantly increased, using massive amounts of materials, water and energy. The mass consumption of resources contributes to serious problems, such as global warming, material depletion and the generation of enormous waste. It is widely accepted that the United Kingdom will have to deliver significant improvements to its waste infrastructure over the coming decades in order to successfully recycle, reprocess, treat and dispose of its waste. In the metabolism of the city, Lehmann (2012), defines sustainable urban metabolism as a vision of industrial organisation that applies the lessons of natural ecosystems to environmental management, where waste from one process becomes inputs and opportunities for another (Lehmann & Crocker, 2012). According to a new study published by the Department of Environment, Food and Rural Affairs (DEFRA), resource efficiency could generate an extra £3.58bn for UK businesses by 2020 (DEFRA 2015). Waste generation is a natural phenomenon and the amount of waste produced can be directly associated with changes in culture and the way of life. These changes bring with them a huge quantity of complex waste streams, which contains considerable amounts of nutrients, which have the potential to be recycled. Rethinking the way we deal with material flows and changing behaviour in regard to waste streams can contribute to significant improvements for curbing environmental degradation and global warming (Lehmann & Crocker, 2012). In his argument for "the economics of permanence," Schumacher (1973) implies a profound reorientation of science and technology is required. Emphasising a need for methods and equipment, which are cheap and accessible to virtually everyone, and also suitable for small-scale application. At present, not only is it virtually impossible to know the true environmental and ecological impact of the products we consume, but also the origins, the processes of manufacture and the cost of transportation. Kimbrell (2002) argues, that the distance between the consumer and production has created a tragic disconnection of the environmental consequences of production and consumption. Tompkins (2002) describes it as a cultural crisis rooted in the transformation from an essentially agrarian culture to one that's completely industrialised. It is clear that a holistic understanding and integrated approach to design and urban management are essential for the effective resolution of urban waste. In present circumstances it is advisable that waste products from one industry should be investigated with an intention to be used as raw materials for other industries.

The rapid expansion of global coffee consumption increased from 4.2 million tonnes in 1970 to 8.1 million tonnes in 2010, an increase of 91 per cent. With consumption growing by 12 per cent in Western European markets (ICC, 2011). In 2014, the coffee shop market outperformed the UK retail sector, with significant sales growth of 10.7%, equating to £7.2 billion in turnover. The coffee shop sector has been in growth for 16 consecutive years and is one of the most successful markets in the UK economy (Foottot, 2014). According to the Allegra World Coffee Portal definitive report, the UK coffee market is estimated at 18,832 outlets and predicted to exceed 27,000 by 2020 (Foottot, 2014). In the United Kingdom coffee consumption take various forms, including soluble and filter coffee. The preparation of the beverage and the location of consumption are largely influenced by national culture. However, coffee grounds (filter coffee) are a single use product and the total waste generated from the disposal of coffee is equal to all imports and sales. The environmental impacts of coffee are enormous, with large quantities of solid and liquid wastes being generated globally (Roussos et al., 1998; Hue et al., 2006; Lui et al., 2011). This is due to the dramatic change of cultivation methods. Coffee is cultivated in tropical and subtropical regions at high elevations and naturally grows under a shaded canopy of trees, which provide a valuable habitat for indigenous animals and insects, as well as preventing topsoil erosion and eradicates the need for chemical fertilisers. However, due to the

increased market demands in recent years, this innocuous form of agriculture has been superseded by *sun-cultivation* techniques. Originating in the 1970's, sun-cultivated coffee is produced on plantations, where forestry is cleared so that coffee is grown in rows as a monoculture with no canopy. Coffee farmers were encouraged to replace their traditional and supposedly inefficient farming methods with the higher yielding techniques, which resulted in deforestation (Moore 2014). In a life cycle analysis of coffee, Salmone (2003) reported cultivation and consumption of coffee as the two largest contributors towards negative environmental impacts (Hui & Price 2011). The process of separating the commercial product (the beans) from the coffee cherries generates enormous volumes of waste material in the form of pulp, residual matter and parchment. Over a 6 month period in 1988, it was estimated that processing 547,000 tons of coffee in Central America generated as much as 1.1 million tons of pulp and polluted 110,000 cubic metres of water each day. This excess waste can also play havoc with soil and water sources as coffee pulp is often dumped into streams, severely degrading fragile ecosystems (Moore 2014). In the United Kingdom average annual imports during the period 1997 to 2010 totalled 3.4 million bags. Among the ten leading countries supplying coffee to the United Kingdom, re-exports from other importing countries, Germany (13.6%), Netherlands (7.6%), Spain (4.1%), Ireland (2.4%), France (2.3%) and Italy (2.1%), accounted for 32.2% of the total compared with 41.2% coming from exports by Vietnam (14%) Brazil (11.7%), Columbia (9.4%) and Indonesia (6.1%), (ICC, 2011). In the United Kingdom, the waste generated from total import of coffee grounds are either landfilled or processed at municipal facilities with other organic wastes. Coffee consumption in a city can take various forms; this study is interested in the out-of-home market and the location of consumption. It covered those food service establishments in Leeds where coffee is served. Of the 5,067 food businesses registered under the local authority of Leeds (Leeds City Council, 2015), 1892 are registered to serve coffee (Food & Health, 2014). The beverage maintains a social character in the city as consumption is widely distributed across bars (176 outlets), café (557), canteens (168), pubs (371), restaurants (387) and various leisure centres (248) see Figure 1. Costa Coffee holds a dominant share of the branded market in Leeds with a total of 17 outlets. Whitbread PLC evaluated waste generated by weight for their Costa chain stores and found that organic food & coffee grinds was the biggest contributor of waste produced followed by paper waste at 65.7% and 21.2% respectively (Costa, 2012). With the average Costa chain store producing approximately 20kgs of waste coffee grounds per day (Gourlay, 2014). This provides an enormous opportunity for waste diversion and resource recovery in the city of Leeds with the city generating approximately of 38 tonnes of waste coffee grounds per day.

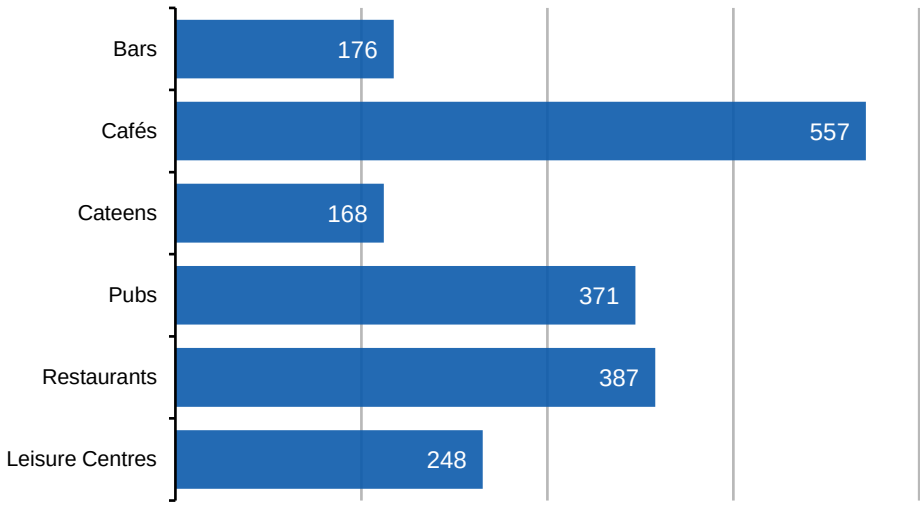

Figure 1. Distribution of coffee consumption in Leeds.

Waste coffee grounds represent an under-utilised high nutrient material with potential, as compost for horticultural use therefore recycling through vermicomposting can be a sustainable, low cost alternative to disposal. The available literature on vermicomposting waste coffee grounds is limited but some studies have evaluated its use as a horticultural amendment, as a mushroom growing medium, as compost feedstock, and as biofuel feedstock (Liu & Price, 2005; Barreto et al., 2008; Kondamudi et al., 2008). Composting technologies have been widely applied to transform raw organic feedstock into stabilised humus-like materials (Liu & Price, 2005; Tiquia et al., 2002). The biotransformation process is mediated by microbial biomass under idealised moisture, oxygen, pH, carbon (C) and nitrogen (N) conditions. Vermicomposting has been used to process a wide range of feedstocks, including coffee pulp, livestock manures, and food wastes (Liu & Price, 2005; Lopez, 2001). Earthworms can play a significant role in the management of waste coffee grounds. There are many species of earthworms with the potential for waste management, but the most commonly used are *E.fetida*, and *E.hortensis*. They are ubiquitous and many organic wastes are naturally colonised by the species. They can tolerate a wide range of temperatures and live in organic wastes with a good range of moisture contents (Edwards & Bohlen, 1996). The aims of the study are to evaluate the use of vermicomposting biotechnology as a viable option for the diversion of waste coffee grounds.

2. METHODS

2.1. VERMICOMPOSTING

Vermicomposting is a decomposition process involving interactions between earthworms and microorganisms. Although the microorganisms are responsible for the biochemical degradation of the organic matter, earthworms are the crucial drivers of the process. They fragment and condition the substrate, increasing surface area for microbiological activity and altering its biological activity. Earthworms act as mechanical blenders, and by comminuting the organic matter, they modify its biological, physical and chemical status, gradually reducing its C:N ratio, increasing the surface area exposed to microorganisms and making it much more favourable for microbial activity and further decomposition (Domínquez, 2004). Vermicomposting systems are designed to maintain conditions favourable to the most rapid decomposers, the mesophilic bacteria. The combination of earthworms and mesophilic bacteria are used to rapidly stabilise the organic chemical compounds, reducing the loss of valuable nutrients.

2.2. VERMICULTURE PROJECT

The Vermiculture Project was established as a social enterprise to help coffee shops operating in the food service sector in Leeds transition towards zero waste. The aims are to provide landfill diversion and resource recovery services for coffee shops and to evaluate the potential for waste coffee grounds to be bio-transformed into a stabilised horticultural compost for use in organic food production. On the 22nd September 2014 the project started a landfill diversion and resource recovery service for two of Leeds Beckett University's food court cafés; located at both City and Headingley campuses. The waste coffee grounds are collected daily along with shredded paper and are being recycled using the vermicomposting experiment. The experimental project adapts four replications of the "Oregon Soil Corporation Reactor". The vermiculture compost system is a continuous-flow vermicomposting bin. The original concept for the continuous-flow system was devised by a team of researchers at Rothamsted Experimental Research Station, UK in the early 80's. The concept takes advantage of the fact that composting worms typically prefer to remain quite close to the surface of whatever material they happen to be living in, generally moving towards the most recently added organic wastes, leaving higher concentrations of their castings behind. The vermiculture compost bins measure 1220mm in length by 915mm wide by 915mm in height and are located in a shade tunnel at the Landscape Resource Centre & Experimental Gardens (LRC), Leeds Beckett University, Headingley Campus, Leeds (53.825251"N, -1.598081"W). The experimental study is being conducted over a 12-month period.

2.3. BIN 1 & BIN 2

The bins were constructed using 18mm thick marine plywood and insulated with 25mm thick Celotex TB4000 insulation boards to provide additional insulation for composting during the winter period. They were loaded on site on the 3rd of October 2014 with a thin layer of newspaper. This is done to absorb any extra moisture and to restrain migrating earthworms from escaping into the harvest chamber. Bin 1 was loaded with 30kg of waste coffee grounds, pre-composted for 21 days and Bin 2 with 30kg of freshly collected waste coffee grounds (no pre-composting). The 21 days of pre-composting organic waste is done to avoid exposure of earthworms to high temperatures during the initial thermophilic stage of composting (Adi et al., 2009; Nair et al., 2006). It is also done to provide a readily available food source during inoculation because microorganisms constitute an important nutritional component to the earthworm's diet (Edwards & Bohlen, 1996). In both bins 3.4kg of shredded paper, 5 litres of water and 1kg of *E.fetida* was added, and on the 6th of March 2015 an additional 2kg *E.fetida* and 2kg *E.hortensis* was added to both systems.

2.4. Bin 3 & Bin 4

The bins were constructed using 18mm thick marine plywood and insulated with 65mm polypropylene insulation foam boards. They were loaded on site on the 6th of March 2015, with a thin layer of newspaper, 35kg of pre-composted waste coffee grounds (60 days), 1.7kg of shredded paper, 3 litres of water, and 2kg of *E. fetida* and 2kg of *E.hortensis.* The aims of the experiment are to evaluate the potential for waste coffee grounds, which are high in nitrogen (Adi et al., 2008; Dinsdale et al., 1996) to be decomposed through vermicomposting. Also to assess a vermicomposting system inoculated with a mixed colony of earthworm species, *E.fetida* and *E.hortensis* for transforming waste coffee grounds into a stabilised horticultural compost for use in food production. The experimental study evaluates two different ratios of waste coffee grounds (WCG) to shredded paper (SP), to determine the rate of waste processing for waste coffee grounds (kg/m^3 bed/week) for a processing system operating under UK conditions. The objectives are to analyse moisture content, temperature, and pH levels of the vermicompost, and measure chemical characterisation of the composting feedstock against cast produced by the earthworms to determine plant macro and micronutrients

3. Results and Discussions

3.1. Temperature

Temperature is the most important factor affecting microbial metabolism during composting. It is either a consequence or a determinant of the microbial activity. (Vallini et al., 2002) It is an important parameter in monitoring the composting process and determining compost quality. It is also strongly correlated with microbial activity and in relation to composting stages is used to determine the conditions suitable for the proliferation of different microbial groups, i.e. meso and thermophiles (Lui et al., 2011; Tiquia at al., 1996). The composting stages based on temperature, mesophilic, thermophilic, pre-composting, and ambient temperatures are clearly displayed for the four-replication vermicomposting experiment in Figure 2. Decomposition usually occurs in three stages characterised by the most active organisms. Psychrophilic bacteria begin the process at temperatures below 21°C, which was observed on day 7 by the colonisation of microbial activity to the underside of the newspaper bedding see Figure 3. A peak temperature of 12°C was recorded on day 7 in Bin 3 with the lowest temperature of 10°C recorded in Bins 1 and 4. Mesophilic bacteria dominate between temperatures of 21-38°C (Domínquez, 2004), and the presence of the bacteria was evident from compost temperature in Bins 1 (30°C), 2 (22°C), 3 (30°C) & 4 (33°C) on day 14. At temperatures over 38°C thermophilic bacteria take over and the presence of the bacteria was also evident from compost temperatures on day 18 in Bins 1 (45°C), 3 (48°C) & 4 (46°C) which signaled the thermophilic stage of decomposition. However, a peak temperature of 50°C was recorded on day 25 in Bin 1, after which temperatures gradually waned towards a range of 30°C on day 28. The ambient temperature during the composting period from 6 Mar 2015 to 7 April 2015 averaged 7.7°C, and ranged from 1 to 15°C. The different species of earthworms' response to temperature differentials during the study period was observed and it was found that *E.fetida* were more tolerant to differential temperatures

compared to that of *E.hortensis.* The difference between the 21 & 60 days pre-composting of waste coffee grounds and temperature was marginal. However, in the no pre-composting bin low temperatures were recorded throughout the study period, only reaching a peak temperature of 35°C on day 25 and compositing through psychrophilic and mesophilic stages of decomposition only.

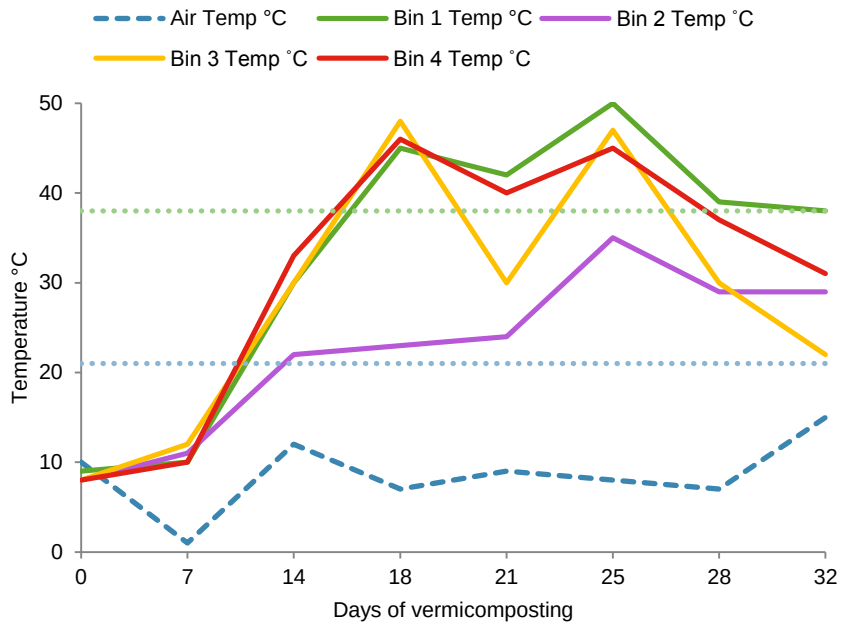

Figure 2. Changes in daily average temperature during the period 6 Mar. 2014 to 3 Apr. 2015.

Bin 1	Bin 2	Bin 3	Bin 4
30 kg of pre-composted waste coffee grounds (21 days)	30 kg of freshly collected waste coffee grounds (no pre-composting)	35 kg of pre-composted waste coffee grounds (60 days)	35 kg of pre-composted waste coffee grounds (60 days)
3.4 kg of shredded paper	3.4 kg of shredded paper	1.7 kg of shredded paper	1.7 kg of shredded paper
3 kg of *E.fetida* + 2 kg *E.hortensis*	3 kg of *E.fetida* + 2 kg *E.hortensis*	2 kg of *E.fetida* + 2 kg *E.hortensis*	2 kg of *E.fetida* + 2 kg *E.hortensis*
5 litres of water	5 litres of water	3 litres of water	3 litres of water
Thin layer of newsprint	Thin layer of newsprint	Thin layer of newsprint	Thin layer of newsprint

Table 1. Summary of inoculation contents for each vermicomposting bin.

Figure 3. Microbial activity recorded on day 7 of vermicomposting experiment.

3.2. Moisture

Moisture is of crucial importance in maintaining microbial activity within a composting matrix because decomposition slows dramatically in mixtures fewer than 40% moisture (Domínquez 2004). There are strong relationships between the moisture contents in organic waste and the growth rate of earthworms (Domínquez, 2004). In vermicomposting systems, the optimum range of moisture contents for most species has been reported to be between 50 and 90% (Domínquez 2004; Edwards 1998). *E.fetida* can survive in moisture ranges between 50 and 90% (Domínquez 2004; Sims and Gerard 1985; Edwards 1998) but grows more rapidly between 80 and 90% in animal wastes (Domínquez 2004; Edwards 1998). Reinecke and Venter (1985) reported that the optimum moisture content for *E. fetida* was above 70% in cow manure. The average moisture content of compost in Bins 1 and 2 was recorded at 73% and 74% respectively during the composting period from 3 October 2014 to 3 April 2015. Both bins recorded the lowest moisture content of 10% on the 9 Jan 2015, see figure 5. Prior to this the system was left idle for a two-week period due to the holiday season (no records obtained during this period). It was observed that earthworms and microbial activity had dramatically slowed during this time. However, the choice of shredded paper provided a hospitable living environment for the earthworms. Earthworms usually consume their bedding as it breaks down, and it is important that it is a slow process, as it was observed that heating occurs in the food layers (waste coffee grounds) of the vermicomposting system and not in the bedding. The choice of shredded paper provided the earthworms with a high absorbency material, which absorbed and retained moisture, allowing the worms an environment to thrive. This was evident after the holiday season because worms were found in the high-absorbency material the worms an environment to thrive. This was evident after the holiday season because worms were found in the high-absorbency material season

because worms were found in the high-absorbency material and survive the period of reduced moisture.

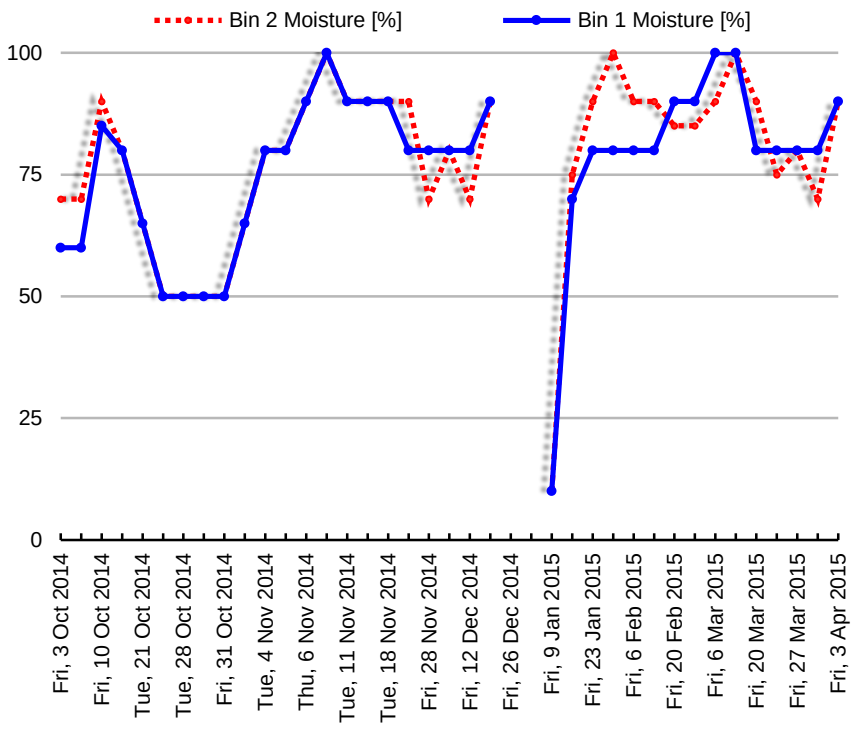

Figure 5. Changes in moisture content of compost during the period 3 Oct. 2014 to 3 Apr. 2015.

3.3. pH

Most species of epigeic earthworms are relatively tolerant to pH, but when given a choice in the pH gradient, they moved towards the more acid material, with a pH preference of 5.0. However, earthworms will avoid acid material of pH less than 4.5, and prolonged exposure to such material could have lethal effects (Domínquez 2004; Edwards and Bohlen 1996). It is widely believed that waste coffee grounds are acidic but as the study clearly displayed consistent pH values around neutral (7.0) were recorded throughout the experiment. In general, the pH of worm beds tends to drop over time, however, the pH values recorded at the start of the experiment was recorded at 7.0 which has been consistently maintained. Microbes driving compost stabilisation operate best in the range of pHs between 6.5 and 8.0 (Vallini et al., 2002) and as waste coffee grounds are neutral it represents a valuable feedstock which can sustain microbes for compost stabilisation.

3.4. C:N Ratio

The ratio of carbon to nitrogen (C:N ratio) in organic matter added to soil is of importance, because net mineralisation of the organic matter does not occur unless the C:N ratio is of the order of 20:1 or lower. Earthworms can have major influences on nutrient cycling processes in many ecosystems. By turning over large amounts of organic matter, they can increase the rates of mineralisation of organic matter, converting organic forms of nutrients into inorganic forms that can be taken up by plants (Edwards, 1996). In the managed compost operation special attention was paid to the ratio of carbon to nitrogen in the waste and moisture levels of the material as it broke down. The ratio of waste coffee grounds to shredded paper (WCG:SP) used was aimed at generating compost with a C:N ratio between 25 and 30:1. A weekly feeding program was adapted for the experiment using 19kg WCG: 5kg SP for Bins 1 & 2 and 19kg WCG: 2.5kg SP for Bins 3 & 4. On the 31st March 2015, 1kg of finished compost was harvested from Bins 1 & 2 and sent for chemical analysis. Analysis of the compost composition has not yet been completed but will be published at a later date.

CONCLUSION

In recent years, vermicomposting has emerged as a simple, easily adaptable and effective biotechnology for recycling a wide range of organic wastes for agricultural production. The technology is advantageous over thermophilic compost because it contains a considerable amount of organic acids, such as plant growth promoting hormones and humic acids. It also has high water holding capacity, low C:N ratio and low phytotoxocity (Pant & Wang, 2014). The initial results of this study indicate that waste coffee grounds have the potential to be vermicomposted as a primary feedstock. It found methods of inoculation for Bin 1 loaded with 21 days of pre-composted waste coffee grounds more effective than Bin 2 loaded with the non-pretreated waste. In relation to microbial activity and composting stages, the study found conditions in Bin 1 more favourable for decomposition. Bin 1 composted through all three stages of decomposition with an active population of psychrophilic, mesophilic, and thermophilic bacteria, while the conditions in Bin 2 were only favourable for psychrophilic and mesophilic bacteria. Bin 1 contained the most active population of microorganisms and was able to breakdown the waste coffee grounds at a much faster rate than Bin 2. Bin 1 processed 12.25kg of waste coffee grounds more than Bin 2 at a rate of 6kg/0.375m^3 bed/week. In the 30 weeks of landfill diversion and resource recovery the experiment successfully recycled and processed a total of 595kg of waste coffee grounds and 55kg of shredded paper, at a processing rate of 20kg/1.5m^3 bed/week producing zero waste.

To gain a true understanding of the potential that exists for vermicomposting, it is important to look at the 'Big Picture'. Currently, waste coffee grounds are mixed in with general waste and disposed of in a general collection bin. Businesses contract private waste management companies for the disposal of their waste and charges depend on size and frequency of their collection. These charges include the rental of collection bins and a duty of care charge. The true cost is only established when contracts are set up with the waste management company. However, WRAP estimates that waste costs businesses in the food and drink supply chain approximately £4 billion annually, with the sector producing 4.1 million tonnes of waste per year (WRAP, 2013). Businesses are being placed under increasing pressure to reduce their overall rate of waste to meet UK and EU limits on the amount of biodegradable municipal waste sent to landfills. Currently, there are 1892 food service establishments registered under the local authority of Leeds to serve coffee and there exists an opportunity within the city for the waste stream to be diverted, recovered and recycled using the biotechnology. Estimates reveal that approximately 266,000kg of waste coffee grounds can be recovered within the city weekly and made available as a primary feedstock for vermicomposting. If managed properly the waste stream can contribute to helping businesses meet targets on the amount of biodegradable municipal waste being sent to landfill. Vermicomposting can provide an opportunity for waste generators to divert their waste into local communities for beneficial uses, such as organically produced compost for organic food production. Currently only 4.2% of the UK farmland is organically managed, which is equivalent to 738,700 hectares. The study reveals that there is an existing opportunity for waste coffee grounds to be sustainably managed using vermicomposting on a commercial level at centralised sites. An estimated 266 tonnes of waste coffee grounds can be sustainably managed and processed at a rate of 266,000kg/19,950m^3 bed/week using a worm population of approximately 53,200kg of *E.fetida* and *E.hortensis* to organically produced compost. The biotechnology can contribute to significant improvements to existing waste infrastructure and also be used as a resource to bridge the gap between waste and organic food production. Our findings also indicate an opportunity exists for further research into the use of waste coffee grounds as an alternative for renewable energy production (biofuel) as alternative to disposal.

ACKNOWLEDGEMENTS

The author would like to acknowledge Dr. Alison Phair and Alan Simson for their kind words of wisdom and encouragement. I would also like to thank Mark Warner, Louise Hartley, Lorraine Foster, Joanne Jolley, Adrian Appleyard, and Robin Brinkworth for their help in making the project possible. The

project is funded in part by the Leeds Beckett University Enterprise Services, UnLtd Social Enterprise and the Higher Education Funding Council for England (HEFCE).

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FEEDING A CITY: WHAT DO ACADEMIC RESEARCHERS THINK SHOULD BE ON THE URBAN FOOD SYSTEM'S PLATE

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Keywords: Urban, Food System, Food Security, Sustainable City.

Abstract

Developing a more sustainable urban food system is viewed as a route to tackling food insecurity, public health, and environmental challenges, and there has been significant re-engagement with the food system at the city scale in recent years. But to what extent do the factors currently being researched put us on a trajectory to delivering food systems that will function well in a changing future? This paper presents the findings of a review of urban food systems literature, exploring how the academic community understands and interacts with the urban food system, and to what extent existing approaches are effectively addressing the full range of urban food challenges. The review highlights a vibrant area of research with an exponential increase in contributions over the past decade. There are a number of subject areas that have received particularly strong focus and there is notable emphasis on the North American region. We identify that enquiry into local and alternative food systems is dominating the discourse and we critique the extent to which this addresses the full spectrum of challenges facing the urban food system.

Harris, J., Dougill, A. and Owen, A. (2015) **Feeding a city: what do academic researchers think should be on the urban food system's plate** *In;* Gorse, C and Dastbaz, M (Eds) *International SEEDS Conference,* 17 – 18 September 2015, Leeds Beckett University UK, Sustainable Ecological Engineering Design for Society.

INTRODUCTION

Over the last century, cities have become an increasingly important spatial, political, economic, and social unit. A majority of people around the world now live in cities and humanity's transformation from a predominately rural to a predominately urban population is well documented (UN Habitat, 2011) (Foresight, 2011) (United Nations, 2010). The performance of cities now determines the health, quality of life, sustainability and security of the majority of the world's people, both directly for urban residents and indirectly through the impact of cities on wider rural populations.
Feeding a rising urban population is now an accepted social, technical, environmental and resource challenge and there has been growing acknowledgement of the need to actively engage with the food system at the city scale to address this (FAO, 2011) (Morgan and Sonnino, 2010), (Kaufman, 2009) (APA, 2007) (ICLEI and RUAF, 2013). A range of actors are contributing; from producers and consumers through to researchers and policy makers.

For researchers, the 'who, what, where, and how' of feeding cities (the 'urban food system') presents a multi-dimensional research area that is being approached from a variety of angles. At the same time, the city scale provides an interesting vantage point from which to view the increasingly wide ranging body of academic literature on food systems.

AIMS

The aim of this review is to explore the depth and scope of academic literature relating to urban food systems by considering the following questions:

- What areas of focus (from here on described as 'themes') emerge from the urban food systems literature? Which themes are explored in depth and which are not?
- What are the key issues and perspectives explored within each theme?
- Do particular elements of the food supply chain receive greater focus than others?
- Has the focus on particular themes, supply chain elements, or geographic regions changed over time?
- Do the themes identified address the full range of urban food challenges?

METHOD

This structured review of academic literature has involved categorising articles related to urban food systems. The search terms "Food System*" AND ("City" OR "Cities" OR "Urban" OR "Metro") were used within bibliographic databases Web of Science and Scopus selected for their relevance to the subject area. The searches yielded a total of 466 articles (133 from Web of Science (Search date 11 February 2015) and 333 from Scopus (Search date 17 February 2015). Results were filtered by publication date. Prior to 1989, Scopus results showed an average of only a single article per year. From 1989, this rose to three articles and has climbed steadily since. Consequently, only articles from 1989 onwards were considered in this review; 322 in total (excluding overlaps between databases and articles not published in English). To be considered relevant for review, the article needed to explore issues relating specifically to the urban food system, that is, the production, processing, distribution, sale, consumption or disposal of food in the urban environment, combinations of these elements, and/or the functioning of the system as a whole. The article had to retain a primary focus on the urban environment rather than a passing mention; articles were typically classified as not relevant where they failed to have a substantive urban focus. A total of 266 were considered directly relevant and taken forward for detailed classification and categorization. This review has aimed to capture articles that discuss food issues within the context of the urban food system.

Authors approached their study of the urban food system from a wide array of academic positions and areas of expertise. A purpose of this review was to explore this breadth. To identify the range of themes addressed, each article was categorised based on the article's purpose as stated in the title and abstract. A subset of 50 articles was reviewed and an initial set of themes were identified. The remaining articles were then categorised on the basis of these themes; new themes were added as required. The complete set of themes is listed below. Once this exercise was completed for all 322 articles, a check was performed to ensure consistency within each theme and consolidate overlapping themes. In virtually all cases, the appropriate theme was clear from an article's title and abstract however, where required, the full text was reviewed to provide further clarity. The quality of individual articles was not assessed during this process. Where an article addressed multiple themes, the primary theme was recorded. Articles were also classified based on the element of the urban food supply chain on which they focused, including: production and processing, supply and distribution, access, consumption, and waste disposal. Finally, articles were classified by their region of geographic focus. Many articles were case studies of particular cities and/or explored the urban food system from a clear geographic perspective.

RESULTS

Thematic Focus

The review identified 11 themes (areas of focus for the literature), broadly defined as follows. All articles primarily addressed one of these themes.

- *Local Food Systems* - Food systems derived from, and operating within, the 'local' area, functioning as an alternative to global / industrial food systems.
- *Health and Wellbeing* - Health, nutrition, diet, and obesity among urban populations at both individual and community scales.
- *Environment* - The environmental impact (including carbon emission intensity) of the food system (local or otherwise).
- *Food Security* - Food security and poverty in the urban environment. Primarily relating to availability and accessibility of food but with mention of how food is used where it related to the broader theme of food security as opposed to consumption characteristics.
- *Vulnerability, Risk and Resilience* - Food system (or system component) risk, vulnerability and resilience in the face of internal and external stresses and shocks.
- *Governance & Planning* - Processes, systems, approaches, policy mechanisms and governance structures used to engage with, and manage, the urban food system.
- *Justice and Sovereignty* - Explorations of values, principles and philosophies around the nature of, and right to, food.
- *Food Safety* - Identification and management of food safety risks within the urban food system or in supply chains for urban residents.
- *Education and Engagement* - Initiatives to promote improved understanding of, and engagement with, the food system.
- *Demand Characteristics* - Understanding food demand drivers and characteristics of individuals and communities.
- *System Analysis* - Quantification of the food system through mapping and/or modeling where the primary focus is on a greater understanding of the functioning of the system itself (rather than any of the above themes).

The largest set of articles (64 articles, 24% of relevant articles) focus on Local Food Systems. These articles explore a need to move away from a global, 'industrialized' food system to a more local (or 'alternative') one, maximising the potential benefits this approach might offer for more environmentally sustainable, socially-just, and ethical, localised production and distribution systems. There is relatively greater focus on urban agriculture (including animal husbandry and more informal

urban gardening) as opposed to other peri-urban and regional production models that might support localisation (e.g. community supported agriculture, direct marketing initiatives including farmers markets and promoting urban rural linkages). A majority of these articles focus on food production as a vehicle to achieve these desired objectives and there is a very strong bias towards North American neighbourhood and city-scale case studies, for example Philadelphia (Vitiello, 2008) and (Kremer and DeLiberty, 2011), Buffalo (Metcalf and Widener, 2011), New York City (Ackerman et al., 2014), New Orleans (Kato, 2013) and San Jose (Algert et al., 2014). A smaller subset of articles deal with more systemic (as opposed to production) issues including those relating to the nature of, and place for local food systems and their ability to promote positive environmental, social justice, health, and safety outcomes (Bloom and Hinrichs, 2011) (Trivette, 2014) (DeLind, 2011) (Helenius et al., 2007) (Reid et al., 2012). Virtually all of these articles were published after 2008 suggesting that this developed nation focus on food system localisation is a relatively recent addition to the academic research. In addition to the articles considered in this review there is an extensive body of work on urban agriculture originating from the architecture and urban design disciplines. The seminal contribution by (Smit et al., 1996) and more recent publications by authors such as (Viljoen and Bohn, 2014), (Viljoen et al., 2005), (Gorgolewski et al., 2011) and (Mougeot, 2006) provide complementary evidence on the opportunities for food production in urban areas with a strong and distinct emphasis on spatial design, urban environmental quality, and urban planning. Differing routes for dissemination of this work has likely led to its absence from the set of literature considered in this review but its importance to the multi-disciplinary field of local food systems should be noted.

The second largest set of articles (40 articles, 15%) explore Food Security and primarily focus on systemic and access related issues in developing country contexts. There is coverage of malnutrition, urban poverty, and food insecurity in both an Asian (for example (Etzold et al., 2009) (Keck and Etzold, 2013) (Figuié and Moustier, 2009) (Dittrich, 2008)) and African (for example (Battersby, 2011) (Tawodzera, 2011) (Crush and Frayne, 2011) (Crush and Caesar, 2014) (Wegerif, 2014)) context; many articles highlight the role of rapid urbanisation in exacerbating the food security challenge in these regions. A small subset of articles (11) discussing food security in a North American context, published over the past 10 years, focus on food access (i.e. the ability of people and communities to physically and economically access an appropriate diet) as the barrier to food security. Food Security articles did not emerge in other developed country contexts. A relatively small set (11) of articles on Vulnerability, Risk and Resilience provided an interesting and complementary body of work, focusing not just on current food insecurity challenges but on understanding the vulnerability of populations (for example (Fraser et al., 2005) (Ibrahim, 1994) (Alajmi and Somerset, 2015)) and a focus on how these communities have responded to disturbance ((Smith and Lawrence, 2014) (Singh-Peterson and Lawrence, 2014) (Keck and Etzold, 2013)).

Equally significant (in scale) bodies of work focus on the themes of Environment, Health and Wellbeing, and Governance and Planning. Demonstrating many similarities to, and overlaps with, the work on local food systems, literature relating to environment and planning focuses almost exclusively on a developed country context (predominately North American) and is dominated by single city case studies. Work by Pothukuchi and Kaufman ((Pothukuchi and Kaufman, 1999) (Pothukuchi and Kaufman, 2000)) made a seminal contribution to a now active food systems planning community in the US and Canada. Articles by (Reynolds, 2009) (Hardman and Larkham, 2014) and (Carey, 2013) discussing Food Strategy and Food Charter development activities in London, Birmingham and Bristol respectively provide an interesting UK comparison to the North American work. The significant (if less numerous) contributions to this area of work by authors operating in a developing/transitioning country context such as (Rocha and Lessa, 2009) and (Lynch, 1995) should also be noted; Belo Horizonte and Dar Es Salam (for example) have long been recognised as powerful examples of holistic food systems planning in a developing/transitioning context. While many authors appear to view promotion of environmentally sustainable and local

food systems synonymously, for the purposes of this review these topics are addressed separately; a number of authors ((Sonnino, 2013) and (Carroll and Fahy, 2014) for example) support this distinction by recognising in their work, the risks associated with promoting local food as sustainable food.

Work on Health and Wellbeing is one of the most homogenous themes with articles generally exploring the way that managing the urban food system might result in improved diet and health outcomes for residents. There is a clear focus on obesity and non-communicable disease management in both a developed and developing context ((Zhai et al., 2014) (Swinburn et al., 2011) (Libman et al., 2015) (Chan et al., 2010) (Ashe and Sonnino, 2013) (Gittelsohn et al., 2014)); the structural barriers to a healthy diet such as poor access and food deserts ((Reisig and Hobbiss, 2000) (Markowitz, 2008) (Libman et al., 2015) (Smith and Miller, 2011) (Alkon et al., 2013)); and the role of local production in improving diet, again in both developed and developing countries ((Cohen et al., 2012) (Pearson, 2013) (Popkin, 2014) (Poulsen et al.)). Surprisingly few articles (five) focus solely on Food Safety despite this being an important driver for food policy and public engagement in food issues.

A relatively small subset (eight) focus on the successes of awareness raising around food system function through formal and informal education (notably, (Edwards and Mercer, 2010) (Cohen, 2010) (Giefer, 2014)).

Discrete, but complementary, bodies of work explore the wholesale and retail elements of the supply chain and their effects on consumption across variety of geographic regions (within Systems Analysis, for example (Eisenhauer, 2001) (Cadilhon et al., 2006) (Sage, 2010)) and other drivers of food choices including willingness to pay for environmental/sustainability features (Demand Characteristics, for example (Wahida et al., 2013) (Veeck and Veeck, 2000) (Dittrich, 2009) (Stagl and O'Hara, 2002)).

A more quantitative approach to Systems Analysis emerged in studies aimed at: documenting in more detail the food sheds (Peters et al., 2009) (Porter et al., 2014), using GIS to map food systems (Eckert and Shetty, 2011) (Taylor and Lovell, 2012), and quantifying food flows (Zhou et al., 2012).

Figure 1 displays graphically frequency of academic articles by theme area.

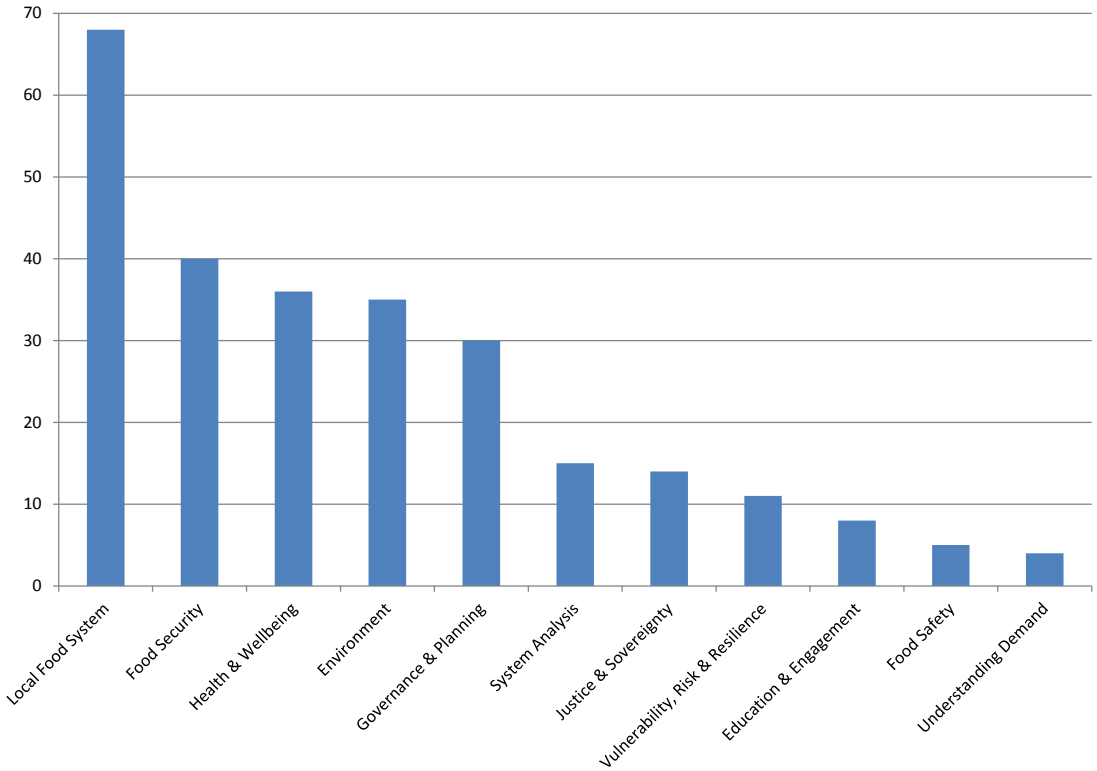


Figure 1 Frequency of Academic Articles by Theme and Supply Chain Focus

Food Supply Chain focus

In order to gain a greater understanding of the relative emphasis placed by researchers on different elements of the urban food system, articles were also classified by the element of the supply chain that they focused on. The supply chain was divided into six stages:

- *Production and Processing (urban)* – Production within the urban boundary including formal urban agriculture activities, animal husbandry, and informal food related gardening.
- *Production and Processing (local)* – Production from the urban fringe or hinterland (i.e. peri-urban agriculture) and wider agricultural activities that are linked to the urban environment through supply and distribution systems (e.g. Community Supported Agriculture, Farmers Markets, etc.).
- *Supply and Distribution* – Movement of produce from point of production to point of sale or acceptance by end user.
- *Access* – Movement of people to their food source (e.g. retail outlet, market, production area, etc).
- *Consumption* – Food selection, purchasing and consumption practices.
- *Waste & Disposal* – The management of food waste in the urban environment.

Table 1 and Figure 2 present the breakdown of the literature by food supply chain stage.

Table 1 Academic Articles by Food System Focus

Supply Chain Stage	No. Of Articles	% of Total
Production (Combined)	84	33%
Production (Urban)	*60*	*23%*
Production (Regional)	*24*	*9%*
Supply & Distribution	30	11%
Access	31	12%
Consumption	21	8%
Waste	2	1%
System	98	37%
Total	266	100%

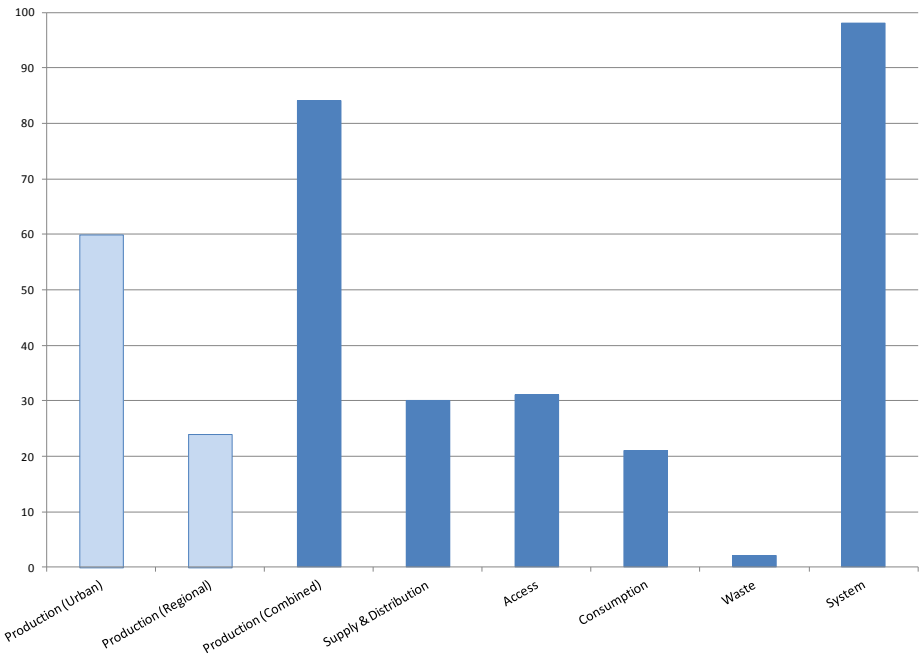


Figure 2 Frequency of Academic Articles by Supply Chain Focus and Theme

Sources considering the system holistically (or multiple elements of the supply chain) are the most common, incorporating 37% of all relevant articles (98 articles). The functioning of the food system is addressed from a range of perspectives, the more common being system governance, public health, localisation, and environmental sustainability.

Food production represents the next largest area with just under a third of all relevant articles focusing on production within the urban environment (23%) or in the local hinterland (9%). This work reflects a growing interest in the role that local (urban) agriculture might play in addressing a range of environmental, social, health, and economic challenges facing urban residents. This emphasis is relatively recent (70 of the 83 articles published since 2009) and growing, with many authors advocating the potential benefits of localising food production (in addition to the city based case studies listed above, see also (Ackerman et al., 2014) (Blecha and Leitner, 2014) (Turner, 2011) (Vitiello, 2008) and (Smith and Jehlička, 2013).

Surprisingly few articles within this literature set address food waste.

Geographic focus

The vast majority of articles reviewed presented a developed country (notably North American) focus (refer Figure 3).

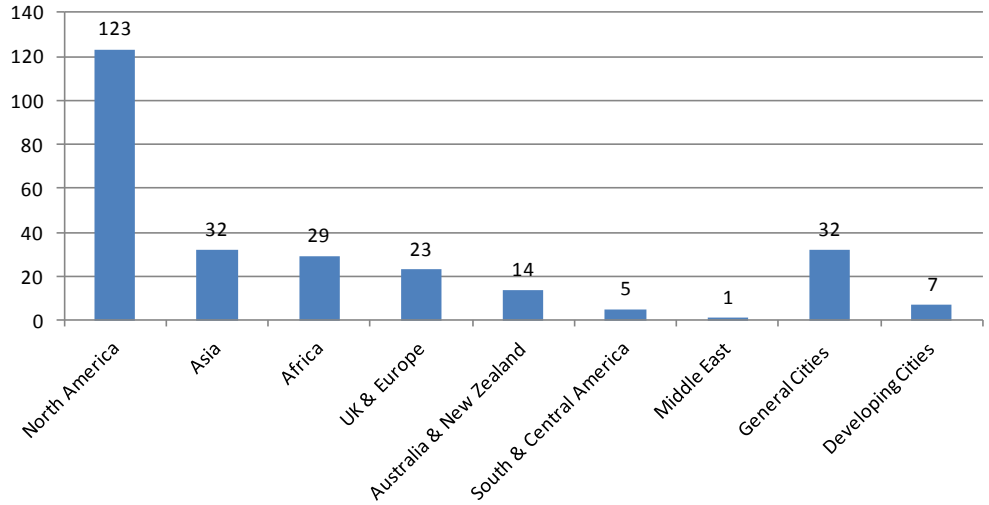
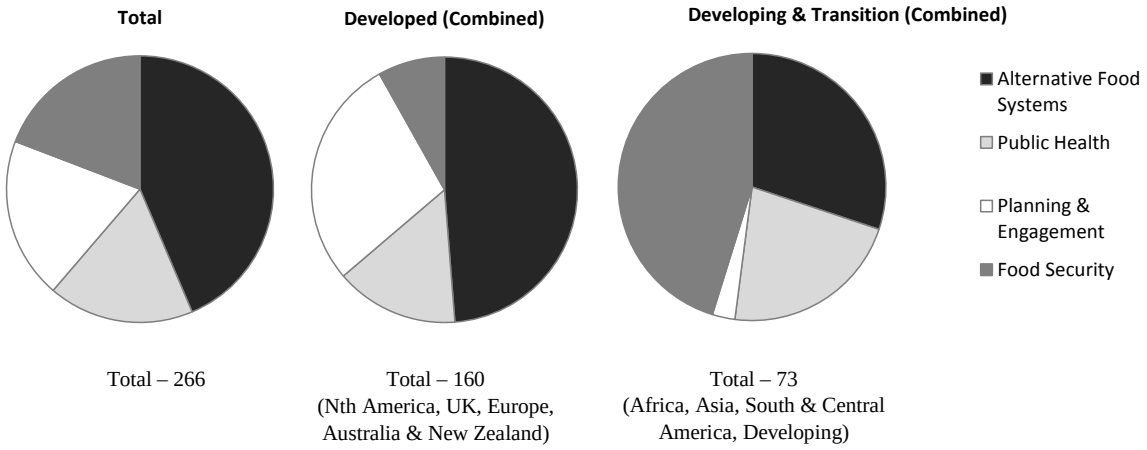


Figure 3 Frequency of Academic Articles by Geographic Focus

Further, when comparing activity between geographic regions, clear differences emerge. Academic literature discussing urban food systems in North American, UK and European contexts (Shown in Figure **4** as 'Developed (combined)') focuses more frequently on the themes of Local Food Systems, followed by Planning and Engagement, and Public Health. Articles exploring a Developing & Transitioning context place far greater emphasis on Food Security with Systems Analysis as the next most frequently occurring. Vulnerability, Risk and Resilience also receives a greater focus in these contexts. Articles related to food justice and sovereignty are entirely restricted to North America.



For presentation purposes, themes have been grouped to provide the charts presented in figure 4.
Alternative Food Systems *– local food systems, environment, system analysis;*
Public Health *- health & wellbeing, food safety, demand characteristics;*
Planning & Engagement *– planning & governance, education & community engagement; food sovereignty;*
Food Security *– food security and urban poverty, vulnerability, risk and resilience.*

Figure 4 Thematic focus by Geographic Region (proportion of articles)

Maturity of Literature

This review presents an interesting snapshot of a growing area of research. The past 10 years show a substantial increase in the rate of publication in the area of urban food systems, rising from just six papers in 2004 to 55 papers in 2014 (a nine fold increase), see Figure 5. While complementary areas of urban food research such as food security, sustainability and public health represent more substantial bodies of literature, the rate of increase in publications for these fields is significantly lower than those with an urban systems focus. For example, over the same 10 year period, the areas of food security[1] (six fold increase), diet and health[2] (two fold increase) and sustainability and environment[3] (four fold increase) all experienced slower rates of growth. Bodies of work related to food security and health, without an urban focus, also displayed lower rates of growth. That said, it is clear that research related to food issues, urban or otherwise, is an expanding field; refer to Figure 6 for the growth of wider urban food fields in comparison to urban food systems literature.

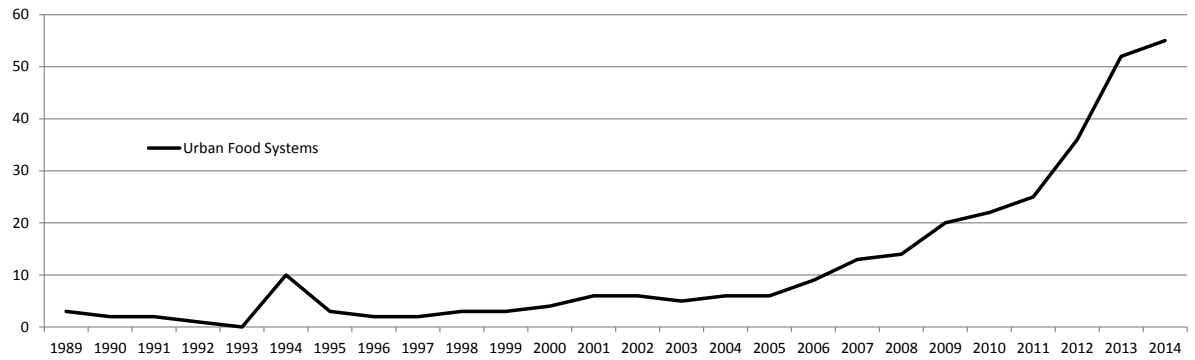


Figure 5 Number of Publications by Year (Urban Food Systems)
Source: Reproduced from Scopus search results accessed February 2015

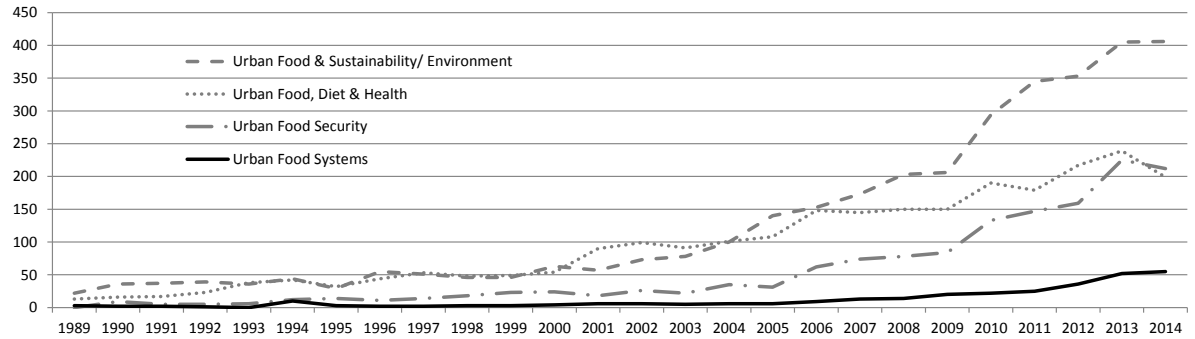


Figure 6 Number of Publications by Year (Urban Food Themes)
Source: Reproduced from Scopus search results accessed June 2015

CONCLUSIONS

This literature review confirms an increased focus over the last decade on urban food systems as an area of academic interest. The breadth of the literature (evidenced by the identification of 11

[1] Scopus Search June 2015, (urban or city or cities or metro) and ("food security" or "food insecurity")
[2] Scopus Search June 2015, (urban or city or cities or metro) and food and (diet and health)
[3] Scopus Search June 2015, (urban or city or cities or metro) and food and (environment or sustainability)

themes) also suggests that a diverse range of drivers are acting as catalysts for researchers' engagement with a wide variety of urban food issues.
With a quarter of all articles focusing on local and alternative food systems (from a thematic perspective) and a third of all articles focused on local production (from a supply chain perspective), understanding the role and contribution of localised food systems has clearly been a priority research area. Many authors cite the importance of decoupling food production and consumption from a globalised system as a route to securing the potential positive environmental, economic and social benefits that a local food system may offer city residents (and rural farmers). However, the extent to which a localised food system has the capacity to address the full range of challenges facing cities remains questionable. For cities in developed countries especially, addressing the urban issues associated with food security, supply chain vulnerability, food safety, consumption choices and health outcomes, and environmental protection is likely to require an understanding of, and engagement with, the existing (industrialised and globalised) food system that appears to be lacking from this body of literature.

The commonly addressed themes of food security, environment, and governance and planning present an interesting contrast between developed and developing regions.

For example, while the prevalence of articles on governance and planning is buoyed by the activity of North American researchers, food security receives relatively less consideration within the literature for developed countries. This is surprising given the commonly acknowledged food insecurity and food poverty challenges in developed countries globally (Food Ethics Council, 2010) (Dowler and O'Connor, 2012).

Further, articles focusing on developing and transitioning countries make up less than a third of those reviewed and only 12% (33 of 266 articles) primarily addressed food security in these countries yet these geographic areas still represent the majority of the world's population suffering from food insecurity challenges (FAO, 2014). A high level search using the Scopus database confirms that "urban food security" is a large area of academic work (circa 600 search results, 4 June 2015). At the same time, networks focused on urban food issues in both developing and developed countries (for example the Resource Centre on Urban Agriculture and Food Security, the Food and Agriculture Organisation Food for the Cities Program, and the UK's Sustainable Food Cities Network) are actively working (and publishing) on food security, sustainability and resilience challenges in these contexts. There appears to be a lack of alignment between research focus, academic publication, practitioner activity, and policy pressures in these areas.

The themes of food waste and food safety both appear to be somewhat underrepresented in urban food systems literature. This seems surprising given their importance as part of the urban food supply chain and as food research topics in their own right. Exploring these topics through an urban systems lens appears to be a further area of opportunity.

Our cities need urban food systems that are many things: healthful, environmentally sustainable, resource efficient (and circular), low carbon, economically viable (and vibrant), socially just, culturally appropriate, safe, secure, resilient, and well governed. The literature considered in this review shows breadth and depth reflecting several of these areas. Public health, environmental sustainability, governance, and security are well established areas of research. Areas such as resources efficiency and waste management, system resilience, and carbon emission reduction are less well covered. Bringing these issues together to consider the urban food system holistically, as a critical urban infrastructure system, remains an area of research opportunity.

LIMITATIONS

This review has focused on collating and analysing a body of literature related to urban food systems with a view to establishing an overview of general themes, patterns and trends. It is not an exhaustive examination of any one theme or geographic area but a distillation of those studies that have a clear city-scale and systems focus to their work. The review has also not considered the individual quality or academic impact of papers considered in this review and it is acknowledged that frequency of publication in a particular area does not necessarily equate to depth and quality of inquiry. The review is intended to be an introduction to an expanding, multi-disciplinary area of research.

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Sustainable Buildings

A SENSIBLE APPROACH TO LOW CARBON AND HEALTHY BUILDINGS

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Keywords: Life cycle analysis [FDES] LCA, home insulation, CO_2.

Abstract

House insulation reduces energy usage, lowering heating costs, and reducing CO_2 emissions. However insulating materials vary in the CO_2 emissions they produce in manufacturing, a fact consumers may not realise. Life Cycle Analysis (LCA) ascertains the CO_2 impact of manufactured goods allowing comparison. Here the results of LCA on a range of environmentally friendly insulators are presented. Natural Fibre Insulators (NFI's) are produced from natural or recycled products unlike conventional materials. How do these products compare in their overall CO_2 impact? What are the benefits of LCA and how comprehensive are they?

Garlovsky, D. (2015) **A sensible approach to low carbon and healthy buildings** *In;* Gorse, C and Dastbaz, M (Eds) *International SEEDS Conference,* 17 – 18 September 2015, Leeds Beckett University UK, Sustainable Ecological Engineering Design for Society.

Introduction: Different insulators, different environmental effects

Improving residential insulation is often considered a panacea. Energy requirements are lessened which reduces heating costs and saves money. The associated reductions in carbon emissions play a valuable contribution to fighting global climate change and preserving precious energy resources (Martin, 2007). Promoting improved insulation provides an ideal opportunity for U.K. policy makers to mediate the impact of rising fuel prices by reducing household energy demand. The U.K. aims to reduce greenhouse gas emissions by over 80% by 2050 (Murphy, R. J., Norton, A. and Campus, S. K., 2008). Using Low Carbon (LC) materials is a critical component in meeting the global challenges of global warming and help in the transition to a low carbon economy.

In addition to the conventional insulation materials traditionally used, there are now naturally based materials available, often referred to as Natural Fibre Insulation (NFI). The market for such "green" building products is growing rapidly. It is projected to reach £354 billion by 2020, according to a report by Global Industry Analysts (Environment Leader, 2014). This rise is being driven by a multitude of factors; including government regulation, increasing energy and resource costs, green building materials becoming less expensive, plus the reduced risk of allergic respiratory infections from natural materials.

The use of such NFI materials is being promoted, for example in the Code for Sustainable Homes (UK Government Department of Communities and Local Government, 2006), which emphasises that building materials are sourced responsibly, and the emissions of CO_2 are considered through the Global Warming Potential (GWP) value. The Energy Performance Certificate Scheme (UK Government Planning
Department, 2007) categorizes products according to environmental impact thus aiding consumer choice. The environmental performance of LC insulation is superior to conventional insulation (Schmidt et al. 2004).

However often consumers [e.g. homeowners, construction companies, architects] may not realise nor wish to take into account that different insulating products vary in their CO_2 impact due to material used in the manufacturing supply chain and energy consumption. The manufacture and disposal of insulators results in CO_2 emissions despite their positive influence on CO_2 emissions by aiding energy saving. Insulating material can also have negative environmental effects as they influence air quality and increase indoor pollution (Spengler and Sexton, 1983). There is a correlation between poorly conceived energy efficiency efforts, indoor air quality, and the rise in asthma and allergic diseases in the U.K. (Sharpe et al., 2015). It is acknowledged that there is a lack of reliable, independent data about the environmental impact of both NFI materials and more traditional insulators (Murphy et al., 2008). This means little comparison has been made between the two types of products. How can the environmental effects of insulators be assessed and compared?

Method: Life Cycle Analysis
What is an LCA?

A Life Cycle Analysis (LCA) is a method to assess the entire CO_2 impact of any manufactured product. CO_2 emissions resulting from manufacture, use, and disposal are included (USEPA, 2010; PAS 2050, 2008). Such a LCA thus quantifies the overall CO_2 impact of a product. This better represents the true value of materials in environmental protection rather than simply considering values during its active use. Applying an LCA is vital to following the principles of a Circular Economy (Ellen Macarthur Foundation, 2013). This is one that is restorative by design, and which aims to keep products, components and materials at their highest utility and value, at all times. Different forms of LCA exist, including those including only manufacture of products ready for delivery to suppliers at the factory

door (cradle-to-gate), or encompassing manufacture and use of the product until it no longer functions (cradle-to-grave), or even including disposal of the product or recycling (cradle-to-cradle).

Performing an LCA

Criteria have been established for the conducting of a LCA (e.g. PCA, 2050). There are typically four stages (Curran, 1996). Firstly, the aims and goals of the LCA are established. Secondly, the steps in the manufacture process are ascertained. Thirdly, an assessment of the environmental impact of each step is made. Lastly, the results are interpreted and decisions made on the basis of the effects seen at each step.

Example One: LCA comparing Natural Insulators

Murphy et al. (2008) performed a 'cradle-to-grave' LCA on a number of natural fibre insulating materials and compared them to conventional materials, following the standard protocol laid down in ISO 14040. The products examined were:

- *Thermafleece,* produced in Bradford is produced from Sheep's Wool;
- *Isonat,* produced in Lyon is made from hemp (Murphy et al., 2008).
- Plus the conventional products, *Rockwool* and *Knauf Crown Loft*.

They also performed a marginal analysis, examining the carbon production at each stage of the manufacturing process to identify where optimisation could occur. This provides a Global-warming potential (GWP), which is a relative measure of how much heat a greenhouse gas traps in the atmosphere. It compares the amount of heat trapped by a certain mass of the gas in question to the amount of heat trapped by a similar mass of carbon dioxide. A GWP is calculated over a specific time interval, commonly 20, 100 or 500 years. As it is perceived that NFI materials will have an inherently low environmental impact, the chosen benchmark products were BREEAM A rated. Information on market leading materials produced by Knauf and Rockwool were used as benchmarks for evaluating environmental performance of the NFI's.

They found that the environmental impact of NFI and the conventional fibres studied was broadly similar. The results can be seen in Table 1. Generally NFI's were broadly similar to "A" rated products in the Building Research Establishment (BRE) Green Guide to Specification. However the GWP_{100} of Thermafleece was particularly low. The GWP_{100} of Isonat suffered because of transportation and its greater density. The products of Knauf and Rockwool had poor GWP_{100} in comparison.

NFI offered great potential in lowering GWP_{100}. With Isonat, drying out the product, adding polymers, and transportation causes much impact. Another feature of the Murphy et al. (2008) study is the identification of the impact of the end of life stage of the products. Landfill is identified as the most likely destination of products and the effect of this is ascertained. Most carbon emissions were caused through manufacture, such as the addition of flame-retardants. Efforts at reducing impact should be concentrated here. The replacing of polymer, reducing insulator thickness, and choosing another flame retardant material, could all aid in reducing CO_2 emissions further.

Example 2: Inno-therm®/Metisse®
***What is* Inno-therm®/Metisse®**

In July 2013, production of Inno-therm® was transferred to Le Relais in northern France, and offers Metisse® under the Inno-therm® brand as a thermal and acoustic insulation range. Inno-therm®/Metisse® is an insulation material manufactured from recycled denim/cotton (Jordeva et al., 2014). Over 80% of the product is recycled cotton/denim. The raw material is sourced from France. It is a proven LC insulation product in energy requirements both in manufacturing and performance. It

has met all the required requirements of UK and European Technical standards. Being recycled it reduces textile waste sent to landfill. It is estimated that 619kt consumed textiles is collected for reuse and recycling every year, and an additional 820kt of clothing and household textiles, which is currently consigned to landfill, could be diverted (WRAP, 2013). The manufacturing process uses 80% recycled cotton/denim [3 jean's/m² for 100mm thickness].

Inno-therm®/Metisse® has low embodied energy and can be recycled (WRAP, 2013). In comparison with conventional products such as wood wool board (980kg/tonne) and mineral wool (1,050kg/tonne) Inno-therm®/Metisse® has an embodied CO_2 of 393kg/tonne of insulation product. The material is non-itch/toxic and will not cause allergic reactions. Its thermal properties [0.039 Wm-1K-1], in the design of new build or refurbishment allows one to reduce timber sizes, thus having cost savings while still achieving good U – values. It has end user benefits, as in installing, it won't itch or irritate the installer and there are no health concerns with cotton.

***First LCA**:* Initial research, conducted by a doctoral candidate, was begun in 2011 at the School of Architecture, University of Sheffield. This investigated the supply chain and manufacturing processes of the recycled cotton/denim insulation (Timmis, 2011). The production steps in Inno-therm®/Metisse® were identified, systems boundaries defined, and carbon emissions quantified following the Carbon Trust (2008). The data of the conventional insulation product was directly accessed from the Ecoinvent database (ECOINVENT, 2015), the world's leading database of consistent, transparent, and up-to-date Life Cycle Inventory data. However, the database did not offer information as detailed as the company that manufactures the recycled insulation, and only the result of LCA was given. The GWP_{100} value (Global Warming Potential) of conventional insulation obtained was an average value. This lack of specific product information and data lowered the credibility of the research.

Timmis (2011) identified four discrete stages in the production of Inno-therm®, each of which accounted for carbon emissions. These stages are illustrated in Figure 1. In the first stage recycled material is retrieved. Secondly, it is processed into fibres; flame retardants are added and the new material is mixed with polyester. Thirdly the new fibrous material is processed and packaged into a form suitable for distribution. Fourthly and finally the new product is transported and distributed.

The study found that the first stage, namely obtaining material for recycling caused the emission of the greatest amount of carbon, 244 kg/tonne. Manufacturing resulted in 123.8 kg/tonne. Processing into a form for sale accounted for only 13.0 kg/tonne and distribution 12.1 kg/tonne. Thus obtaining the raw material caused most damage in carbon emission terms. Transportation, followed by electricity use were the main components of obtaining the raw material that accounted for these carbon emissions. Later transportation and packaging of the Inno-therm® itself resulted in little carbon dioxide emissions.

***Second LCA**:* Heyuquing (2014) performed a second, more ambitious, study in 2014 within the Management School, at the University of Sheffield. This extended this research and compared the total carbon emissions of the recycled insulation to a selected conventional insulation product. A 'cradle-to-cradle' LCA, examining carbon emissions from sourcing to disposal of the product was performed. This LCA extended the scope of the initial research begun in 2011 and also identified areas where emissions could be reduced.

Data on Inno-therm®/Metisse® was obtained direct from Recovery Insulation Ltd., a social enterprise company, the distributors primarily in the UK of Inno-therm®/Metisse®. Information of the conventional product was obtained from the Ecoinvent inventory which lists CO_2 emissions from various insulators. The end-of-life phase emissions were taken into consideration, which covered the

disposal activity of any waste produced in manufacturing supply chain. Although LC insulation is recognized to have lower impacts on the environment than conventional products, this final stage of a product's lifespan still needed to be examined. A GWP_{50} over 50 years was used as the standard for carbon emissions. Data was obtained direct from manufacturers. Where data could not be obtained directly BUWAL, Ecoinvent databases were utilised. The BUWAL database allows transport costs to be ascertained.

All stages of production from sourcing of natural material to disposal of final product were assessed and amounts of carbon produced estimated. Manufacturing of Inno-therm®/Metisse® was found to be the stage at which most carbon emissions were produced, with a GWP_{50} of 1.24 kg CO_2. Figures for transport were 0.038 kg CO_2, installation 0.001 CO_2, and at the products end of life 0.03 kg CO_2. Inno-therm®/Metisse® compared well with the conventional insulator examined in terms of CO_2 emissions.

A feature of both analyses was that they identified that carbon emissions were lower or comparable with conventional products. The recycled nature of the product meant that Inno-therm®/Metisse® was seen as a more sustainable product than conventional products.

Discussion: What are the benefits of LCA?

The studies show the potential benefits of a LCA, and the limitations.

- *Comparison*: As the study by Murphy (2008) shows LCA allows comparison of materials, providing an easy to compare figure for the environmental impact of a product. Murphy (2008) was able to compare natural fibre insulators with conventional types.
- *Quantification of environmental impact*: An LCA is an attempt to place numbers on the environmental impact of a product, thus making an abstract concept more concrete.
- *Identifying improvements*: LCA allows areas where CO_2 could be saved and identified, thus improving the manufacturing process. For example Timmis (2011) identified stages in the sourcing of materials where emissions could be saved. Timmis (2011) identified the locally sourcing of materials as the most important stage to consider, as this stage contributed most to carbon emissions. Heyuqing (2014) however, found that manufacturing processes was responsible for most carbon. A one-step recycling and a reduction in the input of additives during the production process were suggested. Murphy et al. (2008) made a number of recommendations including the scaling up of production, reducing the amount of flame retardant chemicals used.

Positives of the* Inno-therm®/Metisse® *LCA's

The LCA's on Inno-therm®/Metisse® showed a number of positive benefits of LCA:

- *Identification of manufacturing steps:* Both Timmis (2011) and Heyuqing (2014) successfully identified steps in the manufacture of Inno-therm®/Metisse® where CO_2 emissions were caused. For example Timmis (2011) successfully identified treatment of recycled cotton fibre with flame retardant chemical as a step in the manufacturing process. This demonstrates the value of LCA's in breaking down complex processes into simpler stages where CO_2 emissions can be easily identified.
- *Quantification of CO_2 emissions:* The study by Timmis (2011) most thoroughly provided exact measures of CO_2 emissions. For example differentiation of transportation emissions were most meticulously broken down into those produced through ferries and lorries. LCA's thus help place concrete values on previously abstract concepts.
- *Final destination*: Most LCA's on insulators are 'cradle to grave', and thus cease to consider what happens when the product leaves the factory. Heyuqing's (2014) attempt to study CO_2

impact after this, considering disposal, was laudable, but ultimately relied on guesswork. The study shows the importance of considering the CO_2 impact of products in all stages of their life.

- *Identification of areas for improvement*: Timmis (2011) identified many areas where reductions in CO_2 emissions could be made, For example reducing the low melt polyester binder content would result in a reduction of 11.9 kg CO_2 per tonne of insulation.

But the studies on Inno-therm®/Metisse® illustrate the challenges and limitations of LCA's:

- *Identifying steps:* The study by Heuyqing (2014) which although ambitious was unrealistic due to lack of information. Ascertaining CO_2 emissions for long lasting products such as insulation once they have been manufactured can be difficult.
- *Statistics*: Alterations in the production process are often not taken into account. For example Inno-therm®/Metisse® is now manufactured in France with the brand name Inno-therm®/Metisse®, where 80/90% energy resource is from nuclear as compared to UK, meaning its production results in lower carbon emissions. The studies on Inno-therm®/Metisse® fail to take this change into account.
- *Lack of data*: The studies on Inno-therm®/Metisse® are limited by the data which is available to them. Timmis (2011) mentions the problems with lack of data in the assessment made. Insufficient data may result in false conclusions being made. For example Timmis (2011) performed a 'cradle-to-grave' analysis because of the difficulties in obtaining information for products postproduction. Heyuqing (2014) used a mean value of GWP for comparisons based on data from the ECOINVENT website, as more detailed data was lacking for Rockwool and thus made doubtable conclusions. If more extensive data was available a more exact comparison could be made.
- *Varied Environmental Impacts:* The studies illustrate the limitations of considering only one aspect of a products environmental impact; namely CO_2 emissions. Often the environmental benefits of such products are many and various. Recycled or natural fibre materials are benign, making them easier and cheaper to install and dispose of. Although the overall environmental benefits were not considered by Heyuqing (2014).

Similarly when examining a product's carbon impact, thought must be given as to all ways in which a product may influence carbon emissions. For example Heyuqing (2014) failed to take into consideration that Inno-therm®/Metisse® is a much better insulator than conventional products, meaning a substantially lesser amount is required than for conventional materials or that the reduced heating required lowers carbon emissions. This has associated advantages regarding costs and a products carbon impact.

What are the advantages of LCA for natural insulators?

LCA's allow easier comparison for consumers of naturally based and conventional products. Even though there are a number of alternative LC insulation products currently available, the suppliers of conventional insulation are well established. Contractors are familiar with the products. LC insulation products are often produced by small insulation manufacturers and thus unable to increase market presence.

Price provides a further market barrier for LC insulation. Conventional products are sold to the public at subsidized rates, which creates a distortion in the market. LC products do not benefit from this subsidy. There is no technical reason why LC insulation products should not be offered in DIY stores with similar subsidies. Use of LCA would allow better comparison for consumers and aid their establishment in the market.

Future research

In light of the research that has been conducted gaps were identified that will require further research in 2015. For example, lack of available data from conventional insulation manufacturers for example on energy usage during the production process, hindered research in 2014. There were limitations to the reliability of the data that could be obtained.

Research in 2014 did not look into how the different thermal insulation performances would affect the functional unit. The correct functional unit would need to be re-established to remove any variability. As we need to compare like with like - e.g. convert results into units of insulation. The economic benefit of adopting recycling activities was not identified in the research. The result of the research concentrated on the LCA. Data related to the end-of-life phase of the conventional insulation product was absent and the CO_2 emission amount of insulation that goes to landfill was not accessible.

One objective of future research for this recycled-based insulation will focus on low-energy processing in reducing emissions during manufacturing through the substitution of the synthetic temperature activated binder fibre using thermoplastic proteins from biological sources or recycled alternative.

A doctoral candidate will again extend the research in 2015 by:

1. Reassessing LCA and environmental performance of the recycled insulation and comparing to conventional insulation.
2. Further study how the manufacturing processes of the recycled insulation could be optimized to reduce its carbon emissions in the manufacturing supply chain.
3. Finally, look at the full economic benefit by establishing a £ value in the use of an LC insulation.

Conclusion

LCA is invaluable in showing the lifetime carbon costs of recycled insulated material. LCA highlights where significant quantities of carbon emissions are released and where emissions could be reduced. They also show the impacts the supply chain and manufacturing processes have on carbon emissions in recycled-based insulation. Though the values of carbon emissions by conventional insulation products have been calculated, lack of available data hinders comparison with recycled products. There is a lack of reliable information on the impact of Natural Fibre Insulation materials in general (Murphy et al. 2008).

The LCA's used, as examples did not consider the economic benefits to adopting NFI, LC and recycled insulation. LCA primarily focuses on the environmental benefits in terms of CO_2 emissions of adopting recycled-based insulation. It would be beneficial to expand the analyses of the recycled-based insulation into a full LCA allowing direct comparison with other conventional and LC insulation products (e.g. Thermafleece, Sheep's Wool and Rockwool, etc.) taking this into account. Comparison with naturally derived binder product and/or product with 100% recycled content would be pertinent.

In summary, the principles of a Circular Economy, namely using low carbon materials and resources, should be followed at all stages of a products manufacture, including sourcing energy from sustainable sources when insulation is manufactured and in the supply chain of such materials. The full life cycle costs of products should be considered.
In a world where lower carbon and healthy buildings are valued, to quote W.E. Deming (1994):

> *"If you improve quality costs will go down and value goes up".*

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FIGURES AND TABLES

Table 1: Summary of the main products discussed. Information accessed from products websites.

