ECSEE 2015
Official Conference Proceedings
ISSN: 2188-1146

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Official Conference Proceedings

ISSN: 2188 - 1146

The International Academic Forum (IAFOR)
Sakae 1-16-26-201
Naka Ward, Nagoya, Aichi
Japan 460-0008
ww.iafor.org

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Depositions of Acid Aerosols and Black Carbon from Biomass Burning over the Sakaerat Biosphere Reserve Forest, Thailand

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The European Conference on Sustainability, Energy & the Environment 2015
Official Conference Proceedings

Abstract
Burning of biomass is an important source of acid aerosols and black carbon emissions into the atmosphere. In the tropics, the formation of secondary organic and inorganic aerosols depends on meteorological parameters. High humidity and rain washout both air borne gas and aerosol concentrations. We monitored the concentrations of aerosols associated with biomass burning from July to December 2012 at the Sakaerat Biosphere Reserve (SBR) - a UNESCO Man and Biosphere (MAB) reserve. Considerable biomass burning is known to occur in the vicinity of SBR. All meteorological instruments were installed on 36 m tower. Air samples were collected by the filter packs method. The organic acids identified samples included citrate, tartrate, malate, formate, acetate, succinate and lactate. The concentration of organic acids was 6, 27 and 100 times higher than black carbon, sulfate and nitrate, respectively. We used the inferential method to determine the deposition flux of aerosols. The deposition of organic acids was obtained in the ranges of 4.9–51.0 µg $m^{-2}min^{-1}$; black carbon, 1.2–7.8 µg $m^{-2}min^{-1}$; sulfate, 0.2–0.5 µg $m^{-2}min^{-1}$ and nitrate, 0.3–1.0 µg $m^{-2}min^{-1}$. The deposition depended on the atmospheric concentration and deposition velocity of each component. The deposition velocity also varied with season and canopy surfaces

Keywords: acid aerosol, black carbon, deposition, biomass burning, inferential method

Introduction

Biomass burning represents an important source of atmospheric aerosols and greenhouse gases (Streets, et al., 2001; Menon, et al., 2002). It is widespread, especially in the tropics (Crutzen, et al., 1990; Cao, et al., 2006). It is a common practice during the dry season in Thailand to burn crop wastes left on lands in order to promote agricultural productivity and higher crop yield. Biomass burning leads to emissions carbon monoxide (CO), hydrocarbon (HC) and soot or black carbon (BC). Further reactions in the presence of light; transform these primary gases and aerosols to secondary aerosols, including organic and inorganic acids through gas-to-particle conversion (Zhang, et al., 2010; Donahue, et al., 2011). Deposition of these primary and secondary aerosols can harm our ecosystem.

Organic acids are organic compounds consisting of low molecular weight, monocarboxylic acids (MCA) and high molecular weight, dicarboxylic acids (DCA). MCA are found in larger amounts than DCA (Keene, et al., 1988; Yu, et al., 1999b). Organic acids have acidic propertied, high water solubility, hygroscopic and cloud condensation nuclei activity (Yu, et al., 2000). Generally, organic acids are formed from products of incomplete combustion of fossil fuels and biomass. It occurs through photochemical reactions and biological processes (Kawamura, et al., 1993; Limbeck, et al., 1999; Chebbi, et al., 1996). Organic acids can be found in urban, rural and remote atmospheres around the world around the world (Kerminen, et al., 2000; Kubátová, et al., 2000; Röhrl et al., 2001; Limon-Sanchez, et al., 2002; Souza, et al., 1999).

The size of BC particles spans from a few nanometers for atmospheric aerosols (BC) to a few centimeters for charcoal fragments of combusted plant materials (Wang, et al., 2011a). Immediately after fires, emitted BC particles smaller than 1 µm may become airborne, China and India released approximately 25-35% of total global BC into the atmosphere (Ramanathan, et al., 2008) in 2006. BC concentrations were monitored every 5 minutes starting from September 2003 – August 2004 in Xi'an, China (Cao, et al., 2009). Daily average BC concentration was 2-65 µg m^{-3} with minimum concentrations occurring during summer and peak concentrations in winter. A study of BC concentration at 8 locations in India was carried out in 2009 (Beegum, et al., 2009). The BC concentration was found to vary from 27 µg m^{-3} in the urban areas to 0.065 µg m^{-3} on a rural island. Schmidt, et al., (2001), made a comparative analysis of BC in Australian soils (Schmidt, et al., 2001). They measured BC formed in eight soil samples by six established methods. All methods involved removal of the non-BC components from the samples by thermal and/or chemical means. The remaining carbon is operationally defined as BC.

Little data exist on organic acids in tropical climates. The purpose of this study was to characterize the types and concentrations of organic acids derived from biomass burning around the United Nations Educational, Scientific and Cultural Organization (UNESCO) designated Sakaerat Biosphere Reserve (SBR) forest in the Northeast Thailand. We monitored concentrations of the organic acids: citrate, tartrate, malate, formate, acetate, succinate and lactate as well as the inorganic acids, sulfate, nitrate and nitric acid. We also monitored BC. Deposition rates of aerosols were also estimated.

Materials and Methods

Site description

The experiments were conducted in the forests of the UNESCO designated Sakaerat Biosphere Reserve at an elevation of 300 m above sea level in the Northeast of Thailand (14°30´13.68"N, 101°57´8.67"E). The area is mainly covered by two major species types: Dry Evergreen Forest (DEF) and Dry Dipterocarp Forest (DDF). This study conducted in DDF. The heights of trees vary between 20-27 m. The climate is tropical (warm and humid) and is affected by an annual monsoons, with a rainy season from June to October and a dry season for the rest of the year. Temperatures at SBR averaged 24-33 $^\circ C$. In the dry season, slashing and burning of biomass are a common practice in the area and emission of smokes (Figure 1) can be seen from the 36 m tall micrometeorological tower. This tower was established to install meteorological instruments to monitor: 3-D ultrasonic anemometer, ambient temperature, relative humidity and net radiation recorders to monitor variation of climate around the area. The tower and attachment of 3-D anemometer and filter packs to collect air samples are shown in Figure 2.

Figure 1: Forest fire and emission of smoke in the vicinity of Sakaerat forest

All samples were collected simultaneously during July to December 2012. This period covered the wet (July–September) and the dry (October–December) climate conditions. The collection procedures and concentration analyses were performed as follows;

Black Carbon

Two sets of a two-stage filer pack were used to collect BC. They were placed on the tower at 34 m above the ground and 6 m above the tree canopy. The filter papers were made of cellulose. The air suction was set at a constant flow rate of 10 L min^{-1}. In order to investigate the diurnal variation of aerosol formation sample collection was split into daytime (6:00-18:00 hrs) and nighttime (18:00-6:00 hrs). The thermal heating method was used to determine BC. The samples collected on cellulose papers were heated to 105 °C for 1 hr to dry up the water content and then burned at 375 °C for 24 hr. The weighted differences determined the amount of BC.

Figure 2: Aerosol and Black Carbon collectors on a 36 m- high tower at SBR

Organic Acids

Air samples were collected by a 3-stage filter pack. The first and second filters were made of Teflon and nylon. The third filter was cellulose paper impregnated with 6% K_2CO_3 and 2% glycerin. The air flow rate was controlled at 10 L min^{-1}. Collection was made for 7 days per month from July to December 2012. The substances collected on filters were extracted with deionized water and analyzed by ion chromatography (Khlystov, et al., 1995; Orsini, et al., 2003).

Sulfate and Nitrate

The procedures used to collect samples for inorganic acids sulfate (SO_4^{2-}) and nitrate (NO_3^-) were the same as those used for organic acids.

Particle Size Distribution

An electrical low pressure impactor (ELPI) ELPIVI 4.0: DEKATI was used to determine the atmospheric particle number per volume with size distribution over the area of study. The air sample was drawn in by a pump at a constant flow rate of 40 L min^{-1}. Aerosols were classified by size interval and the cut diameters (size of particles collected with 50% efficiency) of stages 1–13 were 0.03, 0.06, 0.11 0.17, 0.27, 0.41, 0.66, 1.02, 1.66, 2.52, 4.49, 6.80, and 10.0 μm, respectively.

Results and Discussion

Climate Condition

Meteorological parameters are important factors influencing atmospheric formation of aerosols and later their depositions onto the earth surfaces (Mcmurry, et al., 1989; Vasconcelos, et al., 1994). This study monitored the ambient temperature, wind speed, humidity and net radiation real time. With the tropical climate, the ambient temperatures did not vary significantly (Figure 3) and the average ambient temperature ranged from 25 °C during the wet season (July–September) to 20 °C in the dry season (October–December). The wind speed varied between 0.7–1.5 m/s. Due to the low wind speeds throughout the experimental period (July–December), transport of the aerosols to locations more than 10 km from the emission sources was unlikely. Hence, the aerosols collected in our samples were probably from biomass burning sources. Relative humidity reached the highest value of 87% in September concurrent with the peak rainfall (97 mm). Precipitation was minimal in November and December in the area. Relative humidity decreased to 77% in the dry season.

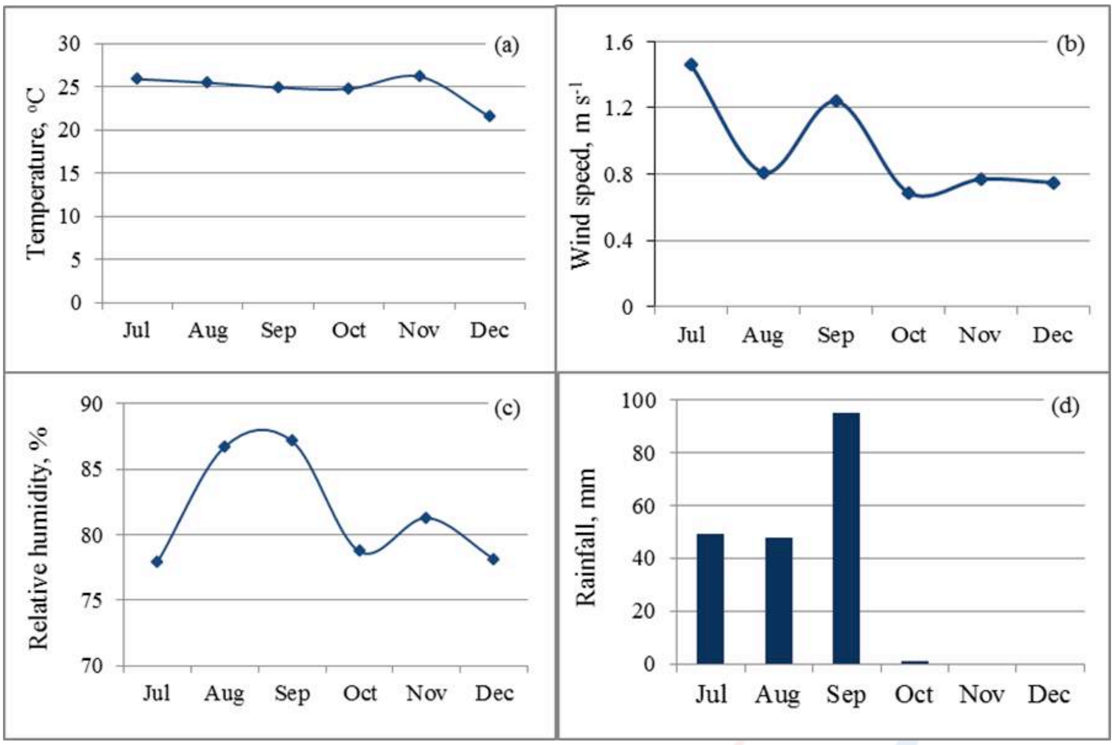

Figure 3: Climate conditions at the experimental area in the SBR forest

Particle Size Distribution

Most of particulates collected were smaller than 1 μm (Figure 4) with the most particles 0.1 μm in size. In wet season, only 4,000 particles per cm^3 were detected due to the effect of rain wash out (Figure 4). The highest concentrations 10,000 per cm^3 occurred in the dry season with the peak of 20,000 particles per cm^3 were being observed in July. The peak occurred during a transitional period from dry to wet season. However, peaks in particulate concentrations in the dry season were probably associated with three types of biomass burning which occurred at that time agricultural land preparation for the next-crop; fires set illegally in the forest to catch wildlife, and naturally occurring forest fires caused by very dry weather conditions.

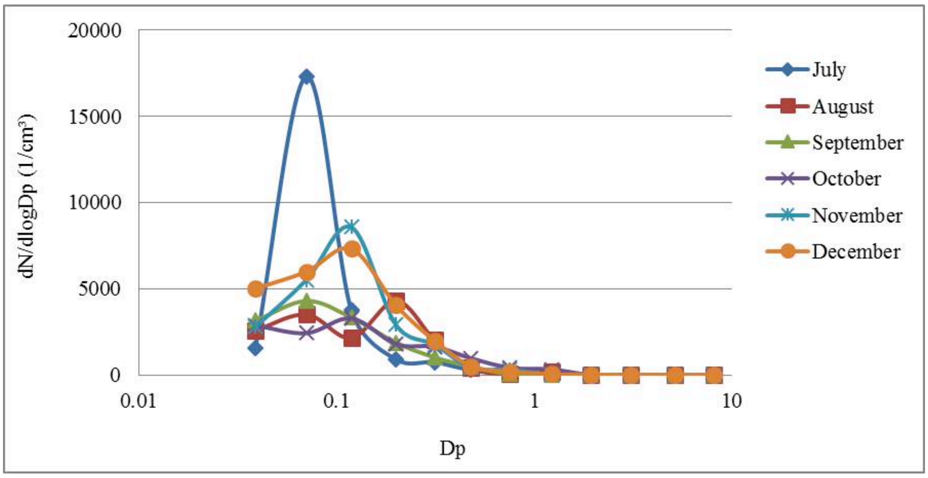

Figure 4: Size distribution of aerosols from biomass burning

Black Carbon
Atmospheric concentrations of BC were observed to vary seasonally condition (Figure 5). BC decreased to the lowest value in the wet season due to washout effect by rainfall and increased in the dry season due to more biomass burning. BC concentrations ranged from 4–17 µg m^{-3}. Time of day also influenced BC concentrations with higher values occurring during the daytime. Most biomass burning activities were carried out during the day.

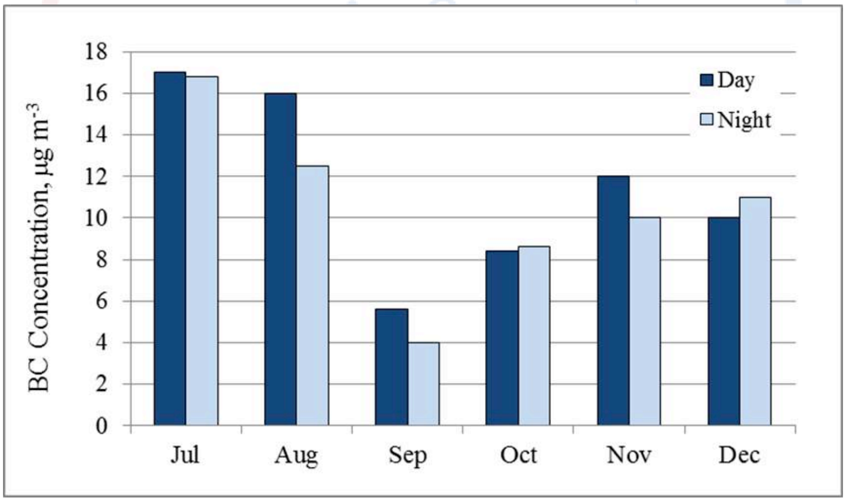

Figure 5: Diurnal variation of BC concentrations over the SBR forest

Organic Acid
The important organic acids comprised mainly citrate ($C_3H_5O(COO)_3^{3-}$, tartrate ($C_4H_4O_6^{2-}$), malate ($C_4H_4O_5^{2-}$), formate ($CHOO^-$), acetate (CH_3COO^-) succinate ($C_4H_4O_4^{2-}$) and lactate ($C_3H_5O_3^-$). Organic acid in the atmosphere are subsequently deposited on the earth's surface as acid rain which can be determined to ecosystems (Dolske, et al., 1985; Galloway, et al., 2004). Our analyses showed lactate occurred in the highest concentrations (~14 µg m^{-3}), followed by acetate (~11 µg m^{-3}) and citrate (~9 µg m^{-3}) (Figure 6a). The overall concentration of organic acids was as 110 µg m^{-3} which was 6 times higher than BC. Organic acids are formed though transformation of primary gases (hydrocarbon group of alkane, alkene and alkine) by photochemical

reactions with hydroxyl radical (•OH) (Sander, et al., 1976; Richards, et al., 1983; Huntzicker, et al., 1984). The hydroxyl radical is the main oxidant in forming or deforming the organic acids in the atmosphere. It should be noted that citrate and tartrate concentrations were lower in the dry season compared with others.

Diurnal variation on organic acid concentrations was observed with concentrations of all species decreasing at nighttime. This was due to the fact that the photochemical reaction was less active and the biomass burning activities were reduced at nighttime (Figure 6b).

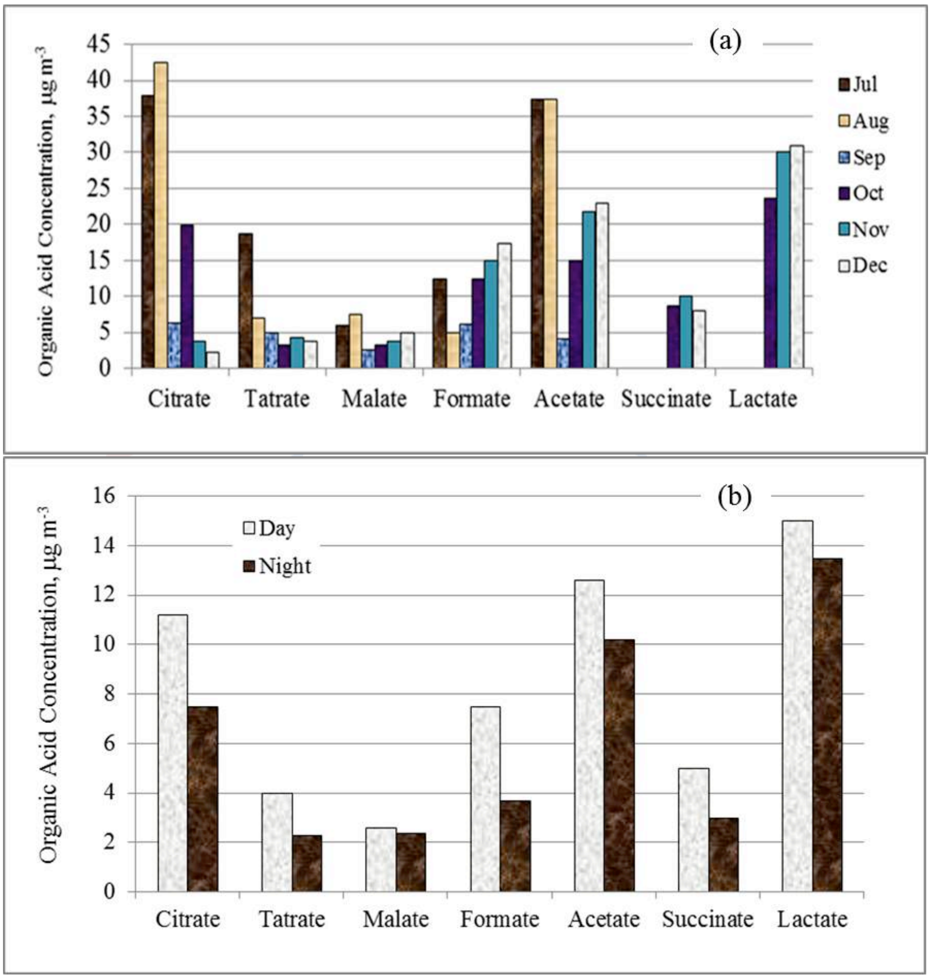

Figure 6: Organic acid concentrations over the SBR forest
(a)Types of organic acids and (b) Diurnal variation of organic acid concentrations

Sulfate and Nitrate

The primary pollutants (SO_2 and NO_x) generated from biomass combustion (in this study) were slowly oxidized with the presence of water in atmosphere to form Sulfuric and nitric acids. Upon further reaction with cation mediums, they eventually transform to sulfate and nitrate aerosols (Matsumoto, et al., 1996; Matsumoto, et al., 1998). However, only a small concentration of sulfate and nitrate was obtained by this study (Figure 7). Low concentrations of sulfate were found in the ambient environment because of the low sulfur content in the biomass being burned (less than 1%) (Tillman, et al., 2012). Nitrate concentrations were also very low because biomass burning in the open air provided low combustion efficiency. In practice, the combustion temperature for biomass burning is around 700–800 °C. The formation of

NO_x is slow when the combustion temperature is below 800 °C. There were no distinguishable differences between daytime and nighttime concentrations of these acid compounds (Figure 8).

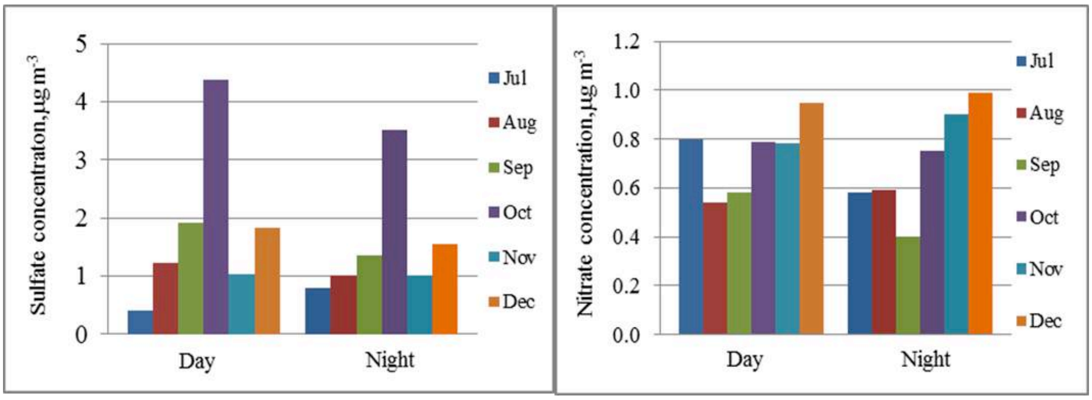

Figure 7: Diurnal variation of sulfate and nitrate concentrations over the SBR forest

Aerosol Deposition

Deposition of aerosols onto the earth's surface can cause damage to terrestrial ecosystems including forests. Although it is a slow accumulation process, damage to forests will ensure when the amount of aerosol deposition exceeds the soil's critical load (Galloway, et al., 2004). The quantity of aerosol deposition or flux (F) generated through biomass burning can be estimated using the inferential method, $F = V_dC$. Where V_d is deposition velocity in cm s^{-1} and C is average local concentration, µg m^{-3}. The monthly measured concentrations of aerosols and V_d used for each category calculations are shown in Figures 8a and 8b. The total organic acid concentrations were observed to be 6 times higher than BC, 27 times higher than sulfate and 100 times higher than nitrate at peak values. A large seasonal difference in concentration was seen in the case of organic acid in which the lowest concentration has occurred when the rainfall reached the highest millimeter reading (see also Figure 3d).

The deposition velocity, V_d varied with meteorological conditions (Figure 8b). The monthly V_d values varied between 0.26–0.76 cm s^{-1} for organic acid, 0.24–0.77 cm s^{-1} for BC, 0.18–0.85 cm s^{-1} for sulfate and 0.34–0.95 cm s^{-1} for nitrate. A difference in V_d was occurred between the wet and the dry seasons (Figure 8b). A study by Matsuda (2012) at SBR forest concluded that V_d was high in the leafless season (dry season) and low in leafy season (wet season) (Matsuda, et al., 2012).

Figure 8c shows variation in aerosol deposition. Deposition increased during the period of October to December when both the concentration and V_d were high and decreased during the period of August to September when the concentration and V_d were low. Deposition of aerosol in July was also high due to the transitional period from wet to dry season. The low deposition rates were observed in wet season due to atmospheric wash out by rain. Deposition of organic acids ranged from 4.9–51.0 µg $m^{-2}min^{-1}$; BC, 1.2–7.8 µg $m^{-2}min^{-1}$; sulfate, 0.2–0.5 µg $m^{-2}min^{-1}$ and nitrate, 0.3–1.0 µg $m^{-2}min^{-1}$. The results of this study show that organic acids from biomass burning are more important contributors of acid components to forests than sulfate and nitrate.

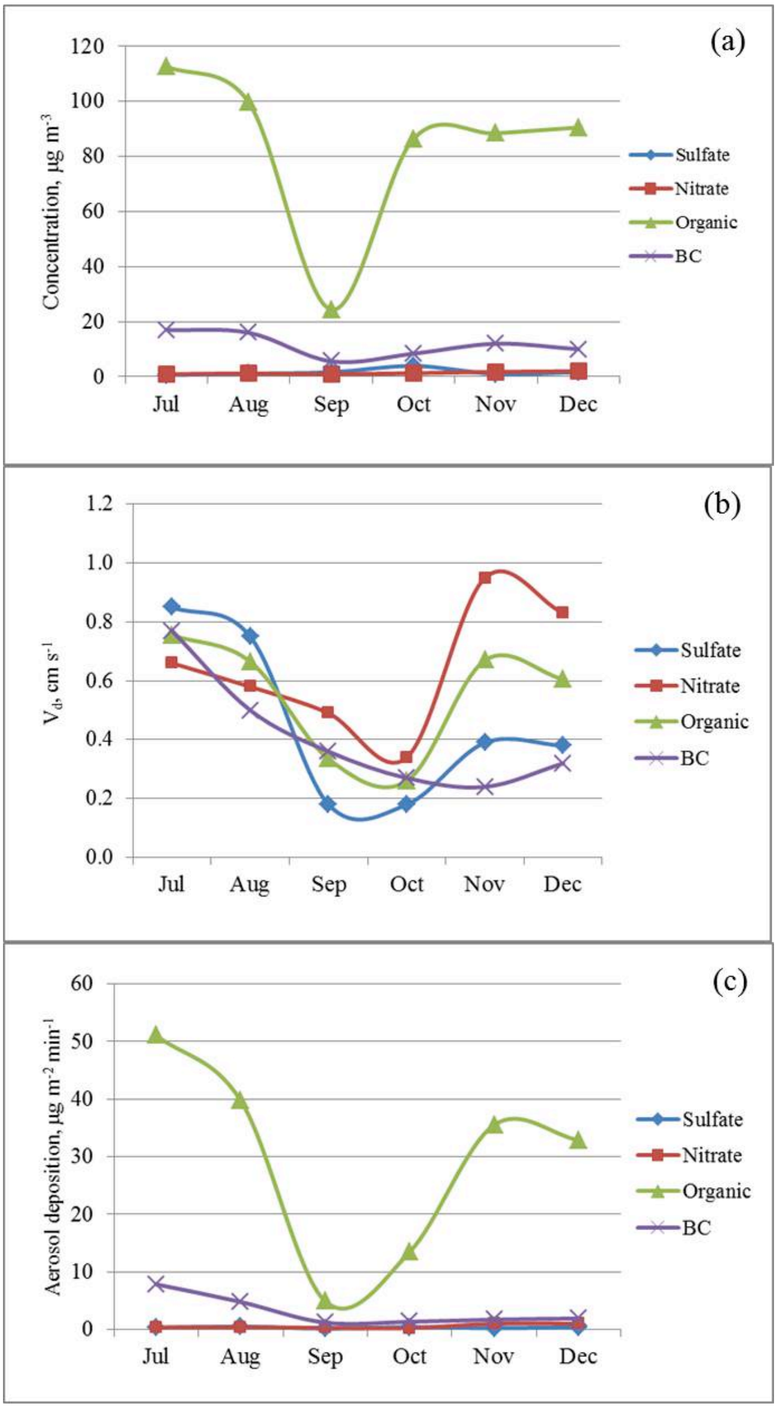

Figure 8: Comparison of aerosol (sulfate, nitrate, organic acid and BC) over the SBR forest
(a) Monthly concentration, (b) Monthly variation of deposition velocity and (c) Deposition comparison of aerosol from biomass burning

Conclusions

Aerosols from biomass burning constituted a substantial amount of organic acids. It was found that the concentration of organic acids was 6, 27 and 100 times higher than black carbon, sulfate and nitrate, respectively. Hence, the organic acids should be placed as a priority constituent of our ecosystem. Deposition of aerosols determined by the inferential method varied with atmospheric concentration and deposition velocity. The deposition velocity also varied with local conditions, i.e. meteorological parameters, season and canopy surfaces. Reports on deposition velocity of aerosols are very few, especially in tropical climate. More researches on deposition flux and deposition velocity are needed.

Acknowledgements

The authors wish to thank Dr. Kazuhide Matsuda, Tokyo University of Agriculture and Technology, Faculty of Agriculture Field Science, Japan for his support on use of the micrometeorological tower in Sakaerat Biosphere Reserve forest.

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The Properties and Suitability of Corn Stover for Co-Gasification with Coal in a Computer Simulated Downdraft Gasifier System

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The European Conference on Sustainability, Energy and the Environment 2015
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Abstract
Characterization of corn stover and coal were undertaken in order to compare their properties and determine the combustion characteristics of both feedstocks. The study was also intended to establish whether corn stover is a suitable feedstock for blending with coal for the purpose of co-gasification based on composition and properties. Proximate and ultimate analyses as well as energy value of both samples including their blends were undertaken and results showed that corn stover is a biomass material well suited for blending with coal for the purpose of co-gasification, given its high volatile matter content which was measured and found to be 75.3%, and its low ash content of 3.3% including its moderate calorific value of 16.1%. The results of the compositional analyses of both pure and blended samples of corn stover and coal were used to conduct computer simulation of the co-gasification processes in order to establish the best blend that would result in optimum co-gasification efficiency under standard gasifier operating conditions. The final result of the co-gasification simulation process indicated that 90% corn stover/10% coal resulted in a maximum efficiency of about 58% because conversion was efficiently achieved at a temperature that is intermediate to that of coal and corn stover independently.

Keywords: Proximate analysis, ultimate analysis, calorific value, co-gasification, coal, corn stover.

1 Introduction

Coal is the most widely used primary fuel internationally, accounting for about 36% of the total fuel consumption of the world's electricity production [1]. An excess of 255 million tons of coal is produced in South Africa and almost three quarters of that is consumed domestically with 77% of South Africa's energy needs directly derived from coal [1, 2, 3]. Although a non-renewable feedstock, coal can be effectively combined with biomass feedstock to produce a synergistic effect during gasification [4]. This process produces a low carbon footprint on the environment. Gasification is an alternative energy conversion technology that converts organic materials into usable energy in the form of syngas. On the one hand, the technology has attracted enormous interest for the past several years within thermochemical conversion technologies as it has been proven to offer higher efficiencies in comparison to combustion [5], while on the other hand it has been a promising renewable energy technology for the supply of thermal energy and generating electrical power. However, there are challenges associated with the use of this technology such as biomass supply which is limited and varies with season, low energy density of biomass which results in low production, expensive for long distance transportation etc. These challenges result in higher capital and production cost. Coal gasification on the other hand, though an established technology is also faced with the issues of high reaction temperature which most gasifiers cannot achieve and if achieved in most cases, combustion of the resultant syngas usually occur leading to low conversion efficiency. The risk of reaching extremely high temperatures that may result in pressure build up is another shortcoming related to coal gasification as this may lead to explosions. Taking these challenges into account therefore, it is more economically attractive and less technically challenging to co-gasify biomass with coal.

Co-gasification of biomass with coal has its own challenges which are related to the uncertainties associated with how to mix them. The optimum percentages of various biomass and coal blends required for enhanced conversion efficiency under standard gasifier operating conditions remains an issue yet to be addressed. Other issues related to co-gasification of biomass and coal includes gasifier type as well as choice of gasifier operating parameters which, to a great extent, determines the product gas composition and quality. Biomass and coal differ greatly in terms of properties and composition. While coal contains mainly carbon, biomass is a complicated mixture of complex compounds such as cellulose, hemicellulose, and lignin as well as extractives and minerals with relatively high amount of oxygen which makes them low energy density fuels [6]. These properties play a vital role during co-gasification because they come as factors which influence the co-gasification process [7, 8]. Various researchers have reported an increase in the efficiency of a co-gasification process by increasing the ratio of biomass in the blend. Kezhong et al., 2010 [9] reported an increase in H_2 and CO_2 yield when the biomass ratio was increased from 20% to 33% during co-gasification. Kumabe et al., in 2007 [7] studied the influence of the amount of biomass with respect to the molar ratio of CO, H_2 and CO_2 in the product gas when they co-gasified varying proportions of blended Mulia coal and Japanese cedar in a downdraft gasifier system at 1173 K. They reported that the syngas composition varied according to the ratio of biomass in the blends. This study, therefore sought to establish the properties and composition as well as proportion of corn stover and coal that would be suitable for co-gasification and that would in itself result in optimum efficiency of the co-gasification process, employing computer simulation.

2 Materials and method

2.1 Sample preparation and characteristics

The biomass material used for this study was corn stover, and the coal used was a low grade sub-bituminous coal. Both samples were obtained in the Eastern Cape Province of South Africa. A coning and quartering method was applied for size reduction of the samples using a Condux-Werk Wolfgang bei Hanau mill so as to obtain smaller fractions as required by the analytical instruments for analysis. The size obtained for the samples were in the range of 25μm to approximately 1mm. The blends of corn stover and coal were prepared in the following ratios: 100% CS (Pure material), 90% CS/10% CL, 80% CS/20% CL, 70% CS/30% CL, 60% CS/40% CL, 50% CS/50% CL, 40%, CS/60% CL, 30% CS/70% CL, 20% CS/80% CL, 10% CS/90% CL, 100% CL (Pure material). Where CS and CL represents corn stover and coal respectively.
C Calculating the usefulness of a fuel requires an understanding of its characteristics [10]. The following sub-sections present the most important analyses relevant to the thermal conversion of the materials under study.

2.1.1 Calorific value of samples

The calorific value of both pure and blended samples of corn stover and coal were determined by a CAL2K model oxygen bomb calorimeter. This was done by calibration with a 0.5 g of benzoic acid before taking measurements. A 3 000 kpa pressurized oxygen environment was used to achieve this. Figure 1 show the oxygen bomb calorimeter used during the analysis.

Figure 1: An oxygen bomb calorimeter

2.1.2 Elemental analysis

The weight fractions of the individual elements contained in both pure and blended samples were determined by a ThermoQuest elemental analyser. About 5 mg of each sample were combusted in the instrument at approximately 1000°C after mixing with an oxidizer in a tin capsule. Figure 2 presents the elemental analyser used for this study.

Figure 2: A thermoquest elemental analyser

There are catalysts downstream of the combustion chamber of the instrument to ensure complete oxidation. Combustion products such as CO_2, NO_2, SO_2 were produced and were catalytically reduced to C, N_2 and S. The gases were then separated by gas chromatography and their concentration measured by a thermal conductivity detector.

2.1.3 Thermal analysis

A TGA 7 thermogravimetric analyzer was used to study the thermal degradation behavior of both pure and blended samples of corn stover and coal. A 5.08 mg of each sample was heated over a temperature range of 20ºC-1000ºC under a nitrogen atmosphere at 20°C/min heating rate. This analysis was undertaken in order to establish the thermal behaviour and the temperature of the co-gasification processes of both pure and blended samples of corn stover and coal. The thermogravimetric analyser used for the thermal analysis of both pure and blended samples of corn stover and coal is presented in Figure 3.

Figure 3: A thermogravimetric analyser

2.1.4 Co-gasification simulation process

A mathematical model modified by Jayah *et al*., 2003 [11] and designed specifically to simulate the gasification performance of a typical downdraft gasifier system was used to conduct computer simulation of the co-gasification processes of both pure and blended samples of corn stover and coal for maximum efficiency. The proximate and ultimate analyses as well as the calorific value results of the samples obtained in section 3 were used during calculation of the conversion efficiency of the co-gasification processes of the samples. A detailed description of the simulation programme has been presented in our previous paper [10]. For optimum co-gasification efficiency, the normal operating parameters/conditions of a downdraft gasifier are presented in Table 1.

Table 1: Normal operating parameters of a downdarft gasifier [11].

Fuel properties	Value	Gasifier operating conditions	Value
Carbon (%)	39.6	Throat diameter (cm)	94.0
Hydrogen (%)	6.7	Throat angle (°)	90.0
Oxygen (%)	52.1	Insulation thickness (cm)	0
Nitrogen (%)	1.59	Thermal conductivity (W/cm K)	0.87
Fixed carbon (%)	19.3	Temperature of input air (K)	293
Bulk density (kg/m^3)	0.25	Air input (kg/hr)	44.5
Diameter of particle (cm)	1.0	Heat loss (%)	12.8
Moisture content (%)	8.7	Feed input (kg/hr)	40

3 Results and discussion

3.1 Energy content of pure and blended samples

The calorific values gave a clear indication of the energy contained in the samples and were obtained after analysis by the oxygen bomb calorimeter. Increasing the biomass content during co-gasification enhances calorific value due to higher composition of hydrocarbons in biomass [12, 13]. The results of the calorific value of the pure and blended samples of corn stover and coal are presented in Figure 4.