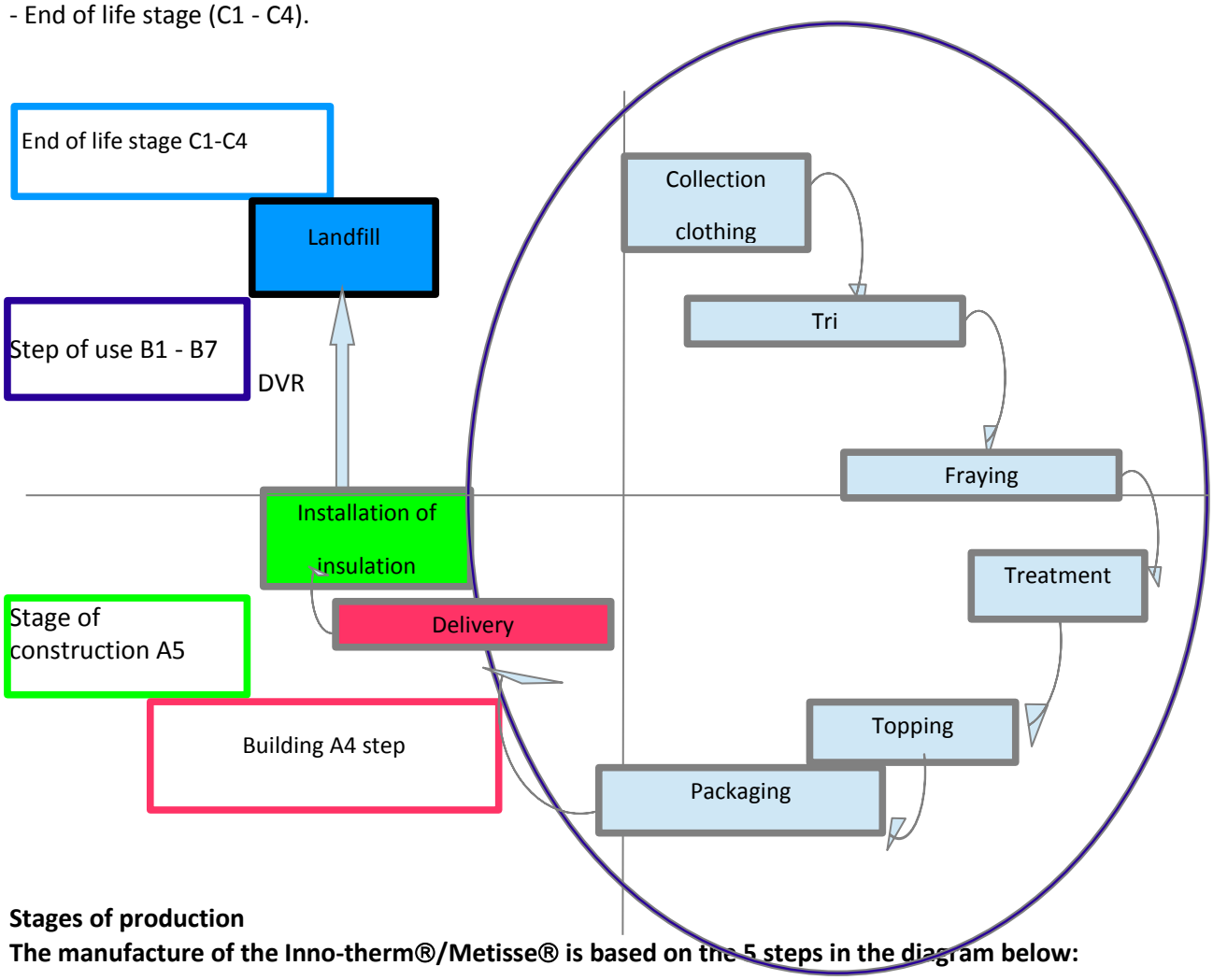
Product	Raw Material	Production	u-value	Thermal Conductivity W/m/k	Density
Thermal Inno-therm®/Metisse®	Blue Denim Cotton	France	0.19	0.039 W/mK	20-25
Thermafleece Original	Sheepwool	UK	0.13-0.16	0.038 W/mK -	25
Isonat	Hemp fibre	France	-	0.039 W/mK	35
Rockwool	Minerals	Wales	0.13-0.25	0.039W/mK	25
Crown Loft	Glass Fibres	Wales	0.2	0.044W/mK	10

Figure 1: The manufacturing process of Inno-therm®/Metisse®- re: Environmental and Health Product Declaration, June 2015

Stages of life cycle

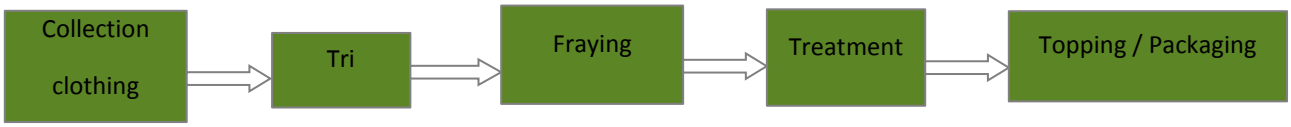
As described in the diagram below, it takes into account the impacts throughout the life cycle of the product, that is to say:

- Production step (A1 - A3)
- Stage of construction (A4 - A5)
- Life (B1 - B7) implementation stage
- End of life stage (C1 - C4).



Stages of production

The manufacture of the Inno-therm®/Metisse® is based on the 5 steps in the diagram below:



The challenges of implementing low carbon retrofit in existing buildings – attending to installers and micro-enterprises

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Keywords: Retrofit, energy efficiency, intermediaries.

Through analysis of qualitative data from home energy retrofit projects we look for influences of human behaviour on energy use in the home, beyond the boundaries of the building and its design, recognising that energy use is not determined solely by the rational decisions of building users, or of the building's designers. Our focus is on retrofit which encompasses a range of changes to existing buildings to alter energy use. Decisions to incorporate new energy technologies into the home (both energy efficiency and renewable energy technologies), and how those newly installed technologies are then used, are shaped by the advice and action of intermediaries, including energy efficiency advisers and energy technology installers. These intermediaries are often micro-enterprises employing 3 people or less. Understanding the nature of this influence, and how it might be directed to increase energy efficient behaviours, is an overlooked opportunity. Intermediaries take account of a range of factors in their work, including perceived client motivation, previous experience, availability of knowledge and experience in their networks, and risks and costs associated with innovation. Our exploratory study found that influence was greatest at the pre-installation stage, and that the influence which could be exercised post-installation was not realised (Owen and Mitchell, 2015).

The challenges of implementing sustainability in existing buildings – attending to installers and micro-enterprises

NOTE: this paper is substantially based on an earlier version of a paper in press from 9th July 2015. That paper is Owen, A & Mitchell, G. 2015 "Outside influence – some effects of retrofit installers and advisors on energy behaviours in households" Indoors & Built Environment, in press

1.0 Introduction

Energy use in the home is not determined solely by the rational decisions of building users or designers. Where householders are contemplating changing their homes in ways which may influence energy use, decisions to incorporate new energy technologies and how those newly installed technologies are then used, are shaped by the action of intermediaries, including energy efficiency advisers and the installers of energy technologies. Understanding the nature of this influence, and how influence might be directed to increase energy efficiency, is an overlooked opportunity, particularly in the context of the number of people advising on and installing energy technologies. A UK trade association representing small and medium sized building firms recently reported that the market value of refurbishment and renovation of existing homes was up to £6 billion per annum (Federation of Master Builders, 2014) and each refurbishment project offers an opportunity for energy use reductions.

1.1 Background – Retrofit and the role of Intermediaries

Retrofit is used here to encompass a range of activities in repairing, improving and maintaining buildings, incorporating innovations that shape energy use directly or that influence user behaviour to reduce energy use.

The influence of householders in effective energy retrofit has been widely studied (e.g. Risholt and Berker, 2013, Galvin and Sunikka-Blank, 2014, Wilson et al., 2013) and there is extensive research on inhabitant behaviours that change energy consumption, exploring the effect of individual values (e.g. Andrews et al., 2011, Mirosa et al., 2013), the household's social practices and habits (e.g. Marechal, 2010, Shove, 2009), lifestyle stages and choices (Schäfer et al., 2012). This work is neatly summarised as "buildings don't use energy, people do" (Janda, 2011). However, this paper starts to look beyond the household, and explore the role of specific intermediaries who influence the households. A wide range of intermediaries, performing different roles, has been identified in the study of infrastructure transition and renewable energy more narrowly (Guy et al., 2010, Hyysalo et al., 2013) and it is generally found to be helpful to focus on the function of the intermediary rather than their form i.e. the type of organisation that the intermediary is found within This paper focusses narrowly on two specific functions of the intermediary: advising on technologies

that householders can consider for adoption, and installing those technologies. Installation is taken to include commissioning. This could be considered to exclude the dominant role of the intermediary identified in innovation diffusion literature, the role of promoting an innovation (Rogers, 2003). However, in the cases generating our data, promotion of energy conservation technologies is implicit in the work of advisers and installers, since they worked within area-based schemes intended to increase the amount of energy technology adoption.

The intermediaries within this paper's scope may have a purely advisory role, for example the energy efficiency adviser or Green Deal Assessor who assesses the need for insulation or a change to heating systems, or advice may be integrated with implementation, with a building contractor or heating engineer specifying a retrofit job and implementing the measures specified. The technical standard PAS2030 which sets the clear requirements for Green Deal and other retrofit work does include reference to commissioning activities, but with a purely technical focus, requiring installers to ensure that equipment is installed and commissioned in strict accordance with the manufacturer's specification (BSI, 2014).

In developing the sociotechnical approach, new ways to think about the structure of the retrofit system are being proposed, such as a "middle out" approach considering the role of intermediaries, rather than top down (regulatory) or bottom up (individual behaviour) approaches (Janda and Parag, 2013). It is suggested that this approach might help overcome some of the evident divides between drivers, values and action (Blake, 1999). In the "middle-out" analysis, intermediaries who have a professional role in retrofit projects are identified both as "enablers" of different solutions, and as "aggregators" of knowledge and understanding from a range of businesses and trades (Janda and Parag, 2013). In some retrofit cases, the home owner is also the retrofit installer. Analysis of the characteristics of these innovators and the STS they are part of has revealed that the interplay between amenity and energy efficiency is important, and that individuals often engage in mutual learning with their advisers and tradesmen (Galvin and Sunikka-Blank, 2014).

While there are many large firms in the construction sector, this paper focuses on the smallest firms, micro-enterprises, typically tied to one specific locality, with customers who are individual home owners and occupiers. Taken together, small construction firms likely to be undertaking retrofit are a large group supporting significant employment. UK figures also suggest that three quarters of all firms who work on residential property employ three people or less while the proportion of such small firms is slightly higher for the allied trades of electricians, plumbers and heating engineers ((Office for National Statistics, 2012) cited in (Owen et al., 2014)) . For these three trades, electricians, plumbers, heating engineers, allowing for one person per firm only, there are at least 95,000 individuals in these types of firms whose work could influence and accelerate domestic property retrofit in the UK.

The issue of skills and capacity in the retrofit sector should also be considered. A review of retrofit projects across five European countries found that the skills of stakeholders, including installers, were critical to the success of refurbishment in both financial and

carbon terms and that intermediaries were often key actors in a local area (Huber et al., 2011). An analysis of why energy efficiency measures are not adopted at an economically efficient rate generated a list of market failures, including constraints on intermediaries' knowledge and information (Gillingham et al., 2009). Equally, a lack of "suitably skilled installers" is recognised as a limiting factor on microgeneration in the UK (Bergman and Eyre, 2011), with a deficit in installers' skills also identified as a barrier in the specific case of heat pumps (Bergman, 2013).

Given this background, and the clear need to improve our understanding of the influence of the intermediary in energy retrofit, we now turn to an empirical analysis to identify the nature of that influence.

3.0 Method

We draw on qualitative data gathered in a study of household adoption of low carbon energy technologies in five case studies of area-based schemes in England. Each area-based scheme aimed to increase the rate of adoption of particular technologies (energy conservation, microgeneration, or a specific form of microgeneration such as PV) but did not encourage or facilitate a whole house approach. This examples therefore start from the point of considering to adopt energy technology, rather than starting from the point of considering home renovation. Using a semi-structured interview technique, data was gathered from householders, scheme managers, and the advisers and tradesmen who specified and installed energy technologies (Owen, 2013). In total, 54 individuals were interviewed across the five schemes, for the original study, a sampling frame which provided representation across three roles (householders, scheme managers, installers/advisers) and which appeared to lead to data saturation for the original research questions(Owen, 2013). For the specific analysis we present here, a subset of the data from advisers and tradesmen has been revisited, together with data from householders who specifically mentioned, without prompting, the role of such intermediaries. This subset comprises 22 interviews with individuals across a range of technologies and area schemes (Table 1). We emphasise that this is not a representative sample for the primary concerns of this paper, but rather a dataset allowing for exploratory analysis.

Technology	**Role and number of sources**
Insulation	Installer Programme Manager
Air Source Heat Pumps	Homeowner and adopter (3 homes) Surveyor and installer (2 individuals) Programme Manager
Photovoltaic cells (PV)	Homeowner and adopter (2 homes) Installer Programme Manager
Energy conservation technologies	Installer (2 individuals)

	Programme manager (2 individuals)
Micro hydro	Homeowner and adopter Homeowner and non-adopter Installer
Solar thermal	Homeowner and non-adopter
Biomass	Homeowner and adopter
All renewable microgeneration	Surveyor and installer

Table 1: Data sources for analysis of role of intermediaries

Framing retrofit measures as innovations to existing buildings allows theoretical models of innovation diffusion to be used as the starting point for analysis. The basic innovation chain describes the innovation adopter (here, the householder), gathering knowledge, being persuaded to adopt an innovation, making a decision which is implemented and, finally, receiving some sort of confirmation which embeds the innovation (Rogers, 2003). A similar pattern is found in the "expectancy value" psychological models used to explain environmental behaviours by individuals (here, again, householders). In these models, a set of starting conditions (antecedents) form an intention which leads to an action with some result from that action (Ajzen, 1991). Where analysis has been directed at energy retrofit specifically, the householder remains the focus with households thinking about renovation, deciding to renovate, planning the detail of renovation and then experiencing renovation (Wilson et al., 2013). The review in section two has highlighted that this householder focus overlooks the role of the intermediary adviser or installer. To structure our analysis, we integrated the stages from the theoretical approaches, separating process stages where a distinct intermediary influence might be identified. This gives us the follow stages:

a) Pre-installation: Identifying the retrofit opportunity;
b) Pre-installation: Identifying retrofit options ;
c) Pre-installation: Selecting options ;
d) Installation: Retrofit activity;
e) Commissioning retrofit measures;
f) Post-commissioning: Use and maintenance of retrofitted home.

Qualitative data from transcripts and field notes of semi-structured interviews were analysed for statements or assumptions with respect to the following questions: At what stages of thinking about changing energy technologies in the home do intermediaries have most influence? What types of roles have distinct influences and how do these relate to the capacity of the intermediary and the capacity of the household? How do these personal capacities connect to what is technically feasible in the home? This was, in effect, a form of template analysis (King, 2004). Data collection had been designed to investigate householder behaviour, and not to investigate these research questions specifically, so the findings presented and discussed below are indicative, but suggest areas which would be fruitful to explore further in order to understand, and change the influence of intermediaries on the behaviour of building users.

4.0 Results

We organise the findings from our analysis using five of the six stages identified above. Because the context of our data is that it is drawn from case studies which targeted energy retrofit activities, we could not identify distinct influence of intermediaries in the very first stage: exploring the opportunity to retrofit.

4.1 Pre-installation – identifying and selecting options

Intermediaries influenced future energy use by identifying technology options and highlighting the opportunity provided by retrofit (or the problem that it fixed). The opportunities introduced by intermediaries in their conversations with householders in our data included increasing usable warm space, reducing bills or, very occasionally, reducing carbon impacts. An important capability for the adviser at this stage is to link householder interests and motivations to changing (reducing) energy demand. What building users want from retrofit activity is more likely to be a change in amenity, such that the retrofitted space is better suited to their lifestyle needs (Wilson et al., 2013, Maller et al., 2012, Maller and Horne, 2011). The adviser must therefore be able to link the aspects of retrofit which reduce energy demand to the features desired by the householder e.g. an extension, to provide a play room or a larger family kitchen, needed to be cosy and so high levels of insulation could be justified.

4.2 Pre-installation – selecting options

Within the pre-installation stage, intermediaries then influenced, or directed, option selection. This might be based on their interpretation of the user's needs, on prior experience, or on information received. A needs assessment was then coupled with assumptions on the suitability of given technologies to meet those needs. Thus solar hot water installation might be deemed appropriate for a household with children, whilst a constant low level heating solution might be considered more important than a timed facility for older occupants with limited mobility. In terms of prior experience, an installer may have had poor experience with a particular manufacturer (in our data, this was the case for biomass boilers) or with the rapid development of a particular technology. The well informed intermediary needs to be able to counter the beliefs and experiences of other actors, whether they are the householder client, individuals that the client respects in their social network, or even other tradesmen:
One of the issues associated with individual building retrofit is that every building and householder will require a bespoke solution, with cost implications that are particularly important for SMEs that dominate private property retrofit. In one case study, the heating engineer observed:

4.3 Installation

At the installation stage, intermediaries in our case studies influenced how people felt about their retrofit activity and hence the degree of engagement building users (householders) had with the potential to reduce energy use after retrofit. There was near-universal dislike from householders of the disruption caused by retrofit activity, and if this was not managed well, the resulting negative impression stayed with the householder and influenced their belief about the effectiveness of the retrofit actions. With an air source heat pump, a particularly bad experience of installation in terms of disruption and damage to property, led one building user to believe that there was no difference in energy consumption before or after and doubt as to whether the equipment was working properly at all. In comparison, another householder who found the installation process well managed, had affectionate feelings towards the new heating system and overlooked teething problems with operation as unusual occurrences, easily overcome (Owen et al., 2012).

Installers we spoke to held a clear idea of the information that customers needed well in advance of the installation for it to be successful. This included information that the installer felt should be obvious, such as the need for someone to be present to let the team in on the day that cavity wall insulation was to be installed, as well as the need to balance technical and non-technical information:

4.4 Commissioning

For large retrofit measures, such as the installation of new heating systems, commissioning was recognised by installers as part of their role, but the need to communicate the commissioning process to the householder was not always considered important. With some retrofit measures that could reduce energy use, the intermediary played an important role in installing retrofit measures in such a way that they were used as intended. For example, one energy conservation adviser recounted how free, low energy light bulbs mailed by electricity suppliers were rarely installed. However, after the adviser put in the new light bulbs (and carried a small step ladder with him to ensure that he could access light fittings), replaced the householder's light shades and switched the lights on to illustrate the quality of light, he felt confident that those light bulbs would stay in place.

4.5 Post-commissioning: use and maintenance

For these case studies, post-commissioning work was minimal. Installation was seen by building users (householders) as the end point of the retrofit process. Whether the installer influenced the building users during and after commissioning was largely dependent on whether the building user expressed an appetite for behaviour change. Even the installer who described himself as "evangelical" about the need to change behaviours and reduce energy demand did not broach the subject if the client did not ask for more information. This installer had, however, written some supplementary guidance on energy use in the

home which he left with his clients as part of their information pack when installation work was complete.

Several individuals expressed a desire to go back in a month or two after their installation visits and remind clients of how to operate their retrofit measure effectively, or how their habits might be altered to make the most of the opportunities provided by retrofit measures. However without funding for the additional time involved, such follow up visits were not viable.

The difficulties of effective commissioning and post commissioning are implicit in advisers' and installers' preferences for 'fix and forget' technologies. In microgeneration, photovoltaic cells are an example of 'fix and forget'; once correctly installed they will generate electricity whenever there is incident sunlight. The additional behavioural changes required by the buildings users, such as changing the time when appliances are used to make best use of PV-generated electricity, are rarely actively promoted or explained. These behaviour changes rely on user motivation, and yet they could be encouraged by small shifts in intermediary behaviour at the commissioning stage, and post-commissioning, with a follow up to tweak both technology performance and user response to the technology.

5.0 Discussion

Our exploratory dataset showed that intermediaries (specifically advisers and installers) influenced householders at several stages of the retrofit process, affecting whether they adopt technologies or commit to some kind of associated behaviour change. Intermediaries' influence is related to their technical and social capacities (Owen et al., 2014) so successful transformation of our built environments to support reduced energy use will require changes in installer and adviser behaviour, reflecting the particular socio-technical challenges of current homes and households.

Much of the focus of current building policy is on the technical competence displayed during retrofit activity and quality assurance of the job done. Green Deal installers must be accredited, and microgeneration installers must also register under the Microgeneration Certification Scheme (Microgeneration Certification Scheme, 2013). Accreditation is, however, perceived as a cost by many of the micro-enterprises who carry out retrofit work and, if higher value work cannot be assured, there is little motivation to undertake the extra activities to gain accreditation particularly if they entail financial or opportunity costs. Equally, the Building Regulation process and inspection, while considered essential as providing a set of minimum standards and providing some protection to building users in terms of quality assurance, does not provide any incentive to increase the focus on reducing energy use, as long as current regulations are met.

Perhaps it is fortunate then, that the influence of intermediaries at both pre- and post-adoption stages appears to be more significant, since there may be opportunities to change

intermediaries own behaviours, and therefore impact, at these two stages. For intermediaries who work at the pre-adoption stage of retrofit activity, a clearer and more consistent understanding of how to link what their clients see as the problem to be solved through retrofit (e.g. high energy bills, more usable space), with opportunities to reduce energy use through behaviour would be helpful. The householder's perception of the intermediary's technical competence and expertise is closely linked to the other competences they display in communicating with the householder and the care they display towards the home being retrofitted. Our findings in this study, which focussed on private owner-occupiers, is echoed in studies of social housing tenants where trust is a critical part of the relationship between expert and householder with a direct influence on householders' responses to retrofit technology (Brown et al., 2014).

The period immediately after installation or retrofit, when the building is handed back to its users, is a critical stage. Extending professional and technical standards to cover a wider definition of commissioning activities, beyond simply installation in accordance with the manufacturer's specification, would provide a consistent level of expectation. If the manufacturer has not specified how technology should be commissioned to ensure the user operates it optimally (and there is little incentive for a manufacturer to do so at present), then the installer is not required to think about information provision and support to the user either. After commissioning, standard expectations of follow up and maintenance activities, with routine recognition of the costs of these activities as part of the required package, would reduce the risk of behavioural changes associated with retrofit being ephemeral.

At each stage, the influence that an intermediary might wield interacts closely with the interests, capacity and motivation of the building user. Being able to respond to a user or client's interests, and identify ways to shift their willingness to act and change behaviour appears to be an opportunity to use intermediaries to help realise the full potential of energy retrofit measures in homes.

6.0 Conclusion

While the role of designer and of building users in shaping energy use is readily recognised, there is also influence from intermediaries – specifically advisers and installers, often micro-enterprises - who appear to be an important part of the building's socio-technical system**.** Intermediaries play a particularly important role during installation and commissioning where a technology is unfamiliar to the household, suggesting that shifts towards novel technologies will require changes in the approaches and capacity of installers and advisers. In these case studies the influence, and legitimacy, of intermediaries waned rapidly once technology had been installed.

This paper is exploratory, drawing on a small number of research participants in a study originally designed for another research purpose. Intermediaries will take account of a

range of factors in their work, including perceived client motivation, previous experience, availability of knowledge and experience in their networks and risks and costs associated with innovation. There is the need to understand drivers and constraints on intermediaries in the retrofit system and how energy retrofit activities in particular fit into mainstream repair and refurbishment work. Equally, intermediaries can be considered in the context of innovation diffusion as adopters themselves, deciding what technologies are brought into the pre-installation stages of the retrofit chain. As with householders, intermediaries will vary in the degree to which they are keen to innovate. Mainstream energy retrofit of the scale required by carbon targets requires rapid acceleration of innovation diffusion so that it becomes a majority practice.

Our data also suggested that networks (spatial, technical, commercial and social) play an important role in shaping the intermediary's ability and willingness to deliver energy retrofit measures. More detailed and systematic study of these networks could lead to more comprehensive understanding, and potentially modelling, of how building retrofit functions, and therefore how it might be enhanced.

By treating retrofit actions as a staged process, and by recognising the connected influence of a range of intermediaries, building design considerations and householder's preferences, targeted measures might be introduced in the supply chain, and in professional and technical standards, such that intermediaries are empowered to act as more effective agents in the transition to a low carbon economy.

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Energy and Sustainability

LEAN CONSTRUCTION AND SUSTAINABILITY: TOWARDS SYNERGETIC IMPLEMENTATION

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Keywords: Construction, Lean, Project, Sustainability.

Abstract

The synergy between lean and sustainability is marginally exploited in construction. To reverse this trend, this project that is at the preliminary stage is aimed at proposing a method for the co-generation of value with the simultaneous implementation of lean and sustainability in the construction industry. Although the planned research design is case-based because of objectivity and subjectivity reasons, this paper emerges from a structured review of the literature. The reviewed literature shows understandings of what constitute 'value' may be contributing to the status quo in this context. Instead of 'business-as-usual' view of value (economic), the concept of shared value may integrate lean and sustainability in construction. In general, further empirical work is needed to evolve methodical ways of focusing on this dimension of value in construction. The future work should endeavour to unravel: 'how and why' the concurrent implementations of lean construction and sustainability should evolve in the sector?

Emuza, F. (2015) **Lean construction and sustainability: towards synergetic implementation** *In;* Gorse, C and Dastbaz, M (Eds) *International SEEDS Conference,* 17 – 18 September 2015, Leeds Beckett University UK, Sustainable Ecological Engineering Design for Society.

BACKGROUND

The nature of the construction industry is changing in response to intricacies of 'Green Building', 'Green Construction', and 'Green Economy' that are all drivers of sustainable development. Whether it is the approach to project implementation or new business models, it is becoming clearer that things must be done in a different way (de Valence & Runeson, 2011). Thus, the practice of construction management must make sense of improvement initiatives such as lean construction, and sustainability (Green, 2011). The construction management literature refers to lean and sustainability as compatible initiatives based on a common focus on waste reduction (Ma, 2011; Mollenkopf et al., 2010).

Though there is a plethora of work on lean and sustainability in construction, limited research has addressed their integration. This limitation necessitates the exploration of the synergies available through improved concomitant implementation, which ensure that important trade-offs that may arise through mismatches between lean and sustainability are addressed. When lean construction enables value added activities to flow in the production environment, reduced environmental impact manifest due to optimum logistics (Wu, 2003) and concurrent value is created in the process.

The aim of this paper is to report on the literature findings that have emerged from a study that aimed at the integration of lean and sustainability in the delivery of construction projects. The paper begins with highlights of the diverse viewpoints of value in the next section. Thereafter, a synopsis of lean and sustainability in construction is highlighted to provide a platform for the discussion on their possible integration. A discussion on the relationship leads to the conclusion summarised, the theoretical paper.

CONCEPT OF VALUE

The rationalisation for lean and sustainability in construction is tied to value. The concept of value revolves around economic return and moral standards (Kamakura & Novak, 1992). Value can be seen as what is good in human life, and a person's willingness to pay a price in return for a good or service (Graeber, 2001). The later approach to value is aligned with economic considerations. The focus on economic considerations is a basis for the comprehension of value in the construction industry (Forbes & Ahmed, 2011). The emphasis in the construction industry is on exchange and money that is seen as a fundamental index of value (Carruthers & Babb, 1996). As Boztepe (2007) suggests, user value could be construed to be an exchange and use, a sign, and an experience. The exchange approach indicates that value arises from price and the desire of a client for the product and thus, value is objectively determined by price. The unit of analysis of value in this approach is the exchange situation. As a case in point, the inference for design and construction is to ensure the quality of finished buildings through its functionalities.

The lean construction philosophy took cognizance of this approach when it advocates the removal of waste and the generation of value in the flow of activities in the construction process. In other words, value is desired by project actors at various levels of the construction process (Forbes & Ahmed, 2011). Within the experience approach, value is said to come from the interaction between the user and a product with a specific socio-cultural situation. Value is therefore objectively and subjectively determined. The unit of analysis is always the point of experience, which refers to the product as the element that brings about the experience. The implication for design and construction can be found in the need to comprehend the makeup of such experience.

A subjective inference exists between the experience approach to value, and sustainability. The traditional model of economic, environmental and social sustainability emerged from the 1987 Brundtland report. Sustainability in the built environment has sought to address these three major aspects through both objective and subjective lens. Sustainable development that meets the needs of the present without compromising the needs of the future has been the centre of industrial and academic discourse as a result of the impact of human activities on the environment (Kibert, 2009). From a technical point of view, the experiences of sustainability through green building are driven by overall management policy, site management, and procedural issues. Such issues are not limited to energy use, health and wellbeing, pollution, transportation, land-use, ecology, resources (materials), and water.

The literature has shown that macroeconomic trends are driving firms to create sustainable business models built on the traditional model of sustainability. Shared value encourage firms to create value in a way that goes beyond short-term economic gains by considering a broad set of factors that determine long-term success of the business. The objective of the way of thinking about shared value is to optimise value for the firm and the larger society in which the firm operates (Porter & Kramer, 2006; 2011). It entails creating economic value concurrently with societal value by addressing needs and challenges.

It is important to note that the concept of shared value began with the realisation of the fact that organisations may have been creating value by optimising short-term financial gain in the place of broader influences that determine their long-term success. According to Porter and Kramer (2011), the concept of shared value acknowledges that societal needs instead of conventional economic needs, define markets. They note that the concept recognises that social weaknesses often create internal cost for firms in the form of wasted energy, and costly accidents, to mention a few. Shared value can evolve when construction firms, for example, reconceive their products and services within the context of their location in the market / sector. When firms also engage in exercises that redefine their perception of productivity in the value chain, shared value could spring up. As an illustration, when contractors follow a transformation, flow and value (TFV) perspective of their processes, wastes of production can be plugged out and productivity can be improved (Koskela et al., 2013). The economic aspect of value is therefore relevant to shared value.

LEAN IN CONSTRUCTION

The interconnection of activities required for the design and construction of buildings involves the interplay between people, technology, and machine. Such interplay increases the complexity of a construction product (Bertelsen, 2003). This interplay also requires the astute coordination of diverse forms of resources to realise the planned progress of work. However, fatalities, injuries, cost overrun, defects, time overrun, low productivity and many other problems characterise the current construction management approach, which is focused on activity management (Sherratt, 2015).

Because of the current state of the practice of construction management, improvement of performance is an imperative need for project actors in the construction industry. To fulfil the improvement requirement, lean was introduced into the industry to satisfy clients by creating customer value (Koskela, 1992; 2002). The introduction of the concept of lean into the construction sector focuses on the alleviation of design and construction problems by propagating efficient processes. Through its origins in the Toyota Production System (TPS), lean is now applied as an innovative way to manage the design and construction of projects with the use of tools which could address project constraints such as complexities and uncertainties (Forbes and Ahmed, 2011). It is however notable that in practice, lean construction continues to be conceptualised and sanctioned differently, depending on the project context, although it may act as a catalyst for change in the workplace (Green, 2011).

SUSTAINABILITY IN THE BUILT ENVIRONMENT

Sustainability in terms of economic, environmental, and societal needs (Elkington, 2004), plus resilience and regeneration (Du Plessis and Cole, 2011), is a complex subject in the built environment. The built environment represents a multifaceted system that places substantial pressure on the wider environment. For instance, buildings have major environmental impact through material extraction and manufacture, construction, operation and demolition. The construction management literature suggests that sustainability in the built environment involves the creation of buildings that generate minimal physical waste (in construction and operation) while utilising limited energy and water. For such buildings to come into existence, actors in the sector need to recognise relevant industrial policies, legislation, and regulations; apart from understanding the impact of climate change, land use, pollution, and ecology on the environment. This is important as the size and nature of current building stock has resulted in high energy usage, a high carbon footprint and a major contribution to climate change (Sheth *et al*., 2008).

Improvements in building design and construction practice can thus be made through a systems view that suggests that effective change will happen through: changing the values of stakeholders; redefining who qualifies as stakeholders and their roles; and understanding the fact that actors integrated within a project team would exhibit different value dimensions (Du Plessis and Cole, 2011). Such value dimension would influence the choices of actors in a given construction project. Therefore, the roles of stakeholders in engendering sustainability have to change in response to applications in the built environment (Feige *et al*., 2011). In other words, a change in the espoused values of actors could be a prerequisite for improved sustainability in the built environment (Cole, 2011; Nishida and Hua, 2011).

LEAN CONSTRUCTION AND SUSTAINABILITY

The concepts of lean and sustainability are relevant to the practice of construction management. With regard to using lean construction concepts to realise sustainability goals, Peng and Pheng (2011) show that lean production philosophy has practical contributions, which can be adopted by the construction industry to achieve improved energy consumption, carbon emission and production efficiency performance.

To explore the integration of lean and sustainability in the construction context, a content analysis was undertaken through the international group for lean construction (IGLC) conference proceedings by Emuze and Smallwood (2013). The IGLC papers were targeted at the preliminary stage of the study mainly because all papers in the conference are lean related. The IGLC sustainability related conference papers are indicated in Table 1. These papers are already lean related as they have been published in lean construction annual conferences. It was observed that sustainability topics were not presented until 1998 in IGLC annual congresses. From 1998 to 2014 however, 32 sustainability related papers have been presented. The papers mostly address the environmental aspects of the traditional model of sustainability as none of the analysed papers explicitly addressed the social and economic aspects of sustainability. This observation points to a clear need to analyse papers from other construction management conferences in order to comprehend the economic and social element of the triad of sustainable development. It is notable that 59.4% of the papers were presented between 2012 and 2014.

For illustration purposes, the findings of selected papers are herein discussed. The notable study was that of Novak (2012), which explored the synergy between lean construction and sustainability. Using exemplary lean projects as a unit of analysis, Novak (ibid) contends that a strong correlation

exists between the cohesiveness of lean thinking and the level of collaboration in terms of the delivery of sustainability values. The significance of the study by Novak (ibid) is the opportunity for the concept of value to shift construction management from restrictive overtones to a paradigm of positive sustainability prosperity. In the case study, Novak (ibid) conclude that the relations between lean and sustainability was optimised mainly because the project actors focused on the concept of value.

Table 1a: IGLC sustainability related conference papers (1998-2014)

Year	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**Subtotal**
Sustainability	1	0	0	0	1	1	0	1	0	4

Table 1b: IGLC sustainability related conference papers (1998-2014)

Year	2007	2008	2009	2010	2011	2012	2013	2014	**Subtotal**
Sustainability	4	2	2	0	1	7	8	4	28

Using the focus on value in the examined lean construction papers and the extant management literature as evidence, it can be argued that the proposition shown in Figure 1 deserve further studies. Though lean construction and sustainability are well researched, the synergy between them is not well explored – separate applications dominate the literature. Area of synergy is a place where user value can be created at the project level and shared value can be promoted at the strategic level. The synergy is enabled with the use of appropriate lean construction principles and tools for managing business and project aspects of construction. The use of lean construction principles and tools would also have to look beyond economic considerations, but also consider the environmental and social impact of the work to be done, either on site or off site – shared value.

The idea behind Figure 1 supports the view that limited environmental impact implicitly provides both economic and social gains in the community (Ofori, 1992). For example, dust from construction activities; hazardous materials and the release of non-biodegradable material into the environment have health implications for construction workers and the general public.

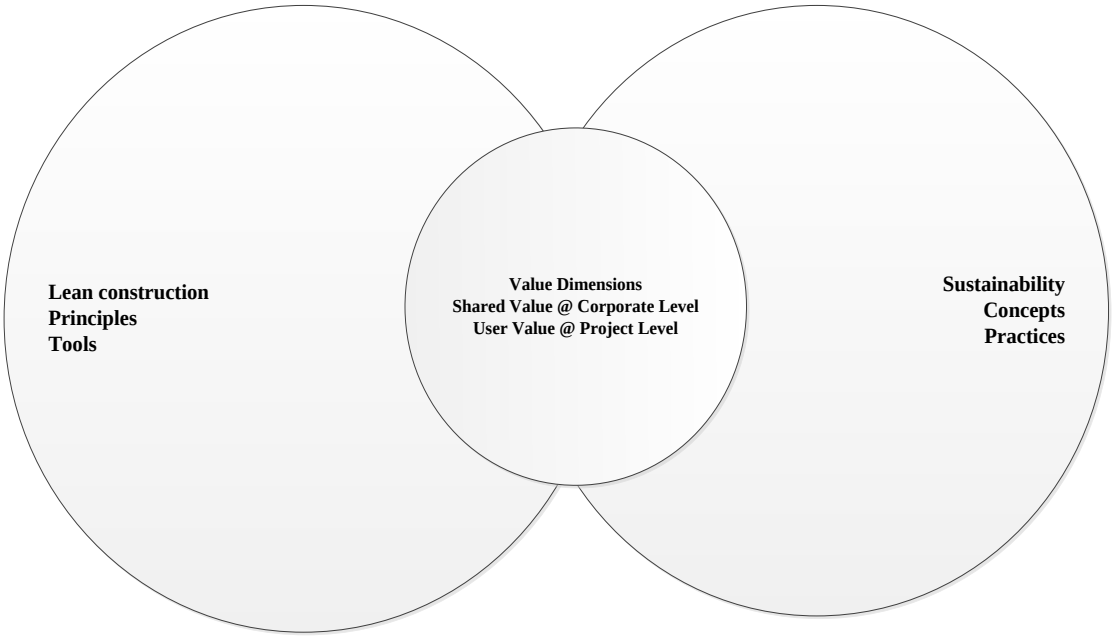

Figure 1: Value dimensions derivable by integrating lean and sustainability

Waste (non-value adding activity) is a major lean principle, which is addressed at the design and construction phases of a building project. The efforts expended on the identification and elimination of waste impacts on the creation of value at the strategic (business) and project levels in construction. Creating the shared value shown in Table 2 would emerge from the considerations and deliberations, which informs decisions and actions at the interface between lean and sustainability. The waste elimination model of lean in which the heuristic principles can be used to enhance value adding activities and standardize production outputs (Forbes and Ahmed, 2011) has been used in Table 2. As a case in point, a survey of construction professionals in the United Kingdom (UK) indicates that there are benefits associated with an integrated implementation of lean construction and sustainability. Gains of the synergy include improved corporate image and sustainable competitive advantage, improved process flow and productivity, improvement in environmental quality and increased compliance to clients' requirements (Ogunbiyi et al., 2014).

Lean tools such as Just-in-time (JIT), 5S, value analysis, daily huddle meetings, and value stream mapping (VSM) are the common tools that could enable the realization of sustainability goals (Vieira & Cachadinha, 2011; Ogunbiyi et al., 2014). 5S could help to maintain a clean and organized worksite; and VSM (which shows product and information processes) engenders improved understanding of value and the steps required to reduce waste (Vieira & Cachadinha 2011). VSM as a tool can be used for economic, environmental and social purposes in a project. Similarly, Carneiro et al. (2012) observe that the complementarity between lean and sustainability results in the general elimination of waste and the addition of value to customers (Table 3). For example, considerations in project areas related to water and energy efficiency would find congruence with customer value and continuous improvement.

Table 2: Lean, sustainability and the creation of shared value in construction

Waste elimination principles	**Sustainability concepts**	**Creating shared value**
Reduce share of non-value adding activities: Clearly identify the process that delivers what the client value (the value stream)	Economy and society – individual firm and market should be profitable; location and orientation of activities should address the needs of host communities	Economic and societal benefits yields value, which are integral to competing for business
Reduce variability: Clearly specify value from the perspective of the ultimate client / increase output value through systematic consideration of customer requirements	Environment - proximity to materials to be used so that carbon footprint of site activities is reduced	Joint organisational and community value creation with consistent improvement of output value
Reduce the cycle time: Reduce cycle time to reduce management efforts, interruptions and increase delivery time to the customer	Economic and society - an organisation / an institution is an economic and social entity in need of prosperity	Integral to profit maximization is the need to reduce the duration of task accomplishment
Compress lead times: Make the remaining value adding steps flow without interruption by managing the interfaces between different steps / simplify by minimising the number of steps, parts and linkages	Society - people within an organisation – in a corporate context, would be able to limit the non-uniformity in inputs and outputs	This can be driven with appropriate policy interventions that are company specific and internally generated
Increase flexibility: Let the client pull – do not make anything until it is needed; and when it is needed, make it quickly / increase output flexibility	Adaptation – to keep system balance, there is a need to allow flexibility in processes	Realign company budget to engender processes that meets the needs of all stakeholders

Evolved from: Porter and Kramer (2011); Koskela (1992); Constructing Excellence (2004); WCED (1987)

While sustainability is been driven by legislation and business needs, strategic options are the main reason for the adoption of lean construction (Senaratne & Wijesiri, 2008). Because construction workers are often ignorant of the flow of activities that create waste, principles underpinning lean construction and sustainability can be used to engender continuous improvement in the sector.

Table 3: Areas of lean construction and sustainability synergetic opportunities

Considerations	**Continuous Improvement**
Actions focused on development density and community connectivity, alternative transportation, site development, storm water design, heat island effect, Light pollution reduction, enhance project implementation process, could limit CO_2 emissions on construction sites.	Sustainable sites
Water use reduction, water efficient landscaping, innovative wastewater technologies, could alleviate the pressure on fresh water needs of communities.	Water efficiency
Building energy systems, limited energy demand, optimum energy performance, and energy measurement and verification contributes significantly to low energy consumption in the industry.	Energy efficiency
In construction, ways of possible elimination of wastage include material waste management, demolition waste management, and material reuse.	Resource efficiency
Outdoor air delivery monitoring, increased ventilation, indoor air quality, pollutant source control, thermal comfort, daylight extent, view and orientation of building enhances the well-being of users.	Environmental quality

Inspired by Carneiro et al. (2012)

The abstraction in Figure 1 and the tables in this paper however require a plan of action in order to operationalize them. Future empirical study to follow this initial literature review should be able to show how a shift in value proposition among project actors would promote sustainable development. The notable gap in the literature that could be bridged pertains to the method that would allow the integration of lean and sustainability for the delivery of construction projects.

The idea of user value and shared value is the main contribution of this paper. The introduction of shared value provides a platform for taking evidence of value from the project level to the corporate level within the lean construction community.

CONCLUSION

Lean construction and sustainability targets 'more-for-less' ideas of efficiency for both physical and process inputs used for production. Through established linkage between lean and sustainability, customer value and continuous improvement can receive required attention in production. The conceptual idea in this paper argues for the exploitation of the synergy between lean and sustainability to create user and shared value. Shared value, which is promoted and created at the corporate level of an enterprise, subsumes the user value that is often created at the project level. An example of creating shared value can be enacted with the transformation of the procurement system.

However, this concept of shared value is limited in that it is yet to be empirically examined. The application of the concept to case projects should provide insights about how this concept of value would emerge through the synergetic application of lean construction and sustainability for the realisation of a project. Given that this paper is based on reviewed literature, further research is required to answer the questions, which are beginning to emerge. The further study will attempt to make provision for both context and analytic generalisation (Creswell and Clark, 2011; Yin, 2014). Before the field work can begin, a larger corpus that includes secondary data from major construction management conferences shall be conducted to ensure that critical factors are not omitted in the analysed document. Databases to be consulted would include ARCOM (Association of Researchers in Construction Management) and COBRA (Royal Institution of Chartered Surveyors). The principal research question to be answered shall take cognizance of the gaps in the literature by addressing 'how and why should the concurrent implementations of lean construction and sustainability evolve in the sector'. The intent of further research shall address:

- areas of synergy between lean construction and sustainability;
- why the synergy between lean construction and sustainability is not significantly explored in the sector;
- the concepts of value useful for the integration of lean construction and sustainability in projects, and
- the methods for co-generation of value for project actors, end users and societal stakeholders.

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ENERGY CONSUMPTION OF MOBILE PHONES

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Keywords: energy efficiency, Windows Phone, smartphone's energy consumption.

Abstract

Battery consumption in mobile applications development is a very important aspect and has to be considered by all the developers in their applications. This study will present an analysis of different relevant concepts and parameters that may have an impact on energy consumption of Windows Phone applications. This operating system was chosen because limited research related thereto has been conducted, even though there are related studies for Android and iOS operating systems. Furthermore, another reason is the increasing number of Windows Phone users. The objective of this research is to categorise the energy consumption parameters (e.g. use of one thread or several threads for the same output). The result for each group of experiments will be analysed and a rule will be derived. The set of derived rules will serve as a guide for developers who intend to develop energy efficient Windows Phone applications. For each experiment, one application is created for each concept and the results are presented in two ways; a table and a chart. The table presents the duration of the experiment, the battery consumed in the experiment, the expected battery lifetime, and the energy consumption, while the charts display the energy distribution based on the main threads: UI thread, application thread, and network thread.

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ACKNOWLEDGEMENT

This work was supported by the PERCCOM programme and Erasmus+ programme.

INTRODUCTION

In recent years, the smartphone market has received a significant boost. According to eMarketer, the number of smartphone users has grown from 1.13 billion in 2012, to 2.03 billion in 2015 (Emarketer.com, 2015). This trend yields a prediction of around 2.5 billion smartphone users by 2017. This means that around 30% of the world's population will own such a device. There are two dominant operating systems that run on these smartphones: iOS and Android. According to the same source, in the last quarter of 2014, the percentage of smartphones which support Android was 76.6%, while the smartphones which support iOS was only 19.7%. The remaining 3.7% is split between the Windows Phone operating system with 2.8%, BlackBerry operating system with 0.4%, and the other 0.5% others' operating systems.

Although the difference between the first two operating systems and the rest is large, in the future these statistics will change. Staistica portal predicts that operating system market in 2017 will look like this: the Android market will decrease to a value around 68.3%, the iOS market will decrease to a value around 17.9% and the Windows Phone market will increase up to 10.2%. The data suggests the fact that Windows Phone operating system is in continual development and in the future it could be a competitor for Android and iOS operating systems.

According to Statistica portal in October 2014 (www.statistica.com, 2014) there were 1.3 million applications in App Store, 1.3 million applications in Google Play and only around 300.000 applications in Windows Store. TheNextWeb.com presents an articles (Protalinski, 2014) in which a spokesperson from Microsoft confirms that the number of application from Windows Store reached 300.000 in June 2014 and the fact that "in the past year alone the Windows and Windows Phone app catalog has grown 94%, while the number of active developers has grown by 50%.". According to the newest statistics from Microsoft (news.microsoft.com, 2015), in March 2015, there were 585,000 applications in Windows Store. It is noted that the increasing rate of application development is very high, thus promoting Windows Store to become a competitor for App Store and Google Play. This is the reason for conducting experiments for Windows Phone in this study and to conduct a detailed analysis of the concepts and controls used by Windows Phone developers.

According to Smart2020 report (Webb, 2008) information technology and communication (ICT) consumes around 2% of the world's energy. This number can be compared to the total energy consumed by the airline industry. In 2020 the mobile phones will represent 1% from the ICT carbon footprint and the mobile network will represent 13%. It is very difficult to calculate very precisely the energy consumed by a smartphone, because this is not only an object used for communication. When a user charges his phone every day or maybe two times per day the total amount of energy consumed by a smartphone will become considerable. Another important factor that should be considered when the energy consumption is calculated, is the whole internet infrastructure. Nowadays the data generated by smartphones and transferred across the internet is significant and it grows continually, because the number of users that access the internet through a smartphone is in an upward trend.

The aim of this study is to compare concepts and controls that are used for developing Windows Phone applications, and to establish a set of rules that can be used by any developer that wants an energy efficiency application. There will be a predefined number of rules that will be tested and which will cover the UI part, the processing part and the network part.

This study makes the following contributions: it investigates the energy consumption of Nokia smartphones running on Windows Phone 8.1 operating system; it investigates the energy consumption of specific Windows Phone controls; it investigates the energy consumption of specific

programming concepts; it provides a set of rules, which will optimize a mobile application from an energy point of view.

RELATED WORK

Smartphones' energy efficiency is a new research domain and it is growing in parallel with the development of the smartphones. Nowadays there are many components like the processor or screen that can be optimized, but the battery is not one of them yet. This is why it is very important to have control over the battery and to know exactly which part of the application consumes more energy and why.

Related studies to this paper address the following issues: tools that measure energy consumption (Pathak, Hu and Zhang, 2102; Hao et al., 2013; Jung et al., 2012); overall consumption (Corral et al., 2013; Xia et al.,2013; Carroll and Heister,2010; Hahnel et al., 2012); cloud services (Namboodiri and Ghose, 2012); and network measurement (Namboodiri and Ghose, 2012; Wilke et al., 2013; Andreucetti et al., 2014). Moreover, there are some studies that attempt to improve the battery life. One of these studies is investigated by Parkkila and Porras (2011). The mobile phones field is not the only one where researchers are trying to find some "green" optimizations. Networking is another area of research where a lot of optimizations are made. An example in this category the research by Drouant et al (2014) and Pattinson and Robinson (2008).

Notably, most of the studies focus on the hardware components or on the network. The software component is not analyzed in detail in any of the papers. All of the studies are platform independent, so they can be made for Android, iOS or Windows Phone. For example, one study presents the energy consumption of a display in general but not the factors that influence this consumption. The research in this paper addresses this identified gap. It attempts to go a step deeper and to analyze different factors that can influence the energy consumption of a mobile application. From Corral et al. (2013) work, it is a known fact that the display component is one of the components that consumes the most energy in an application. What is not known is the underlying cause of this phenomenon and how to improve the energy consumption. The purpose of this paper is to identify a part of the element that consumes most of the energy.

METHODOLOGY

As already mentioned in the Introduction, the purpose of this research is to provide a set of rules that can be used by developers in order to obtain mobile applications that are more energy efficient. Nowadays, there are a lot of operating systems for smartphones, such as: Android, iOS, Windows Phone or Jolla. Each of these operating systems has many particularities, so it is very difficult to obtain a set of rules that can be applied to all operating systems. This study will focus only on one specific operating system, Windows Phone 8.1, a product of Microsoft Company released in April 2014.

Tools

The development of the applications for Windows Phone 8.1 can be made using Microsoft Visual Studio 2013. This software is an IDE (integrated development environment) from Microsoft. It can be used for developing desktop applications, websites, web services, Windows applications and mobile applications. Besides Visual Studio, another tool is required in the development process: Windows Phone 8.1 SDK.

The third tool that is really useful is Windows Phone Application Analysis tool. This tool is used for monitoring and profiling an application:

- Profiling – evaluating either execution-related or memory-usage aspects of a mobile application.
- Monitoring – evaluate the behavior of the application.

The output generated by this tool can be general or in detail. The general output is a summary of all parameters that are measured while the detailed output is a graph that presents the energy distribution during the execution of the application.

The last tool used for this study is Microsoft Expression Design 4, which specializes in graphic design. It is used for complex objects that can be exported in different formats, like: XAML format or PNG format.

Experiments' methodology

The set of rules obtained is based on some common concepts that are used in programming or on the improvements that Microsoft brought into Windows Phone SDK. Oren Nachman, developer for Microsoft, said in one of his talks entitled "Windows Phone 8: Performance and Optimization for Developers" (Channel 9, 2012) that the performance of an application can be measured in "feelings". This means that a user who uses an application feels that the application is fast, that every action is processed immediately, that scrolling through pictures will not block the application and that navigating through pages is really smooth. This is the reason developers are focusing a lot on these aspects and try to optimize them. Also, the tools that are used by developers offer new controls that should be faster, more responsive and consume less memory. One aspect that is not always taken into consideration when a mobile application or a new control is developed is the battery consumption. The method chosen for this research is an experimental method. According to the Oxford English Dictionary, an experiment is "a scientific procedure undertaken to make a discovery, test a hypothesis or demonstrates a known fact". This method is the most suitable for our research because currently only assumptions are made about whether the new controls are more efficient than the old ones, or whether one concept is more efficient than another one.

Experiments' components

The main criterion that is applied in the selection of the elements that constitute the experiments is the diversity in terms of applications' components. It is very important to have at least one element from each component of a mobile application tested.

The basic structure of a mobile application contains three components:

- **Frontend component** or the User Interface – it refers to the controls that are displayed to the user.
- **Backend component** – it refers to all the processing made by an application: data processing, command handlers and services connections.
- **Web services component** – it refers to all the services that are stored on servers, and which expose the Create/Read/Update/Delete functionality.

Accordingly, we can group the elements listed above in the following three groups:

Frontend components	VirtualizedStackPanel (Msdn.microsoft.com, 2015), StackPanel Msdn.microsoft.com, 2015), ListBox Msdn.microsoft.com, 2015), LongListSelector Msdn.microsoft.com, 2015), ProgressBar Msdn.microsoft.com, 2015), Opacity Msdn.microsoft.com, 2015), Visibility Msdn.microsoft.com, 2015), Storyboard Msdn.microsoft.com, 2015), Image background creation, background property (Msdn.microsoft.com, 2015)
Backend components	Assembly, recursive function, iterative function, page constructor, onNavigatedTo event for (Msdn.microsoft.com, 2015), Thread, multithread, for (Msdn.microsoft.com, 2015), while (Msdn.microsoft.com, 2015), base64 string format (Tools.ietf.org, 2015), Image build action (Developers.de, 2015), synchronous loading, asynchronous loading, image decoding (Msdn.microsoft.com, 2015), image format: PNG (W3.org, 2015), JPG (Whatis.techtarget.com, 2015), XAML (Msdn.microsoft.com, 2015)
Web Services components	Clouds (SearchCloudComputing, 2015)

Table 2 Experimental Elements

Hypotheses

After the decision has been made on experiments in this research, the next step is to identify the hypothesis. Due to the fact that the controls and concepts that are to be tested are used in different contexts, it is impossible to have only one hypothesis. For this reason, the components are grouped based on their functionalities and followed by the formulation of a hypothesis for each group. Based on these groups a number of 25 hypotheses have been derived, tested and discussed in this paper. The hypotheses are presented in Table 2:

	Hypotheses
1.	The darker colors used as background for a mobile application consume less energy than the brighter ones.
2.	A JPG file format consumes less energy than a PNG file format in a mobile application.
3.	Storing a visual object as image consumes less energy than storing the same object as XAML.
4.	Using background threads consumes less energy than using the UI thread.
5.	A static object consumes less energy than an animated object.
6.	Using image decoder to size consumes less energy than using the default decoder.
7.	Using asynchronous methods consumes less energy than using synchronous methods.
8.	Using “Visibility” property consumes less energy than using “Opacity” property.
9.	Using a determinate progress bar consumes less energy than using an indeterminate progress bar.
10.	Using a “LongListSelector” control consumes less energy than using a “ListBox” control.
11.	Setting “Build type” property to “Resource” for an image, consumes less energy than setting the same property to “Content”.
12.	Storing a set of images in JPG format consumes less energy than storing the same images as base64 format.
13.	A “for” loop consumes less energy than a “while” loop.
14.	Using several threads to complete an operation consumes less energy than using one thread to complete the same operation.
15.	Executing a heavy processing operation in constructor consumes less energy than executing the same operation in “OnNavigateTo” event.
16.	Using an iterative function consumes less energy than using a recursive function.
17.	Using a “StackPanel” control consumes less energy than using a “VirtualizingStackPanel” control.
18.	Using one assembly, for storing the resources, consumes less energy than using several assemblies.
19.	An animated object that is created in the XAML file consumes less energy than an animated object that is created in procedural code.
20.	An image stored locally consumes less energy than an image stored in the clouds.
21.	A video file stored locally consumes less energy than an image stored in the clouds.
22.	An audio file stored locally consumes less energy than an image stored in the clouds.
23.	A JPG file format stored in clouds consumes less energy than a PNG file format stored in clouds.

24.	Downloading an image and accessing it locally consumes less energy than accessing the picture multiple times in clouds.
25.	Processing an operation locally consumes less energy than processing the same operation in clouds.

Table 3 Hypotheses for the experiments

For each of these experiments one or two applications are created and executed. These applications are executed several times and an average value is shown as the final result. For collecting the results the Windows Phone Application Analysis software is used. The data collected are: battery charge remaining, the execution time and the battery consumption. After obtaining the battery consumption, the energy consumption is calculated using the following formula:

E = QV where E is energy (Wh), Q is charge (Ah), and V is Voltage (V).

The value for voltage depends on the phone that we are using. Consequently, the voltage for a specific phone: Nokia Lumia 1320 is 3.7 Volts.

Experiment configurations

The experiments for this study are device dependent. This means that the collected results are specific for a device. The configurations that are used for the experiments can be found in the following table:

Property	**Value**
Battery voltage	3.8V
Nominal voltage	3.7V
Battery type	BV-4BW
Emulator type	720p
Emulator resolution	1280x720
Brightness	100%

Table 4 Device configuration

As it can be noted in the above table the only phone dependent values are: the battery and screen resolution. This means that we should obtain different numbers for different emulators, but the rules obtained are universal (i.e. can be applied to any device). Three threads are being measured: UI thread, application thread and network thread. The UI thread is phone-dependent because it is dependent on the resolution screen. The battery properties are important for the transformation of battery consumption to energy consumption. Since the battery is the same type for a specific device it does not influence the final result. All the experiments are tested on an emulator. The interface of the emulator is depicted in Figure 1.

Figure 7 Application snapshot

RESULTS AND DISCUSSIONS

For each experiment there are two types of output: first output is a table which presents the duration of the experiment, the battery consumption, the energy consumption and an estimated value of the remaining battery life. The second output is a graph, which presents the distribution of battery consumption based on the main threads: UI thread, application thread and network thread. In order to obtain a result, several executions of the same experiment are made. This paper presents details of several experiments and a set of rules obtained.

Visual object storing

Aim: To investigate the impact of storing a visual object as Extensible Application Markup Language (XAML) and as image on energy consumption.

	Time (s)	Battery consumption (mAh)	Battery charge remaining (h)	Energy consumption (Wh)
XAML format	**10.50**	**0.28**	**15.90**	**0.001036**
PNG format	**10.34**	**0.25**	**16.41**	**0.000925**

Table 5 Visual object storing – energy consumption

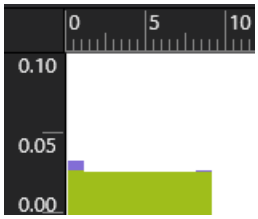

Figure 8 XAML format

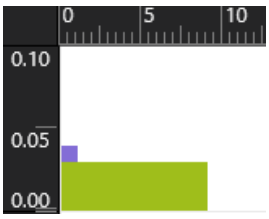

Figure 9 PNG format

Based on the results of these experiments it can be concluded that it is more efficient to work with images than with XAML objects. The difference is not very big in terms of energy consumption, but if millions of applications that display images are considered, this can be a considerable improvement. Also from the user's experience point of view, it is a big improvement considering the fact that the battery will last longer. This difference occurs because when using XAML, the application will create an object for each tag and this can load the processor more, while in the case of image files the processor has to render an image that is stored locally and this will happen faster. For more complex

objects the difference will grow. In Figure 2 and Figure 3 it is noted that the energy consumed by the UI thread (green color) is the same in both cases. The only noticeable difference is the energy consumed by the application thread. In this case, it can be concluded that more energy is required for creating the XAML object than to decode a picture.

Control hiding

Aim: To investigate the impact of "visibility" property and "opacity" property on energy consumption.

	Time (s)	Battery consumption (mAh)	Battery charge remaining (h)	Energy consumption (Wh)
Visibility	**20.71**	**1.26**	**6.83**	**0.004662**
Opacity	**20.63**	**1.33**	**6.44**	**0.004921**

Table 6 Control hiding – energy consumption

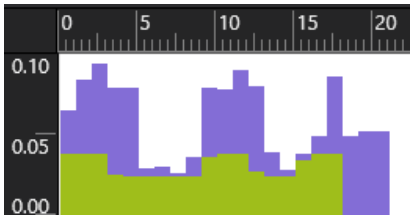

Figure 10 Visibility property

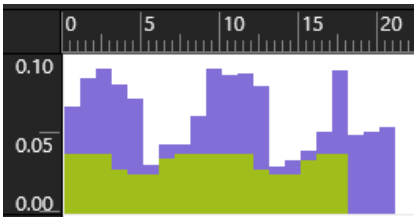

Figure 11 Opacity property

Both the applications executed are the same; it is observed that the energy consumption is different. The difference is 0.07 mAh, which happens because the Opacity property will keep the rectangles in memory, in order to improve the speed of the application. Even though the application with enabled Opacity is faster, it costs more in terms of energy consumption. In the first graph (Figure 4) it is noted that the energy consumption of the UI thread is lower because the objects are deleted. In the second case (Figure 5), even if the objects cannot be seen on the screen, they are stored in memory so more energy is consumed. From Figure 4 and Figure 5 some interesting facts have been observed. The energy consumed by the application thread (purple color) is similar in both cases. There are small differences, but not significant ones. The energy difference that appears in this experiment is related to the UI thread (green color). It can be seen in Figure 4 that the UI thread consumes less energy while the objects are hidden. If the Opacity property is set, the energy consumed by the UI thread does not drop like in the previous case.

Progress Bar consumption

Aim: To investigate the energy efficiency of a determinate progress bar and an indeterminate progress bar.

	Time (s)	Battery consumption (mAh)	Battery charge remaining (h)	Energy consumption (Wh)
Determinate	**15.68**	**0.37**	**17.57**	**0.001369**
Indeterminate	**15.46**	**0.42**	**15.24**	**0.001554**

Table 7 Progress bar – energy consumption

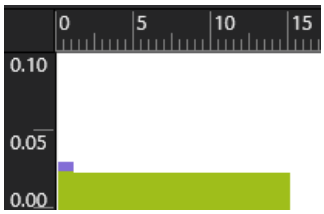

Figure 12 Determinate

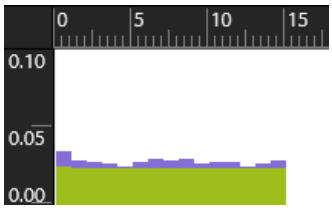

Figure 13 Indeterminate

As it can be seen from the charts above the determinate progress bar is more energy efficient than the indeterminate one. This happens because the indeterminate bar is an animation which is shown all the time and which requires some processing. The determinate progress bar is based on a value so it does not require any repetitive pattern. This fact can be noticed in Figure 6 and Figure 7. The application thread (purple color) consumes more energy for an indeterminate progress bar because it supports the animation during the execution. In Figure 6 it can be seen that it is required energy only when the application is launched. The UI thread (green color) consumes the same amount of energy in both cases. These controls can be used in different cases, but the determinate one ought to be the preferred option.

Image format

Aim: To investigate the impact of displaying a set of images that is in a JPG (Joint Photographic Experts Group) format or in a base64 string format.

	Time (s)	**Battery consumption (mAh)**	**Battery charge remaining (h)**	**Energy consumption (Wh)**
JPG	**11.68**	**0.30**	**15.99**	**0.00111**
Base64	**11.30**	**0.30**	**15.90**	**0.00111**

Table 8 Image format – energy consumption

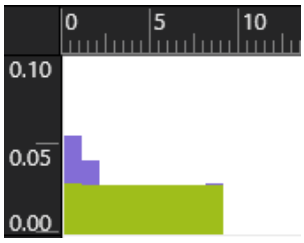

Figure 14 Base64 format

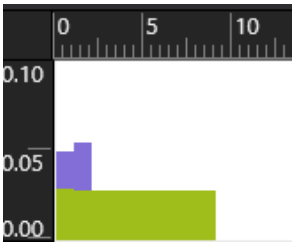

Figure 15 JPG format

The battery consumption is equal in the both cases considered above, so it is not relevant if images are kept as JGP or as strings. Although the battery consumption is equal, it can be noticed that the distribution of application thread is different. In Figure 8, it can be seen that it requires a lot of energy for computation (purple color) at the beginning, but after that it drops significantly. In the second case, it can be seen that the time for all the computation is longer. The energy consumed by UI thread (green color) is similar in both cases.

Loop instructions

Aim: To investigate the energy efficiency of two loops instructions: for and while.

	Time (s)	**Battery consumption (mAh)**	**Battery charge remaining (h)**	**Energy consumption (Wh)**

For	**21.67**	**0.56**	**16.10**	**0.002072**
While	**21.73**	**0.56**	**16.12**	**0.002072**

Table 9 Loop instruction – energy consumption

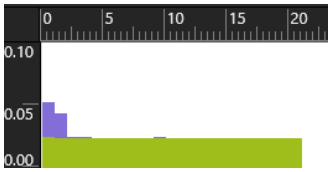

Figure 16 For loop

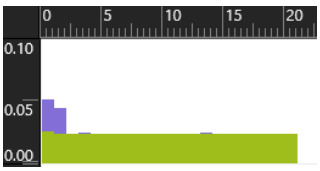

Figure 17 While loop

Based on the results in Table 8, there is no difference between these two commands. This happens because, as previously mentioned, the only difference between the two instructions is the syntax. From Figure 10 and Figure 11 it can be seen that the energy consumption distribution of both UI thread (green color) and application thread (purple color) are the same in both cases.

Threads

Aim: To investigate the energy efficiency of an application that uses one thread and of an application that uses more threads.

	Time (s)	**Battery consumption (mAh)**	**Battery charge remaining (h)**	**Energy consumption (Wh)**
Single thread	**53.33**	**1.98**	**11.23**	**0.007326**
Multithread	**52.32**	**1.26**	**16.58**	**0.004662**

Table 10 Threads – energy consumption

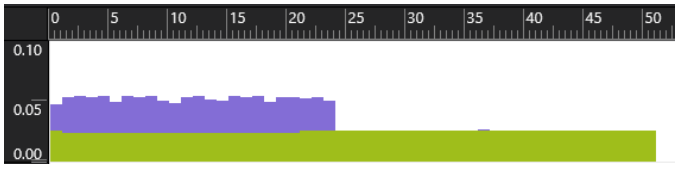

Figure 18 Single thread

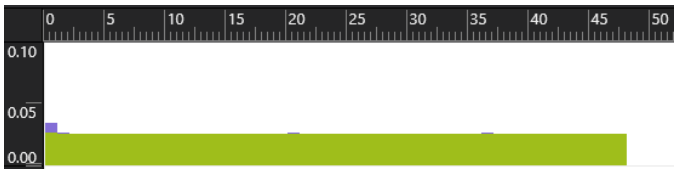

Figure 19 Multithreading

As it can be seen from the charts above, the difference between the two approaches is significant. From Figure 12 and Figure 13 it can be noticed that the energy used by the UI thread (green color) is the same in both cases. There is a big difference in the application thread (purple color). For the single thread, it can be observed that it has required a lot of time to calculate all the numbers, which means a lot of energy wasted because the CPU is working. In the second case, the energy consumed by the application is very small because all the computations are done at the same time, in different threads. In the first case, 25 seconds are needed for processing while in the second case the results are shown immediately.

Function type

Aim: To investigate the energy efficiency of an application that uses an iterative function compared to an application that uses a recursive function.

	Time (s)	Battery consumption (mAh)	Battery charge remaining (h)	Energy consumption (Wh)
Iterative	**25.28**	**0.61**	**17.29**	**0.002257**
Recursive	**26.73**	**0.77**	**14.55**	**0.002849**

Table 11 Function type – energy consumption

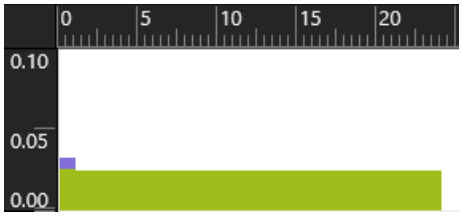

Figure 20 Iterative function

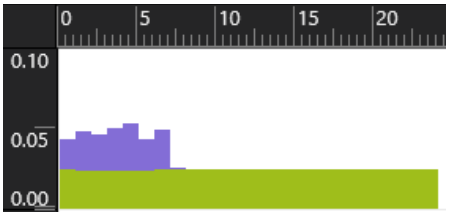

Figure 21 Recursive function

The application that uses an iterative function is more efficient according to the graphs above. It is noticed that the recursive function requires more time to compute and it also consumes more energy (purple color). Moreover the user has to wait until all the results are loaded before the application can be used. In the case of the iterative function the amount of energy that is required is very low. Furthermore, it can be seen that in this case, the application is faster due to the fact that the thread is busy for a shorter span. The energy consumed by the UI thread (green color) is similar in both cases.

Storing images

Aim: To investigate the impact of displaying a set of images that is stored locally in comparison with a set of images that are stored in a web page.

	Time (s)	Battery consumption (mAh)	Battery charge remaining (h)	Energy consumption (Wh)
From internet	**21.96**	**0.92**	**10.00**	**0.003404**
Stored locally	**21.43**	**0.69**	**13.00**	**0.002553**

Table 12 Storing images – energy consumption

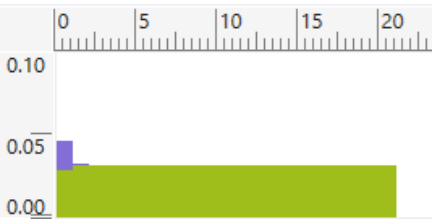

Figure 22 Image stored locally

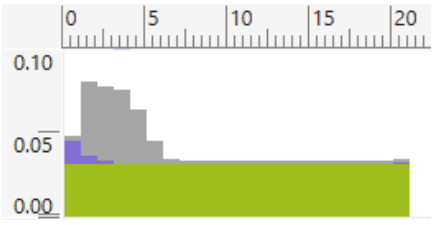

Figure 23Image downloaded

Loading images from different sources has a big impact on the total energy consumed by a mobile application. The application that stores the images locally consumes less energy than an application that requests the images from a web page. From Figure 16 and Figure 17 it can be noted that the UI thread (green) and the CPU thread (purple) consume the same amount of energy in both applications. The difference between the applications is made by the network (gray): the experiment presented in Figure 16 shows there is no energy consumed by the network while the one in Figure 17 shows a significant amount of energy that is consumed by the network.

Image format (JPG and PNG) in clouds

Aim: To investigate the impact of displaying a PNG (Portable Network Graphics) file format and a Joint Photographic Experts Group (JPG) file format, that is stored on a web page, on energy consumption.

	Time (s)	Battery consumption (mAh)	Battery charge remaining (h)	Energy consumption (Wh)
JPG	**21.01**	**0.74**	**11.90**	**0.002738**
Stored locally	**25.36**	**1.09**	**9.67**	**0.004033**

Table 13 Image format in clouds – energy consumption

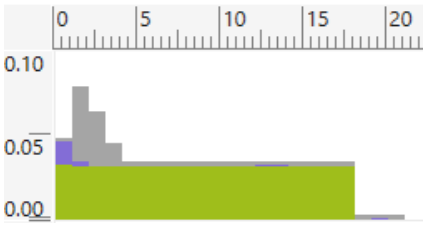

Figure 24 JPG file format

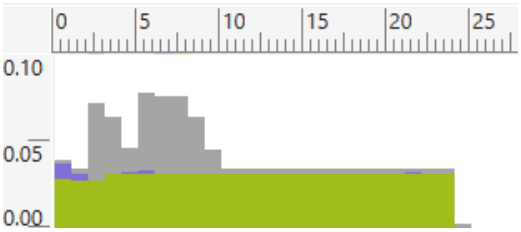

Figure 25 PNG file format

This experiment reveals the fact that working with JPG format is "greener" than working with PNG format, if the images are stored on a website. From Table 12, it can be noted that the difference between these two formats is significant. In Figure 18 and Figure 19, it can be observed that the difference in the consumed energy is made by the network thread (gray). The UI thread (green) and the application thread (purple) have similar values. The distribution of the energy consumed by these two threads is also similar. The energy consumed by the network thread differs because of the images' file sizes. After the transformation from JPG in PNG (using http://image.online-convert.com/convert-to-png website), the files stored as PNG have a bigger size than the JPG files, and that is why the application that displays the PNG files consumes more energy.

Images – multiple access

Aim: To investigate the impact on energy consumption of displaying multiple times the same picture from a websites and the impact on energy consumption of downloading a picture and displaying it from a local source.

	Time (s)	Battery consumption (mAh)	Battery charge remaining (h)	Energy consumption (Wh)
From the same URL	**31.28**	**0.96**	**13.54**	**0.003552**

Download and display locally	**31.19**	**1.02**	**12.74**	**0.003774**

Table 14 Multiple access – energy consumption

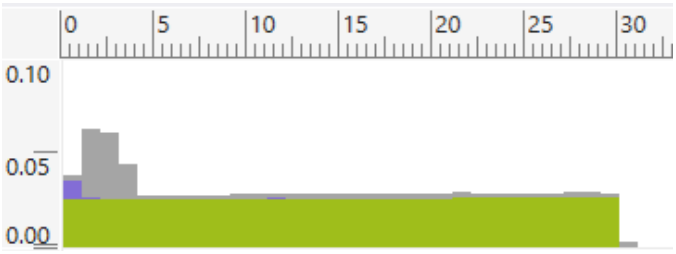

Figure 26 Application that display the image from the same URL

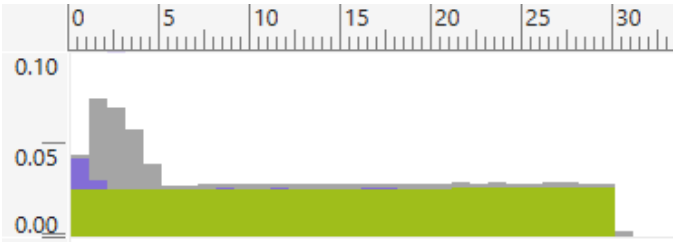

Figure 27 Application that save and display the images

From this experiment it can be noticed that the application which displays the images without saving them consumes less energy than the application which first downloads the picture. Figure 20 and Figure 21 show that the energy consumed by the UI thread (green) is similar in both cases. The energy consumed by the application thread (purple) differs in these cases because it requires extra processing for saving the picture. The network thread (gray) consumes, also, less energy in the first case. Another fact that can be noticed is that each application makes a single request for the picture. In the first application this happens because of the cache mechanism that is implemented by default in Windows Phone 8. In the second case there is one request because we are downloading the image and using it after that from a local source.

Heavy processing operation

Aim: To compare the impact on energy consumption of an operation that is run locally to an operation that is run in clouds.

	Time (s)	**Battery consumption (mAh)**	**Battery charge remaining (h)**	**Energy consumption (Wh)**
Cloud	**42.34**	**1.73**	**10.23**	**0.006401**
Locally	**40.08**	**1.02**	**16.41**	**0.003774**

Table 15 Heavy processing operation – energy consumption

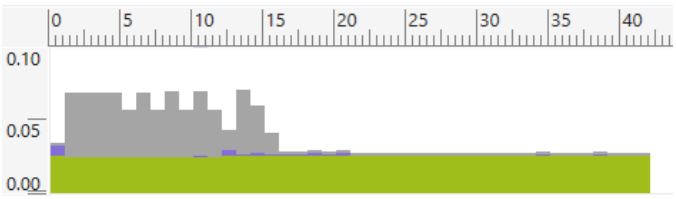

Figure 28 Cloud processing

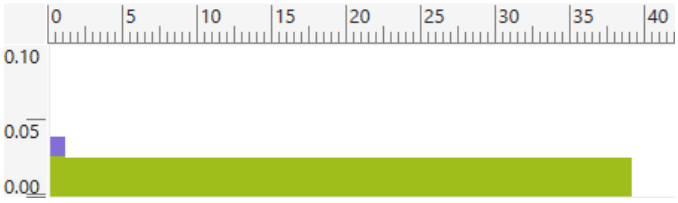

Figure 29 Local processing

The execution of some operations can significantly influence the energy consumption of an application. It can be seen in this experiment that executing some operations locally can save a lot of energy. From Table 14 it is noted that the difference between these two applications is significant. Figure 22 and Figure 23 show that the UI thread (green) consumes the same amount of energy in both cases. In Figure 23, the application thread (purple) requires some energy only at the beginning while processing the data. For the other application the application thread consumes energy during the execution of the application because the data received from server has to be processed. The network thread (gray) shows a difference between these two applications, because in the first case there is a significant amount of energy consumed by this thread, while in the second case, the energy consumed by the network thread is 0.

Decoding threads

Aim: To investigate the impact of displaying images using backgrounds threads and using the UI thread on energy consumption.

	Time (s)	**Battery consumption (mAh)**	**Battery charge remaining (h)**	**Energy consumption (wh)**
With CreateOption attibute	**33.49**	**1.27**	**10.96**	**0.004699**
Without CreateOption attibute	**34.19**	**1.38**	**10.37**	**0.005106**

Table 16 Decoding threads – energy consumption

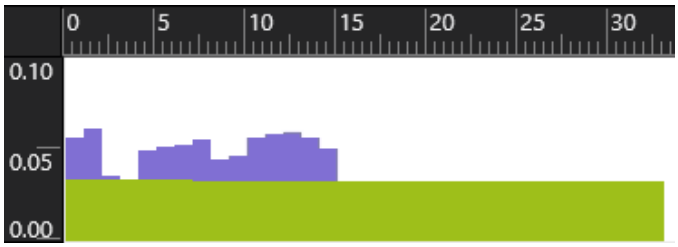

Figure 30 CreateOption Attribute set to BackgroundCreation

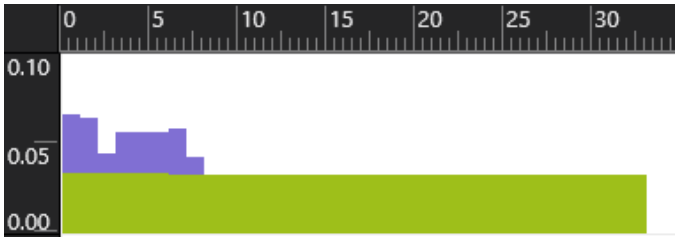

Figure 31 Without CreateOption attribute set

This experiment shows that the energy consumed by these two applications is different. From Table 15, it is noted that decoding an image in a separate thread is more efficient than using only one thread. Regarding the energy distribution, it can be seen that the UI thread (green color) generates the same

amount of energy in both cases while the application thread (purple color) generates less energy when using background threads. Another fact that can be noticed in the charts is the processing time. In the first case the application thread is working for 15 seconds while in the second case the application thread is working for 7 seconds. This happens because when using more than one thread, the tasks are executed in a parallel way. When all the processing is made by one thread it takes more time to decode all the pictures.

Animations

Aim: To investigate the energy efficiency of an application that displays an animation created in XAML file compared to an application that displays an animation created in procedural code.

	Time (s)	**Battery consumption (mAh)**	**Battery charge remaining (h)**	**Energy consumption (wh)**
XAML	**10.80**	**0.29**	**15.51**	**0.001073**
Procedural code	**10.51**	**0.29**	**15.30**	**0.001073**

Table 17 Animations – energy consumption

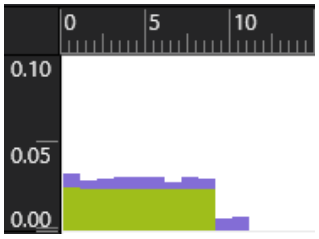

Figure 32 Code behind

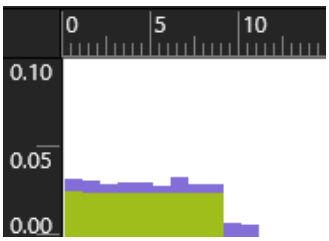

Figure 33 XAML format

The charts above show that the energy consumption of the two applications is the same. This happens because the animation is the same in the both cases. Consequently the energy consumed is equal. It is noted that running the animation in the composition thread or in the UI thread gives the same effect. It might be possible to find some differences if the UI thread is overloaded. From the Figure 26 and Figure 27 it is observed that both the UI thread (green color) and application thread (purple color) have a similar distribution of the consumed energy and of the amount of energy consumed.

From the total number of 25 experiments (see Cristea, 2015), the assumed hypothesis was true in 14 cases. The hypothesis is not relevant in 5 experiments and it is false in 4 cases. Two hypotheses are inconclusive. Table 17 presents a summary of the results obtained from these experiments (note the third column is the energy efficiency rule):

Hypotheses	Status	Rule
Hypothesis no.1	Confirmed	Use darker colors in Windows Phone applications
Hypothesis no.2	Not relevant	The PNG or JPG file format does not influence the energy consumption of a mobile application
Hypothesis no.3	Confirmed	Use PNG format instead of XAML format for displaying images
Hypothesis no.4	Confirmed	Use “CreateOption” attribute for all the pictures
Hypothesis no.5	Confirmed	Use static objects instead of animated ones as much as possible
Hypothesis no.6	Confirmed	Use decoder to size when the dimension of the image control is known
Hypothesis no.7	Confirmed	Use asynchronous loading for pictures
Hypothesis no.8	Confirmed	Use Visibility property for hiding an object instead of Opacity property
Hypothesis no.9	Confirmed	Choose a determinate progress bar if the context allows this
Hypothesis no.10	Rejected	For the basic use of a list use a “ListBox” control
Hypothesis no.11	Confirmed	Use “Resource” value when developing mobile applications
Hypothesis no.12	Not relevant	Either JPG format or Base64 format can be used for displaying pictures
Hypothesis no.13	Not relevant	Either “for” or “while” loop can be used in developing a “green” application
Hypothesis no.14	Confirmed	Use multi-threads in a mobile application
Hypothesis no.15	Rejected	Use “OnNavigateTo” method for data initialization
Hypothesis no.16	Confirmed	Use iterative functions instead of recursive ones
Hypothesis no.17	Rejected	Use “VirtualizingStackPanel” inside “ItemsControls” elements
Hypothesis no.18	Not relevant	Either storing the resources in a different assembly or in the same assembly, the energy consumption is the same
Hypothesis no.19	Not relevant	An animated object can be created either in XAML file or in procedural code
Hypothesis no.20	Confirmed	User images stored locally
Hypothesis no.21	Inconclusive	-
Hypothesis no.22	Inconclusive	-
Hypothesis no.23	Confirmed	Use JPG format if the picture are stored in clouds
Hypothesis no.24	Rejected	Access the images directly from web service rather than downloading them
Hypothesis no.25	Confirmed	Process data locally

Table 18 Rules obtained after running the experiments

CONCLUSIONS

Developing a mobile application has to be based on the user experience. Nowadays a user expects an application that is fast and responds to any input. The battery consumption is another aspect which is really important for a user, but which is associated most of the times with the phone and not with an application. It is true that the energy consumption of an application is not the same for two different mobile phones, but most of the energy consumption is application dependent. This study reveals the fact that there are some concepts, such as single threading, which consumes more energy than similar concepts (multithreading), which give the same output. For a developer it is very important to choose the right approach in order to offer the user the best experience when using an application and a longer battery life.

The second reason for this study is sustainability. Each experiment shows the energy consumed by each tested concept or control. The value obtained can be used for calculating the total impact that an application can have on the environment. This is an important aspect because nowadays ICT produces 2% of the total energy consumed in the world. This percentage will grow, because the ICT domain is in a continuous development, so it is very important to reduce the energy in all the aspects. There are studies conducted in this domain, but most of them focus on Android phones or on iOS phones. Windows Phone is not very popular at the moment, but, according to the sources presented in the Introduction section, there will be an increase in the next years. One aspect that could be very interesting to study is the energy consumption of each operating system and to compare the differences between them. Another future work will be exploring the relationship between energy consumption and different hardware components on the same platform. For example, it would be interesting to know the relationship between the energy consumption and the size of the screen, or the screen type. This study could help the producers to choose the right components for future models of phones.

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FIELD NOTES FROM A COMBINED SOLAR RECHARGING HUB AND COMMUNITY WATER POINT IN THE GAMBIA: HOW SUSTAINABLE TECHNOLOGY CAN IMPROVE LIVELIHOODS IN PERI-URBAN AND RURAL GAMBIA

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Keywords: Gambia, sustainable technology, community energy, rural livelihoods, off grid electricity.

Abstract

Access to mobile phones in Sub-Saharan Africa has increased sharply in recent years and has brought opportunities both to connect to loved ones and to access information, for example gathering information e.g. regarding agricultural markets and public services. The latter is particularly significant where other information sources such as newspapers and television are not widely available. This recent growth rate has corresponded with decreasing mobile phone costs. Interestingly, many households have access to mobile masts before they have access to infrastructure such as health services, all weather roads, electricity or clean water i.e. they live off grid and are often prepared to travel significant distances to recharge their phones even though this means they use disproportionate resources of time and money to do so (Manchester and Swan, 2013). Swan and Cooper (2013) found that people had been prepared to travel up to 2km in Malawi to charge their phones and in the area of our project site people had previously travelled up to 4.5km.

The past five years have seen the emergence of a range of novel solutions for recharging cell phone batteries across different parts of Africa (Swan and Cooper, ibid). The impact is potentially greatest in rural areas which have generally not had access to telecommunications previously. However, their use may be hindered by lack of access to electricity to keep phones charged. Electricity is acknowledged as a key driver of economic growth and yet in Sub-Saharan Africa only 30% have electricity and in rural areas the figure is 14%. Many rural communities also lack access to safe water in sufficient quantities to maintain health and to create livelihood opportunities.

Access to information via mobile phones and to an improved and secure water supply creates various opportunities for peri-urban and rural smallholders to enhance their income and develop further small enterprises to enhance their livelihood security. This paper discusses the early impact of access to mobile phone recharging facilities and a community water supply in a peri-urban community in the Gambia with reference to the communities' perceptions of their possibilities to derive more secure livelihoods from these services. This is a new community facility and the intention is to study its impact over time.

Kenny, O., Logan, I., Swan, A. and West, J.(2015) **Field notes from a combined solar recharging hub and community water point in the Gambia: how sustainable technology can improve livelihoods in peri-urban and rual Gambia** *In;* Gorse, C and Dastbaz, M (Eds) *International SEEDS Conference,* 17 – 18 September 2015, Leeds Beckett University UK, Sustainable Ecological Engineering Design for Society.

1. Context

1.1 Access to mobile phone recharging facilities and sustainable water in Africa

The rapid growth of mobile phone ownership in Africa in recent years has been well documented with two-thirds of households now having at least one mobile phone (Gallop, 2014). Mobile markets are having an increasingly significant impact upon African economies even in the current situation whereby only 32% have access to electricity (Nique and Opala, 2014). Mobile phone ownership now incorporates members of the lowest social economic groupings within many global north and global south countries (Heeks and Cernea, 2008). Since 2003, it is reported that cell phone subscriptions have grown faster in Africa than in any other region (UNCTAD, 2009). A recent survey undertaken in 17 sub-Saharan African countries indicated that 57% of the surveyed adult population owned a cell phone (Gallop, 2011). The level of cell phone ownership was reported to vary significantly across each of the study countries; ranging from 16% in the Central African Republic up to 84% in South Africa. The same study also indicated that an average of 53% of the surveyed adults living in rural areas have a cell phone; compared to 69% of urban dwellers.

The problem of broken water infrastructure in rural Africa is well documented, with various studies reporting 20–50% of all surveyed hand pumps as being out of service (RWSN, 2004). When these pumps malfunction, the local communities will often have to resort to using less protected water-sources, which can increase their exposure to a wide range of water-related diseases. Such operation and reliability problems have been attributed to a wide range of factors including: insufficient local financial resources to fund necessary repairs; a limited access to spare parts; a limited technical capacity within the user community; inappropriate project implementation and/or technology choice, limited post-construction monitoring and support from external agencies (Harvey and Reed, 2013).

Closer access to improved water supplies also has a range of potential benefits: the ability to meet minimum standards for water consumption -ideally 15 litres per person per day (WHO 2013) produces better health status which in turn enables people to be more economically active; time saved from water collection enables women (who are the main water collectors? Cite the source) to engage in other productive activities; the reduction in the drudgery of carrying water reduces the incidence of neck and back problems for women; if girls are not required to collect water it reduces a constraint on their school attendance. Pilot studies of remote monitoring of pumps have been promising in sustaining water accessibility with fewer days lost to breakdowns (Nique and Opala, 2014).

1.2 The Idea

In an attempt to address one of the key factors, namely that of insufficient local financial resources to fund necessary pump repairs, local communities and support agencies have explored various income generation activities connected to the operation of the water point. These typically seek to raise money to fund the water point's ongoing upkeep and repair costs. One such example would be the use of borehole runoff, and other excess water, to irrigate crops that could then be sold; with some of the subsequent revenue used for the borehole's maintenance costs.

The government of the Gambia recognises the role of public private partnerships and their effectiveness in delivering and extending public services (GoG -nd). Given this context, the project is testing a smart-battery rental system for recharging of mobile phones in rural Gambia using solar powered mobile battery packs distributed to and initially accessed through

a network of local village shops as activation stations. Having been charged at the charging station, battery packs are distributed to the shops where people take their mobiles to be charged for a small fee. This model also provides a small income to shop keepers and to the agents who service them.

1.3 Field Testing

The pilot system is being field-tested in the coastal south of the Gambia quite near to the town of Gunjur, adjacent to the expanding village of Kunkujang-Gunjur and within a few km of the hub village of N'Yofelleh. Solar panels, a water pump/concrete-lined well and a large water tank (in a secure compound) will provide water and power for local communities. The researchers are still working through assumptions regarding the interplay of weather conditions, demand and capacity for both water and recharging facilities (Swan *et al*., 2015). Once proved, it is assumed that the technology will be particularly applicable further off grid where there is likely to be greater unmet demand and fewer alternative operators.

1.4 The technology & business model

The technical team are developing security for the battery packs such that they are only unlockable upon payment, that they will then only activate for a set period and that they will only work with the Mobile Power system so that there is no benefit in not returning them. The business model thus intends to substitute technology for trust but also operates in a way that provides some income locally through the use of local agents and village shops. However, technology cannot completely substitute for trust and a key feature of the business model is the relationship among the project team and the local presence and familiarity with the area of the local agent: this will be difficult to replicate in a new area. The income generating potential is also being investigated during the pilot phase.

Figure 1: Mobile phone art in Tanji, the Gambia

2.1 Rural Livelihoods Security in the Gambia: Resource Poor/Technology constrained

It is widely acknowledged that poor peoples' livelihoods are more secure and less vulnerable to shocks, such as adverse weather or severe ill-health and hence unexpected costs as well as inability to work, if they are more diverse (Carney, 1998, Ellis, 1999). Thus, if one enterprise among several has a bad year, other income streams can compensate. Livelihood potential depends on peoples' capital endowments and entitlements i.e. ownership of or access to natural, social, human (skills and knowledge), physical (infrastructure) and financial capital. The context in which they find themselves i.e. the policy environment and whether it is supportive in practice is also significant in determining livelihood options. Access to infrastructure, mainly roads and electricity, make a significant difference to livelihood possibilities in terms of what

can be produced and where it can be sold. A given farm, depending upon its location and access to physical capital, can decide to grow perishable crops if there is good market access and can otherwise decide to preserve by freezing or add value by processing.

Smallholder farmers in the Gambia are resource constrained which, together with institutional weaknesses, has prevented them from accessing improved technologies and so they remain poor and unable to be as productive as they could be (Somda et al., 2005).

Mobile phones represent an access to innovation which in offroad/offgrid Africa is rare. The rapid take-up of mobile phones in the Gambia (as well as elsewhere in Africa) illustrate the enthusiastic response to the availability of innovative technology in areas which have long been hampered by lack of access in all senses. This access to mobile phone technology has been facilitated by the private sector which seems better placed to do this.

The access to information offered by mobile phones also has potential to facilitate the entry of other innovations not yet identified. There is however a need to be mindful of the social interface or gap between technology/expertise and communities which has often failed to be bridged in the past. It is understood that it is incumbent upon professionals to think about how they communicate across this divide and how technology is developed which is accessible and appropriate to the user.
In the business sphere, access to new 'markets' also encourages innovation among business to develop products for new situations and environments - rather than to adapt existing technology from elsewhere. The development of mobile banking in Kenya is an example of this - actually using more advanced technology than that used in many OECD countries.

2.2 Potential benefits for communities: Improved Facilities and Livelihood Enhancement

The field trial involves a solar powered well and facilities for mobile phone recharging (as above). This has potential for many benefits to local communities. By itself, the water will enable access to clean water in an area with few wells so reducing the drudgery of water collection for women and girls. However, the benefits of improved water may only be realised with additional attention to how water is managed in the home to prevent contamination from multiple users accessing water stored in the house.

There is also the potential for vegetable growing in the dry season which has benefits for household nutrition as well as sales. This is in the context of the Gambia importing significant amounts of food since domestic production is insufficient to cover consumption requirements. In addition, the operation of agricultural markets could potentially be enhanced by the use of mobile money (WFP, 2011). The potential to engender excess petty traders competing with each other (Little, 1999) is noted and it clear that it is important to encourage communities to diversify and add value to their agricultural produce e.g. by preserving fruits and vegetables for sale in the dry season to avoid this as far as possible. Greater income from vegetable growing could also lead to purchases of motorised and non-motorised transport (in the latter case creating employment to produce e.g. carts and trailers locally) to get produce to market.

Having more assured access to mobile phone charging facilities will enhance their benefits including saving trips to recharge them, access to services, market information and information in general. A later phase will enable clients to take the battery pack home for the rental period and hence use it also e.g. to power house lights which will give a safer

environment than the current kerosene lamps and candles and so reduce incidence of burns and smoke pollution as well as better light by which to do homework.

Availability of solar power will create additional employment directly e.g. as agents, and indirectly as greater use of mobiles enabling people to access i) information to improve their incomes ii) access health/transport to health facilities). There is also potential for using solar power for processing of agricultural produce to enhance value and longevity. The availability of solar-powered light when battery packs are taken home will also reduce accidents from candles and enable children to do homework as well as accessing homework information online via mobile phone.

3. Methodology

This is the initial stage of what is planned to be a longitudinal piece of qualitative work which will examine the benefits to rural communities in the Gambia of access to off-grid electricity and improved water sources. Informal and unstructured or semi-structured interviews are deemed the best way to elicit the views of the participants in this case. In formal surveys, the realities of rural deprivation are often missed (Chambers, 1983). In choosing this approach, the researchers also drew on extensive field experience and the practice of development using rapid and participatory rural appraisal.....Chambers quick and dirty

This paper is based on a short visit to the study area at the start of the research project. As the researchers were new to area and had limited time, it was decided that focus groups would be the best approach to use in order to elicit a range of views in the time available. Aggregation of data from focus groups is well established in development research and their findings have been influential across a range of policy and practice (Chambers, 2008). Our focus groups were mainly distinct cohorts - service providers (shop keepers, agent, community workers), community in vicinity of project site: adult men, adult women, youth -male and female, women with established vegetable gardens in adjacent areas close to Gunjur.

4. Field visit & Future Work

Initial findings are based on visits to the project site, discussions with key informants, agents, shopkeepers, field workers and focus groups with men, women and young people close to the project site. It is intended to follow up these initial encounters longitudinally during the implementation of the pilot to track impacts on the local community as well as observe the operation of the business model for mobile phone recharging.

4.1 Trust v Technology?

The balance of trust and technology in the business model is interesting as the latter- however sophisticated - does not substitute for the former and perhaps never can. Although the technology is designed to remove/reduce the need for trust it is still integral to business operations as the location of the pilot, the construction of the facilities and the key players involved have all come together through serendipity and connections forged long ago in different contexts. The trust basis of these relationships is the foundation of the whole scheme and serious thought must be given to how this will be reproduced or created in later phases in other parts of the Gambia or elsewhere.

4.2 Capacity & Demand

The recharging facilities had only been operating for a short time when we visited in April 2015 but were already proving popular to the point of oversubscription, this was evidenced by the shopkeeper in N'Yofelleh setting up an additional battery-based system to cope with demand. We found widespread ownership of mobile phones among young and old, male and female with some differentiation is usage. Men used mobiles to save them self a long walk only to be told "He has travelled" when the person they sought was not at home; women –although they did not immediately identify this as business use – take calls from traders with orders for vegetables for the market; young people, in common with their peers elsewhere, used their mobiles to go on Facebook and access YouTube. There was very little use of texting although people knew it was cheaper than calls. There was also good knowledge of the relative benefits of different mobile phone service providers. Adults emphasised their importance for keeping in touch with the rest of the household and for summoning assistance.

4.3 Literacy & mobile phone use

When talking to focus groups, we observed that several people asked others to record their names (for research ethics purposes) indicating a level of non-literary. The fact that most people used their phones mainly for calls and seldom for texting may relate to this. In terms of advertising recharging services, it will be necessary to use mobile phone art (the examples here are from Tanji) and develop pictorial explanations of the sign-up process. We also intend to explore whether it is possible to link to other local initiatives such as literacy programmes or health promotion campaigns.

Figure 2: Mobile phones for hire, N'Yofelleh

4.4 Gender Equity & mobile phone use

The gender balance of mobile phone ownership was fairly even, though women had usually acquired their phones some time after their husbands. In this short visit during the dry season, an impression was gained that women are using their phones for business more than men but this needs to be further investigated. In considering the potential for employment in this type of business, it may be necessary to be proactive in encouraging women to take up opportunities as agents – possibly via women's groups. There is potential to provide business advice and mentoring so that people can make best use of their mobile phone to enhance their knowledge and income.

Conclusion

The technological solutions for the business model are close to being finalised which will enable further expansion. However, in any area the initial business model with small shops as recharging points will expire as more people acquire off-grid electricity. Also, the issue of trust will have to be addressed if the business is to expand into new areas where the team do not have existing social connections.

Access to mobile phone recharging off-grid, together with sustainable access to enhanced water supplies has potential to enable communities to diversify and expand their livelihood options and so achieve greater security and be less vulnerable to livelihood shocks. However, people who live some distance from infrastructure – notably electricity and road networks – will continue to have limited options for enterprises to enhance their livelihood security unless other circumstances change. The Millennium Villages Project is an example of an integrated approach to livelihood improvement which may alleviate concerns by integrating a range of initiatives, including mechanical power and other energy systems as well as income generating for agroculture and related processing (Adkins *et al.,* 2010) Thus in the Gambia too there is a need for joined up thinking and working in conjunction with other initiatives and to be vigilant in not encouraging people to pursue the same enterprises in competition with each other.

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Impact, Health and Environment

NHS ASSET RECONFIGURATION WITH SPECIFIC REFERENCE TO FUNCTIONAL USE AND PATIENT PATHWAYS: A SUSTAINABLE APPROACH TO ASSET MANAGEMENT

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Keywords: Assets, Patient-Pathway, Reconfiguration, Integration, NHS.

Abstract

The NHS has evolved into a system that is renowned for being one of the most comprehensive domestic healthcare providers in the world. However, the size and complexity can challenge its ability to offer an integrated health care service that many perceive it should.

The implications of delivering such a sizable and complex system also means that it is one of the UK's largest financial burdens as well as a key UK asset. However, critics have raised concern with regard to the ability of the health service to develop an integrated patient pathway. One particular challenge is to capture and understand the needs of patients and to effectively align clinical services. To meet patient needs effectively, without unduly placing additional burden on the country, requires resources to be aligned. At the moment it is suggested that the physical assets are not effectively utilised and in some cases unable to meet practitioner and patient needs.

By case study method, this paper presents a proposal for research which seeks to identify requirements and map the resources and use of physical assets to meet the patient and practitioner needs. The specific focus of the research will identify reconfiguration factors and reasons for under-utilisation. Through review and expert feedback a more effective asset model will be proposed and validated. This paper provides a review of methods used to assess the NHS building stock and offers a model for critical feedback and further development.

Redmond, K. and Gorse, C. (2015) **NHS asset reconfiguration with specific reference to functional use and patient pathways: a sustainable approach to asset management** *In;* Gorse, C and Dastbaz, M (Eds) *International SEEDS Conference,* 17 – 18 September 2015, Leeds Beckett University UK, Sustainable Ecological Engineering Design for Society.

Introduction

The NHS owns a total of 6.9m hectares of land. Its floor space is estimated at 28.4m square metres (this is excluding primary care premises) and has an estimated re-instatement value of c£90bn. Many of the NHS properties are underutilised and a significant amount of its estate is in poor condition or not fit for purpose (Stevens, 2015). The situation is not sustainable. The estimated unoccupied floor area of NHS acute organisations is 1.5m^2 (NHS Buildings: Obstacle or Opportunity, the King's Fund, (NHS, 2013)

NHS assets must be managed effectively to ensure they are being used efficiently and that they are positively supporting the delivery of health and social care. Assets that are in the right place at the right time, appropriately configured, suitable for their purpose and well-maintained will help patients have a positive experience, improve staff productivity and ensure the NHS achieves value for money from its investment in assets (NHS 2014b; Stevens, 2015).

The delivery of patient care takes place within a building that has to meet specific and specialised standards set out by the NHS premises assurance model – these standards and specifications will alter depending on the type of care to be delivered. The standards apply to existing assets, as well as new build, primarily in the acute healthcare sector.

This study aims to help identify an effective and 'fit for purpose' NHS estate, for a specific Trust, that supports an integrated patient care pathway. Integration is achieved by developing and implementing a strategy for a Trust(s), and the associated health systems, through an accurate asset database, complemented by graphical visualisation. Information and data from such a database will aim to indicate characteristics including location, function, general condition, size, amenities, service offering, age and strategic value of buildings within a Trust environment. Knowing the location and other characteristics outlined, of existing premises within any NHS Trust, will allow healthcare (in whatever form to match the clinical patient pathway standards) to be provided in the most appropriate and 'fit for purpose' facilities. By collecting, collating and structuring data, relating to the NHS estate, in a form that is manageable, the study aims to support greater coordination of health and social services in order to improve patient pathways and health outcomes.

By gathering, assessing and understanding specific NHS buildings and identifying agencies with clinical patient pathway data, a foundation model for future healthcare developments and refinement can be produced, which could be used by Trusts, health commissioners and auditors.

Literature Review

The National Health Service (NHS) has a responsibility to account for the stewardship of its publically funded assets (existing and proposed), which includes the provision, management and operation of an efficient, safe estate that supports clinical services and patient care (NHS, 2014). With a book value estimated at c£40billion, the existing NHS estate has the potential to make and deliver savings as well as reduce costs, whilst supporting the delivery of healthcare (NHS, 2013). The vision set out by the NHS Five Year Forward View, captures the drivers for the estate and patient care, which are to be undertaken to help meet the UK Government's need to increase efficiency of the public sector estate and new / refurbishment build programs. Accordingly, a significant step-change in the way local and national strategic NHS assets and estate plans are achieved is required (NHS, 2014). Stevens (CEO of NHS England, 2015), recently confirmed in the October 2014 Health Service Journal (HSJ) that an estimated £7.5bn of existing NHS estate was un-utilised-space that is currently used for non-clinical purposes and a further £4.2bn of backlog maintenance was needed to bring NHS estates up to a standard that could be sustained for clinical use and patient care.

The health service is part of a complex health system comprising of a set of functions that broadly include governance, finance, planning, commodities workforce, service delivery programs,

information systems and assets (World Health Organisation, 2007). Cruz and Marques (2013) categorise this type of healthcare system into three main areas when dealing with the delivery of medical care - infrastructure, clinical services and soft facilities. Infrastructure, in this instance means the physical building, including, air conditioning, lifts, ventilation, water and energy.

Constantly changing healthcare demands, such as disease patterns, ageing populations, changing demographics, technology, growing public expectations and increasingly stringent standards, continually provide new challenges to policy makers and healthcare providers (Thompson and McKee, 2004). Integration and integrated health services are seen as ways of gaining efficiencies, meeting clients' needs and improving health outcomes (Reynolds and Sutherland, 2013). The World Health Organisation (WHO) defines 'health integration' as "combining different kinds of services and operations to ensure and maximise collective outcomes" (World Health Organisation, 2008). Integrated health care can be characterised as 'vertical', which is the different levels of service delivery ranging from a community setting, to primary care e.g. General Practitioner (GP) or clinic, to Acute care as part of a typical hospital offering, all common in the UK. It is also seen as 'horizontal', which are simply healthcare providers who work at the same level e.g. GP/dentist/pharmacist (Shigayeva et al., 2010).

The UK Government's Healthcare Strategy document supported by the Five Year Forward View, produced by the NHS Trust Development Agency (TDA) is pushing for greater integration of healthcare between community and primary providers in an attempt to ease the pressure on the acute hospital offering, which will include estate reconfiguration, with support at differing levels, via the private sector. This is despite researchers producing evidence that this type of initiative has not delivered the patient benefits expected (Moore et al., 2014).

The need to address the current position regarding the NHS estate on a local level was highlighted by one North of England NHS Clinical Commissioning Group (CCG) in October 2014, who identified that approximately 60% of the estate space was under-utilised. The inefficiency identified was of concern and the need for more efficient clinical patient pathways was raised. As the empty space was clinically limited and unsuitable for decanting, the operating costs were inefficient and did not meet the NHS CCGs current minimum requirements. More importantly, the assets did not meet the current and future needs of patients.

Developing an effective approach to support the NHS estate and patient care is problematic because of the complexities of the health sector. Such complexities extend to: reliable monitoring and measuring, understanding risk-sharing, forecasting demand, constantly evolving quality standards, technological advances, patient volumes and isolated regulatory groups; all impacting on the infrastructure (Cruz and Marques 2013). There is a need to ensure that data collected to support change is accurate, consistent, regularly provided and prevents the political changes that have influenced many initiatives; which have created unintended consequences when measuring NHS operations and the estate (Mannion and Braithwaite, 2012).

Cruz and Marques (2013) compared the effectiveness of the three recognised models of public-private partnerships (PPPs) that have been used extensively all over the world, mainly in the UK and at the request of Governments, with the aim of creating efficiencies within the intertwined healthcare system. They define the three models, starting with the base option, which includes infrastructure (estates) and ancillary service offering (commonly seen in the UK). This initial model is then expanded to include, clinical management/services (model two) and then again to include clinical management and primary care units (model three). Their comparisons do highlight benefits when attempting to deal with healthcare services as part of a vertical health system, but only when all stakeholders are openly and constantly engaged. However, they also highlight the complexities within NHS systems: conflicts of interest and drivers between public and private sectors; the need for integrated thinking between health planners, designers and clinical service management and their respective needs;

which can be delivered through the study. When dealing with issues relating to infrastructure (estate management) in isolation it has been suggested the outcomes were not worthwhile or necessarily value for money (Pollock et al, 2002). Cruz and Marques (2013) and Pollock et al, (2002), outline the difficultly in understanding how private sector partners monitor, assess and therefore plan an effective estates strategy for the public benefit and the critical patient care pathway. This may become even more complex as a result of the introduction of new sophisticated models and arrangements developed in the UK e.g. joint venture Limited Liability Partnerships (LLPs), created to deal with existing estates programs, ancillary services and in certain areas clinical services.

The design and architectural sector approaches asset-estate issues and its needs from the perspective of creating a usable and practical space that has some understanding of the end users' requirements with initiatives and methodologies such as participatory design, user-involvement, collaboration, lean design management and decision-making tools, reflected in the NHS evidenced based tools listed below (Kpamma, et al., 2104).

Integrated Healthcare and Patient Pathways

The increase in population and therefore patient numbers, the variable treatment results obtained sometimes as a result of location, avoidable hospital admissions, complications and the increasing high medical cost for the NHS and individualsraise sustainability concerns that will ultimately affect us all (O'Neill et al., 2012; Drewes et al., 2012; Elissen et al., 2012; Lemmens et al., 2011; Smith et al.,2012; Wolff et al., 2002; Vogeli et al., 2007).

Tackling the increases, variable treatments and high medical costs outlined above requires new strategies and interventions, which will involve closer cooperation between many specialised, general healthcare providers and multiple healthcare organisations, like hospitals, general practices, community settings and home care, to reduce fragmentation and costs and also to improve health outcomes (Busse et al., 2010). The reactive and highly specialised hospital care that characterises the European and UK system is inappropriate; moving care services into the community and general practice and placing care as close to the patient's home as possible could be part of the solution (Bodenheimer et al., 2002; Bodenheimer 2008; Strandberg-larsen and Krasnik 2009; Nolte et al., 2012).

A recent General Practioner (GP) led study in North Staffordshire, England (Moody and Williams 2014), which focused on developing enhanced primary care service for residents in nursing homes (a community based service that delivered care in the nursing home and patient's residence) in the area found the 664 patients had a 20% decrease in unscheduled admissions. This was compared to a 9% increase for the 450 patients not subject to the enhanced service. It is known that the general cost of supporting patients in a GP led community setting as opposed to an acute setting are less by 75% (NHS Five Year Forward View, October 2014), however, no cost benefit analysis was carried out in the study led by Moody and Williams.

Healthcare demands are dictated by disease patterns, ageing populations, demographics, technology, public expectations and legislative standards, all of which are in a continual state of flux, providing challenges to healthcare providers and their associated buildings (Thompson and McKee, 2004). Developing a software tool to capture these complexities around patient care and mapping them to the NHS's estates has been shown to be problematic (Cruz and Marques 2013). This is a problem because of the various data sets required, their size and the sensitivity (personal, political, legal) surrounding some of the information, all of which needs to be considered simultaneously if robust solutions are to be developed short and long term.

Research Methods

By case study method, this project seeks to identify requirements and map the resources and use of physical assets with an acute health Trust to meet the patient and practitioner needs. This will involve the simultaneous mapping and measuring of assets via 2D conversion or laser scanning into a 3D model. Once accurate data is obtained regarding the assets, current clinical and patient pathway assessments will be overlaid with data from the acute practitioners. The specific focus of the research will identify reconfiguration factors and reasons for underutilisation. Through review and expert feedback, from the information tools below (which are supported by acute clinical bodies), a more effective asset model will be proposed and validated. This research will provide an opportunity to review the effectiveness of current methods used to assess the NHS building stock, via the tools below, and will offer a new software model for further testing, which will include a new process model for critical feedback and further development.

The development of a software tool will allow NHS Trusts to improve their ability to match their estate to their dynamic healthcare demand. This will allow trusts for the first time to consolidate their existing asset databases and registers which currently capture data in compartmentalised ways, and it will be complemented by graphical visualisation to assist user interpretation.

Data on the Trust's specific buildings that will be captured includes location, function, condition, size, amenities, service category, age and strategic value. Compiling these data in one place for the case study NHS Trust, will allow it to be better able to match its facilities to clinical patient pathway standards, therefore making it more 'fit for purpose'.

By better understanding of existing NHS Trust buildings and identifying links with clinical patient pathway data, Trusts, commissioners and auditors can make changes to existing building configurations and plan for future needs more effectively.

Attempting to find efficiencies in a Trust's infrastructure (estate management) in isolation from the clinical pathway have been shown to result in poor value for money because the type of clinical pathway defines the building standard and specification required. This means that it is essential to combine, review and assess various relevant data sets to produce coherent and useable outputs for a Trust through the vertical and horizontal healthcare pathways that are scalable and flexible to suit the different supply and demand elements in each regional Trust.

In the proposed study, in addition to collecting building related information, data will also be obtained to align assets to current clinical and patient pathway assessments. A large proportion of the data will come from existing databases including Estates Return Information Collection (ERIC); NHS Premises Assurance Model (PAM); Activity Data Based (ADB); Strategic Health Asset Planning and Evaluation (SHAPE); Hospital Episode Statistics (HES).

This project will aim to isolate healthcare Trust's requirements based on a holistic assessment of the clinical service supply, demographic health demands and the existing estate provision. This type of assessment has not been developed specifically from a physical asset perspective based on clinical and patient requirements. Elements from each of the databases mentioned will provide the foundation from which to develop a robust software assessment tool.

The issues of measurement, monitoring and design (including master planning), regarding the NHS and its estate, have been addressed by the NHS ERIC, PAM and SHAPE data sets, by Government, NHS and the bodies that influence the patient care pathway, and therefore the estate that houses the delivery of the medical service. A wide range of evidence-based, design and mapping tools have been developed by the Department of Health, NHS with the assistance of associated groups (public and private) which can be broadly categorised into sections as follows. Qualitative and/or quantitative data may be included.

- Compliance - NHS Premises Assurance Model (PAM); Activity Data Based (ADB). Quality & Risk Profiling codes (QRP) and Estates Return Information Collection data (ERIC).

- Enhancing Efficiencies and Effectiveness – Strategic Health Asset Planning and Evaluation (SHAPE); Hospital Episode Statistics (HES) data.

- Sustainability in Healthcare – Building Research Establishments Environmental Assessment Method (BREEAM); Chartered Institute of Building Services Engineers (CIBSE).

The ADB is supported by Health Building Notes (HBNs) and Health Technical Memoranda (HTMs) these generate room layout sheets and room data sheets that comply with the UK Department of Health Estates and Facilities guidance, a design benchmark/guide for all new build and refurbished healthcare assets (National Health Service, Procure 21plus, 2014). The status of the document's produce is 'best practice' guidance rather than mandatory and the autonomous nature of the NHS means that each organisation takes responsibility for implementing the guidance or otherwise. However, such bodies as the Health & Safety Executive (HSE) and the Care Quality Commission (CQC) who both have a range of enforcement powers, do expect to see HBNs and HTMs being adhered to. The CQC specifies a number of outcomes one of which is the "safety and suitability of premises" - it explicitly cites HBNs and HTMs as guidance that they expect to be followed, which provides some form of base standard for NHS estates.

The PAM data is a system-wide nationally consistent approach to providing organisation board-level assurance of the quality and safety of premises in which NHS clinical services are delivered. The rigorous PAM self-assessment methodology uses robust evidence, metrics and measurements to demonstrate that a healthcare providers' premises achieve required statutory and nationally agreed standards on safety, efficiency, effectiveness and the staff/patient experience. Specifically, PAM sets out a performance spectrum across a range of key deliverables in five domains; Finance/value for money; Safety; Effectiveness; Patient Experience and Board Capability. These domains create a mechanism that supports the respective Trust organisation's ability to demonstrate baseline compliance for healthcare registration and regulation, as well as providing verifiable evidence that premises are playing their part in supporting the objectives of the NHS Operating Framework and comply with the associated performance management systems. ERIC is a method of recording numerical and geometric estates data, this data can be captured, collated, completed and input by any NHS employee and is therefore considered inaccurate and inconsistent. The Hospital Estates and Facilities Statistics is the national data warehouse for England for ERIC data. By reviewing and analysing ERIC data, which has been collected annually since 1999/2000, commencing with 2013/14 and reviewing thereafter in 2015 and again in 2016, it is expected a view of the current NHS estate can be developed and that of a specific Trust. Although, this will only provide broad acute estate data, individual asset analysis will still need to be undertaken with clinical and patient pathway agencies over-laid at a later stage. ERIC data is made up of quantitative data provided by all English NHS Trusts on an annual basis and is wide-ranging in its output, although the accuracy of the data is sometimes questionable. Starting ERIC data collection from 2013/14 enables the study to assess the impact of the new mandatory data capture process for ERIC data as part of the PAM reporting procedures.

The SHAPE data is an in-house NHS system, which is a web-enabled evidenced based application that informs and supports the strategic planning of services across a whole health geographical economy in order to deliver health and social care more efficiently and effectively, while enabling decisions to be made regarding the patient experience of the healthcare system. SHAPE can help, as a result of the capture of high level healthcare asset information and the demographic make-up those assets support, articulate the potential enhancement of an integrated health and social care system that shifts certain healthcare services' pathways away from hospitals to primary and community care settings. The data provides very basic visual graphical representation of the location of health care facilities, which is currently used by the NHS for consultation with various interested groups regarding

the potential introduction of new or relocated services and proposed changes to existing patterns of healthcare delivery.

SHAPE uses the Hospital Episode Statistics (HES) data managed by the NHS Information Centre for Health and Social Care (HSCIC) on behalf of the secretary of State for Health. The HES data derives from all NHS Trusts in England including acute hospitals, primary care, ambulance and mental health. HES data has been collected and reviewed since 1987. HES data collects a detailed record for each episode of admitted patient care delivered in England by NHS hospitals or delivered in the independent sector but commissioned by the NHS. SHAPE also utilises data from ERIC to enable NHS users to benchmark their estates performance against peers. By mapping existing service provision SHAPE facilitates high level identification of gaps in health and social care delivery and potentially areas of under/over provision.

By combining elements of the above data sets the aim is to visually map the current healthcare estate, for a specific Trust and clinical service within the assets, whilst simultaneously identifying the unused or un-utilised estate which could be considered for specific improved care pathways. The clinical services and associated patient pathways which could be reconfigured for primary or community delivery will need to be assessed based on availability of facilities and the potential improvement to the patient experience and health outcomes.

Three specific NHS acute Trusts, based in the North of England, have been approached by private sector partners who have over 25 years of successful NHS engagement, both acute and primary systems, regarding a building assessment. All have agreed to commence the process with one Trust providing immediate access to the acute estate for geographical mapping. The mapping will provide high level building measurement data capture, an outline of the building along with current planned and actual use. A comparison of the data captured through this process will then be compared to the data held within the NHS tools above relating specifically to assets. All data captured along with the comparison assessment will be held in a newly created software tool or within an existing tool(s) with the capacity to house such data e.g. TAHPI, Health Facility Briefing System, Maximo/Tririga (IBM), Autodesk, Revit, all of which are available to the study.

No patient interviews or questionnaires are expected to take place at this point. There will be a need for clinical practitioner and estates professional input, via interview, to assess the current pressures, processes and procedures once the physical building information has been collected and the relevant existing data tools mentioned earlier have been added. No specific patient data will be requested. Generic and anonymised health related group pathway data will be obtained via the HSCIC, SHAPE and NHS England tools mentioned earlier. A licence for the use of this data has been granted to this study via the NHS and Public Health England. Localised data relating to specific acute Trust health related groups will be obtained, if required, through and with the consent of the Trusts.

Initial Results and Discussions

The ERIC data examined by the study for one specific Trust highlighted potential major discrepancies between the data reported by the Trust to NHS England and what is perceived as actual asset use within the acute estate. The main finding, following a review with the specific Trust estates team, within the data related to 'none functionally suitable space' and 'none use of space' within the acute Trusts estate, which amounted to 54% of the estate, this included clinical and non-clinical space. Based on the data this meant on 46% of the acute Trust estate was available for clinical and non-clinical services. The entire, specific acute Trust estate was estimated to be 180,000m^2 in size, with 85% of the buildings less than 40 years old. It is still not clear if this information is correct with further assessments being carried out with the acute Trust.

The study will commence with a similar comparison with the two other acute Trust estates teams to understand the potential margin of error within the ERIC and/or specific Trust data. Once completed and an accurate, detailed, measured map can be produced, the patient flow data will be added in line with the Trusts and patients' requirements as well as that of the study program.

The potential discrepancy highlights the need to a closer inspection, mapping and registering of the NHS acute estate, if the problem is repeated with the two subsequent Trusts involved in the study.

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URBAN LOCAL FOOD PRODUCTION – THE ROLE OF ALLOTMENTS?

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Keywords: Local food policy, urban farming, community gardens, allotments, sustainable food production.

Abstract

There is renewed interest in local food production in cities deriving from concerns about urban sustainability, food security and related issues. Much academic and policy attention is evident, with particular interest shown in community gardening and similar local collective food projects. In this paper we argue that the well-established allotments system is often undervalued and deserves more attention than it is receiving within local food strategy discourses. Allotments play an important role in the local food cycles of many European cities including the UK. This paper examines what role allotments play in meeting urban food needs and considers how they might be better supported. Interviews conducted with allotment activists help provide some perspective on how the allotment infrastructure could grow and flourish.

Dickinson, I. and Thomas, K. (2015) **Urban local food production – the role of allotments?** *In;* Gorse, C and Dastbaz, M (Eds) *International SEEDS Conference,* 17 – 18 September 2015, Leeds Beckett University UK, Sustainable Ecological Engineering Design for Society.

Introduction

> "The Government recognise that allotments are valuable green spaces and community assets providing people with the opportunity to grow their own produce as part of the long-term promotion of environmental sustainability, health and well-being, community cohesion and social inclusion…"
>
> Andrew Stunnell, Government Parliamentary Spokesman (HoCL 2012 p.2)

There is much interest in the future of urban local food production (ULFP) in cities. This interest is driven by a number of concerns including:

- Worries about food security at a time when global population is growing and food production potential seems to be relatively fixed (food security – URBACT, 2012)
- Concerns about the sustainability of cities and the potential for local food production to enhance sustainability (sustainable consumption – Seyfang, 2007)
- The potential for local food production to promote aspects of social solidarity in cities such as 'community cohesion' (Turner, 2011)
- Ideas about the role of ULFP in enabling low-income groups to buy healthy food more cheaply – now reinforced by austerity-linked impoverishment (food justice/ austerity urbanism.

All of these concerns have been addressed separately by a large and growing number of research projects and urban policy discourse groups, and sometimes holistically as elements in a broader discourse about 'transitions' to new ways of organising urban living (URBACT network on Sustainable Food in Urban Communities).

A great deal of work has been done recently on new ways to promote ULFP (e.g. Local Environment, 2011) but relatively little attention has so far been paid to long established and still vibrant urban ULFP mechanisms. Allotments in the UK and their equivalents in other EU countries are widespread in the urban areas of Europe, often dating back centuries but boosted greatly in the early 20th Century and remain widespread and popular yet rarely figure prominently in recent discourses on ULFP. There may be 3 million allotment-type gardens across the EU which suggests considerable potential for reappraising the role they can play as ULFP issues gain more political visibility (Jardins-Familiaux.org). Despite their extent such gardens are, to quote the heading of one EU society paper "extremely valuable - grossly underestimated - shockingly unknown" (Zijdeveld, nd).

However allotments are becoming increasingly 'known' and visible to policy-makers as a result of growing research, often supported by the EU, in countries including Germany and the UK (COST, 2014). Sondermann (2014) reports that Germany retains 1.2 million allotments or Kleingärten/ Schrebergärten which are regulated by a Federal law, the Bundeskleingartengesetz, which regulates plot size, design and aspects of management whilst land use plans, Flächennutzungs-/ Bebauungs-/ plane, safeguard allotment zones from development pressures. Sondermann also usefully compares the traditional allotments form with emerging modes of urban gardening which he calls 'community gardens' and 'street/ guerrilla gardens' and this classification accords with the taxonomy of most recent writing about ULFP in the UK. Despite the weighting of academic attention to the new forms (e.g. in Germany Rosol, 2010), and widespread lack of data on the new forms of ULFP, it is clear from figure 1 that ULFP in Germany is hugely reliant on traditional allotments provisions.

Form of gardening	Quantity	Origin	Function	Form of regulation
Allotment gardens Kleingärten (small gardens)	appr. 1.2 Million.	mid 19th ct.	Leisure and recreation, food production	Formalised (Bundeskleingartengesetz, national act on small gardens), highly institutionalised
Community gardens Gemeinschaftsgärten appr. 400, since the late 1990s,	appr. 250-400	late 1990s	social and ecological objectives, food production	non-formalised, regulations on local level
Street gardening scheibenbegrünungen	(not countable)	Since 1980s	beautification of ighbourhoods and street spaces, political protest	legal or illegal uses of public spaces, depending on local regulations

Figure 1: forms of urban gardening in Germany (Sondermann, 2014, p. 16)

Not all EU countries are experiencing a revival in allotments – in Latvia, for instance allotments are in long-term decline as this post-Soviet era economy is more able to import fresh food, incomes are rising and migration is reducing demand for plots in cities (Lidaka, 2014).

In this paper we explore the allotments movement in the UK to see where allotments stand within current discourses of increasing ULFP. We do this in two stages. First we sketch out a brief outline of the 'state of UK allotments' using both academic sources and official policy statements. As part of this we outline some of the arguments being put forward by a new wave of local food production proponents. Second, we take an in-depth look at one of the more active local allotment associations in a large UK city to get a feel for both how official policies on allotments at local and national level are moving.

In our study of the Leeds Association we present perspectives gleaned from interviews with two leading lights in the group carried out in spring 2015. We are able, through this method, to make some initial assessment of the robustness of allotments in a leading UK city and also to query the degree to which current ULFP discourses have affected allotments.

Allotments in the UK

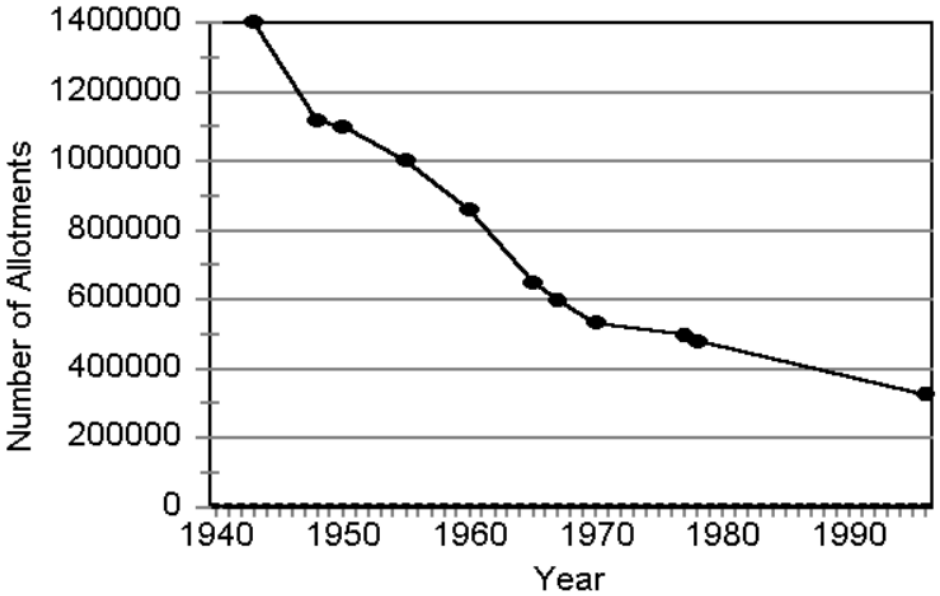
In the UK the spread of urban allotments began in earnest in the early 20th century as a way to enable working class urban dwellers to grow their own food both as a means to gain access to cheap food and reconnect with nature and, at a time of war and insecure national food supply, to help citizens to 'dig for victory' (Crouch & Ward, 1988). Allotment Laws from 1908 and 1922, still in force, require local councils to supply allotments - a small plot "which is wholly or mainly cultivated by the occupier for the production of vegetable or fruit crops for consumption by himself or his family" (Wiltshire & Geoghegan, 2012) where there is a demand, although this law has proved difficult to enforce (HoCL, 2012). After wartime allotments fell into decline as demand reduced with growing disposable incomes and easy access to cheap vegetables and fruit as the supermarket chains dominated the UK food market, often driving out local food suppliers and outlets in their quest for scale economies. Allotments fell out of favour and were popularly associated with older white males rather than the increasingly diverse urban communities that grew up in UK cities.

In policy terms allotments were rarely paid much attention except when threatened by development proposals and local councils (who often owned the land) were tempted to cash in on their development value and/ or release scarce land for housing development. The legal protections offered allotments were then tested in the court of public opinion and numerous local public scraps resulted. Local planning authorities (LPAs) often adjudicated these scraps and the allotments became briefly present in public discourses. The LPAs, faced with pressures to provide development land and,

sometimes, attractive development profits to boost council coffers together with local resistance to losing green spaces, were placed in a quandary. At such times the allotments were sometimes seen as less of a local food growing resources and 'green urban lung' and more as a scruffy collection of aesthetically unappealing sheds that offended planners' and councillors' sensibilities (HoC Environment, Transport and Regional Affairs Committee, 1998).

There has been a substantial long-term decline in plots in England from a peak during the 'digging for victory' era to the present time. Fig '2' shows a decline from 1.4 million in 1943 to roughly 330,000 by 1996. Also, despite the urging of the HoC Cttee Committee in 1998 for better provision of allotments, the number of urban allotment plots lost to development amounted to more than 50,000 from 1996 to 2006 as councils sought to accommodate more high density housing developments within cities (DCLG 2011 cited in HoCL 2012, p.7).

Figure 2: Allotment Numbers 1943-1996



Source: HoC Environment, Transport and Regional Affairs Committee (1998), para 46.

A 'rediscovery' of allotments is said to date from the 1970s when a 'growing environmental ethic' in response to global environmental sustainability movements became established and increasingly embedded in subsequent years (Howe & Wheeler, 1999). A very popular BBC Television situation comedy series, The Good Life, from 1975 to 1978 was based on a suburban couple's attempt to live self-sufficiently and sustainably off the produce of their own garden and this is likely to have raised awareness of food self-sufficiency in the UK and piqued interest in allotments. The term 'living the Good Life' is still sometimes used by politicians to refer to the allotments movement (e.g. DCLG 2011 cited in HoC 2012, p.7). However during the 1970s allotments remained in decline and this led to a partial redefinition of their purpose as 'leisure gardens', following an official inquiry in 1975, with some loosening of rules on the amount of food produced by some councils to maintain demand for plots. Allotments were being recognised as places of refuge for some from increasingly pressurised urban living, as a source of wellbeing, not just as productive growing spaces.

Another aspect of this resurgence is said to be a growing openness in the West to urban food growing practices in developing countries ranging from Africa and China to the Caribbean, where even in hectically burgeoning cities (by EU standards) urban food production rates were found to be much

higher than in Europe (Hough, 1995). Part of the renewed interest in ULFP, which overlaps into allotments, is a sense of urgency about the sustainability and resilience of local food systems in the West. This has a number of dimensions, according to Morgan and Sonnino (2010), including volatile global food prices, concerns about food supply resilience related to climate change and population growth, urban sprawl consuming productive agricultural land in Europe, and nutritional deprivation in low-income neighbourhoods. The urban food riots that occurred in a number of cities globally, as world food prices rose dramatically in 2008, are seen by some as a portent of future urban social tensions related to food availability and price (URBACT, 2012).

Allotments are said to be a more productive and sustainable basis for food production than the same acreage of arable farmland, with higher soil fertility, more composting, lower soil compaction, etc. (Edmundson et al, 2012). This suggests that food production on urban allotments could contribute significantly to food security, although the early 20th century levels where allotments are said to have produced 10% of the UK's food on 1% of the land surface would require radical measures to achieve again (Crouch and Ward, 1997). However, UK government food policy shows little interest in allotments. The Government's 'vision for a sustainable and secure food system for 2030' (DEFRA, 2010) makes one brief mention of allotments in an education section but is more concerned with corporate food production and distribution, although there are also references to healthy eating initiatives. Of the latter, only one - Healthy Towns – has in places involved allotments. Whilst the strategy also talks of making land available for community food growing this is discussed in terms of temporary land release by landowners, not something that allotment associations would find attractive or practical, and allotments are not discussed in that section (DEFRA, 2010, p19).

In the UK a growing demand for allotments has been linked to a combination of heightened environmental awareness and of food ethics, allied with the kind of middle class identities exhibited in the Good Life series. As Wiltshire & Geoghegan comment "[….]the vernacular allotment is now back in fashion, but with new values attached, firmly centred on environmentally friendly production and shared with many participants in many forms of collective growing" (Wiltshire & Geoghegan, 2012, p.340). This turn to collective growing is the aspect of ULFP that attracts most academic attention, but there is a danger of constructing a false dichotomy between 'individualist' allotments and 'collectivist' community gardens. Wiltshire & Geoghegan point to this apparent dichotomy which seems to be based on the allotments legislation making no provision for collective plots, only plots for individuals/ families. However there is plenty of collective endeavour present in the ways that allotments are managed and maintained and, increasingly, shared between individuals.

There is much collective effort involved in the appointment and running of allotment associations, maintaining communications with councils, annual prize awards, shared facilities maintenance (water supply, paths, car parks, fences, manure delivery and allocation, etc.) all of which is done voluntarily by plot holders and requires collective engagement (Crouch and Ward, 1997). Mutual support and advice, especially for new members, is a feature of allotments mentioned by allotments associations in our survey. Although some of the collectivity of the early days of allotments may be diminished (e.g. shared collections of tools and site meeting huts seem to have reduced), reflecting broader social trends (vis. Putnam's (2000) 'Bowling Alone'), allotments may still be seen as sites of local social capital formation to some extent.

Also worth mentioning in relation to ULFP are the many initiative supported by EU funding streams which have enabled numerous local/ regional food production and marketing projects to take place, such as 'local food identity' and 'eat the scenery' projects from Interreg projects such as Sustainable Open Spaces and Sustainable Urban Fringes (SURF, 2012). These are underpinned by a more general policy of the EU to protect and promote regional foods in the global market through the EU protected food names scheme. Often the funding has been used to enable small networks and collectives of food producers to develop local brands and marketing strategies to promote consumption in nearby

cities. In a few cases local community-based food growing projects to improve residents' access to cheap and nutritious food and to promote engagement by ethnic minorities have been supported (Incredible Edible Todmorden).

Separately to EU projects (although often drawing on EU regional or rural support funding) there have been many UK government sponsored local growing initiatives, mainly under the heading of urban regeneration but, increasingly in recent years, with some health service funding. The urban regeneration initiatives tended to be motivated by a desire to promote social inclusivity and interracial understanding in ethnically diverse city neighbourhoods whilst the health-funded initiatives tend to have been aimed at promoting physical and mental wellbeing in deprived areas with worse than average health levels. Similar motivations can be found in urban ULFP projects in Germany and the Netherlands (COST, 2014).

Allotments rediscovered

Who and what is driving the 'rediscovery' of allotments (Howe & Wheeler, 1999)? Well before the 2008 food riots, allotments had experienced significant increases in demand, most notably in London and in other major cities. The government was claiming in 2011 that the increase in demand was being partially met with extra plots – nearly a thousand in 2011 - and that the new Localism Act 2011 would help local communities to deliver additional plots through bottom-up action via the new Neighbourhood Plans system (HoCL, 2012, p4).

> "New neighbourhood planning provisions in the Localism Act also provide communities with a means to boost the number of sites with powers to protect existing allotments and identify new plots".
>
> Andrew Stunnell, Government Parliamentary Spokesman (HoCL 2012 p.4)

One reason for the uplift in political interest in allotments may be related to the 'discovery' of allotments by the urban middle class which may be leading to 'gentrification' of allotments reflecting the gentrification of many city quarters across Europe, especially in capital cities such as London. This may partly reflect a growing interest by policy makers to rearrange the public realm in accordance with middle class values as middle classes colonise or recolonize formerly working class districts and seek to make use of the formerly working class facilities such as allotments (Imrie & Raco, 2007). The increased spending power together with greater political clout of the gentrifying residents may have served to increase both demand for and local political protection of allotments (Rosol, 2010).

A widespread perception of allotment plot holders being predominantly white, old and working class, said to present a barrier to women and younger people seeking plots, seems to be in the process of transformation. A gender balance memo by David Crouch reported in 1998 that female plot holders increased from 3% of the total in 1969 to 15% by 1994, also NAS reported in 1998 that age profile is not dominated by older groups (HoC Environment, Transport and Regional Affairs Committee, 1998) and this change is confirmed by the Leeds respondents reported below. It seems therefore that former perceived barriers to more inclusive allotmenting are being rapidly overcome and that allotments are becoming more inclusive in gender, ethnicity and class terms.

Allotments in Leeds

We wanted to check which of the factors mentioned in the literature as affecting allotments and their relationship to other aspects of ULFP were present on the ground so we approached the Leeds & District Allotment Gardeners Federation (LDAGF). The LDAGF is the Leeds area group of the UK National Allotments Society (NSALG), which is 'the voice of allotmenteers up and down the country' (NSALG website). The Leeds group is one of the most prominent in the UK, with quite a high media profile and a set of active officers engaging in both national and broader debates, such as a strong

presence on the EU-wide forum for allotmenteers – (www.jardins-familiaux.org/e_start.html). Part of the LDAGF's high media profile is a High Court case in 2014 when the LDAGF successfully challenged Leeds City Council's process for raising rent levels on allotments, mentioned later.

We interviewed two of the LDAGF officers to gauge their perceptions of the present state of allotments in the city and of allotment operations more widely. This is a first stage in a planned wider research process which will engage with a broader sample of respondents but we judge the interview responses to be sufficiently in depth and of good enough quality to justify some interim commentary, especially in view of the underrepresentation of local case study material in the literature on ULFG. The responses enable us to focus on five key aspects of 'allotmenting': site operation and management; demand levels and rental charges; the evolving profile of allotmenteers, connections with local food initiatives and future trajectory of Leeds allotments.

The **operation and management of allotment sites in Leeds** reflects the broader national picture. There are 92 allotment sites registered in the city with 34 managed by Leeds City Council (LCC) and 62 self-managed by site-based associations (the respondents here represent self-managed sites). The LDAGF promotes self-management of sites for a number of reasons. They consider self-management permits more immediate and hands-on intervention both to help plot holders get started and to respond to those who prove neglectful or inconsiderate. Early intervention in disputes is more effective when done on-site. LCC has one allotment officer with 34 sites to manage remotely. Self-management also gives access to external funding such as Lottery funding, which has been widely used in Leeds sites to provide communal facilities such as toilets and secure tools stores. Indeed the Leeds Fed sees itself as a pioneer of allotment self-management, something that the Council failed to embrace with the enthusiasm it should have:

> "It started in 1984, around that time. Leeds was a pioneer area for self-management and was looked up to by other cities as being a really good example" (Respondent 2)

Levels of demand for allotments sites in Leeds has fluctuated over time, reflecting the broad national demand patterns discussed above. This is shown by a peak waiting list of over a hundred across the city up to a few years ago and a big drop in demand since 2010. This recent drop is thought to reflect falling incomes of potential plot holders together with rising rent levels (which have been widely discussed in local media). It may also reflect a 'reality check' for recent recruits tempted by the modishness of allotments.

> "I don't think there is a massive issue around the supply of allotment plots. I don't think there is a massive shortage against demand for Leeds." (Respondent 1)

> "On my site, two years ago we probably had a waiting list of 15-20. We've got vacant plots at the moment" (Respondent 1)

> "It could also be a fashion thing, that people have….you know, allotments were very popular and popularised and everyone wanted one. Then people found out that actually growing vegetables was quite a time-consuming hard work." (Respondent 2)

The rent issue, very active in Leeds recently, seems to be a factor inhibiting demand. The court case was more a pyrrhic victory than a practical one as rents did rise once LCC followed correct procedure, but it is thought allotment rents in Leeds remain equivalent to those in other cities. As well as headline rent levels the Council has changed the rent subsidies system. Old age pensioners used to get a 50% rent discount but that has been reduced to 20% which has hit a lot of plot holders. In addition the service charges for water supply etc. – on top of rent for self-managed sites – are increasing. The respondents estimated that rents had doubled in 3 years. When combined with reduced discounts this amounts to significant cost increases for the typical pensioner plot holder, more than tripling in some cases. The motivation for the LDAGF court case was more about upholding the principle that

LCC needed to deal seriously with allotments and allotmenteers and not treat them as minor players in a city-wide spending cuts process. Despite the court case there seems to be little animosity with the Council, rather much sympathy with LCC's predicament in the current austerity regime.

One common adaptation to attract newcomers has been to offer smaller plots, with many sites offering half-size and quarter-size plots. These are both easier to manage, especially for beginners, and cheaper to rent. A downside is that quarter plots are too small to accommodate sheds so investment in communal tool stores, toilets etc. is needed to make sites attractive.

However the striking reduction on demand in recent years suggests strong rental sensitivity may undermine the viability of some sites. The respondents mentioned the spatial variation in demand for plots with potential plot holders reluctant to look much beyond their neighbourhoods even if there are no local plots available and more distant plots are vacant. It was not clear why this was so but reasons may include a desire for walkable journeys to plots, lack of car ownership etc.

When asked about the **changing profile of allotment plot holders** the respondents confirmed that some of the broader evolution of allotmenteers from the traditional domination of older white working class males noted nationally could be seen in Leeds. Although no statistics are gathered on age, gender, ethnicity of plot holders the respondents reported that plot holders are getting younger, with more women, more families and a higher proportion of BME groups represented on allotments.

> "Now there's a lot more women on our site, a lot of families and a lot of young people, as well as retired people of course and a lot of couples working together on plots." (Respondent 2)

> "We have a lot of Chinese people on our site, a lot of them from the University. Once somebody joins then their friends want to and they like to garden together. And it's very interesting because they grow different things than English people would grow and they're very intensive in their gardening, so it's a real encouragement to people, so we've got a mixture" (Respondent 2)

> "Mine is more mixed, because we straddle three Wards. We've got a mixture of different ethnicities and a mix of social, people that are on benefits, up to university lecturers, so we've got a real cross-section on our site." (Respondent 1)

We were interested in whether the LDAGF was involved with any community growing or similar recent **initiatives in local food production**. The respondent answered from the perspective of their own sites and a more strategic overview will also be sought, but their comments permit a grassroots allotmenteers perspective to be gauged. Both were aware of the Leeds Feeds initiative in the city. Respondent 2 mentioned there was no formal link with the allotments site but some allotmenteers were linked to Feed Leeds. They also suggested a food growing cultural gap between the newer community gardening stance and allotmenting, perhaps echoing the more 'individualistic' stance of allotments:

> "Allotment gardening is about growing crops that you are going to eat and people are investing time and effort in that and some of these people are expert growers. They are growing really good quality crops. It's a lot of hard work, so the idea that you would do all that and then let someone else pick it, strikes some people as being a little odd." (Respondent 2)

> "There are some elements of Feed Leeds that are OK. I think some of it is a bit wishy-washy. Allotments are a completely different environment to growing in a park or on a roundabout or guerrilla gardening or whatever." (Respondent 1)

This scepticism is linked to an appreciation of gaps between the needs of poorer communities and the community resources available to promote and support local food growing:

> "On an allotment site it's hard enough getting people to run an allotment site and be on the committee and do all that stuff. The very places that would benefit from 'food for free' or a community garden are the places where people to run it don't live. So in poor areas of the city where there is real food poverty, they can't afford to buy fresh vegetables or they don't know how to go about growing them, where they would really benefit from a community garden, they don't happen in those areas. Because the people who run them live in middle class areas. That's the dilemma I think."

However the respondents did say that the LDAGF had become more 'outward looking' and sought to engage with local food initiatives, if only to seek mutual benefits, as a matter of policy. Respondents mentioned a schools growing competition to engage with potential future allotmenteers:

> "[…] for the last 50-odd years we've run a competition annually around allotments. We want to bring schools into that, so that's encouraging the next generation of allotmenteers." (Respondent 1)

This was not easy because of the lack of fit between school terms and growing/ harvesting seasons. Another instance of being outward looking is the involvement of some sites with health and wellbeing initiatives:

> "Yes, on my plot we have a local community group who work with a group of predominantly widowed or single men who are isolated and wouldn't necessarily come out. And we've got this group on our plot who are fantastic, they've got two plots now and they come out as a group once a week, they grow, they take it away and cook it. And some of them now come on at the weekends and outside of the organised times and you can just see the benefits of that" (Respondent 1)

If the respondents had limited involvement with community growing initiatives this should not be taken to support suggestions that allotmenting is individualistic and non-communal and, by implication, less socially constructive than community gardening (Wiltshire & Geoghegan, 2012) . The self-managed orientation of the Leeds sites suggests a high degree of communal operation which could be seen as building social capital. The respondents indicate a high level of mutual self-help in many ways. One example of this is the communal toilets and tool store built on one site using Lottery funds obtained through the efforts of the plot holders. Other examples include collective work parties to help maintain sites in the absence of much material support from the council.

> "I run a volunteers group on a Thursday morning. People turn up, they use their own tools a lot of time, they come there and all they do is work on the common areas on the site. They're not working on their plot, they're doing it for the common good, clearing up, planting the wildlife area, cutting the hedges, cleaning the composting toilet out." (Respondent 2)

There is also a strong feeling that well managed sites are an asset to the local community, providing a welcome green space in areas that may lack parks.

> "In some of the areas, they're beautiful sites and they're an asset to the area [….] If they had just been left to rack and ruin and for kids to go in and set fire to and all the rest of it, they'd have had local residents complaining about eyesores. And we keep them tidy." (Respondent 1)

This concern that sites contribute to the amenity of their areas may reflect concerns that badly maintained 'eyesore' site are more vulnerable to loss for development once surrounding residents see

sites in a negative light. The idea of allotments as 'eyesores' that undermined local amenity is sometimes reflected in official comments, for instance in the comments of town planners to the 1998 report (HoC Environment, Transport and Regional Affairs Committee, 1998).

The **future trajectory of allotments in Leeds** was discussed briefly, in particular how the LDAGF and the LCC would coexist in future. Despite the recent High Court case there was little animosity against LCC and a good deal of pragmatic forward thinking. The respondents understood the severe financial constraints affecting the council and were actively pursuing ways to develop a productive partnership with LCC. They thought they had a positive relationship with the very small allotments team and that the politicians on LCC were becoming more pragmatic and positive towards LDAGF.

> "If whichever government we have continues with severe cuts on public services, that's bound to have an impact on local services. In Leeds the allotments are overseen by Parks and Countryside; they've been cut. If they continue to be cut and lose staff, then it's bound to have an impact on us." (Respondent 2)

Crucially the respondents did not feel under any pressure from LCC to release sites for development, as they were aware had happened in other places, so future progress was likely to hinge around finding cost-effective ways to run allotment sites which relied little on LCC resources. In this respect the self-management ethos of LDAGF and its long experience of running sites with minimal council support were seen as critical. The council was seen as having missed earlier opportunities to support self-management more wholeheartedly but to be now more open to doing so.

> "[….] hopefully we've made our point. They certainly seem more willing to get a better relationship with us, so we're hopeful." (Respondent 2)

No reference was made to the potential role of 'community' food initiatives in the future trajectory of Leeds allotments but the expansion of interest in such projects suggests there may be some mutually beneficial prospective relationship.

Conclusions

Our research uncovered a rich and growing research field in urban local food production, one where allotments deserve to occupy a higher profile. As an exploratory study a number of potential future research direction suggest themselves. Our limited survey of the Leeds allotment association indicates there is much potential for extending the interview strategy to provide a wider range of local examples. One could expect, for example, variations in demand levels in areas with different income levels, which might affect the viability of sites in different cities. Also one might expect variation in local council policies on allotments, perhaps less cordial than the evidently quite benign relationship found in Leeds. In addition the presence or absence of local food growing movements and projects, such as 'incredible edible' may impact differently in different cities.

Alternatively a more intensive case study approach applied to Leeds should be able to tease out in greater depth how local urban food actors interact, which should help identify opportunities for greater collaboration within the urban food movement.

Our research suggests that allotments are becoming higher profile in policy terms and that in at least one major city good progress is being made in transforming their accessibility. However the potential of allotments to contribute to the current urban food production movement seem to be under-realised. It seems clear that allotments should play a prominent role in any future strategies for urban local food production. However current and recent discourses about ULFP tend to play down if not ignore their potential for doing so. This may be because of the perceptions by local food activists that allotments are too 'mainstream' to engage with avowedly radical ULFP projects or it may be to do with clichéd perceptions about the dominance of allotments by older, white working class males who may

not embrace demands from women or ethnic minorities. Whatever the reasons, this kind of distancing between food activists and allotmenteers is not confined to the UK and can be found at least in Germany (Sondermann, 2014). The extensive nature and wide geographic spread of the allotment resource in UK cities, together with the reported recent downturn in demand for plots, at least in Leeds, suggests great potential for some form of coordination between community gardeners and allotmenteers.

The Leeds respondents reported how allotments have adapted to changing demands and expectations of local resident over time. There has been considerable rethinking of plot size, for instance, with many half and quarter size plots now provided. The social and wellbeing dimensions of allotments have been recognised and connections made to mental health and wellbeing causes, for example, and there is a long tradition of links to schools to help educate children in plants and natural growth processes.

The financial sustainability of sites in a time of public spending cuts, a widespread concern of allotmenteers, is being addressed in Leeds by engaging with the City Council to promote further the already well-established practices of self-management by plot holders acting communally. This under-appreciated aspect of allotment gardening suggests, certainly in the Leeds context, that there could be a good deal of mutual benefit to be gained by collaborations between the new generation of community gardeners and those in the allotments community.

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AN INVESTIGATION INTO BUILDING PHYSICS IN THE FIELD AND THE TESTS USED TO CHARACTERISE BUILDING PERFORMANCE

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Keywords: Building performance, assessment, methods, and energy.

Abstract

According to the Energy Information Administration (EIA, 2013), the consumption of world energy is predicted to rise by 56% from 2010 to 2040. International Energy Outlook 2013 suggests that the factors responsible for this increase are rapid economic progression and increasing population (EIA, 2013). According to Eichholtz et al. (2010), the building industry accounted for 35-40% of the world energy consumption, and stakeholders in this sector have placed sustainability high on their list of objectives.

Referring to the '67 Temple Avenue house' case study, findings revealed that only 71% of the predicted reduction in heat loss was achieved (Miles-Shenton et al., 2010; Miles-Shenton et al., 2011). These disparities between the modelling assumptions and construction techniques used in this project could however be questioned on reliability grounds in order to rectify the possible disparities. It is important to ensure that buildings are designed from the onset to minimise environmental impact throughout the building life cycle including actual operational performance and energy use reduction. For this reason, there is the need to assess the performance of the building in context, and the need to close the gap. Therefore, this paper focuses on identifying the gap and evaluating the accuracy of methods used to assess building performance.

Akinrinola, O. and Gorse, C. (2015) **An investigation into building physics in the field and the tests used to characterise building performance** *In;* Gorse, C and Dastbaz, M (Eds) *International SEEDS Conference,* 17 – 18 September 2015, Leeds Beckett University UK, Sustainable Ecological Engineering Design for Society.

1.0 Introduction

The UK Government has a commitment to meet EU targets of a 20% reduction in greenhouse gas emissions and primary energy consumption, alongside a 20% improvement in overall energy efficiency, across all EU Member States, by 2020. In the UK, approximately 37% of GHG emissions arise from buildings, of which 26% arises from commercial buildings (CCC, 2013). This has stimulated a desire to make buildings low carbon (Godwin, 2011). The Government has set ambitious targets for incremental changes to building regulatory standards that are intended to achieve zero carbon new housing by 2016 (NHBC Foundation, 2009). Research conducted by Gillot *et al.* (2013a) indicates that the level of GHG emissions can be reduced by improving the thermal performance of a building. There is currently an increase in the amount of research on building physics and the results show that the theoretical designed and modelled levels of energy demand and carbon emissions of buildings are not generally what it is really in practice (Gillot *et. al.,* 2013b).

Although design solutions exist for the construction of very low, and zero carbon housing, there is considerable concern that many of these solutions are untried and untested within the context of mainstream housing production in the UK. Furthermore, there is evidence of a performance gap i.e. buildings do not perform as well as they were anticipated at the design stage (Baker, 2011; Rye *et al.,* 2012).

The inability for a building to provide the expected levels of energy efficiency and carbon emissions could have a potential effect on the whole supply chain (O'Mara and Bates, 2012). There is the possibility of having some structural faults in the process of constructing a building. It would be quite unfair to place the entire blame on those responsible for constructing the final product. Doran (2000) contends that there are two main factors that can be responsible for under-prediction of energy demands and emissions; the first factor is the design models, which may not be an accurate representation of the building systems, and secondly that a building could possibly due to some reasons, fail to be constructed according to the design specification.

In addition, the complexity in the design and construction phase as well as numbers of interrelated contributing factors could potentially lead to underperformance of a building (Miles-Shenton *et al.*, 2010; Miles-Shenton *et al.*, 2011).

Evaluation of the differences between expected and actual energy performance of a dwelling can be carried out via detailed comparison of data obtained from design stage results to that of the post construction data. In light of this, the next section therefore discusses factors that can lead to the apparent gap which appears to exist between design stage and post construction data with special emphasis on thermal performance.

1.1 Evidence and Contributing Factors

Efficiency of energy in housing has in recent years received greater attention, this has driven the increasing amount of research undertaken in this area. This research focuses not only the design stage assessment, but also the as-built monitoring of building performance. There is a huge amount of investment and funding in this regard in order to investigate the difference between the predicted energy performance of a building (and hence it's CO2 emissions) and its performance in practice (Miles-Shenton *et al.*, 2010; Miles-Shenton *et al.*, 2011).

Also, there is an increasing use of standardised design stage assessments (through use of Standard Assessment Procedure (SAP) 2009) and the emergence of post construction testing techniques in order to assess the performance of buildings (De Meulenaer *et al*., 2005). Evidence shows that detailed monitoring and evaluation studies are largely confined to houses built specifically for research or demonstration projects (such as the BRE Innovation Parkand the Creative Energy Homes (CEH) at the

University of Nottingham). Some other notable projects are the construction or upgrades of homes in conjunction with developers, house builders and other external parties, which are subsequently inhabited. A typical example is the 67 Temple Avenue house (Miles-Shenton *et al.*, 2010; Miles-Shenton *et al.*, 2011). There is however limited amount of information that can be made available for scrutiny due to confidentiality issues and data protection.

Recent reports gathered from a Government-led project to evaluate the contributing factors to the underperformance of homes also show that design-stage models and as-built testing require significant improvement in order to deliver a sound estimation of housing performance (Zero Carbon Hub, 2013). Technology Strategy Board Building Performance Evaluation project (TSB, 2013) has successfully showed that, nine out of the 13 buildings initially examined, did not meet their design-stage thermal performance levels. Interestingly, the average airtightness level measured on the spot was twice that calculated based on theoretical data (Colmer, 2013). There have been suggestions from the National House Building Council (NHBC) and Zero Carbon Hub (National House Building Council (NHBC), 2012; Zero Carbon Hub, 2013) on the key factors that could lead to the supposed difference between the designed data and as-built performance.

Literature highlighted six main areas (modelling, input procedures, building designs, the construction process, materials & systems performance and post construction evaluation techniques) that will need to be genuinely addressed to reduce the gap. There must be clear-cut answers as to the model type and the underlying calculation methodology which must be sufficiently accurate. Practitioners are advised to use the recommended model which is SAP. The Input Procedures is seen to include human error during data compilation, inaccurate data origin, and the entry protocols also have an impact. With regards to building design, there are questions on how accurate and complete the design information are, as well as the question on design simplicity, as some of the performance gaps are traceable to the complexity of the design which makes the process of construction very challenging. Also during the construction process, it is important to know if buildings are built with the original intent/plan using suitable skilled workforce or are substituted with products of the same standard as the original specification. Performance of Individual Materials and Systems is another factor that has been identified as a possible reason for performance gap, and there is question on how reliable the laboratory test results for materials and systems that are being used in practice are. In addition to this, the robustness and reliability of the post construction evaluation techniques is also important in closing the gap between predicted performances and actual performance of a building.

Having identified the possible causes of performance gap, this paper further examines some of the techniques used to measure the performance of a building, particularly when determining the building air tightness and the fabric heat loss i.e. thermal efficiency and fabric performance. The following sections will provide an overview of the evidence to support the contribution of many of these aspects to the underperformance of dwellings. Therefore, the overall objective of this paper is to focus on the potential reasons why a significant gap exists between the designed and actual performance of the UK dwelling system.

1.1.1 Building Air Tightness

Air tightness testing is used to measure the air permeability of the building envelope to determine airtightness in order to achieve quantitative measure of compliance of new-build housing with minimum Building Regulations Part L standards. The process involves pressurisation from which air leaks are more obvious and may be detected using a smoke detection technique. The value obtained from the measurement is inputted into the SAP model to obtain a true value of the Dwelling Emissions Rate. According to White (2014), the public datasets relating to the results of the test are not widely available, even though the results still serves the most integral and comprehensive basis upon which to compare predicted and post construction performance of a dwelling. After mandatory air pressure testing was introduced in 2006, a significant improvement in building air tightness levels was observed

as a drop from 33% to 3% of houses tested failed to meet the minimum acceptable value. On the other hand, despite achieving the minimum acceptable standard for background infiltration in new building widely, i.e. 10 $m^3/(h.m^2)$ @ 50Pa, buildings will need to achieve beyond this minimum (CfSH Level 3) in order to reach the high levels of thermal efficiency necessary to meet zero carbon performance (White, 2014). Also, while compliance with Building Regulations standards might have been satisfied, a building could still underperform when comparison is made between the design-stage and as-built background infiltration rates. Initial results from 13 properties included in the Technology Strategy Board research programme reveals average actual air pressure test result of 4.1 $m^3/(h.m^2)$ compared to the design stage predicted mean value of 2.1$m^3/(h.m^2)$ (Colmer, 2013). The reported difference is largely due to incorrect data being inputted during the modelling process accounting for the significant underperformance.

Analysis of 44 houses during the Stamford Brook Project at Altrincham, Cheshire, shows the mean air tightness value was calculated to be 4.5 $m^3/(h.m^2)$ @ 50Pa (Wingfield et.al.,2011b).This was within limits of Building Regulations compliance, and the results are comparable with those recorded in literature with recorded mean values between 6.43 and 11.1 $m^3/(h.m^2)$@50Pa (ARUP, 2003;Grigg, 2004;Johnston et.al.,2006).

It is possible for the true performance of the buildings under evaluation to be masked by the mean air tightness test value. Further analysis by Wingfield *et. al*. (2011b), on the distribution of air tightness results across the 44 dwellings at Stamford Brook revealed that the data varies from approximately 1.5 to 10 $m^3/ (h.m^2)$. With the design, air tightness was set at 5$m^3/(h.m^2)$, and improving the mean key value, almost one third of the 44 properties still failed to meet the level of tightness (Wingfield *et.al.,*2011b).

This observed trend is quite common, as demonstrated in results reported by other studies. One of such studies is the BedZed development comprising 82 mixed type dwelling, located in Hackbridge, London (Wingfield *et.al.,* 2011a). The building was originally designed to deliver to net zero carbon levels, its airtightness results were three times that of the design air permeability target of 2 $m^3/(h.m^2)$ (ARUP, 2003). Also another instance is the Elm Tree Mew; a project situated in York house (Miles-Shenton *et al.*, 2010; Miles-Shenton *et al.*, 2011) which consists of six dwellings built to achieve CfSH Level 4 standards, the mean airtightness value reached was 7 $m^3/(h.m^2)$, which doubled the design stage calculation of 3 $m^3/(h.m^2)$ (Wingfield et. al., 2011a). This is a proof that a minimum air tightness compliance target of 10 $m^3/(h.m^2)$ can be achieved and improved upon, but it does not give any clear information regarding the failure of constructed dwellings to meet design stage airtightness values. Furthermore, investigations using thermal imagery suggested that other factors like complexity of design details and the continuity of the air barrier, poor seal to service penetration, poor seal around windows and doors, lack of attention to junction between walls and ceilings, as well as integration of trickle events could possibly add to the differences (Johnston *et. al.,* 2006;Wingfield *et.al.,* 2011b).

The above outlined issues to a large extent relate to those identified as key air leakage pathways in Building Regulations guidance and best practice documents. It is best advised that the design should include a continuous barrier to air movement that maintains constant contact with the insulated layer (Department for Communities and Local Government (DCLG), 2010), avoid complex detailing in order to achieve an airtight envelope, and to close off all ducts at all open ends. It is also important to avoid designs that may be difficult to construct, and also to carefully integrate components and openings elements, paying attention to joints between building components, as well as sealing all service penetrations through the building envelope and elements.

1.1.2 Fabric Heat Losses

The coheating test is a very important tool for measuring whole dwelling heat loss of a fabric. It works by heating the interior of a building to a uniform temperature and then recording the amount of electrical energy needed to retain this temperature over a certain period of time (Wingfield *et al.*, 2010; Johnston *et al.*, 2012). Coheating test is the most commonly used technique in the UK to assess the as-built Heat Loss Coefficient (HLC) in order to evaluate fabric heat losses in a building. Much of the work undertaken in this field has been limited to specific research projects, partly due to the length of time needed to gather reliable data from tests and also the need to get official permission to gain access to unoccupied dwellings whilst the research is ongoing. These factors however have limited the amount of specific research projects already undertaken in this field (Department for Communities and Local Government (DCLG), 2011.

The majority of the test carried out showed that the actual value failed to meet the design stage calculated HLC, with the divergence against measured HLC values ranging from approximately 5% to 125% over predicted data. Bell (2013) reported on the work carried out by Leeds Beckett University that the number of coheating tests completed had exceeded 50 in number, and the full sample showed a similar range of design.

Investigations carried out by Stafford, (2012) on four dwellings, showed an improvement in measured HLC compared to their expected values. In this study, two tests were undertaken on existing dwellings and the other two were carried out using highly performing houses. It was reported that the confidence level in the predicted HLC was not high due to a large amount of assumed data being included in the SAP model. According to Stafford (2012), the other two highly performing houses were able to achieve these results after necessary actions were taken to deal with the observed heat loss pathways and therefore are not truly representative of the level of performance gap originally observed. It is believed that the value hides the actual performance gap of some of the properties, with a difference of up to 60% being recorded in one case (Colmer, 2013; Johnston, 2013). Similar studies carried out by Guerra-Santin, (2013) showed an increase in measured HLC above design-stage HLC values for two PassivHaus compliant properties, with predicted and on-site values being 53.3 W/K vs 62 W/K and 34.1 W/K vs45 W/K for each dwelling respectively.

The measured heat losses in the studies reported by Johnston, (2013) and Guerra-Santin, (2013) were indeed still very low, thus, the maximum disparity between the modelled and coheating test data was not as large as for some of the attributes that possess lower percentage gap results as described in the study by Stafford, (2012).