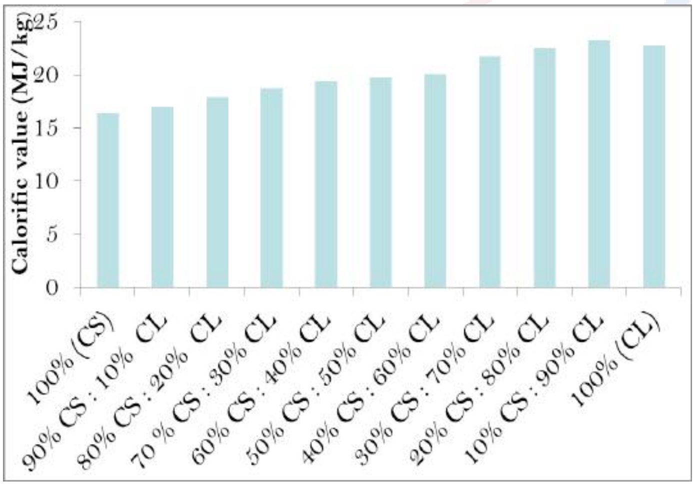

Figure 4: Energy content of pure and blended samples of corn stover and coal

The difference in calorific value between the pure materials as well as their blends is quite noticeable from Figure 4. The pure coal sample has a much higher calorific value (22.8 MJ/kg) compared to the 100% corn stover with ca 17 MJ/kg. This difference in calorific value could also be correlated to the concentration of C and O_2 in the samples (elemental composition in Figure 5). A 1% increase in carbon concentration will elevate the calorific value by approximately 0.39 MJ/kg and coals generally have calorific values greater than biomass because of lower degree of oxidation [14]. In contrast, the calorific values of the blends vary in accordance with the ratio of coal to corn stover in the blends. Calorific value increases with increasing ratio of coal in the blends.

3.2 Proximate analysis of pure and blended samples

Table 2 shows the proximate analysis results of both pure and blended samples of corn stover and coal. These were obtained from the TGA plots in Figure 6. This analysis was undertaken in order to compare the physical properties of corn stover with those of coal including their blends and establish the properties that would influence the co-gasification processes of both pure and blended samples under standard gasifier operating conditions. The weight percentages of fixed carbon in the pure and blended samples were obtained by difference.

Table 2: Proximate analysis of pure and blended samples of corn stover and coal

Pure samples								
Coal (wt%)					**Corn stover (wt%)**			
MC	VM	FC	AS		MC	VM	FC	AS
0.2	25	24	50.8		8.7	75.3	19.3	3.3
Blended samples								
Blend					**CL:CS (wt%)**			
Ratio (%)					MC	VM	FC	AS
90:10					2.5	23	29.5	45.2
80:20					2.6	27.3	27	43.1
70:30					3.1	32.5	25.4	39
60:40					3.4	35.4	36.9	24.3
50:50					4.2	48.9	29.6	17.3
40:60					5.4	53.6	28.2	12.8
30:70					5.9	55.1	28.4	10.6
20:80					6.5	66.4	19.8	7.3
10:90					7.6	69.8	17.9	4.7

Note: MC= Moisture content, VM= Volatile matter content, FC= Fixed carbon, AS= Ash content, CL = Coal, CS = Corn stover

The values obtained for both pure and blended samples in Table 2 are within acceptable ranges found in the literature. Comparing the properties of the pure samples with those of the blended, it could be easily noticed that a typical South

African sub-bituminous coal used for this study has high amount of ash in comparison to corn stover which showed quite a relatively low ash composition. Ash content of coal varies over a wide range and this variation occurs not only in coals from different geographical areas or from different seams in the same region, but also from different parts of the same mine which results primarily from a wide range of conditions that introduces foreign materials during or following the formation of coal [15]. The reason for the high amount of ash in the pure coal is most likely due to the influence of extraneous mineral matter introduced during mining operations where the coal was obtained. The difference in the pure and blended samples is also quite evident from Table 2 as the blends with higher percentages of coal exhibited higher ash contents. Some of the blends with higher ratios of corn stover also exhibited higher ash contents. This is also due to the nature and source including other conditions such as growth processes, growing conditions and handling before analysis of corn stover as well as doses of fertilizer and pesticides used during growing season, which are highly important for some elements such as K, N, P, S and certain trace elements. However, high amount of ash is undesirable as it could cause agglomeration, slagging and fouling as well as deposition and corrosion during gasification; therefore, to avoid these challenges during co-gasification, feedstock ash content must be below 6% [10, 16].

The difference in volatile matter content between coal and corn stover can also be observed in Table 2. This is linked to differences in properties between the two feedstocks. Fuels with high volatile matter content is always better for gasification because they tend to vapourize before combustion compared to fuels with low volatile matter content which burns primarily as glowing char and this affects the performance of the combustion chamber of the gasifier which is usually taken into account when designing gasification systems [17]. Moisture content of the pure coal material is relatively low compared to the corn stover and varies in the blends according to the percentage of corn stover in the blends. High feedstock moisture content lowers the temperature inside the combustion unit of the gasifier and will lead to an increased fuel throughput, thereby increasing the volume of flue gas released [18]. The fixed carbon of coal is higher (24%) than that of corn stover which is again as a consequence of the difference in physical properties between corn stover and coal. In contrast, the fixed carbon content of the blends showed a slight variation due to the ratio of volatiles in the pure coal. Fixed carbon is calculated as a function of moisture, volatile matter and ash content, and the uncertainties of these properties affect the uncertainty in the concentration of fixed carbon [10]. The fixed carbon content of the blends were also in narrow ranges due to the amount of volatile matter and moisture as well as ash driven off in the sample during thermal analysis.

3.3 Ultimate analysis of pure and blended samples

Figure 5 shows the ultimate analysis data obtained after CHNS analysis of the pure and blended samples of corn stover and coal.

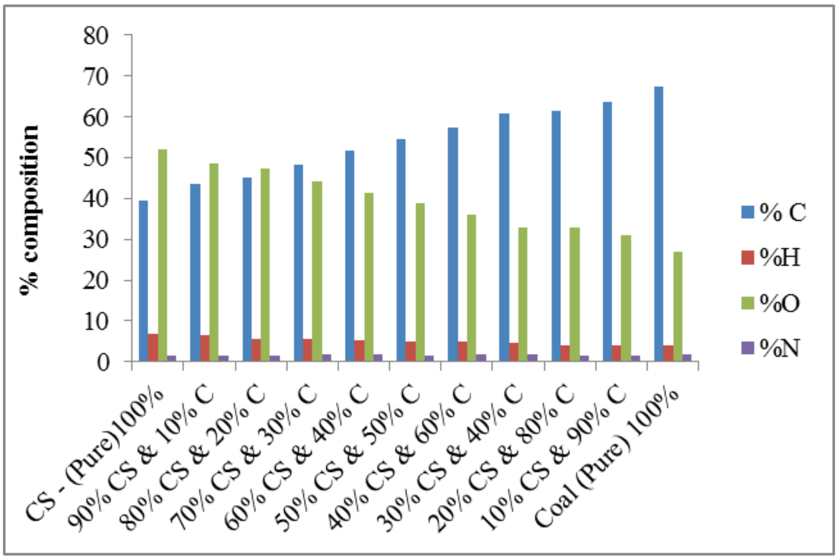

Figure 5: Ultimate analysis of pure and blended samples of corn stover and coal

The elemental analysis of corn stover and coal including their blends showed that the main chemical constituents of the samples are C, H_2 and O_2, which is due mainly to the organic nature of both feedstocks. However, the percentage composition of C in pure coal (67.5%) is almost double that of pure corn stover (39.6%), which supports the fact that coal chiefly, contains C. According to the trend in Figure 5, the percentage composition of C increased with increasing percentage of coal in the blends, while that of O_2 decreased with decreasing ratios of corn stover in the blends. H_2 composition also decreased quite slightly with decreasing percentage of corn stover in the blends. This is attributed to the differences in properties between corn stover and coal. C and H_2 are oxidized during co-gasification by exothermic reactions forming CO_2 and H_2O. The content of C and H_2 has a positive contribution to the calorific value of the fuel and the CO_2 formed is emitted as a major product of complete combustion because incomplete combustion in the oxidation zone of the gasifier can lead to emissions of unburnt carbon based pollutants such as hydrocarbons, polycyclic aromatic hydrocarbons, tar and soot [10]. O_2 will reduce the energy density of the fuel [19]. However, the presence of O_2 is important to start the syngas formation process as it reacts with C and H_2 in the feedstock to form CO_2 and H_2O. The CO_2 formed reacts with C in the feedstock to produce CO as described by equation 1.5 in section 1.1. N_2 in the fuel is almost entirely converted into gaseous N_2 and nitric oxides (NOx, [NO, NO_2]) during co-gasification. One of the main environmental effects of combustion of coal and biomass is caused by the emission of NOx [20]. NOx can be formed through reaction pathways such as reaction of N_2 with O_2 radicals at high temperatures (above 1300°C) and the amount increases with increasing temperature. It could also be formed from airborne N_2 at yet again, temperatures above 1300°C but under low O_2 conditions in the presence of hydrocarbons [21, 22]. The most important mechanism in gasification systems is the formation of NOx from the oxidation of fuel N_2 during a series of elementary reaction steps and emission increases with increasing fuel N_2 content [23]. However, the major influencing parameters for NOx formation include air supply, combustion zone geometry and temperature, as well as type of gasification technology used 24]. Emission related problems for solid fuels exceeding emission limits can be expected at fuel N_2 concentrations above 0.6 wt.%. N_2 composition in the blends is quite minimal and poses no environmental concern during co-gasification.

3.4 Thermal behavior of pure and blended samples of corn stover and coal

The rate of degradation of a sample during thermogravimetric analysis is an indication of the thermal behavior of the sample under gasification [10]. Figure 6 shows the weight loss of pure and blended samples of corn stover and coal obtained after thermal analysis using a thermogravimetric analyzer, and carried out under a nitrogen flow rate of 20 ml/min. The maximum temperature reached was 900°C at 20°C/min heating rate.

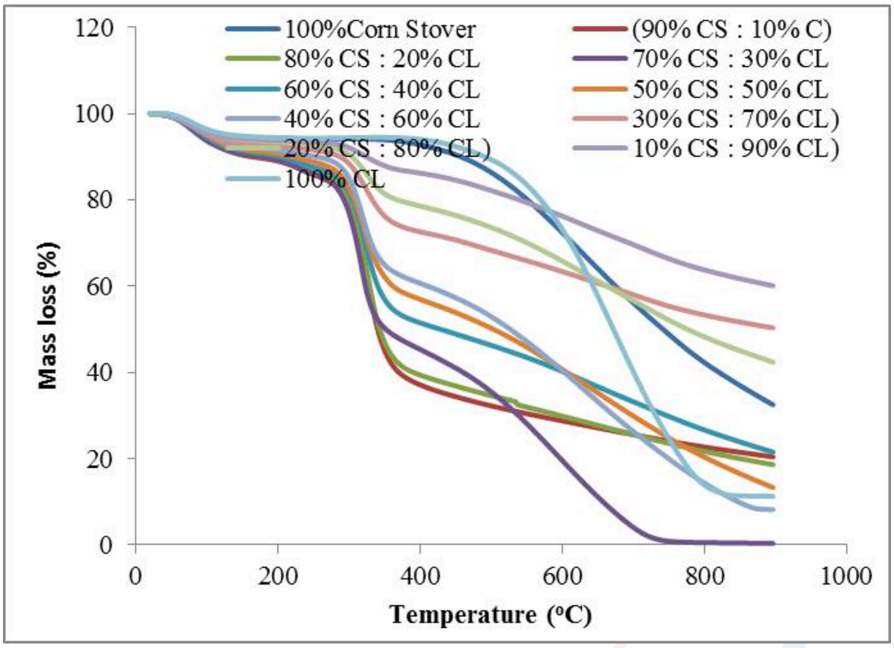

Figure 6: TGA of pure and blended samples of corn stover and coal

It is quite clear from Figure 6 that pure coal degrades over a wider temperature range when compared to pure corn stover. The blends with higher percentages of coal assumed essentially the same shape with degradation occurring at a much wider temperature range due to reduced content of volatile matter in coal (according to Table 2 in section 3.2). However, an initial mass loss occurred at 105°C temperature for all samples except for the 70% CS:30% CL (70% corn stover: 30% coal) with initial mass loss occurring at a much higher temperature (130°C). This initial mass loss is due to the evaporation of moisture from the samples. Rapid weight loss due to devolatilization in the 100% corn stover started at 400°C which is considerably lower than the temperature corresponding to the start of devolatilization of 100% coal at 530°C. At all mix ratios, the curves corresponding to the blends maintained essentially the same shape and position and displayed three stage weight losses with the last stage of devolatilization occurring at a much higher temperature (600-800°C) due to char oxidation. This observation is again excluding the 70% CS:30% CL blend which is characterized by four weight loss stages due to much higher volatile matter content of corn stover in the blend, with its last stage of weight loss occurring at 715°C. In general, and in relation to co-gasification, starting from room temperature, to a temperature corresponding to 1000°C, all samples would have completely degraded leaving some amount of ash whose concentration would depend on the composition of the mineral matter content of the feedstocks for co-gasification, and the conditions of co-gasification.

3.5 Computer simulation of the co-gasification processes of pure and blended samples of corn stover and coal

Gasification efficiency is an expression of the energy content of gaseous products to energy content of biomass, coal or a mixture of them as solid fuel [25]. It is an important factor that determines the actual technical operation and the economic viability of using a gasification system. The computer simulation programme described in section 2.1.4 was used to undertake the simulation of the co-gasification processes of both pure and blended samples of corn stover and coal. Figure 7 shows the efficiency plot of the co-gasification processes of all samples obtained after computer simulation.

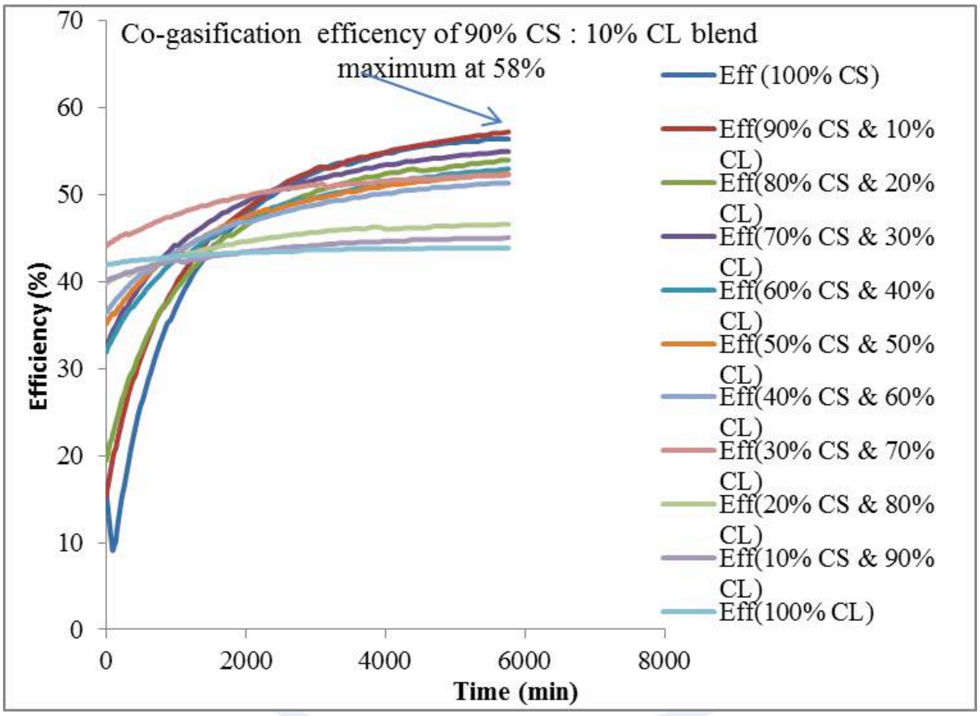

Figure 7: Simulated efficiency of the co-gasification processes of pure and blended samples of corn stover and coal

As evident from Figure 7, although there are no significant differences in the efficiency of some of the blends, while for some other blends a significant difference could be noticed. The blend 90% CS/10% CL resulted in maximum efficiency of approximately 58%. This optimum efficiency was achieved because conversion was efficiently reached at a temperature that is intermediate to that of coal and corn stover independently. Another reason for the optimum efficiency may also be due to catalytically active components in corn stover. The conversion efficiency of a gasification process among other factors also depends on the catalytically active components in the feedstock [26]. The gasifier operating parameters/conditions presented in Table 1 were also other factors responsible for the optimum co-gasification efficiency shown by the blend (90% corn stover/10% coal), as well as the ratio of corn stover in the blend. Raising the ratio of biomass in a co-gasification process increases the efficiency of the process [27].

3.6 Comparison with experimental data

A comparison between the simulated process studied and experimental data from the literature was undertaken for this study and results presented in Table 3.

Table 3: A comparison of the simulated results from this study with experimental data from the literature.

This study

Blend ratio (%)	Materials blended	Gasification efficiency (%)
90:10	Corn stover : Coal	58
80:20		53.5
70:30		54.4
60:40		52.6
50:50		51.3
40:60		50.8
30:70		49.3
20:80		46.1
10:90		44.9

Previous authors

Blend ratio (%)	Materials blended	Gasification efficiency (%)
90:10	Wood : Coal [28]	50 – 95
80:20	Wood : Coal [28]	43
70:30	Pine chips : Coal [29]	Improved H_2 eff. From 17% to 22%
60:40	Mulia coal: Japanese cedar [7]	47.9
	Coal : Pine chips [30]	Improved efficiency
50:50	Woody biomass : Coal [7]	65 – 85
	Indonesian Tinto coal : Sawdust [30]	45
40:60	Coal : pinewood [28]	48 – 62
	Coal : pine chips [31]	Improved efficiency
30:70	Bagasse : Coal [32]	55.03
20:80	Pine chips : Coal [29]	Continuous and stable operation/Improved efficiency
10:90	Coal : Pine sawdust [12]	82.3
	Coal : Almond shell [12]	77.7
	Coal : Olive stones [12]	81.6

It can be clearly seen from Table 3 that there is only about 5 to 8% variation between measured and simulated results. Therefore, it is fair to say that the model used for the simulation of the co-gasification processes of pure and blended samples of corn stover and coal can be applied for further analysis with acceptable accuracy. The validated model was used to study the effect of process efficiency. The simulations result concur with the experimental data found in the literature and are useful in predicting experimental observations reasonably well based on process efficiency.

4 Conclusions

The properties and suitability of corn stover for co-gasification with coal in a computer simulated downdraft gasifier was investigated in this study and the most suitable corn stover/coal blend for co-gasification established based on efficiency. The blend established was 90% CS/10% CL because conversion was independently achieved at a temperature that is intermediate to that of corn stover and coal. However, results also showed that the suitability of corn stover and coal for co-gasification depends on a number of factors which included the composition and properties of both feedstocks and the ratio of blending as well as the operating conditions of the gasifier. Furthermore, a comparison of the simulated data from this study and experimental data from the literature showed similar results in terms of efficiency, implying that a laboratory scale or a large scale downdraft gasification system for the purpose of co-gasification of corn stover and coal can be designed using simulation results. The study established that corn stover is a carbonaceous feedstock suitable for co-gasification with coal in a downdraft gasification system properly designed to accommodate the properties of both feedstocks.

Acknowledgements

The authors wish to acknowledge the Fort Hare Institute of Technology, University of Fort Hare, Eskom, the National Research Foundation and the Govan Mbeki Research and Development Centre for providing financial support for this research. Their support is deeply appreciated.

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Effect of Seed Size on Seed Germination Rate of Adansonia Digitata from Five Natural Populations in Malawi

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Official Conference Proceedings

ABSTRACT
In Malawi, deforestation has largely eroded much of the indigenous fruit tree germplasm, one such fruit trees is *Adansonia digitata* L. (baobab). There is need to comprehend the variation that occurs between and within populations of *A. digitata* if sustainable use is to be achieved. A study was carried out to assess seed size effect on germination rate of *Adansonia. digitata* from five natural populations in Malawi, namely Mwanza, Salima, Karonga, Chikwawa and Likoma. 2500 seeds were collected and seed traits (weight, width and length) were measured using Vernier calliper and digital balance TR-2101, germination parameters were analysed in the green house at Mzuzu University. There were significant variations (P<0.001) in mean seed weight, width, length between populations. Differences were found in mean seed weight 0.37g to 0.58g, mean seed width from 8.87mm to 10.10mm and seed length from 10.87mm to 12.48mm. Differences were also found in seed weight between families. In Chikwawa families ranged from 0.4777g to 0.7439g, Mwanza from 0.3958g to 0.6112g, Likoma from 0.2995g to 0.4674g, Salima from 0.3799g to 0.5875g and Karonga from 0.4151g to 0.6115g. There were also significant variation (P<0.001) in the interaction between pre-treatment and provenances but no significant variation for interaction between pre-treatments (P=0.599). From these results, it is concluded that there is substantial variation in seed weight, seed width and seed length in *A. digitata* from five populations. It can be further concluded that variations observed are strongly genetically controlled. Future research should strive to partition genetic variation and environmental variation.

Keywords: variation, population, interaction, effect

CHAPTER 1: INTRODUCTION

1.1Background information

Arid and Semi- arid Africa is blessed with various trees which provide medicinal and non –medicinal values. Among these plants is the baobab (*Adansonia digitata*) which is a fruit- producing tree belonging to the family Bombacaceae (Rashford, 1994). *Adansonia digitata* is important to the livelihood of the people of Africa. It provides food, shelter, clothing and medicine as well as material for hunting and fishing (Benker, 1983). Thus the baobab can be said to be one of the most precious natural resources in the African continent (Venter and Venter, 1996).

1.2 Problem statement

The increasing demand for some major parts of the plant has led to its over-exploitation. As a result existing trees sometimes fail to form fruits or disperse seeds leading to scarcity of its wildlings. Unfortunately there is insufficient information pertaining to its domestication particularly on how seed size may influence seed germination rate of the species. It is against this background that this study was undertaken.

1.3 Objectives of the study

1.4.1 General objective

- The main objective of this study is to investigate the influence of seed size on germination rate of *A. digitata* seed.

1.4.2 Specific objectives

- To determine how seed size affect seed germination of *A. digitata*
- To determine how provenance variation affects seed size of *A. digitata*
- To determine how families affect seed size of *A. digitata*
- To determine how pre-sowing treatments affect seed germination rate of *A. digitata*

1.4 Hypotheses

- There is significant effect of seed size on seed germination rate of *Adansonia digitata*.
- Pre-sowing treatments have significant effect on seed germination rate of *Adansonia digitata*.

1.5 Significance of the study

Once the appropriate seed size is known, it will be easy to promote it on the seed germination of *Adansonia digitata* and one will be able to know how families and provenances affect seed size on seed germination rate of *A. digitata*.

CHAPTER 2: LITERATURE REVIEW

2.1 Botanical description

Adansonia digitata L. is a delicious, massive and majestic tree up to 25m high, which may live for hundreds of years. It has thick, angular wide spreading branches and a short, stout trunk which attains 10-14m or more in girth and often becomes deeply fluted (Sidibe and Williams, 2002). The baobabs are comprised of eight species with large, spectacular, nocturnal flowers (Baum, 1995). The baobab is pollinated by bats (Galago crassicaudatus) and insects but is also adapted for wind pollination.

2.2 Distribution and ecology

Adansonia digitata is widespread throughout the hot, drier regions of tropical Africa. *Adansonia digitata* specifically does well where the annual rainfall is in the range of 150mm to 1500mm at elevation ranging from sea-level up to 1250m (Wickens, 1982; Wilson, 1988; Carlowitz, 1991; Fenner, 1980). As stipulated by Sidibe and Williams (2002) the baobab has an extensive root system and high water holding capacity. It characteristically occurs on free-draining sandy-textured soils but not on deep sand. In terms of temperature baobab can tolerate very high temperature (mean maximum 40-42°C in West Africa) and for minimum temperatures, can survive as long as there is no frost (Simpson, 1995).

2.3 Seed variation and germination

According to a study by Igboeli *et al*., (1997) heavier seeds have low germination rate but give rise to seedlings of greater mass as compared to lighter seeds. According to Addy and Esteshola (1984) seed size of A. digitata could differ between different species of plants. Baobabs are quite easily grown from seed although they are seldom available in nurseries. Sidibe and Williams (2000) argues that direct seeding into the field has not been successful; hence seedlings are mainly raised and transplanted into the field at 10m×10m spacing. The hole size is 60×60×60cm.

CHAPTER 3: MATERIALS AND METHODS

3.1 Experimental site

The experiment was conducted at Mzuzu University within Mzuzu City. Temperature for the area ranges from 13.5 - 20.9ºC and receives rainfall of up to 1150mm per year (Atlas of Malawi, 1983).

3.2 Experimental materials

The seeds of *A. digitata* were collected from Mwanza, Salima, Karonga, Chikwawa and Likoma populations in Malawi. After collecting the seeds, the pulp was removed by washing away the dry powdery coating. As Donahue (1995) recommends, five seeds from each fruit were randomly selected; mass (g) was weighed using analytical balance and length (mm) and width (mm) measured using a Vernier calliper.

3.3 Laboratory methods

The collected fruits were taken to the laboratory at Mzuzu University where seed weight, width and length were measured. Seed weight was determined using the digital balance TR-2101 graduated to 2100g. Seed width and length was measured at the middle of each seed and from end to end respectively using vernier calliper (MDL 005) graduated to 0.02mm.

3.4 Experimental Design and seed germination

The experiment was a 3 × 5 factorial design arranged in a Complete Randomized Design (CRD). The two factors were pre-sowing treatments and provenances. The three pre-treatments were; seeds soaked in hot water over night, seeds nicked with a secateur and seeds not pre-treated (control). The experiment comprised of fifteen treatments. Each treatment was replicated four times with twenty five seeds in each replicate (4 × 25) making 100 seeds per replicate. Thus, 2500 seeds were used for the experiment. Seeds were sown in tubes and watering was done twice a day (morning and evening) for 50 days until the seeds stopped germinating.

3.5 Data collection

Germination counts were made daily and recorded on a seed germination assessment sheet until there was no more seed germination. A seed was considered germinated when the plumule had emerged above the soil surface. The data collected was transformed to get lead of the zeros which were present, Peterson (1991).

3.6 Data analysis

Data was subjected to analysis of variance (ANOVA), using Genstat Statistical Package (3rd Edition), so that the variations in fruit characteristics could be tested. The data was analysed as an unbalanced randomised complete design. The statistical model used was as follows;

$Y_{ijk} = \mu + A_i + B_j + AB_{ij} + \varepsilon_{ijk}$

$_i = 1, 2, 3, 4$

$_j = 1, 2. . . 15$; Where,

μ is the overall mean

$A_i{}^{th}$ effect of factor A

$B_j{}^{th}$ effect of factor B

AB_{ij} ij^{th} interaction effect

ε_{ijk} is the random error for observation

Fischer's Least Significant Difference (LSD) was used for pair comparison. Using Genstat Statistical Package (3rd Edition), Coefficient of variation (CV) was calculated for each parameter to determine the precision with which the treatments are compared. Mean seed germination percentages were firstly transformed into arc sine values in order to normalise the data before the analysis of variance was performed to determine significance between treatments.

CHAPTER 4: RESULTS

4.1 Variation of fruit parameters between provenances

4.1.1 Seed weight

Figure 1 shows variation in mean seed weight (g) between five populations of *A. digitata*. The results showed significant differences in the seed weight between provenances (F=570.45, P<0.001) (Appendix 1). The heaviest seeds (0.58g) came from the Chikwawa population whereas Likoma population exhibited the lightest seeds (0.37g) (Figure 1). However LSD (Appendix 10) indicated that mean seed weights for Chikwawa, Mwanza, Salima and Karonga were similar.

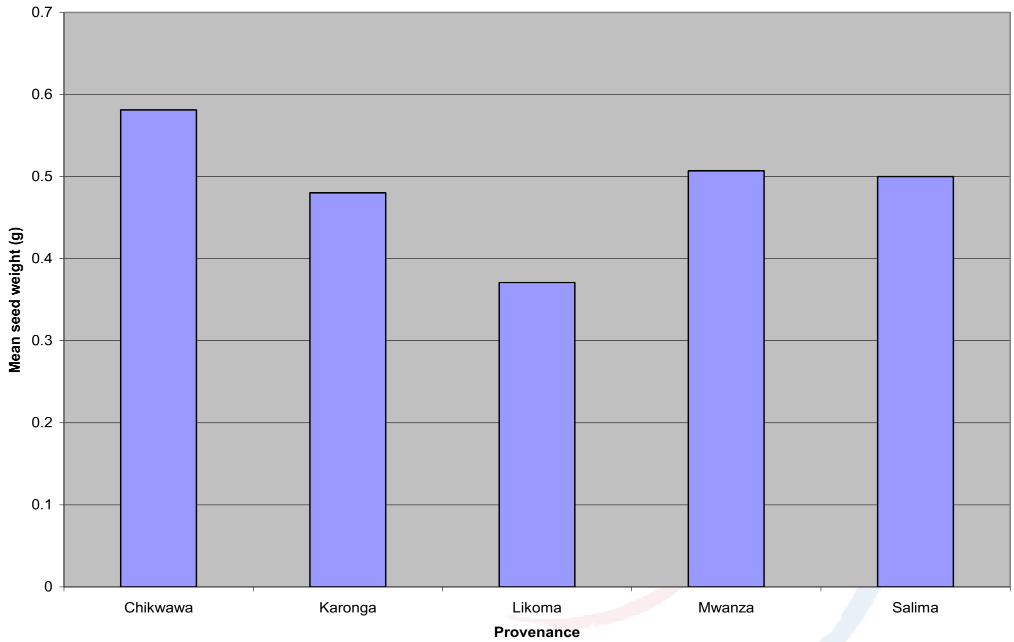

Figure 1: Variation of *Adansonia digitata* in mean seed weight between five populations

4.1.2 Seed width

Figure 2 shows variation in mean seed width between populations of *A. digitata*. Results show that there were significant differences in seed width between provenances (F=177.84, P<0.001) (Appendix 2). The population with highest seed width was Chikwawa with a mean width of 10.10mm and the minimum value was 8.87mm, observed from Likoma population (Figure 2). The LSD (Appendix 10) shows that mean seed widths for Chikwawa, Mwanza, Salima and Karonga were similar except Likoma.

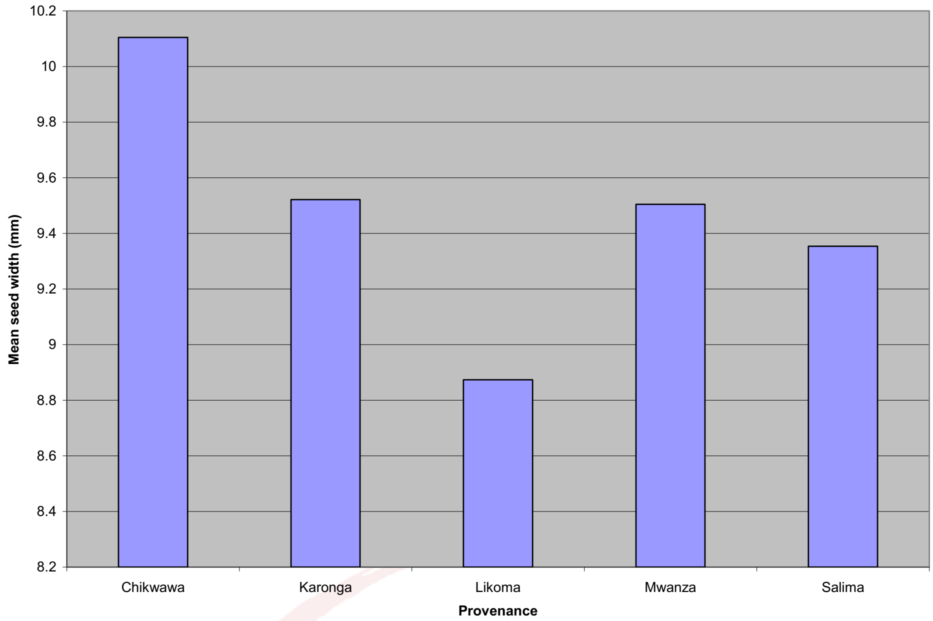

Figure 2: Variation of *Adansonia digitata* in mean seed width between five populations

4.1.3 Seed length

Figure 3 shows the variation in seed length between five populations. There were significant differences in seed length between the five populations (F=233.79, P<0.001) (Appendix 3). The results showed 12.48mm (from Chikwawa) as the maximum seed length and 10.87mm (from Likoma) as being the minimum mean seed length. The LSD (Appendix 10) shows that there were no significant differences between Chikwawa, Mwanza, Karonga and Salima except Likoma.

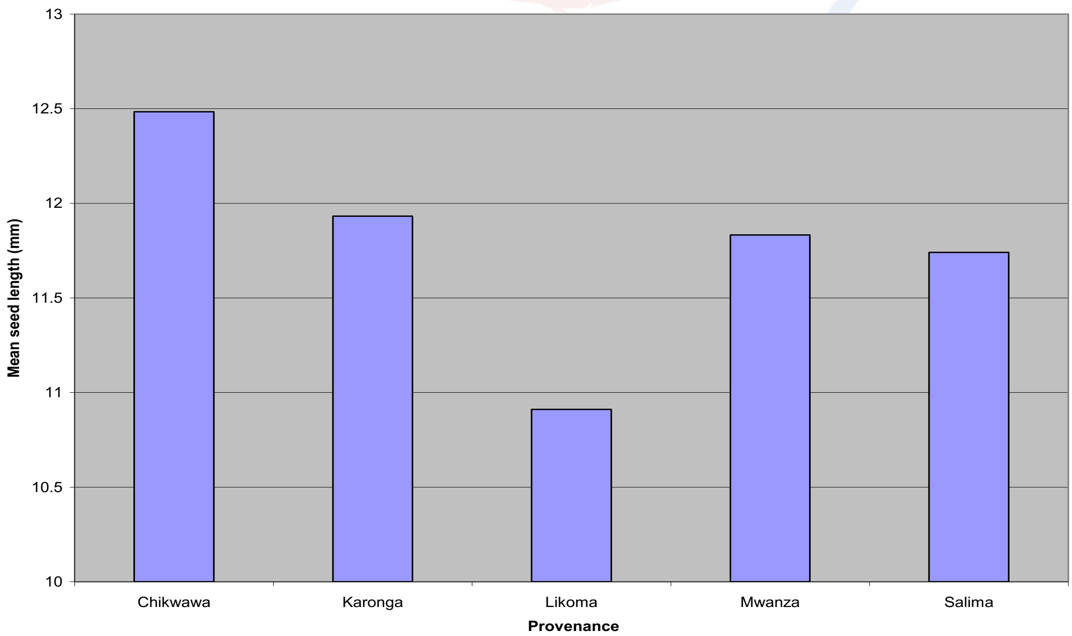

Figure 3: Variation of *Adansonia digitata* in mean seed length between five populations

4.2 Variation of seed weight within population

4.2.1 Variation of seed weight within Karonga population

Appendix 11 shows variation in mean seed weight within Karonga population. The results disclosed significant differences in mean seed weight between trees (F=29.53, P<0.001) (Appendix 4). The heaviest seed had a weight of 0.6115g. This seed was from tree number 3. On the other hand, the lightest seed (0.4151g) was observed from tree number 5 (Appendix 11). The average weight of seeds was 0.4779g.

4.2.2 Variation of seed weight within Chikwawa population

Variation in mean seed weight of A. digitata within Chikwawa population is shown in Appendix 11**.** There were significant differences (F=31.02, P< 0.001) (Appendix 5) in mean seed weight between the trees in Chikwawa population. *Adansonia digitata* showed heaviest seed of 0.7439g and lightest seed of 0.4777g from tree number 2 and 6 respectively (Appendix 11). The average weight recorded was 0.5751g.

4.2.3 Variation of seed weight within Mwanza population

Appendix 11 shows variation in mean seed weight of A. digitata within Mwanza population**.** The results showed significant differences in mean seed weight between trees (F=61.87, P<0.001) (Appendix 6). The heaviest seed (0.6112g) came from tree number 12 while the lightest weight (0.3958g) was observed from tree number 1. The average seed weight observed was 0.5159g (Appendix 11).