In order to get more accurate and comparable data, heat loss parameters (HLP) are often used (White, 2014). The HLC value divided by dwelling floor is worked out to calculate a normalised effective whole house u-value measured in W/m^2K (Sutton *et al.,* 2012). On the other hand, only a few studies to date have reported the results based upon HLP indicator of performance.

In addition, the findings from the coheating test have led to further investigation into reasons for divergence between the design stage and post construction HLC values. In the work conducted at Elm Tree Mews, the design stage HLC was calculated to be 127.5 W/K, yet the measured value was found to be higher by over 50% the value which was at 196.4W/K, and when ventilation losses were removed, the fabric heat loss differs by almost 70% (Wingfield et. al., 2011a). Investigation into factors contributing to the performance gap however shows that there were several aspects (Bell *et. al.,* 2010) influencing either the predicted or measured HLC: 1) Underestimating at design stage the amount number of timber used in making roofs and wall construction (this accounted for 23% of the gaps); 2) Miscalculation of the thermal effects on the bridge which accounted for 25% of the gaps; 3) lack of awareness of party wall thermal bypass mechanism which contributed to about 30% of the

discrepancy and the final differences arise from the change of window supplier without accounting for change in specification which is responsible for about 21% of the gaps.

In a similar investigation undertaken at Stamford Brook, six dwellings were tested, and the difference between calculated and measured HLC ranged from 7 5%-103% (Wingfield *et. al.,* 2008). Results from the two dwellings that were analysed shows a 46W/K absolute disparity between the two values and the presence of a party wall thermal bypass mechanism (using thermal imaging) accounted for about 43% of this unexpected heat loss while approximately 33% are due to complex joints in building construction and the resulting thus increases in thermal bridging calculations. According to Wingfield *et. al.,* (2011b), background ventilation losses and air movement in the building fabric could be responsible for other heat loses.

A study on the effects of a party wall bypass as a key heat loss pathway have been studied previously and the mechanism was linked to air movement in the cavity resulting from conduction, and external wind effects around the building. (Lowe *et. al.,* 2007 and Wingfield *et. al.,* 2007).

Investigation that measures insitu u-value has been on-going for a number of years, with differences in construction u-values ranging from 30% to over 160% as compared to that stated by the manufacturer and those used in design models (Siviour, 1994; Wingfield, *et al.,* 2008; Wingfield *et al*., 2011a; ZeroCarbonHub,2013).

In-situ u-value measurements on 57 different wall constructions conducted by Baker, (2011) showed that heat flux sensors were used to measure heat flow through the material under consideration and temperature sensors to monitor internal and external temperatures. The study found that 44% were lower, 42% were said to be approximately equal to and 14% were higher than the calculated value (Baker, 2011).

There has been concerns that the differences between the predicted and the actual values could be worsened by poor workmanship as the design u-value is based on tests undertaken in laboratory conditions rather than following installation in actual building site condition, and thus, no account is made for gaps in insulation layers or thermal bridge effects (Zero Carbon Hub, 2013b).

Issues like change of products in the final building construction with no later adjustment of details made in the model has also been identified as a point of concern as these can arguably impact upon the reliability of data (Doran, 2000; Dowson *et al*., 2012).

Guerra-Santin, (2013) stated that there is need to bypass faults in the design stage calculation to ensure agreement between design and measured u-values as failure could be difficult to remedy once at the construction stage. Considering that post-construction testing techniques can be very important in terms of evaluating key indicators of thermal performance, there are militating factors such as large temperature differences between inside and outside of building which can limit the testing period in the UK to the winter months as well as solar radiation which can potentially affect the coheating test results by making data unreliable (National Physical Laboratory (NPL),2012).

2.0 Conclusion

In recent times, results from assessments showing a gap between predicted and measured performance of UK housing has been on the increase with more work to be undertaken to fully understand the connecting causes between the design, construction processes and final physical performance of buildings (Stafford, 2012).

The result obtained using the Standard Assessment Procedure (SAP) methodology to provide an accurate indication of as-built performance has been challenged. This is as a result of little adjustments that are allowed for standardised values in calculations and the use of manufacturer's data for

parameters such as u-values and system properties, which may inject elements of optimism because the expected result is already bias into the model.

Increase in the number of properties that is required to be subjected to mandatory air-tightness testing on large scale developments (National House Building Council (NHBC), 2011) is attributed to changes to Building Regulations Part L. This new initiative is introduced to ensure increased standards of building practices and to establish a kind of early identification of issues involving design and construction due to divergent problems with design and construction matters.

The subject of building energy performance is quite complex because there are several interrelating factors affecting the overall amount of energy demand of a building. Some factors such as the materials and systems introduced into a design will have a huge impact on energy consumption and carbon emission. The paper confirms there is an increasing amount of evidence to support the existence of a gap between the predicted and actual performance of UK housing however, it is still an area where more work is required to be fully undertaken and care should be taken to understand the causal links between the design and construction processes and the final physical performance of buildings.

3.0 Recommendations for future work

The reliability and robustness of the coheating test methodology and assessment of improvements would be further investigated in order to resolve limitations. It is recommended that a wider data set should be used during the investigation in order to understand the sensitivities of the various parameters for different housing types. This test will be undertaken on a long term, using a single building to allow data to be gathered for the same property under different weather scenarios.

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Sustainable Initiatives

SUSTAINABLE COASTLINES -THE CASE OF THE GAZA STRIP

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Keywords: Beach Litter, Coastline, Gaza Strip and Sustainability.

Abstract

Sustainable development is not possible without safeguards to maintain a healthy, clean and productive natural environment. In particular, ocean and coastal ecosystems play a central role in shaping the earth's climate and supporting both biodiversity and economy. The issue of beach litter is critically contributing to beach degradation which has adverse effects on marine life and beach users. Explicitly, the Gaza Strip Coastline is subjected to extensive illegal dumping operations of beach litter. This problem is posing a threat to both marine life and people in the Gaza Strip. Furthermore, it has direct implications on the future prospect of sustainable development of the local population.

Although beach litter has received worldwide increasing attention in recent years, few studies have explored this phenomenon across the Gaza Strip Coastline. One significant barrier to enforcing a mitigating approach to Beach Litter in the Gaza Strip is the lack of a reliable science-based data. Addressing Beach Litter within the context presented, this research will fill the current scientific gap of different aspects associated with Beach Litter in the area.

Specific information on the sources, composition and quantities of generated beach litter were presented in this study. In addition, the perception of beach users on aspects related to beach litter was investigated. Results presented in this research map the first step along the path of sustainably managing the Gaza Strip Coastline.

Hamouda, H., Abu-Shaaban, Nadine. and Al-Swaity, E. (2015) **Sustainable coastlines – the case of The Gaza Strip** *In;* Gorse, C and Dastbaz, M (Eds) *International SEEDS Conference,* 17 – 18 September 2015, Leeds Beckett University UK, Sustainable Ecological Engineering Design for Society.

INTRODUCTION

Sustainable development as a concept has become a centre of debates stimulating worldwide interest. As such, it aims towards conservation and preservation of natural resources to ensure the attainment of human needs for present and future generations. Such a prevailing trend is driven by ongoing or merging global challenges including; poverty, inequality and environmental degradation.

Although sustainable development has given rise to extensive concern on an international level, difficulties are still present in setting out an effective implementation framework. Specifically, both developed and developing countries view sustainability from different angles, as developing countries emphasize social and economic aspects of sustainable development. Meanwhile, in the context of developed countries, more focus is placed on the environmental dimension.

Sustainable development is not possible without safeguards to maintain a healthy, clean and productive natural environment. In particular, ocean and coastal ecosystems play a central role in; food and energy generation, regulating climate and provision of leisure services to the community. In essence, conserving and enhancing such ecosystems is of universal concern.

Marine litter is a worldwide complex and multi-dimensional problem which has a wide spectrum of environmental, economic, health and aesthetic implications. In particular, marine litter is considered to be a critical measure of sustainability governing; consumer behaviour, waste management and environmental pollution.

Generally, marine litter can be classified into one of three basic types; beach, benthic and floating litter. As reducing beach litter is a challenge, positive actions across society, public, industry and policy-makers is required. In essence, tons of pollutants are being discharged into the Mediterranean Sea every year from different counties surrounding the Mediterranean basin. Gaza is a narrow strip of land along the Mediterranean coast consisting of five governorates including Gaza, Middle, Northern, Khanyounis and Rafah. With a population of approximately 1.7 million and a total area of 365 km^2, it is considered to be one of the most populated regions across the world. Additionally, it is among the world's areas that witnessed a climate of economic fluctuation and political instability. The rapid population growth, limited land resources, vulnerability of the aquifer, imposed siege on the Gaza Strip (GS), limited waste management infrastructure and undeveloped environmental management plans have caused various problems. Such problems include deterioration of natural resources and natural habitats.

Currently, GS is confronted with an environmental, aesthetic and human health crisis related to the extensive volume of marine litter generated along the coastal area. Such accumulated waste has a low biodegradable nature, such as plastic, which poses a serious threat to the ecosystem. However, due to the various sources of debris, in the form of illegal dumping across the coastline and sea-based activities, controlling this activity is a complicated task.
In response to increasing environmental problems and growing awareness of adverse implications attached to marine litter, developing a sustainable strategy to proactively address such an issue is urgently needed. The aim of this study is to investigate the wider context of the environmental, economic and social impacts of marine littering on coastal communities with the GS region as a case study.

The objectives of this research study are to:

- Investigate the Beach Litter phenomenon along the GS Coastline.
- Identify possible sources of Beach Litter.
- Determine the composition of Beach Litter in the area.
- Quantify the quantities of Beach Litter.
- Preliminary assess the public perception and attitudes towards beach litter.

LITERATURE REVIEW

As defined by the United Nations Environment Program, marine litter is 'any persistent, manufactured or processed solid material discarded, disposed or abandoned in the marine and coastal environment"(UNEP, 2011). Marine litter has been of growing quantities since the beginning of the 20th century (Verlis *et al.,* 2013). Furthermore, the composition of marine litter has changed over years posing a threat to the marine and coastal environment across the world. Generally, marine litter originates from many sea-based and land-based sources and it can be categorized into one of three basic types; beach, benthic, and floating litter (Galgani *et al.*, 2013). Beach litter describes the mass of debris along the coastal beach. Meanwhile, benthic litters include a significant proportion of litter that enters the sea body and remains in the marine environment. Finally, floating litter generates at sea from fishing vessels and shipping where it directly threatens marine life (Ryan, 2009).

A number of surveys on the abundance and categorization of beach litter have been conducted on beaches around the world. Prior to the Edyvane *et al*. (2004) annual survey, the majority of washed ashore litter originated from commercial fishing activities within the Great Australian Bight. In addition, Ramirez-Llodra *et al.*(2013) study in Spain, Owens *et al*.(2011) study in small island developing states and Topçu's (2013) study in Turkey found that the most abundant litter types were plastic, glass, metal and clinker. Additionally, studies on benthic marine debris are becoming more popular recently. The types, abundance, distribution and sources of benthic marine litter found in four Greek Gulfs (Patras, Corinth, Echinades and Lakonikos) have been presented in literature, Koutsodendris *et al.* (2008). Litter items were sorted into material and usage categories. Plastic litter was found to be the most dominant material category followed by metal and glass. Based on the typological results, three dominant litter sources were identified; land-based, vessel-based and fishery-based. Thus, the same results were obtained through Poeta *et al*. (2014) study in Italy. Furthermore, Ioakeimidis (2014) found that plastics were predominant in all study areas. Composition and abundance of persistent buoyant litter were investigated in Rech *et al.* (2014) study at riversides and on adjacent coastal beaches of four rivers flowing into the Pacific Ocean. The results confirmed that river transport has an important impact on litter abundances on coastal beaches.

Marine litter is a significant environmental problem inherently linked to individuals' purchasing, use and disposal behaviour. The adverse effects of man-made debris in the marine environment have recently been reviewed by many researchers (Hastings and Potts, 2013; Debrot *et al*., 2014). In this context, recently several modelling studies on marine litter were published. Neumann *et al*. (2014) simulated the drift of marine litter in the southern North Sea with a PELETS-2D model. In addition, Rosevelt *et al*.(2013) used a mixed model approach to investigate both the season and location influence on litter abundance. Furthermore, canonical correlation analyses, linear regression, and nonparametric analyses of variance were used by Schulz *et al.* (2013) to identify different temporal trends of beach litter.

The impacts of marine litter extend to environmental, social and economic spheres. Such impacts are multifaceted in the GS area with the phenomenon of illegal dumping of beach litter along the coastline. The main barrier for managing and sustainably developing the coastline is the lack of reliable information on the amount, distribution, and variation of beach litter in the GS.

THE GAZA STRIP COASTLINE

The GS shore is a part of the Mediterranean basin and also connected to the Atlantic Ocean via the Strait of Gibraltar. It is situated in the south part of Palestine and south-east of the Mediterranean. The Gaza coastal line is 42 km long, between 6 and 12 km wide and covers an area of 365 km^2 (Figure 1). The currents that run along the coast of the GS are a continuation to the current that runs along to the southern coast of the Mediterranean from west to east.

GS is located in the semi-arid zone with an approximately population of 1.7 million. It consists of 5 Governorates, the North Governorate, Gaza Governorate, Dair-Al Balah Governorate, Khanyunis Governorate, and Rafah Governorate. The area has very limited water resources; the main source of water in Gaza is the shallow aquifer that underlies the whole Gaza Strip. This aquifer is highly vulnerable to pollution, because the aquifer is underlying sandstone, sands and gravel that cannot trap the organic and non-organic pollutants.

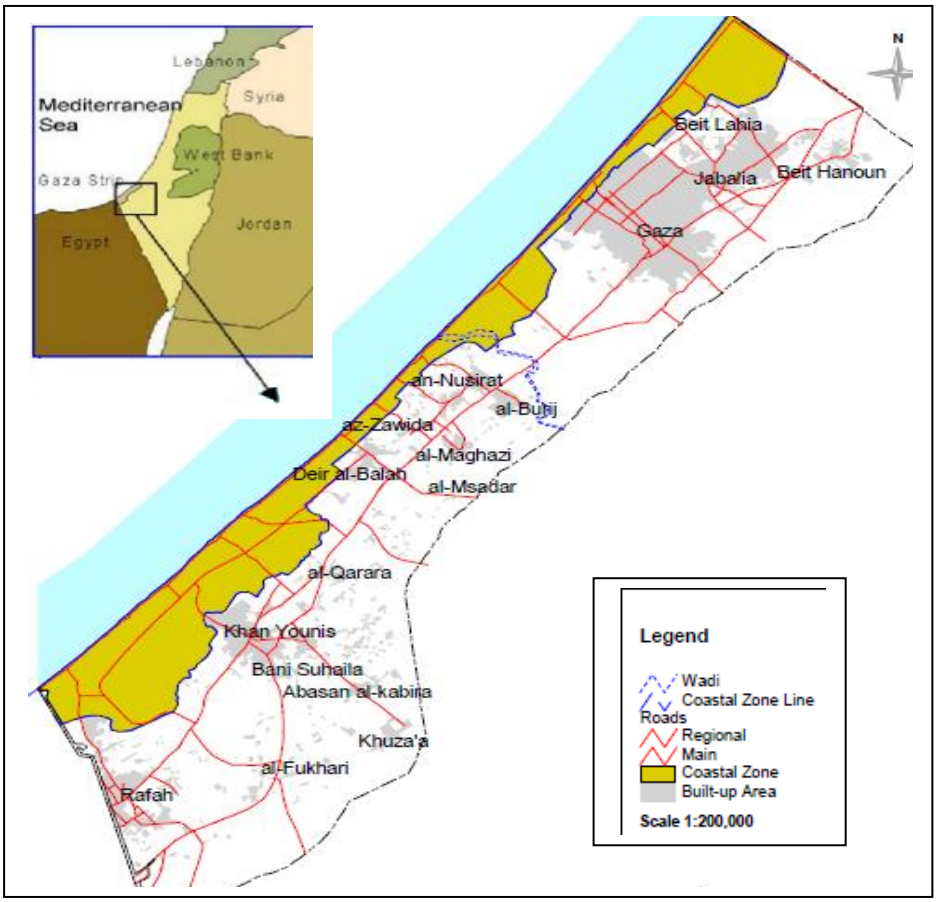

Figure 1.Gaza Strip coastline in the Mediterranean context

Official Landfill Sites in the Gaza Strip

Three main landfills are available in the GS located along the eastern boarder of the GS. Meanwhile, the remaining waste is dumped and burned in either uncontrolled dumping sites or scattered vacant lands. All of the three official solid waste sites, namely Gaza_Joher Al-deek with total area of 140 dunum (1 dunum = 1000m^2), Dair-Albalah with total area of 60 dunum, and Rafah with total area of 27 dunum have approached their capacity since year 2008 (Saleh *et al*., 2013).According to the Environmental Quality Authority (EQA), Gaza landfill has liner and leachate collection systems, whereas the two others do not as they are located on impermeable ground.

DATA COLLECTION & ANALYSIS

In order to develop a realistic and efficient beach litter management program, it is necessary to have information and data on the sources, amounts and distribution of the beach litter. Samples were collected for eight months, starting from March and ending in October, along the GS coastline i.e. Baitlahia, Jabalyia, Gaza, Nuissurat and Dair Al-Balah. This time period would be considered representative of typical GS's coastline conditions; as it targeted the spring and summer period reflecting low usage and peak tourist season.

Concurrently, the analysis has been conducted on a monthly basis and the average of the eight months was presented in the result. Random samples were collected in the first week of every month for five consecutive days from the dumping ground. These samples were thoroughly mixed and a 100 kg sample was taken. Then, wastes were manually segregated and categorized into various components on-site.

Furthermore, to preliminary assess the public perception and how strongly attitudes are held towards beach litter; unstructured interviews were conducted covering 2000 persons. Basic socioeconomic aspects were also inspected; such as place of residency, gender, age, level of education. Each questionnaire took 10-15 minutes to complete and was carried out during the working days and weekends.

Sources of Beach Litter in the Gaza Strip

Samples were selected at 11 sampling stations to cover the GS shore area as indicated in Table (1); where small, medium and large volumes are in the ranges of 80-85 ton/day, 140-160 ton/day and 600-620 ton/day respectively. Results revealed that the general public is the main contributor to shoreline litter, accounting for 46% of litter. Other sources included fishing, sewage and construction rubble (Figure 2).

Station	Coordinates		Volume
	N	E	
1	31º 56` 00.0	34º46` 69.7	Medium
2	31º56` 65.0	34º47` 46.5	Large
3	31º54` 77.9	34º45` 63.4	Small
4	31º55` 23.3	34º45` 91.0	Small
5	31º54` 31.4	34º45` 21.9	Medium
6	31º52` 87.0	34º43` 70.9	Medium
7	31º49` 12.2	34º40` 32.2	Large
8	31º49` 12.2	34º40` 32.2	Small
9	31º46` 13.4	34º37` 36.1	Medium
10	31º41` 12.6	34º32` 20.2	Large
11	31º42` 31.8	34º33` 59.0	Large

Table 1. Locations of collected samples along the GS Coastline

Figure 2. Photos of the GS coastline

The coastline plays an important role in the life cycle of people living in the area of the GS. As such, it is considered to be the place for public leisure, tourism and a source of national income. Results showed that 60% of the recreation places are classified as public places; meanwhile, the remaining 40% are resorts and private places. On average, the number of beach visitors per day is estimated to be 120,000. With the imposed closure on the GS, the beach is considered to be the only outlet for people in the area. Additionally, citizens of the GS depend on sea fish as a main source of food in spite of in place restrictions which limit fishermens' activity. Consequently, excessive fishing accompanied by the use of prohibited toxic chemicals appears to have adverse implications on marine life. Particularly, the accumulation of toxic substances in the food chain as fish feeds on it.

Furthermore, the continuous discharge of untreated sewage water from the Gaza Strip in the Mediterranean shores seriously polluted the sea. This is mainly caused by the electricity shortage in the GS; as in many occasions the wastewater treatment plant totally halted and consequently the wastewater is being disposed into the sea without any treatment. Another concern is the construction rubble resulting mainly from wars. With only a small proportion being recycled and re-used, disposing of such rubble at the coastline is a common phenomenon.

Composition of Beach Litter in the Gaza Strip

Various components have been found along the GS beach which are dangerous to humans and the environment. The following list elicits the main items presented:

- Plastics (fragments, bags, containers).
- Food residues from fast food consumption.
- Polystyrene (cups, packaging).
- Glass (bottles, light bulbs).
- Rubber (gloves, boots, tires).
- Paper and cardboard.
- Cigarette filters, tobacco packets.
- Construction debris (timber, pallets, concrete).
- Cloth (clothing, shoes).
- Metals (soft drink cans, metal wastes).
- Medical waste (used syringes).
- Sanitary or sewage related debris.

As shown in Figure (3), wastes generated have a large proportion of organic waste, followed by plastic and paper.

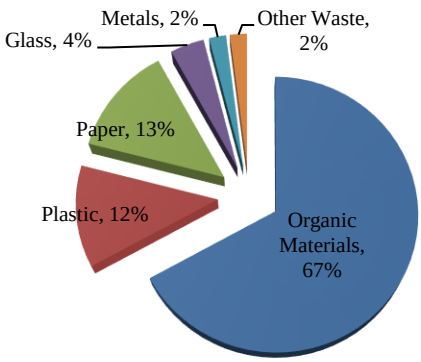

Figure 3. Overall Waste Composition

The correlation between the socioeconomical factors, such as population growth, human behaviour and income level, and the composition of waste have been well established in previous studies (Rouse et al., 2008; Scheinberg et al., 2010; Wilson et al. 2012). Along the GS coastline, approximately 67% of the total waste quantity is of organic origin. Results show consistency with the findings in published literature, which show that low and medium income cities have a large proportion of organic waste compared to high income cities.

The persistence of plastic litter and the associated environmental hazards are well documented in literature (Hirai,*et al.*2011;Webb,*et al.* 2013).All of which highlighted the fact that plastic is a durable material known for its resistance to the natural degradation process.

In a marine life setting, the discharge of plastic in the form of water bottles, jar lids, milk jugs and toys can pose threats to wildlife, humans and the environment through a number of ways. Aquatic animals may suffer injury or even death through entanglement, laceration, suffocation, and ingestion of floating plastic (Thompson *et al.*, 2009).Chemicals added to plastics are absorbed by human bodies and have been found to alter body hormones. The implication of this problem can be further extended to children as it is evident that children are particularly vulnerable to the adverse effects of such chemicals and commonly can lead to death (Salameh *et al.* 2003).

Quantities of Collected Waste

In order to estimate the waste generated per day, an exercise was undertaken to weigh the waste transported to dump site. The rate of waste collected in different regions along the Gaza Strip beach is summarized in Table (2). All of which is disposed randomly at uncontrolled waste sites. Results indicate that the daily average waste produced per person is 0.81 kg.

Location	Waste (ton/day)	Population	Specific Production
Baitlahia	80-85	90299	0.91
Jabalyia	140-160	221400	0.68
Gaza	600-620	700000	0.86
Nuissurat	62-65	83000	0.77
Dair Al-balah	75-80	78000	0.96
Khanyounis	160-180	220000	0.77
Rafah	120-140	203370	0.69

Table 2. Rate of Waste Collected from Gaza Strip Coastline

As indicated earlier, the vast majority of the generated waste along the GS coastline is of organic origin, therefore, it must be quickly collected and transported to proper sites for treatment. Accumulation of such waste forms bad smells, attracts rats and mosquitoes and eventually causes many diseases.

Traditionally, the solid waste management in the GS, including collection and disposal, is the responsibility of municipalities. The level of service provided by different municipalities is considered to be inadequate due to the lack of financial and technical capacity. This includes: shortage of fuel used for transport with high fuel cost, increased maintenance cost of vehicle and decreased lifespan of vehicle due to roads' bad conditions. This situation is further elevated by the delay of salary payments to people involved in the waste collection and disposal process.

Additionally, with the three official land fill sites unable to accommodate further waste, accompanied by the increasing amounts of generated waste, practices of random landfills and illegal beach litter dumping along the GS coastline are becoming a strategy leading to a tragedy. Firstly, soil and ground water quality are severely influenced by random landfills. The impact of leachate on both soil and ground water has been well covered in literature (Alslaibi, *et al*., 2010). Furthermore, the excessive pumping in an effort to meet the increasing water demand in the GS area is causing saltwater intrusion, which is another important problem that adds another challenge to the usability of water for irrigation and water supply.

Questionnaire Analysis

The highest percentage of respondents was categorized by the 'middle aged' segment (25-50 years old) with almost similar frequency of males and females; which reflects a greater interest of this age group in seaside tourism. Results showed that there was a great tendency to beach litter; as 55% of respondents were found to be beach littering along the GS coastline. Meanwhile, the remaining 45% participants dispose their waste either at the allocated public bins or back home. In addition, analysis revealed that factors related to age, income and residency greatly affect littering behaviour. This can be explicitly explained as both young and low income participants practice beach litter more often than those of a higher age group or with higher income. Respondents expressed lack of knowledge about what the beach litter is and how dramatic these issues are to health and environment. In particular, results showed that there are apparent differences in perception between educated and

non-educated respondents. Comparatively speaking, educated participants seem to be more aware and concerned with natural beach values and the current environmental degradation.

CONCLUSION

Sustainable development is becoming an issue of fundamental importance to people in both developing and developed countries. In essence, the protection of the Gaza Strip coastline from pollution is a local challenge with global impacts. This paper has explored the beach litter phenomenon along the Gaza Strip coastline in an effort towards sustainably developing the area.

This study attempts to fill the information gap on the generation and composition of beach litter in the Gaza Strip. Results revealed that the general public are the main contributor to beach litter and the average waste generation is 0.81 kg/person/day. In addition, findings revealed that organic waste dominated the characterization of beach litter, followed by plastic. Random landfill and illegal dumping along the coastline are found to be the final destinations of generated beach litter; which has major impacts on the environment and human health. The amount of beach litter being collected and randomly filled was quantified with Gaza Governorate occupying the top position. Furthermore, lack of public awareness and ignorance related to the collection and disposal of waste along the coastline was diagnosed. Collectively, there is an urgent need to develop a sustainable regime for beach sustainable development.

From the collected data, a number of recommendations can be drawn to sustainably preserve the Gaza Strip coastal values to combat beach litter:

- Regulations regarding illegal waste dumping must be set and enforced.
- The collection and disposal system should be further developed to cope with the increasing amounts of waste.
- Strategies to minimize beach litter must be developed; introducing the concepts of reducing, re-using and re-cycling of waste along the coastline.
- Environmental awareness regarding the impact of beach litter must be promoted among various stakeholders.
- Further research should be conducted aiming at quantifying the amounts of waste being illegally dumped along the GS coastline. Then, to assess the wider impacts of such practice on the Mediterranean Sea.

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GREEN SERVICE LEVEL AGREEMENT

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Keywords: SLA, Green IT, Sustainability, IT ethics.

Abstract

Nowadays, when most businesses are moving forward to sustainability by providing or getting different services from different vendors, Service Level Agreement (SLA) becomes very important for both the business providers/vendors and for users/customers. There are many ways to inform users/customers about various services with the inherent execution functionalities and even non-functional/Quality of Service (QoS) aspects through SLAs. However, these basic SLA actually did not cover eco-efficient green issues or IT ethics issues for sustainability. That is why Green SLA (GSLA) should come into play. Green SLA is a formal agreement incorporating all the traditional commitments as well as green issues and ethics issues in IT business sectors. GSLA research would survey on different basic SLA parameters for various services such as network, compute, storage and multimedia in IT business areas. At the same time, this survey would focus on finding the gaps and incorporation of these basic SLA parameters with existing green issues for all these mentioned services. Finally, this research would also focus on the integration of green parameters in existing SLAs, defining GSLA with new green performance indicators and their measurable units. This proposed GSLA could help and clarify different service providers/vendors to design their future business strategy in this new transitional, sustainable society.

Ahmed, I., Kilmova, A., Rondeau, E. and Rybin, A. (2015) **Green service level agreement** *In;* Gorse, C and Dastbaz, M (Eds) *International SEEDS Conference,* 17 – 18 September 2015, Leeds Beckett University UK, Sustainable Ecological Engineering Design for Society.

INTRODUCTION

SLA is defined as *a formal document between an IT service provider and one or more customer outlining Service Commitment* [1]**.** The main issue is that, there were many ways to inform customers about various services with its inherent execution functionalities and even non-functional/QoS aspects through SLAs. However, these traditional/basic SLA actually did not cover eco-efficient green issues. Currently, cloud and grid computing and many data centres act as most promising service providers. These computing and communication industries provide different services in comparison to traditional computing with some scalability benefits. At the same time, cloud services are offered at various levels: Infrastructure, Platform and Software as a Service [2]. At each level, they maintained a SLA with respect to their parties. Therefore, this shows the growth rate of SLA in recent times as well as the need for Green SLA for sustainability. Presently, the revolution of ICTs in daily average life has also resulted in the increase of GHG, due to continual increase in "carbon footprint''. In 2007, the ICT sector produced as much GHG as the aero industry and is projected to grow rapidly [3, 4]. If ICT has a negative impact on the environment, it can be used for greening the other human activities (logistic, city, industry etc). Indeed, the dimensions of Green Informatics contributions are: the reduction of energy consumption, the rise of environmental awareness, the effective communication for environmental issues and the environmental monitoring and surveillance systems, as a means to protect and restore natural ecosystems potential [5]. At the same time, many IT companies or service providers think about their business scope in the light of a green perspective. Therefore, with the increased attention that green informatics is playing within our society, it is timely to not only conduct service level agreements for traditional computing performance metrics or only on energy or carbon footprint issues, but also to relate the effort of conducting green agreements with respect to 3E (Ecological, Economic and Ethics) sustainability pillars. Therefore, the journey of Green SLA is getting importance in the IT business world. This research did a thorough survey for finding more eco-efficient green performance indicators for network, storage, compute and multimedia services in ICT industry. Additionally, a new green SLA proposed which covers all the existing green performance indicators as well as some other missing indicators covering three pillars of sustainability.

The rest of the work is organized according to 3 sections- the next research review section discusses some existing scientific theory and practical works based on basic SLA which did not consider any environmental indicators and green SLAs for different services. Basic SLA and existing green SLA parameters also derive and organize in detail through an existing empirical viewpoint. The results and contribution section provides an idea of newly proposed green SLA for sustainability. The conclusion gives some discussion and describes a few challenges to make proposed SLA greener.

RESEARCH REVIEW

This GSLA work did a rigorous literature review and survey based on existing work in the field of SLA, green SLA, green computing, energy optimization in IT industry, impact of ICT on environment and natural resource, IT ethics issues, IT for Sustainability etc. In the findings, green SLA research divides its work based on basic SLA and then existing green SLA for various types of services from their providers. The existing theory and empirical work on basic SLA and green SLA is discussed in the following sections.

Literature Review

There are several works on basic SLA and green SLA for different services. Most of the researches regarding SLA were survey based on only one or two services. Some work has been done on modelling, monitoring or automating basic SLAs. There are very few specific works found only on Green SLA. Several specific papers are found regarding performance metric for distributed computing industry

(cloud and grid computing). Some researchers focus only on the importance of adopting Green issues including IT ethics in the ICT field.

Basic SLA:

Salman A. Baset [6] gave an idea for presenting SLA for different cloud service providers. He surveyed some well-known public IaaS providers and found a common anatomy of basic SLA with some common metrics. In [7], Hyo-Jin Lee *et al.* offered a general SLA monitoring system architecture that could be used to monitor service levels provided by some network, Internet and application service providers. Their work showed a much clearer idea of finding some QoS parameters, measurement metrics for various services. In contrast, Li-jie Jin *et al.* [8] presented another approach to model and understand the relationship between customers and some web service providers, which is very important for designing basic SLA and Green SLA. Adrian Paschke *et al.* contributed to a systematic categorization of basic SLA content with a particular focus on SLA metrics in IT industry [9]. They categorized five basic IT object classes and their performance indicators in SLA. Jani Lankinen *et al.* [10] surveyed security profiles of some existing well known storage service providers like Amazon, Apple iCloud, Dropbox etc. In [11], the paper presented SLA for voice and Internet services covering basic performance indicators.

Green SLA:

Klingert *et al.* [12] introduced the notion of Green SLAs. However, their work focused on indentifying known hardware and software techniques for reducing energy consumption and integrating green energy. In [4] and [5], the authors showed the impact of ICT in a natural environment and resources in this world. Zacharoula S. Andreopoulou [5] proposed a model ICT for Green and Sustainability whereas SMART 2020 report [4] gave the idea of GHG emission from the ICT sector. Gregor Von Laszewski *et al.* [13] invented a framework towards the inclusion of Green IT metrics for grids and cloud computing. According to Md. E. Haque *et al.* [14], high performance computing cloud providers offer a new class of green services in response to practicing explicit sustainability goals in their field. Robert R. Harmon *et al.* [15] defined the term Green Computing as the practice of maximizing the efficient use of computing resources to minimize environmental impact. They also discovered that, sustainable IT services require the integration of green computing practice such as power management, virtualization, cooling technology, recycling, electronic waste disposal and optimization of IT infrastructure. Finally, the white paper [16] provided some qualitative parameters in cloud service SLA which was very important for proposing Green SLA. In [17] and [18], the authors discussed one of the most promising concepts in Green SLA- IT Ethics issues. In their research, they showed the concepts of organizing ethics programs in IT industry.

Empirical Work Review

In the findings on existing empirical work, green SLA research splits its work based on basic SLA and then existing green SLA for various types of services from their providers such as Network, Compute, Storage and Multimedia [19]. In the basic SLA section, findings are divided into four main services as network, compute, storage and multimedia [19]. Most of the performance indicators in basic SLA sections were quantitative parameters and they were simple to evaluate, control and monitor.

Basic SLA for Network services:

Usually network services include connectivity and switching as well as advanced network systems and management functions for well-known network service providers. The basic SLA for network specifies service level commitments which are applied to measure and evaluate network performance and give proper support for all clients. Usually, from different network service providers, the following

performance indicators [7, 9, 11, 13] found in their SLAs are- *Network Availability, Delay, Latency, Packet Delivery Ratio, Jitter, Congestion, Flow Completion time, Response time, Bandwidth, Utilization, MTBF (Mean Time Between Failure), MTRS (Mean Time to Restore Services), Solution time, Resolution time, LAN/WAN period of operation, LAN/WAN Service Time, Internet access across Firewall, RAS (Remote Access Services).* Among these performance indicators, only *Internet access across Firewall* and *RAS* were subjective indicators- there is no standard procedure to evaluate or calculate these indicators. Some indicators like *Bandwidth, Utilization, and Congestion* are related to link capacity whereas *Availability*, *Delay, Jitter, Response Time* etc. are associated with time related information for different network service providers.

Basic SLA for Compute Services:

Most of the cloud and grid service companies provide computing service to their consumers.Recently, the Service Oriented Architecture (SOA)has also come into the computing field. The main point is that there is research on building middleware SLA infrastructure for computing services. Some of the current work: the European Union–funded Framework 7 research project, SLA@SOI, which is research on aspects of multi-level, multi-provider SLAs within service-oriented infrastructure and cloud computing [20]. The basic SLA parameter [9, 11, 13, 16] for computing services are- *Broad Network Accessibility, Multi-tenancy, Rapid Elasticity, Scalability, Resource Pooling Time, Solution Time, Response Time, Availability (MTBF & MTTR), Capacity, Virtualization, Delay, Resolution Time and Logging & Monitoring.* Here, *Broad Network Accessibility, Multi-tenancy* and *Logging & Monitoring* were informative indicators presented in their SLAs.

Basic SLA for Storage Services:

The storage services are typically handled by the cloud storage provider. Interestingly, today's cloud storage SLA just ensure uptime guarantee but not data availability and data protection. In some cases, traditional SLA just mention about data storage security and backup but there is no proper authority or standard to check their commitments. Some common basic SLA performance indicator [7, 9, 11] for storage services are as follows- *Availability, Response Time, Maximum Down Time, Uptime, Failure Frequency, Period of Operation, Service Time, Accessibility, Backup, Physical Storage Backup, Transportation for Backup, Size, Data Accessibility, Security.* Among all these parameters, some of them are just informative such as *Accessibility, Backup, Physical Storage Backup, Transportation for Backup,* and *Security.* These parameters might vary according to human perspective too.

Basic SLA for Multimedia Services:

Multimedia service SLAs are classified into three broad areas- Audio, Video and Data. It is challenging to monitor and evaluate some qualitative indicator such as *Mean Opinion Score (MOS)* and *Lip Synchronization* for one way video, conferencing or in videophone. These could be varied between different consumers at the same time. Most of the SLA indicators for multimedia services for different applications are *Information Loss (PLR), Jitter, One way Delay, MOS, Lip Synchronization, and Security Policy* [21].

Existing Green SLA:

Most of the green SLA performance indicators correspond to traditional high performance distributed computing environment such as grid and cloud computing. Currently, several IT industries and businesses provide their SLA with green computing practice. Green SLA surveys show that most of their green SLAs are mainly focused on energy/ power, carbon footprint, green energy, recycling

issues. Additionally, several existing green SLA also demonstrated their productivity issues with a necessary monitoring unit. Table 1 depicted the performance indicators and their unit for different services considering green computing practices. The table has several headings. *Green Computing Domain* is the category of green computing practices in IT industry; *Performance Indicator Name* is the notion which used an evaluating, monitoring metric for defining performance in green SLAs, and then their short definition in various industries as the *Description* column and finally the measurable unit as the *Unit* column. All these performance indicators help various service providers and consumers either to design or to choose services mainly with respect to energy consumption, renewable energy usages, carbon emission issues and productivity issues in recent days. Here, some data centres' performance evaluating metrics are also presented. *Data Centre Productivity* (*DCP)* [22], *Data Centre Energy Productivity* (*DCeP)* [13, 22] and *Heating, Ventilation, Air-conditioning* (*HVAC)* [23] indicators are still difficult to assess and control in some data centres' SLAs as they do not have any measuring units. The *Analysis Tool* and *EnergyBench* [15] used to inform about productivity in grid computing also do not have any measuring unit to evaluate or monitor in their SLAs. In some cases, *Carbon Usage Effectiveness* (*CUE)* and *Green Energy Co-efficient (GEC)* [22] consider only on usages stages but these indicators are closely associated with some other indicators such as *Recycling* [19, 24]*, e-Wastage* [24], *Energy Cost* [25]*, and Total Power Consumption* [25]. Some of these performance indicators need to be defined newly and precisely and should state in their green SLAs according to government laws and standard. Some indicators could not be generalized as traditional green computing practices. Therefore, they just categorized as "others" in the tables.

Table 1. Performance Indicator for different services considering existing green SLA

Sl. No.	Green Computing Domain	Performance Indicator Name	Description	Unit
1.	**Energy/ Power**	Total Power Consumption [15, 25]	Amount of total energy consumed while providing services;	kW-h (Kilowatt-hour)
2.		PUE (Power Usages Effectiveness) [13, 19, 22, 23]	Fraction of total energy consumed by the service of a data centre to the total energy consumed by IT equipments;	Number (1.0 to ∞) Or Dimensionless
3.		DCiE (Data Center Infrastructure Efficiency) [13, 20, 23]	To calculate the energy efficiency of a data centre;	% (Percentage)
4.		CPE (Compute Power Efficiency) [22]	Total amount of power needed for computing;	Watts
5.		SPECPower [13, 22]	Power consumption per server on a given workload to complete;	Watt
6.		JouleSort [15]	Amount of energy required to sort different size of records in data centre;	kW/J (Kilowatt per Joule)
7.		WUE (Water Usages Effectiveness) [22]	Ratio of the annual water usages to the IT equipment energy;	Liter/kW-h

8.		TDP (Thermal Design Power) [23]	Maximum amount of heat generated for which the cooling system is required;	Watts
9.		ERF (Energy Reuse Factor) [22]	Amount of reusable energy like hydro, solar, wind power etc used outside of a data center;	Number [0 to 1.0]
10.		ERE (Energy Reuse Effectiveness) [22]	Measuring the profit of reusing energy from a data center;	Number [0 to ∞]
11.		GEC (Green Energy Co-efficient) [22]	Amount of green energy used to provide services in green grid computing usually on usage stages;	Number [0 to 1.0]
12.		ITEE (IT Equipment Energy Efficiency) [26]	Ratio between IT equipment used and their energy consumption;	% (Percentage)
13.		ITEU (IT Equipment Utilization) [26]	Ratio between total energy (kWh) of all IT equipment and their total energy specification (Power rating in kWh);	Number
14.		HVAC (Heating, Ventilation, Air-conditioning) Effectiveness [23]	Ratio between the IT equipment energy to the HVAC system energy;	Dimensionless
15.		Cooling System Efficiency [23]	Characterizes the overall efficiency of the cooling system (including chillers, pumps, and cooling towers) in terms of energy input per unit of cooling output;	kW/ton (kilowatt per ton)
Sl. No.	**Green Computing Domain**	**Performance Indicator Name**	**Description**	**Unit**
1.	**Carbon footprint**	CUE(Carbon Usages Effectiveness) [22]	Calculation of greenhouse gases (CO2, CH4) release in atmosphere usually on usage level;	KgCO2 per kW-h
2.		DPPE (Data Center Performance Per Energy)[26]	Ratio between Data center's throughput (work) by carbon energy;	Number [0 to 1]
1.	**Recycling**	e-Wastage Or IT Wastage [23]	Amount of IT wastages per product, services, process, facility or even the whole industry;	Gm (Gram)
2.		Recycling [19, 24]	Percentages of IT equipment to be recycled at a given specified time period;	% (Percentage)
1.		DCP (Data Center Productivity) [22]	To calculate the amount of useful work done by data centre;	Not Available

2.	**Productivity**	DCeP (Data Center Energy Productivity) [13, 22]	Quantifies useful work compared to the energy it requires; it can be calculated for an individual IT device or a cluster of computing equipment;	Not Available
3.		Analysis Tool[15]	Performance per watt in green grid computing;	Not Known
4.		EnergyBench [15]	Throughput of work per Joule for computing;	Numeral Rating
5.		ScE (Server Compute Efficiency) [22]	To find the specific server's computing efficiency (Server Health);	% (Percentage)
1.	**Costing Information**	Energy/Power Cost [25]	Cost of power consumed per kilowatts hour used including renewable energy cost;	Currency [according to law]
1.	**Others**	SWaP (Space, Wattage and Performance) [13, 22]	Ratio between performance and space x watts;	Not Available
2.		User Satisfaction [11,13]	Satisfaction level of a user while getting services;	Number [0 to 5]
3.		Mean Opinion Score (MOS) [11,13, 27]	Human's view for measuring the quality of a network; specially for audio and video;	Number [1 to 5]
4.		Reliability [13]	Service delivery to the intended user without interruption;	Number [0.0 to 1.0]
5.		Air Management Metric [23]	Finding the difference between the supply and return air temperature in some data centre;	F (Fahrenheit)
6.		UPS System Efficiency [23]	Ratio of the UPS output power to the UPS input power;	% (Percentage)
7.		Risk Assessment [11, 13]	Percentage of systems are involved in security threat; very few SLA mentioned it;	% (Percentage)

RESULTS AND CONTRIBUTIONS

In existing green SLAs, most of the performance indicators mainly focused on energy consumption issues and productivity concern in cloud and grid computing industries (Table 1). Most of them did not consider recycling, radio wave, toxic material usage, noise, light pollution for sustainable development. Moreover, people's interaction and IT ethics issues, such as user satisfaction, intellectual property rights, user reliability, confidentiality etc. are also missing in current green SLA. The next section discusses the proposed performance indicators of green SLA for achieving sustainability from the 3Es perspectives (Ecological, Economical and Ethical). Figure. 1 shows the concepts of 3Es relationship, that an ICT engineer can use as a guideline to respect all the facets of sustainable development. The following tables explain each of the performance indicators and their measurable unit for proposing new green SLA.

Figure 1. 3Es for Sustainability

Ecological Point

Recycling- The recycling of ICT equipment impose into their whole life cycle. This is a very complex indicator and needs to be sub-divided as reuse, refurbish, sub-cycling and up-cycling. According to [19, 24], the Recyclability Rate of an equipment ranges from 0 to 1. Again, at each stage of recycling, it needs to consider the *CUE, GEC, Energy Cost* (Table 1) because recyclability includes energy consumption and carbon emission simultaneously. Recycling information should be put into green SLA according to government laws, directives such as Waste Electrical and Electronic Equipment (WEEE) Directive (2012/19/EU) by European Union (EU). There are also some voluntary recycler standards in US like e-Steward and Responsible Recycling (R2) Practices.

Toxic Material Information- Electric and Electronic products contain several toxic materials such as Beryllium, Cadmium, Lead, and Mercury etc. These chemical elements and their compound both cause serious health hazards and also make the environment polluted. Beryllium is used in manufacturing computer motherboards and is acutely and chronically toxic to humans, mainly affecting their lungs [28]. Cadmium and its compounds is used in some switches, many laptop's batteries and in some older CRTs monitors as phosphor coating. These materials and their compounds are also toxic to humans, affecting kidneys in the long run [28]. Lead is usually used for primary electric solder on printed circuit boards. Lead could damage to the nervous system and blood system in human body [28] and also causes severe air pollution. In some switching devices and batteries, mercury could be used which is highly toxic. Mercury has a high level impact on human nervous system [28]. All these toxic materials should have a safety limit which need to be defined or restricted by a third party or governing body such as Directive on the Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment (2002/95/EC) from the EU, commonly known as RoHS Directive. The information about the usage of these toxic materials in IT and ICT field should be stated clearly for making SLA greener.

Obsolescence Indication- The services, process, product or technology used or produced by a company for profit will become obsolete after certain period. Therefore, it is a matter of urgency in ICT industry to indicate or label product's life time with obsolescence indicators [29] according to the product's raw materials' scarcity, demands, usages limit etc. at different stage of product's life cycle. These indicators should be stated in a proposed green SLA to create awareness for both customer levels and company levels for achieving sustainability. It might be complex to indicate or determine the obsolescence of ICT equipment because it depends on different variables associated with equipment's production cost, raw material scarcity, energy issues and user's interaction. Additionally, Optimum Obsolescence [30] indication would help to decide when an ICT equipment product needs to be reused, recycled or land filled. There is no standard to indicate this parameter in SLAs until now but it might be related to product life cycle costingand recyclability rate indicators.

Radio Wave Information- The electromagnetic radiation emitted by electronic equipment in IT industry, is a controversial topic in the scientific community. The health effects of radio waves were intensively studied and most of these studies found that the EMF (electromagnetic field) is thermal

and also associated with frequency ranges and energy [19]. These radiations might cause severe health hazards such as brain cancer, heart diseases and even leukaemia. To avoid this electromagnetic effect, the government of each country defines the maximum level of EMF generated by wireless antenna and their maximum *Specific Absorption Rate (SAR)* value [19]. The EMF levels and safety [according to SCANTECH, Australia] use the following measuring units- *Gauss (G), Tesla (T)* for EMF values; *Gray (Gy)* and *Sievert (Sv)* for measuring radiation effects on human tissues. This radio wave information should be stated in the green SLA according to government's defined level clearly and precisely.

Noise Pollution- The network engineer who works in a data centre might need guidelines and regulations to control noise pollution in his/her workplace. The noise generated from a data centre causes hearing loss permanently [31]. OSHA and NIOSH- these two US government agencies look after the limit of noise level in work places. The noise pollution level might be stated on a green SLA using adecibel (dB) measuring unit. Moreover, the noise created by ICT equipment such as the ringtone of a cell phone might also responsible for some sort of pollution as it can become disturbing and irritating for other people. This type of pollution might be subjective and easily prevented by increasing awareness among the cell phone users.

Visual Pollution- The aesthetic aspects of ICT industry, for example- installing an antenna in a beautiful landscape or on a roof top. This could create the hypersensitivity affect [19] and these might be very much subjective to each human being, such as the Perception of Affective Quality (PAQ) [32] is an individual's perception of an object's ability to change his/her neurophysiological states as feeling either good or bad.

Light Pollution- Computer screens generate light pollution affecting health [19]. According to the American Optometric Association, Computer Vision Syndrome (CVS) causes headache, blur, dry eye, eyestrain, sleep disorder etc. The safe computing practice and awareness might help to decrease CVS. There is still no standard or measurable unit for light pollution level but it should be mentioned in proposed green SLA.

The next Table 2 demonstrates the proposed green SLA from ecological point of view and their proposed measurable units.

Table 2. Green SLA proposal considering the Ecology pillar for sustainability

Sl. NO.	Performance Indicator Name		Description	Domain	Unit
1.	Recycling Rate (RR)	Reuse	Amount of ICT product reuse/ percentage of ICT equipment refurbished/ percentage of IT equipment sub cycled or up cycling;	Network, Multimedia, Compute, Storage	gm (gram) OR % (Percentage) OR RR[0~1] [19]
		Refurbish			
		Sub cycling			
2.	Toxic material limit/ Toxic material Usage Level		Information about using toxic material in ICT products and their limit level;	Network, Multimedia, Compute, Storage	Preferred/ Acceptable
3.	Obsolescence Indication		Indication about the perfect time to change ICT equipment;	Network, Compute, Storage,	Labeling according to laws

4.	EMF Level/ Radiation Effect Level	Amount of electromagnetic energy radiation; usually the strength is measured by frequency;	Network, Multimedia, Compute, Storage	T (Tesla) / G (Gauss) OR Sv (Sievert) / Gy (Gray)
5.	Noise Pollution Level	The noise emitted from ICT equipment e.g. ringtone of Cell phone, noise in data centre;	Network, Multimedia,	µdB/dB (micro decibels)
6.	Visual Pollution Level	The aesthetic aspect of ICT industry e.g. installing an antenna in a beautiful landscape or roof top;	Network, Multimedia, Compute, Storage	Subjective OR *PAQ* [31]
7.	Light Pollution Level	The light pollution generated by ICT equipment e.g. Computer Screen;	Network, Multimedia, Compute, Storage	Subjective

Economical Point

Carbon Taxation- A number of countries have implemented carbon taxes [33] or energy taxes and *Cap and Trade System* [34] that is very effective to reduce Green House Gas (GHG) emissions while stimulating technological innovation and economic growth. The taxation may create political or social unrest in some countries; therefore it may be difficult to impose. In the 1990s, a carbon/energy tax was proposed at the EU level but failed due to industrial lobbying, but in 2010 the European Commission implemented a pan-European minimum tax on pollution under the European Union Greenhouse Gas Emissions Trading Scheme (EU ETS) [33] which is quite successful. According to this new plan, 4 to 30 euro would be charged per tonne of carbon emission. On the other hand, in US, the *Cap and Trade* gave more assurance to decline GHG emission and also have some political advantages [34]. Therefore, according to different countries' economic, social or political culture, carbon taxation or *Cap and Trade* policy should need to be established and this information needs to put in a green SLA.

Building Design Cost- Information for designing cost, manufacturing cost, renovation cost and finally dismantling cost of a data centre should also be included in the proposed green SLA. The cost of building design indicator also associated with carbon emission indicators in each steps. Therefore, it might not be difficult to assess and monitor.

Cooling Cost- The cooling system costing information needs to be mentioned in the proposed green SLA. It includes energy (electric power, renewable energy) costing, infrastructure (humidity, temperature monitoring) and transportation costing for cooling the whole site. This indicator becomes complicated because of *HVAC, Air Management Metric* and *Cooling System Efficiency* indicators in existing green SLA (Table 1) and these might need to be newly defined. Moreover, carbon emissions also need to assess the transportation of cooling equipment for the sites.

ICT Product Cost- ICT product costing considers the whole life cycle of a product such as manufacturing from raw materials, transportation, usages and dismantling. This indicator is also associated with the carbon emission indicator from existing green SLA. Additionally, recycling indicators also pose a concern when dismantling a product is considered. The Life Cycle Assessment LCA [35] needs to be considered in this parameter. ICT Product Cost indicators thus become very complex to assess and monitor in green SLA.

Table 3 shows the economic performance indicators and their measuring unit for evaluating proposed green SLA.

Table 3. Green SLA proposal considering the Economic pillar for sustainability

Sl. NO.	Performance Indicator Name		Description	Domain	Unit
1.	Carbon Tax		Tax for carbon content on fuel in most cases; this should be charged according to government laws;	Network, Multimedia, Compute, Storage	Currency (dollar)
2.	Building Design Cost		Information about an energy efficient building infrastructure and their costing including dismantling;	Network, Multimedia, Compute, Storage	Currency (dollar)
3.	Cooling Cost		Amount of cooling cost in a data center or percentages of renewable energy usage for cooling;	Network, Multimedia, Compute, Storage	Currency (dollar)
4.	ICT Product Cost	Manufacturing	Considering the life cycle assessment of an ICT product and their costing;	Network, Multimedia, Compute, Storage,	Currency (dollar)
		Transportation			
		Usage			
		Dismantling			

Ethical Point

Mostly, the green computing practice focuses on the ecological and economical point but usually neglect humans' interaction and ethical aspects [19]. The use of ethics in IT and ICT field covers many indicators such as *Satisfaction level, Intellectual Property Right, Reliability, Confidentiality, Security and Privacy, Gender/Salary/Productivity Information.* All of these indicators are usually subjective metrics, thus making green SLA assessment difficult. The ICT Company should analyze social responsibilities towards *Customers, Employee and Community* [19, 36]. Table 4 gives the idea of these responsibilities as performance indicators with respect to ethics for greening SLA to achieve sustainability.

Table 4. Green SLA proposal consider Ethics pillar for sustainability

Sl. NO.	Performance Indicator Name	Description	Domain	Unit
1.	Satisfaction level [Customer, Employee, Community]	Whether the customer, employee and community are satisfied with; [usually defined by third party or community]	Network, Compute, Storage	Rating OR *CSI* [37]
2.	Intellectual Property Right [Customer, Employee, Community]	IPR means copyright, patents of users' data; no hacking; royalty etc.	Network, Multimedia, Compute, Storage	YES/NO
3.	User Reliability	Whether customer reliability preserved by the company; reliability between employee and company;	Network, Multimedia, Compute, Storage	Rating
4.	Confidentiality	Information should be kept confidentially and also available for	Network, Multimedia,	Rating

			customer, employee or for community;	Compute, Storage	
5.	Security & Privacy	Authentication & Authorization	Rules regarding security and privacy should clearly be stated and defined or not; usually it could be defined third party or government law.	Network, Multimedia, Compute, Storage	High / Medium / Low OR Preferred/ Acceptable
		Access Control & Privilege Management			
		Data Geographic			
		Data Integrity			
		Transparency			
		Physical Security			
		Termination Management			
6.	Gender Balance Information		The information about gender balance in an organization;	Network, Compute, Storage	YES/NO
7.	Salary Balance Information		The salary balance of an organization in IT industry;	Network, Compute, Storage	YES/NO

CONCLUSION

This green SLA research surveyed different basic SLA parameters for network, compute, storage and multimedia services in IT and ICT business arena. The research review section demonstrated most of the basic SLA performance indicators and their measurable unit but did not cover any eco-efficient green computing practice. On the other hand existing green SLA covered most of the current green metrics and their measurable unit which are presented using Table 1 in different computing industry. Additionally, Table 1 also showed today's concerns were mainly on energy issues and productivity through the greening lens. Missing performance indicators and their influences on green SLA with respect to 3Es were discussed in the results and contributions section. Table 2 to Table 4 lists all proposed performance indicators and their measurable units. Parameters suggested for making SLA greener may cause some challenges in future. For example, new green SLA might be too complex to assess, control or monitor; some performance indicators need to be defined accurately, which has association with other indicators; most of the subjective, qualitative indicators related with ethics issues need to be standardisation or governed and authorized by proper laws and directives. Moreover, it is very important to mention here that the defintion of Green SLA is crucial in development of Green ICT solutions and requires a long time to be standardised. The standardisation of green indicators is the main issue as mentioned by the ITU-T report (2012). Sometimes it is difficult for an ICT engineer to respect all the performance indicators mentioned in basic SLA and the ones in green SLA. In this regard, some models should be developed to help ICT engineers to mitigate the complexity of managing all the indicators and their interactions in green SLA and thus the proposed green SLA would be realistic for consumers in a short time. However, this research would provide a new dimension and strategy for well-known service providers to achieve a win-win situation with their consumers for achieving sustainability in the near future.

Acknowledgements

This research was fully supported and funded by *PERCCOM Erasmus Mundus Program* of European Union. The authors would also like to show their gratitude and thanks to all the partner institutions, sponsors and researchers of PERCCOM program.

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Sustainable Resources and Policy

Education

EFFECTIVE WEB-BASED ENGINEERING AND TECHNOLOGY CURRICULUM FOR RURAL HIGH SCHOOLS

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Keywords: Web-based, curriculum, online, quality, effective, rural, engineering, technology, high school, secondary education.

Abstract

Rural high schools have traditionally lacked access to the most up-to-date engineering and technology curriculum and teaching resources. Recently, the use of communication technology has allowed improved access to engineering and technology teaching and learning resources where they would otherwise not be available. With relatively standard technology and limited travel requirements, recent developments have enabled changes to curriculum delivery that should not only provide materials but significantly improve the teaching and learning experience. However, the effectiveness of these new media and teaching practices at improving learning outcomes remains an unanswered question.

In order to evaluate the effectiveness of a novel, web-based technology education program, Southern Utah University developed a pilot, the Technology Intensive Concurrent Enrollment (TICE) 1010 course. The course, initially taught to 23 students at Gunnison High School, was implemented Fall Semester 2013. There were three main objectives to the pilot program. The first objective was to test the newly developed curriculum. The second objective was to evaluate synchronous team teaching to a rural high school using video conferencing software. The third objective was to determine if the delivery of the curriculum was effective from the students, instructors and stakeholders' perspective.

"A Guide to Quality in Online Learning" (Butcher & Wilson-Strydom, 2012) was used as the curriculum developmental framework. Quality Matters (QM) provided scoring rubric and pedagogic theory. Additionally, both "Double Loop Learning" (Batista, 2006) and "Online Community of Inquiry theory" (Garrison, 2007) influenced the pedagogic approach.

The pilot program was evaluated using a peer review, with critique and incremental observation provided by students, instructors and stakeholders (administrators). The triple perspective from students, educators and administrators helped to triangulate and broadly measure what was considered effective and where further development was needed. The instruments and processes used to collect the data are presented and discussed, as are the initial analysis and results.

The information in this paper will provide the background and context to the research process and a review of the literature. It will also discuss how the literature was applied to develop the web-based curriculum, and will provide a brief insight into the data collected from the pilot courses. Next, the existing literature will be compared to the data that was collected. The last part of this paper will be used to discuss the future direction of the TICE program.

Cozzens, R. (2015) **Effective web-based engineering and technology curriculum for rural high schools** *In;* Gorse, C and Dastbaz, M (Eds) *International SEEDS Conference,* 17 – 18 September 2015, Leeds Beckett University UK, Sustainable Ecological Engineering Design for Society.

1.0 Introduction

Engineering and technology programs in rural high schools have always struggled (Howley et al, 2012). Some of the main challenges are discussed below. There are several barriers to delivery of appropriate technology and engineering content in rural high schools. One barrier is the small numbers of students available for recruitment into engineering and technology programs. Another challenge for rural educators includes the breadth of their teaching loads. It is not uncommon to find educators delivering five different subjects (Howley et al, 2012). With such teaching loads, it is difficult to maintain a level of expertise or certification for all subject areas. Additionally, the cost for maintaining a technology lab and keeping a certified instructor can be prohibitive, especially when considering the small size of many rural technology programs. Such challenges can prevent high school students from having the same engineering and technology learning opportunities that are provided in more densely populated urban areas.

In order to address the unique needs of rural high schools, SUU (Southern Utah University) has piloted and is now offering a web-based engineering and technology course. The course is offered as concurrent enrollment. High school students receive both college and high school credit for the course. There are several different delivery methods for this course: online, hybrid, and a supplement for face-to-face.

The course applies pre-prepared, web-based curriculum, concurrent college credit, professor remote classroom support, and remote training workshops via GoToMeeting, a multimedia video conferencing platform. This novel program now offers students in rural high schools similar engineering and technology learning opportunities as students in larger metropolitan areas.

1.1 Overview of this Research

This research started with the publication of the first CATIA V5 (Computer Aided Three Dimensional Interactive Application). The CATIA V5 Workbook was first developed in 2001. CATIA V5 is software used in the design work in the automotive industry as well as the aerospace industry. The first web-based CATIA V5 Workbook Website was published in the year 2003. Data regarding the effectiveness of these workbooks in improving student learning has been collected for 14 years. The lessons learned from these data have been applied to the university engineering and technology curriculum at SUU, and were also used in the development of the pilot TICE curriculum. To date, international papers and presentations regarding this web-based engineering and technology curriculum have been published (publications listed in Appendix A). The following information provides a more detailed outline of each research phase.

1.2 Phase I

The original research on web-based engineering and technology curriculum started in 2001 with the publication of the CATIA V5 Workbook. The motivation was to provide more CATIA V5 solid modeling training to practitioners around the world remotely, eliminating the cost of time and travel while increasing the knowledge and skills of educators. This prompted the development of the CATIA V5 Workbook website, which at one time had up to 2,000 subscribers from around the world. Data was collected from the subscribers which were used to make improvements to the website and content.

1.3 Phase II

The data obtained in the initial research phase were applied to the engineering and technology curriculum at SUU. Additionally, SUU offered concurrent college credit to high schools within the region. A majority of the region consisted of small rural high schools in which engineering and technology programs were in jeopardy of being shut down (Means et al, 2014). To promote the growth of engineering and technology curriculum, the State of Utah Education System provided an opportunity for grant aid in the development of STEM (Science Technology Engineering and Mathematics) curriculum. The grant was called TICE (Technology Intensive Concurrent Enrollment). SUU took the lead on this grant opportunity by leading a state-wide team to develop a web-based engineering and technology curriculum. Data obtained in Phase I of the project was coupled with the concepts from the Quality Matters (QM) (Butcher & Wilson-Strydom, 2012). Collectively, this provided the theoretical framework Community of Inquiry (reference Literature Review). The course was titled Introduction to Engineering and Technical Design (IETD) and was developed during the 2012-2013 academic year.

1.4 Phase III

The IETD course was piloted by 13 different high schools across the state of Utah during the 2013-2014 academic year. The pilot consisted of three different delivery methods, as shown in Table 1.

Table 1:

Delivery Method	Number of Schools
High school instructor	10
High school instructor led with support by SUU Faculty (using GoToMeeting)	2
Online Independent	1

SUU also offered the IEDT class as a face-to-face college course to freshman attending SUU. The data collected from these classes was used by Utah System of Education (USOE) to evaluate the course, and was then applied to the Double Loop Learning Theory to improve the curriculum (Argyris, 2011). The updated course was available across the state of Utah in the 2014 Fall Semester, where 26 different high schools taught the IEDT curriculum. Again, data was collected from these courses and used to improve it in the next phase.

1.5 Contributions of this Research

Generally, the contribution of this research could not only help preserve the existing engineering and technology programs in rural high schools, but could also provide the avenue to developing new programs. This Utah-specific data could be extrapolated nationally, with many remote schools throughout the nation benefitting from these findings (Cozzens, 2013). Specifically, this research focuses on the following objectives:

1. Define effective web-based engineering and technology curriculum through the collection of multiple experienced-based perspectives.

2. Determine the factors and components that contribute to the effectiveness of a web-based engineering and technology curriculum. Data was obtained from Double Loop Learning Theory, a literature review on web-based technology curriculum development in rural secondary education, and the pilot IEDT course. From these sources, factors contributing to the effectiveness of curriculum delivery were identified (Batista, 2006). Previous studies did not clarify what factors or components contribute to the effectiveness of a web-based engineering and technology curriculum.

3. Develop a pragmatic framework to define a standard for effective web-based engineering and technology curriculum. Frameworks for defining standards exist in other areas of study, but there is not an accepted standard in the engineering and technology area that specifically applies to web-based curriculum. The U.S. Department of Education in their report stated that when making decisions on effective curriculum, educators need to keep in mind the different types of students and the different subjects, in this case, engineering and technology (Means, 2014) .

1.6 Summary of the Research History

The TICE grant has provided the state of Utah the opportunity to assist in achieving the objectives in Governor Herbert's Educational Plan (Kearl, 2010). Globally, Governor Herbert's plan aims to meet employer needs and improve the economic status of individuals by training 66% of the population of Utah to obtain either a board approved certificate, Associate's degree, Bachelor's degree or Master's Degree by the year 2020. This research fulfills the following objectives outlined in the PACE plan.

1. Reach young students.
2. Provide STEM (particularly engineering and technology) -related curriculum to small rural schools (providing access to all students).
3. Help students complete a degree by receiving concurrent high school and college credit.

On a much larger scale, the contribution of this research could not only help preserve the existing engineering and technology programs in the state of Utah, but provide the avenue to starting new programs, particularly in rural high schools. There are numerous rural schools throughout the nation that could benefit from these findings especially with the dwindling resources.

2.0 Literature Review and Implementation of Theory into Curriculum

Because web-based education was such a newly emerging educational platform in the early stages of this project, identifying and implementing the best standards for web-based teaching and learning was a critical component to the success of this project. The educational frameworks used in developing the curriculum for TICE were the "Ten Steps to Effective Web-Based Learning" (Cook & Dupras , 2004), a variation of Quality Matters (Butcher & Wilson-Strydom, 2012) and Khans E-Learning Framework (Kahn, n.d.). Collectively, these accepted standards were used to gauge the quality of the curriculum.

The focus of the current research phase has shifted from frameworks and standards to evaluation of the student-teacher interaction. Feedback is obtained from the students, instructors and stakeholders. Because of this shift, a review of the literature surrounding learning styles and strategies is in order. According to Harriman (2011), the key to designing curriculum that best promotes learning involves assuring that the instruction and the delivery mechanism congruently meet the needs of the student. Before being able to meet the needs of the students, the instructor must know and understand student needs. Because there are many various learning styles, the TICE curriculum has implemented a free and easily accessible survey known as the Visual, Aural, Reading & Writing, Kinesthetic (VARK) assessment tool (Cherry, 2014).

The curriculum has also incorporated the Community of Enquiry Framework by which students' transition from passive learning to empowered, active learning by which they produce inspired work. An effective course requires the learners to be engaged and active in the learning process and incorporating this theory into the curriculum will help facilitate the effectiveness of the course (Garrison, 2007).

Tawfeek stated that students sometimes feel isolated and cannot work without constant guidance (Tawfeek, 2014). He (or she) also stated that a majority of online students need to be extrinsically motivated. In face-to-face classes, the direct interaction with the instructor and consistent assignments are generally enough to motivate students. Everson (2009) developed a community of learners to help provide them with opportunities to learn from each other, share their findings, and become involved with their fellow students. A sense of community is more likely to motivate students to succeed.

From the literature review, it becomes clear that online courses will not provide a successful learning platform for every student. Because learning styles vary widely, it is critical to know and understand what the student is bringing to the class in the form of foundational knowledge, learning skills, and learning style of each individual to determine whether online learning will be successful. It has been explained, "To succeed in autonomous online learning environments, it helps to be a highly motivated, self-regulated learner" (Artino, 2009).

Massey's (2014) research for Cengage Learning showed that students using online and digital content improved their academic performance by 52%. The same research showed that the students were also significantly more engaged because of the content included in the course.

These are main theoretical concepts that have been implemented into the IEDT curriculum based on the literature review. There are many studies that discuss the importance of online curriculum standards, such as Khans Framework and QM's scoring rubric. The gap in the existing literature is how to apply this quality to the theory of the Community of Enquiry (Garrison, 2007) to make the course effective. This is why the students' motivation, background and opinion is so critical.

3.0 Methodology

3.1 The Process

The data was collected using action research which is a specific variation of Evaluation Research. McMillan and Schumacher (McMillan, 2001) state "Evaluation Research focuses on a particular practice at a given site(s). The practice may be a program, a product, or a process" In this research, the product is web-based engineering and technology curriculum. Action Research is specific to education and learning using web-based technology and applying it to the engineering and technology curriculum. Even though Action Research is often mentioned as lacking a distinct theoretical base, it is a powerful tool in stimulating social change and exploring how to modify a situation or practice. Ferrance's (2000) definition of Action Research is, "It is a reflective process that allows for inquiry and discussion as components of the "research." Often, action research is a collaborative activity among colleagues searching for solutions to everyday, real problems experienced in schools, or looking for ways to improve instruction and increase student achievement". The information learned from Phase I and Phase II of this research has been implemented (Ferrance, 2000).

Since triangulation can enhance the accuracy of the data, it has been applied to this research. The original concept of triangulation was developed by Denzin (1978). He points out in his paper the term triangulation has also been called mixed methods, multi-methods and multi-strategy. The original definition is not just the combining of qualitative and quantitative methods in studying the same research phenomenon, but is clarified by Hussein (2009) as he states: "Triangulation is to be more precise as it aims to reveal complementarity, convergence and dissonance among the findings". Triangulation is known to strengthen action research and enhances the accuracy of the data by collecting data from at least three different sources. Murphy (2011) uses John Godfrey Saxe's parable of the Three Blind Men and the Elephant. The three blind men are using touch to describe the elephant

resulting with each description being different, yet still correct. To get the totality of truth, all three viewpoints must be considered. This is very similar to using triangulation in Action Research because it allows for the gathering of various view points from several different sources.

3.2 Continuous Improvement

In Phase I, the goal was to find the most efficient method of delivering CAD training to practitioners. In the beginning, the only method available was through the workbook, but eventually access to the online (web-based) training on the CATIA V5 Workbook Website allowed web-based learning to be an option. The Phase II goal was to apply lessons learned from Phase I as well as implement the frameworks and theories learned from the literature review to develop a quality web-based introductory engineering and technology curriculum for USOE (Utah State Office of Education) under the TICE Program. The goal of Phase III is to collect and apply the data from the pilot courses to improve the course and verify that it is not only a high quality curriculum but also an effective one from the perspective of the student, instructor, and stakeholders.

4.0 Collected Data

The focus of this research was to define what makes effective engineering and technology curriculum and determine how it can efficiently be delivered to rural high schools. The reason this is important is as Badjou & Dahmani , (n.d.) stated "…the need to develop online science and engineering programs is both pressing and crucial." Even though it is pressing and critical, it needs to be effective, it needs to have the components and factors that make it effective, and how to implement it in the most effective manner. The IEDT curriculum has already received the quality stamp from Southern Utah University Online Quality Review Board using a variation on QM rubric.

The teachers were interviewed using semi-structured interview questions as well as survey questions using Surveymonkey.

4.1 What is Quality web-based engineering and technology curriculum?

The first part of research question one, asks: What is effective engineering and technology curriculum? To answer this question, six instructors that attended the UACTE Midwinter Conference in February 2015 and also taught the IEDT course were interviewed. In the interview they were asked numerous questions, but the questions listed below addressed the definition of effective engineering and technology curriculum.

The first question was, "In reference to online engineering and technology curriculum what is the difference between 'quality' and 'effective'"? The responses were as follows:

- They are the same.
- Quality can take time. Effective can take less time.
- I would say a course to be effective has to have quality. They go "hand in hand".
- Quality is having the right materials available and effective is if the students will engage.
- Quality provides flexibility for the instructor with resources and support materials. Effective covers the objects but may not inspire the student to want to learn more.

- Available resources determine quality retention by dealing with content in multiple ways determines effectiveness.

The second question was, “In your opinion, what is effective web-based engineering and technology curriculum?” Their responses are listed below.

- Curriculum that has "need to know information" that can be easily accessed and processed back for assessment.
- Has a lot of useful information.
- A curriculum that covers and answers all questions.
- Having the information outlined that can lead the students to the objectives and goals for the course.
- A course that gives students the tools and knowledge to see future application beyond the course. To have the desire to apply what they learn to projects of their own design.
- Latest technology, consistency in content, ability to navigate information and find all relevant information, and pathway to build on skills in sequential manner.

The third question was used to determine what the instructors thought the administration considered to be effective web-based engineering and technology curriculum. The question was, “In your opinion, how does your administrative stakeholder define an effective web-based engineering and technology curriculum?”

- Anything they don't have to deal with, but that gets the job done.
- No idea.
- Yes, they hold the "purse strings" and control the development of new processes.
- They want to see college credit or certificates if possible.
- High Test Scores.
- If it is fun and engaging

The fourth question was used to determine what the instructors thought the students considered to be quality engineering and technology curriculum. The question was, “In your opinion, how do students define an effective web-based engineering and technology curriculum?”

- Doable.
- Students care about how easy it is to use. If they can find things fast and easy to maneuver, I think they will define it as a quality web-based curriculum.
- One that answers all their questions and meet their individual needs.
- They want a course that is fun and challenging, not overly rigorous.
- They look forward to experiencing the content.
- If they pass the final examination.

The fifth question was used to determine if the instructors were aware of any standard or framework. The question was, “What standard or framework do you use to determine the quality of an online or hybrid engineering and technology curriculum?”

- The TICE courses are well designed and the support is excellent.
- Material presentation follows a specific path.
- Are the students able to reach the objectives and goals? Also, it must attract others to the course.
- If there is enough information to provide the start and middle of a project. The instructor provides the finish. There should be foundational information that can be autonomously learned by the student.
- Checklists available through online department or Chico state checklist

The sixth question was used to determine if the instructors were aware of any quality standard used at the school. The question was, “What standard or framework does your school use to determine the quality of a web-base or hybrid engineering and technology curriculum?”

- My school doesn't have a clue and is only involved to a point where they trust that if the University is involved, then it must work.
- No idea.
- ??
- Can the students do something with the things they have learned?
- None that I am aware of.
- Review through canvas or online teaching department

The seventh question was used to determine if the instructors thought that the IEDT curriculum that they taught was a quality engineering and technology curriculum. The question was, “In your opinion is the IEDT curriculum, an effective engineering and technology curriculum (please justify your answer)?”

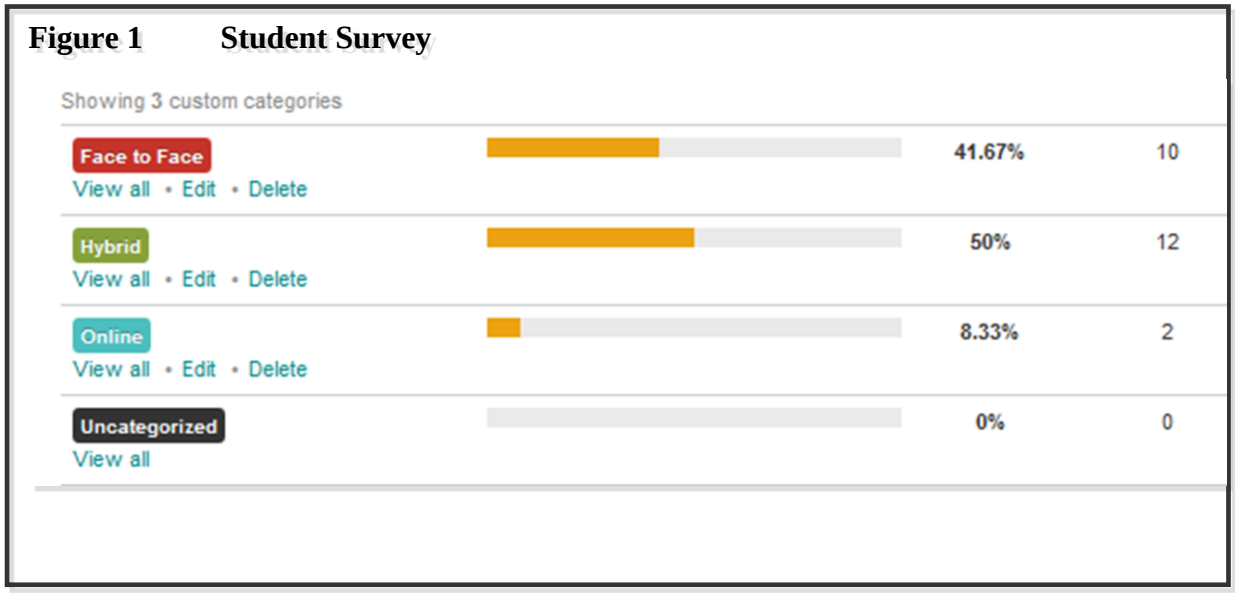
- Yes.
- Close enough. Sometimes things don't work such as pictures.
- Yes it is, the course contains all the information and materials needed by the student to be successful.
- This is my first experience with canvas but it has flowed pretty well and the students are learning.
- I feel that it is, there may be more content than needed, but it is there and gives the instructor autonomy to use what they desire. Like a text, they choose the chapters to teach, which to skim, and which to not cover. Students can develop a passion for the content with the materials provided.
- Yes

4.2 How can Quality Web-Based Engineering and Technology Curriculum Effectively be delivered to Rural High Schools?

This is the second part of research question one. The previous section provided insight on how the instructors define quality web-based engineering and technology curriculum.

To answer this question a survey was given to the administrators, instructors and students of the schools that took the IEDT course Fall Semester 2014. The class was offered using three different formats. The formats and number of students experiencing each delivery format is listed in Figure 1. The first delivery format was face-to-face with the curriculum on Canvas as a supplement to the class. The second delivery format was a hybrid with team teaching between the high school instructor and the university instructor. The university instructor used Gotomeeting to teach selected modules of the curriculum. The third delivery format was online. Two students took the course online on their own with the exception of three presentations using GoTomeeting by the university instructor.

Figure 1 Student Survey



4.3 Student Surveys

The following is the data collected from the students. The data in Figure 1 represents how many students took the course using either face-to-face, hybrid or online. There were several metrics used to measure the effectiveness of course in terms of students. Those metrics are listed in the Table 2 shown below and compared to the different delivery formats.

Table 2 Student Surveys

Metric	Online	Hybrid	Face-to-face
1 Gender	M=2(100%) F=0(0%)	M=11(91.67% F=1(8.33%)	M=9 (90%) F=1(10%)
2 Race/ethnicity	White=1 (50%) Hispanic=1(50%)	White=9 (75%) Hispanic=3(25%)	White=6 (60%) Hispanic=2(20%) Asian/Pacific Islander=1(10%) Black or African American=1(10%)
3 VARK Learner Type	Multimodal=0(0%) Visual=1 (50%)	Multimodal=5(41.67%) Visual=3 (25%)	Multimodal=7(70%) Visual=1 (10%)

	Kinesthetic=1 (50%) Read/write=0 (0%)	Kinesthetic=1 (8.33%) Read/write=1(8.33%)	Kinesthetic=2 (20%) Read/write=0(0%)
4 Willingness to work hard	Excellent=2 (100%) Good=0 (0%) Average=0 (0%) Other=0 (0%)	Excellent=8 (66.67%) Good=3 (25%) Average=1 (8.33%)	Excellent=5 (50%) Good=3 (30%) Average=1 (10%) Other=1 (10%)
5 GPA	4.0=0 (0%) 3.8-3.9=2 (100%) 3.6-3.79=0 (0%) 3.4-3.59=0 (0%) 3.2-3.39=0 (0%) 3.0-3.19=0 (0%)	4.0=2 (16.67%) 3.8-3.9=3 (25%) 3.6-3.79=5 (41.67%) 3.2-3.39=1 (8.33%) 3.0-3.19=1 (8.33%)	4.0=0 (0%) 3.8-3.9=1 (10%) 3.6-3.79=1 (10%) 3.4-3.59=3 (30%) 3.2-3.39=0 (0%) 3.0-3.19=3 (30%)
6 Rigor Level	L1=0 (0%) L2=1 (50%) L3=1 (50%) L5=0 (0%)	L1=0 (0%) L2=3 (25%) L3=8 (66.67%) L5=1 (8.33%)	L1=5 (50%) L2=5 (50%) L3=0 (0%) L5=0 (0%)
7 Technology glitches	No=2 (100%) Yes=0 (0%)	No=10 (83.33%) Yes=2 (16.67%)	No=8 (80%) Yes=2 (20%)
9 Was the course engaging?	Excellent=0 (0%) Good=1 (50%) Average=1 (50%) Poor=0 (0%) Don't Know=0 (0%)	Excellent=2 (16.67%) Good=8 (66.67%) Poor=1 (8.33%) Don't Know=1 (8.33%)	Excellent=1 (10%) Good=7 (70%) Average=2 (20%) Poor=0 (0%) Don't Know=0 (0%)
10 Recommend	Extremely likely= 0 (0%) Very Likely=0 (0%) Moderately likely= 2 (100%) Slightly likely=0 (0%) Not Likely=0 (0%)	Extremely likely= 3 (27.27%) Very Likely=6 (54.55%) Moderately likely= 1 (9.09%) Not Likely=1 (9.09%)	Extremely likely= 0 (0%) Very Likely=3 (30%) Moderately likely= 6 (60%) Slightly likely=1 (10%) Not Likely=0 (0%)
11 How effective was the course help meet the Objectives	Excellent=0 (0%) Good=1 (50%) Average=1 (50%) Poor=0 (0%) Don't know=0 (0%)	Excellent=1 (8.33%) Good=7 (58.33%) Average=1 (9.09%) Poor=1 (9.09%) Don't know=1 (9.09%)	Excellent=1 (10%) Good=8 (80%) Average=1 (10%) Poor=0 (0%) Don't know=0 (0%)
12 Assessment	A=2 (100%) A-=0 (0%) B+=0 (00%) C+=0 (0%)	A=6 (50%) A-=3 (25%) B+=2 (16.67%) C+=1 (8.33%)	A=9 (90%) A-=0 (0%) B+=1 (10%) C+=0 (0%)
13 Motivation to succeed	Learn E&T=2 Heard Value=1 Recommend=1 Required=0 Solidworks=1 It fit my schedule=1	Learn E&T=1 Heard Value=1 Recommend=1	Learn E&T=5 Heard Value=2 Recommend=0 Required=7 Solidworks=2

Survey Question 14

What were the criteria the students used to judge the quality of the course?

- The online students did not have an answer
- The web-based students answered:
    - How much I learned
    - How prepared and easy it was to understand
    - How much I enjoyed it
    - The difficulty
    - Overall quality and information
    - Quality of video presentation and information
    - Catches attention and informs well
    - If it helped in any way
- The face-to-face students answered:
    - Past experience
    - Did I learn anything?
    - My learning styles
    - Just how I feel about it at the time
    - Content difficulty, quality of teaching

4.4 Instructors' Surveys

The following is the data collected from the Instructors that taught the IEDT course. There were several metrics used to measure the effectiveness of course in terms of students. Those metrics are listed in the Table 3 shown below.

Table 3 Instructors' Survey Data

Metric	Online	Hybrid	Face-to-face
1 Gender		M=1 (100%) F=0 (0%)	M=5(62.5%) F=3(37.5%)
2 Race/ethnicity		White=1 (100%)	White=6(75%) Asian/Pacific Islander=2(25%)
3 VARK Learner Type		Multimodal=0 Kinesthetic=1 (100%)	Multimodal=1(712.5%) Visual=3 (37.5%) Kinethetic=1 (12.5%) Aural=1 (12.5%) Read/write=2(25%)
4 Willingness to work hard		Excellent=1 (100%)	Excellent=5 (62.5%) Good=3 (37.5%) Average=0 (0%) Other=0 (0%)
5 GPA		3.8-3.9=0 (0%) 3.6-3.79=0 (0%) 3.4-3.59=1 (100%)	4.0=0 (0%) 3.8-3.9=0 (0%) 3.6-3.79=2 (25%) 3.4-3.59=0 (0%) 3.2-3.39=2 (25%) 3.0-3.19=3 (37.5%) <2.0=1 (12.5%)
6 Rigor Level		3=2	Q16?

7 Technology glitches		No= Yes=	?
8 Overall Effectivity		Good= NA=	?
9 Was the course engaging?		Good=1 (100%)	Excellent=4 (50%) Good=3 (37.5%) Average=0 (0%) Poor=0 (0%) Don't Know=1 (12.5%)
9 Recommend		Very Likely= NA=	?
10 How did the course help meet the Objectives		Extremely=1 (100%)	Extremely=3 (37.5%) Quite=4 (50%) Moderately=1 (12.5%) Slightly=0 (0%) Not at all=0 (0%)
11 Assessment		A=0 (0%) A-=1 (100%) B+= 0 (0%) B=0 (0%) C+=0 (0%) Other=0 (0%)	A=0 (0%) A-=0 (0%) B+=5 (62.5%) B=2 (25%) C+=0 (0%) Other=1 (12.5%)
12 Criteria that they used to judge from		Excellent=0 (0%) Good=1 (100%) Average=0 (0%) Poor=0 (0%) Don't Know=0 (0%)	Excellent=4 (50%) Good=2 (25%) Average=1 (12.5%) Poor=0 (0%) Don't Know=1 (12.5%)
13 Motivation to succeed		Learn E&T= Heard Value= Recommend=	?

4.5 Administrators' Surveys

The following is the data collected from the administrators' survey. There were several metrics used to measure the effectiveness of the course in terms of students. Those metrics are listed in the Table 3 shown below.

Table 4 Administrators' Survey Data			
Metric	Online	Hybrid	Face-to-face
1 Gender		M= F=	M=3 (75%) F=1 (25%)
2 Race/ethnicity		White=	White=4 (100%)
3 VARK Learner Type		Multimodal= Kinesthetic=	Multimodal=2 (50%) Visual=2 (50%) Kinesthetic=0 Aural=0

			Read/write=0
4 Willingness to work hard		Excellent= (100%)	Excellent=4 (100%) Good=0 Average=0 Other=0
5 GPA		3.8-3.9= 3.6-3.79= 3.4-3.59=	4.0=0 3.8-3.9= 3.6-3.79=2 (50%) 3.4-3.59=1 (25%) 3.2-3.39= 3.0-3.19= 2.5-2.99=1 (25%)
6 Rigor Level		3=	1=0 2=0 3=0 4=4 (100%) 5=0
7 Technology glitches		No= Yes=	No=2 (50%) Yes=2 (50%)
8 Overall Effectivity		Good= NA=	Extremely likely=2 (50%) Very Likely=2 (50%) Moderately Likely=0 Slightly Likely=0 Not at all Likely=0
9 Was the course engaging?		Good=	Excellent=2 (50%) Good=2 (50%) Average=0 Poor=0 Don't Know=0
9 Recommend		Very Likely= NA=	?
10 How did the course help meet the Objectives		Extremely=	Extremely=2 (50%) Quite=1 (25%) Moderately=1 (25%) Slightly=0 Not at all=0
11 Assessment		A= A-= B+= B= C+= Other=	B+=3 (75%) Other=1 (25%)
12 Criteria that they used to judge from			- The lesson was systematic and included real-world applications and examples from industry.
13 Motivation to succeed		Learn E&T= Heard Value= Recommend=	

4.6 What are the Factors that contribute towards an "effective" web-based engineering and technology curriculum?

There are external factors such as administrative decisions made before the class actually happens. These transparent decisions are beyond the scope of this research. It is assumed that the administration adequately supports the course, if they do not then nothing else will matter. The factors that do affect the class such as the attitude, background, and foundational knowledge that both the instructor and student bring to the course is within the scope of the research.

4.7 Summary of the Collected Data

There were numerous things that emerged from the data collection and analysis, but the items indicated above were the most relevant items found in the research. From this data, the major changes made for the Spring 2015 they were:

1. The modules numbering system was simplified.

2. The navigation of each module using canvas was simplified. Previously, there were multiple ways of accessing the materials and assignments. This confused students so the access was made more linear. We created an e-book with built in tabs on Canvas for the students to use. All of this information was taken out and replaced with an e-book in PDF format.

3. Assignments were consolidated so it did not appear to be as overwhelming. Each assignment was directly tied to a course objective; if it was not, it was removed.

4. Lesson plans were prepared for the instructors who wanted them (as suggestions).

5. The Final Assessment test bank was refined. The confusing questions were either restated or removed. If the question could not be tied directly back to the course objectives, it was removed.

5.0 Discussion and Recommendation

In the previous section, there were six different metrics used to assess the instructors' definition of effective web-based engineering and technology curriculum. There was one additional question asking the instructors to differentiate between the term "quality" and "effective". One of the six instructors interviewed was aware of any existing scoring rubric to determine the quality of a particular curriculum. The scoring rubric the instructor pointed out was the checklists used by online department at Chico State. This check list is similar to the one used at SUU, which is based on the QM Scoring Rubric. The remaining 5 instructors listed several of the items found on the QM scoring rubrics. Combining the list from the instructors' responses represented only 8% of all the items found on the QM scoring rubric. This means that the instructors considered the curriculum quality even though they were listing a significantly small percent of the required items to meet the quality standard.

The literature is pretty clear about the definition of quality, it is defined by QM, Khan's Framework (Kahn, n.d.) and others like it. All the schools and curriculum that were reviewed in this research used some version of QM scoring rubric or Khan's Framework to determine if the curriculum met the listed standards. If the curriculum meets the QM or specific schools' variation of the QM Rubric it is approved as Quality but it does not make it effective.

The literature reviewed stated that the student must be engaged and motivated. Some students are intrinsically motivated while others need to be externally motivated. This motivation can be enhanced

by pedagogical application to digital and interactive tools. The student having a sense of belonging in a community is also helpful. This community needs to be facilitated by the instructor. This means the instructor has to be properly motivated and knowledgeable regarding the community of enquiry theory. The VARK Survey (Cherry, 2014) can help both the student and instructor understand how the student learns most efficiently.

The collected data represented in tables two, three and four are broken down into four different categories. The first is background information, which consists of questions one and two. The second is the learning style, which is question three. The third is different questions to help define effective curriculum, these questions are four, five, six, nine, ten, eleven and twelve. The last category of question is if there were any technology problems, question seven.

The data was collected so the answers between the students in the face-to-face class, the hybrid class and the pure online class could be compared. The data shows that all the students were similarly motivated.

The data was also collected so the perspective of the student, the instructor and the administration could be compared. The difference between table two, three and four provide different lenses or perspectives of what an effective web-based engineering and technology curriculum would look like.

The collected data does support the literature review. Even though the literature and the collected data support one another there is a gap in existing literature. There is QM and Khan's Framework that defines quality web-based curriculum. There is the community of inquiry theory, VARK (Cherry, 2014) and other individual publications that can contribute to making a quality curriculum effective but there is no single framework that brings all of these concepts together.

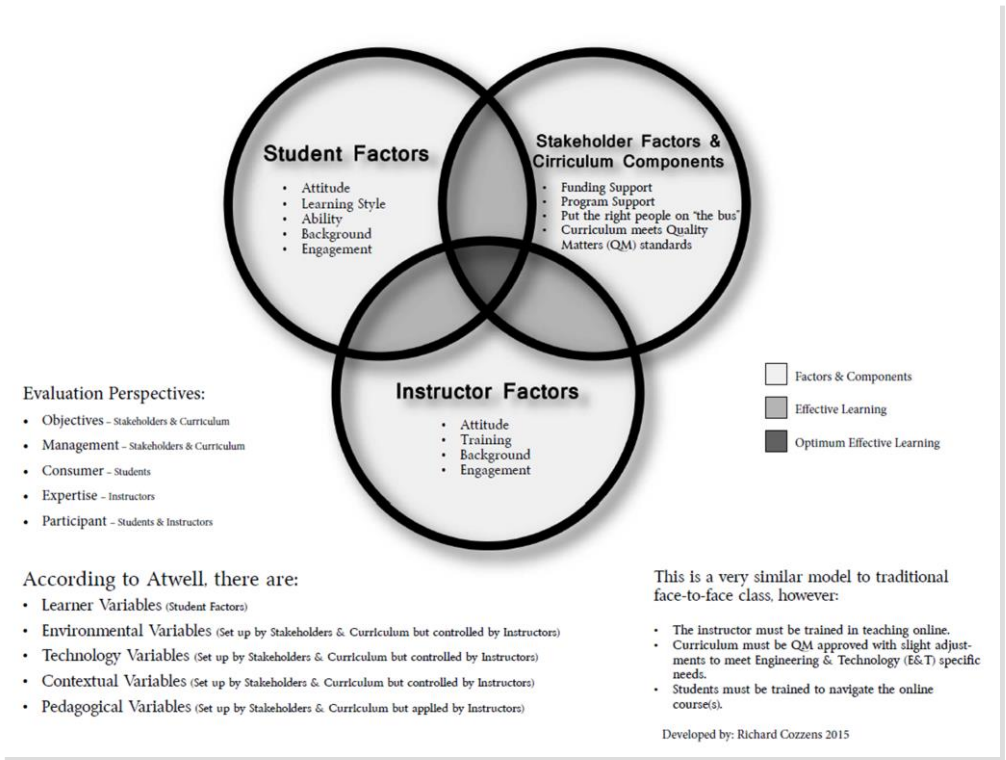
The contribution of this research is bringing all these proven concepts together in one framework. QM and Khan's Framework along with all the external factors such as administration support (funding) make up the Stakeholders one third of the diagram. The students' attitude, learning style, ability and engagement makes up the other one third of the diagram. The last one third of the diagram is the instructor (attitude, training, background and engagement). The only time when a web-based curriculum can be defined as effective is when all three of the circles overlap as shown in Figure 3.

Conclusion and Future Direction

The IEDT curriculum has been accepted and used in the state of Utah for two years now. The data has been used to rebuild the curriculum from the reviews and surveys of students and teachers. It has led to fine tuning and improvement of the curriculum and its ability to ensure an effective means of teaching regardless of the method it is delivered to students in. The curriculum has been a huge success. Twelve out of the thirteen instructors perceived the course as being extremely beneficial to every engineering and technology program in the state. From the students surveyed, 94.55 % of the students would recommend the course to fellow students. All of the students agreed that the time spent on the curriculum was worth their time.

An additional TICE grant was awarded to the same curriculum development team that applied the literature, data and now the newly developed effective web-based learning framework to their web-based engineering and technology curriculum. The team will be applying the lessons learned to a new "Engineering in the 21st Century course this semester.

Figure 3 Most Effective Web-Based Learning



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Appendix A

Publications and presentations on the research

"Feasibility of Web-Based Training for Engineering and Technology."	Ethicomp2008 conference	
"What is Quality Web-Based CAD Training"	Ethicomp2010 conference	
"YouTube: An effective CAD Training Resource"	ASEE Conference	2012
"Development of an Open-Source Concurrent Enrollment Course that Introduces Students to the Engineering Design and Documentation Process"	ASEE 2013 Conference	

SUSTAINABLE EDUCATIONAL INFRASTRUCTURE IN COLOMBIA AS TRANSFORMING SOCIETY TOOL: ROCHESTER SCHOOL STUDY CASE

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Keywords: LEED, green school, sustainable curriculum.

Abstract

LEED consultancy for Rochester School (K-12 private school) evaluated and integrated multiple sustainable strategies, which led it to achieve the 2014 LEED Gold as the first certified school in Colombia and first Gold level in Latin America.

Colombia has been adopting green building as "marketing strategy" to promote sustainable practices into the building sector. Green schools as educational facilities aim to be used as educational living text books.

Based on sustainable strategies, Rochester School has been implementing a "sustainable integrated curriculum" using infrastructure as a main "living study text". Strategies such as water treatment are used for science lessons; landscape integrating artificial reservoir and native vegetation on a natural corridor are used to foster fauna biodiversity; there's also a "Rochester bird guideline" as an integrated project.

An organic recycling program is based on composting to support native-tree orchards. This program is the main resource for Chia Municipality reforestation program. Guided by teachers, students from kindergarten to middle school are in charge of growth and crop; high school students, parents, staff and volunteers from Chia lead reforestation activities.

Rochester school has been recognized by national and international organizations such as Kimberly Clark Foundation – Ekco-Awards recognition for Exceptional Places to Work in 2013, BIBO-WWF in 2014 as "Academy – Best Environmental Practices", "Green Project Challenge - 2014" first place. Since 2012 Rochester School is leading "Green Apple Day" in Colombia and "Our Choice", an integrative K-12 networking initiative based on sustainability educational strategies for schools since 2014.

Campos, L. (2015) **Sustainable educational infrastructure in Colombia as transforming society tool: Rochester School study case** *In;* Gorse, C and Dastbaz, M (Eds) *International SEEDS Conference,* 17 – 18 September 2015, Leeds Beckett University UK, Sustainable Ecological Engineering Design for Society.

Introduction

Rochester School was founded in 1959 as a K-12 private educational institution with English as a second language and good educational standards. Since 2000 the School Board wanted to move to a new location with open areas, good infrastructure for arts, a swimming pool, innovative classrooms and environmentally friendly strategies.

In 2010, the board found a field located in the Chia municipality, which met the main requirements to develop the new project. Ed Design Consultants, a US specialized firm in educational infrastructure was consulted in order to integrate the best architectural guidelines to improve educational programs. In January from 2011, ManCo Ltd was hired to advise the project in order to assess LEED (Leadership in Energy and Environmental Design) certification.

Considering a new approach, sustainable strategies were integrated not only to build and operate a green infrastructure. The main objective was to implement a living text book in order to make it part of a new sustainable curriculum allowing students, teachers, staff, families and visitors an easy access to learn about sustainability and transform society.

Methodology

In order to comply to the standards of LEED certification, future operation and new sustainable curriculum development and strategies were defined as follows:

Re-design Project	Main Goal
Architectural Design	To maximize daylighting and views, use of regional and low-VOC materials, open green areas, minimum parking based on local requirements, carpooling preferred parking, interconnected blocks, general and detailed drawings in CAD. Classroom blocks considering Educational HUB concept, recommended by Ed Designs Consultants. Operational and Educational purposes.
Energy Efficiency – Energy Model	Energy savings based on design case no less than 2,082.3 kWh x 10^{3} (Baseline). Software Trace 700 recommended by LEED EAp2. Operational and Educational Purposes.
BioClimatic	Initial natural ventilation evaluation considering ASHRAE (62.1; 55) standards required by LEED IEQp1 Design Builder software use. Operational Purposes.
Mechanical Ventilation	Air renovation (No air conditioning) for classrooms, and air conditioning for data centre design based on ASHRAE (62.1 and 90.1) standards required by LEED IEQp1 and EAp2. Operational Purposes.
Acoustical	Design and measurement verification were required based on LEED IEQp3. Operational and Educational purposes.
Renewable Energy	Solar power for swimming pool heating and showers; photovoltaic arrangement supplying energy no less than 2% of total energy demand. Operational and Educational purposes.

Lighting	Maximum daylighting use, LED luminaries, external lighting to reduce lighting pollution, sensors and controls. ASHRAE 90.1, IESNA 9, IESNA RP-33 and RETILAP considered norms, DIALUX, AGI 32 and AutoCAD software refereed. Operational and Educational Purposes.
Hydraulic and Waste Water Treatment	Minimum water consumption savings in 20%; efficient water (low consumption) toilets, urinals, showers, and lavatories; tertiary water treatment system; treated water reused for sanitary discharges and landscape irrigation. Operational and Educational purposes
Landscape	Native species, low irrigation requirement. Operational and Educational purposes.

Rochester School New Site in January 20th from 2014 was accomplished to LEED for Schools certification requirements, obtaining LEED Gold Certification. Rochester School is the first LEED Gold certified School in Colombia and Latin America (See photo 1).

Photo 1. Rochester School LEED Plate

Sustainable Curriculum

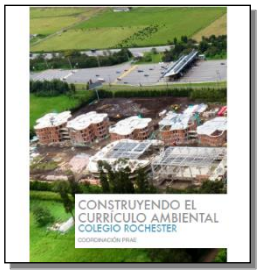
Educational goals

Rochester School based on previous NAAEE[1,2,3,4] (North American Association of Environmental Education) guideline's evaluation and Colombian Educational Ministry guideline's [5] evaluation considered how to integrate the implemented sustainable strategies in order to define the main educational goals for a New Sustainable K-12 curriculum thus teaching students, also adults how to

evaluate environment, how to teach and learn about biology, earth sciences, chemistry, math, physic, social sciences, art, language and other areas using as main text book the green (sustainable) infrastructure.

Association of Fish & Wildlife Agencies [(6)] recommendations regarding a logic sequence and how to implement a curriculum were considered as a main logic methodology reference, enhancing the school's use as a living text book.

In order to support teachers, Educational Environmental Project (PRAE – Proyecto Educativo Ambiental Escolar) prepared in 2013 an original document "Construyendo el Curriculo Ambiental – Colegio Rochester" (Building Environmental Curriculum – Rochester School) as its first tool.



Building Environmental Curriculum - Rochester School (Original Document)

Considering a mixed methodology (as a pilot), the main questions were defined in order to establish priorities for integrated and transversal educational projects, as follows:

- Which environmental problems must be a priority?
- Which priorities are based on general community requirements?
- Who are the final users?
- Which are the teacher's roles regarding integrated and transversal projects?
- Which implemented strategy will be useful for each grade?
- How will teachers enhance knowledge strategies on each grade?
- How will all areas be integrated based on one sustainable strategy?
- How many hours should be considered for each topic?

Based on the answers, the main environmental topics and implemented strategies as educational tools and grades were defined.

Implementation

In order to evaluate how curriculum is working, the following questions were asked to the teachers:

- Do you believe the students understood the message?
- Do you perceive any change on the students' knowledge, skills or attitude?
- Would you propose modifications to the activities?

Results

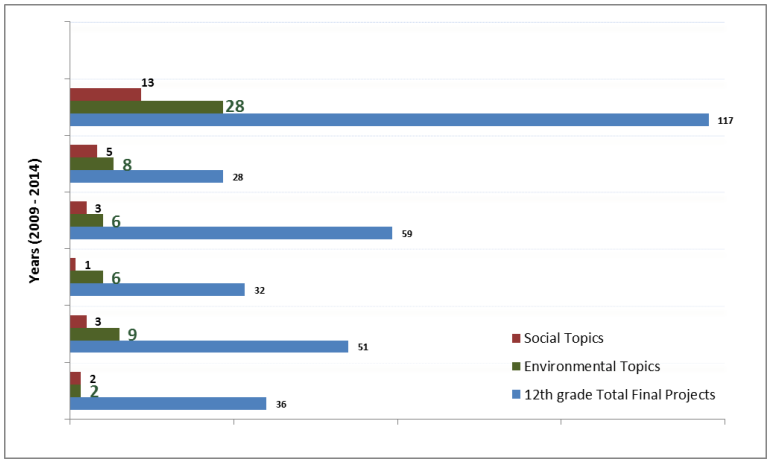
Based on sustainable strategies, transversal educational projects were proposed considering as minimum 10 weekly hours/student/sustainable topics.

General sustainable education areas are shown on Table 1.

Table 1. Sustainable Education - Curriculum

Learning Area	Environmental Topic	School Tool	Grade
Water	Water Footprint	Tertiary Waste Water System Water Efficiency	All grades
Energy	Ethical and sustainable use of Energy	PV and Sun panels; efficient lighting design.	All grades
Landscaping	Native species / biodiversity/ecology topics	Sustainable Landscape	All grades
Waste Recycling	Organic (compost and vermiculture) Non-organic (recyclables)	General food organic waste from cafeteria and snack bar. Recyclables	All grades
Urban Agriculture	Food Security	Composting and Orchards	All grades
Biodiversity and Conservation	Rochester School as Habitat	School as Natural Corridor	All grades
Indoor Environmental Quality	Air Quality and Health	Classrooms / IEQ implementation	9-12 grades

Between the 2009 – 2014 period, 12th grade final projects are considering more environmental (sustainable) and social topics (see Graph 1). Percentages since 2012 are 20-30% in new sustainable infrastructure compared to 5.5 – 17.6% (2009-2011) old school.



Graph 1. 12th grade Final Projects. Environmental and Social Topics Evolution

Relevant results are described as follows:

Water Footprint: Based on sustainable measures, mainly tertiary waste water system, students are learning measures and behaviours in order to reduce their water footprint, also water bodies' preservation and reduction of pollution. Biology students are learning, in a practical way, about prokaryote cells and organic material degradation, the nutrient cycle, cells population growth and ecological concepts. Chemistry students learn about water quality and the use of special kits to monitor treated water on site.

Ethical and sustainable use of Energy: Learning is improved to understand PV and solar panels' function compared to natural photosynthesis process, also climate change. Energy savings are evaluated in math area for statistical analysis.

Waste Recycling: Organic recyclables are used for composting, enhancing organic material degradation knowledge and chemical topics. Compost is used for orchards and vermiculture. Recyclables are selected and reused for: a) acoustical isolation using *Tetra Pak*, b) cardboard and recycled paper are used to make recycling paper and chairs (cardboard), c) plastic bottles (from students homes) are used for greenhouse construction, insects traps and orchards, d) learning about biodiesel, soap, glycerine and antibacterial gel preparation from used kitchen oil.

Urban Agriculture: Orchards using composting are the main tool to learn about food production, vegetal physiology, vertical crops (using recycled plastic bottles) and a special project regarding in situ aromatic plant crops and health benefits.

Landscaping: The science area uses native vegetation. Rochester School supports the native reforestation program of the Chia municipality based on specific native trees orchards. A special project simulating Andean Bear (*Tremarctos ornatus*) habitat and preservation are learning projects under way.

Biodiversity and Conservation: School and its bird fauna is a special project which develops an observer guide. Andean Bear as an "umbrella species" on the Andean ecosystem is an inter-institutional project with the National Parks Agency – Chingaza Park and La Laja Foundation. Also, a photographic register of species which use the school as natural corridor, such as the native opossum (*Didelphis sp*).

Special Projects focused on Energy: National Energy Development Agency (UPME in Spanish) named Rochester School as its first ally in order to design and develop Energy Efficiency and Schools as Teaching Tool for Colombian K-12 public Schools. Its main goals are: a) To reduce energy

consumptions, b) Classrooms improvement to increase learning levels, c) Increase scientific energy and efficiency learning enhancing renewable sources, d) Develop didactic guidelines regarding energy and e) Curriculum standards and guidelines based on renewable and efficient energy.

Rochester School as education tool for K-12 and University Programs: Since its construction phase Rochester School receives K-12 students and undergraduate technical students' visits from engineering, architecture and biology programs. Also, graduate programs students from LEED Course (Pontificia Universidad Javeriana and Green Building and Universidad Colegio Mayor de Cundinamarca) in advanced technical visit.

Rochester School Awards and International Events: Rochester school has been recognized by national and international organizations such as Kimberly Clark Foundation – Ekco- Awards recognition for Exceptional Places to Work in 2013, BIBO-WWF in 2014 as "Academy – Best Environmental Practices", "Green Project Challenge - 2014" first place. Since 2012 Rochester School leads the "Green Apple Day" in Colombia and "Our Choice" an integrative K-12 networking initiative based on sustainability educational strategies for Schools since 2014.

Sustainability Policy: Based on the school mission, the Rochester School Board implemented a general Sustainability Policy in order to operate & maintain school considering: green purchase, green cleaning products, healthy food, and environmentally friendly O&M activities programs.

Future Projections

For the next three years, Rochester School is planning have a fully integrated Sustainability Curriculum with workshops and courses open to all the community. Also, Rochester School is considering promoting a national initiative for specific organization leading green schools in Colombia and Latin America.

Conclusion

As the first LEED Gold certified school in Colombia, Rochester School is leading a new educational scheme based on sustainable educational curriculum, promoting new initiatives to transform society based on education in order to face our local and global challenges posed by Climate Change.

Acknowledgements

The author wants to thank the Rochester School Board, Mr. Peter Gerber (Ed Design Consultants), MSc Jorge Quintero, Project Team, Contractors, staff but specially teachers, parents and students for all their support and accepting challenge to be leaders for the transformation of the Colombian society.

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A WEB-BASED ENVIRONMENTAL TOOLKIT TO SUPPORT SMES IN THE IMPLEMENTATION OF AN ENVIRONMENTAL MANAGEMENT SYSTEM

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Keywords: Environmental management system, Environmental toolkit, Small and medium-sized enterprises, IT for greening.

Abstract

With small and medium sized-enterprises (SMEs) taking up the majority of the global businesses, it is important they act in an environmentally responsible manner. Environmental management systems (EMS) help companies evaluate and improve their environmental impact but they often require human, financial, and temporary resources that not all SMEs can afford. This research encompasses interviews with representatives of two small enterprises in Germany to provide insights into their understanding, and knowledge of an EMS and how they perceive their responsibility towards the environment. Furthermore, it presents a toolkit created especially for small and medium-sized enterprises. It serves as a simplified version of an EMS based on the ISO 14001 standard and is evaluated by target users and appropriate representatives. Some of the findings are: while open to the idea of improving their environmental impact, SMEs do not always feel it is their responsibility to do so; they seem to lack the means to fully implement an EMS. The developed toolkit is considered useful and usable and recommendations are drawn for its future enhancement.

Schmidt, M., Pattinson, C. and Kor, A. (2015) **A web based environmental toolkin to support SMEs in the implementation of an environmental management system** *In;* Gorse, C and Dastbaz, M (Eds) *International SEEDS Conference,* 17 – 18 September 2015, Leeds Beckett University UK, Sustainable Ecological Engineering Design for Society.

INTRODUCTION

Environmental sustainability becomes increasingly important in times when limited resources become scarce and climate change becomes visible. Over the past decades, the necessity for taking action towards becoming more eco-friendly in all areas of today's life has become increasingly evident. The responsibilities defined by the concept of sustainability, in which the current generation meets their needs while allowing the next generation to meet theirs (United Nations, 1987), has to be met by all areas of today's generation. This includes the industrial and business sectors which have a significant impact on the environment.

With a current global development that threatens the previously defined concept of sustainability, many organizations and institutions have taken steps towards influencing a more environmentally friendly future. The European Commission is one example by laying out a strategy for achieving a more resource-efficient Europe by 2020 (European Commission, 2014). Other incidents of measures towards a more sustainable development are the SMART 2020 report (The Climate Group, 2008) that focuses on green strategies and objectives in the area of Information Technologies, or the Flash Eurobarometer report of 2012 (European Commission, 2012) that analyses the areas of impact and the potential of small and medium-sized enterprises.

While research has been conducted in various fields, the need for measures that support small and medium-sized enterprises in the improvement of their environmental impact is still on its way to being widely acknowledged. In spite of their relatively small size, small and medium-sized enterprises can have a significant impact on the environment (Frijns and Van Vliet, 1999; Hillary, 1998). First environmental actions have been taken that target the area of SMEs in particular. An example for such an action is the Green Action Plan for SMEs provided by the European Commission (European Commission, 2015a).

Environmental regulations for SMEs are often highly desirable but still only voluntary. Hence, providing frameworks for implementing an environmental management system is currently one of the most favored options to increase their environmental awareness and use of sustainable strategies.

RELATED WORK

Sustainability

Sustainability is an important aspect of today's society. The demand for limited resources is getting increasingly high while those resources, such as crude oil or coal, are becoming increasingly rare. Hence, acting in an environmentally responsible and sustainable manner is highly important especially for businesses which have a significant impact on sustainability. Therefore, it is important to first understand the concept of sustainability. The terms sustainability and sustainable development have been defined on March 20, 1987, by the World Commission on Environment and Economy in their Brundtland Report as "… development that meets the needs of the present without compromising the ability of future generations to meet their own needs." (United Nations, 1987). The definition implies a responsibility towards future generations that has to be respected within all areas of our current generation and is especially applicable to environmental sustainability. Handling natural resources in a way that is sustainable and allows future generations to meet their own needs with regards to those resources is the sense the term sustainability will be used in for the purpose of this research.

Sustainibility in Industry

The business industry generates a major environmental impact which needs to be regulated on order to secure sustainable development. Here, the main focus for environmental responsibility in that area often lies on large companies. They have a respectively large, mostly disadvantageous impact on the environment and, thus, on a sustainable development. Though these companies are far smaller in number than small and medium-sized enterprises, their environmental footprint is much more significant. Hence, research has been conducted on large enterprises and measures have been developed to improve their environmental performance.

In comparison, small and medium-sized enterprises are often excluded from environmental regulations and responsibilities. However, even though their individual impacts are not as significant, with SMEs counting for 90% of the European market (European Commission, 2015b), their combined footprint has a tremendously disadvantageous potential. Thus, there is an explicit need to provide SMEs with the tools to optimize and limit their footprint. A widely accepted means for improving an enterprise's environmental impact and sustainable acting is an environmental management system (EMS).

Environmental Management Systems

Environmental management systems provide guidance for voluntary action of businesses that seek support in improving their environmental impact. Extensive research has been conducted to prove the effectiveness of an EMS implementation with regards to improving a company's environmental footprint. A variety of benefits is associated with its implementation but, at the same time, a number of concerns and barriers have been expressed in previous research which will be presented shortly in this section.

Two of the most commonly used EMS are the ISO 14001:2004 standard for environmental management systems which has been developed by the International Organization for Standardization (International Organization for Standardization, 2004a) and the EMAS Eco-Management and Audit Scheme, developed by the European Commission (European Commission, 2015c). Both standards comprise the same principal steps that require an organization to develop an environmental policy and to go through the stages of planning, implementation and operation, checking and corrective action, and the management review. With the EMAS, companies additionally need to publish a report on the environmental performance of their sites (Hillary, 2004). The two standards aim to be applicable to both large as well as small and medium-sized companies but due to its slightly less strict requirements and because it is said to have been designed with the small chip shop owner in mind (Dodds, 1997), the ISO 14001:2004 appears to be the preferred model for SMEs. Maier and Vanstone (2005) further showed that in September 2004, there have been 4,019 EMAS-registered sites in Europe compared to 23,000 ISO 14001 certificates. On a global scale, more than 66,000 ISO 14001 certifications had been awarded. These figures indicate a higher acceptance and broader implementation of the ISO 14001 as environmental management systems standard. Thus, it is the standard that will be used as basis for the system developed in this research.

Environmental Management Systems in SMEs

The European Commission describes SMEs as follows, "The category of micro, small and medium-sized enterprises (SMEs) is made up of enterprises which employ fewer than 250 persons and which have an annual turnover not exceeding 50 million euro, and/or an annual balance sheet total not exceeding 43 million euro." (Commission of the European Communities, 2003).

Even though their benefits have been proven and discussed widely, EMS are still implemented more by large enterprises than by SMEs. This is largely due to the environmental pressure that is put on large organizations due to their significant impact but also to the resources they have that can be invested into properly developing a certifiable EMS. SMEs, on the other hand, have a smaller individual impact on the environment but, while their combined impact is not exactly known (Seiffert, 2008; Zorpas, 2010), it is often estimated to lie at approximately 70% of the overall industrial pollution (Frijns and Van Vliet, 1999; Hillary, 1998).

Acknowledging the significance of their combined pressure on the environment, ongoing research has been conducted in the field of SMEs and EMS and barriers have been determined that often hinder SMEs from implementing environmental management systems. Apart from the fact that many do not feel it their responsibility to implement such a system, other important factors are limited financial resources, a lack of expertise knowledge, the complexity of the EMS, a lack of awareness regarding their responsibility as well as solutions, and a lack of motivation (Blundel et al., 2013; Chan, 2011; Hillary and Burr, 2011; Nulkar, 2014; Seiffert, 2008; Zorpas, 2010).

In spite of the barriers, numerous benefits speak in favor of the implementation of an EMS and have motivated a growing number of SMEs to do so. The main benefits include cost savings over time, risk aversion, improved environmental performance inside the company, improved corporate image as well as improved relation with stakeholders and clients, better marketing options, pollution prevention, enhanced legal compliance, and conservation of resources (Blundel et al., 2013; Chan, 2011; Hillary, 2004; Hillary and Burr, 2011; Maier and Vanstone, 2005; Nulkar, 2014; Seiffert, 2008; Zackrisson et al., 2000; Zorpas, 2010). Maier and Vanstone (2005) found that the main motivation companies have for implementing and certifying the ISO 14001 is primarily to improve their environmental performance and to enhance their corporate image which is followed by a desire to gain competitive advantages and improve their relations with stakeholders.

METHODOLOGY

EMS Methodology

The ISO 14001 EMS methodology lays the basis for the development of the target system that is a simplified version of an environmental management system.

The ISO 14001 Environmental Management System is part of the ISO 14000 family defined by the International Organization for Standardization and focuses on environmental management. At the moment, the ISO 14001:2004 version is used for EMS but the standard itself is currently under revision. An updated version is expected to be available by the end of 2015 and will be named ISO 14001:2015. The revision will ensure the standard's compatibility with other standards and focus on a better understanding of a company's context. According to ISO (International Organization for Standardization, 2015), the principal changes will relate to the following points:

"Increased prominence of environmental management within the organization's strategic planning processes"

"Greater focus on leadership"

"Addition of proactive initiatives to protect the environment from harm and degradation, such as sustainable resource use and climate change mitigation"

"Improving environmental performance added"

"Lifecycle thinking when considering environmental aspects"

"Addition of a communications strategy"

This standard follows the Plan – Do – Act – Check principle (International Organization for Standardization, 2004b). This refers to the process cycle an enterprise is expected to go through when implementing an EMS.

In more detail, the ISO 14001:2004 outlines five steps, each of which encompasses several documentable sub-steps. The five steps are: 1) environmental policy, 2) planning, 3) implementation and operation, 4) checking and corrective action, and 5) management review in the end. The target system will focus mainly on the planning phase.

EMS Methodology

In the area of systems engineering, the systems development life cycle (SDLC) describes the phases associated with the entire life cycle of systems development. According to Hoffer et al. (2002), SDLCs differ from organization to organization and the number of their phases varies. However, generally, it consists of: a) the systems analysis, b) the systems design, c) the system development, d) the system integration and testing, and e) the systems maintenance. Those will be the phases included in the systems development life cycle of this research (Yeates and Wakefield, 2004).

Research Methodology

Interviews

The interviews are conducted with representatives of two small German enterprises, as defined by the European Commission (Commission of the European Communities, 2003).

Enterprise one is a cosmetic retail store in Berlin that is part of a larger company but is run independently on a franchise level. Decisions regarding merely the shop in Berlin are made by the local manager and franchisee. It is a small enterprise with 14 employees that has started business in 2001.

The second enterprise is a micro start-up business in the IT sector, situated in Berlin, as well. It was founded in 2009 and currently has nine members of staff. The enterprise moved from working on a home office-basis to working in the company's office in January 2015.

The language used for the interview questions and the language of the toolkit is English. In both cases, the representatives have conversational knowledge of the English language and are able to understand and work with the developed system. However, in order to ensure complete understanding of all interview questions as well as of all parts of the toolkit, the interviews were conducted via the video conferencing service Skype™. The interviewees were asked the questions online and translations and additional information were provided whenever necessary. The questions themselves are based on a questionnaire that had been made accessible to them via Google Forms™ prior to the interview. An interview note regarding their anonymity and the processing of their data is sent to the interviewees beforehand.

Ethical concerns about the research have been taken into account and the study has been approved by the research ethics committee at Leeds Beckett University.

Representatives of the management area of these companies (the manager of the retail store and the CEO of the IT company) are interviewed in two cycles, the pre-intervention and the post-intervention cycle. Here, intervention refers to the use and testing of the developed environmental toolkit.

Questionnaires

The human-computer interaction (HCI) of the target system as well as its content are evaluated by a focus group. The focus group of non-experts consists of 13 postgraduate students from the field of sustainable computing at Leeds Beckett University. Thus, the students have background knowledge in green computing and are aware of the necessity of sustainable strategies in the industry. Prior to the questionnaire, they are given a presentation by the author on the environmental management systems, the ISO 14001 in particular, the definition and role of SMEs, as well as a short introduction to the developed toolkit. In the following step, the participants of the focus group are given the URL to the toolkit and asked to use it and evaluate it based on provided questionnaire forms.

In order to enhance the likelihood of receiving accurate and complete responses, the forms are anonymous and consist mainly of grid-based questions in which participants are asked to rate their agreement with given statements. Open questions are asked, too, with the purpose of allowing the focus group to provide feedback that has not been asked for in the grid-based questions.

The questionnaire is divided into the two main parts of human-computer interaction evaluation and content evaluation. The HCI principles chosen for the present research are based on Shneiderman's "eight golden rules of interface design" (2010), Mandel's three "golden rules of interface design" (2013), Nielsen's "10 heuristics for user interface" (2005), and Sutcliffe's HCI principles (1995). The derived principles are the system's consistency, compatibility, predictability, adaptability, economy, user control, structure, match with the real world, error prevention, recognition, flexibility and efficient use, help and documentation, and error handling.

In the content section, participants are presented with statements about the content of the toolkit and are asked to indicate their agreement with each. Again, an open question in the end aims at receiving feedback that has not been targeted in the grid-based questions. The nine statements are

composed of “The content is easy to understand”, “The content is relevant”, “There was sufficient supporting material”, “I would have needed additional explanation for using the toolkit”, “I would have wanted more information on the ISO 14001”, “I would have liked to use a more detailed toolkit”, “I can see the point of toolkit”, “I think the system is useful”, and “Would you want more multimedia included in the toolkit?”.

In the very last section of the questionnaire, the focus group is presented with an open question to add any further comments and recommendations they have with regard to the toolkit that have not been addressed before.

THE ENVIRONMENTAL TOOLKIT

The developed system can be found at www.EnvironmentalToolkit.com. It is a web-based toolkit that aims at supporting SMEs in the implementation of a simplified environmental management system and at allowing them to more easily assess and improve their environmental footprint. It has been developed following the system’s development life cycle.

For the purpose of this research, the ISO 14001:2004 Environmental Management System standard has been highly simplified to make it easier to use for small and medium-sized enterprises that are not experts in the field of EMS and only have limited resources for the implementation of such a system.

The environmental toolkit is divided into two sub-systems. The focus of the toolkit lies on the first system, the “Environmental Management System”, which is a far more simplified version of an EMS that the alternative “Template-Based Environmental Toolkit”. Depending on the proficiency of the user, one of the systems can be chosen. Generally, it is recommended to start with the first system as its implementation is easier and faster so that the second system can function as way of improvement after a company has gained experience and is familiar with EMS.

System 1: Environmental Management System

The “Environmental Management System” has a *Home* and an *About* page which present the toolkit as well as background information on the ISO 14001 standard. The page of the toolkit itself (see Fig. 1) is divided into the three main areas of energy consumption, water consumptions, and recycling. Those areas have been selected as they are considered to be common in most SMEs and to have an environmental impact in the majority of them. At the beginning of the page, a short introduction and guidance to starting the toolkit are provided. Images are used to visualize the three fields and function as additional links that lead to each respective sub-page.

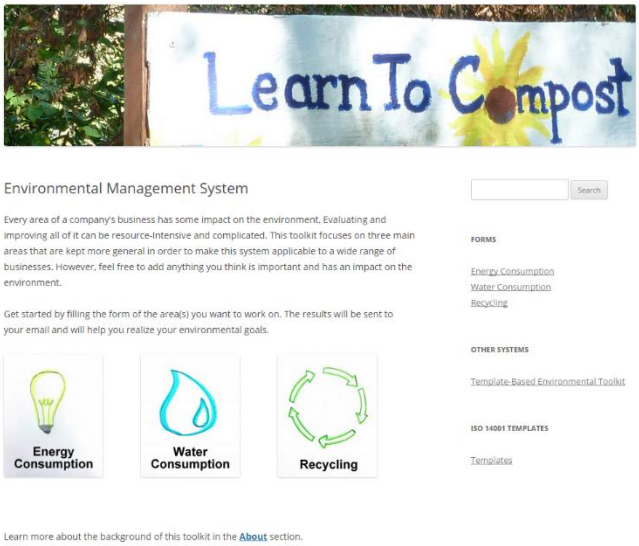

Figure 34: Environmental Management System Screenshot

System 1 – Sub-Pages

Each of the respective sub-pages briefly presents the topic and then links to forms that function as the actual EMS. In the cases of energy consumption and water consumption, links are provided that refer the user to calculators that are offered by external parties, that allow them to assess their current energy or water consumption and to compare their results from before and after implementing the toolkit. For the energy consumption, links are provided to the Electricity Cost Calculator (2015) and to the Water and Energy Calculator (2015). The water consumption section merely links to the Water and Energy Calculator (2015) to guide SMEs towards assessing their own water consumption.

System 1 – Foms

The actual EMS support is provided by the forms that are linked to in each of the environmental impact areas. They follow the ISO 14001:2004 standard by integrating its fundamental steps of Plan – Do – Check – Act to an extent that is considered feasible for the target group of inexperienced users with limited resources. In practice, the forms are divided into areas of: 1) Significant environmental impact, 2) Environmental objectives, 3) Environmental management program and 4) Employee awareness and communication. The provided options have been designed with the purpose of being applicable to many SMEs in general but in particular, they have been selected with the needs of the two German target companies in mind. Their facilities include offices, a cosmetic store, as well as a small storage space.

When using the forms, the user is asked to select the fields that he or she finds appropriate for the respective SME and submit the form. Upon submission of the filled form, the enterprise will receive an email with a document containing the outline of their personal EMS, including their selected areas of significant environmental impact, their chosen environmental objectives, the measures of the environmental management program they want to implement, as well as guidance regarding the staff training and communication. This document is meant to be used as a framework and guidance to help the organization realize the outlined steps

System 2: Template-Based Environmental Toolkit

The “Template-Based Environmental Toolkit” is the first version of the system. During the course of the system’s development, it has been simplified even more and system 1, the “Environmental Management System”, has become the main focus of the toolkit as it is simple and targeted at inexperienced users. Nevertheless, system 2, the “Template-Based Environmental Toolkit”, has been kept inside the toolkit in order to offer users a framework that more closely follows the ISO 14001:2004 standard.

The Template-Based Environmental Toolkit follows the main steps of the ISO standard and provides users with examples and templates that aim at simplifying the process steps of the standard. It is divided into the five main categories of: Environmental Policy, Planning, Implementation and Operation, Checking and Corrective Action, and Management Review which can be found under the section “EMS Steps”. The home page of the system itself links to the following sections: 1) About, 2) EMS Steps, 3) Templates, and 4) Definitions (see Fig. 2).

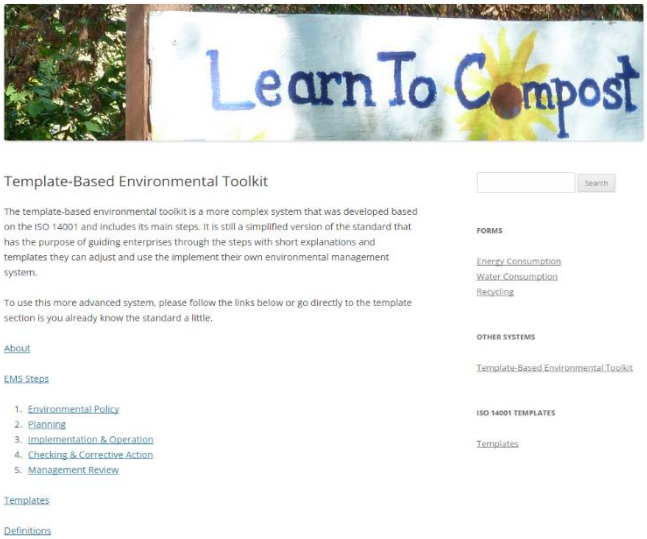

Figure 35: Template-Based Environmental Toolkit Screenshot

Environmental Mangement System – Systems Development Life Cycle

Systems Analysis

The purpose of this research is to develop a toolkit that helps small and medium-sized enterprises implement their own environmental management systems without imposing the same barriers and challenges that have been discussed in the literature review. Thus, overcoming those barriers is a requirement for the system. In addition, pre-intervention interviews have been conducted with the two small German firms in order to define further potential user requirements that must be taken into account for the development of the toolkit. For this purpose, a questionnaire has been provided in support of the interview. The answers are represented in Table 1.

Table 19: Pre-Intervention Interview Results

Interview Question	Cosmetic Retail Store	IT Service Provider
Which business area is your enterprise located in?	Retail in cosmetics	IT services
How many years has your company been in business for?	14	2.5
What kind of ownership best defines your enterprise?	Franchise	Private
What is your position in the company?	Manager	CEO
How many employees/staff members are associated with your enterprise?	14	9
Do you have an environmental policy in place?	Yes	No
Are you familiar with Environmental Management Systems (EMS)?	No	No
Do you have an EMS implemented in your enterprise?	No	No
Do you have any eco-friendly practices implemented?	Yes	Yes
If you answered yes, please list your practices.	Separate garbage, use eco-power	We plant trees at the end of year
Our company carries a big responsibility for the environment.	Agree	Agree
Our enterprise can make an impact on the environment.	Disagree	Agree
Small and medium-sized enterprises (SME) play an important role with respect to the environment.	Agree	Agree
Implementing an EMS is too expensive.	Disagree	Strongly agree
We lack sufficient knowledge for an EMS implementation.	Disagree	Agree
We lack the right technology to implement an EMS.	Agree	Neutral
We do not see potential benefits of an EMS implementation.	Disagree	Disagree
We lack human resources.	Disagree	Strongly agree
Are you satisfied with your current environmental practices?	No	Yes
If you selected "No", please give reasons.		
Please indicate your requirements for an (ideal) EMS.	Make an app for it.	It should be practical and easy to use and adapt to our requirements.

Based on the pre-intervention interviews and on the previously conducted literature review, the following user requirements for the target system are defined:

- Requirement 1: The system must be useful.
- Requirement 2: The system must be easy to use.
- Requirement 3: The system must make SMEs aware of their environmental impacts.
- Requirement 4: The system must inform about EMS.

Systems Design

The general design of the system is based on WordPress™ as its layouts serve the purposes of this work ideally. The design theme Twenty Twelve (WordPress, 2015) is chosen as basis for this toolkit. Thus, the ideas of the system development discussed in the expert reviews are merely implemented in the already existing design.

Systems Development

In order to make the toolkit universally accessible, the content is in the English language and it is hosted on the webserver One.com™ with the integration of WordPress™ as content management system.

One.com™ is a web hosting service that includes hosting tools such as an effortless WordPress integration and 15 Gigabyte hosting space. Both of which facilitate the technical integration of the system.

For simplification purposes, WordPress.org™ is integrated into the website as it already includes many of the needed services and functionalities. It functions as a content management system that is easy to use and to adapt and which allows for an uncomplicated design of the toolkit, as well as the integration of the Google Forms™ which are used for supporting the SMEs in building their own EMS. Even though the system is web-based, the WordPress theme effortlessly adapts to mobile devices and therefore allows the user to work with the system on phones and tablets, as well.

Systems Testing

In order to ensure that the designed system is usable and that the content is relevant, it is tested and validated before its release. There are two kinds of validation applied in this study: expert validation and non-expert validation. The results of the systems testing phase are discussed in the next chapter.

Results and Discussion

Following the development of the system, evaluation processes are conducted in order to validate the toolkit and verify that it complies with the SMEs' requirements. For that purpose, evaluation sessions are held with experts, non-experts, and the target SMEs themselves.

Expert Validation

During the system's development, evaluation sessions are held regularly between the author and Prof. Pattinson and Dr. Kor, both of whom represent the experts in the area of environmental management systems. During those sessions, ideas of the realization as well as the achieved progress by the author are discussed. This procedure helps shape the target system based on the experts' feedback and serves as an additional verification process of the system's requirements.

Non-Expert Validation

The non-expert validation serves at evaluating the toolkit's human-computer interaction (HCI) as well as its content. The non-experts are 13 sustainable computing students that have knowledge of the importance of sustainability in IT but are not experts in the field of EMS.

In order to support the evaluation of the system, the students are provided with questionnaires that contain statements regarding the toolkit's HCI and its content. They are then asked to rate their agreement with each statement. The agreement range is divided into: "I strongly agree", "I agree", "Neutral", "I disagree", and "I strongly disagree". In the following part, the results of the questionnaires will be discussed, using a descriptive statistical approach. Thus, the achieved mean, median, and mode scores will be presented. For this purpose, the answers are first coded into numerical values. Thus, "5" represents "I strongly agree", "4" stands for "I agree", "3" represents "neutral", "2" symbolizes "I disagree", and "1" is used for "I strongly disagree". The mean score represents the average response value, median the middle value, and the mode value the score that has been selected the most.

Human-Computer Interaction

The first part of the validation process focuses on the human-computer interaction. After testing the toolkit, the participants are asked to evaluate the HCI the system provides based on a questionnaire. The calculated mean, median, and mode value for each statement are depicted in Table 2.

Table 20: HCI Evaluation Results

Statement	Mean Score	Median Score	Mode Score
Consistency - The system is consistent (screens, design, etc.).	4.25	4.5	5
Compatibility - The system meets my expectations.	4	4	4
Predictability - I clearly see the actions I can take (icons, links, etc.).	4.39	5	5
Adaptability - The interface is adapted to the way I use it.	4.42	4.5	5
Economy - The steps I have to take are clear and not too many.	4.23	4	5
User Control - I feel in control of the system (I can jump through sections, undo actions if applicable, etc.).	3.92	4	3
Structure - The system appears structured and not too complex. Presented information is relevant.	4.39	5	5
Match with Real World - I understand the language and presented concepts.	4.39	4	5 and 4
Error Prevention - I don't feel like I could make any disastrous errors.	4.23	4	4
Recognition - Objects, Actions, and options are well visible and recognizable throughout the pages.	4.08	4	5 and 4
Flexibility and Efficient Use - I can find shortcuts in-between the sections and use the system flexibly.	4.15	4	4
Help and Documentation - I find help and supporting material easily.	3.9	4	4
Error Handling - I receive clear error messages and corrective action steps.	3.9	4	3

All of the given statements in the questionnaire express a positive perception of the above mentioned criteria and received a majority of positive and/or neutral answers. Thus, no changes needed to be made regarding the HCI of the toolkit. More relevant are the additionally provided comments.

Eight out of the 13 participants of the test group provided additional feedback in this section. The remarks regarding the system's interface and usability are composed of the following comments:

- (a) "The Interface looks perfect to me."
- (b) "It gives me alternative options to course of study or search."
- (c) "Suggest moving EMS Steps from *About* to main navigation bar. Easier to locate."
- (d) "It is usable, focuses on user's goals."
- (e) "Nothing to add – clear system – helpful guide – good result"
- (f) "I like the use of white space. More images would help me, maybe less text. Sometimes the order of navigation around the site is unclear to me. Basic numbered steps/instructions might help."
- (g) "Email requested but no email send. Once the form is completed there are no clear instructions. To use results maybe change 'See previous responses' to 'see results from responses'. Option to close or go back to main page needs to be added."
- (h) "Clear and very simple."

Comments a), b), d), e), and h) are positive and therefore not considered further for the system's development. The suggestion from comment c) has been realized, while the recommendations from f) and g) are disregarded due to time constraints and technical limitations but will be considered for recommendations regarding the future development of the toolkit.

Content Validation

In the content sections, participants are presented with statements about the content of the toolkit and are asked to indicate their agreement with each. Again, an open question in the end aims at receiving feedback that is not targeted in the grid-based questions. The derived mean, median, and mode value for each statement are depicted in Table 3.

Table 21: Content Evaluation Results

Statement	Mean Score	Median Score	Mode Score
The content is easy to understand.	4.39	4	5 and 4
The content is relevant.	4.54	5	5
There was sufficient supporting material.	4.58	4	5
I would have needed additional explanation for using the toolkit.	3.15	3	3
I would have wanted more information on the ISO 14001.	3.39	4	5
I would have liked to use a more detailed toolkit.	3	3	2
I can see the point of toolkit.	4.62	5	5
I think the system is useful.	4.7	5	5

Generally, participants find the content of the toolkit positive. Only in some cases, few individuals expressed disagreement with the provided system. An example of disagreement is that more information on the ISO 14001:2004 standard as well as further details are desired in a few cases. A link to the respective ISO website has been included in the toolkit consequently. The strongest point of disagreement concerned the use of media and a desire for an extended use of, in particular, videos in general but also for the inclusion of images, was expressed. These changes will be considered for the future development of the system.

Again, eight of the participants added further feedback which is composed of the following comments:

- (a) “Nothing to add.”
- (b) “It is fine.”
- (c) “It is good to have less images. However, the banner image does not show aspects of energy and water consumption. It is good it shows environment. It is very simple but I don’t seem to like it.”
- (d) “Instead of submitting another response, I would like to go and select recycling or water consumption.”
- (e) “I find the point ‘Do no use heating/AC when not necessary’ under EM program for lighting a bit misplaced.”
- (f) “Good breakdown of EMS and ISO 14001. A very useful tool for companies that want to change the way they operate. Good awareness and overall experience. […]”
- (g) “A case study of a SME which has used the system might be helpful. This could be a video of a testimonial also explaining what the company did and how easy it was to implement.”
- (h) “It should highlight the likely consequences of not complying with the environmental responsibilities.”

Comments a), b), f) are exclusively positive about the toolkit’s content and are not further addressed throughout the system’s development. Statements c), d), g) and h) remain unchanged due to technical limitations and time constraints but will be taken into consideration for the recommendations concerning the development of the system in the future. Comment e) has led to a change in one of the forms.

SME Validation

In order to assess whether the developed system is applicable for SMEs, the two small German enterprises are asked to test and evaluate the toolkit based on a questionnaire. After including the changes derived from the testing and validation phase, the firms are invited to go through the intervention by using the system and to fill another questionnaire regarding its usability and usefulness.

During the first part of the questionnaire, the firms are asked to provide information about their company as they had been asked in the first questionnaire. This serves to identify the given answers with the company interviewed and be able to relate comments to those provided in the first questionnaire.

The second part focuses on the usefulness and usability of the toolkit. In order to assess those factors, the enterprises are asked the questions depicted in Table 4.

Table 22: Post-Intervention Interview Results

Interview Question	Cosmetic Retail Store	IT Service Provider
Which business area is your enterprise located in?	Retail in cosmetics	IT services
How many years has your company been in business for?	14	2.5
What kind of ownership best defines your enterprise?	Franchise	Private
What is your position in the company?	Manager	CEO
How many employees/staff members are associated with your enterprise?	14	9
Would you rate the Environmental Toolkit as useful?	Very useful	Neutral
Was it easy to use?	Easy	Easy
Did the toolkit raise awareness for the environmental impact of your company?	Yes	Yes
Do feel more inclined to introduce changes after using the toolkit?	Yes	Yes
Would you have needed additional information?	No	No
Do you feel informed about Environmental Management Systems?	Informed	Very informed
What did you miss in the toolkit? What do you think should be added?	Nothing I can think of at the moment.	Pictures (of effects before/after)
Would you recommend using the toolkit?	Yes	If it was more developed, yes.

In this research, it is considered that all of the stakeholder requirements have been met. Furthermore, it is interesting to notice that using the toolkit resulted in the companies feeling more inclined to introduce eco-friendly changes in their work environment than they felt before using the system. The suggestion of more media integration is a point that has been found in the non-expert evaluation, as well, and will be taken into consideration for the future development of the toolkit. While the retail store would already recommend using the system, it is assumed that, after further development and the integration of additional media, the IT service provider would recommend it, as well.

Conclusions and Future Research

The presented research has the objective of developing and testing a web-based environmental toolkit that supports small and medium-sized enterprises in the implementation of their own environmental management systems. In addition, the target toolkit has to overcome the barriers outlined in the literature review and retrieved from the pre-intervention interviews that SMEs often face when attempting to implement an EMS. The human-computer interaction the system provides has been validated by the focus group and its content has been deemed appropriate by the experts, the focus group, and the target users. Based on the evaluation results from the experts, the non-experts, and the target SMEs, the objective of the research is considered fulfilled.

However, certain aspects have not been included into the toolkit from the beginning due to the constraints of this research as well as the non-proficiency of the author in the area of graphics and video-making. Therefore, they are included in the recommendations for the future work on the toolkit. Further recommendations are drawn from the validation processes and are summarized as the following points which will be discussed in further detail below: 1) Develop a mobile application of the system, 2) Expand the research to include more target companies, 3) Incorporate additional areas of

environmental impact, 4) Structure the system more clearly, 5) Include the enterprise's entire supply chain, 6) Include more multimedia.

1) Develop a mobile application of the system

The IT service provider suggested the development of a mobile application prior to the development of the system. As the object was to build a web-based toolkit, this suggestion was neglected for this research but it is a recommendation for the future improvement of the toolkit. Although the implemented design adapts to mobile devices effortlessly, the development of a stand-alone application is still considered beneficial.

2) Expand the research to include more target companies

The presented research has been developed in collaboration with two small German enterprises which added novelty to the field and served as representations of target users. However, it is still a fairly small sample size. In a continued research, it is recommended to expand the sample size and include representatives of enterprises from different fields and different countries. This strategy is expected to add further user requirements to the system and to receive a broader evaluation of the system in order to make it applicable to as many different SMEs as possible.

3) Incorporate additional areas of environmental impact

For simplification reasons, the selected areas of environmental impact in the developed toolkit are limited to energy consumption, water consumption, and recycling. However, enterprises in differed work fields are likely to have different areas of impact. Therefore, fields such as waste water or hazardous waste management are recommended to be part of an improved version of the system.

4) Structure the system more clearly

As found in the non-expert evaluation, the use of the toolkit may be structured more clearly with the use of numbers or steps, for example. However, whether the need for this measure is perceived by more users should be tested by another focus group beforehand. If the demand for this change is confirmed, the toolkit should be adapted accordingly.

5) Include the enterprise's entire supply chain

In its current version, the toolkit merely focuses in three areas of environmental impact that do not consider its supply chain. However, a significant impact potential can be hidden the supply chain which it is recommended to investigate the potential and, if appropriate, include the added aspect into the system.

6) Include more multimedia

The demand for additional multimedia has become clear in the non-expert evaluation as well as the SME evaluation. It was recommended to incorporate more images and include videos that guide through using the toolkit and videos that present use cases of SMEs who implemented the environmental toolkit and show how it affected their company. Interviews with additional SMEs could clarify the need for more supporting material which, consequently, should be integrated in a next step.

The author is aware that the number of potential recommendations is far more than what has been provided. However, presented are merely recommendations that have been noticed during the system's development or that were found during the evaluation phases.

ACKNOWLEDGMENT

This research has been supported by the Erasmus+ program in Pervasive Computing and Communications for Sustainable Development (PERCCOM).

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Monitoring Survey and Assessment

Green IT

IMPLEMENTATION OF GREEN ICT APPROACH FOR TRANSFERRING BIG DATA OVER PARALLEL DATA LINK

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Keywords: Big Data, Cloud Computing, Green IT and Transfer Data.

Abstract

The research is related to Big Data transfer over Parallel Data Link and the main objective is to assist the Saint-Petersburg National Research University ITMO research team, and to apply Green IT methods for the data transfer system. The goal of the team is to transfer Big Data by using parallel data links with SDN Openflow approach. My task as a team member was to compare existing data transfer applications in case to verify which results the highest data transfer speed in which occasions and explain the reasons. In the context of the research, a comparison between 5 different utilities has been done, including Fast Data Transfer (FDT), BBCP, BBFTP, GridFTP, and FTS3. A number of scripts where developed which consist of creating random binary data to be incompressible to have fair comparison between utilities, execute the Utilities with specified parameters, create log files, results, system parameters, and plot graphs to compare the results. Transferring such an enormous variety of data can take a long time, and hence, the necessity appears to reduce the energy consumption to make them greener. In the context of Green IT approach, our team used Cloud Computing infrastructure called OpenStack. It is more efficient to allocated specific amount of hardware resources to test different scenarios rather than using the whole resources from our testbed. Testing our implementation with OpenStack infrastructure results that the virtual channel does not consist of any traffic and we can achieve the highest possible throughput. After receiving the final results we are in place to identify which utilities produce faster data transfer in different scenarios with specific TCP parameters and we can use them in real network data links.

Georgiou, S., Shevel, A. and Anagnostopoulos, T. (2015) **Implementation of green ICT approach for transferring big data over parallel data link** *In;* Gorse, C and Dastbaz, M (Eds) *International SEEDS Conference,* 17 – 18 September 2015, Leeds Beckett University UK, Sustainable Ecological Engineering Design for Society.

INTRODUCTION

Nowadays with the vast and rapid evolution in the field of Computer Science, scientists observe a critical increase of the data which has been produced. The world's technological per-capita capacity to store information has roughly doubled every 40 months, since the 1980s as mentioned by (Hilbert, and Lopez, 2011) and as of 2012. Every day 2.5exabytes (2.5*10^18) of data were created (Taylor, 2011). When the datasets are enormous and complex, it cannot be processed by traditional data processing applications, and that is the reason scientists refer to it as "Big Data" (Beal, 2015). This term is widely accepted as the "Triple V": Velocity, Volume, and Variety. Although Big Data is not a small field of studies, which consists by different aspects like: store, analyze, transfer, preserve, capture, visualize, and etc. In the current research, our research team is focusing on the transfer attribute of Big Data. Our purpose is to transfer Big Data over parallel data links by taking into account the Green IT part which will make it sustainable, since it is a system which is going to run for a long period of time to transfer large amount of data. In case to achieve sustainability in the current work experiments will we executed to identify the most optimal parameters for the data transfer applications since using a large amount of resource will not always transfer datasets faster but it will consume needlessly system resources. According to the Climate Group [15], total energy consumption by computers – including the power consumption and embodied energy of data centres, PCs and peripherals, and networks and devices – accounted for 830 million metric tons of carbon dioxide, or 2 percent of the total world carbon footprint, in 2007.The main goal of the research is to identify which of the data transfer utilities parameters will make the data transfer faster and efficient. Tools/Utilities which are popular for transferring data are: Fast Data Transfer (FDT) by (FDT group, 2013), BBCP by (Hanushevsky, 2015), BBFTP by (IN2P3 group, 2013), GridFTP by (Globus Alliance, 2014), and FTS3 by (Cern IT-SDC group, 2014). The mentioned utilities have common features which make them comparable to each other, like tuneable number of TCP parallel streams, and window size for each parallel stream. Other tools which have been developed to help our research will be explained in details later.

LITERATURE REVIEW

Based on the online document, done provided by (Mangalam, 2014) who introduced ways to transfer large amount of data via network by using different utilities. A proper guideline are given on how to install, configure, and use the utilities and what kind of data transfer speeds it can be achieved in some situations. Although it was not comparative research between the utilities which were tested, and no explanation was given how the tuning of the Linux kernel parameters can affect the dataset transfer. A research conducted by (Ah Nam et al., 2012) compare different single stream utilities with some multi-stream utilities, and concludes that the multi-stream utilities can achieve greater transfer speed, but after eight parallel streams, there is not really a big difference. However, also in this paper, Linux kernel parameters were not given, and the results given do not show if the measured data transfer speed over the data link or transfer speed from disk subsystem to main memory. The amount of time to transfer over global computer network (Internet), depends on the real data link bandwidth and volume of the data (Khoruzhnikov et al., 2015). MPTCP is an interesting protocol (IETF, 2015) which permits to use multiple data links in parallel for single data transfer. MPTCP protocol is implemented as Linux kernel driver. From (Cappiello et al., 2013) research, they suggested a number of different equations to measure the energy consumption and the CO2 emissions, will be proof useful to measure our instances energy consumption in case to know how much the data transfer is affecting the energy consumption on the system. Important aspect, is the greener and sustainable development since it is widely spread from most recent results presented by climate scientists alarming, the greenhouse gas (GHG) in the atmosphere is growing faster than predicted, and the need to reduce the emissions is even more essential. Scientists, economists and policy makers are calling for emissions target of at least 20% below 1990 levels in 2020 as mentioned in the Smart 2020 report from (The Climate Group, 2008). (Drouant et al., 2015) the virtualization concept is a way to reduce the use of

materials, and as mentioned nowadays, the network companies focus on selling communications services instead of network equipment.

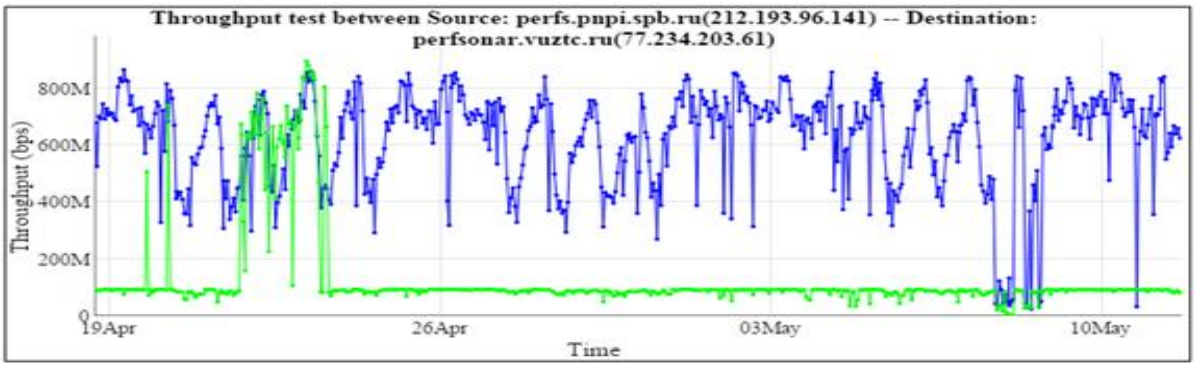
RESEARCH REVIEW AND METHDOLOGY

At the beginning of the research, literature on network tuning parameters and factors which may affect the transfer speed for datasets were examined. A number of different scenarios and scripts were deployed, which are responsible to transfer dataset over the Internet, capture data of the transfer, create log files, and at the end visualize the data by plotting graphs. In case to execute the different scenarios, with different data transfer utilities, and different parameters scripts seems to be the appropriate choice. Each scripts which executes dataset transfer was capturing information and store them into different files. Using this methodology a big collection of data was received to give us the possibility to have a clear view about our research.

A. Research Method

1. Deploying Testbed

To achieve our aims, a testbed was deployed. OpenStack (Icehouse version) is the cloud infrastructure which runs on the current testbed. OpenStack is responsible for the resource management of the testbed, and through the dashboard (GUI for OpenStack resources management), to create a number of different VMs (Virtual Machine) with hardware which can be defined by the user upon creation. Perfsonar web service has been installed to get link measurements from the network. Testbed specifications can be viewed in table 1.



<- 1 month 1 month ->

Timezone: Standard Time)

Direction	Max throughput(bps)	Mean throughput(bps)	Min throughput(bps)
Src-Dst	866.27M	627.16M	24.16M
Dst-Src	896.76M	132.7M	1.28M

Figure 36: Perfsonar Service

2. Scenarios

For the scenarios, we decide to have 2 different VMs instances, 1 of them acts as a sender node and 1 VM as a receiver nodes. All the VMs are using different resources from the cloud to perform data transfer inside virtual environment. For each VM, the necessary software, utilities, and scripts to were installed. It is important to note, that the Linux instances TCP parameters were tuned according the (Esnet, 2015) Lunix Tuning website. VMs have the following hardware specifications:

I. Software: Scientific Linux 6.5 Sender Hardware: 4 VCPU, 8 MB RAM, 80.0GB Hard Disk Drive
II. Software: Scientific Linux 6.5 Receiver Hardware: 4 VCPU, 8GB RAM, 80.0GB Hard Disk Drive

Another scenarios, is to run tests on a real network by having one a VM created on a physically remote server which is located 40 km away from ITMO inside Petersburg Nuclear Physics Institute. The VM which is located on the server in Petersburg Nuclear Physics Institute is the sender node and the one in ITMO university the receiver node. Main reason we decided to do that is because the PNPI network bandwidth overcomes ITMO's bandwidth greatly as it can be seen from the fig. 1. VMs have the following hardware specifications:

I. Software: Scientific Linux 6.5 Sender Hardware: 4 VCPU, 8 MB RAM, 80.0GB Hard Disk Drive
II. Software: Scientific Linux 6.5 Receiver Hardware: 4 VCPU, 8GB RAM, 80.0GB Hard Disk Drive

Table 23: Server specifications

Hardware Type	CPU	Main Memory (RAM)	Hard Disk Drive	Operating System
Server (IMTO)	16 x Intel Xeon E5-2650v2 @2.6GHz	99 GB DDR3	RAID6 100TB	Scientific Linux CE 6.5
Server (PNPI)	16 x Intel Xeon E5-2650v2 @2.6GHz	99 GB DDR3	RAID6 100TB	Scientific Linux CE 6.5

3. Scripts Development

Scripts were implemented to provide the opportunity to launch multiple different scenarios at the time. All the scripts were written in BASH (Bourne Again SHell) scripting language. Different utilities are executed through scripts and results are collected in the end. In order to have a "fair" comparison between the utilities, a script which creates binary data with random length was developed. Reason to have such a script (to create random length data), was to avoid the execution of compression algorithms which some utilities are using. Scripts are written for, the creation of abstract report which will have basic information about for the transfer status, log file, sosreport (system report (Quigley, 2015)) and trace route.

Tracking data are useful when it is needed to reproduce the test measurement as well. Everything has to be written in log directory with date stamps. Presumably this log directory needs to be kept available long time. Obviously storing all conditions and parameters must be done with special script or program to perform saving all test specifications automatically. Apart from transfer data, script is used to plot graphs from the captured data using gnuplot (Gnuplot, 1986). All the scripts source code is available at github: https://github.com/itmo-infocom/BigData.

4. Data Transfer Utilities

Reason which the specific utilities where introduced and decided to be used is because of are one of the most well known utilities, and about of their common features which are listed below:

- Multi-streams transfer
- User can change TCP window size
- Tune I/O buffer size
- Encrypted authentication

B. Research Results and discussion

For the test we used combination of parallel streams (1, 2, 4, 8, 16, 32, and 64) with different window sizes combinations (131072, 262144, 524288, 1048576, 2097152, 4194304, 8388608, 16777216, and 33554432 in Bytes) and dataset of 25 GB and amount of 244 files of 100 - 200 Megabyte each. For each graphs we have 63 points, where each point is a dataset transfer with different parameters. Transfer of data was done between two instances on the same server while testing in Virtual Environment. In the context of BBFTP, is important to mention that the features which are provided by the utility like gzip, rfio, afs and ssl are disabled.

As we can see from the graphs, even increasing the amount of Parallel Streams or the TCP window size it will not produce higher results. If we consider that only to transfer the data from the testbed Hard Disk Drive we can achieve speed near 150-200 MBps (bash command: dd if=/test-data/25GB of=/dev/null) then our data transfer rate cannot excide this boundary, that is also the reason why we see this behaviour on the graphs of Fig. 2 and 3.

After receiving the results from Fig.s 2 and 3 it was clear that in case to achieve higher transfer speed by using multi stream utilities alternative ways had to be used. In that case, we decided to move all the testing data from the HDD into the main memory, and though there using mount NFS (Shrivastava, 2015) to access them.

Fig.s 4 represent the results for utilities BBCP, we can see that the transfer speed have been increased more than 2 times. The access to the HDD comparing the NFS is showing big difference for the utilities transfer speed.