4.2.4 Variation of seed weight within Likoma population

Appendix 11 shows variation in mean seed weight of A. digitata within Likoma population**.** There were significant differences in mean seed weight within trees (F=24.53, P<0.001) (Appendix 7). The seed with greatest weight was from tree number 7, with weight of 0.4674g. The minimum value in seed weight was 0.2995g, observed in tree number 4. The average seed weight was 0.3669g.

4.2.5 Variation of seed weight within Salima population

Appendix 11 shows variation in mean seed weight of A. digitata within Salima population. There were significant differences in mean seed weight (F=96.00, P<0.001) (Appendix 8). The results showed 0.5875g as the minimum seed weight from tree number 10, 0.3799g (tree 15) as being the maximum mean seed weight. The average seed weight was 0.5037g.

4.3 Pearson’s correlation matrix of seed characteristics

Table 1 shows the correlation matrix of the seed traits. The results indicated that there is a significant weak correlation among seed length and seed width (P=0.000). Pearson’s correlation analysis showed that seed length was lowly correlated with seed width (r=0.265, P=0.000). On the other hand Pearson’s correlation analysis showed that there is a linear relationship between seed weight and seed length (r=-0.005, P=0.779) and seed weight and seed width (r= -0.005, P=0.801).

Table 1: Pearson's correlation coefficient of seed characteristics of *Adansonia digitata* in five populations

Seed traits	Seed weight	Seed length
Seed length	-0.005 **0.779**	
Seed width	-0.005 **0.801**	0.265 **0.000**

4.4 Seed germination

Table 2 displays days germination started, days germination completed and the final germination percentages of *A. digitata* seed subjected to various pre-treatments, Analysis of variance indicated no significant differences (P=0.599) between all provenances in terms of pre-sowing treatments. However, Salima population recorded slightly higher mean germination percent (49) whereas Mwanza population had the lowest mean germination percentage of 7 (Table 1). Results also showed significant interaction between pre-treatments and provenances (F=7.24, P<0.001) (Appendix 9).

Germination started with seeds soaked in water over night from Karonga population, seeds nicked using secateur from Karonga population and seeds nicked using secateur from Salima population on the ninth day. As germination progressed, seeds soaked in water over night from Karonga population, seeds nicked using secateur from Karonga population and seeds nicked using secateur from Mwanza population were the first to complete germination after 41 days after sowing.

Table 2: Pre-treatments, days germination started, days germination completed and final germination rate

Pre-treatment	Days germination started	Days germination completed	Final germination percentage
T1	15	45	23.5
T2	13	45	8
T3	12	44	22
T4	11	43	24
T5	9	41	18
T6	9	41	37
T7	18	47	28
T8	16	46	21
T9	13	44	17
T10	17	45	15
T11	11	46	31
T12	11	41	7
T13	16	44	16
T14	15	47	38
T15	9	42	49

T 1: Seeds not pre-treated from Chikwawa population
T 2: Seeds soaked in water over night from Chikwawa population
T 3: Seeds nicked using secateur from Chikwawa population
T 4: Seeds not pre-treated from Karonga population
T 5: Seeds soaked in water over night from Karonga population
T 6: Seeds nicked using secateur from Karonga population
T 7: Seeds not pre-treated from Likoma population
T 8: Seeds soaked in water over night from Likoma population
T 9: Seeds nicked using secateur from Likoma population
T 10: Seeds not pre-treated from Mwanza population
T 11: Seeds soaked in water over night from Mwanza population
T 12: Seeds nicked using secateur from Mwanza population
T 13: Seeds not pre-treated from Salima population
T 14: Seeds soaked in water over night from Salima population
T 15: Seeds nicked using secateur from Salima population

CHAPTER 5: DISCUSSION

5.1 Variation in fruit parameters between populations

The significant differences ($P<0.001$) shown in seed traits between five populations of *A. digitata* (Figures 1, 2, 3 and Appendix 10), may signify that the populations are genetically different. Breitenbach (1985) reported that growth variation of baobabs is the only parameter that is due to genetic origin. On the other hand, Gebauer *et.al*., (2002) and Sidibe and Williams (2002) reported that variation in fruit characteristics of *A. digitata* can either be due to genotypic composition or environment in which the trees are growing. The results agree with the work done in Zambia, which revealed some significant variations in *Strychnos cocculoides* between and within provenances in fruit and seed weight (Mkonda *et.al*., 2003). Hence the variation in the fruit characteristics of *A. digitata* between the five populations could be due to differences in genetic composition.
Results are showing that seed length is more variable (Appendix 10) than seed weight and seed width (Figure 3). This is agreeing with some work done by Ngulube *et. al*., (1997) who reported that variation in fruit traits and seeds collected from natural stands are attributed to genetic control or phenotypic origin or both. Hence, the variation in seed traits of *A. digitata* between the five populations could be due to differences in genetic composition.

5.2 Variation in fruit parameters within populations

Significant differences in seed weight (Appendix 11) observed within the five populations may indicate that individual trees are different genotypes although they may occur under similar environmental conditions. The results are supported by Gebauer *et.al*., (2002); Sidibe and Williams (2002) who found that variation within seed characteristics are due to genotypic differences. The other possible reason for variability within each population could be as a result of mutation (Sniegowski *et.al*, 2000).

Correlation matrix of seed parameters

There are weak correlations between seed length and seed width (Table 1). The weak correlation between the seed length and seed width shows that one cannot conclude by only measuring the seed length to predict the seed width measurements. On the other hand, there was no significant dependency of the seed weight and seed length but also seed weight and seed width (Table 1).

5.3 Germination rate of *Adansonia digitata*

The results from (Appendix 9) show that there are significant differences in germination rate in populations of *Adansonia digitata*. Figure 1 show that in some population germination rate was faster than in other populations. It is expected that the variations in germination rate of *A. digitata* are due to genetic effect because seeds were grown in a homogeneous environment (Raven, *et.al*., 1999). The apparent causes of low germination rate in some populations may be attributed to inbreeding that might be occurring in the provenance as evidenced by an albino observed in the Karonga population (Appendix 13). The results also showed that there were no significant differences in pre-sowing treatments (Appendix 9) where $P=0.599$. This may mean that the variation observed in germination rates was due to genetic composition and not pre-sowing treatments *per se* (Munthali, 1999).

It is observed that, Mwanza had a slow germination rate, while Chikwawa, Karonga, Likoma and Salima had a faster germination rate (Figure 4). Igboeli *et al*., (1997) suggest that the germination rate is not only influenced by the provenance from where the seed was collected, but also the weight of the seed. Large or heavy seeds are an indication of abundant food reserves from the mother tree. But also one needs to use heavy seeds because they store a lot of vitamins (Diop *et al*., (2005).

CHAPTER 6: CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

The study has shown that there are significant differences in seed weight, length and width between and within the five populations of *Adansonia digitata* in Malawi, and these variations affect the seed germination rate. Variation in seed characteristics might be strongly attributed to genetic control than environmental factors. The paper has substantiated that pre-sowing treatments does not affect seed germination rate but the interaction between pre-sowing treatments and provenances affects the seed germination rate of *A.digitata*.

6.2 Recommendations

Based on the findings of the study the following recommendations are put forward:

- The information obtained in this study can be packaged into the extension training kits where rural communities should be sensitised on the need to select superior germplasm for planting.
- Further studies should be done on the effect of seed size on seed germination rate of *Adansonia digitata* L. from provenances of different silvicultural zones. To add on this, heritability studies should be done in order to ascertain how much genes can be heritable from the mother trees to the progenies.

DEFINITIONS OF TERMS

Population: Group of organisms of the same species living together within a common area at the same time
Phenotype: The morphological, physiological, behavioural, and other outwardly recognisable forms of an organism that develop through the interaction of genes and environment.
Genotype: The genetic constitution of an organism, acquired from its parents and available for transmission to its offspring.
Variation: Occurrence of difference among individuals of the same species attributed to differences in their genetic composition or the environment in which they are raised.
Inbreeding: The production of offspring by mating related organisms.
Trait: Observable characteristics.

LIST OF ACRONYMS

ANOVA	Analysis of variance
CRD	Complete Randomised Design
CV	Coefficient of variance
FAO	Food and Agriculture Organisation
LSD	Least Square of Differences
No.	Number
s.e	Standard error
SED	Standard Error of Differences
g	Gram
Cm	Centimetres

APPENDICES

Appendix 1: Population seed weight (g)

Source of variation	Degrees of freedom	Sum of squares	Mean squares	F value	P value
Site	4	10.853069	2.713267	570.45	<0.001
Site. Treatment	57	12.469630	0.218765	45.99	<0.001
Residual	2927	13.921830	0.004756		
Total	2988	37.244529			

Appendix 2: Population seed width (mm)

Source of variation	Degrees of freedom	Sum of squares	Mean squares	F value	P value
Site	4	283.0954	70.7739	177.84	<0.001
Site. Treatment	57	685.4756	12.0259	30.22	<0.001
Residual	2927	1164.8189	0.3980		
Total	2988	2133.3899			

Appendix 3: Population seed length (mm)

Source of variation	Degrees of freedom	Sum of squares	Mean squares	F value	P value
Site	4	560.5717	140.1429	233.79	<0.001
Site. Treatment	57	886.8421	15.5586	25.96	<0.001
Residual	2927	1754.5701	0.5994		
Total	2988	3201.9839			

Appendix 4: Variation within Karonga population in terms of seed weight (g)

Source of variation	Degrees of freedom	Sum of squares	Mean squares	F value	P value
Family_Karonga	8	1.617783	0.202223	29.53	<0.001
Residual	416	2.848598	0.006848		
Total	424	4.466381			

Appendix 5: Variation within Chikwawa population in terms of seed weight (g)

Source of variation	Degrees of freedom	Sum of squares	Mean squares	F value	P value
Family_Chikwawa	15	2.570467	0.171364	31.02	<0.001
Residual	693	3.828280	0.005524		
Total	708	6.398747			

Appendix 6: Variation within Mwanza population in terms of seed weight (g)

Source of variation	Degrees of freedom	Sum of squares	Mean squares	F value	P value
Family_Mwanza	13	2.533346	0.194873	61.87	<0.001
Residual	779	2.453732	0.003150		
Total	792	4.987079			

Appendix 7: Variation within Likoma population in terms of seed weight (g)

Source of variation	Degrees of freedom	Sum of squares	Mean squares	F value	P value
Family_Mwanza	13	2.533346	0.194873	61.87	<0.001
Residual	779	2.453732	0.003150		
Total	792	4.987079			

Appendix 8: Variation within Salima population in terms of seed weight (g)

Source of variation	Degrees of freedom	Sum of squares	Mean squares	F value	P value
Family_Salima	14	4.566091	0.326146	96.00	<0.001
Residual	681	2.313505	0.003397		
Total	695	6.879595			

Appendix 9: Germination rate

Source of variation	Degrees of freedom	Sum of squares	Mean squares	F value	P value
Pre-treatment	2	0.9950	0.4975	0.52	0.599
Pre-Treatment. Provenance	12	83.2465	6.9372	7.24	<0.001
Residual	45	43.1402	0.9587		
Total	59	127.3818			

Appendix 10: Table showing fruit variation in fruit parameters within the population of *A. digitata*

Population	Seed weight (g)	Seed length (mm)	Seed width (mm)
Chikwawa	0.5751a	12.400c	9.932g
Mwanza	0.5159a	11.880cde	9.555g
Karonga	0.5037a	11.804d	9.447g
Salima	0.4779a	11.772e	9.432g
Likoma	0.3669b	10.885f	8.870h
Grand mean	**0.5035**	**11.846**	**9.58**
P-value	**P<0.001**	**P<0.001**	**P<0.001**
LSD	**0.0619**	**0.6949**	**0.5662**

Appendix 11: Table showing seed weight variation within families of A. digitata in (g)

Provenance	Serial number	Family	Mean seed weight(g)
Chikwawa	1	2	0.7439*a*
	2	4	0.6564*b*
	3	12	0.6348*b*
	4	16	0.6214*b*
	5	7	0.5985*b*
	6	1	0.5888*bc*
	7	14	0.5705*bc*
	8	10	0.5652*bc*
	9	15	0.5624*bc*
	10	3	0.5623*bc*
	11	8	0.5604*bc*
	12	11	0.5599*bc*
	13	9	0.5390*bc*
	14	5	0.5332*bc*
	15	13	0.5171*bcd*
	16	6	0.4777*bcd*
Grand mean	**0.5751**		
S.e	**0.07433**		
LSD	**0.06740**		
CV	**12.9%**		
Karonga	2	3	0.6115*a*
	3	2	0.5514*b*
	5	14	0.4919*bc*
	7	11	0.4723*bc*
	8	7	0.4556*bcd*
	11	12	0.4501*bcd*
	12	13	0.4468*bcd*
	13	8	0.4155*bcde*
	14	5	0.4151*bcde*
Grand mean	**0.4779**		
S.e	**0.08275**		
LSD	**0.03451**		
CV	**17.3%**		
Likoma	2	7	0.4674*a*
	3	9	0.4428*a*
	4	3	0.3877*b*
	5	5	0.3839*b*
	6	2	0.3515*c*
	7	6	0.3225*c*
	9	10	0.3108*bcd*
	10	4	0.2995*bcd*
Grand mean	**0.3669**		
S.e	**0.08320**		
LSD	**0.03606**		

CV	**22.7%**		
Salima	1	10	0.5875*a*
	2	9	0.5817*a*
	3	3	0.5800*a*
	4	2	0.5799*a*
	5	5	0.5698*a*
	6	8	0.5613*b*
	7	1	0.5607*b*
	8	12	0.5411*b*
	9	6	0.5214*bc*
	10	14	0.4509*bcd*
	11	4	0.4204*bcde*
	12	13	0.4073*bcde*
	13	7	0.3861*bcdef*
	14	11	0.3841*bcdef*
	15	15	0.3799*bcdef*
Grand mean	**0.5037**		
S.e	**0.05829**		
LSD	**0.02378**		
CV	**11.6%**		
Mwanza	1	12	0.6112*a*
	2	15	0.5545*b*
	3	3	0.5402*b*
	4	14	0.5376*b*
	5	9	0.5342*b*
	6	8	0.5321*bc*
	7	11	0.5319*bc*
	8	2	0.5238*bc*
	9	10	0.5196*bc*
	10	7	0.4790*bcd*
	11	13	0.4684*bcd*
	12	6	0.4520*bcde*
	13	5	0.4170*bcde*
	14	1	0.3958*bcdef*
Grand mean	**0.5159**		
S.e	**0.05612**		
LSD	**0.02047**		
CV	**10.9%**		

Appendix 12: Table showing variation of mean germination rate of A. digitata between provenances

	Provenance					
Pre-treatments	Likoma	Salima	Mwanza	Chikwawa	Karonga	Mean
Control	5.24a	3.98b	3.92d	5.12g	4.90j	4.63
Nicking	4.15a	6.98b	2.47e	4.79g	6.09j	4.90
Hot water	4.59a	6.13c	5.47ef	2.65hi	4.27jk	4.62
Mean	4.66	5.70	3.95	4.19	5.09	**4.72**
LSD	**1.394**					

Appendix 13: Albino in Karonga population

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Ecocinema in the Anthropocene Era

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The European Conference on Sustainability, Energy & the Environment 2015
Official Conference Proceedings

Abstract
The Anthropocene epoch has been proposed as a geological label for the period of Earth's history which began when humans first started to have large-scale influences on the Earth's ecosystems. Ecocinema responds to the ideology that underpins the negative effects of the Anthropocene; the paradigm that humans have dominion over nature and natural resources can be unsustainably exploited for commercial gain. Western culture has defended human mastery of the earth from Plato's conception that the immortal human soul belongs to the world of ideas not nature, to the Judeo-Christian notion that the soul is gifted by an omnipotent God who has given man dominion over all living things, to Descartes' argument that self is separate from matter, and to Locke's (1700) contention that our identity is dependent on our sense-impressions, not our place in the physical world. Modern mainland China has experienced convergent beliefs since Mao's revolution swept away Buddhist, Confucian and Taoist conceptions of human society and its relationship with nature. Since 1979, China's unfettered economic revolution has lifted millions from poverty at catastrophic environmental cost. This paper examines how we moved from animist notions that posited life-force in all entities to our current unsustainable paradigm. It analyzes a number of Western and Chinese films that seek to raise consciousness about the impact we are having on the planet, and finally discusses emergent technologies that could be exploited by ecocinema film-makers to heighten empathy with the non-human other, and reconnect nature with the soul.

Mind-Body Dualism

The concept of mind-body dualism rests in the distinctions human thought has made between the conscious mind, variously represented as spirit, soul and self, and the seemingly mechanistic actions of the human body and the natural physical world it inhabits. It represents a movement of cosmological thought away from animist beliefs which regard all entities, including humans, as having approximately equal life-force. In Western culture, the origin of the conflictive relationship between human beings and nature can be found in Plato`s *The Republic* with his argument that humans possess an immortal soul belonging to the world of ideas. Judeo-Christianity built on this separation by postulating a hierarchy of natural kingdoms predicated on the belief that the human soul is gifted by an omnipotent God. This was in sharp contrast to polytheistic and animist belief systems which saw spirits or gods in every aspect of nature. The new hierarchy posited that there was one omnipotent God under whom humans were in a dominant and exterior position to nature. In this hierarchy, humans hold a special place outside of nature since the divine soul is only present in human beings. Therefore, those who live in cultures steeped in Abrahamic thought perceive themselves as separate from the natural world because it is not their body but their *soul* which characterizes them as individuals (Gilardi, 2008).

This idea found resonance in the Enlightenment approach to how humanity and nature should co-exist. Cartesian philosophy extended the sense that the human soul was separate from the natural world. Evernden (1996) writes in Ecocriticism’s foundational text *The Ecocriticism Reader*: “Since Descartes […] we are not a part of an environment, we are not even part of a *body*. We, the ‘real’ us, is concentrated in some disputed recess of the body, a precious cocoon, separate from the world of matter. Far from extending our ‘self’ into the environment […] we hoard our ego as tightly as we can” (p.98).

Batra (2003) adds that: “The most influential modern reinforcement of the dualist position came, of course, from Descartes, whose 1637 *Discours de la mèthode* contained the notorious *bêtemachine* theory that animals were mere bodies, no more than automata. Both humans and animals bodies could be considered automata, but speech and the soul separated the human from the animal” (p.156).
Locke (1700) extended the distinction between mind and the physical world by rejecting Descartes’ notion of innate ideas, saying instead that we construct our identity throughout our lives from sense perception. Therefore, that which actually leads to self is a conscious memory of self. He argued that although the body changes from baby to adulthood, what does not change, in order to maintain self, is the conscious ability of an individual to link the old sense of self with the young sense of self. The logical conclusion being that someone who has lost this ability to construct a conscious memory of self no longer possesses meaningful identity. Hence, religious and metaphysical conceptions of self moved Westerners away from the sense of belonging to the natural world. With the onset of scientific and industrial revolution, modern man would continue to stress the difference between spirit and body (Gilardi, 2008).

Westerners are not the only ones to reflect on this dislocation from nature. The fracturing of human society from nature has also been one of the consequences of Maoist socialism in China, particularly the disastrous Great Leap Forward, and has been exacerbated by the unfettered economic development that has taken place in China since Mao's death. In the introduction of *Chinese Ecocinema*, Lu (2009) gives a clear explanation of how Mao Zedong's revolution tore apart the traditional Confucian and Taoist relationships of society and nature. Confucianism showed how humans could reduce conflict by respecting hierarchical social relationships, while Taoism expressed the need for harmony with Tao, which in practice meant seeking to live a peaceful life while respecting the natural world. After Mao's death, economic development replaced class struggle as the organizing paradigm, and the Taoist ideal of harmony with nature receded as development devastated the environment (Lu, 2009).

The most important consequence of this separation of self from nature is the current paradigm, propagated worldwide through globalization, that GDP growth is more desirable than sustainability. Both developed and developing nations have, to varying degrees, policies that view nature as something external that can be owned, transformed, and exploited. Evernden (1996) considers that 'what we really mean when we speak of man/environment relationships' is looking 'on the world as simply a set of resources to be utilized […] not thinking of it as an environment at all' (p.98).

Our impact on the world has led to the naming of a new geological epoch, the Anthropocene, from the Greek word meaning human. This epoch has been dated back 8,000 years when human-caused deforestation first caused noticeable rises in greenhouse gas emissions (Ruddiman, 2013), but it is since the Industrial Revolution of the late 18th century that anthropogenic effects on the Earth have achieved exponential rates. Consequences that have led to the realization that humans should not be viewed as separate from the natural world. As Evernden (1996) puts it, we must reaffirm the idea of 'man who is in an environment in which he belongs and is of necessity a part' (p.98).

This reconceptualization is an essential aspect of consciousness-raising in ecocinema. We will therefore describe a series of environmental documentaries that show how the idea of human ownership of nature has been criticized in ecocinema. We will then show how different kinds of ecologically minded films have tried to educate viewers toward an animistic relationship occurring between humans and nature. Finally, we will show how new technologies could help ecocinema create immersive experiences that enhance human empathy toward nature and non-human life.

Owning Nature

Humanity's entitlement to dominate nature has been forcefully challenged by a series of documentaries released since the first photo of the earth, taken in 1972 from Apollo 17, raised global consciousness about the uniqueness and fragility of life. This photo showed our blue world as a unified whole suspended in the hostile blackness of outer space. From this period on ecological movements gathered pace in the industrialized world. One of the most important early examples of ecocinema documentary is Koyaanisqatsi (1982), meaning 'Life out of balance' in the Hopi language. This is the first film of the Qatsi trilogy, followed by Powaqqatsi (1988) and Naqoyqatsi (2002). It powerfully reinforces the contrast between perceived animist integrity and the peril of mind-body dualism with visually stunning images showing a cycle of civilization from pre-history to the space age. It begins with a view of cave paintings and moves immediately to a slow motion frame of a powerful rocket taking off. These two ends of the spectrum of human development are then contrasted with eighteen minutes of beautiful uncontaminated landscape ranging from aerial shots of the desert to mountain scenery. Suddenly an explosion occurs – a clear sign of technological humanity. This is revealed to be a controlled mining demolition. An enormous mining vehicle appears and becomes engulfed in clouds of pollution. The mining infrastructure and pipelines are shown, and pylons are tracked as if marching across the desert landscape. The human mark is straight and linear, in contrast with the flowing form of the natural environment. Images of industrialization become progressively more complex. The sense of exponential population growth is heightened by the speeding up of the film, showing crowds of city dwellers commuting. Finally a rocket explodes in a violent fire ball and debris is seen falling to earth for many minutes before the final scenes of the movie revert back to human cave paintings in the desert.

The commentary of this documentary is provided solely by the musical composition of Philip Glass which provides a "guideline" for an interpretation of the images. The combination of electronic, orchestral and choral music with images of the environment imposes a kind of quasi-emotional narrative that seeks to demonstrate that industrialization cannot progress beyond a certain point. Once a certain level of technological achievement is attained disaster will occur and society will revert back to the Neolithic. This is clearly a political statement reinforcing a strongly political ecological agenda. It shows that the rate of human industrialization is representative of 'life out of balance'; there is no attempt to show an alternative scenario in which sustainable development is achieved.

More recent documentaries explicitly show that we are still very far from this alternative outcome. *Sustainable Table* (Hedges, 2006) and *Food, inc.* (Kenner, 2008) focus on the consequences that our agri-businesses have for ecology and health showing that the GDP paradigm of our contemporary global society, which sees the environment as an external object to be subjugated and exploited, is profoundly unsustainable. However, unlike Koyaanisqatsi (1982), these films argue that a new sustainable conception of human interaction with the environment is required. Al Gore's *An Inconvenient Truth* (Bender *et al*, 2006) underlines global warming as the most serious result of strip-mining the earth and burning ancient trapped sunlight. The inconvenience of this truth refers to the fact that we require a new paradigm in our approach to energy; 'business as usual' will ecologically and economically devastate civilization. Likewise, the contrast between civilization and the environment is powerfully rendered in *Manufactured Landscape* (Baichwal, 2006) which expands and examines the world of Burtynsky's photographs by collecting real-time footage of the original sites shown. It shows the contrast between the improvement of the quality of life brought about by the human ability to adapt the world to its needs and the deep consequences that this is having in terms of environmental destruction. By doing so, the documentary reiterates the need for a completely new way of thinking about the relationship between humanity and nature. A new approach to this relationship is offered by the documentary *Fuel* (2008). This investigation into the environmental and social damage that fuel processing in the United States creates shows how people could make a difference by switching to alternative renewable energies. The final message is explicit:

The Earth is not a thing. It is not a rock. It is a living being. And we are part of that. If we begin to learn to live by the principles set forth in nature we have an infinite abundance of energy, an infinite abundance of resources. We can sustain every living human being. As well as the human beings that will come. The choice is ours: every single one of us. The rest of the journey is up to you (2008).

This call to arms is also the final message of the French film *Home* (Besson, Carot, Arthus-Bertrand, 2009) that tells Earth's story through contemporary images of human and natural environments. It clearly takes an eco-political position with the opening narration: 'Listen to me, please'. After twenty minutes of beautiful scenery and nature, the mark of humanity appears in the form of positive images of pre-industrial agriculture prior to the discovery of fossil fuels. With the advent of industrialization the images and narration change in tone. Images of destruction, deforestation, and overfishing are interspersed with those of animals in natural environments. The narration calls our attention to the consequences of our anthropocentric view of the world: global warming, climate refugees, species extinction, and the fact that in the past fifty years we have more radically changed the landscape than in all previous generations of humanity. But the final message is a message of hope: 'Culture, education, innovation are inexhaustible resources. Millions of NGOs show that solidarity is stronger than the selfishness of nations.' The examples given are the international treaties implemented to protect the world's territorial waters and Antarctica as a natural park. 'This harmony between humans and nature can become the rule, no longer the exception […] it is up to us to write what happens next.' (2009).

The message *Home* forcefully asserts is that we 'have created phenomena we cannot control. Water, air and forms of life are intimately linked, but recently we have broken these links'. The conclusion reflects animist conceptions of humanity's role in the world: 'life is a balance which we have failed to consider. A cycle of life and we are just part of this chain.' (2009).

Cycle of Life

Environmental documentaries are not the first films to raise environmental concerns. As David Whitley (2012) shows, Disney animations have a long pedigree of showing the conflict between the natural world and humanity. One criticism of these films is that Disney animations are ideologically suspect due to their capitalist imperative and anthropomorphism of nature. Anthropomorphism, however, is not necessarily used to give an anthropocentric point of view but can also be used as a way of building connections, no matter how superficial at first glance, between the human and the animal worlds. By having animals' replicate human characteristics, these films afford the viewer an opportunity to interpret a world that for such a long time has been considered external to human experience. If read from this perspective, anthropomorphism helps to build a link, a common place of understanding, between human beings and the natural world in order to stress the notion that by damaging nature we are damaging ourselves. The fact that these films can be commercially successful speaks to both the love of an expertly rendered story and an appetite for connection with the natural world.

The classic cartoon *Bambi* (Disney & Hand, 1942) contrasts the lives of animals living in harmony with nature with the hunters that kill them by burning the whole forest. 50 years later *Pocahontas* (Pentecost, Gabriel & Goldberg, 2005) revisits the utopian myth of the noble savage by contrasting Western individualism with the harmonious animism of the Native American. One of the songs in Pocahontas is *Colors of the Wind* by composer Alan Menken (1995). The lyrics clearly spell out the contrast between animist thought and the exploitative nature of Abrahamic religious thinking:

You think you own whatever land you land on. The Earth is just a dead thing you can claim. But I know every rock and tree and creature. Has a life, has a spirit, has a name. […] The rainstorm and the river are my brothers. The heron and the otter are my friends. And we are all connected to each other. In a circle, in a hoop that never ends (1995).

The understanding that all nature is connected is also present in *The Lion King* (Disney, Allers & Minkoff, 1994). This is clear in the discussion the Lion King has with his son: 'Everything you see exists together in a delicate balance. As King you need to understand that balance and respect all the creatures from the crawling ant to the leaping antelope.' In response to his son's exclamation: 'But, dad, don't we eat antelope', the King replies: 'Yes, Simba, but let me explain. When we die, our bodies become the grass and the antelope eat the grass. And so we are all connected in the great circle of life' (1994).

Although this notion is increasingly espoused by some business leaders and politicians, it is those who are traditionally disenfranchised from power, the artists and conservationists, who first chip away at our complacency. This is particularly evident with contemporary Chinese films that criticize over-development and the grandiose engineering projects that have taken place there. One of the most egregious of these projects is the Three Gorges Dam which was designed to control flooding and generate electricity, but has thoroughly transformed the environment and uprooted communities. Jia Zhangke's film *Sanxia haoren*/*Still Life (2006)* focuses on the loss of traditional ways of life which have resulted. Rapid modernization and commercialization impacting the environment is explored in many recent Chinese films. *Suzhou he*/*Suzhou River* (2000) depicts an ugly man-made environment near Shanghai which is seemingly being redeemed by the presence of a beautiful blonde mermaid. The viewer then discovers that the mermaid is actually a show girl wearing a blond wig, and the disgust engendered at such vacuous titillation is highlighted by the contrast with the loss of the natural river environment. Many of these films do not so much contrast unspoiled nature with over-hasty development, but traditional pre-capitalistic and pre-industrial ways of life with China's post-1990s economy and the acceleration of environmental degradation. There is thus an element of nostalgia present in many of these films. A yearning to live life in balance; to turn the clock back, not just to pre-globalization of the 1990s, but also in some cases to holistic Buddhist ideals that had been all but extinguished in the socialist revolution (Lu, 2009).

This nostalgia for a lost way to interpret the world around us is a leitmotif in ecocinema productions. As an example, the Italian movie: *Le Quattro volte* (2010), inspired by Pythagoras' ideas that each of us has four lives – the human, the animal, the vegetable and the mineral – shows the life of an old goatherd, a goat, a tree, and a pile of charcoal.

In bringing the goats, the tree and the charcoal-burning process to the foreground and relegating the humans to a less dominant position than is customary, Frammartino believes he has given the audience ‘a pleasant surprise: the animal, vegetable and mineral realms are granted as much dignity as the human one.’ (French, 2011).
Frammartino’s comments on this film suggest that the development of animist empathy is a key factor for ecocinema. In this movie the choice Frammartino made is a radical one, he records only the essential sounds present during filming in order to reduce, as much as possible, the human point of view. This starkly contrasts with *Koyaanisqatsi* (1982) which, as has been shown above, uses music as a way to “influence” the viewer towards a particular narrative reading. It is important, however, to note that *Le Quattro volte* (2010) necessarily shows an anthropocentric point of view of the natural world. What film does not? Although an ecological film may try to render an experience to give voice to the living environment, it is not possible to create a language that express such otherness without becoming entirely unreadable. What ecocinema must be able to achieve is a kind of compromise between representing such a complex alterity without reducing it to the simply banal.

Building Empathy

In his 2000 book *Green Screen*, David Ingram shows how Hollywood technology can raise viewers eco-awareness and thus in a way work against its own capitalist interest. And, as Sideris (2010) writes, James Cameron’s use of technology in *Avatar* (2009) is an expert lesson on the building of empathy as part of moral and spiritual growth, both for the main character in the film and the audience in their immersive experience with Na’vi culture. Rather than being just a marketing gimmick, 3D can aid narrative by using stereoscopic depth to underscore emotional intensity (Higgins, 2013). This can be a particularly powerful way of involving the audience in the narrative and thereby eliciting a heightened sense of empathy. *Avatar* (Cameron, 2009) vividly expresses the link between sentient beings and nature in sequences reminiscent of shamanic and animist Native American cosmology. The sentient creatures (read: Native American) are the Na’vi whose world is being colonized for its resources by humans (read: European settlers). In the most poignant scene to underline the animus of all living things, the Na’vi transfers the spirit of the human hero from his crushed body and places it into his avatar Na’vi body. This movement of spirit from one body to another is not represented as a painful experience but as a liberating and harmonious one, since all living things are linked with a connective life-force. Avatar’s building of empathy is so powerful that despite it clearly being based on a counter-factual re-imagining of the European conquest of America, commentators in China have found redolence in their own country’s policies of forced re-settlement (Liu, 2010).

Although 3D movies may improve audiences’ sense of belonging to the world they view, they are still a passive form of communicative media. The next step is to create products that actually allow users to control avatars; films that more effectively induce empathy by giving the viewer the ability to control the main character’s field of vision and actively look around the world through the eyes of the other. Interactive web documentaries integrate various media, such as photos, audio, animation and text, with web technology. The user becomes an active participant who has to navigate through the story. Unlike a linear narrative, a web documentary enables the user to choose which parts of the audio-visual field to interact with. Visual clues are provided to the user indicating pathways through the narrative, but it is up to the user to decide when to pause and examine or when to pass through.

This has been achieved in the ground-breaking film *Metamorphosis: immersive Kafka* (Kardos, 2010). The project was made using remote-controlled, panoramic cameras to film a linear director's version of the narrative. Computer programs were then used to create a 'spherical film' within which 'virtual cameras' could be placed. The viewer is thus able to watch the default director's cut, but when inclined can use a controller to switch to one of the virtual cameras and view the film from any possible angle (Takacs, 2010). The other aspect of active participation available to the audience is a feature the creators call '*Clickable Content (CC)* […] In simple terms CC means that whenever the user clicks on the scene the rendering engine "fires a search ray" from the viewing camera' to find an object of interest, such as a character or an item, that can be expanded to reveal more information to the viewer (Takacs, 2010, p. 7). Although this technology could be seen as another individualistic manifestation allowing the spectator to have an anthropocentric mastery over the living environment, it could also be seen as a possible way to build empathy by giving the user the experience of being one with the character. If used in ecocinema, it could open new directions for those seeking to raise consciousness and re-connect the human spirit with the natural world. This is not controlling the other but becoming part of the ecological whole. The experience could be read as offering an opportunity to de-centre the individual's relationship with their own body. This does not bring animal consciousness into the forefront of the experience but rather operates as a key that can be used to momentarily estrange the human psyche and so allow for a brief window onto the natural kingdom.

Conclusion

It is clear that environmental messages are not relegated to documentaries or niche market art house movies, but are also propagated through mainstream productions such as Disney animations and blockbuster movies. Through the use of apocalyptic fear in documentaries, to the emotional resonance induced by *Bambi* (Disney & Hand, 1942) and *The Lion King* (Disney, Allers & Minkoff, 1994), and from philosophical references made by art house movies to the use of 3D technologies in blockbusters and interactive technology in emerging internet products, all these filmic texts seem to have a clear and common goal: to develop empathy with the natural world in order to generate revenue and/or raise environmental awareness. The visionary movies of Walt Disney achieve this on the most fundamental level; perhaps because children are inherently more susceptible to the message that the natural world is important. By contrast, environmental documentaries evince a much starker and more political message since they cater to the needs of the educated adult who feels impotent in the face of global disaster and thus need intellectual and emotional argument to connect the mind with the physical world. The message of such films is often strident; a call to arms; and as such they may, as is the case with *Home* (Besson, Carot, Arthus-Bertrand, 2009) accompany the documentary with educational materials to further their cause. In contrast, art house movies and blockbusters may involve the audience by invoking a sense of nostalgia for a lost 'paradise', either by contrasting modern civilization with the utopian ideal of the animist noble savage, or by using intellectual and emotional references to favor visions of a pre-globalized world. Internet-enabled Transmedia marketing of such products provides more interactive ways for consumers to engage in the worlds created, and active participation appears to be the emerging trend in ecocinema. But regardless of the technology being employed, the sheer diversity of films that contain eco-cinematic themes is an indication of the appetite for environmental education and emotional connection with the natural world; an appetite that appears to be growing as we question the paradigms that underpin our epoch's most damaging consequences.

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Climate Change and its Implication on Food Security in Tanzania. The Case of Bagamoyo Rural Agricultural Communities

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European Conference on Sustainability, Energy & the Environment 2015
Official Conference Proceedings

Abstract

Dealing with climate change is an economic necessity to avoid serious disruption to global and national socio-economic development (Stern, 2006). The Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) shows an increase of global average air and ocean temperatures leading to wide spread melting of snow and ice, as well as rising global average sea level (IPCC, 2007). While adaptation is an overriding priority for developing countries, mitigation is also a concern. Tanzania's ratification of the United Nations Framework Convention on Climate Change (UNFCCC) and Kyoto Protocol in 1996 and 2002 respectively, is a step towards ensuring that climate change issues are addressed at the national level (URT. 2012). Seven villages in Bagamoyo were selected. A total of three hundred people were interviewed, two hundred and eighty were reached through Focus Group Discussion. One hundred and forty were reached through Participatory Research Appraisal, and fifty four were interviewed as Key Informants. Official climatic data for rainfall and temperature of 37 years were obtained from District Meteorological Office. Mixed model of descriptive statistics and trend analysis/time series was used to analyse climatic data. Official data reveal that it is difficult to conclude that there is a decrease of amount of rainfall in recent years compared to the past. Rainfall and temperature doesn't have impacts on agriculture from the econometric point of view. Temperature has a slight change between years but increase in the recent years. Analysis of information from community members reveals extreme climatic events affecting food security.

Keywords: Climate change, agriculture, food security, adaptation, mitigation, sustainable development

Introduction

It is not possible to predict precise future climate conditions, but the scientific consensus is that global land and sea temperatures are warming under the influence of greenhouse gases, and will continue to warm regardless of human intervention for at least the next two decades (IPCC, 2007). Many people in the world structure their lives in concert with their environmental contexts. For various reasons associated with climate people can become vulnerable, that is, they are at a high risk of negative outcomes as a result of climatic events that overwhelm the adaptations they have in place (Galvin et al, 2004). There is growing concern that Global Environmental Change will further complicate achieving food security particularly for more vulnerable sections of society (Fischer et al., 2002; Rosegrant & Cline, 2003; Parry et al., 2004). If agricultural production in the low-income developing countries of Asia and Africa is adversely affected by climate change, the livelihoods of large numbers of the rural poor will be put at risk and their vulnerability to food insecurity increased (ILO, 2007). New approaches to develop climate smart agriculture and improve the “hydro literacy” of rural communities can help poor farmers better withstand the shocks of a more variable climate (FAO 2012).
Agricultural production and the biophysical, political and social systems that determine food security in Africa are expected to be placed under considerable additional stress by climate change (FAO, 2007). Tanzania, like other sub-Saharan countries is highly vulnerable to effects of climate change mainly because of the lack of stable economic development and institutional capacity (IPCC, 2001). In order to study these processes in a local context, Bagamoyo district is chosen for closer examination. In many respects, the study area represents ‘average’ conditions in rural Tanzania and also provides an example from the hinterland of a growing metropolis, Dar es Salaam. Particularly, the roadside villages in the area have increasingly peri-urban characteristics, and the dynamics of food system change in such rapidly transforming socio-economic environment also require further exploration (Lerner & Eakin 2010).

Trend and Patterns of Climate Change in Africa with Reference to Tanzania

Climate change is already having significant impacts in developing countries and will affect their ability to achieve the Millennium Development Goals (MDGs) (IPCC, 2007; UNDP, 2008). Developing countries, such as Tanzania, are particularly vulnerable because of their high dependence on climate sensitive livelihood activities and low adaptive capacity. The 2004/05 drought and subsequent poor crop yield in many parts of the country have negatively impacted on Tanzania’s efforts to address poverty and ensure food security and has led to severe power shortage (NAPA, 2007). Predictions show that the mean daily temperature will rise by 30C – 50C throughout the country and the mean annual temperature by 20C – 40C. Predictions further show that areas with bimodal rainfall pattern will experience increased rainfall of 5% – 45% and those with unimodal rainfall pattern will experience decreased rainfall of 5%–15%. All these changes will aggravate the situation leading to increased vulnerability of the communities to the impacts of climate change and also affecting the sectors of the economy especially agriculture, water, energy, health and forestry (NAPA, 2007).
Rainfall patterns in the country are subdivided into: tropical on the coast, where it is hot and humid (rainy season March-May): semi-temperate in the mountains with the short rains (*Vuli*) in November-December and the long rains (*Masika*) in February –

May: and drier (*Kiangazi*) in the plateau region with considerable seasonal variations in temperature. The mean annual rainfall varies from 500 millimetres to 2,500 millimetres and above. The average duration of the dry season is 5 to 6 months. However, recently, rainfall pattern has become much more unpredictable with some areas/zones receiving extremely minimum and maximum rainfall per year (NAPA 2007). Temperature in Tanzania also varies according to the geographical location, relief and altitude. This temperature variation has significant impact on the agro-ecological zones. To address the challenge, the government has undertaken several efforts including undertaking a Quick Scan on then Impacts of Climate Change in 2009; preparation of the National Adaptation Programme of Action (NAPA) in 2007, CDM Guide for Investors in 2004 and the Initial National Communication to the UNFCCC in 2003. These have contributed to better understanding of the present and future impacts of climate change and possible opportunities. In this regard a need for a better institutional arrangement has been underscored (URT, 2012).

Climate Change, Agriculture and Food Security

Agriculture is the mainstay of the Tanzanian economy contributing about 23.7% of GDP in the year 2011, 30.9% of export earnings and employs about 75% of the total labour force. Over the past decade, the agricultural sector grew at an average rate of 4.4%. The rate of growth in agriculture is higher than the average annual population growth rate of 2.9%, implying growth in incomes (URT, 2012. Attaining poverty reduction would require an annual agricultural growth rate of about 10% (URT, 2009). The agricultural sector comprises of crops and livestock sub sectors. Policy wise, the agricultural sector relates to crop production taking into account the synergies with other closely related policies like that of livestock, marketing and irrigation. On average, crop production contributes about 19.0% of GDP and grows at 4.1% (URT, 2008) while livestock production contributed about 5.9% of the GDP and grow at 4.3%. Food crop production is growing at a rate of about 2.8%, accounting for about 65% of agricultural GDP while cash crops account for about 10%. Maize is the most important crop accounting for over 20% of total GDP. Food and cash crops account for about 70% of rural incomes. There has been an observed decline in rainfall of 50-150 mm per season (March to May) and corresponding decline in long-cycle crops across most of Eastern Africa (Funk et al, 2005). It is from the light of the problems that this paper seeks to identify the trend and patterns of climate change that can be used for agricultural planning for better livelihoods of people at Bagamoyo district.

Methods and Materials

Study Area

Bagamoyo district is one of 6 districts of the Coast Region of Tanzania. Bagamoyo District as a whole had a total population of approximately 311,740 according to census in 2012. The district is composed of 22 wards (URT Census report 2012), which have a total of 82 villages. Bagamoyo was among 13 districts in Tanzania where the stakeholders' consultation during NAPA preparation were undertaken (Mahenge et al, 2012). In this study, seven villages of Western part of Bagamoyo were selected for closer analysis. The villages are Mkenge, Lugoba, Msoga, Diozile, Mindu Tulieni, Makombe and Saleni.

The reasons for selecting Bagamoyo district includes the average characteristics of the area in the Tanzanian context in terms of several poverty indicators and the dominant role of subsistence farming as the traditional source of livelihood (PHDR 2005). Several studies carried out in Bagamoyo district focused on climate change and food security, marine ecosystem, tourism, settlements and mangroves (Lyimo 2013, Yanda 2013, Mahenge et al, 2012, Mbwambo et al, 2012, Shaghude 2011, NAPA 2007). Different literature revisited shows that population increase leads to expansion of farm lands and grazing lands at the expense of forest and woodland areas. The present understanding of changes as a complex and interactive system involving population change and its impacts on agriculture is inadequate calling for a new study. The presence of rich literatures about the study area provides a good background understanding.

Figure 1. Map of the study area

Source: Bagamoyo District map and survey office

Primary Data Collection

An essential part of the research materials, data were collected during field work periods between September -December 2013 and January-March 2014. Additional secondary data was collected in December 2014. Altogether, the field work was carried out of which the most was spent in the study villages and a few weeks in

Bagamoyo town, Chalinze, and Dar es Salaam where additional information from governmental and private agencies was collected. The field work methods included 54 thematic interviews with key informants, 14 PRA exercises and 28 group discussions (FGD), as well as 300 structured questionnaire interviews.

Questionnaire Survey

A total of 300 household survey questionnaires were conducted where by seven villages were purposively selected and the questionnaire included questions regarding climate change such as seasonal rainfall and temperature, trend and patterns. The relatively high average age of the respondents made it possible to ask about the past events and particularly the situation in the past. In order to put more weight on the historical analysis, several questions basing on past climate and food security were included. During survey, respondents were also given more time to take up additional issues if such appeared. Random sampling was applied in a manner that the assistants or the researcher walked criss-cross through different sub-villages and selected approximately every 20th household for the interview. The average age of the surveyed was 41-55 years, the youngest interviewee being between 18-25 and the oldest above 65 years old. The sample involved about 5.0% of the total number of households in the studied villages according to the population figure from 2012. This means a margin of error of 6.0% with a 95% confidence level for the questions asked from all respondents.

Participatory Research Approach (PRA)

This was used through survey where purposive sampling through selecting adults and elders who have long time experience was used and the response being compared with the one obtained from the records. That's local perception on climate change. This involved both men and women. A total of 14 PRA were organized in all seven study sites/villages (each 2 PRA exercises). Local people from different backgrounds, regardless of their social position in their communities, were asked to participate. By doing PRA, the researcher, local people met development practitioners and government officials to articulate their livelihood conditions, their needs and their views so as to further develop their communities. The voice of the local people is central, since they are the experts of their specific livelihood and social conditions and environment (Kumar, 2002; Narayanasamy, 2009). They reflect the perceptions of the local people regarding seasonal variations on a wide range of items (Kumar, 2002, p. 148). The primary outputs of these exercises were calendars indicating the monthly variations in the climate patterns. Repeating the same exercise in a similar manner in all seven study villages gave some grounds for comparison and verification, which were then further reflected with available data.

Focus Group Discussion (FGD)

They were more participatory than the other PRA exercises, because the role of the researcher was more that of a facilitator of the discussion than a leader who determined the exercise process. Certain topics and questions were set beforehand, but many more emerged during the lengthy discussions. The participants included mostly village council members, women, youth groups and pastoralists. Group discussions are said to build up collective and creative enthusiasm, which leads to sharing familiarizing new ideas and concepts with an outsider who then familiarize with them (Chambers, 1992). In this regard, the population was sorted into groups, and described how each group accesses climate change. In this study, a total of 28

FGD (4 in each village) were organized. In each group, purposive sampling was applied in order ensure equal participation of certain segment of population such as gender, age groups, occupation and marital status.

Key Informants/Thematic Interview

Key informant interviews likewise, enable the study to obtain climate information from people with long term experience on the area as well as expert knowledge thus counterchecking the credibility of data from other sources. The questions involved were experience of climatic and food shocks, success and challenges information. The questions considered also political, economic and socio-cultural issues related to climate variability and food security. In this regards, a total of 56 key informants' interviews were conducted in all seven villages where 9 key informants were selected from each village. These were village elders (both men and women), government officers (national, district, ward and village levels), teachers, charcoal producers, shop keepers and traditional healers.

Demographic Data

Official population data from the area, including numbers of households and age groups by sexes, is available in national censuses made in 2012 (URT, 2012). The analysis started already during the early phases of the field work, so that data collection could be focused on issues and groups that are important for the studied phenomena. Usage of different qualitative and quantitative methods enabled triangulation, a form of crosschecking (Mikkelsen 2005: 96−97; Nightingale 2009). For examination of thematic interviews, group discussions, and conversations that stemmed up during the PRA exercises, the main method was textual analysis involving latent content analysis and matrix displays. Latent content means researcher's subjective interpretation and summarization of particular themes in the texts, which in this case were transcribed interviews. These themes, such as poor availability of rains or food shortages, are not necessarily represented with the same wording by different sources, and thus interpretation is needed (McBurney & White 2009: 234−235).

Findings and Discussion

We look at rainfall and temperature patterns and trend in terms of distribution and intensity, as both have major implications for agriculture and other livelihoods in the area. Looking at the temperature data, overall patterns and trend especially at the number of hot years and mean dry spell durations; the data are relevant to the evaporation rate and to crop production cycles, storage and also indicate the level of risk of heat stress, which affects both crops, and people's health and ability to work. To achieve this, the analysis is divided into first part secondary data analysis (rainfall and temperature) analysis where mixed modal of descriptive statistics and trend analysis/time series are used. The second part is based on primary data analysis (obtained from the field work) through household survey, PRA and FGD where triangulation and researchers interpretation are used.

Mixed Modal with Descriptive Statistics and Time Series Analysis

This part deals with the analysis and interpretation of the study from the quantitative data obtained on amount of rainfall as well as degree of temperature from 1978 to 2014 (37 years). For the purpose of in-depth trend and patterns, a mixed model of analysis was adopted. This model consists of both descriptive statistics as well as time series analysis. To establish the trends and patterns of rainfall average amount of rainfall as well as temperature was used for analysis purposes. The patterns and trend time series analysis was done based on years as well as months for both rainfall and temperature. Years are treated as fixed because they are constant throughout and act as independent variable because they have so many levels. The months are covariate because they are core variable which the investigation of their effects is based upon. The error effect is type III error meaning that the results obtained comes from the output (no influence of external variables). The mixed modal with time series is adopted because of frequency analysis and standard deviations and trend analysis is for observing in depth patterns and trend of rainfall and temperature in years and months and their significance difference.

Table1: Descriptive statistics of rainfall 1978-2014

Year	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
Mean	**234**	**235**	**216**	**234**	**239**	**235**	**248**	**233**	**234**	**207**
Year	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Mean	**238**	**219**	**255**	**220**	**218**	**262**	**222**	**243**	**209**	**199**
Year	2006	2007	2008	2009	2010	2011	2012	2013	2014	
Mean	**261**	**217**	**220**	**203**	**237**	**257**	**216**	**223**	**208**	
Year	**1987**	**1988**	**1989**	**1990**	**1991**	**2001**	**2002**	**2003**	**2005**	**2005**
Mean	**207**	**222**	**231**	**229**	**214**	**199**	**240**	**187**	**227**	**189**

The table 1 above shows the sample distribution of descriptive statistics for rainfall from 1978 to 2014. The statistics shows the average amount of rainfall throughout this period. The average amount of rainfall ranges between 187 and 262 (mm). The highest amount of rainfall was recorded in 1997 (262mm) and least amount was recorded in 2003. The general average trend and pattern show that the differences between the averages amount of rainfall of each year starting from 1978 to 2014 is generally small. Majority of the average amount of rainfall are two hundreds. With a general average rainfall being undulating the differences between the years are not huge. Observation indicates that is difficult to conclude that there is a decrease of amount of rainfall in recent years compared to the past. This is because there is lower and higher average rainfall in both recent and past years. For instance in 2014, 2012, 2011, 2007 and 2006 in comparison with 1978, 1979, 1987, 1980 and 1984. The implication to agricultural practice is that, it is difficult to establish a conclusion that next season there will be an increase or decrease of rainfall. Lastly there might be a seasonal variation rather than the amount of rainfall in a particular year.

Table 3. Model Statistics from time series analysis based on years and months of rainfall

Model	Number of Predictors	Model Fit statistics	Ljung-Box Q(18)			Number of Outliers
		Stationary R-squared	Statistics	DF	Sig.	
Rainfall-Model_1	9	.933	9.397	18	.950	0

The table three above shows the model statistics from the time series analysis on the years and months based on the average amount of rainfall. Rainfall- model_1 stands for one variable which is rainfall. The model result used 9 predictors out of 37 years rainfall variables. Model fit statistics is determined by R-square which is .933 implying that the value fits for model application as it is above .7. A statistical value of the model is rated at 9.397. Statistical Difference or degree of freedom (DF) of 18 and significance of .950 while number of outliers is 0. Rainfall does not raise any problem from an econometric point of view, many variables of such a nature from economic and business time series are non-stationary even after eliminating deterministic trends due to the presence of unit roots. From the model statistics it can be indicated that no significant difference is established between the years and the amount of rainfall as well as their months. This is indicated as (DF= 18, T=9.397, p> 0.05). The stationary R square statistics shows that 93.3% of the time the stationarity of the variable holds.

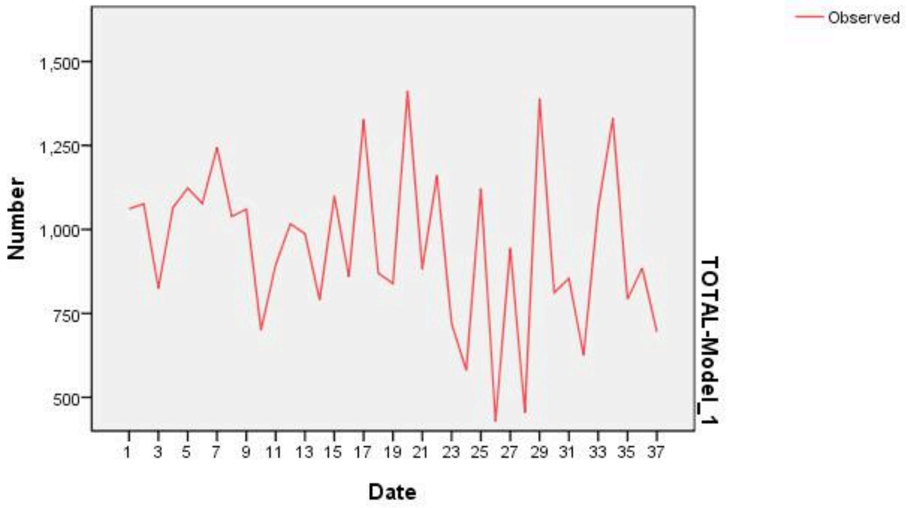

Figure 2. Time series trend and patterns for amount of rainfall from 1978-2014

The above graph shows the time series trend and patterns for the average amount of rainfall from 1978 to 2014. This shows that the general trend and pattern is undulating throughout the 37 year period. 1978 and 1979 shows an increase in the average amount of rainfall experienced across the months with value above 1000, this amount drastically decreased in the year 1980 with little rainfall value less than 1000. The trend led to a sharp increase between 1981 and peaked at 1984 with a rainfall value of 1,250. The trend and pattern continues with a sharp decline between 1984 till 1986 bringing the rainfall value to below 750 and a sharp rise from and fall from 1986 till 1996 and a rise between 1997 through 1999 which recorded the highest amount of rain. The general rise and fall again continued till the lowest amount recorded in the year 2003 with value less than 500. With this the second lowest amount of rainfall was recorded in 2005. From this point the rise and fall of the rainfall was experienced until a second highest amount recorded between 2005 and 2007. There was also a drastic decrease from 2011 to 2014 on the amount of rainfall with the value of the last year recorded with little below 750. From the observations, it is difficult to establish a clear conclusion that in recent years; rainfall has decrease. The evidence is too narrow.

Table 4. Descriptive statistics for Temperature from 1978 to 2014

Year	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
Mean	175	176	176	176	176	176	176	176	176	177
Year	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Mean	177	176	177	177	177	177	177	177	177	177
Year	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Mean	177	178	177	177	178	178	179	178	178	179
Year	2008	2009	2010	2011	2012	2013	2014			
Mean	179	170	178	180	180	179	180			

The table 4 above shows the sample distribution of descriptive statistics for temperature from 1978 to 2014. The statistics shows the average temperature degrees based on approximations throughout this period. The average temperature was considered from both the minimum and maximum temperatures obtained across years and months for the analysis. The average temperature from the stipulated period ranges between 1978 through to 2014. It can be observed that the highest temperature was recorded in 2011, 2012 and 2014 and least amount was recorded in 2009. The general average patterns and trend shows that the differences between the average temperatures of each year starting from 1978 to 2014 are generally minimal. Majority of the average differences are sometimes less than 1. With a general average being undulating the differences between the years are not huge. Additional observation shows that there is an increase of temperature in the recent years compared to the past.

Table 6. Model Statistics from Time series analysis based on years and months of Temperature

Model	Number of Predictors	Model Fit statistics	Ljung-Box Q(18)			Number of Outliers
		Stationary R-squared	Statistics	DF	Sig.	
TOTAL-Model_1	4	.987	12.852	18	.800	0

The table six above shows the model statistics from the time series analysis on the years and months based on the average (minimum and maximum) temperature. Temperature doesn't raise any problem from an econometric point of view, In order to ensure effective trend and patterns in temperature for the period stated the times series model of best fit was done to ensure this stationery variable. The model statistics indicates that due to hugeness of the data no significant difference is established between the years and the amount of temperature as well as their months. This is indicated as (DF= 18, T=12.852, $p > 0.05$). This in effect does not mean that no differences lie between the years and their average temperature throughout the period. The reason may be attributed to the compact nature of the data as well as the minimal differences between each year and months temperature in degrees Celsius.

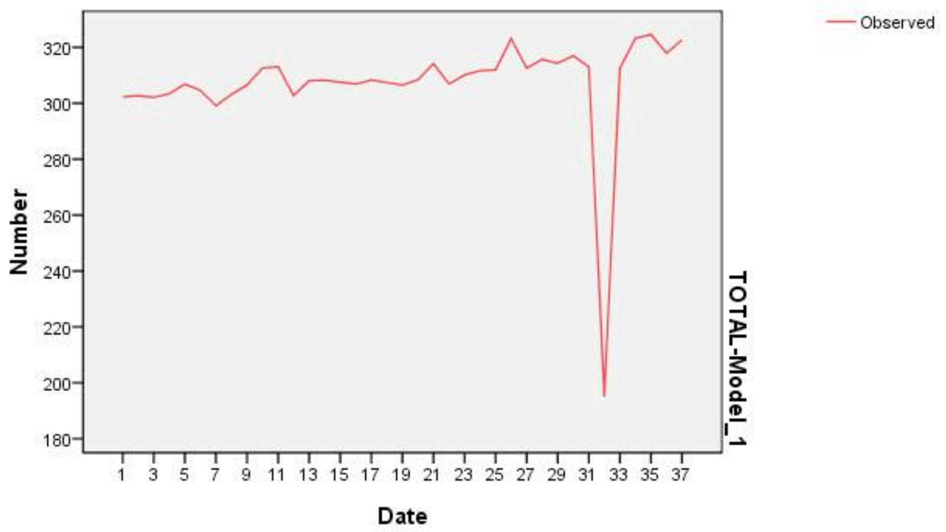

Figure 3. Time series trend and patterns for average temperature from 1978 to 2014

The above figure shows the time series trend and patterns for the average amount of temperature from 1978 to 2014. This shows that the general trend and pattern is undulating throughout the 37 year period. 1978 to 1980 shows a slight increase in the average temperature experienced across the years with value above 300, this amount decreased slightly in the years 1981 to 1983 with a little fall below 300. The trend led to a sharp increase between 1984 and peaked at 2002 with a temperature average value of 320, this lead to a little decline in the continues until a drastic decline in 2009 with a value above 180 and little below 200. The trend and pattern continues with a sharp rise in temperature between 2010 till 2014 bringing the rainfall value to 320 and above. The general rise and fall again continued till the lowest amount recorded in the year 2003 with value less than 500. Generally, with a general undulating trend and patterns of temperature throughout the period, the lowest temperature difference is hugely experienced.

Primary Information on Patterns and Trend of Climate Change

Primary data are used to compare climatic records and local perceptions on climate change. Villagers' observations through survey at all seven study sites/villages indicate that conditions are changing in multiple ways. The challenge for policy-makers is to understand how future climate change might further affect the rural people, and to try to set priorities for adaptation. The timing and intensity of rainfall are no longer reliable; rains early in the season are heavier than they used to be, but later in the rainy season, conditions may be dry. When asked if they observed changes in climate over some years in comparison to the situation today, about 95% said yes. Regarding experience on droughts or dry spells over some years in comparison to recent years 56.3% experienced a lot more, 38.3% experienced more, 2% said there was no change, 2.7% said no less than before, and 0.7% said did not exist at all. Coming to experience on floods in last 20 years and current, only 3.3% said that they experienced a lot more, 1.3% yes more, 35.7% said about the same as before, 50.7% said no less than before, and 9% said they didn't experience floods at all.
Thematic interviews conducted at all villages, indicate that the current trend of rainfall is unpredictable and the future is all about drought. According to respondents interviewed trend shows that climate variability is rampart where by some years ago

there were two seasons of rainfall, that is “vuli” (short season between Sept-January) and “Masika” (long season between March-June), but now the trend has changed to one season and unpredictably. One of the examples given by majority respondents during interviews at Mkenge village was Mkombezi River which had enough water in the past years but during interview in November 2014 the river was dry. Through observation, a researcher witnessed a dry river Mkombezi where by cattle and villagers were fetching water from underground (see figure 2). It was informed that in past years, river Mkombezi provided enough water for domestic use and cattle.
During FGDs, people’s comments show that their main shock being climate change i.e. temperature and rainfall. The trend of rainfall is unpredictable and the amount is small comparing with past. The leanest months are April-June. Some respondents give reasons for climate change in the recent years being deforestation. Villagers complain that the government is too weak to take measures against people involved in deforestation. At Mkwama sub-village (Mkenge village), where the majority inhabitants are Maasai (pastoralists) the major shock in the context of climate is drought. Only in 1997/1998 when the village experienced flooding (Elnino) but since then drought has increased. Interview with some village elders such as former Village Executive Officer (VEO) informed that in recent years the major changes are absence of floods and increased drought as well as change in rain season from bimodal to single season and its variation.
The findings show that majority of people in the study area understand climate change as a change of weather in an area. Other factors explained as change of situation of environment, drought, change in rainfall, and presence of hot and cold, change in temperature, absence of rainfall, and change in condition of season, absence of water and change of wet to dry. Looking at the meaning of climate change, the analysis shows that people are aware of climate change, only that everyone could explain it in different wording. Community perceptions on the indicators of climate change varied but rainfall was the most influencing factor followed by drought, temperature and summer. From this analysis, one can draw a conclusion that community members in the study area are influenced by the agriculture being a rain fed kind of economy.

Conclusion and Recommendations

In this study, the analysis of rainfall data indicates that there is no big evidence of change of trend and patterns over 37 years. But one can establish a seasonal variation within a year from January to December. The model indicates that there is no significant change of rainfall patterns and trend in 37 years from January to December ($p< 0.05$). The analysis on temperature data indicates that there trend and patterns in 37 years doesn’t show huge difference, meaning that the values are too close thought-out. However there is an increase of temperature in the recent years compared to the past. The model reflects that there is no significant difference between temperatures in 37 years and its months from January to December.
The analysis of the trend and patterns of climate change is very important for agriculture planning and implementation. The implication of this on agriculture is that it is difficult to predict whether in the future, rainfall will increase or decrease. No determinants for change of seasonal production yearly. However, the change of seasons within year can help recommendations to farmers for early warning that cropping patterns should determine the kind of crop depending on which month; for instance during low rainfall people can decide to grow crops which do not require high amount of rainfall, and vice versa. The implication of temperature increase can

help crop cultivators on early warning that the existence of pests and diseases may accelerate crop failure which can help adaptation through the use of pesticides and even cropping patterns.

Community perceptions on climate change trend and patterns reveals that in the recent years there has been a decrease of rainfall and increase of temperature. The weather patterns have become unpredictable and this has affected community members in the study area their livelihood activities. Generally agricultural activity in the study area is rain fed and natural resource dependent. It is wealth knowing that community members understand the linkages between climate change and their livelihood. Looking at the future of Bagamoyo district, there is a great deal of uncertainty about climate hazards. No single, clear message emerges from the analysis, and the climate data graphs require careful reading and interpretation.it learned that it is important to be cautious in predicting the future, and to compare different sources of data.

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An Impact Assessment of Green Initiatives of the Central Bank on the Environmentally Sustainable Banking in Bangladesh

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The European Conference on Sustainability, Energy & the Environment 2015
Official Conference Proceedings

Abstract
Environmental concern is at the centre of 'Environmentally Sustainable Banking' or 'Green Banking' policies and strategies. Policy makers in many economies have been undertaking initiatives and formulating rules to support green banking activities by the financial sectors throughout the world. In response to various legislative and regulatory bindings and incentives, a good number of banks in developed countries have been demonstrating their commitment to the earth through incorporating environmental risk in banking. In contrast, the status of environmental management has not been satisfactory in most developing countries, largely due to poor enforcement of existing laws and policies, lack of incentives and inadequate pressure from interest groups. Bangladesh Bank, the central bank of the country, has been helping government in implementing provisions of key environmental regulations in the financial sector and from time to time it has issued a few environmental circulars and introduced refinance facilities to encourage banks for environmental financing mainly in renewable power generation. Especially, the circular issued in 2011 on 'Policy Guidelines for Green Banking' is a remarkable step on the way to developing green banking practices in the banking sector of Bangladesh. Commercial banks' responses are crucial for positive outcomes of these initiatives and for ensuring environmentally sustainable banking. The paper attempts to examine the impact of the Central Bank's initiative on the environmental banking in Bangladesh. The paper identified that though remarkable changes have taken place in terms of green awareness, banks could not attained a number of milestone targeted by the Bangladesh Bank.

Keywords: Green Banking, Environmentally Responsible Banking, Green Financing

Introduction

‘Environmentally Sustainable Banking’, which is also called as ‘Green Banking’, is getting priorities to the policy makers in a number of economies in several instances. In response to the policy initiatives, an increasing number of banks around the world are going green by offering innovative green products, saving resources and supporting the activities that help conserve environment. An environmentally sustainable bank or green bank is expected to use its resources with responsibility avoiding waste and giving priority to environment and society. Such public concern and expectation have grown significantly over last few years mainly due to apparently unusual weather patterns, rising greenhouse gases, and declining air quality that have started affecting economic and social lives remarkably. Today, society demands that economic units and businesses take responsibility for safeguarding the environment. And some production units, business entities, and financial institutions have responded significantly to the demand and expectation of the society.
The corporate entities in developed countries are to operate under various regulatory and fiscal bindings; and there are incentives to promote good corporate citizenship. In response to these, a good number of financial institutions and banks in developed countries have been demonstrating their commitment to the earth through green activities. For example, some banks of USA and EU are among the frontrunners that have embraced environmentally sustainable initiatives. Several big banks have sustainability policies and commitments on climate change, carbon mitigation, bio-diversity, land conservation and internal use of resources. Even green activities of a good number of local level small banks in developed countries have been very inspiring and replicable. In contrast, generally, the status of environmentally sustainable banking has not been satisfactory in developing countries largely due to poor enforcement of existing laws and inadequate pressure from civil society and interest groups. Nevertheless, initiatives of a few central banks in developing regions have created supportive environment to undertake green activities and Bangladesh is one of these few developing countries.

Bangladesh Bank (BB) has been helping government in implementing the provisions of key environmental regulations related to the financial sector and from time to time it (BB) has been issuing environment related circulars and guidelines. Especially, the circular on ‘Policy Guidelines for GB’ in 2011 is a remarkable step on the way to developing green banking practices in the financial sector of Bangladesh. A separate guideline on ‘Environmental Risk Management’ by BB is also in place. In addition, BB introduced refinancing schemes and a few incentive measures to encourage banks to undertake green activities. Available published information indicates positive responses on the part of banks to the BB’s initiatives. It appears that the initial phase of developing awareness and preparation at the top management level of banks is done. Generally, policies are in place and strategies in some areas are also there. However, a lot is to be performed to accrue the true benefits of green practices. It is time for identification of right strategy to move forward by reviewing the green initiatives of the central bank and responses of the banking sector.

On the above background, the paper attempts to examine the impact of the Central Bank’s initiative on the environmental banking in Bangladesh. The specific objectives of the paper are: *One,* to review Environmentally Sustainable Banking or Green Banking policy initiatives of Bangladesh Bank; *two,* identifying supportive legal, policy and market environment for developing GB in Bangladesh; and *three*, examining the responses of commercial banks to the Bangladesh Bank's initiatives; This paper is based on secondary information. Published BIBM studies and BB information are the main secondary information sources.

Environmentally Sustainable Banking: Conceptual Aspects and Stakeholders' Role

Conceptually, the environmental issues have been linked with the concepts of market failure-public goods and externalities (Binger 2003). The concepts of externalities and public goods are closely associated. The Global Public Goods (GPGs) having negative impacts are known as Global Public Bads (GPBs). The results of the global pollutions and emissions like global warming, contamination, disruption of eco-systems etc are GPBs. The negative externalities and GPBs are the burdens of the entire society. Banks contribute both directly and indirectly to this process. A bank is a consumer and a producer by itself and also supports producers and consumers through its financing services. The motivation for providing GPGs arises from a desire to produce or enhance positive externalities and correct negative ones. In the area of environment, reduction of emission and conservation are GPGs (Mercier and Oliver, 2002). It is well recognized that green banking is one of the global initiatives by the stakeholders to save environment. The efforts are expected to bring positive changes in the environment, which are mostly non-excludable and non-rival in nature. Generally, a section of the society directly and the entire society indirectly is the beneficiary of the 'external benefits' offered by banks. Thus, as a whole, the ongoing green banking initiatives by different stakeholders is a GPG where the society as a whole is the target beneficiary (figure-1). In regard to the external benefits, green banking clearly has a direct, positive effect on the environment, but the benefits go much further, reaching into security and cost (Javelin Research 2009).

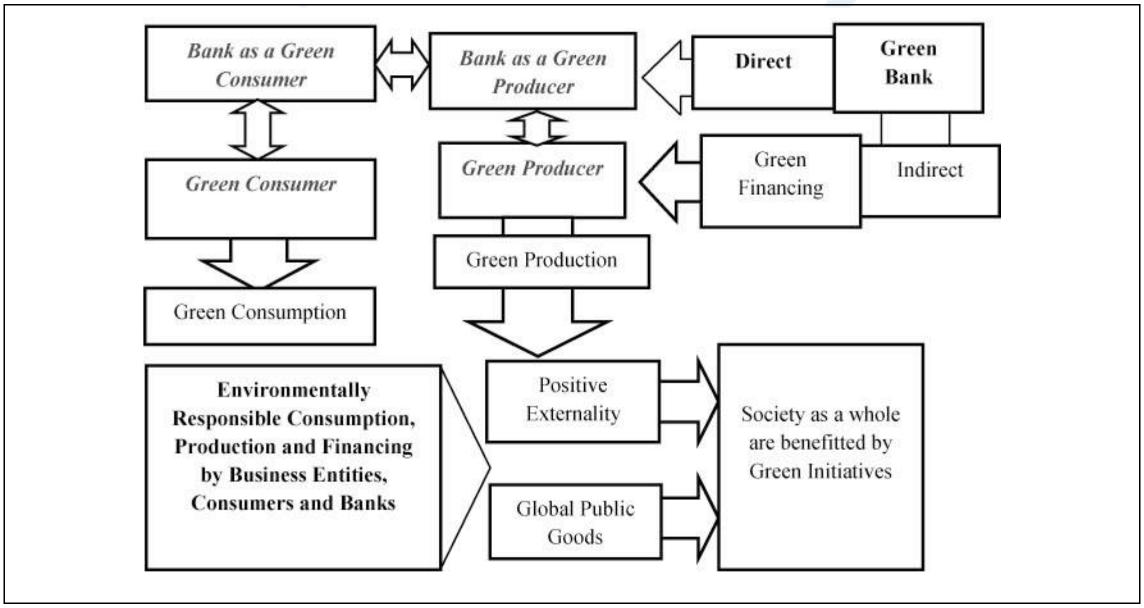

Figure-1: Green Banking and Sustainable Environment

Source: Habib, 2010

To offer effective GB practices, banks require supports of other stakeholders. In the international arena, IGOs and IFIs have been contributing in framing international policy architecture that enables countries and stakeholders to better anticipate and respond to environmental initiatives. Governments are expected to formulate policies, and enact and enforce relevant rules and regulations. As a critical stakeholder of GB, central banks are supposed to formulate rules, policies and guidelines for creating a supportive and congenial environment for undertaking green banking practices. These three stakeholders i.e. IFI/IGO, government, and central bank are expected to play the roles of torch bearers. Government and central banks are also to offer effective positive and negative incentives to the banks. A number of environmental NGOs and Media (and other civil society and academic/research institutions) have been engaged as the watchdogs against financing dirty companies. Practically, these NGOs and media are the pressure group. Some environmental NGOs are also engaged in formulating guidelines and principles for the banking and financial sector. The voluntary initiatives of business firms (the main clients of banks) have been working as a complement to the regulatory approaches and are crucial incentives to the green banks. Business clients could perform role as a vehicle for green marketing for a green bank. Consumers can also offer market incentives to the banks by supporting the green activities of banks and by paying premium.