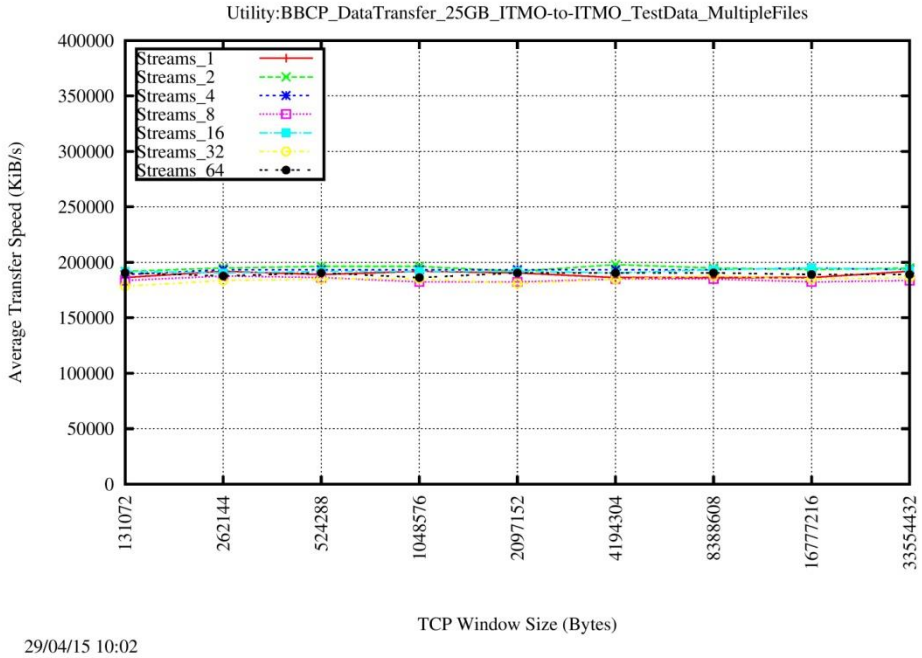


Figure 37: BBCP dataset transfer ITMO - ITMO from HDD

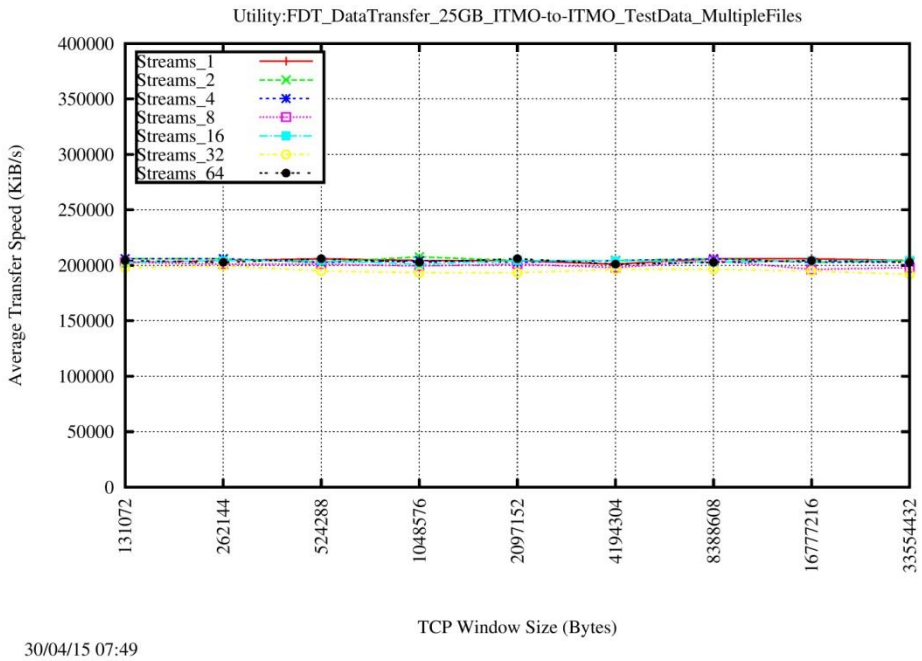


Figure 38: FDT dataset transfer ITMO - ITMO from HDD

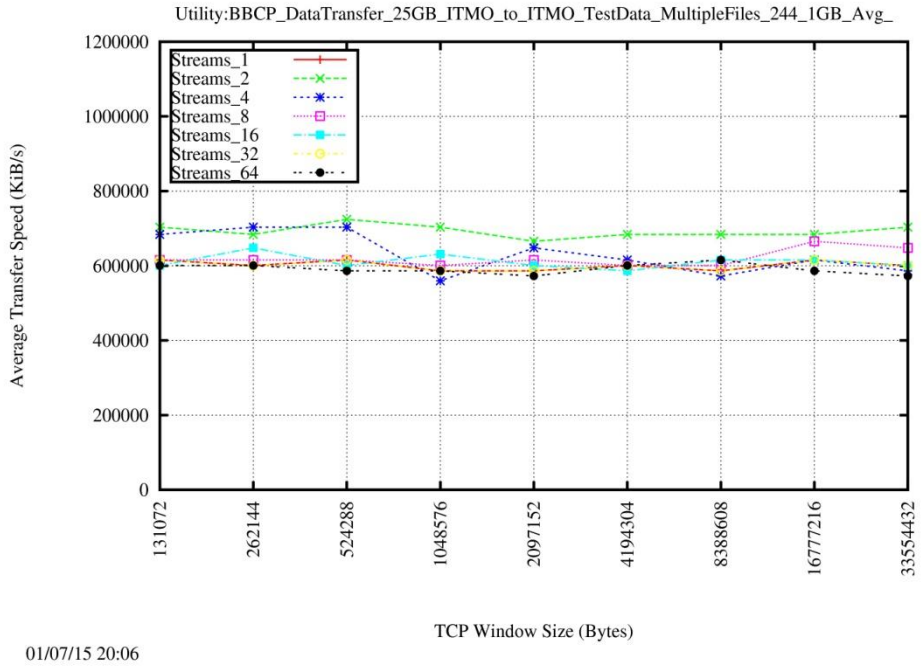


Figure 39: BBCP dataset transfer ITMO - ITMO using NFS

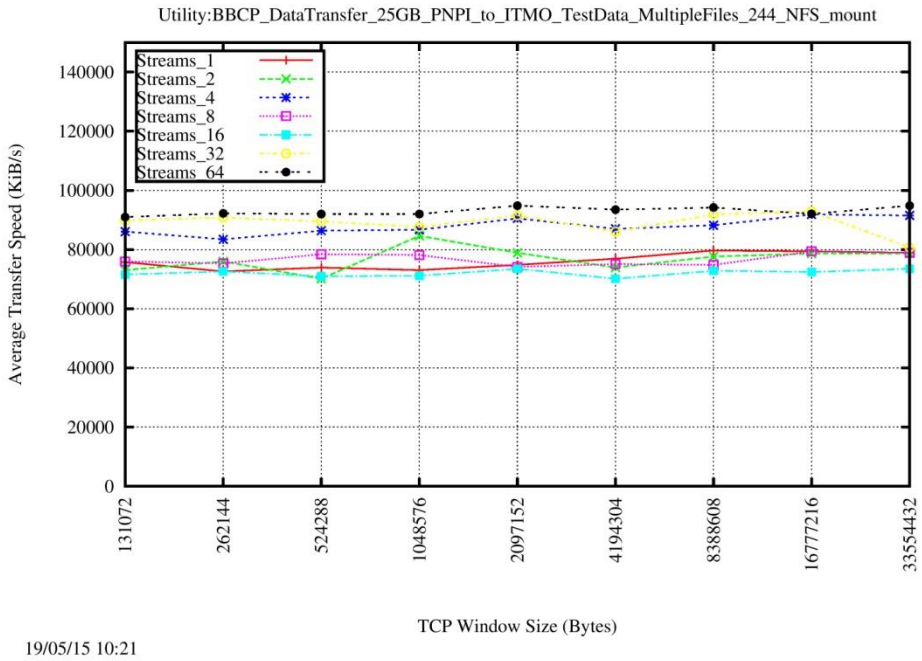


Figure 40: BBCP dataset transfer PNPI - ITMO using NFS

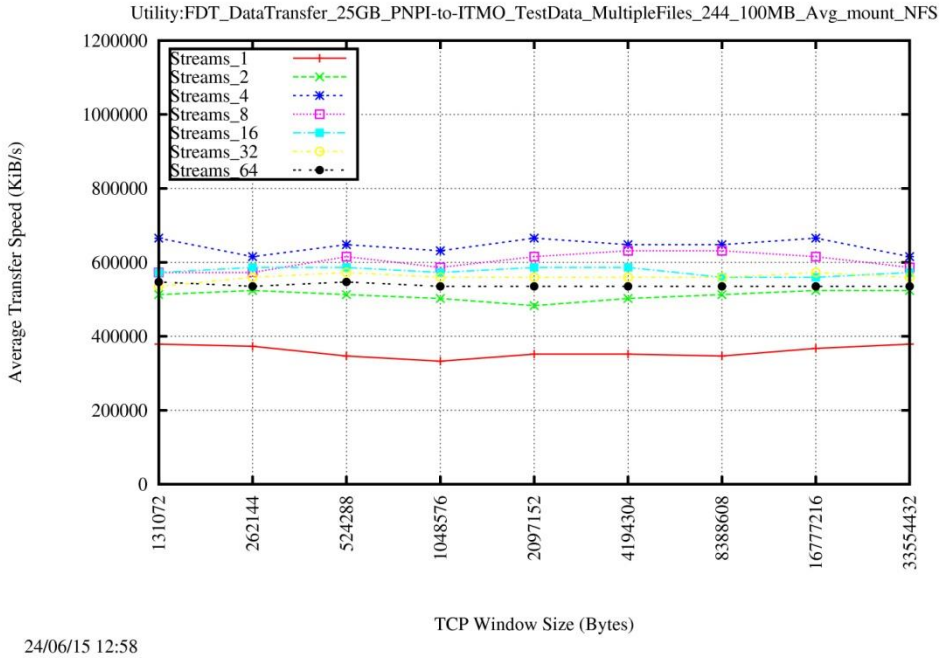


Figure 41: FDT dataset transfer PNPI - ITMO using NFS

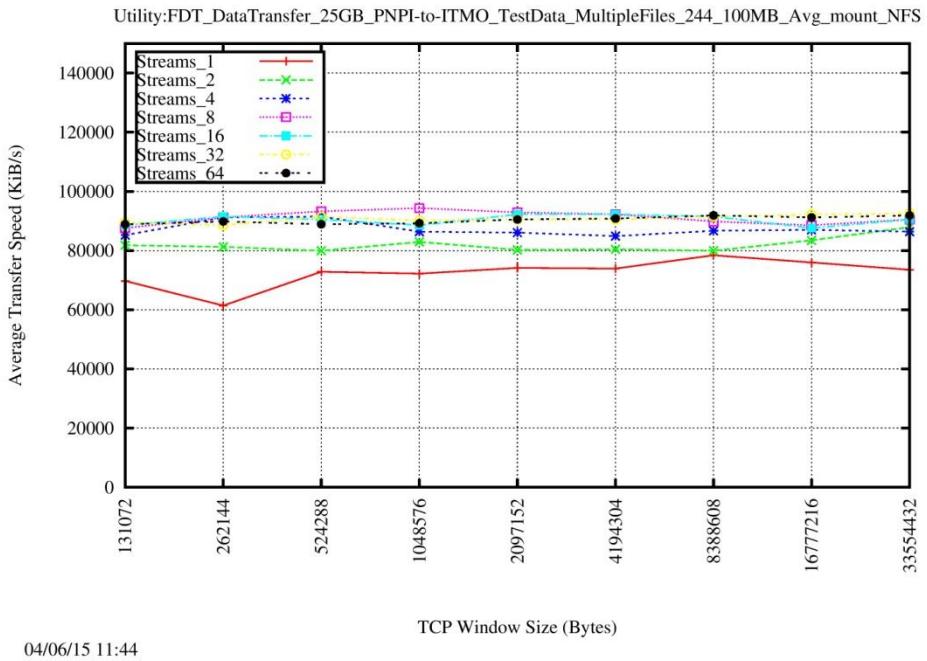


Figure 42: FDT dataset transfer PNPI - ITMO using NFS

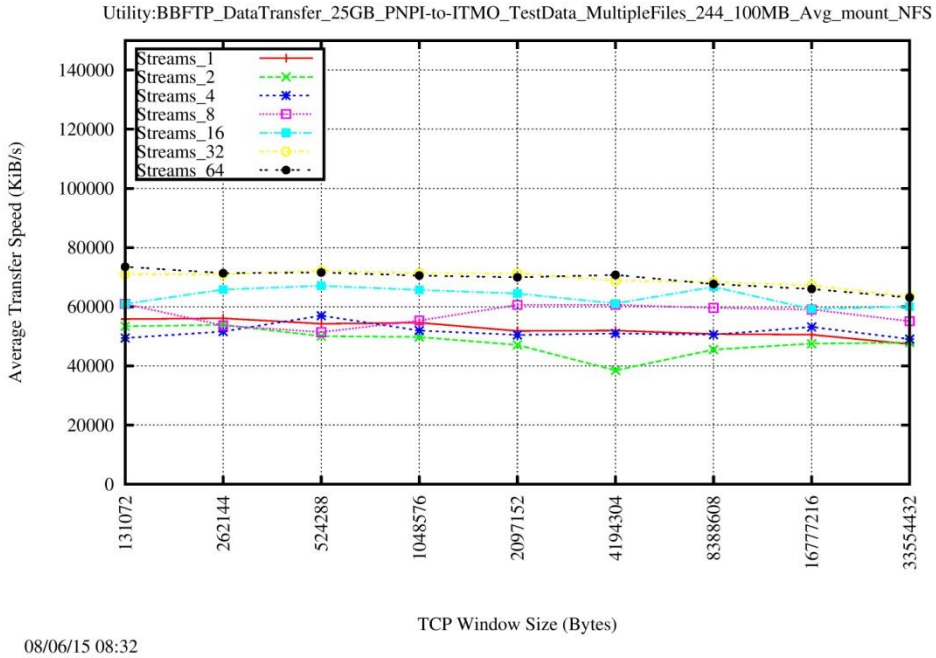


Figure 43: BBFTP dataset transfer PNPI - ITMO using NFS

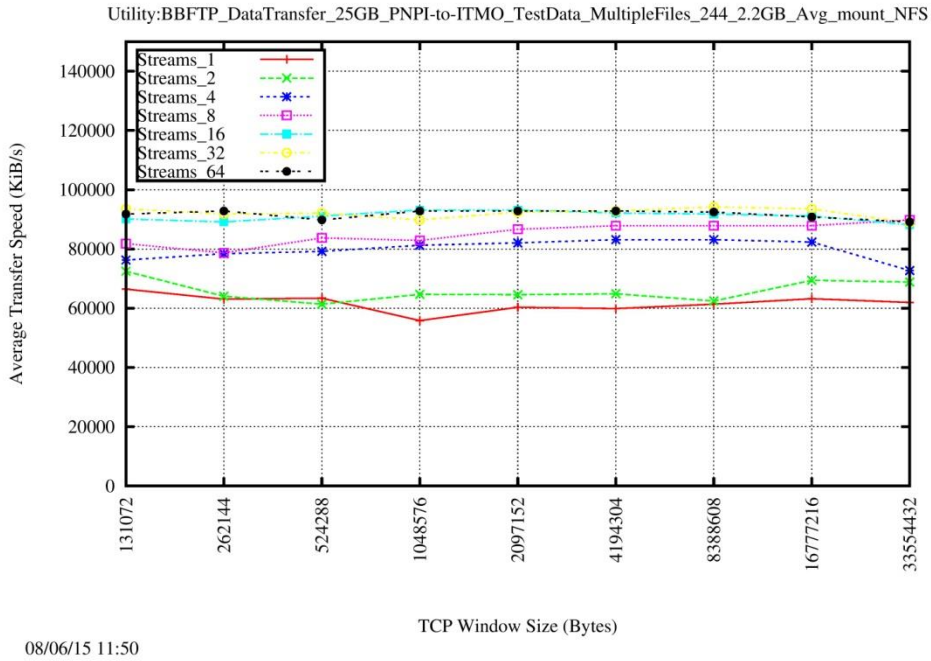


Figure 44: BBFTP dataset transfer PNPI - ITMO using NFS

Fig.s 8 and 9, represents testing of the BBFTP utility with different datasets size like 10 files of 2,5GB (Fig. 9) each instead of 244 files of 100MB (Fig. 8), which had as a result to increase the average

transfer speed (IN2P3, 2015). For the other results in Fig.s 6 and 7 we can experience the scaling increase of the transfer speed while increasing the number of parallel streams.

CONCLUSION AND FUTURE PLANS

A. Conclusion

From the results we acquired, we can see from that even if we increase the TCP window size it does not result as an increase of the transfer speed in the context of virtual environment or the real network. On the other hand it means we do not really need to allocate such an amount of resources for our virtual machines. Taking into account that for each parallel streams main memory will be allocated based on the current TCP window size to transfer the data. To keep our development sustainable, we should consider to use the amount of resources we need, and by having developed this experimental platform we could know which are the optimal parameters to use.

The internal architecture (and features) of the data transfer utility affects the transfer speed. By reviewing the results of the BBFTP in Figs. 8 and 9 based on the implementation we can see by using larger data files we can see increased average transfer speed. Any long term data transfer task would require careful study, for which utility and with which parameters might help to achieve maximum data transfer speed.

The testbed platform, which was deployed during the project can be used to compare any existing or any upcoming utilities for further research and give a collection of information to be analyzed.

B. Future Plans

For the moment not all the utilities which mentioned above were fully tested. Globus toolkit and FTS3 are rather different utilities due to the fact that they need trusted certificates to perform data transfers. Results for both Globus toolkit and FTS3 where received but we are still in no position to understand them.

Dataset which is expected to be transferred for future plans is approximately 100TB. Such a large amount of data may take around 2 weeks for a single transfer, hence is the necessity to have a clear view before starting it. All the scenarios which were tested should be executed also in a real network through a public line. This test will take more time since it’s not a virtual environment and the transfer speed will affected by traffic of other users or one of the links may go down, in that case we can see more changes in the utilities behaviours.

Energy monitoring tool has to be developed for the Virtual machines which can be used to get information about the which utility consumes more energy. PowerTop is a Linux command which could be used by its not implemented for Virtual Machines.

Since this project is at early stages only a single data link was used for the scenarios. For future work more data links are expected to be used in case to achieve higher transfer speed for the Big Data.

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DEVELOPMENT OF AN ECOLOGY-ORIDENTED SDN FRAMEWORK

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Keywords: Software-Defined Network, Green IT, OpenFlow, Energy-Saving.

Abstract

ICT contributed to about 0.83 GtCO2 emissions where the 37% comes from the telecoms infrastructures. At the same time, the increasing cost of energy has been hindering the industry in providing more affordable services for the users. One of the sources of these problems is said to be the rigidity of the current network infrastructures which limits innovations in the network. SDN (Software Defined Network) has emerged as one of the prominent solutions with its idea of abstraction, visibility, and programmability in the network. Nevertheless, there are still significant efforts needed to actually utilize it to create a more energy and environmentally friendly network. In this paper, we suggested and developed a platform for developing ecology-related SDN applications. The main approach we take in realizing this goal is by maximizing the abstractions provided by OpenFlow and to expose RESTful interfaces to modules which enable energy saving in the network. While OpenFlow is made to be the standard for SDN protocol, there are still some mechanisms not defined in its specification, especially related to energy saving. To solve this, we created REST interfaces for setting of QoS (Quality of Service) in the switches which can maximize network utilization. Interfaces and modules for enabling Adaptive Link Rate are also implemented. The usage of multi paths in a network is evaluated for its benefit in terms of transfer rate improvement and energy savings. Hopefully, the developed framework can be beneficial for other developers in creating applications for supporting environmentally friendly network infrastructures.

Satriana, C., Sadov, O. and Grudinin, V. (2015) **Development of an ecology-oriented SDN framework** *In;* Gorse, C and Dastbaz, M (Eds) *International SEEDS Conference,* 17 – 18 September 2015, Leeds Beckett University UK, Sustainable Ecological Engineering Design for Society.

INTRODUCTION

ICT currently contributed to about 0.83 GtCO2 emissions where the 37% of it comes from the telecoms infrastructures. Similarly, the network infrastructure in a data center contributes to about 20% of power consumption (GeSI, 2008). While this number does not seem huge, 3 billion kWh was consumed by the networking elements in the data centers in the United States of America (Greenberg, 2008). Innovation in this area can certainly contribute to not only saving the environment but also improve business by reducing energy costs.

Unfortunately, the rigidity of the current network infrastructures has been said to limit innovations in the network. Nevertheless, Software-Defined Network (SDN) has emerged as one of the prominent solutions with its idea of abstraction, visibility, and programmability in the network. Basically, it is achieved via the separation between the control plane and the forwarding plane of a network switch. The forwarding plane itself is programmable via the interfaces specified by OpenFlow protocol. OpenFlow also specifies the mechanisms needed to exist in SDN capable switches and how these switches can be programmed.

However, if the goal is to utilize SDN to create a more energy and environmentally friendly network, then significant efforts are needed to actually realize it. Currently there is not yet a framework in which users, specifically developers, can make use of to create ecology-related applications. To solve this problem, we propose an ecology-oriented SDN framework in which users can easily use to save energy in their network.

The developed Ecology SDN Framework is designed with idea of maximizing the abstraction feature of SDN and to integrate researched mechanisms to save energy in a network. The framework has some modules including REST API for setting of QoS in OpenFlow switch, Adaptive Link Rate to accustom interface rate to network utilization, and network optimization to increase performance while at the same time saving energy.

This framework is developed as a master thesis for a master degree of Pervasive Computing and Communication for Sustainable Development (PERCCOM). PERCCOM is an Erasmus Mundus Joint Master Degree (EMJMD) which focuses on building a green ICT system.

LITERATURE REVIEW

Software-Defined Network

According to ONF (2012) SDN is defined as the physical separation of the network control plane from the forwarding plane, and where a control plane controls several devices. In other words, SDN allows the network to be programmable.

The logical architecture of SDN is shown in Fig.1. On the bottom layer, the network of physical switches are abstracted and centrally managed through an SDN controller at the control layer. Other than managing the current state of the underlying network, the controller also provides Application Programming Interface (API) which can be used by SDN applications to provide network services such as routing, traffic engineering, energy usage, quality of service and security.

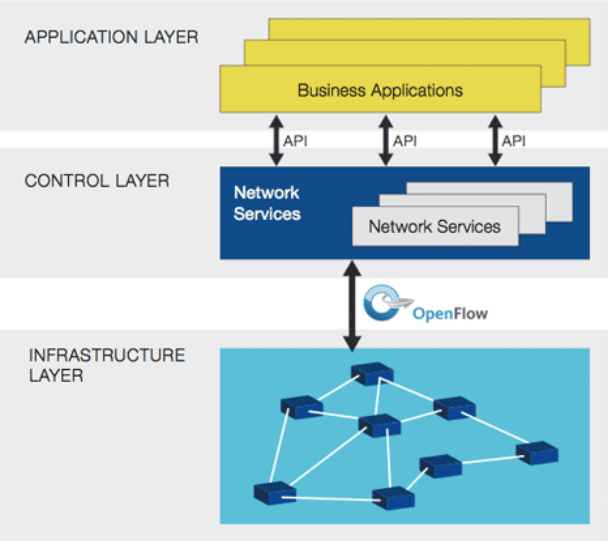

Figure 45. Software-Defined Network Architecture (ONF, 2012)

One particular attention on the architecture is the protocol used for communication between the infrastructure layer and control layer. Currently there is no standard protocol, but the most used one is the OpenFlow. Basically it specifies the instructions or commands which can be executed by the SDN controllers to modify the forwarding tables of the underlying infrastructure layer (phisical or virtual switches). Fig.2 is an example of instruction which can be set on the OpenFlow-enabled switches. Depending on the MAC destination address, MAC source address IP address, and TCP port, a certain packet which matches those fields will be forwarded to port 1 of the switch or forwarded to the controller, based on the value on the action field.

OpenFlow-enabled Network Device

Flow Table comparable to an instruction set

MAC src	MAC dst	IP Src	IP Dst	TCP dport	...	Action	Count
*	10:20:.	*	*	*	*	port 1	250
*	*	*	5.6.7.8	*	*	port 2	300
*	*	*	*	25	*	drop	892
*	*	*	192.*	*	*	local	120
*	*	*	*	*	*	controller	11

Figure 46. Example of OpenFlow Instruction Set (ONF, 2012)

Representational State Transfer

Representational State Transfer (REST) is a coordinated set of architectural constraints that attempts to minimize latency and network communication while at the same time maximizing the independence and scalability of component implementations (Roy fielding, 2002). REST also enables the caching and reuse of interactions, dynamic substitutability of components, and processing of actions by intermediaries, thereby meeting the needs of an Internet-scale distributed hypermedia system.

According to Zhou (2014), adopting REST for SDN northbound API has some benefits such as: decentralized management of dynamic resources, heterogeneous clients, service composition, localized migration, and scalability.

RESEARCH REVIEW AND METHODOLOGY

The research approach adopted in this work is formulative research. This approach is suggested by Morrison and George (1995). They also suggested other research approaches including evaluative research, descriptive research, and developmental research. Formulative research involves development and refinement of theories, models, or frameworks that govern research activities, and support scientific progress through paradigm shifts. Also, most of formulative work involves synthesizing and integrating information and then developing guidelines, models, or frameworks.

Agile software development approach is followed in conducting this research. Pekka (2002) explains that this development approach has some important characteristics such as modularity on development process level, iterative with short cycles enabling fast verifications and corrections, adaptive with possible emergent new risks, incremental process approach that allows functioning application building in small steps, and collaborative and communicative working style.

There are different agile software development methodologies, such as feature driven development (FDD), scrum, rational unified process (RUP), and adaptive software development. Out of these, RUP is chosen as it is more appropriate for iterative development in object-oriented approach. RUP's project lifespan consists of four phases: inception, elaboration, construction, and transition, as depicted in figure 3.

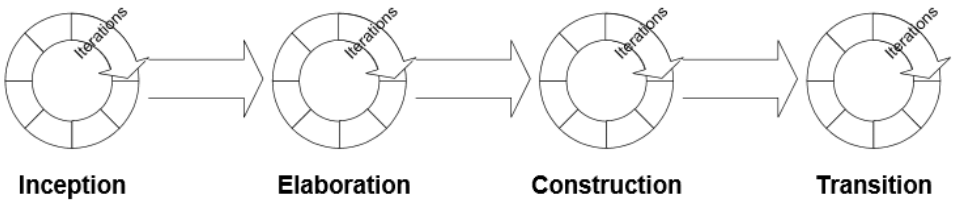

Figure 47. RUP Phases

ECOLOGY SDN FRAMEWORK DESIGN AND IMPLEMENTATION

Inception

Inception phase which comprises of requirement gathering and analysis is the first step in RUP. In our work, we analysed some of the important requirements:

1. Research solutions that makes the network infrastructure to be ecology-friendly.
2. Research the possibility of using SDN which provides abstraction, visibility, and programmability in a network, to implement the solutions.
3. The solution should be implemented in a form of framework which can be utilized by other users or other developers in which to build upon more green solutions.
4. It should have good quality requirements such as modularity, composability, and scalability.

Elaboration

In this step, high level as well as detailed design and implementation is laid out.

There are two main ideas we apply in designing the framework is by maximizing the abstraction provided in SDN through OpenFlow and to implement researched mechanisms to save energy in a network.

Figure 3 shows the high level view of the framework. This framework sits on top of Ryu SDN controller. The main idea is that this framework extends the capability of Ryu which communicates with the underlying physical or virtual network.

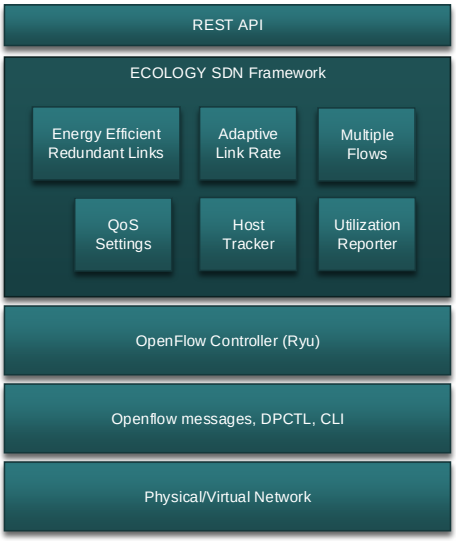

Figure 48. Ecology SDN Framework Architecture

The idea of creating separate modules which serves their own individual functions is to support composability in the framework. This is also an idea borrowed from Service-oriented Architecture which supports in creating small functional services which can collaborate in achieving bigger functionalities. This approach is also good for scalability because in the system, any new application or functionality can get certain data from an already running module instead of implementing its own mechanism.

The individual modules are described in the following subsections.

QoS REST API

OpenFlow defines the mechanisms to access the forwarding plane of a switch and the features needed to be implemented in it through OpenFlow specification (ONF, 2009). But it does not specify the mechanisms for queue settings which can be useful in guaranteeing Quality of Service (QoS) and in implementing the adaptive link rate feature. This certainly becomes a problem when the network consists of switches from different vendors, physical or virtual switch, where each has their own way to configure the queue, decreasing the abstraction nature of SDN itself. To overcome this, we create a RESTful API to set the queue settings in CPqD OpenFlow 1.2 and 1.3 compatible software switches.

Utilization Reporter

Utilization reporter is the component in the SDN framework which reports the utilization of ports in OpenFlow switch by collecting port statistics on the switch. This port statistics consists of data such as the number of packets received/transmitted, number of bytes received/transmitted, number of packets dropped and number of received/transmit errors.

Querying the port statistics requires the Port Utilization to send ofp_port_stats_request to the switch. This action is carried out in a thread and executes the action every certain interval, for example 5 seconds. The calculation of the utilization is carried out with the following formula:

$$\frac{(\Delta Tx + \Delta Rx) \times 8\ x\ 100}{Tmeasurement \times ifBw}$$

Where Tx and Rx is the number of packets received and transmitted on that interface respectively, Tmeasurement is duration since the previous measurement and ifBw is the interface bandwidth or the maximum capacity of the interface.

Energy Saving in Redundant Links

Redundant links in a network are usually used either to increase performance by utilizing both links, or as a backup mechanism when the normal link is down. In this framework we created a sample application which utilized the redundant links when the load of the network require more capacity and turn the redundant link off when such link capacity is not needed.

Figure 2 shows the example network we setup in Mininet. To avoid ARP broadcast storm, we set flow rules so that only one of the ports is used to transmit these broadcast packets

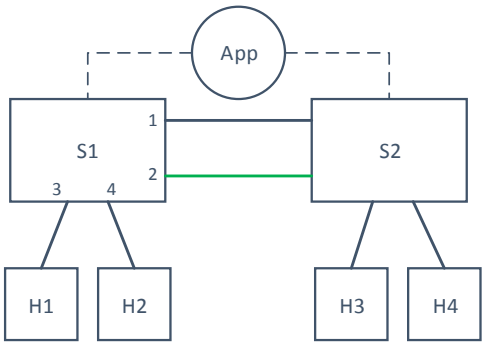

Figure 49. Redundant Link Example Scenario

This is achieved by installing flow rules which will drop packets coming in from port 2 and have Ethernet destination address of broadcast address. Then, to use both links we decided to load balance the traffic. A simple selection mechanism is implemented. Hosts connected to odd port number will go to port 1 and hosts connected to even port number will go to port 2, that is when their destination is a host in another switch. At the same time, the Port Stats module reports the number of transmitted and received bytes on the switch's ports.

Then the module applies the rules depending on the policy specified, such as to disable port 2 when the utilization of port 1 + utilization port 2 is under 90%. The disabling of the port is achieved by sending ofppc_port_down message to the port. Host Tracker module is used to get information of the mac addresses connected to the switches and used in installing balancing flows.

Adaptive Link Rate

According to Gunaratne (2008), 1 Gbps Ethernet Links consume 4 W more than 100 Mbps links, while both idle and fully utilized Ethernet links consume same amount of power. The suggested mechanism to save the power is to use Adaptive Link Rate (ALR), which is by adaptively varying the link rate based on the load or utilization in the network. In this framework we provide modules to change the line speed of switch, which can be combined with the utilization reporter to provide ALR feature.

Multiple Flows

A trivial yet working approach in saving energy is by increasing the performance of network itself during high utilization. By increasing the network performance, the required time to do the work-- in this case transferring the data- can be achieved faster, and the resources involved may rest earlier once the work is done.

In our work we test the working of the module by sending data from H1 and H2 using BBCP tool. BBCP is a tool to securely and quickly (approaching line speeds) from source to target. The network architecture is depicted in figure 6.

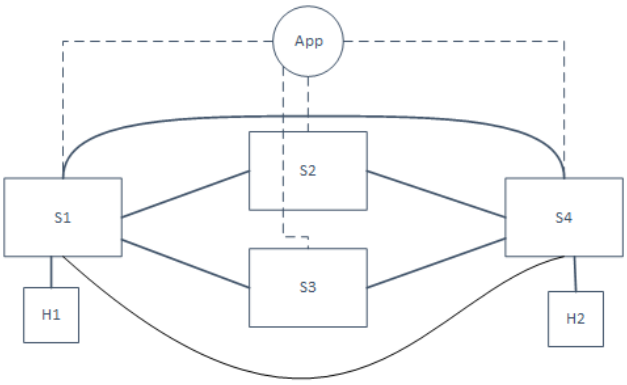

Figure 50. Multiple Paths Network Example

A BBCP streams should be sent from H1 to H2 through the available paths. It is assumed that the available paths are known to the SDN application. These are the paths from H1 to H2:

1. H1 – (Port 3)S2(Port 15) – (Port 15)S5(Port 4)

2. H1 – (Port 3)S2(Port 14) – (Port 14)S3(Port 15) – (Port 13)S5(Port 4)

3. H1 – (Port 3)S2(Port 14) – (Port 13)S4(Port 15) – (Port 14)S5(Port 4)

4. H1 – (Port 3)S2(Port 16) – (Port 16)S4(Port 4)

To achieve the load balancing, BBCP streams from H1 are routed through the different paths. Each BBCP stream can be identified by its TCP source port because each stream has the same TCP destination port (5031), but different TCP source port. The activity diagram below shows the logic used in the application to load balance the BBCP streams:

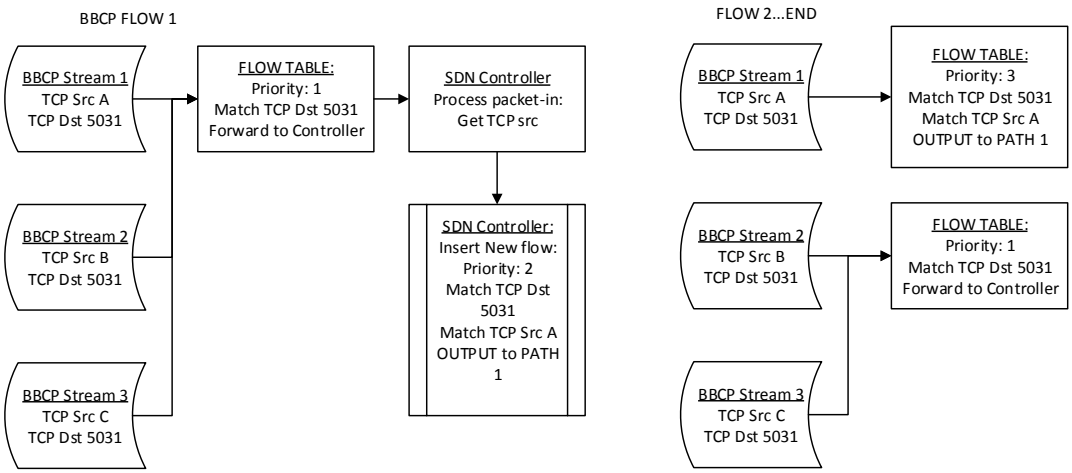

Figure 51. Multipathing Module Flow Diagram

The first incoming BBCP stream from H1 for example will be matched to the flow rule: match tcp_dst 5031. This flow is then forwarded to controller where further processing takes place. This process is to read the TCP source port of the flow and to insert a new flow rule matching the TCP source port and TCP destination port. The next flow coming from this same BBCP stream will then be matched to this new flow rule, for example will be output to path 1, instead of matching the previous rule which will forward it to the controller because the new rule has higher priority.

Broadcast storm due to loops in the network is avoided because these broadcast packets will flow through the default path, for example in this work path 1 from H1 to H2 is used. While BBCP packets are routed through the different paths depending on their TCP source ports.

Host Tracker

The application keep tracks of the hosts connected to the switches. The data that is stored is MAC address of the host, IP address of the host, DPID of the switch and port number in which the host is connected to, timestamp to store the time the mac address is stored to ensure the freshness of the data.

RESEARCH RESULTS AND DISCUSSION

REST API Endpoints

Table 1 lists the REST API endpoints and the service provided at the endpoint. The location of the resource is put next to the HTTP method to access the resource, for example PUT /v1.0/conf/switches/{SWITCH_ID}

Table 24. REST API Endpoints

Endpoint	**Description**
QoS Settings	
PUT /v1.0/conf/switches/{SWITCH_ID}	Set switch address
POST /qos/queue/{SWITCH_ID}	Set QoS settings with data : port-name, queues: min-rate:, max-rate:
GET /qos/queue/{SWITCH_ID}	Get all queues settings in the switch
DELETE /qos/queue/{SWITCH_ID}/{PORT}/{QUEUE_ID}	Delete a specific queue
DELETE /qos/queue/{SWITCH_ID}	Delete all queues settings in the switch
Adaptive Link Rate	
PUT /alr/{SWITCH_ID}/PORT	Activate ALR on PORT with data: enabled:true/false, threshold
GET /alr/{SWITCH_ID}/PORT	Get ALR status: rate, threshold
GET /alr/speed/{SWITCH_ID}/PORT	Get speed of the port
PUT /alr/speed/{SWITCH_ID}/PORT	Set speed of the port, with data: speed
Host Tracker	
Get /host_tracker/hosts	Get all hosts and their information
Get /host_tracker/hosts/{SWITCH_ID}	Get all hosts connected to the switch
Port Modification	
PUT /portmod/{SWITCH_ID}/{PORT}	Power on/shutdown the port, with data: enabled: true/false

Multipath

This multipath test will test if the multipath module is working as expected according to the design explained in the previous section. The energy saving possibility when using the multipath module is also evaluated. The test is executed on the following environment:

1. Mininet version 2.0

2. OVS (Open vSwitch) 2.0.2

3. Ubuntu 14.04 LTS

4. Intel Core i5-3230M CPU@ 2.60 GHz (4 CPUs)

5. Memory of 4096 MB RAM

Figure 6 depicts the topology of the network on which the test will be done. The links are configured at 100Mbps. During the test BBCP Linux utility will copy a 400MB of data from H1 to H2. The number of paths will be varied and the transfer rate and energy consumption of BBCP and OVS will be observed.

Energy measurement is limited to only measuring the energy when utilizing the multipath module in virtual environment. To measure the power consumption, Powertop is used. Powertop is a tool for measuring power consumption and diagnosing power management in Linux.

Below is the method of the energy measurement:
1. Execute powertop to generate report every second.
2. During this time, execute BBCP transfer from H1 to H2, with varying number of streams and paths.
3. Parse and plot energy consumption based on the resulting reports.

Measurement is carried out every second. But it takes time for powertop to commit the measurement and to produce the report. The report is generated every 5 seconds by powertop. In the subsection below, the measurement results are described and analyzed.

Firstly, the number of paths which is used by the multipath module is varied. Energy consumption during BBCP transfer is then measured.

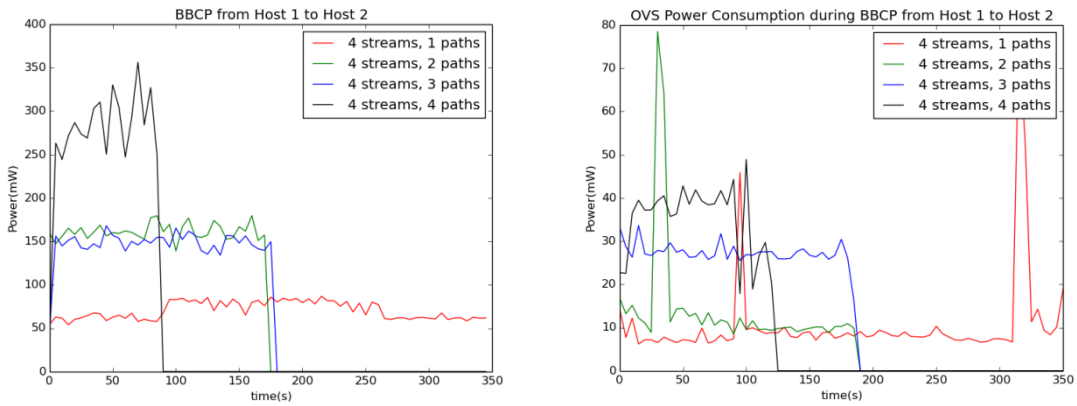

Fig. 8. BBCP Power Consumption with varying paths (left), OVS Power Consumption with varying paths during BBCP Transfer (right)

The energy consumed during the transfer and its transfer rate is also shown in table 1.

Table 25. Energy and Rate of Varied Number of Paths

Configuration	BBCP Energy (J)	OVS Energy (J)	Rate (Mbps)
1 stream 1 path	21.82	5.02	1

4 stream, 1 path	24.6 J	3.76	1.1
4 stream, 2 path	28.2	2.71	2.3
4 stream, 3 path	26.3	5.18	2.3
4 stream, 4 path	24.5	4.36	4.4

The results in table 1 suggest that energy consumption is minimal when using only 1 stream and 1 path. While the energy consumption when the transfer rate is the highest (4 stream and 4 paths, with rate of 4.4 Mbps) is about 24.5 J or around 3 joules more than when using only 1 stream and 1 path. It can also be said that increasing the transfer rate by 400%, only increase the energy by 12.3%. This certainly can be a good reason when to actually use multiple paths. It is also important to note here that we also do not consider the possibility of sleeping the network resources once the transfer completes. Once the transfer complete it may be better to actually sleep some parts of the network. Thus, increasing the transfer rate can possibly yield bigger savings and significantly shorter latency.

CONCLUSION

It can be suggested that the research problem of developing a framework in which other developers can use to create ecology-oriented applications in SDN has been answered to some extent.
The energy mechanisms has been designed and implemented in the context of Software-Defined Network. Through OpenFlow, the support of SDN to apply those mechanisms in the real network is actually good. Even many features in OpenFlow 1.0 have been supportive for implementing them. However, the main problem exists in the physical switch. What is observed is that while they claim to support OpenFlow, many of their implementations not necessarily following the OpenFlow specifications. This has caused some significant problems in the implementation in the framework
Further direction for this research would be to conduct a detailed energy consumption measurement both for physical and virtual environment when using the modules of the framework. Such measurements will be beneficial either to fine tune the framework and to generate more ideas on saving energy in a network

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MODELING THE POWER CONSUMPTION OF ETHERNET SWITCH

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Keywords: Green Networking, Power consumption, Design of Experiment

Abstract

At present, one of the main concerns of green network is to minimize the power consumption of network infrastructure. Surveys show that, the highest amount of power is consumed by the network devices during its runtime. However to control this power consumption it is important to know which factors has highest impact on this matter. This paper is focused on the measurement and modeling of the power consumption of an Ethernet switch during its runtime, considering various types of input parameters with all possible combinations. For the experiment, three input parameters are chosen. They are bandwidth, traffic and number of connections. The output to be measured is the power consumption of the Ethernet switch. Due to the uncertain power consuming pattern of the Ethernet switch a fully-comprehensive experimental evaluation would require an unfeasible and cumbersome experimental phase. Because of that, a design of experiment (DoE) method has been applied to obtain adequate information on the effects of each of the input parameters on the power consumption. The whole work consists of three parts. In the first part a test bed is planned with input parameters and the power consumption of the switch is measured. The second part is about generating a mathematical model with the help of design of experiment tools. This model can be used for measuring precise power consumption in different scenarios and also pinpoint the parameters with higher influence in power consumption. And in the last part, the mathematical model is evaluated by comparison with the experimental values.

Hossain, M., Rondeau, E., Georges, J. and Bastogne, T. (2015) **Modelling the power consumption of thernet switch** *In;* Gorse, C and Dastbaz, M (Eds) *International SEEDS Conference,* 17 – 18 September 2015, Leeds Beckett University UK, Sustainable Ecological Engineering Design for Society.

INTRODUCTION

We are now living in an era of cutting edge technology. Everything is now in the reach of humans, which was beyond imagination, even few decades ago. However this awe-inspiring enhancement in the field of technology has a huge impact on the environment. In coming years, we have the greatest challenge in front of us, which is tackling climate change. Bianzino et al. (2012) mentioned that, power consumption has now become one of the top-most concerns of world industries and the reduction of power consumption has become a primal goal for any industries, because of environmental, economic and ethical reasons. This concern has a strong influence over the field of information and communication technology (ICT). Smart2020 report (2008) published by Global eSustainability Initiative, explains a statistics report on ICT sectors, this report showed that the ICT sector alone was responsible for 2% of global carbon emissions. ICT play a major role in pointing out many environmental problems such as environment pollution, waste management, power and supply management. However, Rondeau et al. (2015) explained that the use of ICT can also have some impact on the environment in terms of ICT footprints such as carbon emission and electronic waste. To minimize the ICT footprint in the environment, there is a need to implement new requirements in order to design a sustainable green network. The number of ICT devices is increasing in an exponential manner. Moreover, Widjaja et al. (2014) mentioned in their article that, currently data centers are growing faster than any other ICT technology, driven by the need for storage, computing and other information technology services. These advancements put lots of concern over the field of electronics designs, ICT, and networking more specifically.

According to Penttinen (2012), in recent years, persistent efforts have been made to reduce unnecessary power consumption, which is usually known as a 'greening' of the networking technologies and protocols. Power-related studies in networks are usually very specific and due to millions of innovations and improvements make it even harder. This work also only focuses on one of the most important devices of wired networks which are the Ethernet switch. Every device has lifelong ICT usage. This starts from manufacturing until dismantling. But here the concern was only during the usage period of the Ethernet switch. The goal is to observe the behavior of the switch with a different variation of a few selected variables and analyze these variations to propose a model which defines the relationship between a few main parameters related to the Ethernet switch and the power consumption. Two models are proposed for measuring the power: one is using full factorial method and another is using linear regression. The first model is based on full factorial which provides a model with fewer experiments and for the more elaborate experimental model, a linear regression model is used. For this work only those parameters are chosen which can be controlled on switch end. That means the plan is to choose only those parameters that network architecture may control during network design. The idea is to get an overall idea about how these parameters affect the power consumption.

RELATED WORK

Several works have been done for both wired and wireless networks in order to find the power consumption pattern on the network device. However the design of an experiment in the field of networking is comparatively atypical.

Related Work in Power Consumption

Gupta, Grover and Singh (2004) did a feasibility study on power management of Ethernet switches. They provided a fair guideline for running an experiment on switches. Christensen, Nordman and Brown (2004) explained how network devices can have impact on environment pollution. Mahadevan and Shah (2010) claimed that, for an Ethernet switch lifecycle, during the use phase the maximum amount of power is consumed. They did a full life cycle assessment and come to this conclusion. Foll (2008) did a similar kind of experiment to find out the power consumption within the Orange Telecom Company. One of the difficult things for this experiment was to decide the parameter. According to Mayo and Ranganathan (2005) and Rivoire and Shah (2007) from a device manufacturer's point of view one of the challenges is to make sure that networking devices such as switches and routers are

power proportional, that means they will consume power proportional to their load and usage like computers and laptops.

Related Work Based on DoE

Zhan and Goulart (2009) used the design of experiment method for analyzing the broadband wireless link for rural areas. On the other hand Totaro (2005) and Gendy and Bose (2003) used the full factorial method for analyzing the mobile ad-hoc network and per hop QoS respectively. Gendy and Bose (2003) examined the per hop quality of service for example throughput, delay, jitter and loss rate by using different input traffic scenario and per hop behavior on routers. Per hop behavior means policy and protocol that have been assigned to a packet during each hop. They used analysis of variance to identify the input which is most significant. These experiments provided a fair idea about how to prepare the test-bed. Mahadevan and Sharma (2009) benchmarked the switch behavior for different parameters. They explained that the switch consumes power proportionately to the load and usage. It differentiated between parameters which have impacts and those which do not have impacts. It helped our work to select the parameter for the experiment.

METHODOLOGY

This section describes the DOE methods that have been used to model the power consumption pattern of the Ethernet switch. Here statistical analysis methods have been applied to identify the most influential parameters affecting the power consumption of the Ethernet switch within the range and domain of these experiments. Two methods have been used to model the equation. One is full factorial method and another is linear regression analysis.

Full Factorial

A Full Factorial DOE provides responsive information about factor main effects and factor interactions. It also provides the process model's coefficients for all the factors and interaction. A full factorial DOE is a planned set of tests on the response variable or variables with one or more inputs factors, with all possible combinations of levels. If we have n factors, with the i-th factor having k_i levels, and if each experiment is repeated for r times, then the total number of experiments: $\prod_{i=1}^{n} k_i * r$.The main objective of full factorial method is learning the most from as few numbers of experiments as possible. It identifies the factors which affect mean and variation which usually helps to identify if the parameter is necessary for the model or not. And then lastly it produces prediction equations which can be used for validation.

Linear Regression Analysis

Regression analysis is the method of fitting straight lines to set of data. As discussed by Robert (2014) in a linear regression model, the variable of interest in this case is power consumption which is predicted from k other variables using a linear equation. If Y denotes the dependent variable or the response, and $X_1, \ldots, X_k$, are the independent variables, then linear regression analysis would be:

$$Y = c + a X_1 + b X_2 + \ldots + z X_k$$

However, here linear regression analysis with two way interactions has been used. It considers all the possible interactions between all the parameters. A stepwise regression method has been deployed which is used in the probing stages of model building to find out a useful subset of factors. The process step-by-step adds the most significant variable or the combination of the variables and removes the least significant variable or the combination of the variables.

RESEARCH METHOD

Parameter and Response Selection

Parameter selection is one of the important issues before starting anything. This work entirely focuses on Ethernet switch behavior and the goal was to include those parameters that can have a major

effect. Rondeau and Lepage (2010) did similar experiments with Ethernet switches and mention few parameters. Mahadevan and Sharma (2009) explained that there is no impact of packet size on the power consumption. Because of that packet size is not considered as a parameter. As discussed earlier for conducting the experiment we have initially considered three parameters, bandwidth or link capacity, number of PCs connected to the switch and traffic on the switch. For the full factorial model only two factors, bandwidth and number of connected PCs have been considered. Traffic load has not been considered because initial experiments show that traffic has rather less impact on power consumption compared to other two variables. For a fixed value of bandwidth and number of PCs connected, regardless the load of the traffic, power consumption does not vary much. Therefore, traffic is neglected for reducing the complexity of the model.

On the other hand for linear regression analysis all three variables are used. IEEE introduced IEEE802.3az energy efficiency Ethernet protocol. Christensen et al., (2010) discussed the management parameters for power consumption. Therefore traffic is introduced considering future aspects which are controlling the power consumption of the switch and also checking the effect of idle mode. The target is to review the Ethernet switch as a black box and observe its behavior in different scenarios. Because of that we only consider those parameters which are directly in relation with the Ethernet switch. Now for bandwidth three different values have been used 10Mbps, 100Mbps and 1000Mbps. As an Ethernet switch has 24 link ports, the number of active connections are varied from 2,4,6,8,10,12,14,16,18,20,22,and 24 connections to cover the whole range. The goal of this work is to provide a power consumption model of an Ethernet switch so it can be used to recognize the pattern of consuming power and control the power consumption later on.

For the experiment only one response is measured which is power consumption in Watts. Power consumption is measured for different combinations of bandwidth and number of PC and traffic.

Experiment Detail

The experiment was done using the architecture of figure.1. A Cisco Ethernet Switch 2960x is used for the experiment. Architecture was designed in a way as every two PCs are acted as a pair. One PC of the pair is sending data and another one is receiving data. In this experiment, a Powerspy2 sensor is used to measure the power consumption of the monitored switch. The data of power consumption is sent in real-time via Bluetooth (Powerspy2 user manual). The necessary information such as minimum, maximum, standard deviation, and average value of power consumption can be obtained by Powerspy2. It provides a precision of three digits after decimal. All the links used the same configuration for link capacity (Bandwidth). That means for every experiment there was only one kind of link capacity. JPerf is used for the traffic generator. Different variations of traffic are generated by it to observe the Ethernet switch behavior. Variation of traffic is done by changing maximum segment size and window size. Maximum segment size varies between 256,512 and 1518 bytes. Window size varies from 1 to 123 kilobytes. Each experiment is run for 10 minutes in order to observe a stable and steady value.

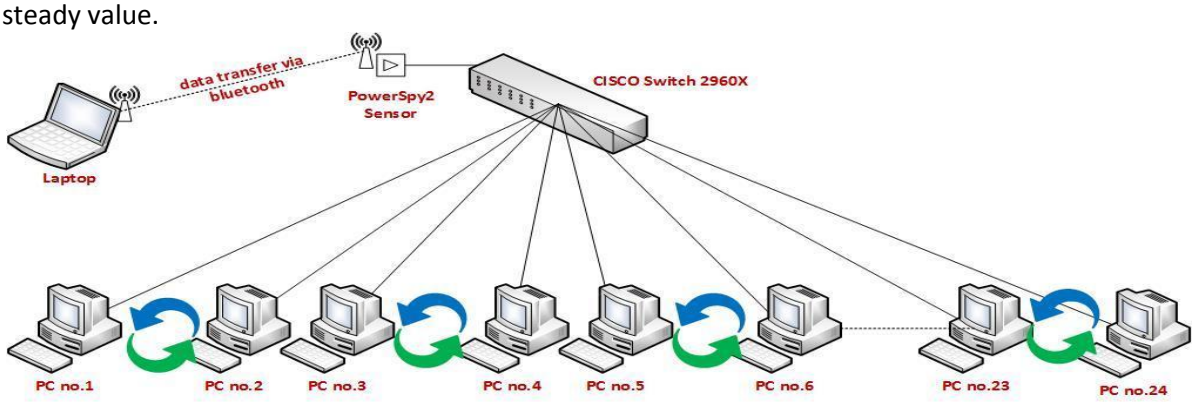

Figure 52: Network Architecture

The 0 connection-scenario is omitted because it is practically impossible for a network to have no connections. At least, the network should consist of at least 2 PCs to communicate with each other. Therefore the scenario starts with 2 PCs and then increases up to 24 PCs to occupy all the Ethernet switch ports. The experiment is conducted considering the most common TCP protocol. TCP is the basic communication protocol for the both internet and intranet.

RESULT AND ANALYSIS

In this section, at first initial insight from the raw data has been discussed. The data pattern is discussed without any model being applied. Then a discussion of the results of our statistical design of experiment, along with an analysis of these results has been made. Visual illustration regarding the impact of the factors on the power consumption is provided.

Initial result

Figure.2 shows the power consumption pattern of the Ethernet switch. To show the combined effect of traffic, bandwidth and number of connected PCs, link load has been used in the x-axis. Link load = Total traffic/ (Number of PC's connected * Bandwidth). For a fixed number of PC and bandwidth, link load is increased by increasing traffic. As we can see without using any analyzing tool, 1000 Mbps bandwidth has a larger impact compared to the other two bandwidths. One more thing is clearly visible is that changing the traffic has clearly very little impact on the power consumption.

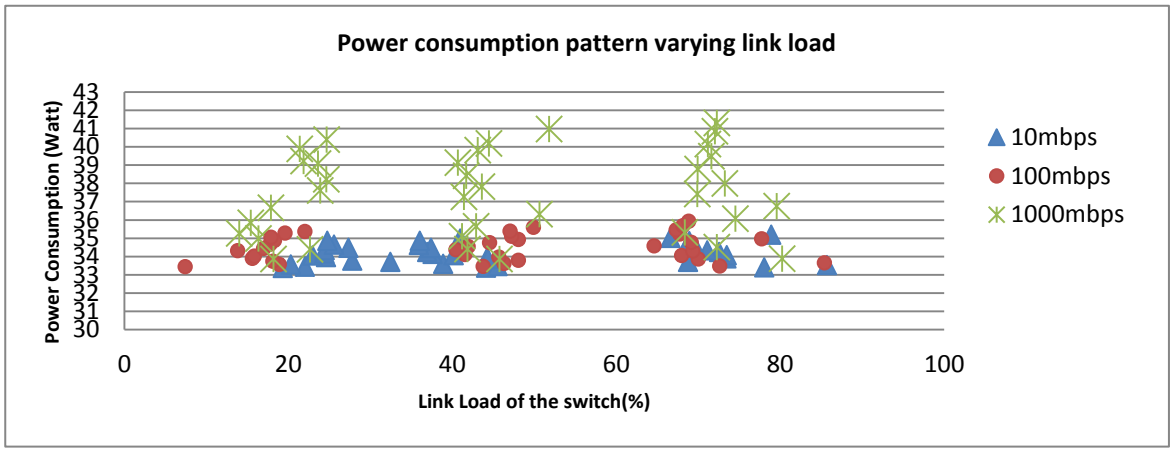

Figure 53: Power consumption pattern varying link load

Analysis by Modeling

In this section results analysis is described. For two different methods data is analyzed and model for power consumption is proposed. At first the full factorial model is presented with an explanation of f-value and p-value. Minitab has been used to do the modeling. F-value is a ratio of mean squares. The numerator is the mean square for the parameter. The denominator is chosen in a way that the expected value of the numerator mean square differs from the expected value of the denominator mean square. But this difference is caused only by the effect of the variable. A high f-value indicates a significant effect of that variable on that model. The p-value for each term tests the null hypothesis that the coefficient is equal to zero (no effect). A low p-value (< 0.05) indicates that it can reject the null hypothesis. In other words, a variable that has a low p-value is likely to be an important addition to the model because changes in the variable's value are related to changes in the response variable. Conversely, a larger p-value suggests that that variable is insignificant for the model and changes in the variable values are not related with changes in the response. For all the equation confidence interval was 95%.

Full Factorial

A Full factorial method generates a model for power consumption of the Ethernet switch based on the number of PCs connected and bandwidth or link capacity. Figure 3(a) shows the main factors effect on the power consumption. As it can be seen for bandwidth (link capacity) there is a really high impact when the bandwidth is 1000Mbps, however the change of power consumption between 10 Mbps to 100Mbps is not so much. On the other hand, the number of PCs shows a rather linear relation with the power consumption. As the number of connected PCs increases the power consumption is also increases. We include a two-way interaction while modeling. It means all the variables combined effect is also considered. In this case a two-way interaction would be bandwidth*PC. This model includes bandwidth*PC in order to get a more precise result.

Figure 3(b) depicts the two-way interaction of PC and bandwidth. Table.1. shows the f-value and p-value of the variables and shows that bandwidth has highest significance. P-value shows that all variables are significant for calculating power consumption. The model has an R-sq adjusted value of 98.53%. It means 98.53% of the time the variation in response variable is caused by these factors.

Source	F-Value	P-Value
Bandwidth (Mbps)	1875.86	0.000
PC	215.39	0.000
Bandwidth (Mbps)*PC	50.15	0.000

Table 26: F-value and P-value of factors (Full factorial method)

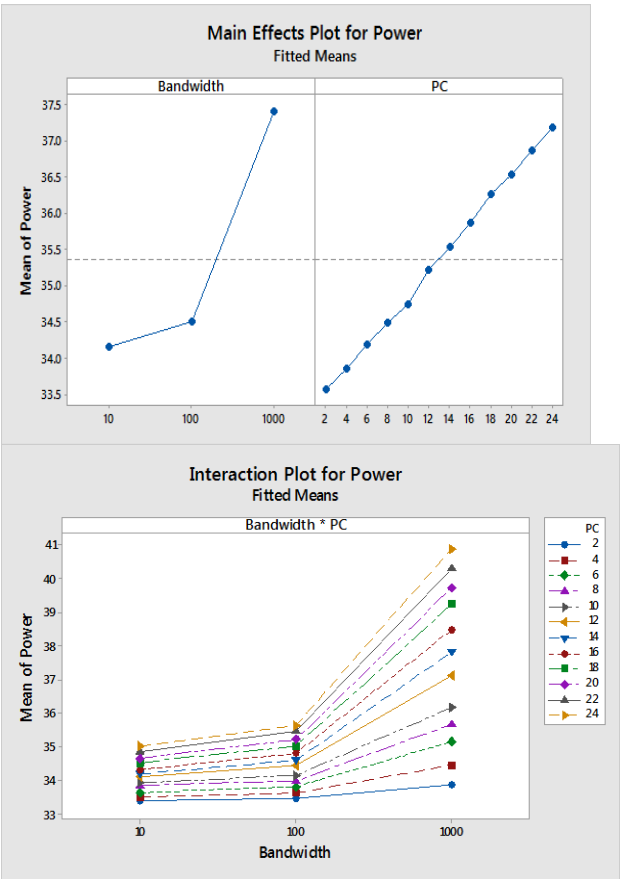

Figure 3: (a) Main effects plot, (b) Interaction plot

The model provides a rather long equation which considers all the possible two-way interaction. Considering {x1,x2,x3} are the different link capacities as {10Mbps, 100Mbps and 1000Mbps} and {y1,y2,y3…,y12} are the pairs of connected pc as {2,4,6,…,12} then the equation looks like this:

Power (watt) = 35.3642 - 1.2012 x1- 0.8470 x2+ 2.0482 x3- 1.7822 y1 - 1.5109 y2 - 1.1661 y3 - 0.8681 y4 - 0.6156 y5- 0.1439 y6 + 0.1726 y7 + 0.5044 y8 + 0.9022 y9+ 1.1731 y10 + 1.5119 y11+ 1.8226 y12+ 1.017 (x1*y1) + 0.839 (x1*y2)+ 0.638 (x1*y3) + 0.539 (x1*y4) + 0.371 (x1*y5)+ 0.085 (x1*y6) - 0.145 (x1*y7) - 0.347 (x1*y8)- 0.538 (x1*y9) - 0.674 (x1*y10) - 0.821 (x1*y11)- 0.964 (x1*y12) + 0.731 (x2*y1) + 0.615 (x2*y2)+ 0.459 (x2*y3) + 0.335 (x2*y4)+ 0.247 (x2*y5) + 0.061 (x2*y6) - 0.092 (x2*y7) - 0.218 (x2*y8)- 0.394 (x2*y9) - 0.477 (x2*y10) - 0.569 (x2*y11) - 0.698 (x2*y12) - 1.748 (x3*y1) - 1.453 (x3*y2) - 1.098 (x3*y3) - 0.874 (x3*y4)- 0.619 (x3*y5)- 0.146 (x3*y6) + 0.237 (x3*y7) + 0.566 (x3*y8)+ 0.931 (x3*y9) + 1.151 (x3*y10) + 1.390 (x3*y11) + 1.662 (x3*y12)

However, a general formula can be deployed from this formula. As there are only two variables, in general there will be two terms for these two variables and one for interaction of these two variables, there will be also a constant term. Therefore for a simple scenario only four terms from the equation will be used.

$$\text{Power (watt)} = 35.3642 + \alpha X + \beta Y + \gamma(X*Y)$$

Where X is set of bandwidth, Y is set of number of active PCs connected and α, β, γ are the co-efficient of the variables. For a given value of bandwidth and number of active PCs the correspondence value of x and y will be one. The rest of the unused value of x and y will be zero. Allocation of different bandwidth is possible for different ports, then the number of variable will also be increased.

Linear Regression Analysis

After doing full factorial, multiple linear regressions analysis is done. As discussed earlier, here traffic is also used as a variable. However, value of traffic depends on bandwidth and number of connected PC. Figure 4 shows the main effects of the variable on the power consumption, which indicates that all three variables have a linear relation. In a linear regression model the whole range of raw value of traffic is considered. This range starts with 3 Mbps where the number of connected PCs is 2 and bandwidth is 10 Mbps and ends with around 17000 Mbps where the number of connected PCs is 24 and bandwidth is 1000 Mbps. Since the range of traffic depends on the number of PCs connected, bandwidth, average segment size and window size. Therefore it is not likely to get the theoretical maximum traffic rate (24000 Mbps). In the graph the effect of traffic is dependent on the PC and bandwidth. Therefore both PC and bandwidth has less individual impact than previous case.

Moreover because of the categorical nature of the bandwidth it shows less impact when it is considered alone. As multiple regressions analysis is used, it also considers the two-way interaction. In the equation only significant variables are shown. Table.2 shows the F-value and P-value which shows that the PC has rather a high F-value compared to bandwidth and traffic. It is due to the nature of the value of the variable.

Source	F-Value	P-Value
Regression	4534.57	0.000
Traffic (Mbps)	50.57	0.000
Bandwidth (MBPS)	5.19	0.025
PC	728.07	0.000
Bandwidth (MBPS)*PC	1455.69	0.000

Table 27: F-value and P-value of factors (linear regression analysis)

The model has a R-sq adjusted value of 99.61% which indicates that whenever there is a variation in the value of y, 99.61% of it is due to the model (or due to change in x) and only 0.39% is due to error or some unexplained factor.

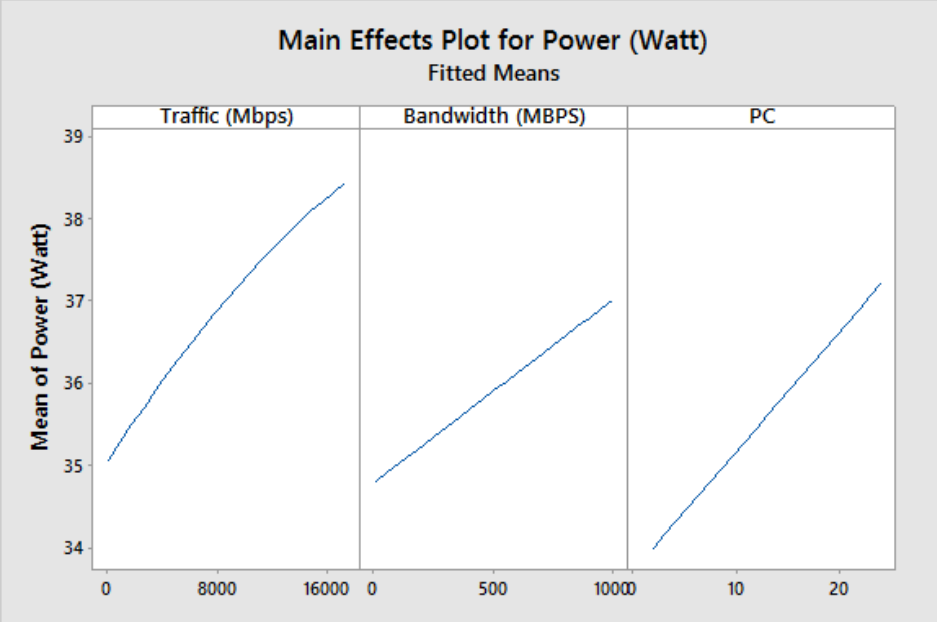

Figure 4: Main effect plot for regression analysis

Linear Regression Equation:
Power (Watt) = 33.2585 + 0.000389 Traffic (Mbps) - 0.001006 Bandwidth (Mbps) + 0.06646 PC + 0.000213 Bandwidth (Mbps)*PC

From the equation it is noticeable that only the interaction of bandwidth and PC is considered and other interactions are ignored because the effects of other two-way interactions are negligible.

Validation of Models

To check the validity of these two different models, predicted values from these models are obtained and then compared with real measured values. A random scenario is chosen in order to validate the model. Figure.5 shows the result of one scenario where bandwidth is fixed with 100 Mbps and a random traffic value is chosen. For a different number of PCs, power consumption value is plotted. As it can be seen, the measured value and the predicted value from the model are close to each other. In this case the mean percentage error of full factorial model and regression analysis model is 0.1% and 0.2% respectively. Mean percentage error is used to find how much the forecasted value differed from the actual value. In the figure.6 a different scenario has been used. Here, the number of connected PC was fixed; for this scenario 10 pc is used. For different bandwidth all the power consumption data is plotted with different traffic. As we can see, the full factorial model provides a straight line for each different bandwidth because traffic is not a parameter for the full factorial. However one important thing to notice is that traffic does not put much impact on the result. Power consumption difference is always less than 1 Watt for maximum and minimum value of traffic in any given scenario. On the other hand regression analysis shows three different plot points for three different values of traffic. In this scenario, the mean percentage error of full factorial model and regression analysis model is 0.5% and 0.34% respectively. In both cases the mean percentage error is very low. This indicates that both models are providing results which are close to the actual value.

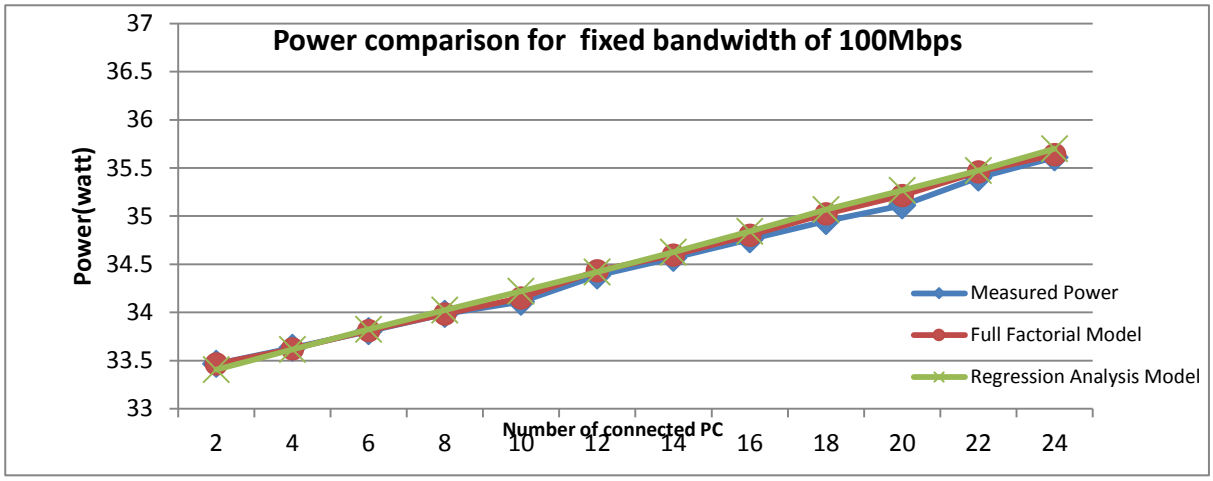

Figure 5: Power consumption comparison for fixed bandwidth of 100Mbps

By comparing the two equations provided by two different models, it can be observed that, for full factorial the model is rather complex where each combination has a different co-efficient even though all of them are not used simultaneously. However, in regression analysis model, the equation is rather simple. Furthermore, a full factorial model provides a rather mean value of the power consumption for a given scenario. However, a regression analysis provides different values for different traffic.

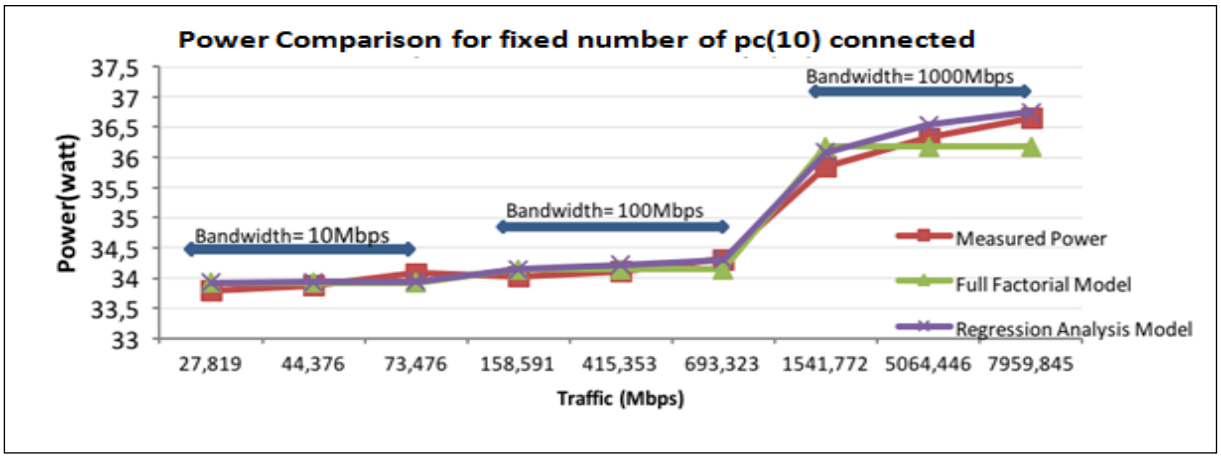

Figure 6: Power consumption comparison with change of traffic for fixed number of connected PC

DISCUSSION

With the advancement of computer networks communication rates have been increased abruptly. This also results in more power consumption. Zouaoui, Labit and Albea (2014) explained some new methods like dynamic adaptation and smart sleeping in order to reduce the power consumption. If the Ethernet switch behavior is explainable then their control will be more efficient. To keep this in mind, this paper's goal was to provide a model that can define power consumption patterns. Here a model for power consumption of the Ethernet switch has been provided based on different parameters.

The Ethernet switch is only a small part of the whole network. The term green networking means greening of the whole network architecture. It focuses on environment as well as methods needed to be cost-efficient. To put an effective impact on the environment through ICT, power consumption of the whole global network architecture needs to be known. This work is another effort towards this target. According to Bianzino et al. (2012) in a year, the maximum amount of power consumed by an Ethernet switch compared to any other networking device. Nevertheless, there are several devices like WIFI hot-spot, and router that needs to be considered in order to get the global architecture.

Moreover, experiments are done in only one Ethernet switch; results may vary for different switches. These things need to be considered for the future. There are also methods like Power efficient Ethernet and Hibernation to be considered. Rondeau et al. (2015) mentioned the correlation between the power consumption and carbon emission on the book. Therefore with the help of these modes another model can be created to calculate the carbon footprint produced by the Ethernet switch. Before controlling power consumption, the first step is to find out the parameters that have impact. The idea is to find out the parameter which has the highest impact and generate a model so that it can be used in future for controlling purpose. With proper development of a global model for overall network architecture of the power consumption it is therefore possible to reduce or at least control the global carbon footprint which is caused by networking devices.

CONCLUSION

This paper presents a novel way to study the simultaneous effects of multiple variables on the power consumption of the Ethernet switch using the Design of Experiment (DoE) method. Statistical analysis is conducted only with the test data and data is taken based on one switch. However the work that has been presented is not limited to the measurement of the Ethernet switch. Similar experiments can be done for all the other network devices in order to get a global picture. Two kinds of models are presented here and a comparison of both models is also discussed. Results help to understand the effect of bandwidth or link capacity and number of connected PCs on the Ethernet switch and traffic on the switch over power consumption. Findings from this experiment can be used to find out the power consumption of the Ethernet switch and eventually help to find out a way to reduce the power consumption.

ACKNOWLEGEMENT

This research was supported by ERASMUS+ and PERCCOM (Pervasive Computing and Communication for Sustainable Development). Partner universities of PERCCOM also deserve a big thank you, for providing insight and expertise that greatly assisted the research.

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PHP SINGLE AND DOUBLE QUOTES: DOES IT MAKE A DIFFERENCE TO ENERGY CONSUMPTION

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Keywords: energy, consumption, efficiency, software, application, rules, green, code, programming language, joulemeter.

Abstract

The increasing rate of carbon and other greenhouse gas emission resulting from the use of IT and other human activities to the atmosphere has become a major source of concern. It has become a matter of great importance for the IT sector to put its house in order by ensuring that its products are effective and efficient, and with little or no negative impact to the environment. Effective and efficient products perform all the intended purposes with reduced consumption of energy resources, and thereby having reduced impact on the environment. Reducing energy consumption of IT products is a key to contributing towards a greener environment. In programming or scripting languages, an end result can be achieved in more than one way. For example, in PHP, a print command can be executed using a single quote and can also be achieved using a double quote, with both achieving the same end-results and without affecting the quality of the intended outcomes. This has led to the research on the energy consumption of selected PHP scripts that perform similar functions: print single and double quote; echo single and double quote, etc… The Joulemeter energy measuring tool is used to measure the amount of energy consumed when run the various PHP scripts.

Olaoluwa, P., Kor, A. and Pattinson, C. (2015) **PHP single and double quotes: does it make a difference to energy consumption** *In;* Gorse, C and Dastbaz, M (Eds) *International SEEDS Conference,* 17 – 18 September 2015, Leeds Beckett University UK, Sustainable Ecological Engineering Design for Society.

INTRODUCTION

IT has been identified as a key factor in reducing the atmospheric carbon and other greenhouse gas content. This can be achieved by producing energy efficient IT products and also by enabling other non-IT sectors to reduce their energy consumption (The Climate Group, 2008). One of the ways IT could help make the environment safer through carbon reduction is by producing energy efficient codes, software and applications. As much as IT hardware manufacturers strive to make their products more energy efficient, an energy-unfriendly software component or program or script can render inefficient of all the energy management functionalities built into the hardware (Murugesan & Gangadharan, 2012). Much research work has focused on energy management software and also green software to reduce the energy consumption of hardware. There is a need for scientific investigation for measuring the actual energy consumed when running a piece of code or application. Therefore, this research aims to investigate the energy consumption when running some PHP: Hypertext Processor (PHP) commands which perform similar functions (e.g. print and echo; use of single and double quotes, etc…). The outcome of this research will be a set of formulated rules that could be used as guidelines for PHP script writers who aim to write energy efficient codes. In summary, the aim of this research is to investigate the energy consumption of selected PHP commands supported by the Joulemeter. A set of research objectives to help achieve the aim is as follows:

- **Research Objective 1:** To conduct a critical literature survey on energy efficiency of software;
- **Research Objective 2:** To write different PHP scripts with similar functions;
- **Research Objective 3:** To conduct quantitative experiments to measure the energy consumption of the PHP codes in Research Objective 2;
- **Research Objective 4:** To analyse results, discuss findings and make recommendations.

LITERATURE REVIEW

ICT Energy Consumption And Environmental Impact

Two percent of the global carbon emission comes from the ICT sector, which includes PCs, Data centres and other peripherals, while the remaining 98 percent comes from all other sectors like health, transportation and the education sector (The Climate Group, 2008). According to this report, the emission from the ICT sector is expected to rise by the year 2020 in a business as usual (BAU) scenario from the recorded 0.53 billion tonnes of 2002 to about 1.43 billion tonnes of global carbon emissions. The increasing carbon emission and other greenhouse gases will have a direct impact on the world climate and will have a drastic effect on the world population if nothing is done about it. As much as there is an environmental impact of green IT, there is also an economic impact (Murugesan, 2007).

The role of the ICT sector in reducing this greenhouse gas emission cannot be overemphasized. As the global demand for ICT products and services (e.g. web services) increases, there is the need for the sector to look inwards and ensure that the direct carbon footprint of its products and services are further reduced (The Climate Group, 2008). The less the energy consumed by these ICT products and services, the less the atmospheric impact of their activities will be.

To reiterate, a lot of research and effort has gone into production of energy efficient hardware and other embedded systems. However, there is also the need for similar focus of attention on the energy consumption of application software developed using platforms such as PHP and Java (Capra, et al., 2011).

What Is Green Software And Applications?

A software or application is referred to as green or sustainable when its direct or indirect negative impacts as a result of its development, deployment, or usage, on the economy, society, humans or environment is minimal (Naumann, et al., 2011). According to them, a green and sustainable software product can be achieved when the developer is aware of the likely negative and also the positive

impacts of the product when it is being deployed. Therefore, there is a pressing need for software product designers and developers to optimize their products in order to make them sustainable.

How Green Software And Applications Affect Hardware Energy Consumption

Software and applications including those built on the PHP platform, for example the PHP calendar (SourceForge, 2014), may not directly consume energy. However, the resident software could affect the manner energy resources is consumed. This is because the software and applications controls the functioning of the hardware as in the case of software-defined hardware (Capra, et al., 2011). Therefore, whatever reduction in energy saving that can be achieved as a result of greener software and applications is of great importance towards a greener and safer environment.

Existing work has addressed the efficiency and behavior of codes as How Green well as determining the efficiency of the energy-saving features of the computer hardware. According to Murugesan and Gangadharan (2012, p. 41), poorly-behaved software hinders the effective working of the energy saving features of the hardware and consequently, leads to reduced battery life and incurs attracts higher energy costs.

PHP Commands and Energy Consumption

PHP is an acronym that stands for PHP: Hypertext Processor. It is a recursive acronym that references itself, which means it is an acronym within an acronym. The first acronym, PHP stands for Personal Home Page (Beighley & Morrison, 2008). It is a server-side programming language. This means that its code is stored in PHP scripts that run on a web server. These scripts usually have a .php file extension. It is used for web development and also as a multipurpose programming language. PHP can be used for server-side scripting, for command line scripting and as a platform for writing desktop applications and programs on all major operating systems such as Linux, Microsoft Windows and the Mac operating Systems (The PHP Group, 2015).

In PHP, some of these commands such as the *print* and *echo* perform the same or very similar roles and likewise, these commands can be written in more than one way, i.e. whatever that needs to be displayed could either be enclosed within single or double quotes. Every software or program code or script written consumes some measure of energy (San Murugesan & Gangadharan, 2012), and it is recommended that one way to make software and applications energy-efficient and environmentally friendly is through their algorithms and data structures. It is suggested that as long as requirements permit and as long as it is effective to get the job done, less complex algorithm should be chosen because they are more energy efficient. Highly recursive algorithms should also be minimized as they can be energy inefficient (Intel Corporation, 2008). To reiterate, the aim of this research is to investigate the energy consumption of different PHP commands and the use of single or double quotes for literal displays.

Metrics, Measurement and Tools for Energy Monitoring

Measurement of energy consumption of personal computers was first performed in detail and published in conjunction with the United States Department of Energy late in the 1980s (Harris, et al., 1988). This was followed by total power estimates used to measure the energy consumption of office IT equipment as described in the Proceedings of the 1990 ACEEE (Koomey, et al., 1996). The first IT energy specification by Energy Star began with personal computers early in the 1990s and since then, the amount of energy used by computers and other IT systems has been a subject of great interest (Johnson & Zoi, 1992). Since achieving higher energy efficiency with the use of IT equipment and its subsystems, and lowering Greenhouse gas (GHG) emissions is the goal of green computing (Murugesan & Gangadharan, 2012), there is a need to discuss energy measurement and monitoring tools.

There are several tools available for measuring power consumption. Such tools include wattmeter, multimeter, power meter and the oscilloscope. These tools record the voltage and current used for

the activity and records the power consumption in watts and the energy consumption in watt hours (GHG Protocol ICT Stakeholder Advisory Group, 2012). Other energy measurement tools include the Kill A Watt (P3 International Corporation, 2015) which allows the calculation of electrical energy expenses at intervals and also help to monitor energy usage. Finally, there is the Joulemeter by Microsoft (Microsoft Research, 2015). This measuring tool provides a great tool for measuring usage of energy in virtual machines, servers, desktops, laptops and software applications individually running on the computer.

Why Joulemeter?

To reiterate, the Joulemeter is chosen for this research because it has the capacity to measure the energy usage of software applications resident on a computer and other IT systems (Microsoft Research, 2015). The Joulemeter is a great tool for measuring and monitoring power usage of IT equipment and is particularly useful for web developers who wish to optimize their software and related services by using energy and power consumption measurement to their advantage.

With a very user-friendly dashboard, the Joulemeter can be used to view power consumption of the computer and also track power usage of specific applications (Microsoft Research, 2011). This provides the opportunity to merely focus on the measuring process of target applications (e.g. the launch of created PHP webpages in Mozilla Firefox) followed by the appropriate measurement of energy consumption. It is very easy to install, calibrate, use and monitor.

METHDOLOGY

A quantitative experiment method is employed for this research. As said earlier, the Joulemeter tool is used for this experiment. It is a software energy monitoring tool that provides the opportunity to monitor the total power utilization of the computer as well as individual power usage of key components of the computer such as the CPU power, Disk power, Monitor power and the Base or Idle power (Microsoft Research, 2011).

Experimental Design

Web pages are created and they contain the following selected PHP commands:

- Echo Single Quote and Echo Double Quote
- Print Single Quote and Print Double Quote
- Concatenate Single Quote and Concatenate Double Quote
- Include Single Quote and Include Double Quote
- Switch Statement Single Quote and Switch Statement Double Quote

The PHP scripts listed above are developed in separate webpages, each of them having exactly the same outputs. For example, the echo single and double quote have the same outputs. The same goes for the Print, Concatenate, Include and the Switch Statement. For easy access and in order to reduce the time spent on navigation from one webpage to the other, all created pages are put together in an index page. These web pages are launched on Mozilla Firefox browser and a Joulemeter experiment is set up to capture the estimated energy consumption of the web page on the Firefox browser. The corresponding result is exported to a .csv file format and analyzed using Microsoft Excel.

Joulemeter and Calibration

The Joulemeter software is downloaded directly from the Microsoft website http://research.microsoft.com/en-us/projects/joulemeter/ and the downloaded Joulemeter setup file is installed according to system specification on the hard drive of the computer to be used for the experiment. The system specification is as follows:

Model: HP Pavilion 15
Operating System: Windows 8.1, 64 bit
Processor type: Intel core i3, 1.80 GHz processor speed
Storage: 500GB
RAM: 4GB

In contrast to the desktop, the laptop does not require any external power metering device such as the Watts Up Pro power meter (Microsoft Research, 2011), and that makes the installation straightforward.

Calibrating Joulemeter (see Figure 1) requires getting the computer's power model (Microsoft Research, 2011). The Joulemeter calibration setup for the laptop is done while running on battery power as specified by the user's manual. The calibration is done manually according to system specification because the tool does not support automatic calibration in Windows 8.1. This manual calibration however, is carried out according to the recommendations in the Joulemeter user's manual. All open programs are closed and all USB devices unplugged before the calibration exercise (Microsoft Research, 2011).

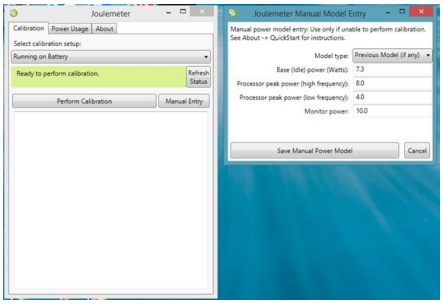


Figure 1: Joulemeter calibration

The following entries are derived from the calibration process as shown in the image above and according to the user's manual (Microsoft Research, 2011):

- Base (Idle) Power, which represents the least energy that the computer consumes when it is turned on, no programs are running, monitor set to its lowest brightness or turned off, and no background activity is going on.
- Processor Peak Power (high frequency), defines the power consumed when the CPU is at 100 percent utilization with the processor at its highest utilization.
- Processor Peak Power (low frequency), which defines the power consumed when the CPU is at 100% utilization while the processor is at its lowest utilization.
- Monitor power, which describes the monitor power consumption.

Data Collection

In preparing for data collection, the Joulemeter is set to target the Firefox (version 37.0.2) browser to capture the energy usage of each page when launched. This is achieved by typing the word "firefox" in the section for "Application Power (CPU only)" in the Power Usage tab as seen in the computer's task manager. This is a recommended procedure for using the

Commands	Energy Consumption of Hardware per line of code				Energy Consumption of Hardware (J/line)	Energy Consumption of Application (J/line)	Average Energy Consumption (J/line)
	CPU (J/line)	Monitor (J/line)	Disk (J/line)	Base (J/line)			
Echo Single Quote	0.059	0.471	0.000	0.573	1.102	0.012	1.11
Echo Double Quote	0.118	0.471	0.000	0.573	1.161	0.016	1.17
Print Single Quote	0.084	0.471	0.000	0.573	1.128	0.009	1.13
Print Double Quote	0.078	0.471	0.000	0.573	1.122	0.015	1.13
Concatenation Single Quote	0.027	0.471	0.000	0.573	1.071	0.008	1.07
Concatenation Double Quote	0.057	0.471	0.000	0.573	1.101	0.013	1.11
Include Single Quote	0.082	0.471	0.000	0.573	1.125	0.016	1.14
Include Double Quote	0.110	0.471	0.000	0.573	1.153	0.035	1.18
Switch Single Quote	0.422	0.471	0.000	0.573	1.466	0.089	1.55

Joulemeter to capture the power impact of a software program (Microsoft Research, 2011). Doing this enabled the measuring tool to target only the estimated power usage of the application on the Central Processing Unit. The location to save the .csv file and the name of the files set as appropriate. On the Joulemeter, the reading for the application power is initiated by clicking on the "Start saving" button clicked and the page is launched to begin data capture.

RESULTS AND DISCUSSION

It is observed from the generated Comma Separated Values (csv) file that the total usage of power by the computer (Total Power) for the process is the sum of CPU Power, Monitor Power, Disk Power and the Base Power. The Application Power is recorded separately by the Joulemeter. In Table 1, we have the following formulae:

$$\textit{Hardware Total (W)} = \textit{CPU (W)} + \textit{Monitor (W)} + \textit{Disk (W)} + \textit{Base (W)}$$

$$\textit{Total Power Consumption (W)} = \textit{Hardware Total (W)} + \textit{Power Consumption of Application (W)}$$

Normalisation of Data

In Table 1, *n* represents the number of lines of codes in the created web page. The collected raw data undergo a series of normalisation in order to provide a fair comparison among the various PHP commands as well as the single and double quotes. Firstly, the webpage launching time is set to t = 2 seconds (note: the rationale for this is that t for 80% of the raw data is 2s), and the power consumption of the hardware, application and the total power consumption are computed accordingly (see Table 1). The values in Table 2 are calculated by using the formula, Energy (J) = Power (W) x Time (s) where the time, t = 2 s.

Commands	Power Consumption of Hardware					Power Consumption of Application (W)	Total Power Consumption (W)	Time (s)
	CPU (W)	Monitor (W)	Disk (W)	Base (W)	Hardware Total (W)			
Echo Single Quote (n=102)	1.500	12.000	0.000	14.600	28.100	0.300	28.400	2.000
Echo Double Quote (n=102)	3.000	12.000	0.000	14.600	29.600	0.400	30.000	2.000
Print Single Quote (n=104)	2.173	12.000	0.000	14.600	28.773	0.247	29.020	2.000
Print Double Quote (n=104)	2.035	12.000	0.000	14.600	28.635	0.397	29.032	2.000
Concatenation Single Quote (n=253)	1.700	12.000	0.000	14.600	28.300	0.500	28.800	2.000
Concatenation Double Quote (n=253)	3.600	12.000	0.000	14.600	30.200	0.800	31.000	2.000
Include Single Quote (n=102)	2.079	12.000	0.000	14.600	28.679	0.396	29.075	2.000
Include Double Quote (n=102)	2.800	12.000	0.000	14.600	29.400	0.900	30.300	2.000
Switch Single Quote (n=18)	1.900	12.000	0.000	14.600	28.500	0.400	28.900	2.000
Switch Double Quote (n-22)	2.700	12.000	0.000	14.600	29.300	0.500	29.800	2.000

Table 1: Normalised Power Consumption Data for Time (t=2 seconds)

Commands	Energy Consumption of Hardware				Energy Consumption of Hardware (J)	Energy Consumption of Application (J)	Total Energy Consumption (J)
	CPU (J)	Monitor (J)	Disk (J)	Base (J)			
Echo Single Quote (n=102)	3.000	24.000	0.000	29.200	56.200	0.600	56.800
Echo Double Quote (n=102)	6.000	24.000	0.000	29.200	59.200	0.800	60.000
Print Single Quote (n=104)	4.346	24.000	0.000	29.200	57.546	0.494	58.040
Print Double Quote (n=104)	4.069	24.000	0.000	29.200	57.269	0.794	58.064
Concatenation Single Quote (n=253)	3.400	24.000	0.000	29.200	56.600	1.000	57.600
Concatenation Double Quote (n=253)	7.200	24.000	0.000	29.200	60.400	1.600	62.000
Include Single Quote (n=102)	4.158	24.000	0.000	29.200	57.358	0.792	58.150
Include Double Quote (n=102)	5.600	24.000	0.000	29.200	58.800	1.800	60.600
Switch Single Quote (n=18)	3.800	24.000	0.000	29.200	57.000	0.800	57.800
Switch Double Quote (n-22)	5.400	24.000	0.000	29.200	58.600	1.000	59.600

Table 2: Normalised Energy Consumption Data for Time (t=2 seconds)

Table 3 shows the second step of normalization where energy consumption is computed for each line of code (i.e. n =1). Consequently, this yields the metric, Joule per line. The goal of this normalisation is to provide a fair comparison for all the parameters set for the experiments. The graphs in Figures 2-4 are plotted based on the values in the normalized values for energy consumption in Table 3 (i.e. t = 2s, and n = 1).

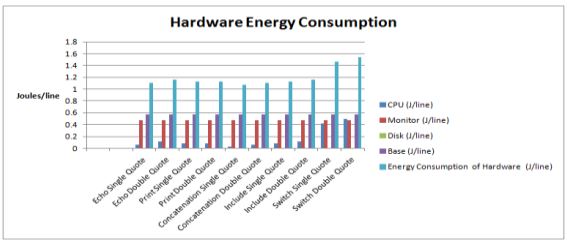


Figure 2: Normalised Energy Consumption of the Hardware per line of code (based on Table 3)

Figure 2 depicts the hardware energy consumption per line of code for the following PHP commands: echo, print, concatenate, include and switch with single and double quotes. The graph shows that the double quote consumes more hardware energy than single quote for all the investigated PHP commands except for the print command. All the PHP commands except for the switch command which seems to consume almost the same amount of hardware energy.

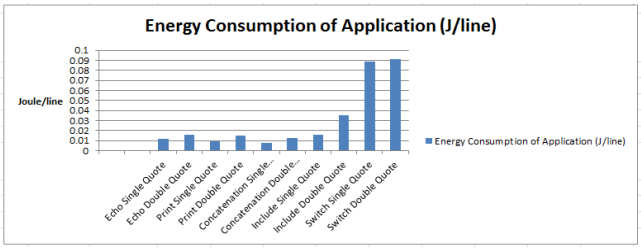
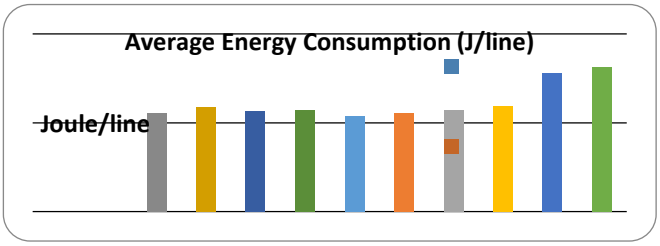


Figure 3: Normalised Energy Consumption of the Software (Application) per line of code (based on Table 3)

In Figure 3, it shows that the normalized application energy consumption for the double quotes exceed that of the single quotes. Just as in the hardware energy consumption, the application energy consumption for the switch commands seems to be the highest. This is followed by the include command with double quote and the range for the rest of the values is only 0.08 J/line. The graph for the average energy consumption for the hardware and application (Joule/line) is depicted in Figure 4. Once again, the average energy consumption for the double quotes is slightly higher that the single quotes. The switch commands have the highest normalized total energy consumption for the hardware and application while the range for the rest is only 0.035.

Figure 4: Normalised Total Energy Consumption for Hardware and Application per line of code



(based on Table 3)

Command	Average Energy Consumption		% Gain
	Single Quote (J/line)	Double Quote (J/line)	
Echo	1.114	1.176	5.63%
Print	1.137	1.138	0.04%
Concatenate	1.079	1.114	3.22%
Include	1.141	1.189	4.21%
Switch	1.555	1.626	4.55%

Table 4: Percentage Gain (Double Quote compared to Single Quote) (based on Table 3)

Table 1 provides an insight into the % gain in the average energy consumption (in Joule/line) of single quotes compared to double quotes for the corresponding PHP commands. The gain seems to be highest for the echo command, while the lowest is the print command. The range for the values in Table 4 is 5.59%.

Aggregation of Data

Commands	CPU (J/line)	Monitor (J/line)	Disk (J/line)	Base (J/line)	Energy Consumption of Hardware (J/line)

Table 5 shows the aggregated normalised energy consumption for all the single and double quotes in Table 3. The graphs in Figures 5-7 are plotted based on these values.

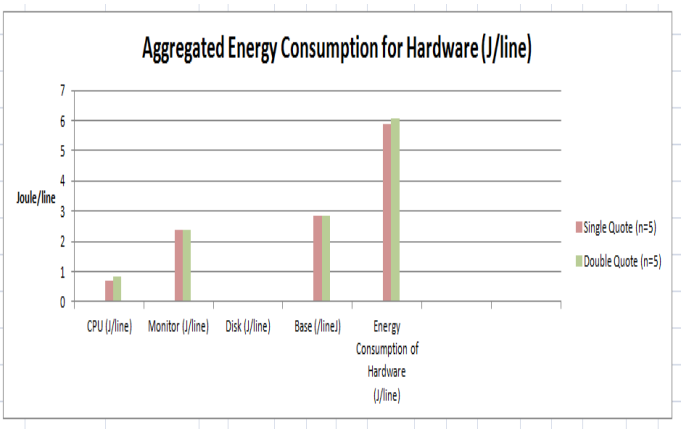


Figure 5: Aggregated Energy Consumption for Hardware (Joule/line)

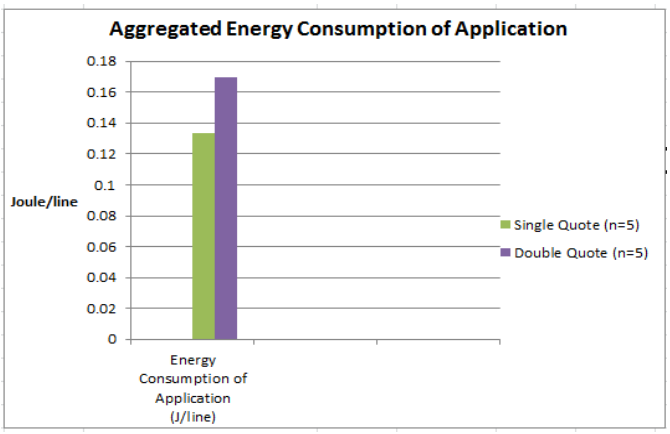


Figure 6: Aggregated Energy Consumption for

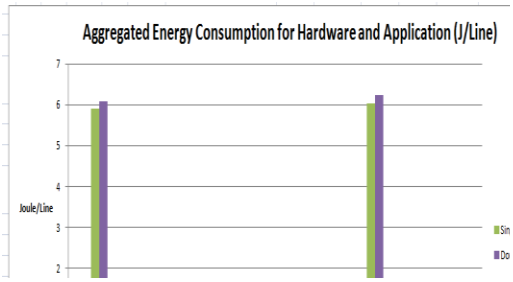


Figure 5 reveals that the aggregated energy consumption for the monitor and base are the same. This is because the outputs for the single and corresponding double quotes for the same PHP command are the same. The aggregated CPU energy consumption for the double quotes are higher than that of the single quotes, thus contributing to a consistently higher aggregated hardware energy. This result is also consistent with the aggregated application energy consumption which is depicted in Figure 6, and Figure 7. In the latter, it shows that the aggregated energy consumption of the application is very much lower compared to the aggregated hardware energy consumption. This means that running application greatly affects the energy consumption of the hardware.

Two tailed t-test for two samples (n = 1 line of code)

The data analysis (in Section IV (A and B) shows that the energy consumption for launching PHP web pages that contain single quotes is lower than that with double quotes. Additionally, Table 4 depicts the positive % gain in energy consumption for single quotes compared to double quotes. However, further statistical analysis is necessary to determine if their energy consumption is significantly different. Consequently, a two-tailed t-test (for two samples) is used to test whether there is any significant difference between the energy consumption for single and double quotes at confidence level (α): 0.05.

Commands	CPU (J/line)	Monitor (J/line)	Disk (J/line)	Base (J/line)	Energy Consumption of Hardware (J/line)			Energy Consumption of Application (J/line)			Total Energy Consumption (J/line)		
					Total (J/line)	Mean (J/line)	STDev	Total (J/line)	Mean (J/line)	STDev	Total (J/line)	Mean (J/line)	STDev
Single Quote (n=5)	0.673	2.354	0.000	2.865	5.892	1.178	0.163	0.134	0.027	0.033	6.025	1.205	0.197
Double Quote (n=5)	0.854	2.354	0.000	2.865	6.072	1.214	0.181	0.170	0.034	0.033	6.242	1.248	0.213

Table 6: Total, Mean and Standard Deviation for the Aggregated Energy Consumption

Two tailed t-test for two samples with unequal variance (n = 1 line of code)

Energy Consumption of Hardware (two-tailed, α = 0.05)	N	df	Mean	SD	t-value	t critical value	significance
Single Quote	5	8	1.178	0.163	0.332	2.305	not significant
Double Quote			1.214	0.181			

Table 7: A two sample t-test with unequal variance at confidence level α = 0.05 for aggregated hardware energy consumption

Total Energy Consumption (two-tailed, $\alpha = 0.05$)	N	df	Mean	SD	t-value	t critical value	significance
Single Quote	5	8	1.205	0.197	0.334	2.305	not significant
Double Quote			1.248	0.213			

Table 8: A two sample t-test with unequal variance at confidence level $\alpha = 0.05$ for aggregated total hardware and application energy consumption

Two tailed t-test for two samples with equal variance (n = 1 line of code)

Energy Consumption of Application (two-tailed, $\alpha = 0.05$)	N	df	Mean	SD	t-value	t critical value	significance
Single Quote	5	8	0.027	0.033	0.346	2.305	not significant
Double Quote			0.034	0.033			

Table 6 provides information on the total energy consumption (Joule/line) for aggregated PHP commands with single and double quotes. Tables 7 and 8 reveal the results of a two-tailed t-test for two samples with unequal variance at confidence level, $\alpha = 0.05$ while Table 9 shows results of similar test for two samples with equal variance. The tests reveal that there are no significant differences between the aggregated energy consumption (hardware alone, application alone, hardware and application) for single and double codes. The confidence level, α is changed to 0.10 and the differences remain insignificant. The conclusion that could be drawn here is that though the hardware and application energy consumption for single quotes seem to be lower than double quotes, there is no significant difference in the gain. Thus, further experiments and tests will be necessary to confirm this finding.

CONCLUSIONS

In this research, a series of data normalization (i.e. t=2s, and n=1 line of code) is necessary in order to provide a fair comparison between the different PHP commands (i.e. echo, print, concatenate, include, and switch) with single and double quotes. In summary, the single quote seems to consume less energy than the double quote in PHP though the t-statistical tests conducted on their differences yield an insignificant outcome. Further rigorous experiments will be necessary to confirm these results. Viewing the fact that green computing is aimed at design, production, usage and disposal of computers and its other subsystems in a way that causes little or no damage to the environment (San Murugesan & Gangadharan, 2012), it is imperative to consider all possible ways of reducing energy consumed as a result of IT or computing related. The compared PHP commands can be used interchangeably, therefore, developers need to opt for the more energy-efficient ones as much as possible. The following issues ought to be addressed in order to further enhance the experimental procedures: (i) it is necessary for the n value (i.e. no of lines of codes) for all the PHP commands with single and double quotes be set as a parameter for the experiments; (ii) conduct repeated experiments for each command.

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Policy Change and Energy

A FIELD TRIAL TO MEASURE ENERGY EFFICIENCY IMPROVEMENTS TO DOMESTIC CENTRAL HEATING USING A DE-AERATOR

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Keywords: de-aerator, degree days**.** domestic heating system, energy efficiency.

Abstract

A field experiment was undertaken to assess how the efficiency of a dwelling's heating system that changes after installing a de-aerator. There was a large degree of uncertainty regarding the level of internal gains being experienced; however the test showed that efficiency improvements of around 6% may be achieved. It was also observed that the dwelling may have been heated more homogenously after the Oxypod was installed however this may have been due to the warmer weather experienced.

Data sample size was a fundamental problem, especially in the after test, substantially limiting reduced confidence in the results. Variations in the internal conditions caused by dynamic effects from solar radiation and the heat transfer between upstairs and downstairs and one-off influences such as the broken window as well as researchers entering and altering the test conditions may have been smoothed out and have less influence on the overall data if the sample were larger. It is recommended that future tests should either be run for longer or at greater $\Delta\vartheta$, preferably undertaken during winter periods, in order to generate more and reliable data.

Results were presented using sensitivity analysis to describe the uncertainty. It is recommended that further data be collected to confirm if this finding can be repeated and that future tests directly measure the heat transfer between adjacent spaces using heat flux plates and to measure the solar radiation entering the space. A further simplification could have been achieved by selecting a case study building that was a detached and to provide solar shading which would result in less complicated heat bypasses and solar gains.

Glew, D., Fletcher, M. and Gorse, C. (2015) **A field trial to measure energy efficiency improvements to domestic central heating using a de-aerator** *In;* Gorse, C and Dastbaz, M (Eds) *International SEEDS Conference,* 17 – 18 September 2015, Leeds Beckett University UK, Sustainable Ecological Engineering Design for Society.

1. Introduction

Concerns over climate change, fuel poverty and fuel security have prompted legislation in the EU to improve energy efficiency in buildings (European Commission, 2010). Buildings are currently responsible for around 45% of the UK's greenhouse gas emissions (Carbon Trust, 2009) and around 80% of energy demand in the home is estimated to be attributable to space heating (Energy Institute, 2012), which equates to around 60% of primary energy use in UK domestic dwellings (Cooper and Palmer, 2013).

Heating system enhancers have been developed which aim through various means to improve energy efficiencies[4]. De-aerators are one such technology that address the problem of air infiltrating into both closed domestic and industrial hot water systems (Pratt and Hollander, 2004, Arvinius and Komorin, 2010, CIBSE, 2010). Commercial products that remove dissolved air in water systems are known to reduce levels of corrosion and magnetite build up, since they create anaerobic environments in which the rusting process for example cannot readily take place, thereby alleviating the maintenance burden (Jones, 1997). However they have recently been claimed by their manufacturers[5] to improve energy efficiencies in some instances by 20%.

Research has been undertaken to show de-aerators are effective in removing air in domestic hot water systems (Ge et al., 2013) however evidence that de-aerator systems yield energy savings is not yet sufficient for them to qualify for assistance under government funding schemes for energy efficiency in the UK (DECC, 2012). There are not yet any publications relating to the quantification or explanations of the theoretical mechanisms by which de-aerators would improve energy efficiency. It is well known that removing air from water will improve its specific heat capacity meaning one can deliver more heat per litre of water, as well as possibly exchanging this heat more efficiently through heat exchangers; however these improvements are theoretically only slight and may not be sufficient to explain the levels being anecdotally claimed. This paper investigates a de-aerator the Oxypod®, in an attempt to quantify the energy savings that it can achieve.

A field experiment was conducted in spring and early summer in 2015 on a dwelling located in Leeds in West Yorkshire, UK. The dwelling has a conventional condensing gas boiler and radiator heat system. Data on the internal and external temperature were used to establish the heating demand for a 48 days prior to the Oxypod being installed and 36 days following its installation. hese heating demands were then compared to the actual heat energy used over these periods in the dwelling to understand any relative change in the heating system's efficiency.

2. Method

The case study dwelling is a four bedroom flat situated above a community centre, shown in Figure 1, built of standard construction, brick and block work with an unfilled cavity, pitched cold roof with tiles and double glazing.

[4] http://www.oxypod.me/detailed-description
[5] http://www.spirotech.co.uk/ and http://www.tadpoleenergy.com/

Figure 1, Case study building

The community centre below was kept at stable temperature for the 84 days of the test using fans and electric heaters, while the existing central heating system was used to provide all the heat in the dwelling, so as to replicate real life conditions. External, dwelling and community centre temperatures were recorded via Eltek logging equipment at 10 minute intervals with sensors placed in the centre of each room on tripods at approximately 1m. A Sonntex 739 heat meter was installed to record the heat delivered by the boiler to the dwelling also at 10 minute intervals via an Eltek pulse transmitter. A new Compact 24SE Vokera condensing boiler was installed for the experiment using a British Gas Hive thermostat. The floor plan in Figure 2 notes the orientation and room configuration of the dwelling. The entrance to the flat was via the ground floor below the stairs and landing.

All TRVs on the radiators were turned to “3” and the thermostat located in the hall of the dwelling was the sole temperature controller. The heating system was set to run continuously for 24 hours per day. In in order to compensate for varying internal temperatures in the dwelling, degree days were calculated using the internal average daily temperatures to predict the daily heat demand. After 48 days the heating system was turned off and the Oxypod was installed and left to run again for 24 hours.

Figure 2, Case study dwelling floor plan

As stated, in order to replicate how the heating system would work under normal conditions there was no supplementary heating or air circulation in the dwelling, thus it was exposed to many dynamic effects from the external environment and the building itself, including thermal interactions with the community centre. As with any field experiment, the results must therefore be considered with consideration to these dynamic effects.

In addition there was an unavoidable change in the air tightness of the dwelling during the after test period when a window was broken at the dwelling. Although this was temporarily repaired it was not sealed to the same standard as the double glazing had offered and will have affected the air tightness in the dwelling. This will have had the effect of reducing the apparent efficiency of the heating system in the after test, i.e. with higher air exchanges the boiler will have needed to work harder to maintain the same internal temperature, thus the after test results will likely appear less efficient than they perhaps would had the air tightness of the property not been compromised.

A final complication was that the boiler occasionally dropped out meaning that there were periods when the building fabric would cool down and need to be recharged effecting the apparent energy efficiency of the heating system.

In order to rationalise how much heat was being delivered against how cold it was, degree days have been used. These were calculated for the before and after periods when considering only the periods when the boiler is working according to mean degree hours CIBSE TM41 guidance;

$$D_{\mathrm{d}} = \frac{\sum_{j=1}^{24} \left(\theta_{\mathrm{b}} - \theta_{\mathrm{o},j}\right)_{\left(\left(\theta_{\mathrm{b}} - \theta_{\mathrm{o},j}\right) > 0\right)}}{24}$$

Where D_d is the daily degree-days for one day, ϑ_b is the base temperature and $\vartheta_{o,j}$ is the outdoor temperature in hour j. The subscript denotes that only positive values are taken (CIBSE, 2006)

3. Results

This section outlines an overview of the data, explores how the degree days were used to calculate the heat demand and then relates these to the actual gas consumption observed, it also presents several sensitivity analyses.

3.1. Overview of test conditions

Figure 3 shows the temperature profiles in the dwelling for the duration of the experiment. Initial observations show that the heating system was not particularly effective in achieving a stable temperature throughout the dwelling. This may have been due to poor air circulation generally but on further investigation, may also have been specifically due to undersized radiators in the North end of the dwelling meaning it was consistently colder. The Southern end in contrast had a larger percentage of glazing which often led to these rooms being warmer.

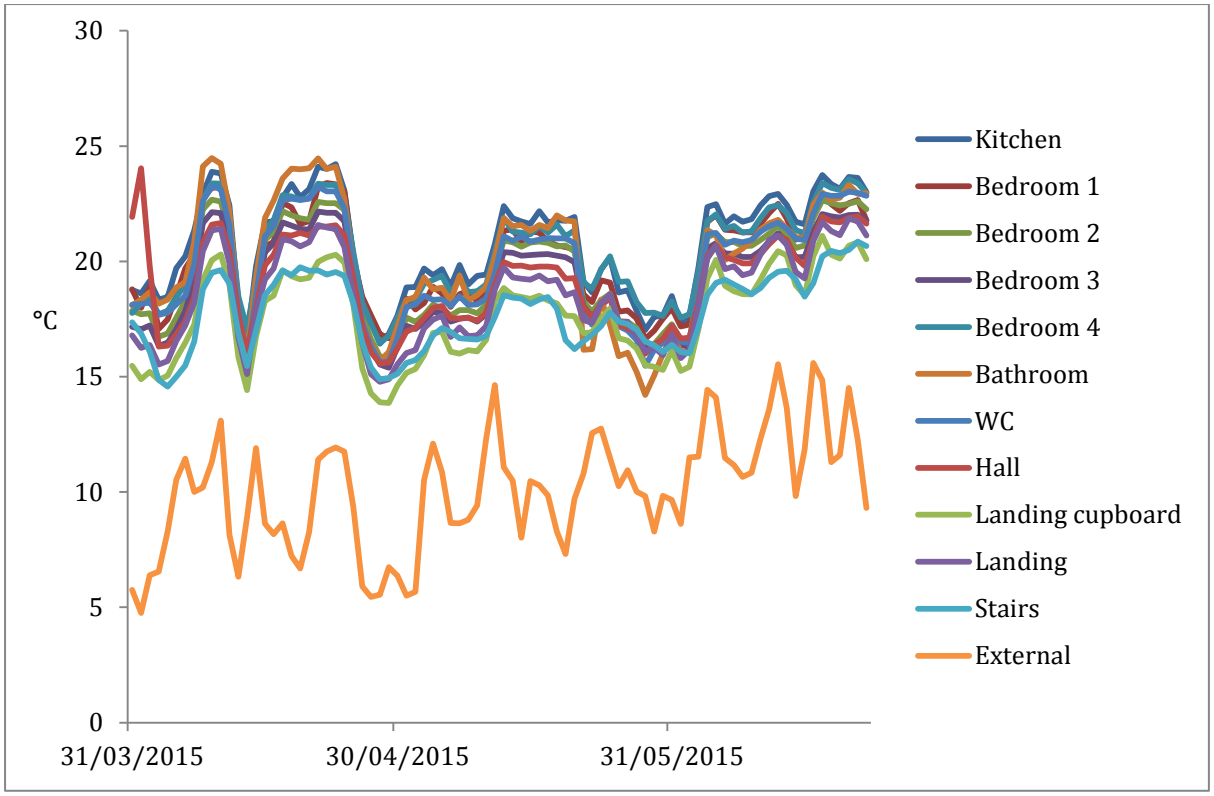

Figure 3, Internal and external temperatures

Such variation in internal temperatures complicates the analysis and its visualisation; to overcome this volume weighting was used to create average daily temperatures for the dwelling. Table 1 shows the volume and respective weighting ratios that were applied to each room to derive the average daily temperatures for the dwelling.

Table 1, Room volume weighting

Room	Volume (m^3)	Weighting (%)
Kitchen	26.9	11.5
Bedroom 1	45.1	19.3
Bedroom 2	31.7	13.5
Bedroom 3	18.4	7.8
Bedroom 4	17.9	7.6
Bathroom	7.2	3.1
WC	4.0	1.7
Hall	28.7	12.3
Landing cupboard	11.8	5.0
Landing	13.0	5.6
Stairs	29.6	12.6

The effect of weighting is to provide one single internal temperature profile that can be used for the analysis, this is shown in shown in Figure 4. Periods of boiler failure can be seen where heat input drops to zero and a time stamp has been made to mark the Oxypod installation date on 18th May 2015.

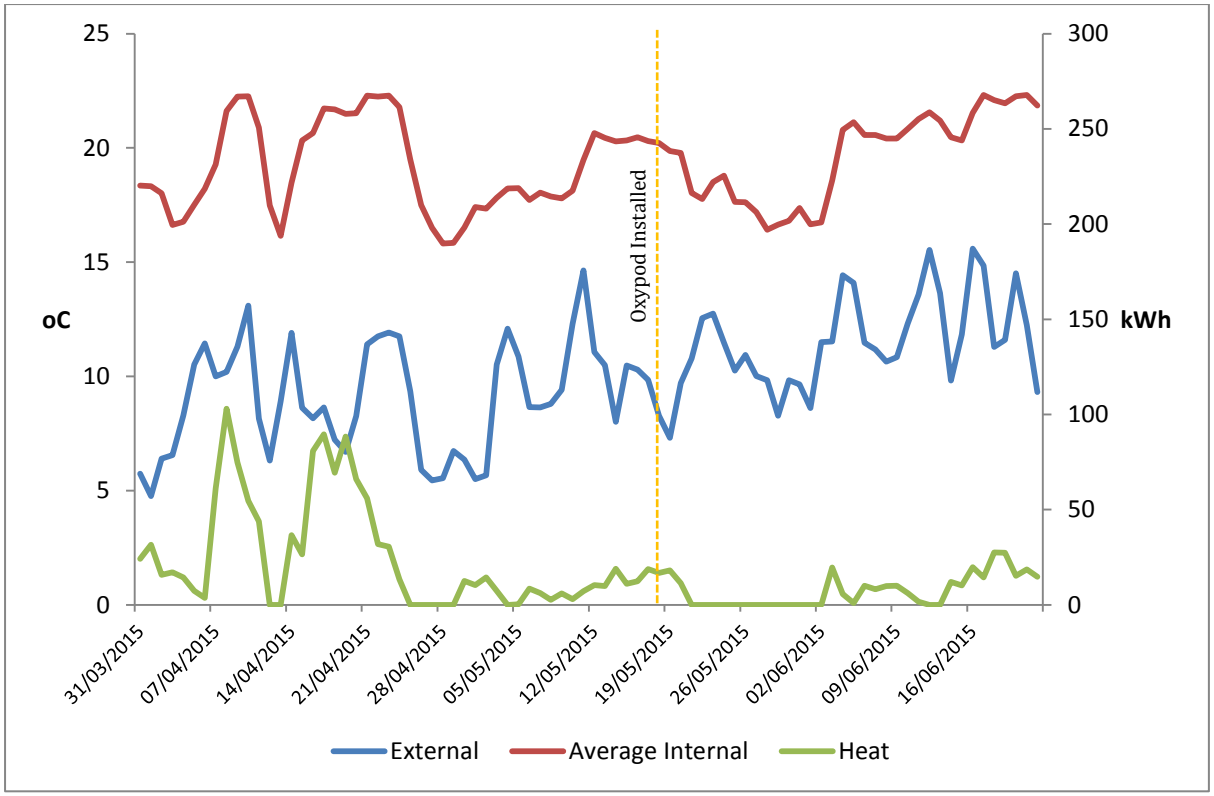

Figure 4, Area weighted average dwelling temperature and heat input

As can be seen, the average daily internal temperature varies considerably, partly due to changing set point temperatures inside the dwelling but also due to solar radiation causing daily peaks. The analysis presented in this paper is based on the volume weighted average daily temperatures.

In the before test, boiler dropouts were observed to be due to the thermostat losing communication with the boiler, several locations were trialled until it was successfully relocated to the South end of the Hall closest to the boiler which was located in the Kitchen. This may have further added to the North end of the building being colder; Figure 3 shows that the stairs, landing and store are shown to be consistently the coolest rooms.

During the after period more significant boiler drop outs are observed, these were believed to be due to the pressure dropping in the heating system as the dissolved air was removed from the water, prompting the boiler to switch off. Since researchers were not always available, site visits were only made sporadically to check the progress of the test and so refilling the system was not often done immediately. One drop out in particular was prolonged at the end of May and into the beginning of June, and it is recommended that future tests using de-aerators only be conducted if daily attendance at or remote control over the field test can be guaranteed. The periods when the boiler was not functioning have been removed from the data prior to the analysis being undertaken.

3.2. Energy consumption

Figure 5 visualises the raw data for the amount of heat delivered in to the dwelling against the heat demand measured by the number of degree days. The before energy consumption per degree day appears to be higher than the after test however no conclusive trends stand out.

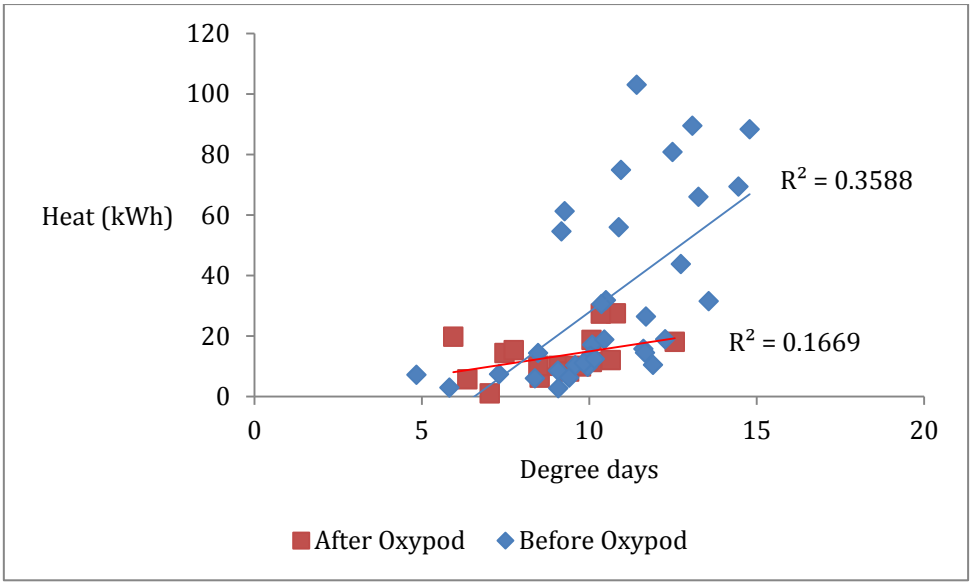

Figure 5, Degree days and delivered heat into the space, including outliers

Further investigation revealed two outlying data points or days; one in the before and one in the after test. These showed large amounts of heat being used seemingly neither related to external temperatures nor did they sit within wider patterns of energy use amongst adjacent days. These are likely to have been caused by researchers visiting the site and disturbing the internal conditions, though it is possible they were the result of some unknown dynamic effect. The sample size is small hence there are too few data points to smooth these irregularities out thus the decision was made to remove these two days from the data set. Figure 6 shows the result of this decision.

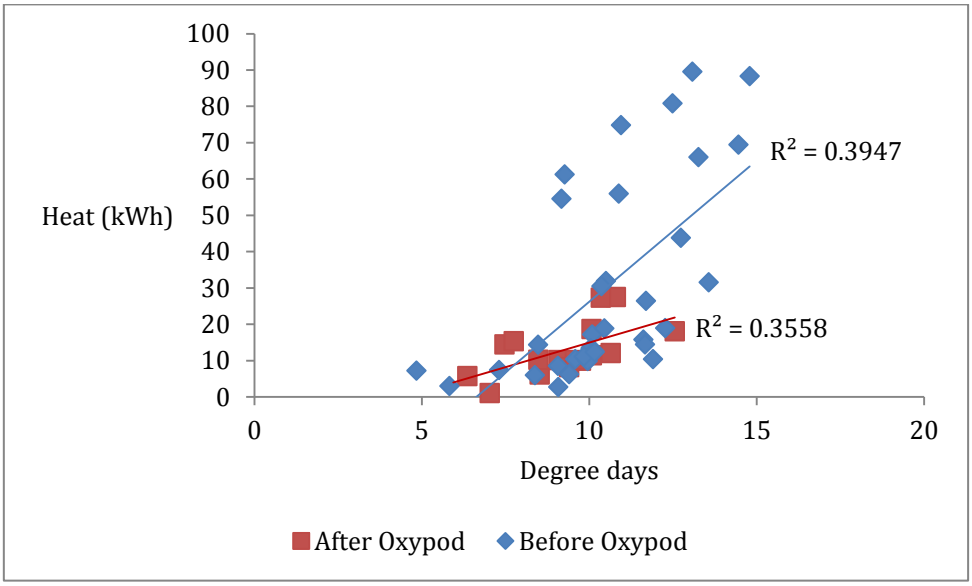

Figure 6, Degree days and delivered heat into the space, removed outliers

The general relationship of the before and after data remains unchanged after the removal of the outliers though as can be seen the r^2 values are substantially improved implying a greater degree of confidence and that these two outliers were indeed anomalies and were removed from the rest of the analysis.

The relationship between heat use and degree days is still shown to be weak which again may be anticipated owing to the small sample size. Both Figures 5 and 6 indicate that in general the Oxypod has resulted in an improvement in the energy efficiency of the dwelling's heating system as represented by the red line being below the blue line. The conclusions drawn from this however are not entirely satisfactory for example the reason why the data produces best fit lines with different gradients before and after the test is unclear. This would indicate that improvements may only be experienced when there is a high heating demand which may be unlikely to be the case.

The data in the before test when there was the highest heating use (i.e. above 30kWh per day) all occur within in the first two week of the study. This suggests that some change in the experiment conditions may have occurred that the researchers were not made aware of; for example windows or external doors not being fully closed or it there may have been some other hidden issue related to either the building or heating system, which had not been used in the preceding 12 months. The first two weeks did coincide with the coolest weather however degree days should have already accounted for this. With this being the case a sensitivity analysis was undertaken excluding the data acquired in the first two weeks of the test, the results of which are shown in in Figure 7.

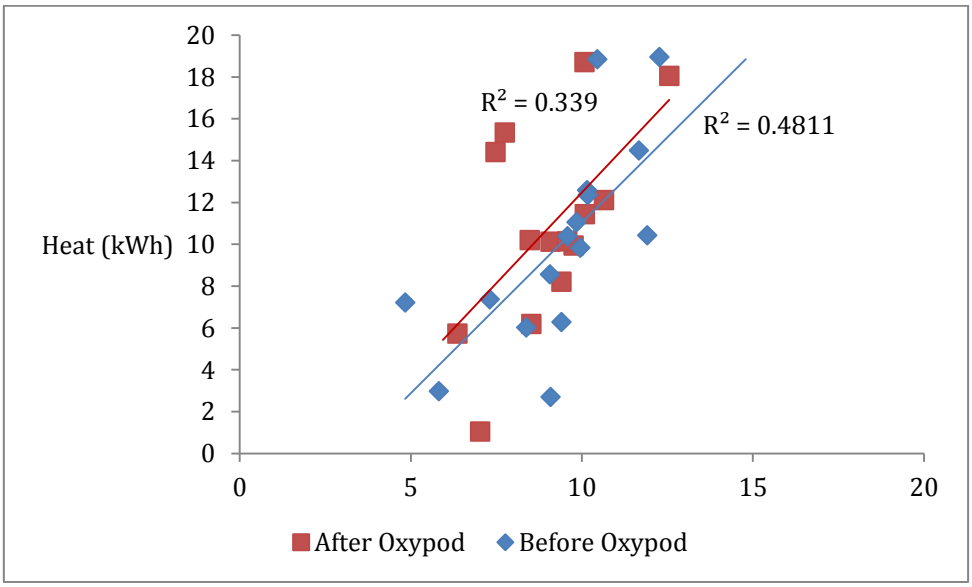

Figure 7, Degree days and delivered heat into the space ignoring first two weeks

Under these conditions the data shows a more satisfactory r^2 and the similarity between the gradients of the lines is noteworthy. In this situation there is virtually no change in the heat demand use per degree day after the Oxypod is installed. The red line for the after period in Figure 7 is now actually above the blue line indicating it may be less efficient, however as mentioned earlier if this were the case it may be due to the fact that the air tightness was compromised during the after test due to one of the windows being smashed and temporarily repaired. Such levels of uncertainty in the data make a robust appraisal of the effect of the Oxypod difficult.

3.3. Degree days

Figures 5, 6 and 7 are generated from raw data before any corrections in the heat demand have been made to account for the internal gains in the dwelling, i.e. where the base temperature for the degree day calculations is assumed to equal the internal temperature. This section next describes how the base temperature for our dwelling has been calculated using an offset temperature, i.e. the amount of internal gains experienced in the dwelling that will offset the gas use for space heating. This is a necessary step since internal gains representing 5°C (*the offset*) into a building with an internal temperature of 20°C means the heating system is only required when the outside air

temperature falls below 15°C (*the base temperature*). The two variables in our case study that determine the internal gains and which therefore affect the base temperature are solar radiation and heat emanating through the walls and intermediate floor from the heated community centre below, no other significant heat sources were present in the building.

The heat provided by the heated community centre and solar gains entering the space were aggregated together and accounted for using the offset method, this was considered a more suitable method since it was not necessary to disaggregate the two types of gains, only the collective influence needed to be accounted for.

In order to calculate the most appropriate base temperature average daily gas consumption is plotted against average daily degree days under a range of offset temperatures as per Figures 5, 6 and 7. The offset temperature which yields the highest r^2 is then selected as having the 'best fit'. This analysis can only take place if there is a critical mass of data points, unfortunately the data were too few in this case study to provide a greater resolution on the specific periods where the internal gains and hence the offset temperature changes thus one offset temperature was selected for the entire test period.

Table 2 explores how varying the internal gains, i.e. the offset temperature, affects how many degree days are be predicated. It is known that degree day calculations are sensitive to their inputs (Woods and Fuller, 2014) and so a sensitivity analysis is undertaken to report a range of values showing how substantially degree days can be manipulated by this method. It is noteworthy how sensitive the number of degree days predicted is to the offset. In addition there is no one stand out optimum offset temperature, with this in mind we will present the results on the energy efficiency of the heating before and after the Oxypod was installed over a this range of offset temperatures.

Table 2, Dwelling base temperature

Offset temperature °C	R^2	Degree days before Oxypod	Degree days after Oxypod
4	0.40	241	90
5	0.41	206	74
6	0.43	172	59
7	0.46	140	45
8	0.49	110	33
9	0.50	83	22
10	0.53	60	14
11	0.56	42	8
12	0.52	28	4
13	0.50	17	2

The data are shown not to provide a very good fit (r^2 value), suggesting the relationship between heat demand and external temperature exists but is quite weak. This lack of confidence is likely to be due to the small number of data collect, but may also be in part due to the heterogeneous test conditions in the dwelling which included boiler dropouts, temperature variations North to South of the building, unrestricted solar gains, inconsistent $\Delta\theta$ between the upstairs and downstairs, as well as changes to the air tightness of the building as a result of the broken window and researchers entering the dwelling.

The calculated degree days in Table 2 range from 13 to 331 over the entire test period suggesting a potentially small sample size, especially in the after test. As a check on the reliability of these

calculations, a degree day estimators[6] has been used to provide a model for comparisons. During April, May and June based on Leeds Bradford airport external temperatures and assuming a 15.5°C base temperature, the model suggest 389 degree days may be anticipated, higher than our prediction, however we only considering 48 days over this period out of a possible 91, using a simplified ratio of 48:91 means the model estimates only 205 degree days over the period. These numbers are in the same order of magnitude as our predictions. Generally speaking degree days sample sizes can be increased by extending the length of a study (not possible in this time bound test) or by increasing the heating set point to exaggerate the $\Delta\vartheta$, (the energy budget in this test was limited). Thus these are limitations to our field experiment that we must accept but we should interpret the results in the context of these.

3.4. Heating heterogeneity

There is some evidence that North end of the dwelling was warmer in the after test. The variance and recorded temperatures is shown in Table 3 indicating Oxypod produced warmer more homogeneous conditions, however these findings may simply be due to the milder external temperatures experienced during this period.

Table 3, Behaviour of internal dwelling temperature

	(°C) Entire period	(°C) Before Oxypod	(°C) After Oxypod
Mean average daily variance	2.0	2.2	1.4
Max average daily variance	5.6	5.6	4.4
Min average daily variance	0.8	0.8	0.8
Mean average daily temperature	20.1	19.6	21.0
Max average temperature	37.2	37.2	34.8
Min average temperature	13.6	13.6	15.5
Mean external temperature	10.2	9.3	11.9
Max external temperature	15.6	14.6	15.6
Min external temperature	4.8	4.8	7.3
North entrance mean external temperature	18.1	17.7	19.1
North entrance max external temperature	20.9	19.7	20.9
North entrance min external temperature	14.6	14.6	16.2

The relatively weak relationship between degree days and gas use may also indicate that the area weighted average temperatures are not able to fully account for the building being at different temperatures in different zones. Installing air circulation fans may have countered this, however in order to replicate real life conditions in the dwelling this was a necessary limitation of the field experiment. Another complication may have been that the heat bypasses entering the dwelling from the community centre may have occurred in some rooms more than others.

3.5. Energy efficiency

The total heat delivered to the dwelling over the entire period was 1,480 kWh, of this 1,200kWh was delivered prior to the Oxypod being fitted and 260 kWh afterwards. As discussed the results are presented for a range of offset temperatures using the data set with the two outliers removed.

[6] http://www.degreedays.net/

Table 4, Dwelling energy efficiency (kWh per degree day)

Offset	4°C	5°C	6°C	7°C	8°C	9°C	10°C	11°C	12°C	13°C
Before Oxypod	4.4	5.0	5.0	7.5	9.5	12.7	17.5	25.0	37.9	61.1
After Oxypod	2.3	2. 3	3.5	4.5	6.3	9.3	15.0	25.8	50.0	124.57
Improvement	48%	46%	43%	39%	34%	27%	14%	6%	-15%	-58%

This shows that Oxypod is likely to have produced improvements in the energy efficiency of the dwelling heating system as has been suggested in anecdotal observations on previous installations[7]. The exact improvement will be dependent on the internal gains that were experienced; the offset temperature with marginally the best r^2 value in our case study was 11°C which would equate to a 6% reduction in heating energy used. In the extreme however Oxypod may have made up to 48% improvements and in the worst case scenario it may have reduced efficiency by 58%.

This table again highlights the difficulty in using the degree day method when data quantity is low and there high levels of uncertainty. In this case study although there are indications that the Oxypod has reduced energy consumption the data are not numerous to have certainty as to which level of savings was achieved in practice, for example in Figure 7 when the heat consumption in the first two weeks of the experiment were removed from the analysis because they appeared to have a particular energy signature compared to the rest of the test, the Oxypod made effectively no change to the energy efficiency of the heating system.

These results hint that a potential improvement may be anticipated from using de-aerators in domestic heating systems though further data are needed to fully understand and quantify this.

4. Discussion and conclusions

In this study a field experiment was undertaken to assess how the efficiency of a dwelling's heating system that changes after installing a de-aerate, the Oxypod. It showed that efficiency improvements of around 6% may be achieved but importantly there was a large degree of uncertainty in the experiment. It was also observed that the dwelling may have been heated more homogenously after the Oxypod was installed however this may have been due to the warmer weather experienced. This field trial has also highlighted several methodological problems when testing such devices which may be important considerations for any future tests aimed at quantifying the degree of energy efficiency improvements that they can achieve, these are briefly discussed here.

More control over the internal conditions in future tests would be preferred so that it was not necessary to use volume weighted average temperatures. The benefit of using air circulation fans would have been to maintain homogenous internal conditions that would have simplify the calculation process, on reflection this might have outweighed the benefit of replicating of real world conditions.

Data sample size was a fundamental problem, especially in the after test, substantially limiting reduced confidence in the results. Variations in the internal conditions caused by dynamic effects such as the heat transfer between upstairs and downstairs and one-off influences such as the broken window as well as researchers entering and altering the test conditions may have been smoothed out and have less influence on the overall data if the sample were larger. It is recommended that future tests should either be run for longer or at greater $\Delta\vartheta$, preferably undertaken during winter periods, in order to generate more and reliable data.

[7] http://www.oxypod.me/testimonials

In order to install the Oxypod it was necessary to drain and refill the heating system part way through the experiment, it was not possible to identify what influence this would have on the efficiency of the heating system since it too would likely removed any trapped air bubbles though would not have removed any dissolved air in the water. However since a new boiler was installed for the experiment for which it was also necessary to drain the heating system fresh water was used from the outset thus it is not anticipated this should be a major concern. Any future test could include a bypassing mechanism so the Oxypod can be turned on without the need to drain the system so that the same water can be used in the before and after test.

The study highlighted the difficulty of analysing energy use in buildings which have variable internal temperatures as well as the importance of being able to adequately control a building's internal temperature. To counter this it used volume weighted average temperatures and followed accepted guidance on selecting an appropriate offset temperature, however there was insufficient data to provide a definitive offset temperature for different periods of the test, for example adjusting the offset to incorporate periods of high solar gains during the summer days for example.

Results were therefore presented over a range of offset temperatures which showed how sensitive the predicted energy efficiency of the heating system was to internal gains. An alternative method in future tests to alleviated reliance on the use of offset temperatures may be to directly measure the heat transfer between adjacent spaces using heat flux plates and to measure the solar radiation entering the space so that these may be accounted for in the analysis. A further simplification could have been achieved by selecting a case study building that was a detached and to provide solar shading which would result in less complicated heat bypasses and solar gains.

In summary there is some evidence to suggest that the Oxypod improved energy efficiency of the heating system by around 6% though this must be firmly caveated by the high degree of uncertainty in the data caused by the numerous limitations identified in this report, chiefly the data sample size being small. It is recommended that further data be collected to confirm if this finding can be repeated.

Acknowledgements

The authors would like to thank Leeds Beckett University for funding the study, Leeds City Council for allowing access to their building and the Goodwin Trust for providing the Oxypod for the study.

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Energy

ECONOMIC ASSESSMENT OF BIOMASS GASIFICATION TECHNOLOGY IN PROVIDING SUSTAINABLE ELECTRICITY IN NIGERIAN RURAL AREAS

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Keywords: Biomass Gasification Technology, Nigeria, Sustainable Electricity, Whole Life Costing.

Abstract

Renewable Energy Technologies (RET) in general, and biomass source in particular, remains one of the means of providing sustainable electricity to rural areas in developing countries. This is because of its strategic value in identifying when and where electricity is really required thus, reducing/eliminating the high cost of grid network. The majority of Nigeria's rural dwellers are farmers and use little or none of their residues at the end of the farming season. Nigeria has also been experiencing dwindling power supply at both national and rural level with accessibility representing only 35% and 10% respectively. The rural areas are the most affected causing significant disruption of their socio-economic settings. Considering the enormous biomass resources in these communities, and they constitute approximately 65% of the country's total population, it is feasible to provide sustainable electricity to these communities through Biomass Gasification Technology (BGT). Cost has been found to be the major constraint in adopting RETs. Hence, this paper aims to evaluate and optimise the unit cost of generating electricity through BGT in Nigerian rural areas. Whole Life Costing approach has been used to evaluate various capacities of BGT. The findings reflect that cost/kW of BGT ranges between US$594(NGN118, 800)-US$3,604(NGN720,800) for capacities between 125kW-10kW. The Net Present Value(NPV)/kWh of generating electricity has been calculated for several scenarios including 125kW, 100kW, 50kW, 32kW, 24kW and 10kW system capacities under 3 different operational hours (8, 12 and 16), with and without feed-in tariff(FIT) incentive is from US$0.015-US$0.11(NGN3.08–N21.79). The only scenario that exceeds the current unit price of generating electricity from fossil fuel source in Nigeria which is averagely US$0.083(NGN16.50) is 8 hour operation without FIT at 10kW capacity. More so, in the event fuel wood price increases by 50%, 75% and 100%, the average increase in NPV/kWh will be 13%, 20% and 27% respectively.

Garba, A. and Kisha, M. (2015) **Economic assessment of biomass gasification technology in providing sustainable electricity in Nigerian rural areas** *In;* Gorse, C and Dastbaz, M (Eds) *International SEEDS Conference,* 17 – 18 September 2015, Leeds Beckett University UK, Sustainable Ecological Engineering Design for Society.

Introduction

A decade after privatization of Nigeria's power sector (2005) with a bid to increase energy accessibility through participation of private sectors, the current electricity generation capacity is less or equal to the figure (4GW) at the commencement of the privatisation. The country supply accessibility at both national and rural areas represents only 34% and 10% respectively (Ikeme & Ebohon 2005). This was further confirmed in April, 2015 by the current Nigeria Minister of power that "Power generation in the country has risen above 4,000 megawatts after hovering between 3,000MW and 3,800MW since January this year. The country's peak generation was 4,011.4MW, while energy generation was put at 3,540MW and the energy sent out was 3,465MW". This is for a population of approximately 170 million. The major causes of this inconceivable condition of the Nigeria energy sector include investment pattern and limitation, economy of gridline network, insecurity (vandalism) of energy infrastructure, transmission and distribution losses (technical and non-technical) and climate change effect (Eberhard & Gratwick 2012; Iwayemi 1994).

This lack of improvement continues to significantly affect Nigerians by disrupting socio-economic settings particularly in its rural communities where approximately two-thirds of the total country's population reside (Bugaje 2006; Ikeme & Ebohon 2006). Thus, utilisation of fuel wood and charcoal (FWC) has become the main source of energy and constitutes between 32%-40% of Nigeria's total primary energy consumption (Sambo 2009).

The electricity problem of Nigeria's rural areas may not be unconnected to centralised electricity supply system used in the country. This is due to investment factor in extending gridline network to rural areas following low capacity utilisation, low load density, distance of the transmission and distribution from load centres to existing grid point and high cost of electricity generation given the high price of fossil fuel (FF) energy sources (Mahapatra & Dasappa 2012); also, grossly insufficient supply of natural gas (<1/3 of the required 1.2 billion cubic feet/day) to the existing thermal station in the country (Ohunakin et. al. 2011). There is also high-energy loss peculiar to Nigeria as result of deterioration of the transmission and distribution facilities (Sambo 2009), up to around 40% (Dasappa 2011; World Bank 2005).

It is acknowledged that Renewable Energy Technologies (RETs) remain the one and only means of providing sustainable electricity to rural areas. Also, RETs can be utilised where fossil fuel sources in conjunction with centralised grid systems are uneconomical; and suitable for powering small scale demands for low income earners peculiar to rural areas. RETs mostly come in modules, which allows capacity increase if necessary in the future. However, RETs have limitations which include high capital cost, intermittency of sources (peculiar to solar, wind), investment deficiency, inadequate policy framework and unregulated electricity production from biomass may lead to food and fabrics crisis (Sopian et al. 2011; Alazraque-Cherni 2008; Shunmugam 2009 & Kaundiya et al. 2009).

It can be inferred from the above that the major problem of RETs is the high capital cost, as it is unaffordable to the majority of the people even in developed countries, let alone for people in developing nations especially Nigeria's rural communities that live below $1.25/day (UNICEF 2011). Otherwise, why are the authorities providing economic incentives for its application? "Renewables are still expensive and cannot compete on commercial basis with other non-renewables without government support" (Otitoju 2010). Hence, the new realization in electricity generation should be sustainable and affordable to the rural households. Although, there are reasonable amounts of RETs literature in Nigeria, very few researches have been undertaken on economic evaluation of RETs in the country. Oyedepo (2012) suggested that further research in Nigeria's RETs should cover "life cycle costing and cost-benefit analyses tool and should be undertaken with urgent priority".

In spite of all policies set by the Nigerian government, like rural electrification funds (to expand electricity access in affordable means) and consumer assistance (to protect poor consumers and low

income earners), it can be assumed that these programme are not yielding meaningful progress yet, considering the numbers of communities without electricity in the country. Following sustainability assessment of RETs in Nigeria's rural areas based on the study by Garba & Kishk (2014), the research reveals that biomass energy source is the best means of providing sustainable electricity for these communities. The adoption of a decentralised biomass energy source in conjunction with emerging gasification technology in mitigating electricity poverty in Sub-Saharan African rural areas, Nigeria inclusive perhaps may be a more viable option in view of their energy demand characteristics. Furthermore, biomass resources are generally available, without supply chain problems and at less or no cost. Hence, this paper aims to evaluate and optimise the unit cost of generating sustainable electricity through biomass gasification technology (BGT) in Nigeria rural areas.

BIOMASS ENERGY

Biomass energy source is the only renewable and organic petroleum substitute. Biomass resources are in different forms and include animal dung, energy crops, forestry and agricultural residues and Municipal solid waste (Zheng et al. 2010). It is the fourth largest energy source after oil, coal and natural gas and accounts for around 14% of global primary energy source (Martinot 2013; Zheng et al. 2010). Biomass is mostly plant derived materials, capable of being transformed to different forms of energy and can quickly be regenerated in different environments (Evans et. al. 2010). Biomass either in solid, liquid or gas form can be used for electricity generation, heating and fuel (Moriarty & Honnery 2011; Martinot 2013). This is possible through thermochemical (combustion, gasification, and pyrolysis) and biological conversion processes (IRENA 2012; Demirbas 2001; Bocci et al. 2014)

Biomass application for electricity generation has increased consistently by an average of 13TWh/year from 2000-2008 (Evans et. al. 2010). Biomass electricity (bio-power) global capacity was approximately 83GW by the end of 2012; generating electricity around 350TWh. Bio-power is majorly (90%) generated from solid biomass fuel and the remainder is from landfill gas, biogas and synthesis gas. All the existing commercial bio-power system together produced approximately 1.4% of electricity generated worldwide. The USA is the leading country in generating electricity from this source with capacity of 15GW (18%) and around half of the total capacity is located in Europe (Martinot 2013). However, biomass demerits include inefficient energy gain following conversion, food price increase, huge water application, deforestation etc. (Shunmugan 2009; Moriarty & Honnery 2011). For more on biomass problems see Bocci et al. 2014 and Ganesh & Banerjee 2001.

Nigeria Biomass Resources

Nigeria's biomass resources include agricultural residues, animal residue, forest biomass and municipal solid waste. The country's biomass resource potential is approximately 1.2 Petajoule (PJ) as at 1990 but this does not include MSW, biogas and a few other sources (Akinbami 2001); while ECN (2005) projected the resources to be around 144 million tonnes per annum. Considering the Nigeria's vegetation pattern (including forest and savannah), the large parts of the country is cultivatable, particularly in the northern region, and also where there is animal dung/droppings and plant residues. The southern part of Nigeria produces a substantial amount of fuel wood in view of its vegetation arrangement. "Nigeria rural areas biomass resources can generate electricity up to 68,000 GWh/year at 30% availability. However, biomass-effective supply chains and overall affordability will ultimately decide its viability for electrical generation" (Garba & Kishk 2014). Even though at the moment, biomass resources cost little or no price in the rural areas, there is likelihood of feedstock (fuel) cost increasing in the near future in view of the competing utilisation requirements from other sources (animal feed, soil stabilisation etc) whenever the application of the BGT presents itself.

Following lack of commercial energy in the majority of Nigeria's rural areas, these communities use traditional biomass means FWC to meet nearly all their energy needs. This represents in excess of 50 million metric tonnes consumption annually and is in excess of afforestation replenishment

programmes in the country (Sambo 2009). Sambo (2009) further argued that the deforestation rate is approximately 3.6% annually. The reduction in forest resources in the country have made fuel wood to be scarce in the rural areas and these communities, particularly women and children, have to travel far in to the forest spending over 4 hours to collect fuel wood for their daily meals. This fuel wood collection is unsustainable considering the time spent, less efficiency (between 5- 12 %), and health effects due to indoor cooking as a result of fuel wood application, which is causing lung problems to over 1.5 million women in developing countries annually. Also, this act is preventing the children from going to school, thereby increasing the illiteracy level in these countries (Sopian et al. 2011; Kennedy-Darling et al. 2008).

Biomass Energy Conversion Technologies

There are numerous technologies available to convert biomass to electricity but these are mainly classified under two headings and include thermochemical (combustion, gasification and pyrolysis) and biological (bio-digester) means. The thermochemical technologies such as combustion, gasification and pyrolysis convert biomass to produce fuel in the form of steam, gas and liquid oil respectively to be utilised in powering plants like Internal Combustion Engine (ICE), gas turbine, generator and fuel cell (Bocci et. al. 2014; Dasappa 2011; Demirbas 2001). Combustion based technology is not suitable particularly for power plants lower than 5MW and has high fuel consumption regime. A small scale gasification system of less than 200kW, using ICE provides superior efficiency around 35% (Dasappa 2011; Fan et al. 2011; Evans et al. 2010). Financially, pyrolysis is the most expensive technology at the moment and has a high operating cost (Evans et.al. 2010). Gasification technology is the emerging biomass conversion technology and is being adopted to improve efficiency and reduce capital cost of biomass electricity generation systems. Also, it can use varieties of feedstock as fuel and cost competitive with FF based power plant (Demirbas 2001). Dasappa (2011) argued that in view of the enormous requirements for generating electricity in Sub-Saharan Africa, a biomass gasification system is among the best alternatives for the African rural communities.

BIOMASS GASIFICATION TECHNOLOGY (BGT)

Gasification is a thermo-chemical process that converts biomass through partial oxidation into a gaseous mixture of syngas/product gas consisting of hydrogen, carbon monoxide, methane and carbon dioxide (Wang et. al. 2008). The major combustible elements of the product gas (PG) are hydrogen, carbon monoxide and methane constituting approximately 45% of the gas (Breeze 2014). The PG is of low caloric value (LCV) containing between 4-6 MJ/kg compared to other fuels such as natural gas between 35-50 MJ/kg due to high nitrogen presence in excess of 50% and other non-combustible constituents.

There are three main gasification technologies including fixed bed, fluidised bed and entrained flow gasifier (IRENA 2012). Considering the low energy utilisation of rural communities only the fixed bed gasifier will be discussed. This is because downdraft gasification technology is basically suitable for small scale power generation ranging from 10 kW to over 100 kW and has been fully commercialised. Also, it has relatively clean gas and low tar (< 10 g/Nm^3) reached in this arrangement; even though the particulates in the gas can be high. Biomass residence time in this configuration is high leading to a high char conversion of approximately 95%. Overall efficiency is low and requires homogenous feedstock to achieve excellent output (Bocci et al. 2014). The entrained gasifier is only used for large application, ranging from 100MW -1,000MW (IRENA 2012); while for application of over 1MW a fluidised gasifier configuration is considered (Bridgwater 2002). BGT can generate electricity at any given time provided there is biomass feedstock availability. It can also provide energy similar to fossil fuel sources for lighting, powering of domestic appliances like refrigerators, television, as well as for industrial applications.

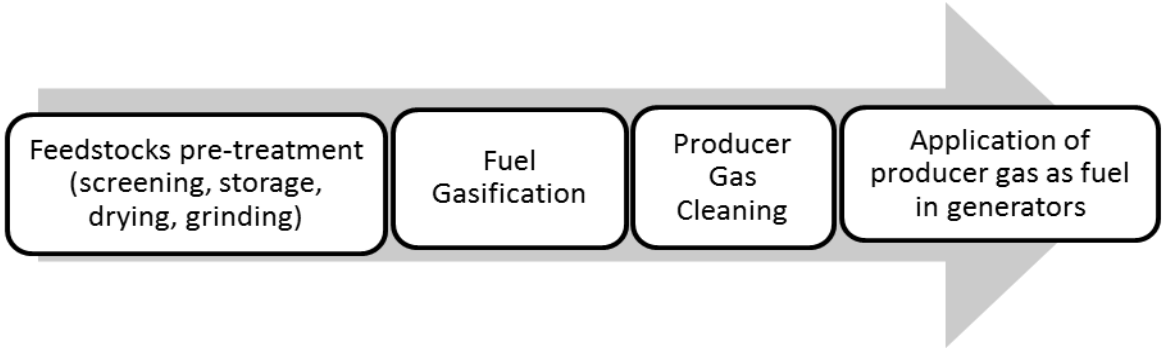


Fig (1): Gasification Processes for Electricity Generation

There are several conditions to be met in selecting appropriate gasification feedstock. The first criterion is the significant availability of biomass resources. Secondly, low humid materials as feedstock (the dryness of the feedstock can be obtained through seasoning or exploitation of power plant heat). Then the size and shape of the feedstocks are also important in order to ensure uniform and consistent feed into the gasifier resulting in consistent and efficient gasification (Bocci et al. 2014). However, the last criterion can increase the operating cost of the whole process. The chemical composition of this feedstock is another factor to be highlighted. The most suitable feedstock for BGT is wood (because of low ash content), maize cobs, coconut shells and rice husks (Bocci et al. 2014; Asadullah 2014). The major economic obstacle of BGT are the ash and tar contents of the resources; meaning the more the ash content, the more gas cleaning exercises, hence increasing operating cost (Bocci et al. 2014). The utilisation of these feedstocks in the gasification process in small gasifier and ICE to generating unit of electricity will require between 1.1 – 1.5 kg/kwh (wood), 0.7 – 1.3 kg/kwh (charcoal) and 1.8 – 3.6 kg/kwh (rice husk) (Mahapatra & Dasappa 2012).

The BGT system sometimes requires a gas cleaning unit mainly because of PG characteristics as highlighted below. The PG used in generating electricity has limitations on the level of impurities concentration to be accepted by the power plant (Asadullah 2014). The wet scrubbing gas cleaning system is the preferred option for ICE generator because the PG must be cool at injection to the engine. While the hot gas filtration gas cleaning system is the best for turbine system (Bridgwater et al. 2002).

The electricity generation from small scale gasification plants is exclusively via Internal Combustion Engines (ICE), but can be burned in combined-cycle gas turbines with better efficiency than the steam turbine driving from biomass combustion (IRENA 2012), and micro Gas Turbines/Fuel Cell (Bocci et al. 2014). This process is mostly for converting wood, wooden and agricultural residues into a gas mixture ready for combustion (Evans et. al. 2010; Demirbas 2001), see figure (1) above for details. For satisfactory ICE operation, the acceptable particle and tar concentration in PG must respectively be < 50 mg/Nm^3 and 100 mg/Nm^3 (Bocci et al. 2014). ICE has matured, fully commercialized and with enough operational experience gain across the world but with limited capacity (< 1 MW) (Bridgwater 1995). BGT electricity costs depend mainly on biomass cost (Mahapatra & Dasappa 2012; Ganesh & Banerjee 2001).

METHODOLOGY

Assessing and optimising the economic competitiveness of BGT in providing sustainable electricity in Nigeria's rural areas is the basis of this study. To achieve this, a Whole life costing (WLC) approach has been used because it systematically sums up the whole cost and revenue related to the asset, from the commencement stage through the operation to the end of the asset. This will allow determining the unit cost of electricity from an energy source. In addition, it can optimize cost of ownership and

running of physical assets by representing their present worth value. Furthermore, WLC helps in making the right decisions at the beginning or during the operation of the asset.

The WLC framework proposed by Mahapatra and Dasappa (2012) has been adapted and modified for use in the current study. The reason for selecting this WLC framework is because it is suitable for evaluating biomass energy source. The carbon trading incentive in the framework is not applicable in the Nigerian power sector at the moment, as such it is being replaced with the Feed-in-Tariff (FIT) incentive strategy in the country and details are as shown in table (2) below. Salvage value and inflation are not considered in this study for ease of calculation. The WLC framework is given by:

$$WLC = \frac{C_G + C_E + (C_F + C_M) \times P(d, n) + C_R \times P(d, n_1) - FIT \times P(d, n)}{L \times h \times n}$$

- Where $C_F = (S_C \times f_{con} \times h \times f_C)$, $C_M = (S_C \times f \times M_C)$, $FIT = (L \times h \times n \times I)$

The details of the nomenclature are as follows: C_G is capital cost of gasifier, C_E is capital cost of engine, C_F is annual fuel cost, C_M is annual maintenance cost, S_C is gasifier rating (kg), f_{con} is fuel consumption (kg/h), f_C is unit fuel cost, M_C is maintenance cost of the system, P is present worth factor, d is discount rate, n life of the project, n_1 life of each component, C_R component replacement cost, FIT is annual feed-in-tariff benefit, I is incentive benefit, h annual operation hours, L is load (kW).

The parameters used for the WLC exercise are as shown in table (1-2). The WLC in this study aims to evaluate and optimise the NPV/kWh of generating electricity using BGT for Nigeria's rural areas. A summary of data collected and analysed are presented in table (3) and figure 2- 3.

Biomass Gasification Technology PGE(US$/kW)	= 2,489 - 1280
Fuel Consumption/Kw (Kg/h)	= 1.4
Fuel cost (N/kg)	= 5.71
Gasifier Lifespan (yr)	= 15year
Engine Life (yr)	= 7.5 year
Annual maintenance cost (N/kW)	= 4.84

Table (1): The parameters utilised

	2012	**2013**	**2014**	**2015**	**2016**
SHP	23.56	25.43	27.24	29.64	32.00
Wind	24.54	26.51	28.64	30.94	33.43
Solar	67.92	73.30	79.12	85.40	92.19
Biomass	27.43	29.62	32.00	34.57	37.36

Table (2): Proposed Renewable Energy FIT Model in Nigeria (Whole Contract Prices N/kwh) (National Electricity Regulatory Commission 2012)

The cost of BGT components were sourced from the manufacturers directly. This is because the literatures reported wide varying figures. The wide difference didn't change with this research work despite sourcing the prices from manufactures. This problem may not be unconnected with the fact that the technology is still an emerging one; also location factors (more expensive in Europe and America but cheaper in India) as highlighted by Breeze (2014) and O'Connor (2011). Ganesh and Banerjee (2001) confirmed that "gasifiers cost in India is much lower than those elsewhere". The cost prices of BGT components, their accessories and installation figure are presented in table (3). Hence, the prices obtained are classified under high, medium and low rates following the above problem.

The costs are presented in US$ for universal understanding, even though the prices are obtained in India Rupee (INR). At the moment a US$ is exchange for INR 62 and Nigeria Naira (N) is 200. The discount rate used is 13% and the figure has been obtained from Central Bank of Nigeria. The figure used for annual maintenance cost has been adopted from the studies of Mahapatrra and Dasappa (2012) and Banerjee (2006).

Manufacturer of Gasifier	Manufacturer (High)			Manufacturer (Medium)						Manufacturer (Low)			
Gasifier/Engine type	DD + PGE			DD + PGE						DD + PGE			
Capacity (KW)	**120**	**70**	**25**	**125**	**100**	**50**	**32**	**24**	**10**	**125**	**100**	**24**	**12**
Gasifier and accessories	110	80	45	95.1	79.3	41	27.66	20.6	14.3	43.8	34.4	23.5	9.37
Chiller (Optional)	20	20	-	-	-	-	-	-	-				-
Wood cutter	10	10	6	-	-	-	-	-	-				-
Dryer	5	5	3	-	-	-							-
Total cost of gasifier	**145.0**	**115**	**54**	**95.1**	**79.3**	**41.0**	**27.7**	**20.6**	**14.3**	**43.8**	**34**	**23.5**	**9.4**
Gas Engine & accessories	100	60	25	53.4	44.2	22	14.4	11.9	6.6	23.45	19.6	8.9	6.3
Civil works	2	1.5	1.5	2	2	1.5	1.5	1.5	1.5	2	2	1.5	1.5
Earthing work	0.4	0.4	0.3	0.4	0.4	0.3	0.3	0.3	0.3	0.4	0.4	0.3	0.3
Total cost of genset	**102**	**62**	**27**	**56**	**47**	**23.8**	**16.2**	**13.7**	**8.4**	**25.9**	**22**	**10.7**	**8.1**
Total Cost of Gasifier+Engine	**247**	**177**	**81**	**151**	**126**	**65**	**44**	**34**	**22.7**	**69.7**	**56.4**	**34.2**	**17.5**
Installation + commissioning	10	10	5	1.5	1.5	1	1	1	1	1	1	0.81	0.78
Price & Design Risk (5%)	12.9	9.4	4.3	7.6	6.4	3.3	2.2	1.8	1.1	3.5	2.9	1.7	0.9
Total Cost of the system	**270.3**	**196.4**	**90.3**	**160**	**133.8**	**69**	**47**	**37**	**24.70**	**74.2**	**60.3**	**36.7**	**19.2**
Cost/KW (US$)	**2.25**	**2.81**	**3.61**	**1.28**	**1.34**	**1.38**	**1.47**	**1.54**	**2.47**	**0.59**	**0.60**	**1.5**	**1.6**

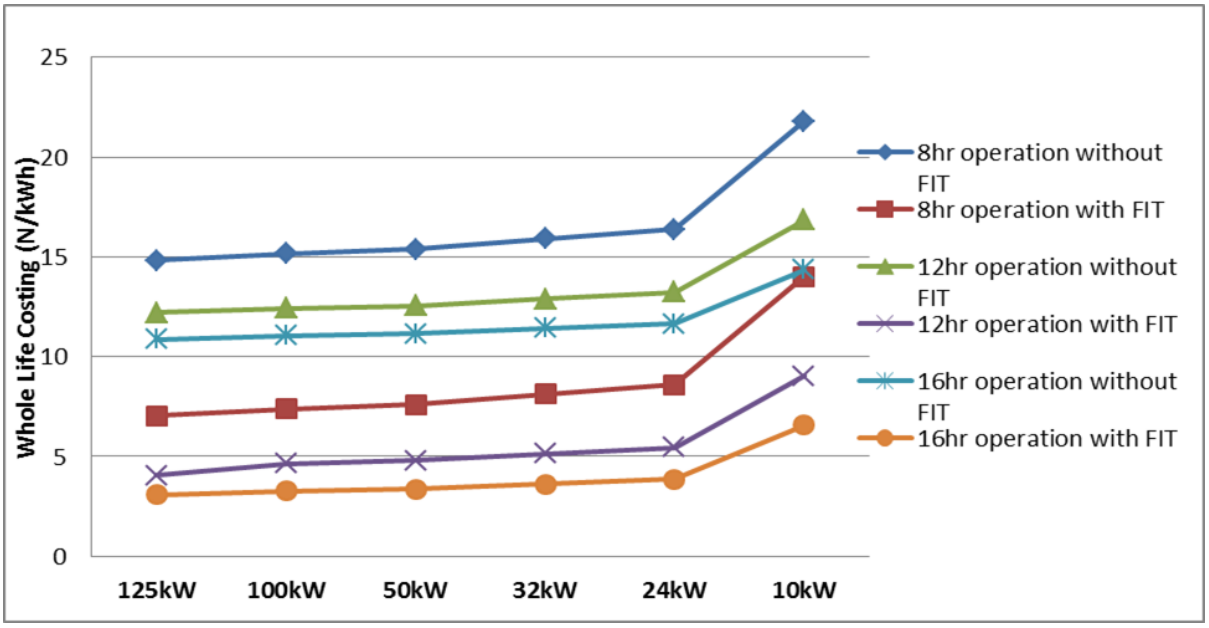
'Note: DD=Downdraft; PGE= Producer Gas Engine

Table (3): The Cost ('000)/kW of BGT in Nigeria's Rural Areas

Fuel wood has been used for this study because of its strategic benefit as highlighted above and the cost price has been obtained from the field survey. A Mitsubishi Canter truck with loading capacity: length (4.2m), width (1.8m) and depth (1.5m) is typically utilised for transportation. The total price of the supply chain including transportation is US$112.50 representing 45 units as classified in the market with approximately 105kg/unit and each unit is sold at US$3.00. Hence, the unit cost of the wooden fuel is N571/ton. This principle has been adopted for other fuel sources, such as corn stover US$3.85/ton and rice husk US$1.90/ton. The low-price of wooden biomass may be connected to the fact that it is an already established market. The biomass fuel consumption figure utilised reflects averages reported in the literature and as obtained from manufacturers.