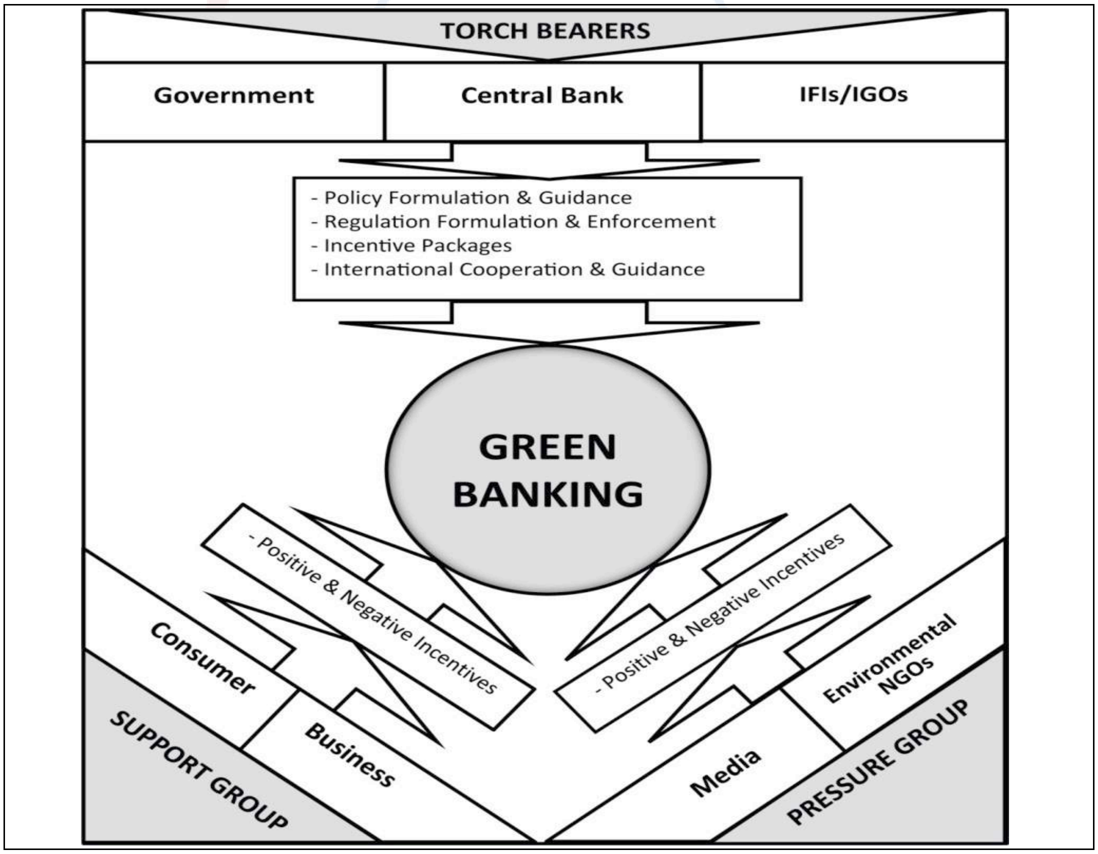

Figure-2: Expected Roles of Stakeholders in promoting Green Banking

Source: Habib et al., 2013

Broadly, GB rest upon five pillars (figure-3). First one is related to the 'green vision' of a bank. It is the basic principle. Practically, activities and operations of banks cannot completely discard environmental harm. In most cases, it is about minimizing harm. Second and third pillars are connected with banks' in-house activities and operation and financing. These are connected with a bank's green efforts to minimize environmental risks and saving scarce resources. Fourth pillar is concerned with supporting other stakeholders and cooperation. Pillar five is about green reporting. Transparency of a green bank is a crucial component in its sustainable operation. It is concerned with providing relevant information and responses of the stakeholders on the activities of banks. All these pillars are integrated and crucial to ensure sustainable green banking.

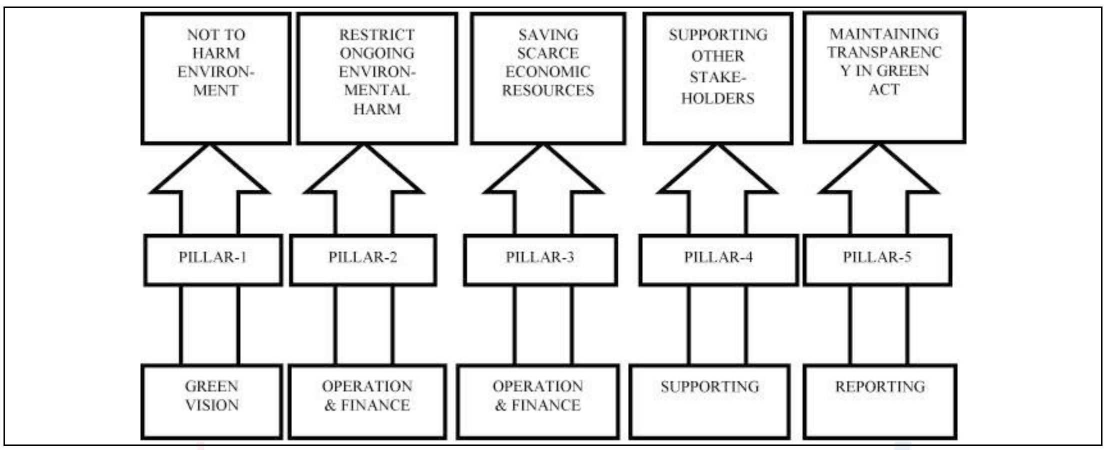

Figure-3: Five Pillars of Green Banking

GB does not only mean including something in the banking activities, rather it is very important to exclude a set of activities (figure-4). In line with the Polluters Pay Principle (PPP), the polluting banks have greater environmental responsibility than that of others. Forcing polluter banks to bear the costs of their activities is also said to enhance economic efficiency. Appropriately applied, policies based on a Polluter Pays Principle (PPP) should enable us to protect the environment without sacrificing the efficiency of a system. Banks face challenge to balance between environmental concerns and business demands.

A Green Bank Should Engage in-
Policy and Strategy Formulation
Environmental Risk Management in Financing
Creation of Green and Risk Fund
Saving Energy and Natural Resources
Green Marketing and Awareness Development
Supporting and Sponsoring Green Initiatives and Events
Designing and Offering Innovative Green Products
Green Marketing, Awareness and Promotional Activities
Monitoring of Green Financing
Waste Management
Offering Incentives for Green Activities
A Green Bank Should Not Engage in-
Financing Technology/Activities without handling Environmental Risk
Supporting/ Financing Energy/Resource Inefficient Activities
Disclosing Misleading and Untrue Information
Disclosing Misleading and Untrue Information

Figure-4: Includable and Excludable in Green Banking Practices

Source: Habib, 2010

‘Sufficient Incentive’, both positive and negative, is a crucial condition for the development of environmental practices by banks. In regard to effective regulatory incentive, it is important that the incentives must be offered in a fair and transparent manner and these must be attractive to the banks. However, the mandatory provisions or legal imposition may not work for long and rather it is important to convert regulation driven approach to market based approach for long run effective environmental protection.

Green financing may not always be attractive to the policy makers in a developing economy when the economy is burdened with severe problems like poverty and unemployment. Developing countries may not afford to discard all economic activities and technologies immediately that are environmentally hazardous. Performing an assessment of the costs and benefits is required before enforcement of any environmental legislation/rules. However, there should be long term planning to handle these projects/activities.

Bangladesh Bank's Policy Initiative to Promote Environmentally Sustainable Banking in Bangladesh

Bangladesh Bank has undertaken certain initiatives to help implement the relevant provisions of environment related acts enacted by the government of the country. In 1997, commercial banks of the country were asked by the central bank to undertake necessary steps for implementation of certain decisions in regard to environmental conservation and protection by the National Environment Committee. Banks of the country were asked to ensure that steps have been undertaken to control environmental pollution before financing a new project or providing working capital financing to the existing enterprises. According to the BB requirements, the industrial units (that may cause environmental pollution) to be established under bank credit would get permission for opening LC to import machineries only after ensuring that the list of machines includes equipments to set up waste treatment plant. Considering the adverse effects of climate change, banks have been advised by BB to be cautious about the adverse impact of natural calamities and encourage the farmers to cultivate salinity resistant crops in the salty areas, water resistant crops in the water logged and flood prone areas, drought resistant crops in the drought prone areas, using surface water instead of underground water for irrigation and also using organic fertilizer, insecticides by natural means instead of using chemical fertilizer and pesticides. Bangladesh Bank has also been taking initiatives for the rehabilitation of cyclone and other natural disaster affected people of the country time to time. Online banking which is considered by many as the starting point of GB, received due attention of the central bank. Banks have been brought under the purview of E-commerce with a view to providing the customers with online-banking facilities covering payments of utility bills, money transfer and transactions in local currency through internet as well.

To promote environmental financing, banks have been advised to finance in solar energy, bio-gas plant, ETP and Hybrid Hoffman Kiln (HHK) in brick field under refinance program of BB. BB introduced Taka 2.0 billion refinance facilities in FY 10 against bank loans for investments in solar energy, biogas plants and ETPs in line with the government's plan to meet 5 percent of the total demand for electricity from green energy by 2015 and 10 percent by 2020.

The comprehensive circular of BB on 'Policy Guidelines for Green Banking', issued in February 2011, is a remarkable step on the way to develop GB practices in the banking sector of the country. As per the circular, commercial banks will have to adopt a comprehensive GB policy by December 2013 as part of the central bank's efforts to make banking practices more responsible to social and environmental causes. Besides introducing internal environment management, the banks are expected to introduce environment friendly green financing to address the environmental challenges of the country. The policy is segregated into three phases. In phase-I, the banks were to develop green banking policies and show general commitment on environment through in-house performances by December 31, 2011. Banks are required to formulate environmental policy and create a GB cell or unit under this phase. A high-powered committee should be responsible for reviewing the banks' environmental policies, strategies and programs. The banks are to allocate sufficient fund in their annual budget for GB; and are to introduce a green office guide for practicing internal environment management. The banks should take measures to save electricity, water and paper consumption as per the requirement.

Instead of relying on printed documents, online communication should be extensively used for office management. Energy saving bulbs should replace the regular ones in branches/offices of the banks and employees should be encouraged to purchase energy efficient cars. Banks are also to create a climate risk fund to finance the economic activities of flood, cyclone and drought prone areas at the regular interest rate without charging additional risk premium.

In phase-II of the Green Policy Guidelines that would not exceed December 31, 2012, the banks have to formulate specific policies for different environmentally sensitive sectors and will have to determine a set of achievable targets and strategies, and disclose these in their annual reports and websites. They are expected to set up green branches and should increasingly rely on virtual meeting through video conferencing. Banks are to develop and follow environmental risk management manual in their assessment and monitoring of project and working capital loans under phase-II. The Phase-III, which was to be attained by December 31, 2013, requires banks to publish independent Green Annual Report following internationally accepted format like GRI with the arrangement of external verification. IN recent time the time line for the GB policy guideline has been extended.

BB prepared and circulated a Guideline on Environmental Risk Management on January 30, 2011 to streamline solutions for managing the environmental risks in the financial sector. The guidelines cover different conceptual aspects, approaches, applicability, stages and benefits of Environmental Risk Management (ERM) by banks. The ERM guideline prescribes a set of sector specific ‘Environmental Due-diligence Checklist’ for financing environmentally sensitive sectors by banks.

Other than the policy and guiding supports from BB, a congenial market environment with active support from government, businesses, NGOs and consumers are crucial for the development of GB practices in the country. Government of Bangladesh has taken some measures for improving environmental governance in the recent years. Recently, a Monitoring and Enforcement Cell has been set up in the DOE to monitor the compliance of conditions set out in the environmental clearance certificate. Moreover, a special project named ‘Clean Air and Sustainable Environment’ has undertaken to identify the sources of air pollution and work out necessary action plans to reduce pollution level in Dhaka. It is encouraging that the DOE is increasingly becoming active and has taken punitive measures against the polluting industrial units during recent period.

One relevant vulnerable area in Bangladesh is inadequate responses and awareness among consumers on the issue. Consumer awareness is still very low with limited market surveillance by consumer organizations. There are probably more and bigger NGOs in Bangladesh than in any other country of a similar population in the world. A few NGOs are actively involved in the environmental sectors of Bangladesh by doing research and advocacy, and as pressure group.

Responses of the Banking Sector to the Policy Initiatives of Bangladesh Bank

Bangladesh Bank’s initiatives have made significant changes in regard to the creation of green governance frameworks in commercial banks. The survey data of the study reveal that as of August 2013, all banks have environmental policies and Green

Banking Cells. Most of the policy documents are replications of Bangladesh Bank's policy guidelines. A few banks have well designed and customized policy documents, however, some documents require fine tuning. According to a BIBM Study (Habib et al, 2013) 75 percent banks have formulated one or more sector specific environmental policy guideline. The BIBM survey finding shows that in almost all banks, top level bank executives are responsible for heading the Green Banking Cell. The number of employees in the cell ranges from 3 to 10. Generally, employees are responsible with the activities of Green Banking Cell alongside other responsibilities. Of the banks, 95 percent have green office guide. Banks are expected to formulate strategic plans as required in Phase-1 of the GB policy circular. In regard to this, 65 percent banks have claimed that they have formulated some kind of green strategic planning (Habib et al, 2013).

Though all banks are supposed to create climate risk fund, the published data of BB indicate that 20 percent banks have no allocation for the fund. According to the BB policy document, the fund should mainly be used to cover additional risk premium and to meet emergency expenditure in the climate risk prone areas. The basic target, as appears in the policy documents, is to ensure regular financing. The fund could be created as part of CSR expenditure; however, it is obviously not simply about performing some philanthropic activities.

Introducing green office guide is a noticeable step; however, only a few banks have notable initiatives in regard to resource inventory preparation and savings of paper, water and power etc. Practically, a very limited number of banks are found to have provision of maintaining inventory of the resource use or consumption of energy and power. These are mainly maintained in terms of expenditure amount. To make it meaningful, it is important that these data should be maintained in terms of the use of units and should be expressed in relation to the attributes like number of employees, number of branches etc. Banks generally do not declare or strategize any target of the reduction of the resource use.

Bangladesh Bank is supporting financing of renewable energy generation and other environmentally benign projects. BB allocates an amount of BDT 2 billion to refinance lending for renewable energy generation, and other environmentally beneficial projects such as effluent treatment projects, energy-efficient kilns for brick fields, and so forth. Utilization trends of the Bangladesh refinance scheme show that BDT1053.5 million has already been disbursed from this BB fund during FY10--FY14 to solar energy, biogas, hybrid Hoffman kilns, and effluent treatment plants. In FY14, about 42 banks disbursed BDT 398.2 billion as green finance (BB, 2014). Following boxes (boxes 1-4) offers a few examples of banks responses to the BB's initiatives.

Box-1: In-House Green Activities by Banks
Use of paper on both sides for internal consumption; Introduction of e-statement for customers; Use of online communication; Arrangement for using daylight; Using energy saving bulbs; Use of Eco Font for printing light impression on both sides of the paper; Using sensor lighting equipment for saving electricity; Common use of table stationeries; Video/Audio conferencing; Efficient use of printer cartridges, Sharing electronic files, voice mail and e-mail instead of paper memos; Use of solar energy/ renewable energy.
Source: Based on Bangladesh Bank published data.

Box-2: Sustainable Green Finance in the Farming Sector
The farmers of a village in a northern district in Bangladesh have been benefited tremendously by the renewable financing programs of Mutual Trust Bank, a private commercial bank in the country. Under the project, bank organizes farmers and conducts feasibility study in order to know the potentials of production. Then, farmers are asked to form a cooperative. This cooperative then gets a legal entity by registering with the appropriate authority. After forming cooperative, they apply for bank loan. In this case, bank offered loans for irrigation pump which is owned by cooperative. Bank also help in procuring pump by contracting suppliers and ensured service facility including installation of pumps. As these pumps are operated by solar, banks made arrangement to install solar panel. Banks also made expenditure to prepare water distribution system. Apart from this, bank took care of back-up facility which is diesel operated in order to ensure smooth flow of water. **Source: Based on MTBL source**.

Box 3: Agrani Bank Promoting Women Entrepreneurship through Green Initiatives
Agrani Bank has been providing loan for plantation at low interest rate in different districts. The bank financed in environment friendly ‘Easy Bike’ which was run by battery but recently Govt. has stopped this initiatives. The Bank offered composite loans for purchasing cow and produce organic fertilizer through Vermi-compost, of BDT 100,000 under ‘Agrani Prani Shampad’ scheme. A good number of women have received financing facilities under the scheme. The bank financed a number of women entrepreneurs.
Source: Agrani Bank Source.
Box 4: Initiatives in line with Global Activities
HSBC introduced fully Solar Powered ATM at Dhanmondi Branch. Tree plantation is a remarkable step of the bank. The bank has initiated ‘Go green’ campaign for business customers. It celebrates the ‘World Environment Day’ (5th June related to Earth Day) by wearing green costumes by all employees of the bank and on the same day they arranged plantation programs and a ‘Quiz Contest’ on environmental issues. The bank also introduces HSBC- The Daily Star Climate Awards to the eminent personalities of the country for their contribution towards protection and preservation of environment. The award is given for four categories of works: Climate change adaptation, Climate change mitigation, Climate change research and knowledge management and Green Business Entrepreneurship. As a part of its commitment, HSBC has set up rain water harvesting devices in two major schools of Dhaka city.
Source: HSBC Source.

As noted earlier, clearance from the DOE is one of the requirements for obtaining finance from commercial banks for the industrial units. Banks have been complying with the requirements. However, the arrangement is playing very limited role in environmental protection. Banks generally follow the ERM guideline of banks as part of their environmental risk management technique, as observed in survey. As per the ERM guideline, banks are supposed to place the high rated projects to the executive board for approval. In most cases, banks do not have policies or guidelines for the approval of these high rated projects. The ERM guideline requires banks to establish and maintain a database of NPLs that are due to environmental reasons and to have a reporting system on an annual basis. Banks are not found to be maintained the database.

There is no doubt that the BB's initiatives have brought remarkable change in terms of awareness and approach of banks. However, changes have taken place mainly at urban areas. More specifically, the awareness is Dhaka centric. Information on green activities by banks is sometimes not even disseminated in the urban branches/head offices. Green marketing or promotional activities are yet to receive popularity in the banking community. A very limited number of training programs were organized for the bank employees on green banking. According to Habib et al (2013), on an average only 2 training programs were organized per bank. However, it is encouraging that 4 percent banks have organized training programs for their customers for awareness development. A few initiatives of banks are really inspiring and replicable. Some banks are using slogans as part of their green marketing and awareness activities. In regard to bank-NGO linkages, there are very limited instances for green causes.

Though there are some scattered activities, generally banks do not have concrete waste management policies or strategies. Some banks have arrangements for waste collection, reuse and recycle of electronic goods and other materials and green tendering. However, a few banks have some inspiring initiatives for in-house waste management and financing. Growing e-waste has been another related problem for banks. Few corporate offices in Bangladesh have taken initiatives regarding their re-use of e-waste. Some are distributing computers to different schools and organizations for reuse.

Generally, banks do not publish separate reports of their green activities or CSR programs. Notable exceptions are two foreign banks that have published Corporate Sustainability Report and Green Banking Report covering some environmental issues in recent years. All the banks report following a prescribed format of the BB. Banks report their CSR and green initiatives in their annual financial reports in accordance with the directive of the BB. Some banks also disclose relevant information through their web sites. Third party evaluation for reporting [as required by phase-3] is absent. Banks generally do not use comprehensive standard reporting formats such as the GRI.

Recommended Steps Ahead

Banks are expected to be evaluated in terms of the green performance by the central bank, media, government or environmental NGOs. This process of evaluation should be transparent and this should serve as an important incentive to the banks. The evaluation process should be designed in consultation with Bangladesh Bank, commercial banks, BIBM, and other related stakeholders considering both the positive and negative impacts of the bank activities on environment. Besides, the netted environmental impact can be used as a yardstick in offering any incentive.

Monitoring and periodic review of the environmental or Green banking activities are crucial for improving green banking practices. Reporting requirement is just one of the key tools to perform this job by the central bank. It has been observed that the published data reported by banks are inconsistent in a few cases. Thus, data validation mechanism and periodic review may complement the reporting requirement by the central bank.

A comprehensive incentive structure is yet to be developed to support green banking activities in the country. Till date, a notable set of incentives is declared in the GB policy framework by BB.To support green banks the performing banks should be awarded publicly. As a negative incentive, the dirty banks (non-complaints) can be penalized by imposing more capital charge under environmental risk.

Energy and power shortage is a very common problem in most developing countries including Bangladesh. It appears that banks have scopes to save electricity and power by maintaining strict office timing and rearranging branch sitting arrangement. Banks may make plan to rely on daylight in selected branches (especially branches located outside Dhaka). Banks may also undertake initiative to finance fuel-efficient car and other vehicles to save energy. To escalate these initiatives better participation of banks and end-users is the precondition. In case of fuel-efficient car, Bangladesh Bank may come forward to facilitate banks under its refinancing schemes as it is an expensive move.

Remarkable changes have taken place in terms of awareness in the banking sector in response to the initiatives of the Bangladesh Bank. However, it is mainly urban or more specifically Dhaka centric. Different training, seminars, symposiums, workshops, etc. can be arranged by the joint collaboration of BB, BIBM, BBTA, BAB, ABB and other concern institutions to improve the understanding of all the bank branches outside Dhaka.

There is no doubt that a country like Bangladesh cannot afford to discard all projects or economic activities only for environmental causes. Significant negative impact of production/economic activities on employment, income, and poverty cannot be ignored. Thus, it is important to identify the sectors or industries where banks should continue financing in spite of their negative impact on environment. There should be long-term planning for these industries to handle environmental issues and all relevant policies should be consistent in this regard.

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Payment for Environmental Services and the Increase of Life and Environmental Quality: A Study of Brazilian Case

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The European Conference on Sustainability, Energy & the Environment 2015
Official Conference Proceedings

Abstract
The water crisis around the world, the increased deforestation and the need of finding new industrial solutions make clear the importance of nature. In this context, the State must stand up for sustainable actions and the Payment for environmental services is a good way to stimulate the citizens to act consciously. The Payment for environmental services (PES) aims for a socially desirable behavior by offering economic incentives in return for practices that can preserve, conserve, recover or improve the ecosystem services. The purpose of this research is to identify the main ideas and discuss environmental Law issues related to Payment for environmental services, mainly about how this public policy incorporate a social justice agenda. PES not just helps to preserve the environment and the ecosystem, but also contributes to the low-income people that usually lives is rural areas. In other words, the PES can help both the person that will receive the payment but also all the citizens around with a better life quality, and, mostly, the environment. To prove this point, a lot of Brazilian cases will be used in this paper, such as: Allowance Forest Program; Remnants Forest program; and Bio-Credit Program. In Brazil, chiefly in the poor regions, the PES has contributed a lot to increase the citizens life. And, as soon as the life gets better, more the community wants to preserve and recover the nature

Keywords: Payment for environmental services - Brazilian cases - public policy

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Introduction

Most of developed nations are adopting, mostly since XX century, the capitalism production model, there is an increase of private exploitation of goods and the accumulation of wealth and the consequent depletion of nature. Thus, the predatory human behavior goes on to become harmful to the environment, especially in the West site of the Globe. The depredation of natural habitats, extinction of animal and plant species and the destruction of ecosystems, water waste and soil pollution are some examples of impacts that threaten the goods distribution such as water and food. The high level of human consumption puts us in collision with a sustainable development. Thereby, the natural resources of our planet show up scarce and finite. Under these circumstances, the need for sustainable consumption and industrial solutions to reduce pollution is more than necessary. In this context of finitude of natural resources and the increase of consumption, the State shall promote public policies to mitigate the harmful effects to the environment. The payment for environmental services (PES) shows up as an alternative to induce consumer awareness by the population.
The PSA goal is to modulate effects in society, to encourage preservation practices and preserve the enrionment. The initial purpose of this paper is to provide a national overview of payments for environmental services, identify some of the major PSAs adopted by federal government, pointing out the social and economic effects of these economic incentives. In addition to environmental benefits. The reasons that make PSA an ideal instrument for public policies will be highlighted as well.

Payment for Environmental Services in Brazil

The economic incentives for environmental conservation has a great importance in the preservation and restoration of biomes and maintenance of natural resources, as well as being strategic in the fight against poverty in rural communities (small farmers, extractive communities, indigenous people, etc.). When they are adopted as public policy, they have the ability to complement or strengthen the instruments of “command and control”, that are traditionally used by the environmental law to materialize the protection, conservation and improvement of ecosystems.

Among the possibilities of economics incentive, the PES deserves special attention. PES has as defining contractual transaction by which the payer of environmental services – government or private source located on the condition that the user of environmental services in his own in a collective name – transfer funds or other form of remuneration to a provider of these services – individual or legal entity, puclic ou private, family or community group, met the eligibility criteria, maintains, or recovers the environmental conditions ecosystems. Its highlighted the worldwide commercialization of four environmental services with greater intensity and frequency, namely: carbon, biodiversity, water and scenic beuty. Each system has a form of payment for environmental service performed, and, in the PES-carbon systems are generally paid per ton of carbon not emitted into the atmosphere or kidnapped. In PES-biodiversity systems, paid up by species or hectare of protected habitat. In PES-water systems, paid by the maintaining or increasing the quantity and quality of water. In PES-beauty scenic systems, you pay for tourism services and photo permissions.

The first PES experience is from Costa Rica, by the end of the 90s. It emerged because the country has faced the highest deforestation rates in the world. The issue became known in Brazil in the 90s as well. At that time, a law about the National Water Resources Policy has established the need to pay for water use and reinvestment in their own watershed. Later, in 2003, with the initiative of the federal government, began a social and environmental development program called ‘‘Proambiente’’, aiming at harmonizing the environmental conservation and rural development processes in the Amazon.
Currently are several PES initiatives in Brazil, such as the “Bolsa Floresta”(Green Grant) in the state of Amazonas, created in 2007, a pioneer in payment for environmental services to populations living in forested areas of the Amazon, committed to reduce deforestation and value the standing forest; the Conservative Water Project in the municipality of Extrema / MG (rivers that integrate the watershed that provide water to Cantareira System in São Paulo), which determines the reward for the environmental service of adoption of soil conservation practices, effective abatement purpose of erosion and sedimentation. The Ministry of the Environment identified in 2010, only in the Atlantic Forest, forty projects of water producers, 33 of carbon dioxide and five biodiversity market.

Another important federal PES is the Program to Support Environmental Conservation, known as "Green Grant". This policy provides quarterly grants of R$ 300.00 for families of settlers, riparian, extractive, indigenous peoples, quilombolas and other traditional communities, living in extreme poverty (monthly per capita income of up to R$ 70.00). To receive the funds, grantees must maintain on a sustainable basis (including economically) the vegetation cover of your property, explore the environment in order to ensure the sustainability of renewable environmental resources and ecological processes, biodiversity and other ecological attributes. In 2010 a Law Institute has researched about PES and has published the book named: "State System of PES: diagnosis, lessons learned and challenges for future legislation" to assess the experiences and the effectiveness of PES legislation in six Brazilian states (SP, MG, AM, AC, ES and PR). The research showed that developed PES programs were able to induce a change of behavior in the interviewed beneficiaries, resulting in the sustainable use of natural resources and the conservation of natural capital. Thus, for example, in Acre state, the State Program for Productive Units Certification modified the traditional system of agriculture adopted by the beneficiaries (family farmers), the Doing abandon the use of fire and replacing it with the use of agroforestry and other techniques such as "sustainable brushed".

In the same direction in the state of Minas Gerais, as a result of joining the program, beneficiaries showed an increase in environmental awareness and the abandonment of wood burning to produce charcoal as a source of additional income. In the state of Espírito Santo, in interviews with the beneficiaries, they made a point of stressing that the gains were visible because the water body that cut their property stopped dry and water quality has being improved. In addition to the environmental gain, the research found many positive effects of a social nature relating to the development of PES programs in each one of the states. Moreover, because of the priority given to small family farmers and traditional communities, it is clear that these programs have a strong component of social and economic inclusion, without compromising its environmental objectives.

Outstandingly, in the case of Amazonas State, satisfaction with the program is not necessarily linked to the value of monetary incentives received by beneficiaries (regarded by them as too low), but rather with non-monetary incentives. They are receiving a lot besides money with the “Bolsa Floresta”, such as radio communicators, ambulances, boats, generators and wells. The same situation was observed in the state of Acre, where the beneficiaries assigned a much higher value non-monetary incentives they received, such as the construction of dams, seedlings of fruit trees, small animals and materials to build chicken coop. In programs with a strong social gore, the diffusion of knowledge of new sustainable techniques was verified by increasing food and economic security of beneficiaries.
From the experience of “Proambiente” and other private initiatives, several draft laws on PES have been proposed within the Chamber of Deputies, the Senate and at the state level, besides being addressed in different policies, laws and government programs. At the same time, it was through local initiatives, led by states, municipalities, basin committees and the private sector that the first practical experience gained strength. Currently, surveys point out that there are over 28 initiatives, including laws and decrees identified at state and federal levels, as well as federal bills still under discussion related to PES and REDD (Reducing Emissions from Deforestation and Forest Degradation) allies, being majority in the Southeast, South and North Brazil.

The establishment of a National Plan for Payment for Environmental Services, currently in the House of Representatives that the PL 792/2007 defines concepts, objectives, guidelines and actions of the National Policy on Payment for Environmental Services (PNPSA) establishes the National Register of payment for Environmental Services (CNPSA), the Federal program for payment for Environmental Services (PFPSA) and the Federal Fund payment for Environmental Services (FFPSA) and provides for the payment of contracts for environmental services. The several types for payment for environmental services are listed in Article 8 of the bill: direct payment provision, community, social improvements previously agreed, compensation linked to emissions reduction certificate from deforestation and degradation, as well as others that should be defined by an specific regulation.

Conclusion

Payment for environmental services has great importance in the preservation and conservation of biomes, but may have a higher scope if the State improves the public policy, both in rural and urban areas. PES current programs have shown, in addition to environmental benefits, positive effects of socio-economic developments for the communities that are the target of this kind of public policy, highlighting the expansion of sustainable techniques, which enhance food security. Besides the direct benefits of PES (social, economic and environmental) that instrument has the ability to democratize access to sustainable technologies.

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Magnetic Separation of Fine Particles from Process Water Circuits in the Steel Industry

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The European Conference on Sustainability, Energy & the Environment 2015
Official Conference Proceedings

Abstract

Within a European collaborative research project aimed at reduction of fine iron-containing particles (0.5µm - 10µm) in steelmaking process water circuits, a new magnetic separation system using permanent magnets has been designed and tested. Hot rolling mill process water for descaling and cooling can accumulate large amounts of suspended solids that can cause spray nozzle wear (influencing product quality), erosion of equipment, clogging, lower performance and hence higher maintenance costs. Low quality water can also cause environmental issues by exceeding the regulatory limits, and higher water consumption from increased blowdown. Removal of these suspended solids is essential. This paper describes research undertaken at a Tata Steel site (UK) in collaboration with BFI (Germany) to develop a new magnetic separation system to efficiently remove the solids and produce sludge with low water content. Results of Computational Fluid Dynamics (CFD) simulations and site trials have been used to optimise the exact positions and number of magnets. Performance of the system was assessed by treating the mill process water. Flow rates of higher than $50m^3/h$, efficiencies greater than 98% and reduction of chemical dosing by 50% have been achieved. In comparison with a typical sand filter, the tested magnetic separator is more compact, produces sludge with 20 times more solids content with water content of only 0.06% of the treated flow compared to 1% -10% of conventional sand filters.

Keywords: steel rolling mill water, steel surface cleaning water, process water, wastewater treatment, magnetic filtration

1. Introduction

During iron and steelmaking processes, scale and iron particles down to 0.5 μm may be formed, entering the cooling and cleaning water systems with flows between 100 m^3/h and 10,000 m^3/h [1, 2 - 14]. In EU 28 there were approximately 169 million tonnes hot rolled steel produced in 2014 [15]. Up to 1% of the steel charged is transformed into scale, including approximately one-fourth as fine scale (< 40 μm) which has to be removed and is hence lost from production [2]. Typical hot rolling mill process water for descaling and cooling can accumulate large amounts of suspended solids that can cause spray nozzle wear (influencing product quality), erosion of equipment, clogging, lower process performance and hence higher maintenance costs. The removal of these suspended solids is essential to improve the product quality and process performance, and reduce costs. Contaminated water can also cause environmental issues by exceeding the regulatory limits, and higher water consumption from increased blowdown. Increasingly demanding national and European policy and legislation such as the EU Water Framework Directive [16], and Industrial Emissions Directive [17], have made it essential to manage and reduce the emissions to water to comply with environmental legislation.

The contaminated process water is normally treated using a clarifier system (settlement tank) with the addition of chemicals to enhance the solids sedimentation rate. This treatment method can be inefficient and expensive to maintain, providing the opportunity for significant efficiency and financial gains as well as environmental improvement. Tata Steel continuously aim at increasing product quality, process efficiency and environmental improvement. As part of a European multi-partner research project, MAGSEP [18] started in July 2012, aimed at the reduction of fine iron-containing particles (0.5μm - 10μm) in steelmaking process water circuits, Tata Steel have collaborated with BFI (Germany) to develop a new magnetic separation system for treating process water. The aim of the project is the efficient and chemical-free removal of iron particles from process waters using strong field permanent magnets in combination with compact design and low back flush flows under 1 % of the treated water. Laboratory and on-site tests, and CFD-simulations are used for the development of a mobile plant with suitable magnet configurations for the efficient iron particle removal at different process water conditions. The project also aims at conditioning and metallurgical reuse (sinter plant, blast furnace) of the separated particles. This paper describes the research undertaken at a Tata Steel site (UK) to develop a new magnetic separation system to efficiently remove the suspended solids from hot rolling mill descaling (Scarfer) water and produce sludge with low water content.

1.1 Steel Surface Treatment Process Water Description

The research was conducted at a Tata Steel site (UK), that produces alloyed steels for the Oil, Gas and Aerospace industries, on a steel billet mill surface treatment (scarfer) plant where oxy-propane flame is used to burn off the surface defects up to a depth of 3 mm. This process is immediately followed by a high pressure water jet to quench and clean the billet surface. The particulate emissions produced by the scarfing process are extracted and passed through an electrostatic precipitator (ESP) to filter the dust particles and allow clean air to be released to the atmosphere. The ESP collection plates are periodically cleaned with a water jet to maintain high performance.

During the scarfing process and cleaning of the ESP solid particles are introduced into the process water circuit. The water circuit consists of a hydrocyclone for the separation of coarse particles, followed by a buffer tank (clear well), Figure 1. The process water is pumped (discontinuously) towards a settlement tank (linear clarifier) with a flow rate of approximately 540 m^3/h. The water is pumped on average for 40 minutes per hour. The scarfing process is operational for 5 days per week. A chemical (flocculant-coagulant) mixture is dosed at the inlet of the settlement tank to aid the sedimentation of the solid particles. Depending on the water levels some of the settlement tank water is discharged to a nearby hot rolling mill cooling water clarifier and replaced by make up water from a local river. Approximately 10 tonnes of sludge per week are removed with a grabber out of the settlement tank. Furthermore, the settlement tank is drained and cleaned once per year.

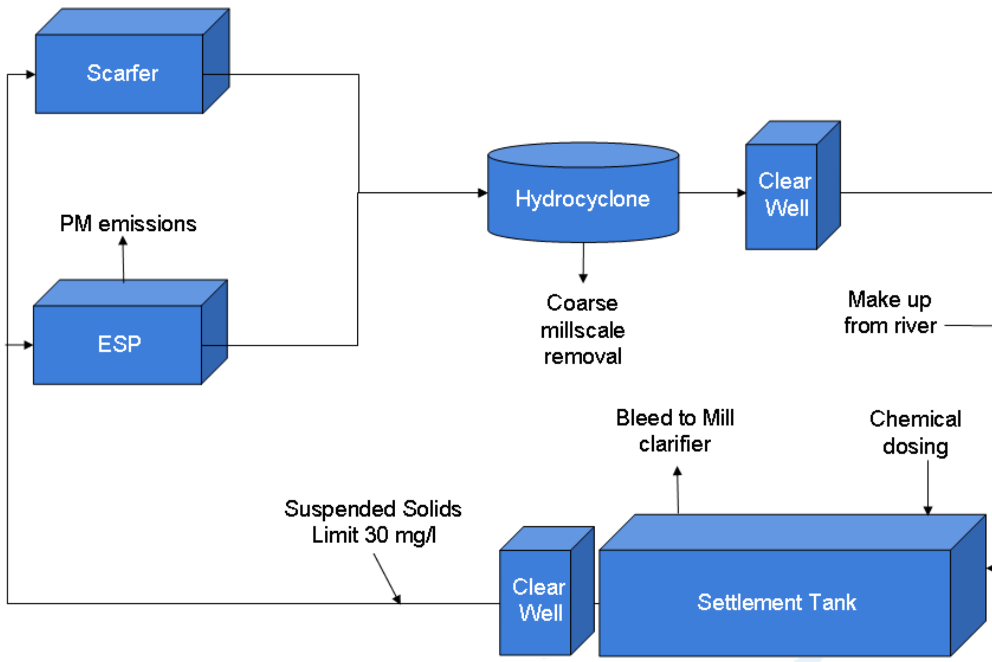


Figure 1 (a)

Figure 1 (b)

Figure 1: Tata Steel scarfer water circuit schematic (a) and settlement tank (b)

1.2 Required Improvements in Product, Process and Environment

Experience has shown that an increase in the suspended solids concentration of a typical scarfer process water can have a significant effect on process performance and product quality. The solids can cause wear of scarfer spray nozzles, which can influence the quenching and cleaning of the product surface. The solids can also cause wear of ESP plates spray nozzles which will influence the ESP efficiency in reducing particulate emissions. The deterioration of process performance and product quality, and environmental issues lead to increased costs of repair and maintenance.

The above scarfer water may have concentrations of up to 350 mg/l that should be reduced to below the process quality and environmental limits of 30 mg/l using the settlement tank, Figure 1. Owing to the variability of the process conditions and the need for a high solids removal efficiency the settlement tank is currently inadequate and expensive to maintain, providing the opportunity for significant efficiency and financial gains. Tata Steel UK decided to be a partner member in a collaborative project, MAGSEP, to look into improving the environmental impact and making savings through lowering costs of water operations by developing a magnetic separator to significantly reduce the suspended solids concentrations in the scarfer water system. Table 1 lists the desired improvements and performance requirements of particle separator at the Tata Steel scarfer water system.

Table 1: Requirements of particle separator at Tata Steel scarfer water system

Requirement 1	High separation efficiency for water reuse Reduced nozzle scaling & wear Reduce maintenance costs Reduce chemical costs
Requirement 2	Minimise space
Required solids concentration	30 mg/l regulatory and process control limit
Required particle size	Less than 50 μm

1.3 Magnetic Separation Technologies

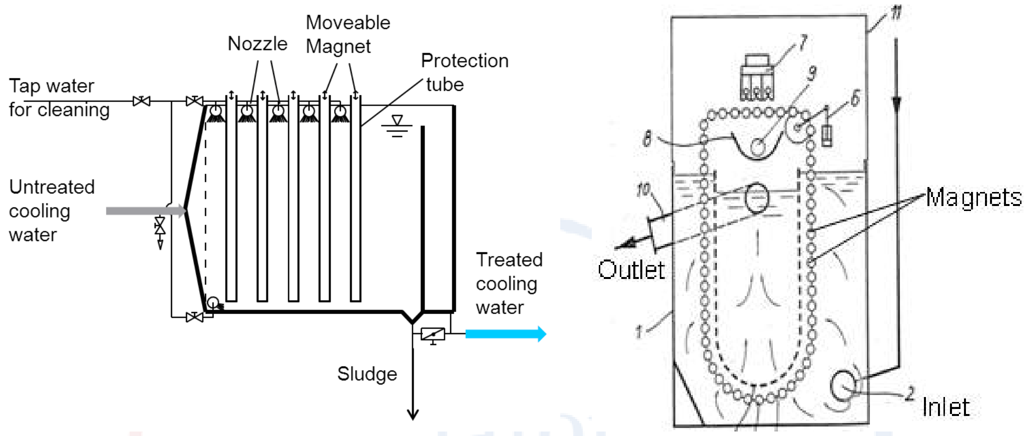
Magnetic separation is preferred to other filtration techniques, such as sand filters, due to its:

- lower operating costs – no consumables or chemicals, less flushing water,
- higher separation efficiency including fine particles down to 0.5 μm,
- reduced space requirement.

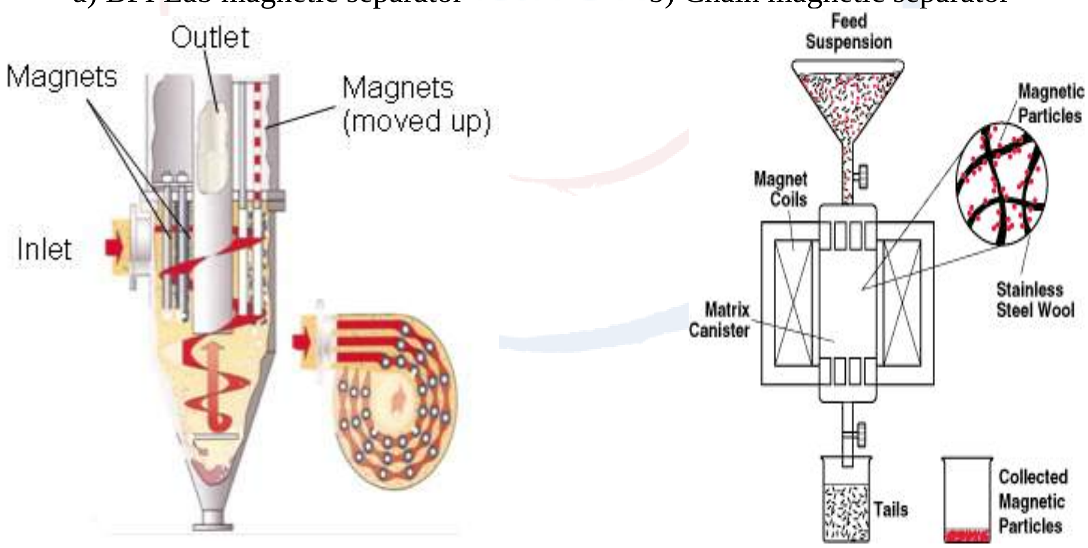
Generally the requirements for the process water are suspended solids concentration below 30 mg/l for hot rolling [5] and 50 mg/l for descaling pumps, with particle sizes below 50 μm [9]. Furthermore, in some cases for continuous casting cooling water particle sizes below 50 μm are required [11]. BFI had already developed a magnetic laboratory-based plant with a design flow rate of 4.5 m^3/h and maximum flow of 10 m^3/h . The magnets are placed in non-magnetic steel protection tubes. The magnets can be moved in and out of the protection tubes by a hydraulic unit. Furthermore, a nozzle system is installed at the top of the tank for cleaning of the protection tubes and further nozzles at the bottom of the tank for the removal of the separated particles after cleaning the magnets. The duration of the water spraying time for cleaning the protection tubes depends on the oil content of process water, generally below 15 minutes. Figure 2 and Table 2 present a comparison of the BFI Lab magnetic separator and conventional magnetic separators. The BFI Lab magnetic separator consists of five lines of permanent magnets alternately offset to ensure that the particles are positioned in the range of the magnetic field and impact the magnets directly because of their inertia. The positioning of magnets and hydrodynamic conditions in the BFI Lab magnetic separator can be adapted to the process water properties such as solids concentration and particle size.

The chain magnetic separator (Patent DE 4130421 A1), Figure 2b, consists of only one line of magnets, decreasing the probability of the particles getting close enough to the magnet to be caught by the magnetic field and impact the magnet surface. The main distinguishing factors between the BFI Lab magnetic separator and the chain magnetic separator are the hydrodynamic conditions (laminar/turbulent) and the positioning of the magnets. A further magnetic separator with permanent magnets is based on a combination of a hydrocyclone with magnetic bars arranged along the main flow direction, Figure 2c. The main difference between the systems is the positioning of the magnets and the cleaning. The magnets are arranged in ten lines, but not shifted in position, so the probability of high particle capture is significantly lower compared to the BFI Lab magnetic separator. A further distinguishing mark is the magnet cleaning procedure, which takes place by stopping the flow, moving out the magnets and blowing in compressed air to create turbulent conditions inside the hydrocyclone. After this, the hydrocyclone is emptied. The described cleaning method requires compressed air (operational costs).

The high gradient magnetic separator (Patent WO 002002081092A), Figure 2d, consists of a tube with a wire cloth (several mesh layers) or steel wool inlet. It is apparent that at the inlet there is a risk of clogging from presence of oil in the process water. The cleaning is practiced by switching off/turning the magnets followed by high pressure back flushing. Trials with water from hot rolling mill or a descaling unit containing 300 mg/l solids, leading to a required cleaning water amount of 7.5% of the treated volume. At a solids content of 90 mg/l, the required cleaning water amount was 2.5% of treated volume. The back flushing time was 14 s [19]. The reported maximum flow rate was 650 m^3/h [20].



a) BFI Lab magnetic separator b) Chain magnetic separator



c) Hydrocyclone mag separator d) High gradient mag separator

Figure 2: Schematics of the BFI lab and other magnetic separators

Table 2: Comparison of BFI lab and conventional magnetic separators

Type of Magnetic Separator	BFI Lab Magnetic Separator	Chain magnetic separator	Hydrocylone separator with magnetic bars	High gradient magnetic separator (HGMS)
Process principle	Flow-through tank with emulsion and metal particles specific arrangement of the magnets (5 lines of offset/shifted)	Magnet bars arranged on two circulating chains, which are immersed in a media (cooling water, emulsion) -perfused tank	Combination of a hydrocyclone with magnetic bars arranged along the main flow direction	Permeable pipe with a magnetizable wire cloth, carried its magnetization / demagnetization by rotating a magnet of opposite polarity or with an electro magnet as magnetic source
Magnet type	Permanent (1 T)	Permanent	Permanent (1 T)	Permanent or electromagnet (1/1.5 T)
Magnet cleaning	Extension of the magnets and spraying of cladding tubes with minimal use of flushing medium	Solid (and oil removal) by mechanical scraper after leaving the tank	Compressed air injection in filled separator and discarding the contents	Deactivation of the magnetic field in the filter cloth through the magnetic rotation and back-flushing of the metal mesh filter and the pipe or switching off the electromagnet
Moving components	None	Engine for chain drive circulation chains with bar magnets	None	None
Wear	None	Wear of the scraper by abrasive metal particles - chains	Wear of the separator by swirling the abrasive metal particles	Clogging of the filter cloth by irreversible buildup (fat, oils)

2. Preliminary Research for Optimization of Design of New Mobile Magnetic Separator

To optimise the design of the new magnetic separation mobile plant all the necessary data and information related to the site application had to be collected. The information included the operating conditions, water sampling and analysis of the scarfer process water, and characteristics of the suspended solids. Additionally, it was necessary to carry out field tests using the existing BFI laboratory magnetic separator at the Tata Steel site scarfer water circuit to obtain essential information on the site implementation requirements and to prevent difficulties with implementation of the new 50 m^3/h mobile magnetic separator. Specifically, the optimum flow rate for maximum removal efficiency and removal rate, magnet cleaning procedure for minimum duration and water use and sludge water content, and minimising chemical dosage have been investigated. Also, results of CFD simulations were used by BFI to complement the site trials to determine the exact positions and number of magnets in the new magnetic separator.

2.1 Scarfer Water Sampling and Analysis

Several water sampling campaigns were undertaken at the Tata Steel settlement tank inlet and outlet to determine the water conditions that the magnetic separator will be required to perform under. Figure 3 shows typical variations of the solids concentrations before water treatment during Sept-Nov 2012. Table 3 shows maximum, minimum and average values for particle concentration, size and composition for different periods in Dec 2012 to Oct 2013. Although, the particle composition analysis showed a highest iron content of 57.5%, it can be more than 80%, which makes it highly susceptible to magnetic attraction.

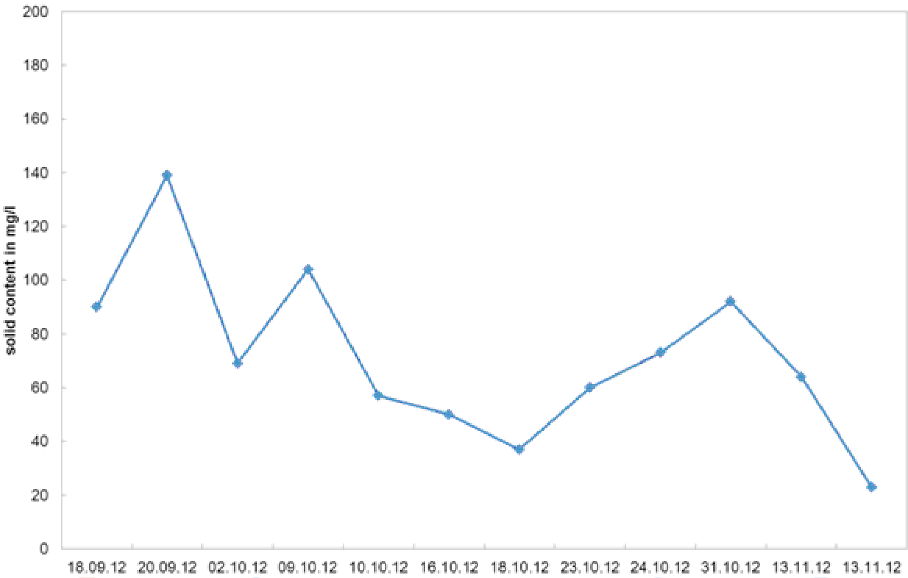


Figure 3: Solids concentrations in scarfer process water before treatment

Table 3: Range of particle concentrations, sizes and compositions in scarfer water

Sampling Period	Dec 2012 - March 2013		June 2013 – July 2013		Sept 2013 – Oct 2013	
Sampling point	Before settling tank	After settling tank	Before settling tank	After settling tank	Before settling tank	After settling tank
Particle concentration [mg/l]						
Maximum	104	86	73	56	178	104
Average	62	42	46	32	64	33
Minimum	23	15	10	8	13	4
Particle size [µm]						
D10	6	6	-	-	3.7	2.2
D50	19	16	-	-	11.5	9.7
D90	49	48	-	-	40.2	47.1
Particle composition [w-%]						
Fe	57.5	41.3	46	56	-	-
Al	4.3	4.4	---	---	-	-
Ni	1.1	---	---	1.5	-	-

2.2 Field Tests with the BFI Laboratory Magnetic Separator

The main aims of the on-site field tests were to:

1) investigate specific requirements and to prevent practical difficulties during future trials,

2) obtain data/information for optimum design of the new magnetic separator.

The BFI Lab magnetic separator consists of 5 lines of 4 magnets each. The magnets are alternately shifted in position to maximise the attraction of particles. The scarfer water conditions have been described in sections 1.1, 1.2 and 2.1. The duration of the field trials was two weeks, and the magnetic separator was operated in parallel with the scarfer water settlement tank to investigate:

- optimum flow rate for maximum removal efficiency and solids removal rate,
- suitable cleaning procedure for minimum duration, water use, and sludge water content,
- influence of chemical addition on performance of magnetic separation.

Figure 4 shows the arrangement of the trial set up within the scarfer water system (a) and a photograph of the BFI Lab magnetic separator (b).

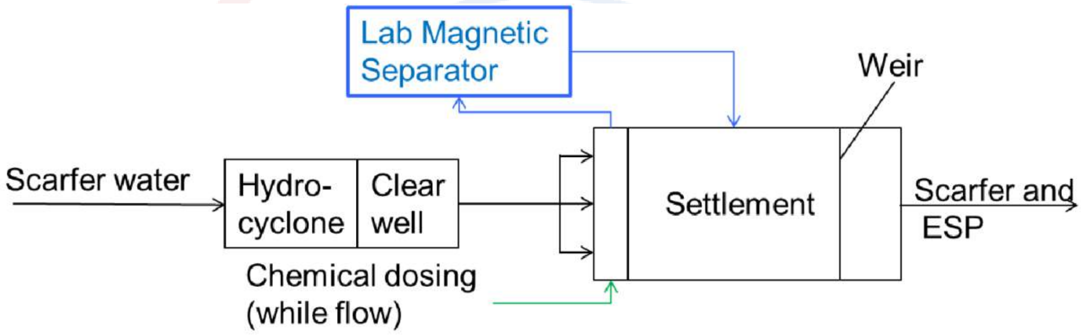


Figure 4 (a)

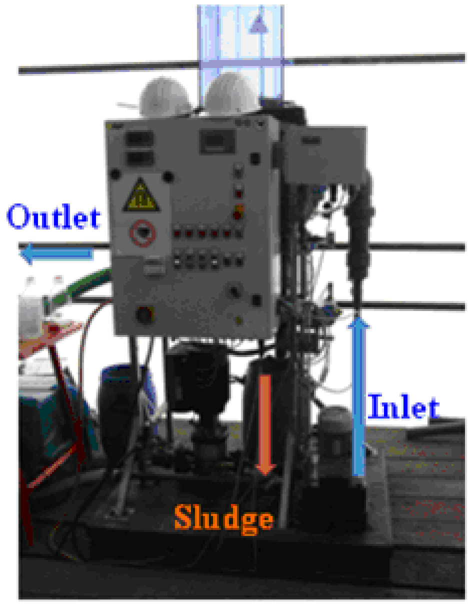


Figure 4 (b)

Figure 4: Trials arrangement of the BFI lab magnetic separator

The first step was the determination of the maximum flow rate that allows an outlet solids concentration below 30 mg/l. The flow rate was increased in steps of 1 m³/h up to a maximum of 8.8 m³/h. Typical water samples taken at the inlet and outlet of the Lab magnetic separator for a flow rate of 2 m³/h are shown in Figure 5.

Figure 5: Inlet, outlet and sludge samples from Lab magnetic separator (2 m^3/h)

During the trials an increase of the solids concentration and a decrease of the removal efficiency with an increase in flow rate was observed, Figure 6. The highest removal efficiency was approximately 98 % and the lowest outlet solids concentration was 5 mg/l which occurred at flow rates of 1 m^3/h and 2 m³/h.

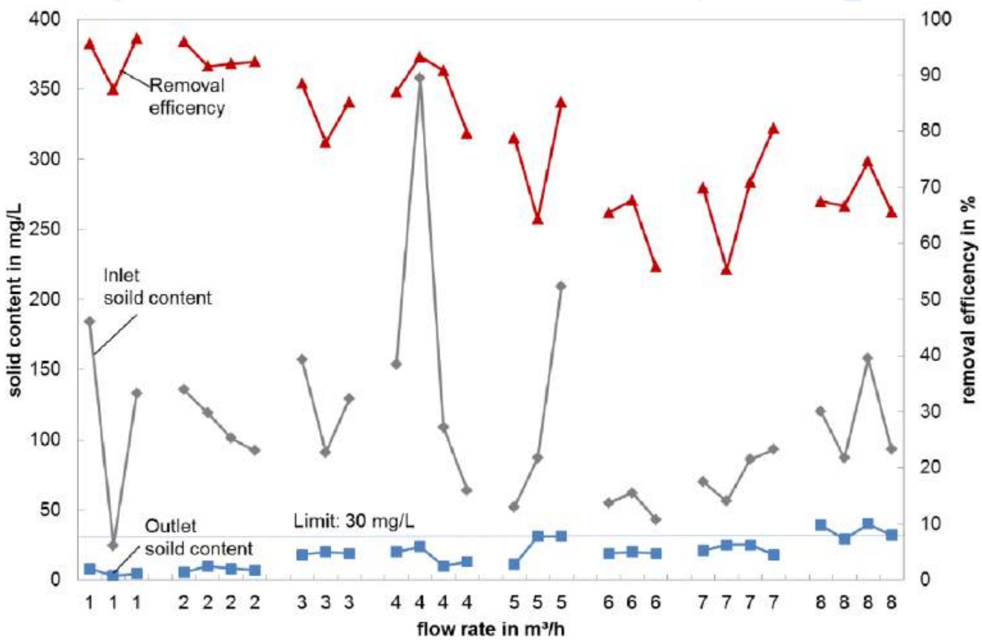


Figure 6: Determination of optimum flow rate for particle concentration < 30 mg/l

The solids removal rate increased with increasing flow rate while the removal efficiency decreased, Figure 7. The maximum solids removal rate with the Lab magnetic separator was approximately 612 g/h, but the solids concentration after treatment (outlet) was on average 35 mg/l which is above the 30 mg/l limit. The optimum flow rate to achieve a combination of high solids removal rate (> 400 g/h) and the required outlet solids concentration could be reached at a flow rate of 7 m^3/h (solids removal rate: 540 g/h, removal efficiency: 70%). These values formed the basis of the calculations of the application of the mobile plant for treatment of the scarfer process water.

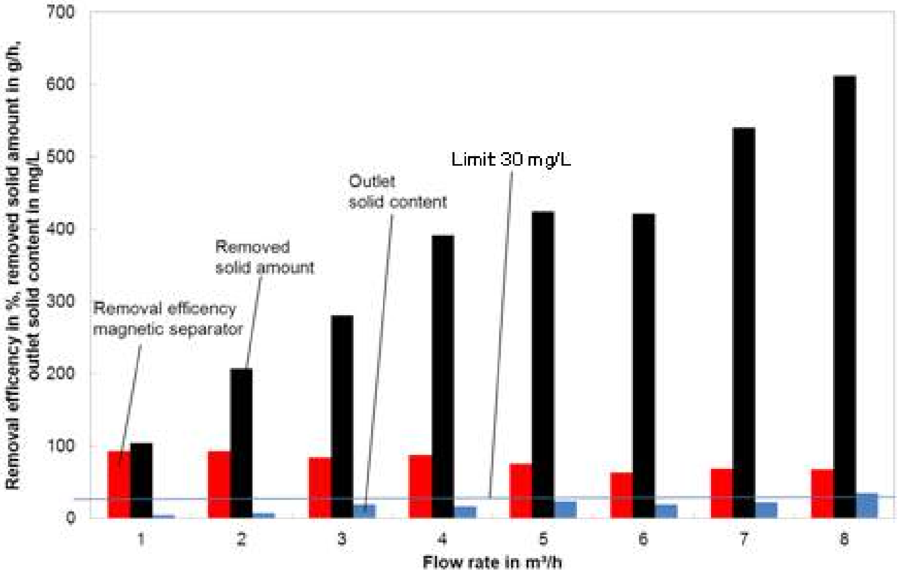


Figure 7: Variation of solids removal rate with flow rate of Lab magnetic separator

Furthermore, the influence of chemical addition at the inlet of the settlement tank and to the magnetic separator was investigated. The absence of chemical dosing leads to higher magnetic separator inlet solids concentration, approximately 200 mg/l (150 - 250 mg/l) compared to periods with chemical dosage with an average solids concentration approximately 120 mg/l (30 - 350 mg/l). Furthermore, an increase in the colouring and turbidity of the water was noticeable when chemical dosing was absent, Figure 8.

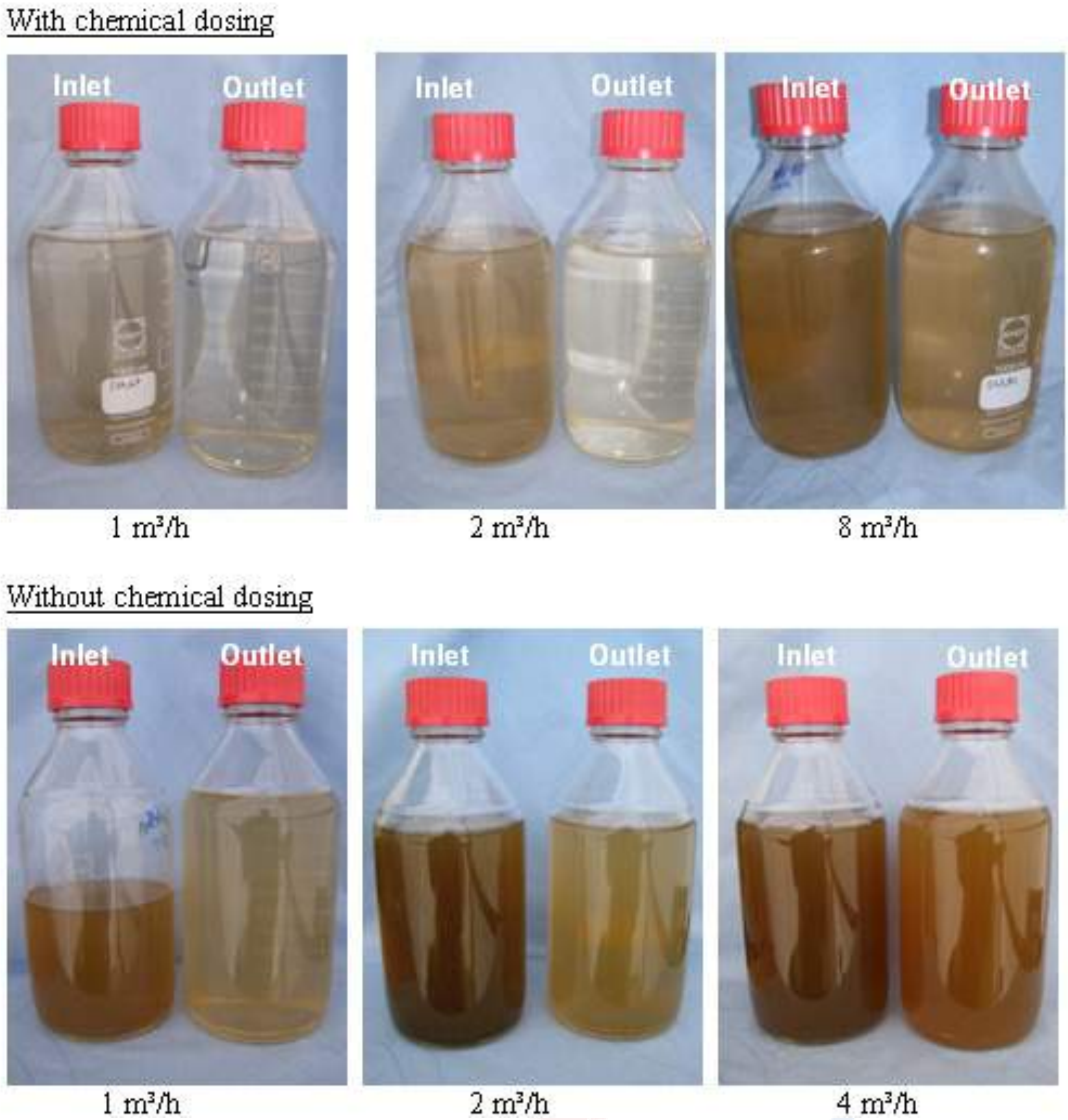


Figure 8: Comparison of inlet and outlet samples of the lab magnetic separator with and without chemical dosing at different flow rates

The trials without chemical dosing demonstrated, that it was possible to remove particles to achieve levels at the outlet below the limit of 30 mg/l at a maximum flow rate of 2 m^3/h with a range of outlet solids concentration from 10 mg/l to 21 mg/l (average 18 mg/l), Figure 9.

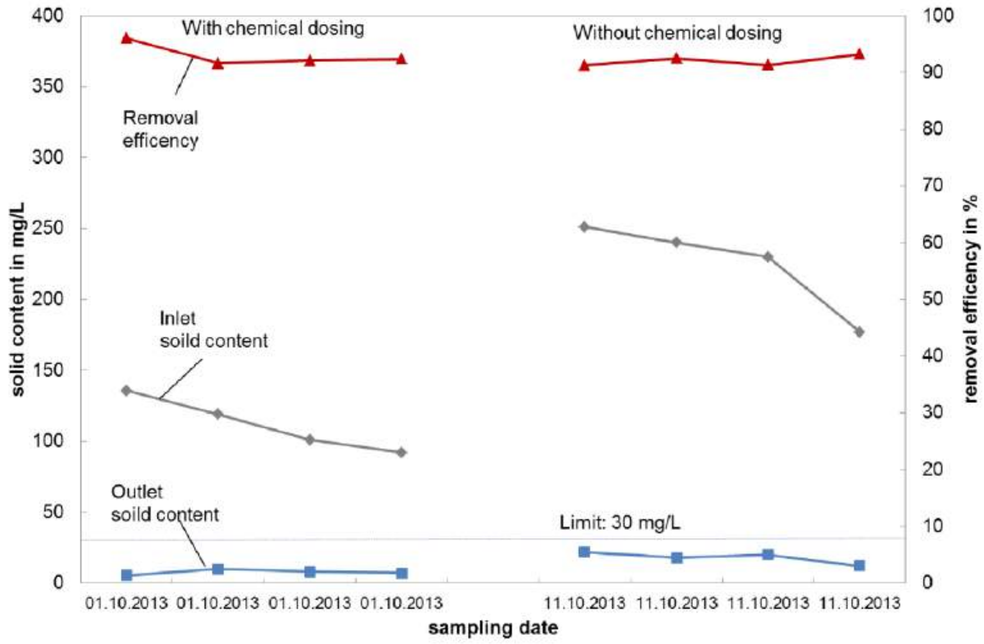


Figure 9: Comparison of Lab magnetic separator outlet solids concentration and removal efficiencies with and without chemical dosing (2 m³/h)

Flow rates above 2 m³/h lead to the solids concentration exceeding the limit value of 30 mg/l, e.g. a flow rate of 4 m³/h with an average outlet solids concentration of 50 mg/l.

The results show that the concept of the BFI Lab magnetic separator (several lines of magnets, alternately shifted in position) is suitable to satisfy the requirements of the Tata Steel settlement tank (outlet solids concentration < 30 mg/l) with and without chemical dosage. At the current scarfer water configuration, a reduction in the chemical dosing rate is possible by using magnetic separation instead of the sedimentation process. The only advantage of using chemical addition will be to "glue" the magnetic and non-magnetic particles together, which may further enhance the removal efficiency.

3. Development of New Mobile Magnetic Separator

The new magnetic separator (50 m^3/h mobile plant) was designed and constructed by BFI based on the lab magnetic separator design, information obtained from the site trials and the CFD modelling. The design consisted of 3 lines of magnets with 12 in each line, alternately shifted in position. After construction, the plant was transported from BFI (Germany) to the Tata Steel site (UK) to carry out the trials for performance evaluation.

3.1 Field Trials of the New Magnetic Separator

Figure 10 (a) shows the new magnetic separator set up for the trials at the Tata Steel site, which is similar to the set up for the trials with the lab magnetic separator, described previously. In this trial the submersible feed pump was placed in the settling area of the settlement tank, Figure 10 (b), instead of the inlet part which was the case in the previous trial. This ensured a continuous availability of solids-containing water.

Furthermore, it allowed a cleaning of the settlement tank and the scarfer water during periods of no production. The range of inlet solids concentration (36 – 670 mg/l) during the field tests of the new magnetic separator in 2014 was similar to the range during the field tests with the lab magnetic separator in 2013. However, in 2014 over 30% higher solids input of 62 kg/h compared to 42 kg/h in 2013 was observed corresponding to an increase in solids concentration of 100 mg/l (to 230 mg/l).

Figure 10 (a)

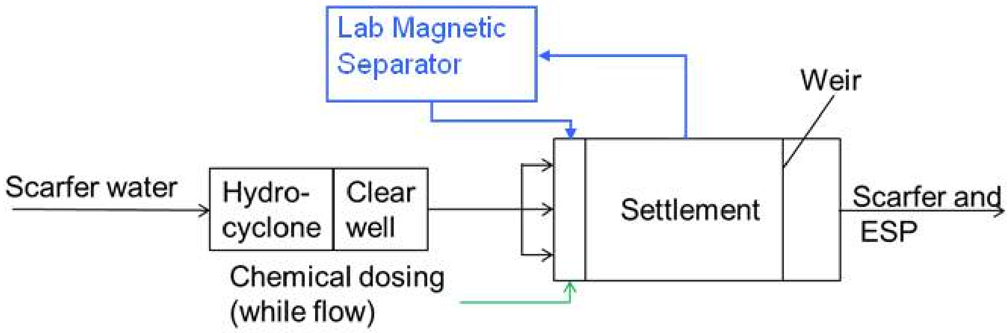


Figure 10 (b)

Figure 10: Trial setup at Tata Steel UK site with mobile magnetic separator

3.2 Performance Evaluation of the Mobile Magnetic Separator

The comparison of the removal efficiencies of the lab and mobile magnetic separator at three different flow velocities, without chemical dosing, showed a good correspondence between the results for a flow velocity of 0.3 cm/s. The achieved outlet solids concentrations for both magnetic separators at flow velocity of 0.3 cm/s were below the 30 mg/l limit. With increasing flow velocity, there was a difference between the results for removal efficiency or outlet solids concentrations of the lab magnetic separator and the mobile magnetic separator, Figure 11. One reason for the decrease in efficiency of the mobile magnetic separator may be the reduced number of magnet lines (lab: 5 lines, mobile: 3 lines) as more magnet lines may allow more particles to be captured. A further reason may be the amount of non-magnetic particles present during the 2014 trials.

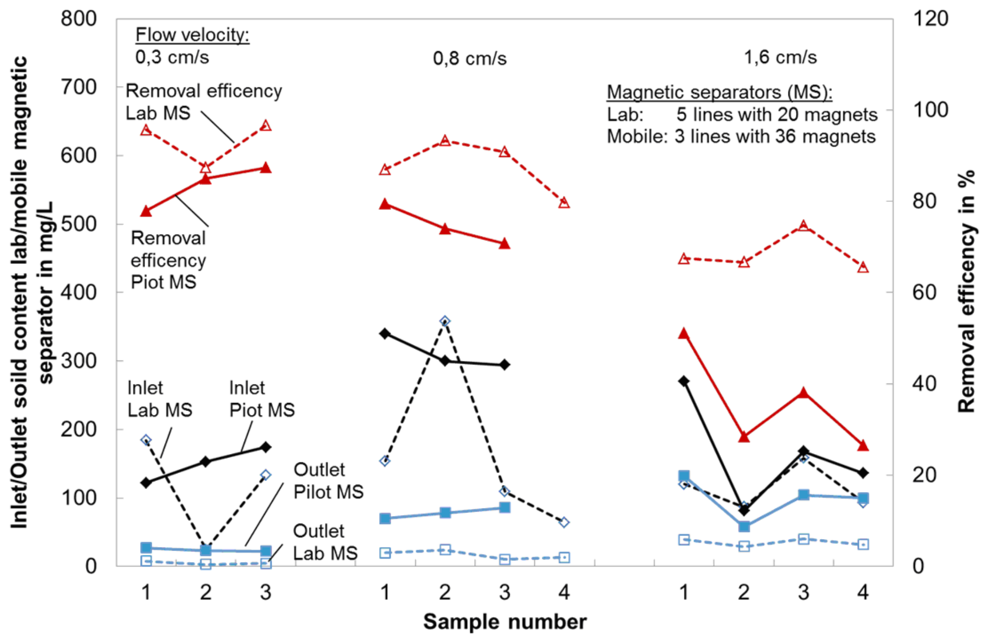


Figure 11: Comparison of outlet solids concentrations and removal efficiencies of BFI lab and mobile magnetic separators without chemical dosage

The long term behaviour of the mobile magnetic separator under operational conditions (varying particle concentrations, flow rates and processed steels) in Tata Steel water circuit has been investigated. During these field tests a total water of 2500 m^3 has been treated in a period of two weeks. In the first part of the work at Tata Steel, the influence of different chemical dosage rates on the removal efficiency and outlet solids concentrations of the mobile magnetic separator were investigated. Dosing rates of 0%, 25%, 50%, 75%, and 100% of the rate normally applied at the settlement tank were used.

Figure 12 and Figure 13 show that, for the exemplary flow rates of 10 m^3/h and 50 m^3/h, a chemical dosage rate of 25% of normal leads to a decrease of the outlet solids concentrations below the 30 mg/l limit. A further increase of the polymer dosage did not lead to a further decrease of the outlet solids concentrations. At the flow rate of 50 m^3/h it was possible to reduce chemical dosing by 50%, achieve 85% efficiency and outlet solids concentrations below the 30 mg/l.