Analysis and Discussion

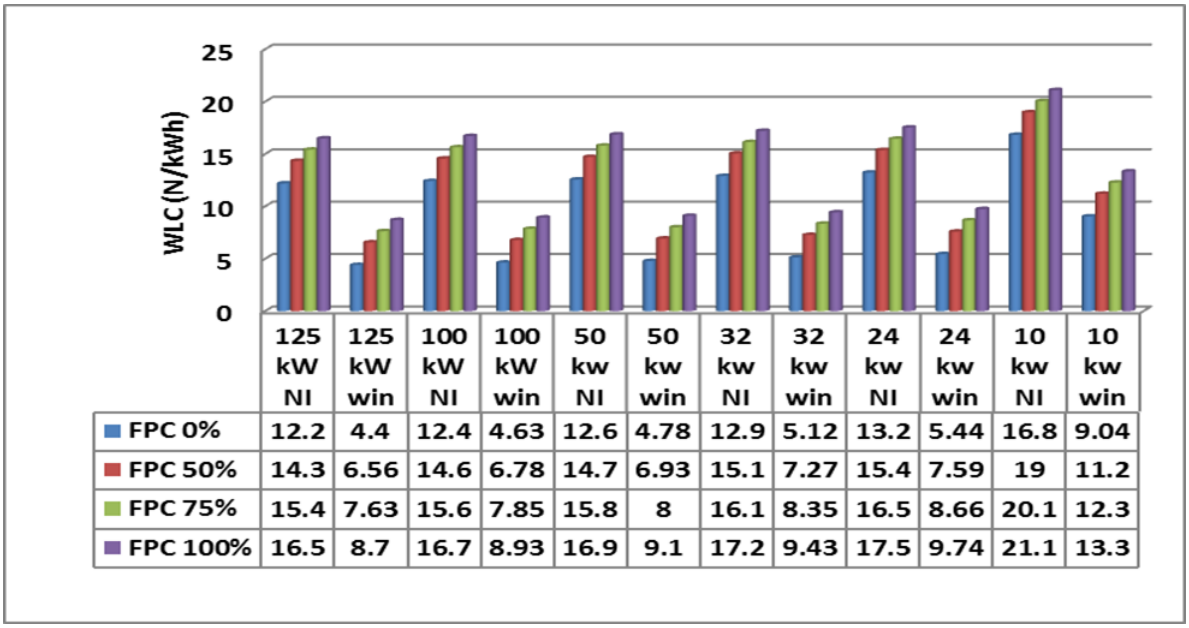
This study considered different capacities of BGT as shown in table (3) above. The unit cost/kW from table (3) above are as follows: *high rate US$2,252-US$3,604, medium rate US$1,289-US$2,489 and low rate US$594-US$1,594.* The high difference noticed is in agreement with IRENA (2012), Nouni et al. (2007), and O'Connor (2011). The economy of scale noticed in the exercise, is indicative that the higher the BGT capacity the lower the cost/kW. In fact the cost reduction between the higher capacity and lower capacity under each of the three rates - higher, medium and low - represent 38%, 49% and 63% respectively.



Rated Capacity (Note -medium rate in table 3 was adopted)

Figure (2): WLC of electricity from BGT

From figure (2), 6 different system capacities and 3 different operation hours have been considered in this study. The WLC of generating unit of electricity from BGT using 12 operation hours without FIT incentive, the NPV/kWh varies from US$0.06-US$0.084 for capacities between 125Kw – 10kW. Using the same variables as above but with FIT incentive, the NPV/kWh ranges from US$0.02 -US$0.045. The lowest and highest NPV/kWh is 16 hour operation with FIT and 8 hour operation without FIT respectively. The findings also reflect that increase in operational hours and increase in system capacity decrease the unit price of generating electricity using BGT. Hence, the overall NPV/kWh of generating electricity from this study is from US$0.015-US$0.11, with only 8 operation hours at 10kW capacity that exceeds the current unit price of electricity in Nigeria, which is averagely US$ 0.083 using a fossil fuel source. This is in agreement with Mahapatra and Dasappa (2012) and Nouni et al. (2007) that biomass source is cost competitive with fossil fuel sources in generating electricity particularly in developing countries but in disagreement with Evans et al. (2010).



	125 kW NI	125 kW win	100 kW NI	100 kW win	50 kw NI	50 kw win	32 kw NI	32 kw win	24 kw NI	24 kw win	10 kw NI	10 kw win
FPC 0%	12.2	4.4	12.4	4.63	12.6	4.78	12.9	5.12	13.2	5.44	16.8	9.04
FPC 50%	14.3	6.56	14.6	6.78	14.7	6.93	15.1	7.27	15.4	7.59	19	11.2
FPC 75%	15.4	7.63	15.6	7.85	15.8	8	16.1	8.35	16.5	8.66	20.1	12.3
FPC 100%	16.5	8.7	16.7	8.93	16.9	9.1	17.2	9.43	17.5	9.74	21.1	13.3

Note: FPC = Fuel Price Change, WIN=With Incentive, NI=No Incentive

Reference: FPC 0% means current fuel price (N 5.71), Daily operation hour: 12hr

Figure (3): Sensitivity analysis (optimising) of WLC of electricity in relation with system capacity, fuel price increase, FIT Incentives, cost of generating electricity

Considering competing alternative uses of the biomass resources in the event of adoption of BGT, there is a likelihood of fuel price changes. The current NPV/kWh of generating electricity without incentive varies from US$ 0.061 – US$ 0.084 for capacities between 125kW -10kw. However, if the prices of the fuel change by 50%, 75% and 100% the cost/kWh of generating electricity from BGT will increase between (US$ 0.072 –US$0.095)-13%, (US$0.08-US$0.10)-20% and (US$0.08 –US$0.11)-27% respectively. This is in agreement with Ganesh and Banerjee (2001) and Mahapatra and Dasappa (2012).

CONCLUSION AND WAY FORWARD

Nigerian rural communities are facing severe electricity shortage as result of the following: investment pattern and limitation, economy of gridline network, insecurity (vandalism) of energy infrastructure, transmission and distribution losses (technical and non-technical) and climate change effect. BGT has been recognised to be the way forward for the current electricity problem, through application of downdraft gasifiers and 100% producer gas engine using wooden fuel. The cost/kW of BGT is as follows: high rate US$2,252-US$3,604, medium rate US$1,289-US$2,489 and low rate US$594-US$1,594. The difference noticed is connected to the fact that BGT is an emerging technology. While the NPV/kWh of generating electricity for several scenarios including 125Kw, 100kW, 50kW, 32kW, 24kW and 10kW system capacities under 3 different operational hours (8, 12 and 16), with and without incentive strategy is from US$0.015-US$0.11. The only scenario that exceeds the current unit price of electricity generation in Nigeria from fossil fuel source, which is on average US$0.083, is 8 hour operation without FIT incentive at 10kw. In the event of BGT adoption in the country rural areas and the fuel prices increase by 50%, 75% and 100%, the average increase in NPV/kWh will be 13%, 20% and 27% respectively. For successful BGT utilisation, the study recommends that National Energy Policy should be sign into law with a view to guarantee private sector participation, encourage decentralised energy generation and sustainable energy plantation in the country.

Acknowledgements

The authors would like to thank two anonymous referees for their valuables comments and suggestions.

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THE DEVELOPMENT OF AN ENERGY INDEX TO ASSESS ENERGY REDUCTION

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Keywords: Energy Consumption, Energy Efficiency, Energy Reduction.

Abstract

This short paper presents a methodology to allow the easy comparison of energy consumption between different flats, during different seasons and at different locations, while keeping a low budget perspective for the work. This methodology develops an energy index to normalise and evaluate the heating energy performance of different properties.

The energy index is based on the energy consumption in kWh, internal temperature and outdoor conditions by the use of degree days. Degree days are calculated based on the location of the property and the internal temperature as base temperature for the calculation. The degree days will be generated according to the period for the meter reading, allowing meter reading to be variable in length but it is advisable to do so on roughly four weeks periods. The normalised energy index is finally generated by combining the meter reading in kWh and the degree days for the reading period.

The energy index methodology is applied to four flats located in East Anglia. Results show that the behaviour changing was effective in reducing energy use and allow to understand energy consumption during different seasons and sudden weather changes.

The use of the energy index methodology presented in this paper should allow energy professionals, tenants and social housing providers to monitor and evaluate the energy use across seasons and locations, the effectiveness of new retrofitted technology and/or the application of behaviour change strategies, while keeping a low budget approach to the data captured and analysis

Jimenez-Bescos, C. (2015) **The development of an energy index to assess energy reduction** *In;* Gorse, C and Dastbaz, M (Eds) *International SEEDS Conference,* 17 – 18 September 2015, Leeds Beckett University UK, Sustainable Ecological Engineering Design for Society.

INTRODUCTION

This short paper presents a methodology to allow the easy comparison of energy consumption between different flats, during different seasons and at different locations, while keeping a low budget perspective for the work. This methodology develops an energy index to normalise and evaluate the heating energy performance of different properties.

The methodology was used by the author during the 'SmatLIFE Retrofit for Business' ERDF project to evaluate the energy consumption of several tenants occupying flats in three different blocks. The main purpose of the analysis was to compare the performance of the introduction of new technology and the effect of a behaviour change strategy. The behaviour change strategy was not only based on the provision of information via environmental education but focused on developing a positive identity associated with engagement in energy saving and green behaviours to achieve energy reductions.

As in any project it happens, budget restrictions do not allow the purchase of expensive smart meter equipment, so low budget alternatives are the next option. The adoption of low budget alternative smart meters generate several issues experienced by the author, such as data lost due to signal drop-offs, long periods unsupervised and/or unplugging of equipment.

Degree days have been around for quite a while and calculation methodologies are well explain in other texts, such as CIBSE (2006) and Krarti (2012), and has been used to forecast energy demand (Hong, 2013).

Degree days takes into account the outdoor conditions depending on location and base temperature.

According to DegreeDays.net, it can be hard to transform degree-days calculations into actionable task with the intention to reduce energy consumption. This is the main purpose of the energy index presented, to allow an easy evaluation while taking into account a low budget approach to the project.

RESEARCH METHODS

The approach for the development of the normalised energy index is based on the following inputs:

- Energy consumption in kWh taking from direct meter readings.
- Internal temperature in degree centigrade.
- Outdoor conditions depending on location, taking as degree days for the particular location.

Meter readings to capture energy consumption are independent on the reading interval as this will be normalised by the use of degree days.

Internal temperature of the property is captured by means of a temperature data logger, such as LogTag temperature data logger. The internal temperature is used as the based temperature to calculate the degree day for the particular location.

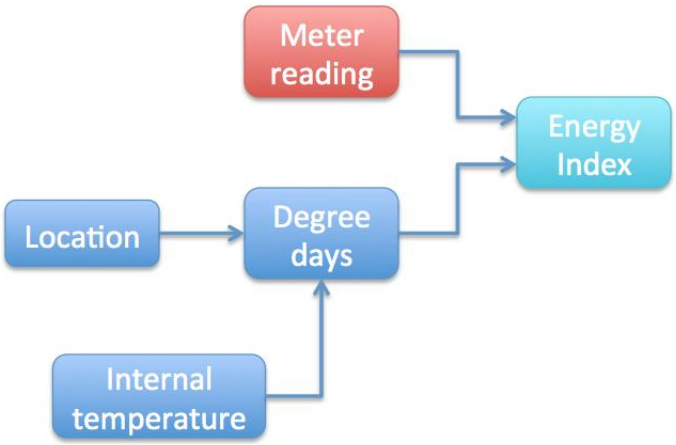

Figure 1. Energy index normalisation methodology

Figure 1 shows the methodology to generate the normalised energy index. Degree days are calculated based on the location of the property and the internal temperature as base temperature for the calculation. The degree days will be generated according to the period for the meter reading, allowing meter reading to be variable in length but it was advisable to do so on roughly four week periods. The normalised energy index is finally generated by combining the meter reading in kWh and the degree days for the reading period.

By using Degree days based on the location of the flat or property to monitor, allow us to generate an energy index, which can compare energy consumptions between different projects at different locations. For example a flat in Glasgow and a house in Southampton, it is expected to use more energy in Glasgow due to the colder weather but the energy index normalised by the degree days allows us to compare like for like both properties as the weather conditions are taking into account. If it is colder a higher degree day is used and if warmer, a smaller degree day is obtained. Furthermore, the degree days are based on the base temperature, by using the internal temperature in the energy index as based temperature, provides a tool to understand when a flat has been reducing energy consumption due to savings by changing behaviour or just by not using the heating system, for which the internal temperature will have been lower than normal and affecting the degree day value and ultimately the energy index for comparison. In another situation, an overheating flat will have used a higher amount of energy, not due to the weather conditions but due to the higher internal temperature and this effect will be captured in the energy index.

RESEARCH RESULTS

The above methodology was used to assess the energy consumption of four flats located in East Anglia.

Meter readings for energy consumption were collected on a rough interval of every four weeks, from October 2013 to June 2014, according to the periods shown in Table 1.

Internal temperature measurements were collected on a 20 minutes interval for each flat. An average internal temperature for the whole collection period was used as based temperature to calculate the required degree days for every period. A calculation of degree days based on daily internal temperature was performed to assess the validity of a whole period of internal temperature averages and it was found a difference of less than 1% in the calculated degree day's value.

Table 1. Meter reading collection periods

Period	Start date	End Date
Period 1	25/10/2013	15/11/2013
Period 2	15/11/2013	20/12/2013
Period 3	20/12/2013	17/01/2014
Period 4	17/01/2014	14/02/2014
Period 5	14/02/2014	14/03/2014
Period 6	14/03/2014	04/04/2014
Period 7	04/04/2014	16/05/2014
Period 8	16/05/2014	13/06/2014

Figure 2 shows the energy consumption for the four flats according to the eight periods of data collection.

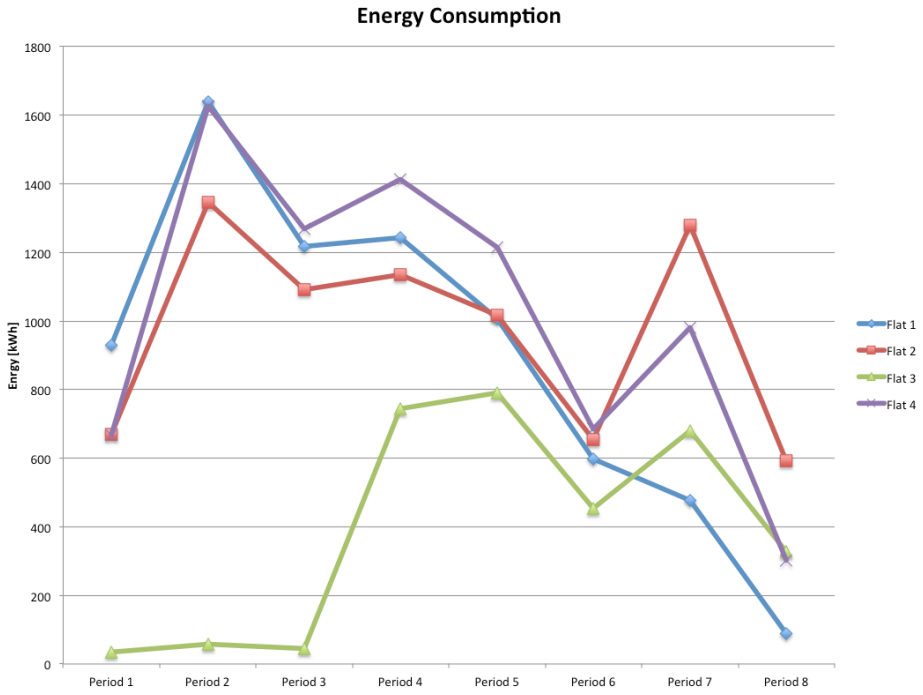

Figure 2. Energy consumption in kWh

According to Figure 2, flat 4 has the higher energy consumption, very closely follow by flat 1. Flat 3 is vacant for the first three periods of data collection. All the flats seem to reduce energy consumption as expected from approaching the spring and summer period. An increase in energy consumption is seen in period 7 during the April-May data collection.

Following the application of the energy index methodology, Figure 3 presents the normalised energy index values for the same four flats. Taking into account the normalised energy index allows us to understand the effect of weather and user behaviour on the energy consumption data presented in Figure 2.

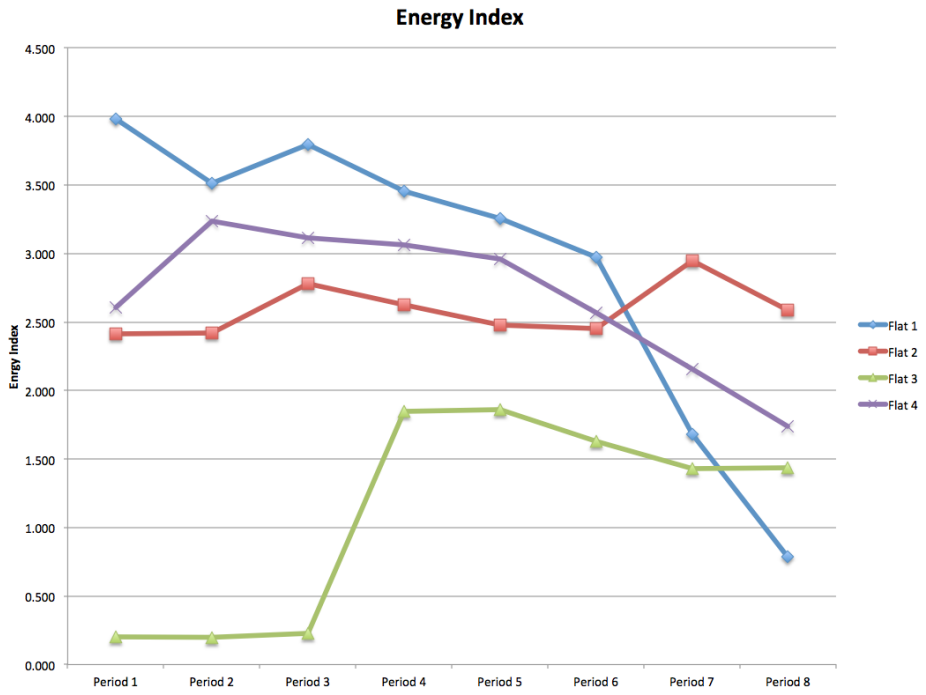

Figure 3. Energy index

It can be observed from Figure 3 that mostly all the flats were reducing energy consumption showing that the behaviour change strategy had been effective in changing the user approach to using energy. Contrary to the observation in Figure 2, flat 1 is the one with the higher energy use but at the same time, it is the flat achieving the highest energy reduction. The sudden energy consumption increase during period 7 was due to a period of cold weather as it is normalised in the energy index graph and actually three out of the four flats reduce their energy consumption during that period.

DISCUSSION

According to the energy consumption form Figure 2, it is expected that the energy consumption will be reducing as the spring-summer period is approaching. While by comparing the energy indexes presented in Figure 3, the energy indexes for every period can be compared to each other regardless of comparing winter months to summer months as the weather conditions are taking into account via the degree day. The observer of the energy index graph can assess if a property has being reducing energy consumption, changing energy use behaviour or if a newly install technology is effective in comparison with previous technologies. Furthermore, the use of the energy index will normalise the energy consumption data to appreciate the behaviour of occupants under heating or overheating their properties.

The use of the energy index methodology provides an easy to use value to be able to numerically or graphically compare the heating energy performance of different properties for non professional people and to make initial judgements on performance.

CONCLUSION

In conclusion, the use of the energy index methodology presented in this paper should allow energy professionals, tenants and social housing providers to monitor and evaluate the energy use across seasons and locations, the effectiveness of new retrofitted technology and/or the application of behaviour change strategies, while keeping a low budget approach to the data captured and analysis.

ACKNOLEDGEMENT

This research was funded by the European Regional Development Fund (ERDF) for the SmartLIFE Retrofit for Business project.

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INFRASTRUCTURE INTERACTIONS: THE BUILT ENVIRONMENT AND THE ELECTRICITY NETWORK

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Keywords: infrastructure, electricity, network, graph theory.

ABSTRACT

Electricity infrastructure is considered a critical infrastructure for the UK, vital to economic prosperity. Current and future changes to the built environment, and the way we use electricity, will increasingly impact on local electricity infrastructure. Understanding the interaction between the built environment and electricity infrastructure is the focus of this paper. Infrastructure can be seen as comprising the physical network, carriers, conversion and storage facilities as well as governance, management and control systems needed to meet functional and social objectives. Studies have considered the nature of interdependency between infrastructures to be geographical/spatial, physical, functional, cyber/informational, logical, mutual or shared elements, resources/inputs, policy, market, budgetary and economic. Infrastructure can be represented using graph, or network, models. A node, or vertex, represents a physical element of the infrastructure, connected to one another by edges. Graph models have been used previously to consider, for example, disruption to resource flows as a result of natural hazard damage, interdependencies between gas and electricity infrastructure, and vulnerability of electricity infrastructure. Building on this previous work, graph theory is used to analyse the interaction between the built environment and the electricity infrastructure when considering the impact of energy efficiency retrofit of domestic properties. These interactions are identified through interviews with energy efficiency retrofit stakeholders. These interactions are then represented in a simple graph theory model.

Walker, S. (2015) **Infrastructure interactions: the built environment and the electricity network** *In;* Gorse, C and Dastbaz, M (Eds) *International SEEDS Conference,* 17 – 18 September 2015, Leeds Beckett University UK, Sustainable Ecological Engineering Design for Society.

INTRODUCTION

The electricity sector worldwide is facing considerable pressure arising out of climate change issues (Eyre and Baruah, 2011), depletion of fossil fuels (Ipakchi and Albuyeh, 2009) and geo-political issues around the location of remaining fossil fuel reserves (Coaffee, 2008). Electricity systems are also facing technical issues of bi-directional power flows, increasing long-distance power flows and a growing contribution from fluctuating generation sources. There is a concern that these systems are vulnerable.

In order for the UK to meet targets for reduction in greenhouse gas emissions, future energy scenarios include:

- decarbonisation of heating energy demand through reduced use of gas-fired boilers and increased use of technologies such as solar thermal and air source heat pumps;
- decarbonisation of transport energy demand through reduced use of internal combustion engines and increased use of electric vehicles (EVs), plug-in hybrid electric vehicles (PHEVs) and fuel cell vehicles;
- increased use of small scale electricity generation technologies such as photovoltaics.

Changes to the way in which we light, power and heat our built environment infrastructure will lead to pressures on the electricity system. The purpose of the work presented here is to better understand the vulnerability of electricity systems within this context.

BACKGROUND

Robustness of electricity systems is seen as a problem requiring multidisciplinary study, with a key challenge to accurately model feedbacks for electricity systems (Brummitt et al., 2013), in order to better understand and avoid situations like that in India in July 2012, where more than 600 million people were left without power over two days (Esselborn). Even relatively small power failures have knock on effects due to the way our infrastructures are linked. For example, power failure at Clapham Junction, London in April 2015 left over 900 people stranded on trains for up to 5 hours.

Investigations of electricity system vulnerability have focussed on shocks to the system associated with weather risks, equipment failure, supply (fuel) failure and price shocks, and analysis has been primarily based on financial measures such as the value of lost load (Chaudry et al., 2009). Whilst N-1 remains the measure of security of supply for the UK electricity system, a recent report on the system's resilience (Bell et al., 2014) argues this N-1 approach does not reflect current and future challenges to the system. These challenges were described as (a) closure of aging assets; (b) decarbonisation of electricity to meet greenhouse gas reduction targets; (c) climate change impacts.

HM Treasury describe drivers of change for UK infrastructure as: obsolescence, globalisation and competition, growing demand and expectations, climate change, and interdependency (Treasury, 2010). They consider energy (along with digital communications, water and waste) to be a critical infrastructure which contributes to UK economic prosperity. For the UK, the management of critical infrastructure such as electricity is complicated by the challenge of dealing with infrastructure in private ownership. Operation and management of critical infrastructures involves a greater number of actors, with increased splintering of management and development responsibility, as a result of privatisation and restructuring policies (de Bruijne and van Eeten, 2007). The tension of infrastructure management is not only between public and private parties. Case studies of Boston (USA) and Cambridge (UK) indicated different government priorities at the national, regional and local level. This fragmented political geography resulted in (national and regional) economic development policies which were instigated to attract private investment in industry which were not appropriately funded to deliver on consequential increased (local) demands for infrastructure and service (Jonas et al., 2010).

Infrastructure can be seen as comprising the physical network, carriers, conversion and storage facilities as well as governance, management and control systems needed to meet function and social objectives (Herder et al., 2008). Studies have considered the nature of interdependency between infrastructures to be geographical/spatial, physical, functional, cyber/informational, logical, mutual or shared elements, resources/inputs, policy, market, budgetary and economic (Bloomfield et al., 2009, Kjølle et al., 2012, Holden et al., 2013, Ouyang et al., 2009b). Economic and political issues were found to be particular indicators of failure for mega projects, for example (Van de Graaf and Sovacool, 2014).

Much of the case study work on infrastructure interaction has been based on natural and man made disaster impacts. Studies of the performance of infrastructure after the World Trade Centre attacks indicated the importance of resilience, robustness and redundancy in recovery (Little, 2003). Cascade failure resulted from building damage, with a ruptured water main flooding underground train tunnels and impacting firefighting efforts. In addition, debris damaged nearby buildings which led to telecoms disruption over a wide area, including the New York stock exchange (O'Rourke, 2007).

The physical and social structures of the energy infrastructure can be represented using network, or graph, models. A node, or vertex, represents a physical element of the infrastructure, connected to one another by edges. A balance equation can be described for each node, comprising inflow, outflow, production, consumption, storage, and discharge components. A review of graph theory for electrical system analysis (Pagani and Aiello, 2013) indicated most analysis had been undertaken at high voltage levels, and that most studies were topological, with a small number also incorporating power flow models. Network models have been used to consider disruption to flows as a result of natural hazard damage (Holden et al., 2013), to investigate interdependencies between gas and electricity infrastructure (Ouyang et al., 2009a), and to investigate vulnerability of electricity infrastructure (Wang et al., 2012). Network models were also used to model communication, power and transport outage in New York, in order to evaluate temporary mitigation methods (Lee et al., 2007). Vulnerability analysis using a standard IEEE-300 electricity network and graph theory showed a similar disturbance size and impact for random node removal and targeted node removal (Sanchez, 2009). This is contradicted by (Pagani and Aiello, 2013), where topological analysis using graph theory showed connectivity of electrical systems was more severely affected by targeted node removal, compared with random node removal. Theoretical analysis of two interdependent networks using graph theory showed that node removal in one network led to percolation of further node removal in the two interconnected networks (Buldyrev et al., 2010). Graph theory has also been used model theoretical links between electricity, gas, heat and communications network components (de Durana et al., 2014, Derksen et al., 2012, Svendsen and Wolthusen, 2007).

These graph or network models are quite different to electricity network models which electrical engineers traditionally use to determine steady state and dynamic power flows. Traditional network power flow analysis can be used to analyse the consequences of a contingency or event on the electricity network. Combined with a probability of occurrence, the consequence of disconnected load with regards duration and extent can result in an estimate of risk analysis for the electricity sector. This method was used to determine the risk of loss of electricity supply for an ICT provider, shops, a train station and others for a case study area in Oslo (Kjølle et al., 2012).

GRAPH THEORY

Suppose we have two infrastructures, A and B. Components of each infrastructure can be represented by nodes (A1-A5, B1-B5 for example), and connections between components can be represented by edges. Figure 1 shows such a network. In three places, the two infrastructures are connected (A1-B1, A3-B3 and A5-B5). We can assume that these connections are necessary for

infrastructure B to operate. This is typical of electricity infrastructure A and water infrastructure B, where some nodes of the water infrastructure B require power for pumping, for example.

If infrastructure A experiences a failure or attack at node 3, node A3 and associated connections to infrastructure A and B are lost. This is shown in Figure 2. Because infrastructure A and B are connected, and assuming nodes of infrastructure B are inoperable if connection is lost to infrastructure A, node B3 and associated connections to infrastructure A and B are lost, as shown in Figure 3.

As a result of the failure/attack, infrastructure A is split into two clusters (A1-A2 and A4-A5) with no direct links between them. Infrastructure B is a larger single cluster (B1-B2-B4-B5). Graph theory can therefore be used to consider the number of clusters created and the connectivity of the graph in order to identify how sensitive particular infrastructure networks are to failure, attack and interdependence.

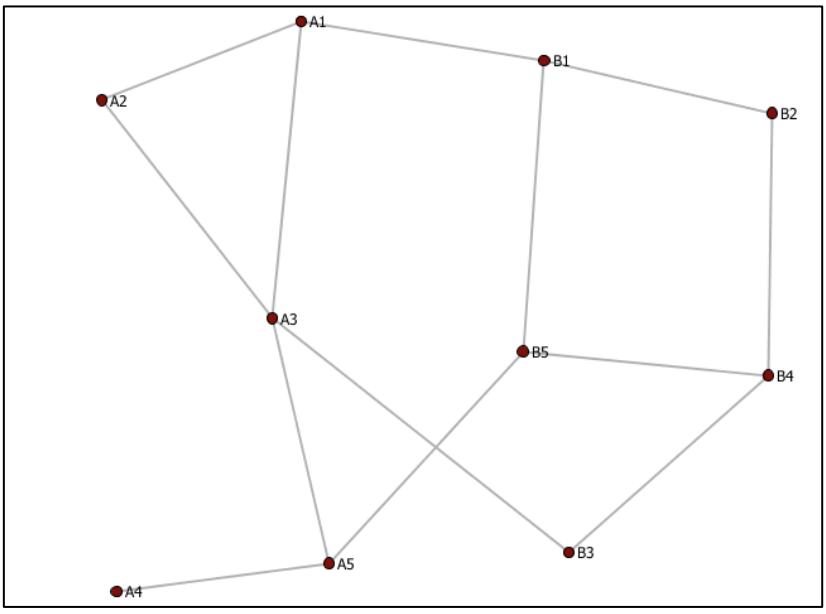

Figure 1. Graph of two infrastructures (A and B) with 5 nodes each.

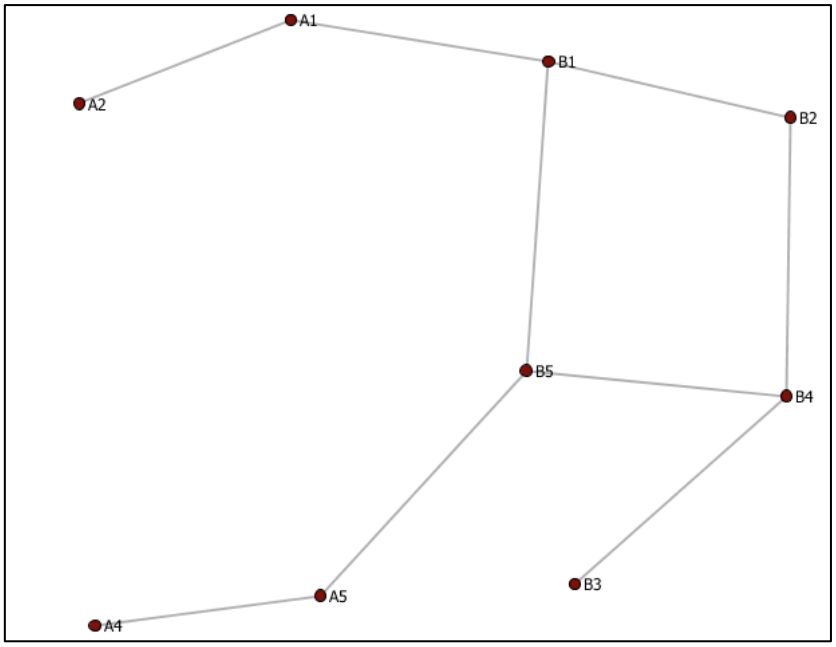

Figure 2. Initial failure or attack on infrastructure A at node 3, connections lost.

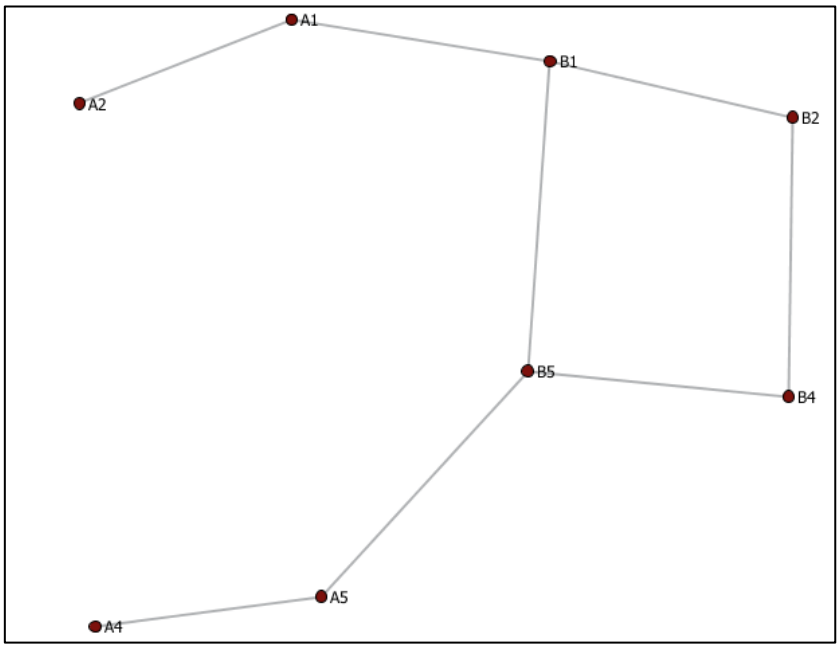

Figure 3. Infrastructure B at node 3 reliant on A3, and so also fails, connections lost.

Graph theory uses nodes and edges to represent networks. These can be physical networks, such as the electricity and water infrastructure example discussed above. The networks can also be of organisations or individuals, and the connections between them.

Graph theory shall be used as the method for analysis and visualisation of the organisations and relationships involved in housing retrofit. By graphical representation of retrofit relationships, critical organisations and critical relationships can be identified. Preliminary results of this stage of work are presented.

Further work will use graph theory to visualise the impact of failure of the electricity network for built environment professionals, to better understand the value of electricity networks in day to day operation of a city.

ANALYSIS OF INFRASTRUCTURE INTERACTIONS

Method

This work intends to visualise perceived organisational networks needed for effective housing retrofit, where the focus of the retrofit is on energy efficiency and carbon emissions saving.

The method is based on work which used graph theory to visualise mental maps of subjective realities of climate change (Reckien et al., 2012).

Interviews were conducted in the North East of England with three groups of stakeholders:

- Planners: Local Authority officers responsible for energy and climate change issues
- Social Housing Provider employees responsible for housing retrofit
- Goods and services providers involved in direct implementation of housing energy efficiency retrofit (i.e. members of the supply chain)

It can be expected that interviewees draw on previous experience to address interview questions, but that no temporal information can be drawn from the response. The response is entirely subjective since the purpose of the interview is to draw out the interviewee's perception of housing retrofit and infrastructure interaction.

Participants were asked a key question. "*Thinking about planning and implementing a retrofit programme for domestic properties in <area relevant to respondent>, which organisations would you deal with*?". The interviewee was asked to brainstorm a range of organisations, to put these onto post-it notes, and to arrange these on a sheet with connections drawn between them. The connections represent relationships, and interviewees were asked to assign a weighting to relationships using a scale of 0 to 10, where 0 indicated an unimportant relationship between organisation X and organisation Y and 10 indicated a very important relationship between organisation X and organisation Y. As a result, the respondents created a mind map of energy efficiency retrofit organisations and the relationships between them.

The data collection is partially completed. Results from the initial four interviews are analysed and presented below.

Data analysis

Interviewees may use different wording for the same ideas, making comparison between results difficult. Following a Grounded Theory approach, the organisations brainstormed as a result of the question shall be coded into a uniform terminology. This enables comparison between interviewee responses. Due to the small number of interviews held, the coding was undertaken in excel rather than a more specialist package like MaxQDA. The frequency of occurrence of organisations into the master group provides an indication of their perceived importance, as does the number of respondents (of the initial four) who identified organisations in the category. The resulting ten nodes in the master group are shown in

Table 28.

Table 28. Master group of nodes.

Node number	Node name	No. of respondents referring to this organisation	Frequency of occurrence
1	Planning/project management role	4	6
2	Internal specialist expertise	3	9
3	Installing organisation	4	5
4	Green Deal organisation	3	4
5	Energy company	4	4
6	Funding organisation	3	5
7	Other projects	3	4
8	External specialist expertise	4	13
9	Technologies supplier	3	3
10	Owner/tenant relations	3	7

Not all respondents listed organisations in all ten categories. However, recoding the responses using these ten categories led to simplification of the network of organisations, for all respondents. In two cases, 17 organisations were simplified to 10, for one respondent 17 organisations were simplified to 8, and for a fourth respondent 9 organisations were simplified to 7. An example mind map for one respondent is shown in Figure 54, showing an initial 17 organisations (nodes) and 33 relationships (edges).

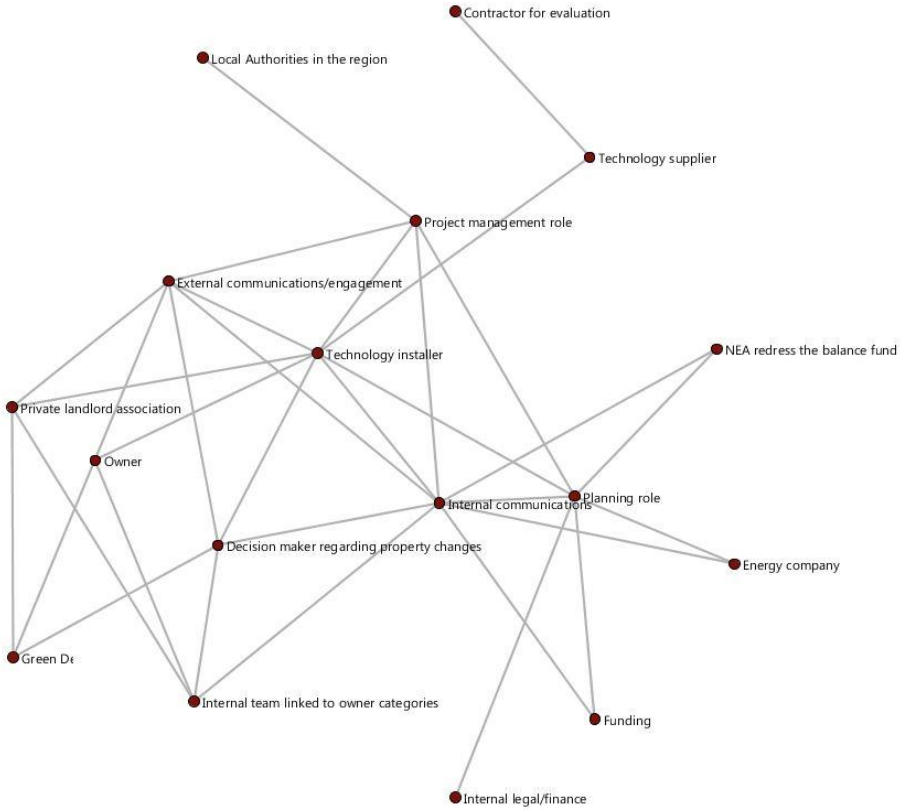

Figure 54. Respondent 3's original mind map.

Respondents were asked to identify relationships between organisations, and give a weighting to the strength of the relationship. Once the number of organisations had been simplified to ten categories, the relationships were recoded. Where a relationship was identified between two organisations which had been recoded into the same category (i.e. planning role and project management role), then the relationship was removed. Where a relationship between two categories was duplicated, then one relationship was retained with a strength which was the average of all duplicates. In this way, the number of relationships in the mind map was simplified for all respondents. This is shown in Table 29. A total of 31 unique relationships between the 10 organisations were identified by the 4 respondents. The 31 edges are described in Table 30, where the edge label refers to the starting node and ending node for that edge. An example for respondent 3 is shown in Figure 55, showing a simplified mind map of 10 organisations (nodes) and 17 relationships (edges).

Table 29. Reduction in the number of organisations and relationships resulting from data analysis.

Respondent	Pre-analysis number of organisations (nodes)	Post-analysis number of organisations (nodes)	Pre-analysis number of relationships (edges)	Post-analysis number of relationships (edges)
1	17	8	30	16
2	9	7	10	7
3	17	10	33	17
4	17	10	27	18

Table 30. Master group of edges.

Edge number	Edge weight	Edge label	Edge number	Edge weight	Edge label	Edge number	Edge weight	Edge label
1	8.67	1-2	11	9.00	2-4	21	8.00	3-10
2	9.80	1-3	12	3.00	2-5	22	7.50	4-5
3	8.50	1-4	13	3.00	2-6	23	9.00	4-7
4	4.25	1-5	14	9.00	2-8	24	9.50	4-9
5	7.67	1-6	15	8.00	2-10	25	7.13	4-10
6	5.60	1-7	16	5.00	3-5	26	4.00	5-8
7	4.42	1-8	17	7.00	3-6	27	6.00	5-9
8	5.00	1-9	18	9.00	3-7	28	6.00	6-9
9	7.50	1-10	19	8.00	3-8	29	10.00	7-8
10	8.50	2-3	20	9.17	3-9	30	5.00	8-9
						31	6.50	8-10

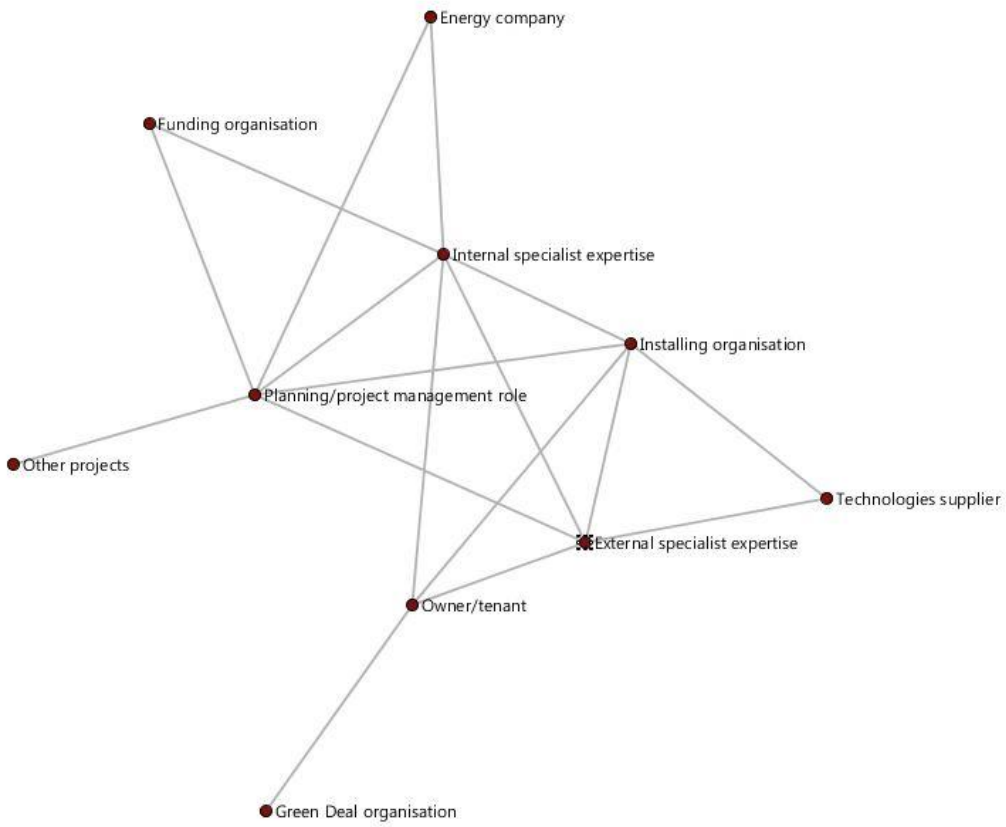

Figure 55. Respondent 3's simplified mind map.

In order to visualise the mind maps from the results, Network Workbench (NBS Team, 2006) was used. Nodes represented organisations, with a size which represents the frequency of occurrence for all respondents. Edges represent connections and relationships, with a label which represents the mean weighting across all respondents. The created mental map, in the form of a weighted graph,

can then be analysed using descriptors such as the degree of nodes and betweenness of nodes. This analysis will enable a robust evaluation of key concepts and organisations in the mind maps created. Based on the initial interviews, a mind map is shown in Figure 56. A further simplification of the mind map was undertaken, to remove all edges with a value below 7 (i.e. to remove the less important relationships). This mind map with reduced edges is shown in Figure 57. The degree and betweenness for the nodes is shown in Table 31. This analysis indicates that the key organisations which respondents considered most crucial to housing retrofit were the planning/project management role, the internal specialist expertise, the installing organisation, the Green Deal organisation and the external expertise.

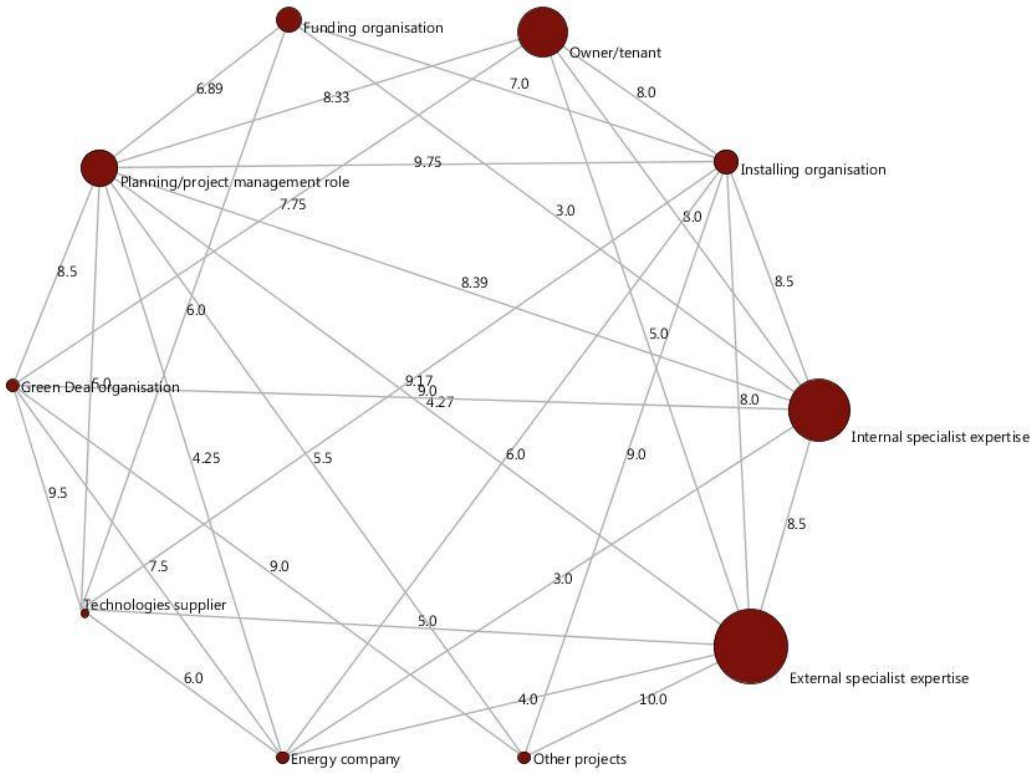

Figure 56. Merged mind map showing 10 nodes and 31 edges (weightings of edges labelled).

Table 31. Degree and betweenness of nodes, will all edges and with reduced edges.

Node number	Node name	Degree (all edges)	Betweenness (all edges)	Degree (reduced edges)	Betweenness (reduced edges)
1	Planning/project management role	9	7.233	4	1.6
2	Internal specialist expertise	7	3.399	5	5.6
3	Installing organisation	8	5.899	7	26.666
4	Green Deal organisation	6	3.233	6	22.666
5	Energy company	6	0.999	1	0
6	Funding organisation	4	0.333	1	0
7	Other projects	4	0.666	3	3.599
8	External specialist expertise	7	3.233	3	0.666
9	Technologies supplier	6	2.333	2	1.6
10	Owner/tenant relations	5	0.666	4	1.6

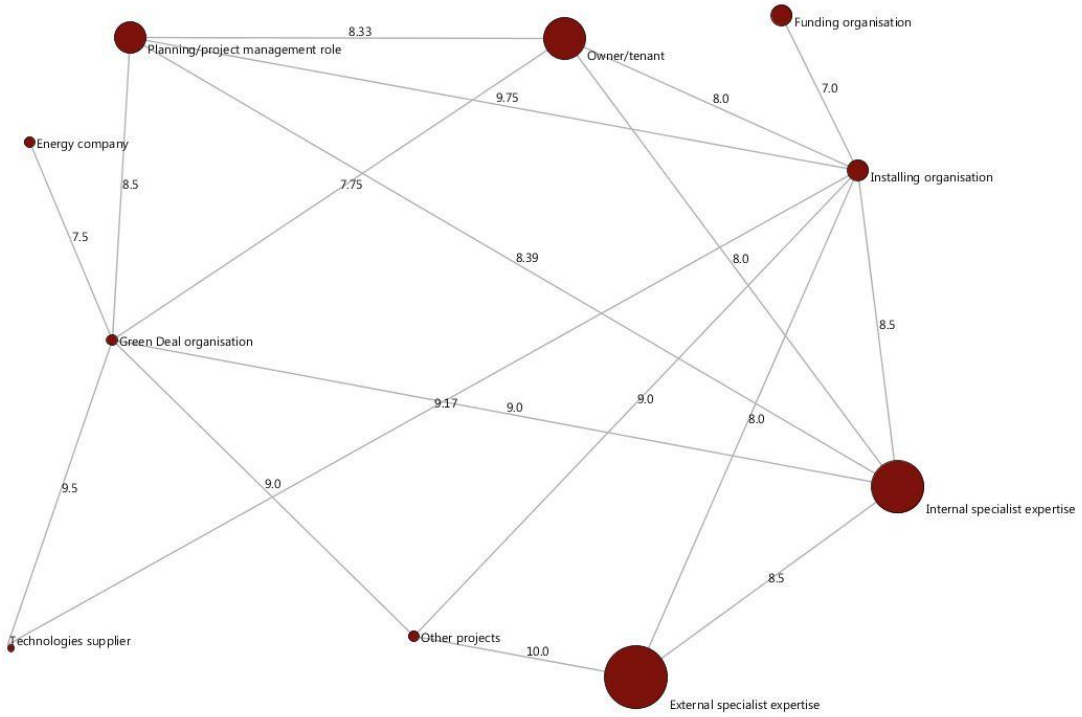

Figure 57. Merged mind map with reduced edges.

Housing retrofit is seen as vital to the delivery of reductions in CO_2 emissions for the UK. As described in the introduction, in order for the UK to meet targets for reduction in greenhouse gas emissions, future energy scenarios include:

- decarbonisation of heating energy demand through reduced use of gas-fired boilers and increased use of technologies such as solar thermal and air source heat pumps;
- decarbonisation of transport energy demand through reduced use of internal combustion engines and increased use of electric vehicles (EVs), plug-in hybrid electric vehicles (PHEVs) and fuel cell vehicles;
- increased use of small scale electricity generation technologies such as photovoltaics.

These proposed changes will affect the way in which we use energy in the home, and in particular the way in which we use electricity.

The results shown here indicate that the energy company was perceived as having a relatively minor role to play in retrofit. The energy company had a relatively low level of degree and betweenness. Once less critical relationships were removed, the energy company only had a key relationship with the Green Deal organisation.

SUMMARY

Using graph theory, relationships between key organisations involved in energy efficiency housing retrofits were investigated. The method for data gathering was face-to-face interviews with three groups of built environment professionals, and further data gathering is ongoing. Preliminary results were represented using graph theory, for visual and analytical analysis of perceptions of organisations and the importance of the relationships between them. Results showed that key organisations, which respondents consider most crucial to housing retrofit, are the planning/project management role, the internal specialist expertise, the installing organisation, the Green Deal organisation and the external expertise. The energy company was perceived as having a relatively

minor role to play in retrofit. If the energy company remains peripheral to housing retrofit moving forward, then energy infrastructure providers in particular will find it more difficult to manage the infrastructure in a proactive, rather than reactive, way.

An improved understanding of organisations and relationships involved in energy efficiency housing retrofit can then be used to investigate, for those organisations which are more central to the process, why they are perceived as such. It can also be a tool to identify the organisations which are most appropriate for targeted training and information, to ensure delivery of targets such as carbon reduction, and to maximise uptake of new technologies such as air source heat pumps.

Future work shall involve application of the network model to investigate interaction impacts of future scenarios for built environment electricity use.

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Change

THE INFLUENCE OF LANDSCAPE ARCHITECTURE ON LANDSCAPE CONSTRUCTION HEALTH AND SAFETY (H&S)

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Keywords: Construction, Health and Safety, Influence, Landscape Architects.

Abstract

The influence of design on construction H&S is well documented in literature, as the concept and practice of 'designing for construction H&S'. However, there is a paucity of literature relative to landscape construction H&S and none relative to the influence of landscape architecture on landscape construction H&S. Furthermore, no research has been conducted relative to the aforementioned, despite landscape construction entailing exposure to numerous hazards and risks.

Given the aforementioned, a quantitative study was conducted among members of the Institute of Landscape Architects South Africa (ILASA), the objectives of the study being to determine, among other purposes, the perceptions and practices of landscape architects relative to landscape construction H&S.

The salient findings include: site handover, site meetings, and site inspections / discussions predominate in terms of the frequency landscape construction H&S is considered / referred to on various occasions; method of fixing predominates in terms of the frequency construction H&S is considered / referred to relative to design related aspects; position of components predominates in terms of the extent design related aspects impact on landscape construction H&S; tertiary landscape architecture education addresses landscape construction H&S to a minor extent; respondents rate their knowledge of landscape construction H&S and 'design for landscape construction H&S' skills as poor, and experience predominates in terms of respondents' acquisition of knowledge of landscape construction H&S.

Conclusions include: landscape construction H&S is considered / referred to on various occasions and relative to design related aspects to a degree; there is a degree of appreciation in terms of the extent design related aspects impact on landscape construction H&S, and landscape architectural programmes address landscape construction H&S to a limited extent.

Recommendations include: tertiary education landscape architectural programmes should include appropriate 'designing for landscape construction H&S' modules as a component of a subject – probably design. The ILASA should develop practice notes relative to landscape construction H&S, and the South African Council for the Landscape Architectural Profession (SACLAP) should include construction H&S in their six work stages (IoW) in a more comprehensive manner.

Smallwood, J. and Kajimo-Shakantu, K. (2015) **The influence of landscape architecture on landscape construction Health and Safety** *In;* Gorse, C and Dastbaz, M (Eds) *International SEEDS Conference,* 17 – 18 September 2015, Leeds Beckett University UK, Sustainable Ecological Engineering Design for Society.

INTRODUCTION

Construction is a hazardous industry in which workers are often exposed to a variety of hazards and risks due to the nature of the work involved. Unless properly managed, the risks often impact negatively on the H&S of workers resulting in accidents, fatalities, other injuries, and illnesses as highlighted by various studies (Smallwood, 2007; Carter and Smith, 2006; Becker, Hecker and Gambetese, 2003). Historically, construction workers have experienced higher rates of deaths and time off from work due to site related injuries and illnesses than most other industries (Carter and Smith, 2006; Haslam, Hide, Gibb, Gyi, Pavitt, Atinkinson and Duff, 2005; Suraji, Duff and Peckitt, 2001). The poor construction H&S record is of great concern to the construction industry (Carter and Smith, 2006; Haslam *et al.*, 2005).

In recent years, the industry has shown an increased interest in the importance of promoting healthy and safe working conditions and practices. A number of studies have advocated for the need to address H&S upstream prior to commencement of construction as a desirable means to further improve the H&S of construction workers (Smallwood, 2007; Haslam et al., 2005; Becker et al., 2003; Gambatese *et al.*, 2005). However, despite the growing evidence of actual and potential benefits of H&S interventions at the design stage, the challenge remains that most designers still rarely perceive the concept of 'designing for H&S' as part of their standard practice (Haslam *et al.*, 2005). Moreover, studies relative to the influence of designers often tend to target end-users, whilst overlooking particularly the H&S of the workers who actually construct the facility or structure (Becker *et al.*, 2003). The problem is compounded by the lack of inclusion of other design disciplines in the studies of previous researchers who have addressed construction worker H&S, but with a bias to architectural and engineering disciplines and to some extent general contractors. Consequently, little is known about the influence of other designers in particular, landscape architectural designers, including their level of knowledge and application of construction H&S principles. It is this gap in the literature that gave impetus to the present study, which seeks to provide a better understanding of the perceptions and design practices of landscape architectural designers within the South African context with a view to contributing to the improvement of construction H&S interventions. Furthermore, landscape construction injury statistics indicate that the sector presents challenges in terms of injury statistics. Therefore, the objectives of the study were to determine the:

- frequency at which landscape architectural practices consider H&S on various occasions and relative to various design related aspects;
- extent to which various design related aspects impact on construction H&S;
- means by which landscape construction H&S knowledge is gained, and
- landscape architects' rating of their knowledge of landscape construction H&S and 'design for landscape construction H&S' skills.

LITERATURE REVIEW

Statistics

Table 1 provides an overview of landscape gardening injury statistics for the years 2008 to 2014 (Federated Employers Mutual, 2015). The mean accident frequency rate of 1.71 indicates that 1.71 per 100 workers experience a disabling injury, which results in a loss of a shift or more after the day of the injury. The highest is 2.04 relative to 2010. The mean for all classes is 3.13, the highest being 3.86 relative to 2008. Then, the fatality rate for the year 2010 equates to 25.8 per 100 000 workers [(100 000 / 7 755) x 2], which is high.

Table 1, Landscape gardening injury statistics for the years 2008 to 2014

Year	Accident frequency rate	Employees (No.)	Accidents (No.)	Fatal accidents (No.)
2008	1.83	8 898	163	0
2009	1.80	9 025	162	2
2010	2.04	7 755	158	2
2011	1.57	8 010	126	0
2012	1.66	8 749	145	0
2013	1.61	8 466	136	2
2014	1.44	8 430	121	0
Mean	1.71			

Although Integrity Insurance (2013) does not cite statistics, they do state that the Occupational Safety and Health Administration (OSHA) in the United States of America (USA) has identified landscape and horticultural services, which include, *inter alia*, landscape construction, as one of the most hazardous industries in the USA. Potential hazards include: motor vehicle and other equipment accidents; ergonomic injuries such as back strains; exposure to noise, heat, cold, chemicals, and insects; amputations; slips, trips and falls; eye injuries, and electrocutions.

The Role of Designers in Construction H&S

All designers are in a unique position to reduce the H&S risks that arise from construction work as they are responsible for critical aspects such as the concept design, detailed design, general design, and working drawings (Hinze, 2006). Designers' decisions and assumptions can have a negative or positive impact on the performance of construction H&S because they directly influence the choice of materials and finishes through their specifications as well as dictating the construction methods (Smallwood, 2011; Haslam *et al.*, 2005). Other design aspects which can affect construction site H&S include the content, size, mass, edge, and surface of materials, position of components, and surface area of components (Smallwood, 2000a).

Currently, the role of designers in designing to eliminate or avoid hazards prior to exposure on the construction site is not optimised. For example, if the documents prepared by a designer are not easy to understand and interpret or the materials specified are too large, cumbersome, heavy or unsafe, not only will this make the project difficult to build, but also increase the risk of workers getting injured or ill during construction (Smallwood, 2011; Gambetese *et al.,* 2005). A design which omits to locate the potential hazards increases the risk of the workers getting injured. Similarly, a design which specifies the use of a heavy material whose method of handling requires repetitive awkward lifting or static postures or buttering will increase the risk of musculoskeletal injuries (Carter and Smith, 2006; Smallwood, 2000a). Becker *et al.,* (2003) suggest that the use of ergonomic redesign to reduce risk factors for work-related musculoskeletal disorders is a prominent application of the concept of designing for H&S. However, they note that that construction workers comprise one group of employees that has previously received limited benefits from H&S through design.

Various studies contend that by dealing with H&S in a project's design, hazards can be eliminated or reduced more effectively during construction and thereby enhancing the H&S of workers (Driscoll, Harrison, Bradley and Newson, 2008; Gambetese *et al.,* 2005; Gambetese, 2005; Smallwood, 2004;

Becker *et al.,* 2003; Haslam *et al*., 2005). In addition to protecting workers, the benefits of incorporating H&S considerations in the early design stages of a project outweigh the costs of expensive redesigns once construction starts (Gambetese *et al.,* 2005). Therefore, construction H&S should be an integral part of the design process.

To minimize risks to workers, designers should be able to identify the hazards and assess the risks that arise from a design and take action to eliminate the hazards as reasonably practicable as possible, minimize risks and make information about the design associated risks known to other parties (HSE, 2007a; 2007b). It is important for designers to be able to understand how a design affects the H&S of the workers who will construct and / or maintain the facility or structure (Smallwood, 2011; Gambatese, Weinstein, and Hecker, 2004). Taking construction H&S considerations into account requires the designer to avoid designs which leave sharp dangerous corners exposed or require manual manoeuvring of heavy building materials or processes which cannot be undertaken by any other method except manual breaking (HSE, 2007a; 2007b). In short, the use of dangerous procedures or hazardous materials should be avoided.

Relating Architectural Landscape Designing to Landscape Construction H&S

Although traditionally landscape architectural designers are not considered as 'primary' designers relative to architects, structural engineers, civil engineers, mechanical engineers and electrical engineers, the principles of construction H&S discussed in previous sections apply to them equally.

In terms of legislation, in the South Africa Construction Regulations 2014 (Republic of South Africa, 2014), the definitions of designer are broad and include landscape architects. Then in terms of the South African Council for the Landscape Architectural Profession (SACLAP), the related identity of work (IOW) only makes three references to construction H&S. Firstly in terms of the benefits of the IOW, better implementation of H&S regulations is referred to. Secondly, advising the client regarding the requirement to appoint an H&S consultant where necessary. Thirdly, monitoring, where necessary, the compliance of the landscape contractor to the H&S consultants.

All designers, landscape architects included, do influence the H&S of construction workers through their designs and specifications which affect the work processes and material selection. Therefore, they ought to be able to eliminate hazardous products, processes, and procedures from a project by making design decisions that take into account construction H&S considerations (HSE, 2007a; 2007b).

Landscaping H&S related literature for example, indicates that for highways and roads, paved shoulders and extended vegetation clear zones are generally assumed to represent H&S related design elements for the end-users (Mok, Landphair and Naderi, 2005). Ironically, for construction workers, the process of paving the shoulder or planting vegetation can actually present many hazards and unsafe working conditions. These may include awkward and restrictive working postures such as kneeling, bending and twisting, or exposure to thorns or pesticides and other toxic products. Therefore, considering that landscape improvements must avoid the creation of unhealthy and unsafe conditions, this paper argues that landscape architectural designers should equally consider the effects of (poor) design on the H&S of construction workers not only the end-user. To further illustrate, a designer could specify materials or processes that do not create dust or involve tedious manual breaking methods (HSE, 2012). Landscape architectural designers should also consider the properties of the material they are specifying and how it is likely to be used during construction and maintenance.

It is important for a landscape architectural designer to, inter alia, understand the important role of vegetation in landscaping and provide detailed information such as type, texture, and position of vegetation and guidelines on methods of planting to support healthier and safer worker performance. The designer should avoid specifying processes which will require the spraying of harmful substances

on the plants and site. Clearly, determining the construction H&S aspects affected by design and vice versa should be an integral part of an architectural landscape designer.

Studies that have investigated the effects of landscape variables on pedestrian health, road side H&S and driver safety fundamentally show that good designs translate into improvements in landscape which decreases accidents (Naderi, 2003; Mok, Landphair and Naderi, 2005; Bahar and Naderi, 1997). However, the studies have generally not extended to construction H&S. Consequently, there is limited documentation and understanding of how landscape architectural designers perceive their role in construction H&S, the extent of their knowledge of H&S and the considerations of construction H&S in their designs. It is the goal of this study to therefore fill this gap by investigating these issues within the South African context.

Despite the fact that design affects construction H&S, unfortunately research shows that in practice, most designers lack construction H&S education and training (Haslam *et al.*, 2005). This is underscored by Gambetese *et al.*, 2005 who argue that although designing for H&S requires integrating construction processes' knowledge into the design, many designers lack formal training in this area and on issues of construction worker H&S and how to design for H&S.

RESEARCH

Research review and methodology

A descriptive study was adopted in the form of a survey of the extant literature. Although there is a paucity of literature related to the subject area namely landscape architecture and landscape construction H&S, there is a substantial amount relative to 'designing for construction H&S'. This resulted in, inter alia, the need to deduce the occasions and the design related aspects when landscape architects consider landscape construction H&S, and the extent to which the design related aspects impact on landscape construction H&S, based upon previous research such as 'The influence of architectural designers on construction H&S' (Smallwood, 2007b) and 'The influence of architectural designers on construction ergonomics' (Smallwood, 2008). Then in terms of the empirical component of the study the quantitative method was adopted due to the nature and quantity of data required. For most fields of research it will be important to state the rationale for adopting a research approach or method of enquiry.

Research Method

A questionnaire consisting of primarily closed end five point Likert scale type questions – 10 / 13 questions were closed end. The questionnaire, accompanied by a covering letter explaining the rationale for the study, and inter alia, assuring of anonymity was forwarded per e-mail to 139 members of the ILASA. 21 Responses were included in the analysis of the data, which equates to a net response rate of 15.1%. A follow up e-mail was sent after a few weeks in an endeavour to enhance the response rate, but with limited success. Possible reasons for the response rate include the subject relative to the practice of landscape architectural design, namely landscape construction H&S.

Descriptive statistics in the form of frequencies and a measure of central tendency in the form of a mean score (MS) were computed in order to present the findings of the empirical study. The MS is based upon a weighting of the responses to the five point Likert scale type questions, and ranges from a minimum score of 1.00 to a maximum of 5.00. The MS thus enables the range of percentage responses to be interpreted, and also the occasions and aspects to be ranked. Due to the number of responses, inferential statistical analysis was not possible.

Research results

Table 2 presents the frequency at which landscape architects consider / refer to landscape construction H&S relative to fourteen occasions, in terms of a frequency range, never to always, and a MS ranging between 1.00 and 5.00. It is notable that 9 / 14 (64.3%) MSs are above the midpoint of 3.00, which indicates consideration of / reference to landscape construction H&S relative to these occasions can be deemed to occur.

It is notable that no occasions are > 4.20 ≤ 5.00 – between often to always / always, however, 5 / 14 (35.7%) are > 3.40 ≤ 4.20 – between sometimes to often / often. It is notable that the top three ranked occasions are downstream during Stage 5, namely site handover, site meetings, and site inspections / discussions. Then fourth ranked preparing project documentation, and pre-tender meeting are Stage 4 occasions. Those occasions ranked sixth to twelfth (50%) have MSs > 2.60 ≤ 3.40 – between rarely to sometimes / sometimes. Evaluating tenders, and pre-qualifying contractors are Stage 4 occasions, whereas constructability reviews, detailed design, working drawings, client meetings, and design coordination meetings are Stage 3 occasions. Client meetings also occur during Stage 1 and 2. Deliberating project duration and concept (design) have MSs > 1.80 ≤ 2.60, and thus the frequency is between never to rarely / rarely. The former occurs during Stages 1, 2, 3 and 4. The latter is a Stage 2 occasion.

Table 2, Frequency of consideration / reference to landscape construction H&S on various occasions.

Occasion	Response (%)						MS	Rank
	Unsure	Never	Rarely	Sometimes	Often	Always		
Site handover	9.5	0.0	9.5	9.5	28.6	42.9	4.16	1
Site meetings	4.8	0.0	4.8	14.3	38.1	38.1	4.15	2
Site inspections / discussions	0.0	0.0	4.8	14.3	42.9	38.1	4.14	3
Preparing project documentation	0.0	9.5	0.0	23.8	38.1	28.6	3.76	4
Pre-tender meeting	4.8	0.0	23.8	19.0	23.8	28.6	3.60	5
Evaluating tenders	9.5	4.8	14.3	33.3	23.8	14.3	3.32	6
Constructability reviews	9.5	4.8	23.8	23.8	28.6	9.5	3.16	7
Pre-qualifying contractors	4.8	9.5	23.8	23.8	23.8	14.3	3.10	8
Detailed design	0.0	14.3	14.3	33.3	28.6	9.5	3.05	9
Working drawings	0.0	19.0	14.3	38.1	14.3	14.3	2.90	10
Client meetings	0.0	0.0	52.4	19.0	19.0	9.5	2.86	11
Design coordination meetings	0.0	9.5	23.8	52.4	9.5	4.8	2.76	12
Deliberating project duration	4.8	23.8	23.8	28.6	14.3	4.8	2.50	13
Concept (design)	0.0	9.5	57.1	14.3	19.0	0.0	2.43	14

Table 3 presents the frequency at which landscape architects consider / refer to landscape construction H&S relative to nineteen design related aspects, in terms of a frequency range, never to always, and a MS ranging between 1.00 and 5.00. It is notable that only five (25%) of the nineteen MSs are above the midpoint of 3.00, which indicates consideration of / reference to H&S relative to these design related aspects can be deemed to be prevalent.

It is notable that no design related aspects MSs are > 4.20 ≤ 5.00 – between often to always / always, and then only one MS is > 3.40 ≤ 4.20 – between sometimes to often / often, namely method of fixing. The MSs of those design related aspects ranked second to eleventh are > 2.60 ≤ 3.40 – between rarely to sometimes / sometimes. The MSs of those design related aspects ranked twelfth to nineteenth are MSs > 1.80 ≤ 2.60, and thus the frequency is between never to rarely / rarely. In reality all the design related aspects affect landscape construction H&S.

Table 3, Frequency at which landscape architects consider / refer to landscape construction H&S relative to design related aspects.

Design related aspect	Response (%)						MS	Rank
	Unsure	Never	Rarely	Sometimes	Often	Always		
Method of fixing	4.8	4.8	9.5	38.1	14.3	28.6	3.55	1
Edge of materials	4.8	9.5	19.0	14.3	33.3	19.0	3.35	2
Position of components	0.0	4.8	19.0	28.6	33.3	14.3	3.33	3
Specifications e.g. hard surfaces	0.0	9.5	9.5	33.3	38.1	9.5	3.29	4
Surface area of materials	23.8	9.5	14.3	19.0	19.0	14.3	3.19	5
Position of vegetation / features	0.0	9.5	28.6	28.6	23.8	9.5	2.95	6
Details	0.0	14.3	14.3	47.6	9.5	14.3	2.95	7
Finishes	4.8	9.5	33.3	19.0	19.0	14.3	2.95	8
Content of material	23.8	14.3	19.0	9.5	28.6	4.8	2.88	9
Mass of materials	19.0	9.5	28.6	14.3	23.8	4.8	2.82	10
Mass of vegetation / features	4.8	9.5	33.3	23.8	23.8	4.8	2.80	11
Method of planting	4.8	19.0	38.1	14.3	9.5	14.3	2.60	12
Design (general)	4.8	9.5	47.6	23.8	4.8	9.5	2.55	13
Texture of materials	10.0	15.0	25.0	40.0	10.0	0.0	2.50	14
Schedule	14.3	23.8	23.8	19.0	9.5	9.5	2.50	15
Plan layout	0.0	9.5	52.4	23.8	9.5	4.8	2.48	16
Content of vegetation	9.5	14.3	38.1	19.0	19.0	0.0	2.47	17
Elevations	0.0	14.3	52.4	19.0	9.5	4.8	2.38	18
Texture of vegetation / features	9.5	19.0	38.1	23.8	9.5	0.0	2.26	19

Table 4 presents the extent to which design related aspects impact on landscape construction H&S in terms of a frequency range 1 (minor) to 5 (major), and a MS ranging between 1.00 and 5.00. It is notable that only five (25%) of the nineteen MSs are above the midpoint of 3.00, which indicates the extent is deemed major as opposed to minor.

It is notable that no design related aspects MSs are > 4.20 ≤ 5.00 – between often to always / always, and then only one MS is > 3.40 ≤ 4.20 – between sometimes to often / often, namely position of components. The MSs of those design related aspects ranked second to tenth are > 2.60 ≤ 3.40 – between rarely to sometimes / sometimes. The MSs of those design related aspects ranked eleventh to nineteenth are MSs > 1.80 ≤ 2.60, and thus the frequency is between never to rarely / rarely. In reality all the design related aspects affect landscape construction H&S.

Table 4, Extent to which design related aspects impact on landscape construction H&S.

Design related aspect	Response (%)						MS	Rank
	Un sure	Minor …….Major						
		1	2	3	4	5		
Position of components	0.0	4.8	9.5	33.3	23.8	28.6	3.62	1
Method of fixing	0.0	19.0	4.8	28.6	28.6	19.0	3.24	2
Content of material	19.0	9.5	14.3	19.0	23.8	14.3	3.24	3
Specifications e.g. hard surfaces	0.0	14.3	9.5	28.6	38.1	9.5	3.19	4
Details	0.0	14.3	28.6	14.3	19.0	23.8	3.10	5
Edge of materials	4.8	14.3	19.0	28.6	23.8	9.5	2.95	6
Position of vegetation / features	0.0	9.5	33.3	33.3	9.5	14.3	2.86	7
Design (general)	4.8	14.3	28.6	28.6	4.8	19.0	2.85	8
Finishes	4.8	19.0	19.0	28.6	28.6	0.0	2.70	9
Mass of materials	14.3	23.8	19.0	14.3	19.0	9.5	2.67	10
Plan layout	9.5	9.5	42.9	23.8	4.8	9.5	2.58	11
Elevations	9.5	14.3	38.1	23.8	4.8	9.5	2.53	12
Method of planting	4.8	28.6	19.0	28.6	9.5	9.5	2.50	13
Schedule	9.5	19.0	23.8	33.3	14.3	0.0	2.47	14
Texture of materials	4.8	23.8	23.8	33.3	9.5	4.8	2.45	15
Surface area of materials	19.0	19.0	19.0	33.3	9.5	0.0	2.41	16
Mass of vegetation / features	4.8	28.6	33.3	14.3	9.5	9.5	2.35	17
Texture of vegetation / features	14.3	28.6	23.8	19.0	9.5	4.8	2.28	18
Content of vegetation	9.5	28.6	28.6	23.8	4.8	4.8	2.21	19

Table 4 provides a comparison of the frequency at which landscape architects consider / refer to landscape construction H&S relative to design related aspects and the impact of the aspects on landscape construction H&S. The 'impact' MSs are only greater than the 'consider' MSs in 7 / 19 (36.8%) of cases, yet lower in 12 / 19 (63.2%) cases. In terms of 'impact' being greater than 'consider' the greatest difference is relative to content of material (0.36), followed by design (general) (0.30), and position of components (0.29). In terms of 'consider' being greater than 'impact' the greatest difference is relative to surface area of materials (-0.78), followed by mass of vegetation / features (-0.45), and edge of materials (-0.40).

Table 5, Comparison of the frequency at which landscape architects consider / refer to landscape construction H&S relative to design related aspects and the impact of the aspects on landscape construction H&S.

Design related aspect	Consider		Impact		Variance
	MS	Rank	MS	Rank	
Position of components	3.33	3	3.62	1	0.29
Method of fixing	3.55	1	3.24	2	(0.31)
Content of material	2.88	9	3.24	3	0.36
Specifications e.g. hard surfaces	3.29	4	3.19	4	(0.10)
Details	2.95	7	3.10	5	0.15
Edge of materials	3.35	2	2.95	6	(0.40)
Position of vegetation / features	2.95	6	2.86	7	(0.09)
Design (general)	2.55	13	2.85	8	0.30
Finishes	2.95	8	2.70	9	(0.25)
Mass of materials	2.82	10	2.67	10	(0.15)
Plan layout	2.48	16	2.58	11	0.10
Elevations	2.38	18	2.53	12	0.15
Method of planting	2.60	12	2.50	13	(0.10)
Schedule	2.50	15	2.47	14	(0.03)
Texture of materials	2.50	14	2.45	15	(0.05)
Surface area of materials	3.19	5	2.41	16	(0.78)
Mass of vegetation / features	2.80	11	2.35	17	(0.45)
Texture of vegetation / features	2.26	19	2.28	18	0.02
Content of vegetation	2.47	17	2.21	19	(0.26)

Table 6 indicates the extent tertiary landscape architecture education addresses landscape construction H&S in terms of percentage responses to a scale of 1 (minor) to 5 (major) and a MS between 1.00 and 5.00. The MS of 2.15 indicates the extent is between a minor extent to near minor / near minor extent as the MS is > 1.80 ≤ 2.60. Furthermore, in terms of respondents' source of knowledge of landscape construction H&S, only 23.8% identified tertiary education whereas 95.2% identified experience.

Table 6, Extent tertiary landscape architecture education addresses landscape construction H&S.

Response (%)						MS
Un	Minor …….Major					
sure	1	2	3	4	5	
27.8	22.2	27.8	11.1	11.1	0.0	2.15

Table 7 indicates the respondents' rating of their knowledge of landscape construction H&S and 'design for landscape construction H&S' skills in terms of percentage responses to a scale of 1 (limited) to 5 (extensive), and a MS between 1.00 and 5.00. The MS of 3.00 indicates the rating is between near limited to average / average as the MS is > 2.60 ≤ 3.40.

Table 7, Respondents' rating of their knowledge of landscape construction H&S and 'design for landscape construction H&S' skills.

Response (%)						MS
Un	Limited ……Extensive					
sure	1	2	3	4	5	
4.8	14.3	14.3	28.6	33.3	4.8	3.00

DISCUSSION

In terms of the current research, 64.3% of the MSs are above the midpoint of 3.00 i.e. landscape architects consider / refer to landscape construction H&S on various occasions frequently as opposed to infrequently. However, architectural practices consider / refer to construction H&S frequently as opposed to infrequently on 71.4% of the occasions (Smallwood, 2000b), and architectural practices consider / refer to construction ergonomics frequently as opposed to infrequently on 64.3% of the occasions (Smallwood, 2008).

In terms of the current research, 25% of the MSs are above the midpoint of 3.00 i.e. landscape architects consider / refer to landscape construction H&S on various design related aspects frequently as opposed to infrequently. However, architectural practices consider / refer to construction H&S frequently as opposed to infrequently on 81.3% of the design related aspects (Smallwood, 2000b), and architectural practices consider / refer to construction ergonomics frequently as opposed to infrequently on 87.5% of the design related aspects (Smallwood, 2008).

In terms of the current research, 25% of the MSs are above the midpoint of 3.00 i.e. extent to which design related aspects impact on landscape construction H&S is major as opposed to minor. However, architectural practices perceive the impact of design related aspects on construction ergonomics to be major as opposed to minor in the case of all (100%) the design related aspects (Smallwood, 2008).

The 'impact' MSs are lower than the 'consider' MSs relative to 63.2% of the design related aspects, which indicates that the respondents' consideration is likely to be related to the perceived impact in that they perceive their consideration to be sufficient.

The respondents' rating of themselves in terms of their knowledge of landscape construction H&S and 'design for landscape construction H&S' skills resulted in a MS of 3.00, which is marginally below the architectural practices' rating of themselves in terms of their knowledge of construction H&S and 'design for construction H&S' skills which resulted in a MS of 3.17.

CONCLUSION

Conclusions include: landscape construction H&S is considered / referred to on various occasions and relative to design related aspects to a degree; there is a degree of appreciation in terms of the extent design related aspects impact on landscape construction H&S, and landscape architectural programmes address landscape construction H&S to a limited extent.

Recommendations include: tertiary education landscape architectural programmes should include appropriate 'designing for landscape construction H&S' modules as a component of a subject – probably design. The ILASA should develop practice notes relative to landscape construction H&S, and the SACLAP should make more comprehensive reference to construction H&S in their six work stages of their IOW. Furthermore, SACLAP accreditation reviews of tertiary education landscape architectural programmes should interrogate the extent to which landscape construction H&S is addressed.

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Appendix A

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