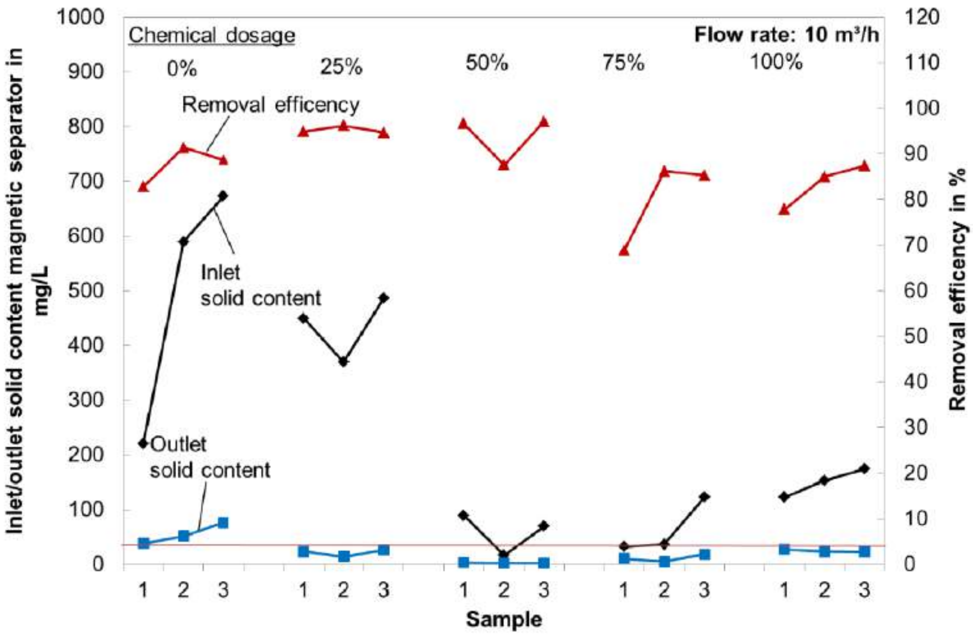


Figure 12: Influence of chemical dosage on outlet solids concentrations and removal efficiency (10 m³/h)

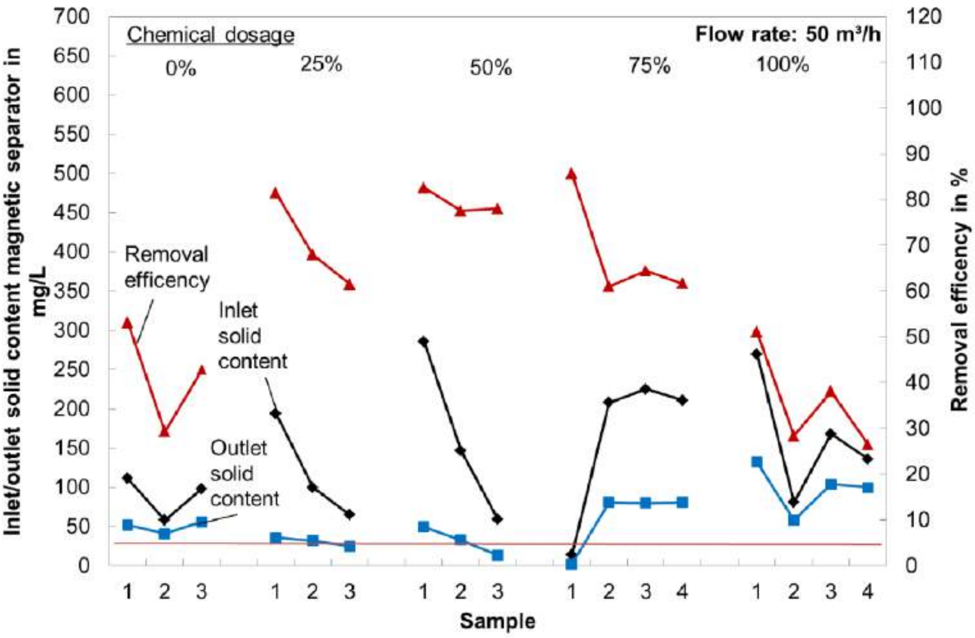


Figure 13: Influence of chemical dosage on outlet solids concentrations and removal efficiency (50 m³/h)

The magnet cleaning performance and suitable cleaning conditions were evaluated mainly by varying the cleaning water pressure between 1 bar to 7 bar and cleaning water spray duration. During the cleaning process, the movement of the nozzle holder and the cleaning water flow were stopped to observe the achieved cleaning efficiency. The following optimum cleaning conditions have been determined for the cases of 0% to 100% chemical dosage:

- Required water pressure:

  - 2 bar with 0% chemical dosage
  - 4 bar with 100% chemical dosage
- Water spray duration: 1 minute
- Magnets maximum sludge loading capacity:140 kg (Figure 14)
- Ratio of produced sludge/treated volume: 0.06%, e.g. 0.12 m^3 sludge after treating 200 m^3
- Solids content in sludge: 12 – 17 wt.-% - (sand filter: < 0.7 wt.-%)

The dosage of chemical required an increase of the cleaning water pressure from 2 bar to 4 bar to ensure a sufficient magnet cleaning. Higher water pressure above 4 bar did not improve the magnet cleanness but increased the cleaning water consumption. The complete cleaning process consists of emptying/filling the tank of the magnetic separator, movement of the nozzle holder and water spraying for a total duration of < 5 min.

Figure 14 (a): Completely loaded magnets

Figure 14 (b): Magnets after cleaning

Figure 14: Magnets completely covered and after cleaning

The performed field tests at Tata Steel site indicated that the developed magnetic separation design provides a suitable treatment process. It has the advantages of low sludge amount with 0.06% of the treated volume, high sludge solids contents up to 17 wt.-%, low fresh water consumption and short cleaning periods (< 5 min), Table 4. Scaling of the magnets (protection tubes) in the tank or wear of the valves and nozzles could not be observed after treating 2,500 m³.

Table 4: Summary of results of field trials with mobile magnetic separator

Solids removal efficencies	up to 98%
Magnet cleaning water pressure	Without chemical: 2 bar With chemical: 4 bar
Magnet cleaning water demand	Without chemical: 60 litre With chemical: 120 litre
Magnet cleaning period	Total < 5 minutes Water spraying < 1 minutes
Sludge amount after cleaning	< 140 kg
Ratio sludge amount to treated volume	< 0.06 %
Sludge solids content	12 – 17 wt.-%
Scaling of magnet cleaning nozzles	None – after treating 2,500 m³
Maximum magnet load	10.5 kg/m²

3.3 Water Quality and Economic Considerations

An estimate of amount of water quality improvement at the Tata Steel scarfer water using the magnetic separator has been calculated, Table 5. Assuming an average settlement tank efficiency of 60%, average continuous flow of 300 m^3/h (discontinuously at 540 m^3/h), with magnetic separator efficiency of 95% and flow rates of 50 m^3/h, 100 m^3/h and 300 m^3/h, the overall scarfer water treatment efficiency can increase to 66%, 72% and 95% respectively.

Table 5: Estimated efficiency improvement of scarfer water treatment

Magnetic separator Flow rate	Proportion of flow treated	Assumed current tank efficiency	Reduction in tank outlet SS	Overall treatment efficiency
50 m^3/h	17%	60%	15%	66%
100 m^3/h	33%	60%	29%	72%
300 m^3/h	100%	60%	88%	95%

The exact cost values of running the Tata Steel scarfer water system were not available, hence approximate cost savings have been estimated. Based on 50% reduction in chemical dosing and 20% water quality improvement approximately 42 k€/a cost reduction may be achieved, Table 6.

Table 6: Estimated potential costs savings using the magnetic separator

Cost type	Current state without magnetic separation	With magnetic separation	Comment
Chemical costs [€/a]	70,000	35,000	Possible 50% reduction in chemicals
Maintenance of Scarfer water system [€/a]	21,000	16,800	Assume 20% reduction in maintenance
Manpower for Scarfer water system [€/a]	12,600	10,080	Assume 20% reduction in manpower
Total costs [€/a]	**103,600**	**61,880**	**Cost reduction 41,720 €/a (>40%)**

4. Conclusions

Typical hot steel rolling process water can accumulate large amounts of suspended solids which influence the product and process quality leading to higher costs, and environmental concerns. Removal of these suspended solids is essential.

The results of the BFI lab magnetic separator field trials at the Tata Steel UK site with no chemical dosing showed a maximum removal efficiency of 98 % and lowest outlet solids concentration of 5 mg/l, which occurred at a flow rate of 2 m^3/h. The removal efficiency was approximately 70 % and outlet solids concentration <30 mg/l at a flow rate of 7 m^3/h. The results of assessment of the mobile magnetic separator showed that at a flow rate of 10 m^3/h with 25% dosing an efficiency of 98% and outlet solids concentration of 5 mg/l could be achieved. At flow rate of 50 m^3/h with 50% dosing an efficiency of 85% and outlet solids concentration of 10 mg/l were achieved.

The field trials illustrated the importance of an efficient magnet cleaning procedure. A low magnet cleaning water consumption (< 120 litres per cleaning) and short cleaning duration (water spray: 1 min, total: 5 min including movement of the nozzle holders, emptying/refilling the tank) could be confirmed. In comparison with a typical sand filter, the new mobile magnetic separator produces sludge with water content of only 0.06% of the treated volume compared to 1% -10% of conventional sand filters leading to significantly lower amounts for dewatering costs.

The research results showed that the BFI magnetic separation design using permanent magnets is a promising technology for the removal of particles from the process water circuits with potential for quality improvement, cost savings and environmental benefit.

Acknowledgements

The research leading to these results has received funding from the European Union Research Programme of the Research Fund for Coal and Steel (Contract number: RFSR-CT-2012-00042).

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Rainwater Harvesting in Nigeria: A Survey of Common Water Supply Practices

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The European Conference on Sustainability, Energy & the Environment 2015
Official Conference Proceedings

Abstract

Rainwater harvesting systems in Nigeria vary in terms of design and operation. To better understand common practice and motivation for collecting rainwater, a questionnaire survey was selected to achieve a representation of the population of Ibadan. A sample size of 1067 was calculated for household respondents (using a population of 2,555,853). 950 households responded to the survey. The survey questions focused on catchment materials, uses for the harvested water, water policy and strategy, water supply and environmental health. Result indicates that corrugated iron sheet is the most commonly used roofing materials for rainwater harvesting (RWH). The most commonly reported use for harvested rainwater was cooking and drinking although greater than 75% of the respondents use their rainwater for potable purposes. 77% of the respondents had no water supply from the public main while less than 25% receive supply. Of the respondents, approximately 61% have a low yield of supply from well sources during the dry season while 39% have supply. Thus, the prevalence of water-borne diseases, in which 61% reported typhoid fever, 19% diarrhea and 17% cholera. Over 60% of the population depend on well water for their supply while 23% rely on borehole and as low as 6.6% harvest rainwater traditionally as a source. In particular, the low reliance on rainwater and the need for an alternative water supply system should be investigated further as the number of RWH systems installed in Nigeria continues to grow.

Keywords: Rainwater Harvesting, Survey, Catchment, Drinking water

Introduction

There is a challenge of lack of supply of pipe-borne water in Nigeria. Hence, many homes have wells sited around the house some distance from the septic tank. The scarcity of piped water has made communities find alternative water sources; groundwater sources being a ready source. Wells are a common groundwater source readily explored to meet community water requirements or address shortfalls (Adelekan, 2010). The most common cause of pollution is attributed to the close proximity of septic tanks to wells and unhygienic use of wells. For instance, some wells have no cover/lids; they are dirty and unkempt, thus making the water susceptible to infection (Onunkwo and Uzoije, 2011). Groundwater pollution is also caused by the disposal of solid or liquid wastes in pits, abandoned boreholes or even stream channels and landfills (Iyun, 1994). These processes result in the deterioration of the physicochemical and biological properties of water (Orebiyi *et al*., 2010).
The challenges to increasing access to improved drinking water is further complicated by disparities in provision, which may be geographical (between urban and rural); socio-economic (between the poor and more economically disadvantaged) or related to the disproportionate focus on water in comparison with sanitation. For example, compared with 72% of Nigerians in urban areas, only 47% of the rural population has access to improved water sources; whilst the ratio of water access to sanitation is only 2:1 i.e. 58% water to 26% sanitation (WHO/UNICEP 2010). Rainwater harvesting (RWH) is an increasing common practice globally. In Nigeria, population growth, pollution of groundwater caused by poor waste management (Beretta *et al*., 2004) and low yield of wells during the dry season (Lade *et al*., 2012) make harvested rainwater an attractive alternative for potable and non-potable (e.g. irrigation, laundry) uses. There is an increase utilization of rainwater in many parts of the world including, US (Thomas *et al*., 2014), Australia (Huston *et al*., 2012), Bangladesh (Karim, 2010) and Korea (Han and Mun, 2008). Individuals continue to modify their dwellings and devise systems to utilize harvested rainwater due to increase concerns over climate change and stress on water resources (United Nations Environment Programme/SEI, 2009).

Few data on the configuration, operation and maintenance of household RWH system exist. Rodrigo *et al*. (2010) surveyed RWH catchment materials and maintenance practices in Australia, Karim (2010) surveyed RWH catchment materials and cisterns in Bangladesh, Ward *et al*. (2008) surveyed RWH catchment materials and maintenance in UK. To our knowledge, no survey has been conducted in Nigeria. Thus, the objective of our survey was to define the most common water supply system, catchment materials and the need for harvesting RWH in Ibadan. Rainwater is abundant in southern Nigeria. Ibadan city receives heavy rainfall during the rainy season with a mean annual rainfall of 1350 mm. Figure 1 shows rainfall data for Ibadan for the period 1980-2009, indicating that there is ample rainwater. The ponds replenished by rainwater each year are major sources of water supply in rural areas. However, poor waste management and unhygienic practices are increasingly polluting ponds, streams and groundwater (Lade *et al*. 2012). Hence attention and effort are needed to address these unhygienic practices, as they deplete sources of water supply. In addition, more sources of potable water supply are needed to augment current under-supply. In the present context, therefore, RWH is being considered as an alternative option for increasing water supply in Ibadan. Research is being conducted to evaluate the potential for RWH by conducting a socio-demographic survey in the study area to determine the rate of water consumption and current water sources.

Study Area

In context, Nigeria has a land mass of 923,768km^2; Oyo is one of these states located in the South-western axis. Ibadan is the capital of Oyo state with an estimated population of 2,559,853 in 2007 [19] and a projected population of 7,656,646 by 2015. Ibadan is located in south-west Nigeria (longitude $3^0$45'-$4^0$00'E, latitude $7^0$15'-$7^0$30'N and is reputed to be the largest indigenous city in Africa, South of Sahara (Figure 2). It is the second largest city in Nigeria in terms of land mass; consisting of 11 Local government areas (Figure 3).

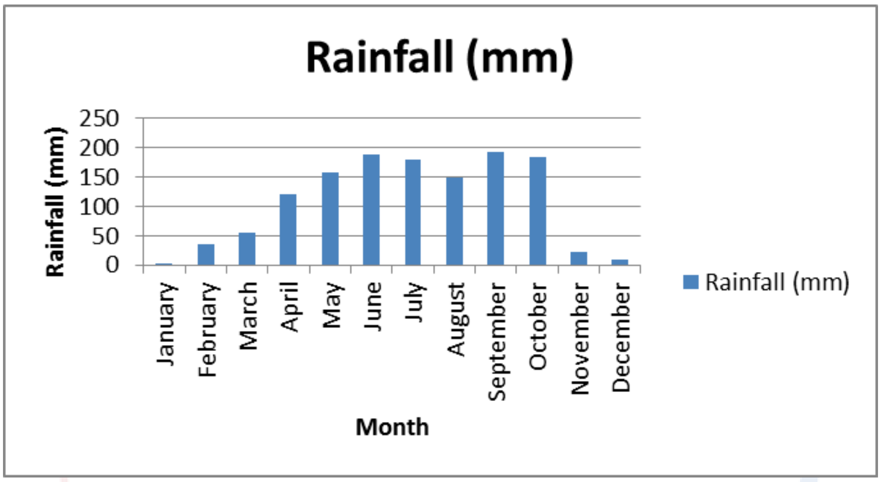

Figure 1 Mean rainfall for Ibadan City for the period 1980-2009 Source (DMS, 2010)

Methodology

Questionnaire survey and target population

A questionnaire survey was designed for householders and tenants. The questionnaire is designed to generate data and consist of closed-ended questions (respondents choose from a given set of answers) and/or open-ended questions (respondents record their views and opinions in full). In order to determine a suitable sample size, a sample size calculator provided by Research Information (2008) was utilised. By using a City population of 2,555,853 (National Population Commission 2006), and a confidence level of ($p <0.05$) (after Munn and Drever, 1990), a sample size of 1067 was calculated for household respondents. A total of 1067 householders participated in the survey, with 950 completing it in its entirety, for an 89 % completion rate.

Questionnaire methodology and weighting of results

The first question asked all respondents to describe their demography: (1) population in the home and (2) local government area of residence. The survey consisted of 33 questions for the household respondents. Statistical analysis such as descriptive and inferential statistics were carried out on the data collected from the questionnaire survey. Since the nature of the variables administered in the questionnaire is univariate, which implies that frequency distribution is required (De Vaus, 2002).

Inferential statistic (chi-square test) is used to estimate how likely the sample pattern will hold in the population.

Results and Discussion

Respondents' population distribution
Figure 4 reveals that 10.8% of the sampled households are two persons. About 14.9% of the households have three persons in them while 12.4% of the households have more than six persons living in them. A percentage as low as 4.8% have one person, which implies that about 69.3% of the population have four or more people living in them.

Respondents' local government area
Figure 5 shows the local government area of the respondents. About 11.4% of the respondents reside in Egbeda and 20.9% reside in Ibadan North, this group represents the largest proportion of the respondents. Those residing in Ido, Ibadan South-west, Ibadan North-west, Ibadan South-east and Ibadan North-East make up the lowest percentage with 3.8%, 2.8%, 5.3%, 3.9% and 4.9% respectively.

Figure 2: Map of the States of Nigeria

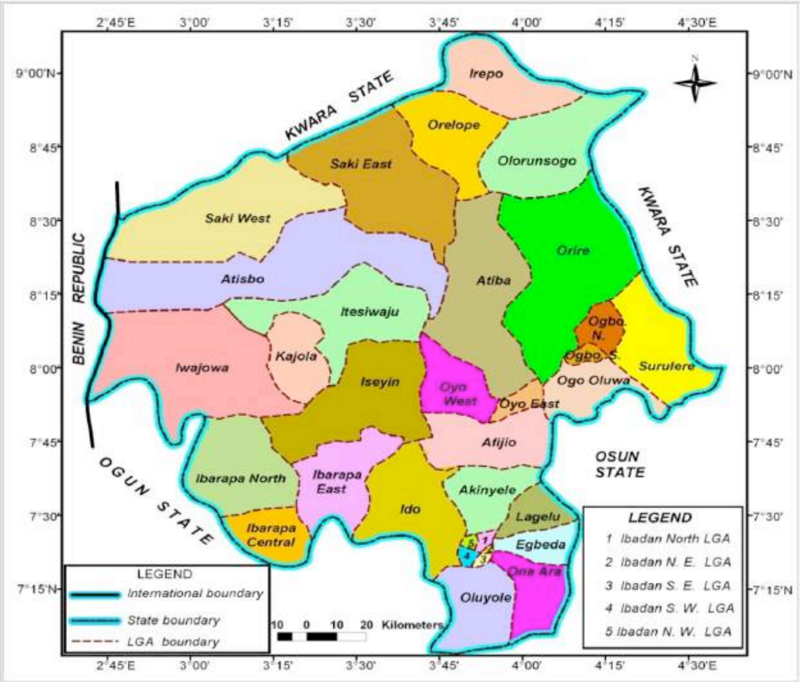

Figure 3: Map of Oyo State showing Ibadan (source: DG 2012)

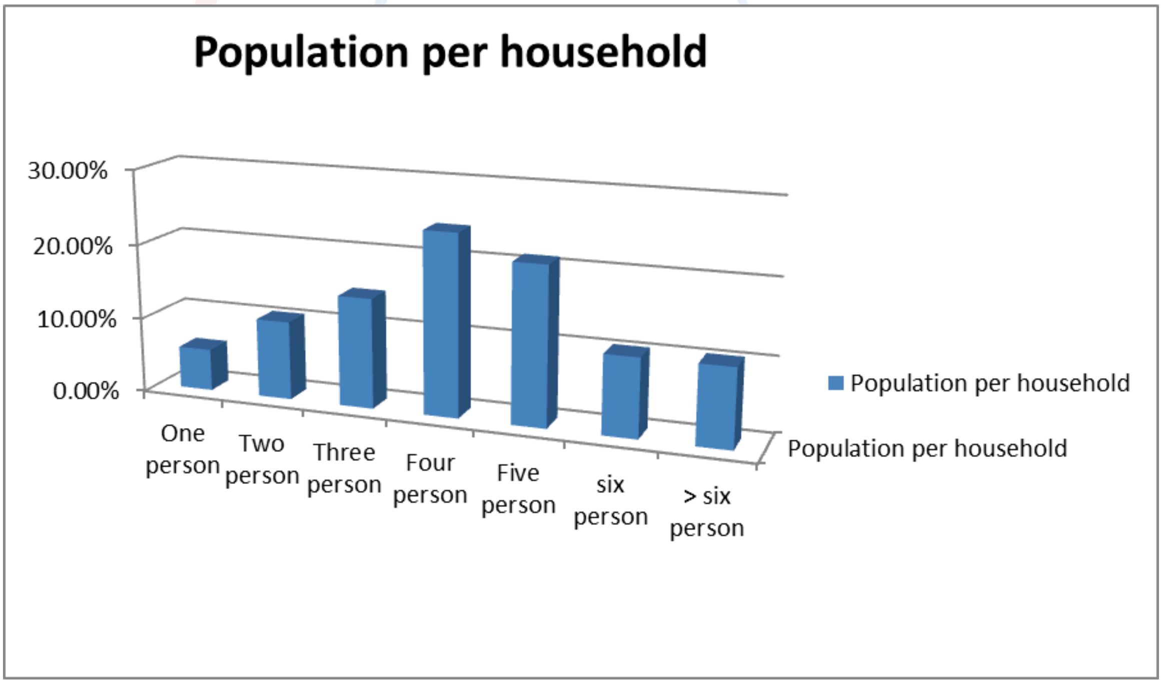

Figure 4: Respondent population distribution

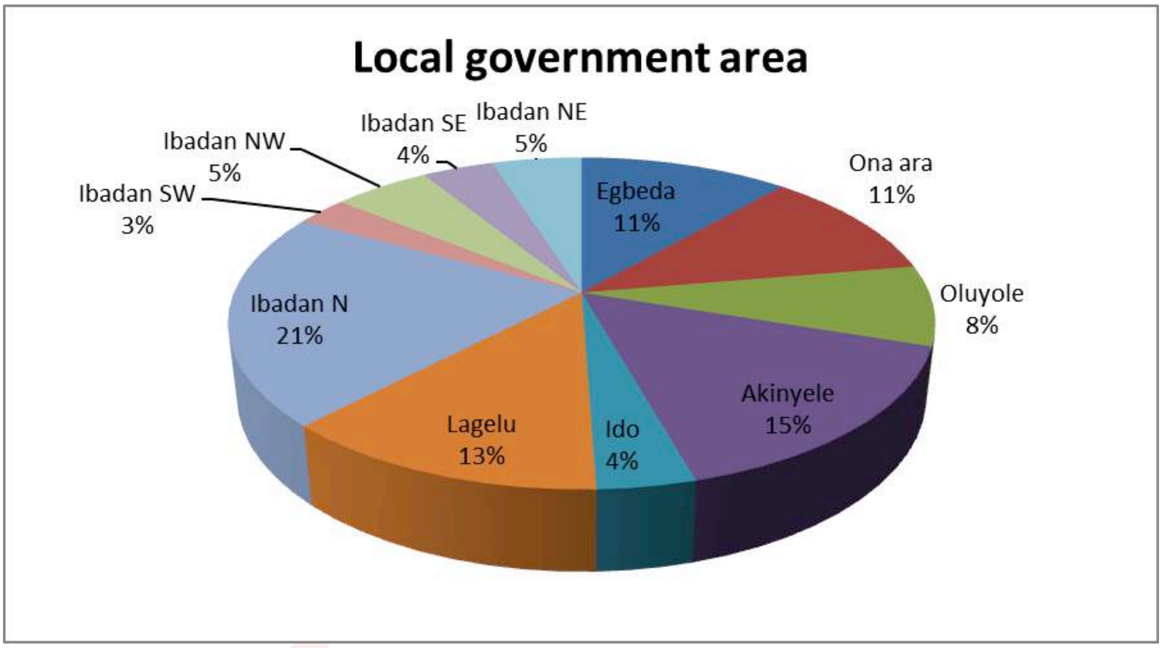

Figure 5: Respondent Local Government areas

Major system components
Figure 6 presents respondents' type of roofing materials. As the roofs are prone to corrosion, the harvested water needs filtration and purification with chlorine to make it potable. Table 1 represents a cross tabulation of the type of roofing materials with household income range. Some 32 and 33% of low income earners use roofing tiles and cement concrete materials, respectively, for their roofs. Some 38% of mid-income earners used roofing tiles and 11% of high income earners used cement concrete. This indicates that people with low income used high quality materials for their roofs, which is expected as people usually take loans from banks and co-operative societies to build larger houses. A chi-square test was carried out to determine the degree of association between type of roofing material and household income (Table 2). This result shows a strong, statistically significant, relationship between the two variables ($p < 0.05$).

Harvested water usage
In terms of the use that people would be willing to consider RWH for, Figure 7 illustrates that the most widely accepted would be (in order of popularity) drinking, cooking, toilet flushing, washing clothes. Few would be willing to use it for bathing animals, car washing, personal washing, garden watering and general outdoor use, respectively.

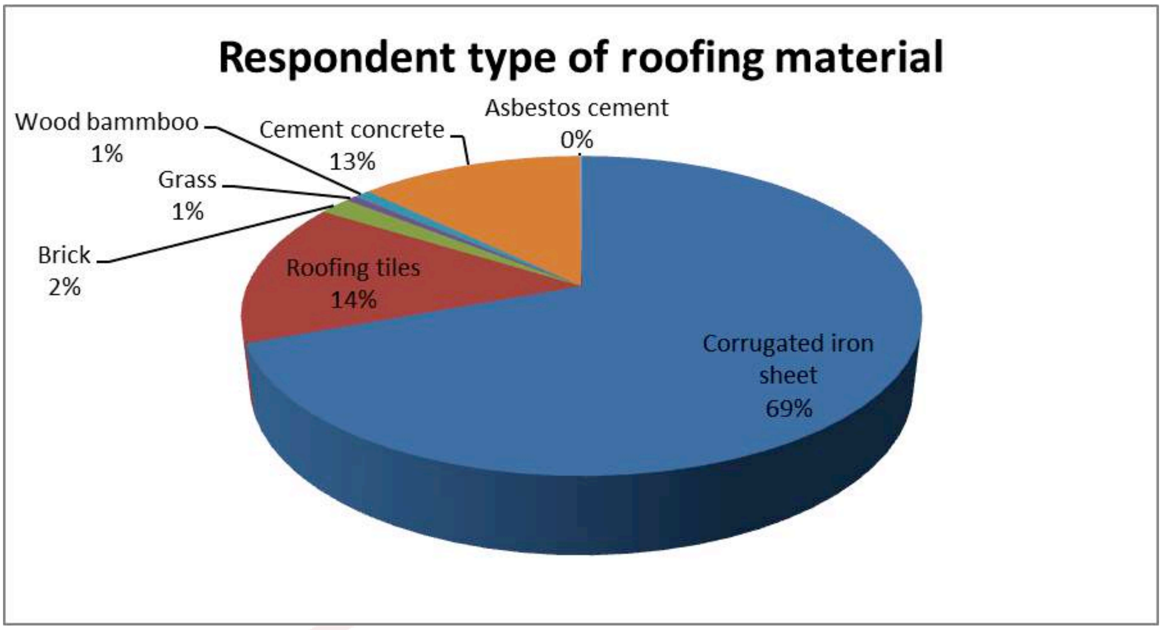

Figure 6: Respondents type of roofing materials

Table 1: Type of roofing material cross tabulation with monthly income range

Respondent Type of Roofing Material	Respondent Monthly Income Range (Naira, 000)						
	<10	10-30	31-100	101-150	151-200	>200	Total
Corrugated iron sheet	216	190	172	50	20	10	658
Roofing tiles	33	46	38	8	9	4	138
Brick	5	4	3	3	2	0	17
Grass	1	0	3	3	2	0	6
Wood bamboo	3	1	2	0	2	1	9
Cement concrete	32	39	23	7	9	11	121
Asbestos cement	0	0	0	0	0	1	1
Total	290	280	241	69	43	27	950

Individual satisfaction with public main supply
Figure 8 reveals that 70% of the respondents chose unsatisfactory with the level of main water supply from Water Corporation of Oyo State (WCOS), while 29.9% of respondents were satisfied. This implies that the WCOS is not providing adequate water supply for the community.

Table 2 Chi-Square tests for relationship between roofing material and monthly income range

	Value	Df	Asymp. Sig. (2-sided) (P)
Pearson Chi-Square	91.788[a]	30	<0.001
Likelihood Ratio	56.567	30	0.002
Linear-by-Linear Association	15.269	1	<0.001
N of Valid Cases	950		

a. 24 cells (57.1%) have expected count <5. The minimum expected count is 0.03.

Current supply sources

Figure 9 shows a low proportion of respondents chose main supply confirming inadequate supply of main water supply in the study area. Few respondents chose stream/river; tank/truck vendors and rainwater. This also confirms that RWH technology is yet to be tapped as an alternative source of supply in the area. Some 579 (60.9%) of respondents depend on well water and 22.9% of respondents depend on boreholes. This indicates that 83.8% of respondents depend on ground-water as their main source of supply. This implies that a large proportion of households possibly have water supply from unhealthy and untreated sources.

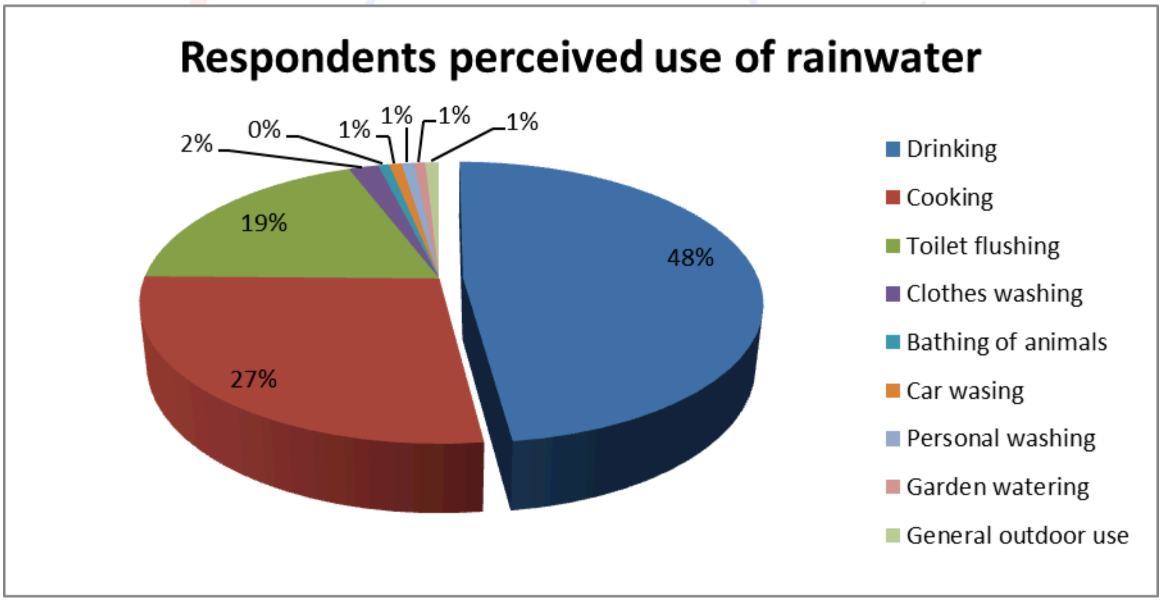

Figure 7: Respondents perceived use of rainwater

Well water yield
Figure 10 reveals 50.7% of respondents said their wells dried up during the dry season; 39.1% said their wells do not dry up and 10.2% are unsure. This indicates over 60.9% experience water shortage during the dry season.

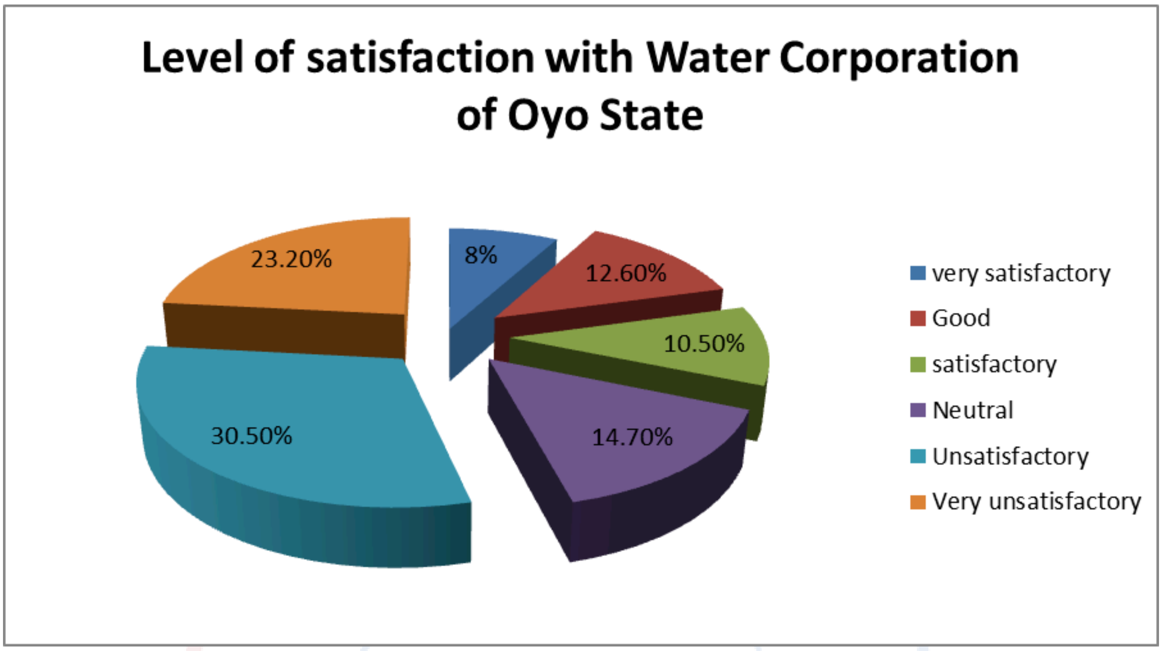

Figure 8: Respondents level of satisfaction with Water Corporation of Oyo State

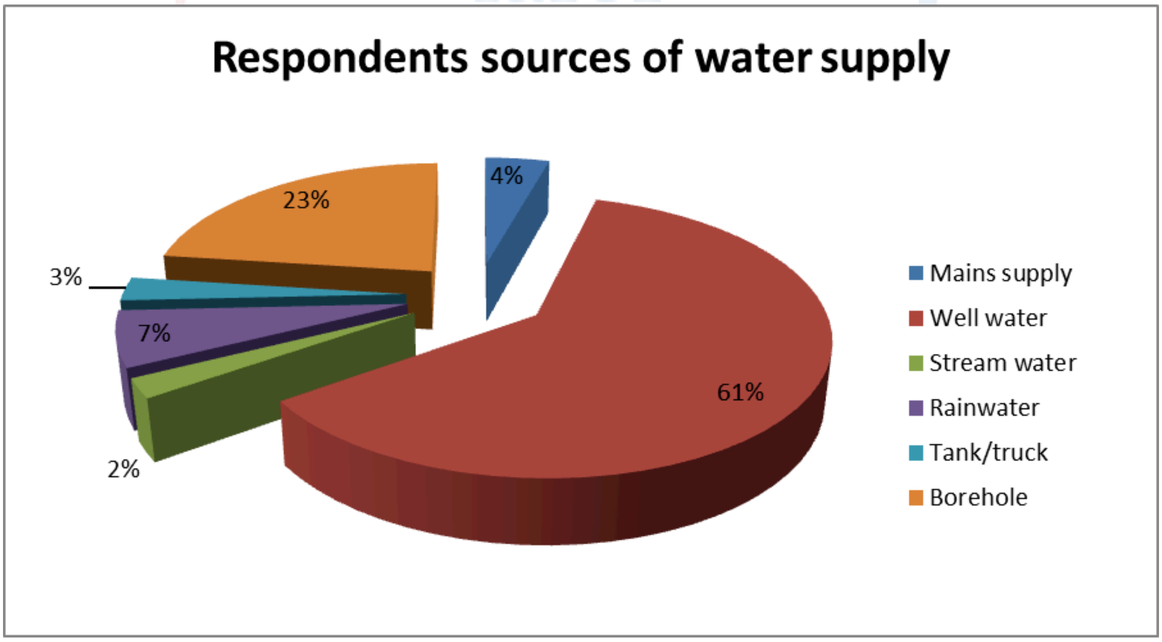

Figure 9: Respondents sources of water supply

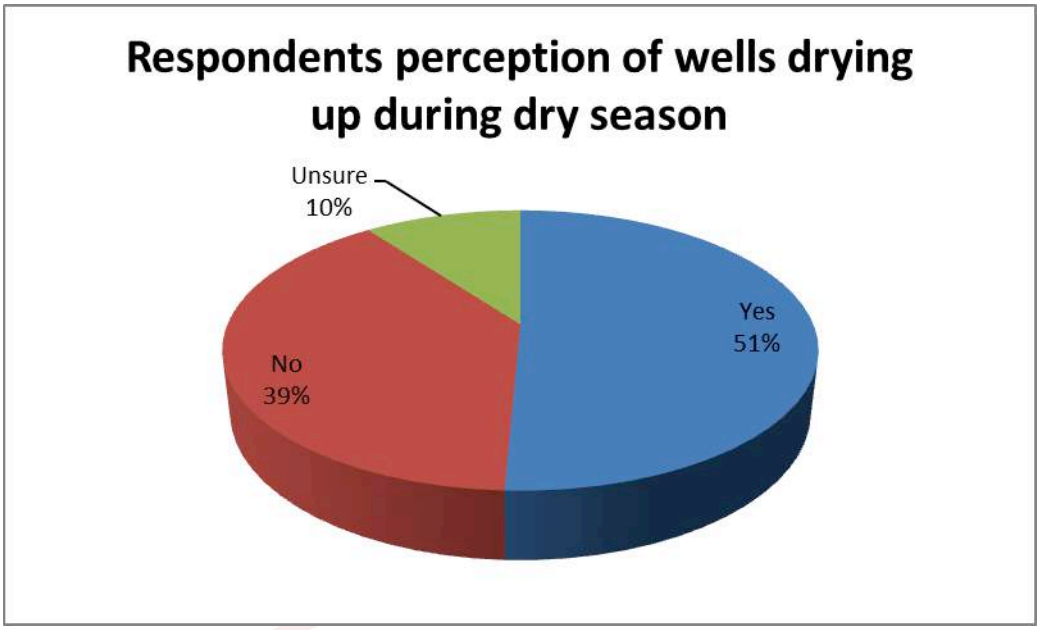

Figure 10: Respondents perception of wells drying up during dry season

Health hazard with drinking contaminated water

Figure 11 shows a larger proportion (581), of respondents, chose prevalence of typhoid fever; some have a prevalence of diarrhoea, while few of respondents water source is free from water-borne disease. This indicates that there is a prevalence of 97.8% of water-borne disease in the study area. This is quite alarming; hence, an alternative source of potable water is urgently needed.

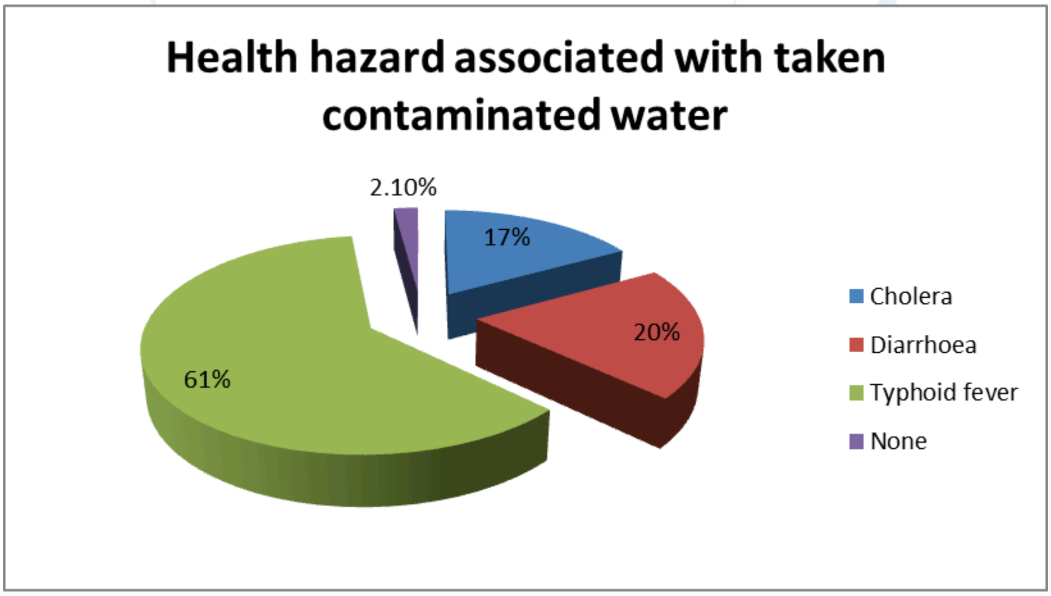

Figure 11: Respondents major health hazard associated with taken contaminated water

Conclusions

A survey was conducted to investigate the most common system set up, catchment materials and the need for rainwater harvesting in Nigeria. Our goal was to identify common water supply systems and the need for alternative source of supply. Householders and tenants were surveyed and responses were obtained. The survey had 89 percent response rate, indicating their willingness to utilize rainwater for domestic purposes. Result indicates that corrugated iron sheet is the most commonly used roofing materials for rainwater harvesting. The most commonly reported use for harvested rainwater was cooking and drinking although greater than 75% of the respondents use their rainwater for potable purposes. 77% of the respondents had no water supply from the public main while less than 25% receive supply. Of the respondents, approximately 61% have a low yield of supply from well source during the dry season while 39% have supply. Thus, the prevalence of water-borne diseases, in which 61% reported typhoid fever, 19% diarrhea and 17% cholera. Over 60% of the population depend on well water for their supply while 23% rely on borehole and as low as 6.6% harvest rainwater traditionally as a source. In particular, the low reliance on rainwater and the need for an alternative water supply system should be investigated further as the number of RWH systems installed in Nigeria continues to grow.

This survey provides essential data about current water supply practices in Nigeria. The result can be used to understand current practice as well as to guide further research into harvesting rainwater for domestic consumption. Further surveys of this type could be conducted with different population by utilizing Nigeria Society of Engineers Forums and groups. In addition, surveys of householders in more remote areas and in the Northern part of Nigeria could provide valuable information on RWH practices for individuals.

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Numerical Analysis for Energy Performance of Ground Source Heat Exchanger Under Environmental Conditions of Istanbul, Turkey

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The European Conference on Sustainability, Energy & the Environment 2015
Official Conference Proceedings

Abstract

By reason of limited amount of natural resources exploited for heating and cooling, and considering that reduction of environmental impact, people should strive to use renewable energy resources. The use of renewable energy sources decreases the energy consumption. Heat pump heating performance and cooling performance depends on the evaporator and condenser temperatures. The evaporator and condenser temperatures are dependents of heated / cooled environment and ambient temperature. Therefore, performance of the heat pumps dependent of source/sink temperature directly. Source temperature is varies with summer and winter seasons. Considering ground source heat pumps, this variation is much smaller than the air, depending on the burying depth. Therefore, the COP of ground source heat pump is higher than the air source heat pumps. The ground can be used as a heat source and it has high thermal capacity. The temperature of the ground becomes relatively constant with depth and its temperature is a periodic function versus time and depth. Heat Pumps usually work with transient conditions. When they bury in environment which has high thermal storage (ρ*Cp) characteristics, the effect of ground heat exchanger on thermal performance affects. Soil characteristics are appropriate for heat exchanger design in Istanbul. In this study, energy performance of the ground source heat exchanger has been evaluated for one year simulation with Computational Fluid Dynamics method according to weather conditions of Istanbul, Turkey. For weather conditions and heat transfer between water and soil, User Defined Function code is studied.

Keywords: numerical analysis, energy, environment, climate change, ground heat exchanger, heat pump, udf

Introduction

In the literature, numerous studies can be found about modeling of the ground heat transfer. To reduce dependence on fossil fuel energy resources and environmental degradation resulting from their usage, renewable energy sources must play a significant role. Geothermal energy, one of the renewable energy resources, can be used to provide electricity, heating and cooling for buildings. Due to mentioned reasons, researchers are still working on this subject to evaluate system's performance and boundary conditions on selected area. The papers which improve this study summarized in this section. The analytical models are based on line source theory (Ingersoll, 1954) or cylindrical source application (Carslaw and Jaeger, 1959). Gonzalez et al. (2012) studied the effect of heat extraction by a GHE (installed at 1m depth) on the soil physical environment (between 0 and 1m depth). Zhang and Haghighat (2009) adopted the FLUENT software, which his based on the finite volume method (FVM), to investigate the thermal behavior of air flowing in horizontally buried ducts. Florides and Kalogirou (2007) reviewed the performance and numerical model of ground coupled heat exchangers. They indicated that the ambient climatic conditions would affect the temperature profile below the ground surface and this should be considered when designing a horizontal-coupled heat exchanger.

Methodology

Numerical study consists of a control volume with pipes buried in soil in parallel and certain distance from each other. Because problem includes so many pipes, smaller volume is selected as control volume to simplify the problem.

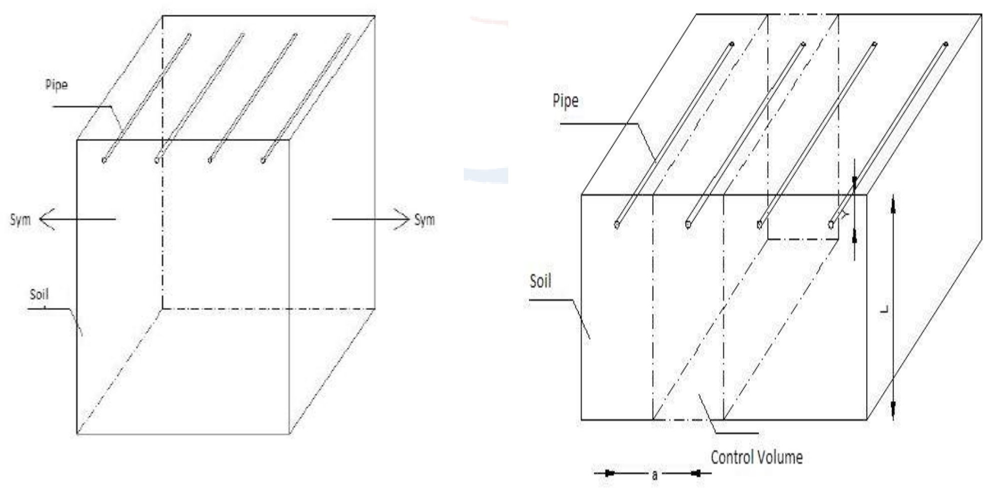


Figure 1: Problem description and selected control volume

a: Distance between pipe centers
y: Buried depth
L: Total depth of model
Boundary conditions of solution domain are as follows;

$$T_0 = T(y,t) \quad ,t = 0$$

$$\left.\frac{\partial T}{\partial t}\right|_{x=a/2} = 0$$

$$\left.\frac{\partial T}{\partial t}\right|_{x=0} = 0$$

$$Q_{top} \ ,y = 0$$

$$Q_{bottom} = 0 \ ,y = L$$

$$Q_{front} = 0 \ ,z = 0$$

$$Q_{back} = 0 \ ,z = Z$$

Soil temperature versus time and depth is calculated in the literature with the equation given below (Krarti et. al., 1995);

$$T(y,t) = T_{t,ave} + T_{t,amp} * e^{-y\sqrt{\frac{\pi}{\alpha P}}} * \cos(2\pi\frac{t}{P} - y\sqrt{\frac{\pi}{\alpha P}})$$

$T_{t,ave}$: Average soil temperature on top (˚C)
$T_{t,amp}$: Amplitude of soil temperature on top (˚C)
y : Burying depth (m)
t : Time period from beginning (s)
P : Period (s)
α : Thermal diffusivity of soil (m^2/s)

To specify all coefficients, the data made inquiries from Turkish State Meteorological Service.

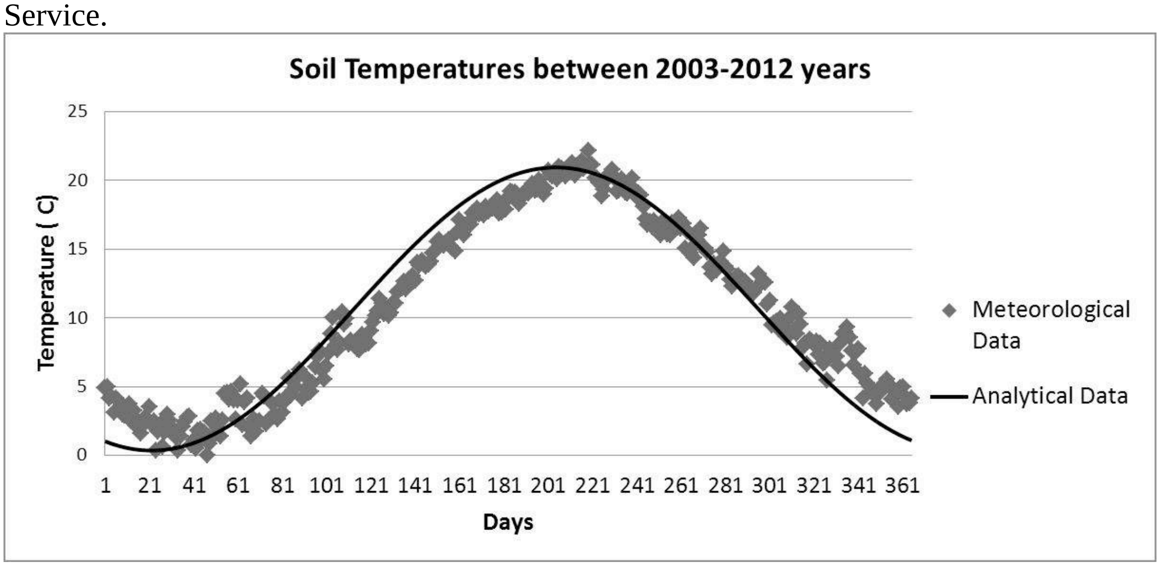


Figure 2: Soil temperature smoothing,

Heat flux including convection, solar radiation, and long wave radiation (diffused and absorbed) is given top of the model as a boundary condition.
The used equations are as follows;

$$\dot{Q}_{conv} = \rho_h * c_p * D_h * \zeta * (T_h - T_{surface})$$

$$\dot{Q}_{solar} = b * S$$

$$\dot{Q}_{longwave\_diffuse} = -\varepsilon * \sigma * {T_y}^4$$

$$\dot{Q}_{longwave\_absorb} = 1{,}08 * \left[1 - \exp\left(-(0.01 * e_h)^{\frac{T_h}{2016}}\right)\right] * \sigma * T_h^4$$

ρ_h	: Air density (kg/m^3)
c_p	: Specific heat of air (J/kgK)
D_h	: Sensible heat coefficient (m/s)
ζ	: Stability function (dimensionless)
T_h	: Air temperature (K)
$T_{surface}$	: Soil temperature at surface (K)
b	: Absorption coefficient
S	: Solar radiation (W/m^2)
ε	: Surface emissivity (dimensionless)
σ	: Stefan-Boltzmann coefficient
e_h	: Vapour pressure (Pa)

Numerical model is generated with Ansys/Fluent 15.0 program. Model size is 0.5m x 8.5m x10m. And it consists of only soil. When fluid is added to the model, time step should be really small and this value is calculated with Courant number.

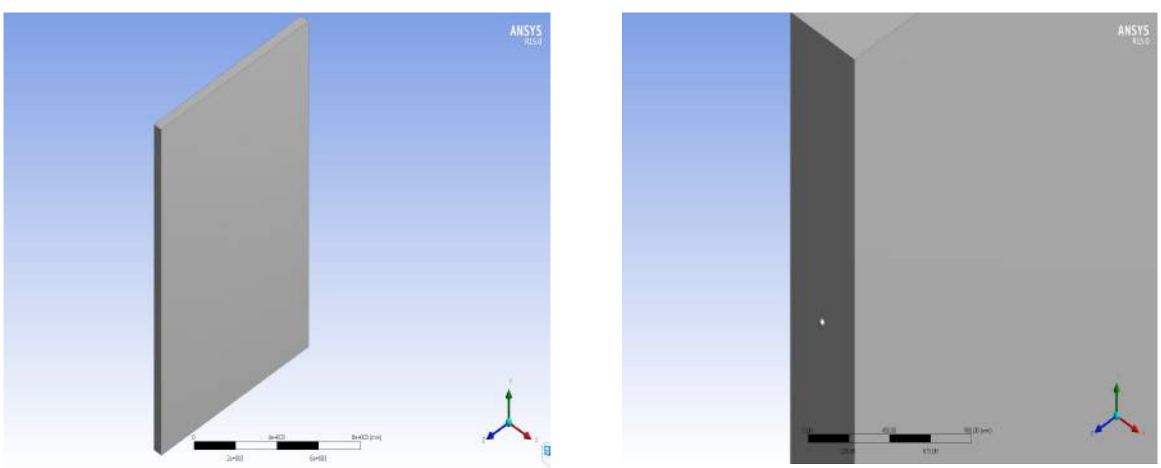


Figure 2: Fluent modelling

Model has 10020 elements and 12243 nodes. Skewness value is 0.54, because it is lower than 1, mesh is appropriate for this model.

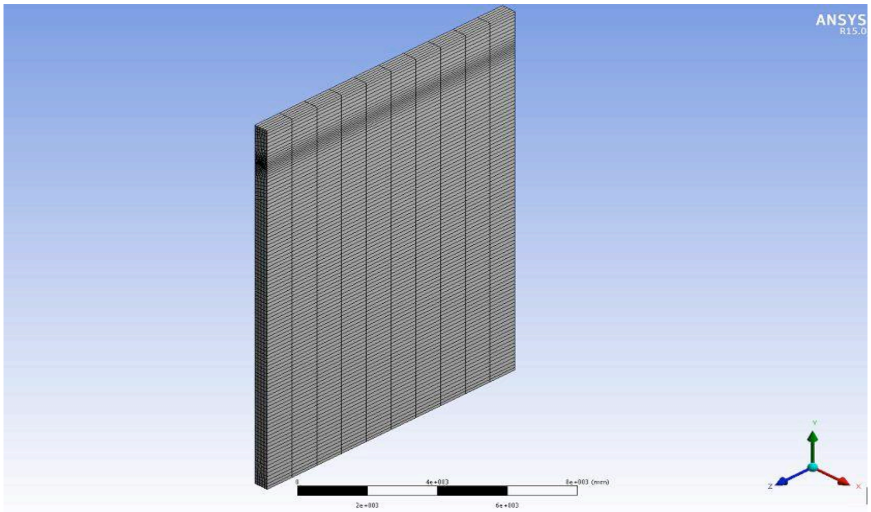


Figure 3: Fluent meshing

Top surface of the model named “top”, bottom surface named “bottom”, front and back surfaces named “wall” and last, right and left sides are named as “symmetry”.

Heat conductivity coefficient (k)	1,274 W/mK
Density (ρ)	1360 kg/m^3
Specific Heat (c_p)	800 kJ/kgK

Table 1: Soil properties used in analysis

Before analysis, Reynolds number should be checked and flow properties should be defined.

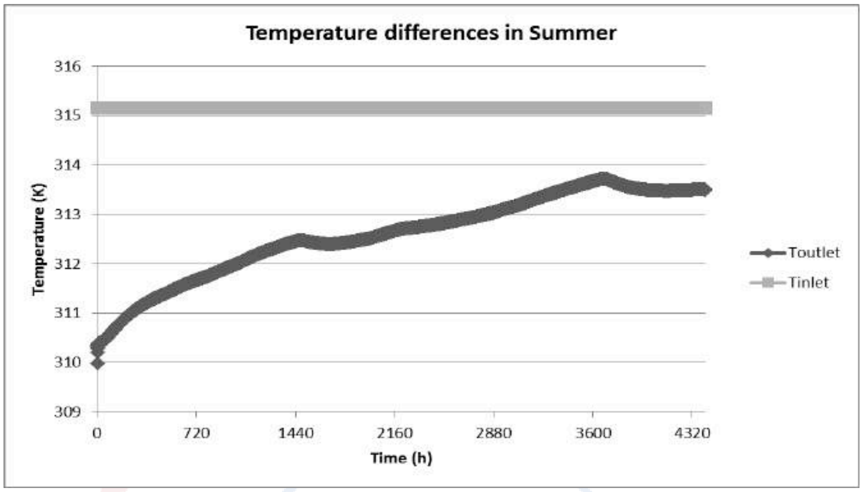
V	0,2	m/s	Water velocity
D	2,48E-02	m	Pipe inner outlet
P	1000	kg/m3	Water density
μ	1,54E-03	Ns/m2	Dynamic viscosity
M	0,096610257	kg/s	Flow rate
Nu	3,36		Nusselt Number
H	74,6516129	W/m2K	Convection coefficient

Table 2: Parameters used in analysis

According to above parameters, flow is transition. Nusselt number calculated considering flow properties. For heat transfer between water and soil and heat flux of top surface, user defined functions are studied. C code is prepared and used in this simulation.

Conclusion

Analyses are divided into two as winter and summer. Winter period is between November and April, summer period is May and October. Periods are started from November and May for winter and summer respectively.



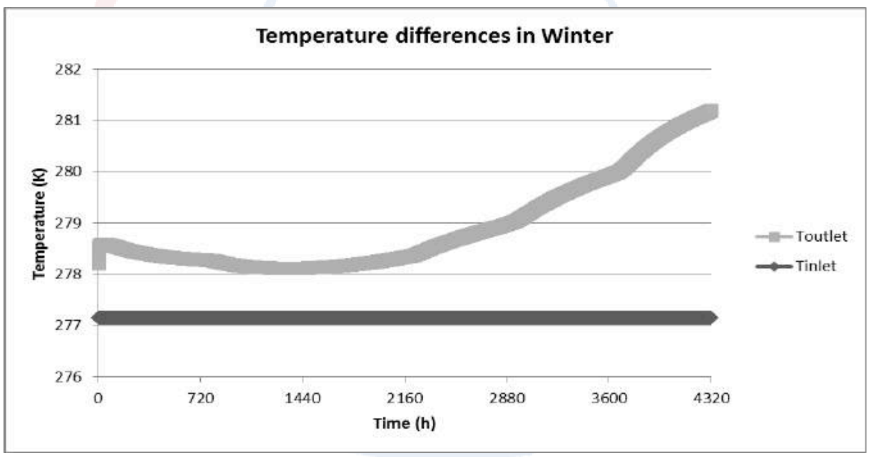
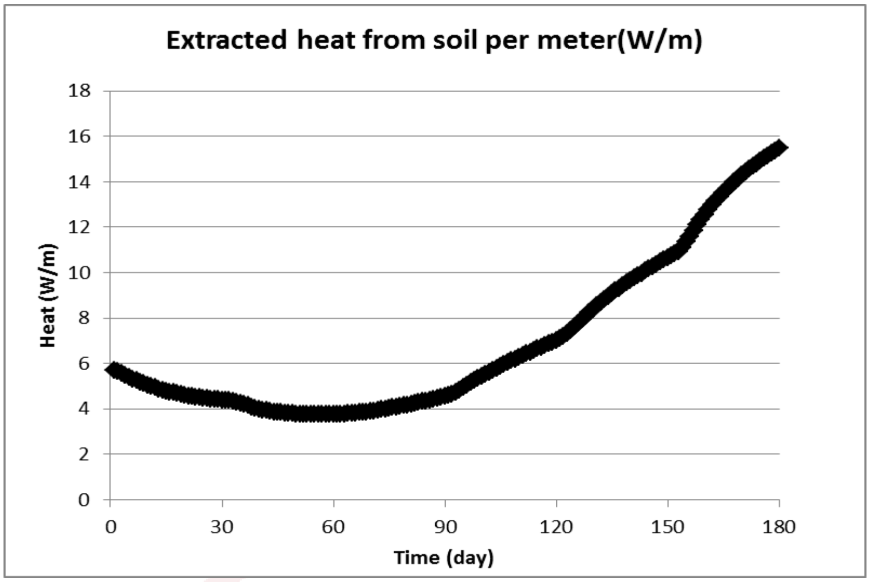
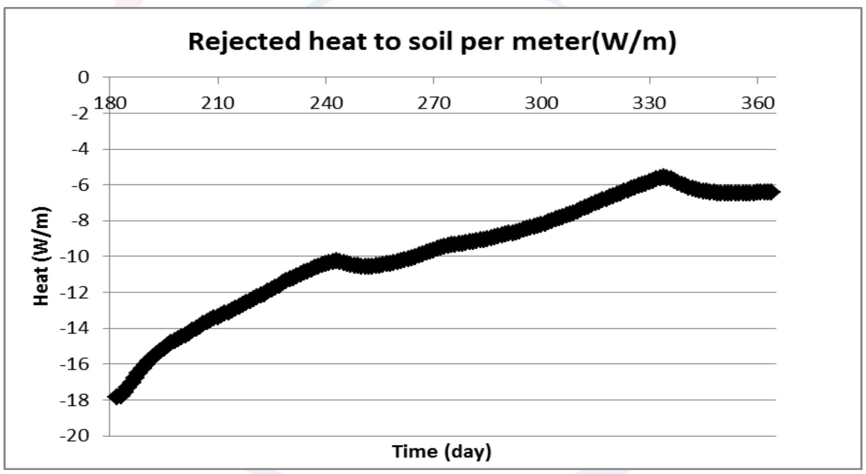


Figure 4: Temperature differences in winter and summer periods

While water inlet temperature is 277.15 K for winter, 315.15 K is used for summer case. Outlet temperature changes approximately 3 °C both summer and winter. To prevent thermal imbalance of soil, it is expected that heat extracted or rejected to soil must not be high. If so, after a limited time period, the system will be useless because there won't be temperature differences between water and soil.



a



b

Figure 5: Extracted/rejected heat to soil per meter in winter (a) and summer (b) case

If temperature differences between water and soil should be higher, pipe distances and pipe depth should be optimized considering system boundaries and possible deterioration of system performance. Studied model shows that in summer, more heat is needed for cooling the water. And with Istanbul conditions, 15W is maximum value per 1 meter pipe.

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Performance Evaluation for a 10 kW Solar Organic Rankine Cycle Power System to Operate in the UK Climate Conditions

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The European Conference on Sustainability, Energy & the Environment 2015
Official Conference Proceedings

Abstract
A considerable amount of medium/low grade thermal energy is available in the form of Renewable sources (solar, geothermal, biomass) and waste heat in industrial processes, which can be feasibly used to reduce consumption of fossil fuels. The Organic Rankine Cycle (ORC) technology is considered as one of the prospective technologies for utilization the above energy sources for power production. Northumbria University (UK) is working on the plans to build a small hybrid solar/biomass ORC plant and this paper presents results of the performance evaluation for a 10 kW subcritical ORC power plant for which thermal energy is provided by an array of solar evacuated tube collectors (ETCs) with heat pipes. The mathematical model of such power plant was developed and Thermolib Toolbox by EUtech Scientific Engineering GmbH was used for numerical simulations. The key components of the system include solar collectors, evaporator, expander, condenser and pump. The simulations of the plant were performed to estimate the variation of its performance during a typical day in Newcastle upon Tyne. The required areas of the solar collectors, evaporator and condenser together with the mass flow rate of the working fluid were determined for the power plant to generate 10 kWe using two organic fluids.

Keywords: Solar energy, Organic Rankine cycle, UK climate conditions

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1. Introduction

The continuous increase in the world population and the rapid development in industry have recently been leading to a tremendous increase in the global energy demand. About 80% of the current global energy consumption is estimated to be from fossil fuels [1]. Also, fossil fuels have finite sources and its consumption rate is much higher than the discovery rate of new reserves. As a result, there has been a growing concern about the fossil fuels being enough to meet the future energy needs. Furthermore, the increased consumption of fossil fuels has also caused environmental problems such as ozone depletion, global warming, and air pollution [2, 3]. These environmental problems together with the growing awareness about the fossil fuels depletion have been driving force behind searches for alternative clean sources of energy to replace fossil fuels. In the recent years, there has been a gradual shift from the overdependence on fossil fuels toward the use of renewable and cleaner energy sources such as solar energy, geothermal energy and wind energy [4].

Solar energy is considered to be one of the most reliable and world largest technically feasible renewable energy source and solar thermal low temperature applications are wide-spread across Europe and throughout the world.

In contrast to conventional Rankine cycle, organic Rankine cycle (ORC) is considered as promising technology for converting low/medium temperature energy sources into useful power, especially in the field of small and medium scale power systems (few kW – 1MW) [5, 6]. Various low-grade heat sources have been reported in the literature to be applicable with the ORC, including solar energy, geothermal energy, biomass and waste heat from industrial processes. Further benefits of this technology comprise simple construction, low maintenance, favourable operating pressures, autonomous operation and high flexibility and safety [7-11]. Moreover, installation of the ORC based systems helps in the reduction of greenhouse gas emissions which would have been produced if fossil fuels were used for the same power generation [12].

Over the last decade, small-scale solar ORCs have become a mature technology and, at the same time, remain the subject for intense research. Twomey et al. [13] tested a scroll expander in a small scale ORC (<1 kW) utilizing ETCs as a heat supply source and R134a as a working fluid. Tempsti et al. [14] analysed a 50 kW combined heat and power (CHP) ORC system powered by low-temperature geothermal and solar heat sources considering three different working fluids. Hossin et al. [15] conducted a dynamic modelling of a small-scale solar ORC system (<10 kW) using R245fa to simulate and predict the whole-day system behaviour at different seasons during the year. Quoilin et al. [6] performed modelling, sizing and evaluation of a solar ORC (3 kWe) powered by single-axis parabolic troughs and integrated with single or double stage expansion machine.

This paper provides performance evaluation and feasibility assessment for a 10 kW solar organic Rankine cycle power system to operate in the UK climate conditions using two different working fluids. The optimal operation mode for each working fluid is identified. Major technical parameters including the heat exchangers' surface area, solar collector area and the expander size are calculated. The outcome of this study will be used for designing and optimization assessment of such a system which is intended to be erected at Northumbria University, UK, and powered by a hybrid solar/biomass thermal heat source.

2. The Solar ORC System Configuration

The proposed solar ORC system consists mainly of two circuits: solar heating circuit and organic fluid circuit, as shown in Fig. 1. The key components of the system include solar collectors, evaporator, expander, condenser and working fluid pump. The evaporator has three sections, namely economizer, evaporator and superheater. The condenser is divided into two sections, namely de-superheater and condenser. Water, used as a heat transfer fluid (HTF), is heated up in the solar circuit using ETCs. The pressurized working fluid from the pump is preheated, evaporated and superheated (if required) to the maximum cycle temperature by extracting heat from the hot water in the different sections of the evaporator. The working fluid vapour then flows through the expander where useful power is generated. The working fluid at the expander exit is first cooled from superheated conditions down to saturated vapour at variable temperature in the de-superheater then it is condensed to saturated liquid in the condenser using cooling water. Liquid working fluid is pumped again in the pump to repeat the cycle. Table 1 shows the operating parameters and specifications of the considered system.

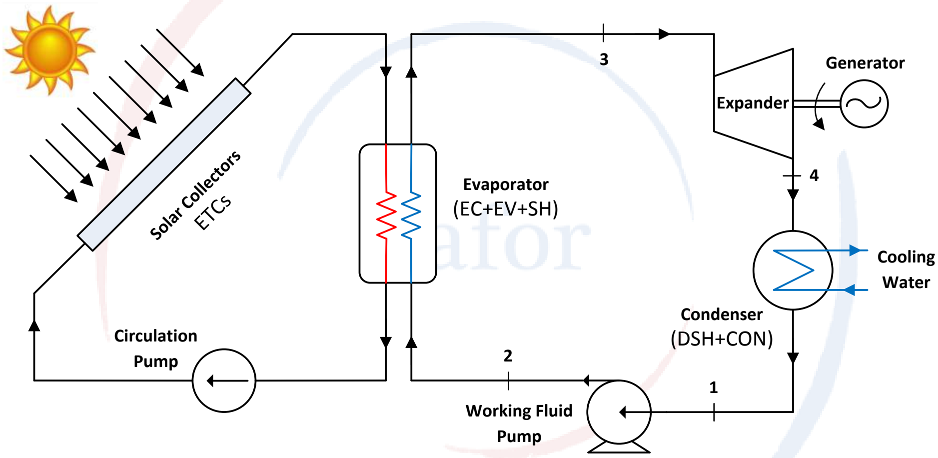

Figure 1: Schematic of the proposed solar ORC system

Table 1: Specifications of the solar ORC

Parameter	Data
Gross power, kWe	10
Heat source inlet temperature, ^{o}C	120
Cooling water inlet temperature, ^{o}C	18
Ambient temperature, ^{o}C	25
Maximum ORC operating temperature, ^{o}C	100
Maximum ORC operating pressure, bar	30
Expander isentropic efficiency, %	70
Pump isentropic efficiency, %	80
Electric generator efficiency, %	98

3. Working Fluid Selection

The working fluid selection is vital for the plant performance, reliable operation and design of the key components of ORC systems [16]. Also, the working fluid selection strongly depends on the system configuration and the available heat source level [5]. In general, the correct working fluid eliminates the possibility of the turbine blades damage, caused by wet liquid droplets at the end of the expansion process [17]. Further desirable features of the working fluid include the suitable pressure range (between evaporator and condenser), high molecular weight, stability at high temperatures. Additional requirements are that these are non-toxic, non-flammable, non-corrosive, low cost and have necessary environmental safety characteristics (ODP, GWP) [18-20]. Detailed studies have been conducted on selection of appropriate working fluids for ORC system by numerous researchers [21-23].
R134a and R245fa are among prospective working fluids which are used in the commercial ORC power plants [22]. These working fluids are suitable for the heat source temperature equal to 150 ^{o}C [18, 23]. R134a and R245fa characteristics match well the heat source available in this study, with temperature of namely 120 ^{o}C and satisfy the environmental and safety considerations.

4. Thermodynamic Analysis

The following general assumptions are used in the analysis of the overall system and subsystems:

- All the components and processes are considered to be at steady state;
- The heat and pressure losses in all system components and piping are neglected;
- The expander and pump are adiabatic with fixed isentropic efficiencies;
- The changes in kinetic and potential energy are not considered.

The general steady state energy balance equation, based on the first law of thermodynamics, can be written as follows:

$$\dot{Q} - \dot{W} + \sum \dot{m}_{in} \dot{h}_{in} - \sum \dot{m}_{out} \dot{h}_{out} = 0 \quad (1)$$

where $\dot{Q}$ and $\dot{W}$ represent the heat transfer and work energy crossing the component boundaries and $\dot{m}$ and $\dot{h}$ represent the mass flow rate and the specific enthalpy of the streams of the system working fluid.
In order to develop the mathematical model for the whole system, a control volume for each component is considered. The energy balance equation (1) is then applied for each control volume.

4.1 The Solar Collector Model

The heat received by the solar collector and transferred to the HTF can be calculated based on the collector energy balance equation as a function of the collector efficiency:

$$\dot{Q}_{in} = G_t \cdot A_{col} \cdot \eta_{col} = \dot{m}_{htf} C_{p,htf} \left(T_{col,o} - T_{col,i} \right) \tag{2}$$

where G_t is the total solar irradiance on the solar collector surface, A_{col} is the collector aperture area, η_{col} is the solar collector efficiency and $\dot{m}_{htf}$ is the hot water mass flow rate in solar heating circuit.

Newcastle upon Tyne city, located in the north east of the UK (54^o 59' N latitude, 1^o 37' W longitude), was selected as a location to evaluate the solar system performance. Craggs et al. [24] measured the global irradiance of Newcastle upon Tyne on vertical and horizontal surfaces for two summers (1994, 1995) and two winters (1993, 1994). They reported that the maximum measured global irradiance for the two summers were in the range of 636-703 W/m^2 and 913-978 W/m^2 for vertical and horizontal surfaces, respectively. In the winter these values decrease to 768-787 W/m^2 and 207-267 W/m^2, respectively. In this study, a value of 700 W/m^2 is used in the simulation.

The thermal efficiency of the solar collector can be expressed in terms of the solar irradiance, mean collector temperature and ambient temperature as:

$$\eta_{col} = a_0 - a_1 \frac{\left(T_{col,m} - T_{amb} \right)}{G_t} - a_2 \frac{\left(T_{col,m} - T_{amb} \right)^2}{G_t} \tag{3}$$

Here a_0, a_1 and a_2 are efficiency equation constants for the solar collector. Table 2 presents the efficiency equation constants of the ETC for which calculations of the system performance have been carried out [14].

Table 2: ETC efficiency constants

Constant	a_0 [-]	a_1 [W/m^2 K]	a_2 [W/m^2 K^2]
Value	0.825	0.91	0.6×10^{-3}

4.2 The Pump Model

The power consumed by the working fluid pump (see Fig.1) is calculated as:

$$\dot{W}_p = \frac{\dot{m}_{wf} v_1 (P_2 - P_1)}{\eta_p} = \dot{m}_{wf} (h_2 - h_1) \tag{4}$$

where $\dot{m}_{wf}$ is the working fluid mass flow rate, η_p is the pump efficiency and P_1, P_2, h_1 and h_2 are the pressures and specific enthalpies of the working fluid at the pump inlet and outlet, respectively.

4.3 The Evaporator Model

The total heat transfer rate in the evaporator, $\dot{Q}_e$, from the HTF into the working fluid is given by:

$$\dot{Q}_e = \dot{m}_{wf}(h_3 - h_2) = \dot{m}_{htf}C_{p,htf}(T_{e,i} - T_{e,o}) \tag{5}$$

where h_2 and h_3 are the specific enthalpies of the working fluid at the inlet and outlet of the evaporator, respectively, and $T_{e,i}$ and $T_{e,o}$ are the temperatures at the inlet and outlet of hot water stream, respectively.

4.4 The Expander Model

The working fluid vapour passes through the expander to generate the mechanical power. The expander output power is given by:

$$\dot{W}_t = \dot{m}_{wf}(h_3 - h_{4s})\eta_t\eta_g = \dot{m}_{wf}(h_3 - h_4)\eta_g \tag{6}$$

where η_t and η_g are the expander isentropic efficiency and the generator efficiency, respectively, h_{4s} and h_4 are the specific enthalpies of the working fluid at the expander outlet under ideal and actual conditions, respectively, and h_3 is the working fluid specific enthalpy at the expander inlet.

4.5 The Condenser Model

The exhaust vapour at the expander exit is directed to the condenser where it is converted to the liquid state by rejecting its heat to the cooling water.
The condenser heat rejection rate, $\dot{Q}_c$, can be expressed as:

$$\dot{Q}_c = \dot{m}_{wf}(h_4 - h_1) = \dot{m}_w C_{p,w}(T_{c,o} - T_{c,i}) \tag{7}$$

where $\dot{m}_w$ is the cooling water mass flow rate, and $T_{c,i}$ and $T_{c,o}$ are the cooling water temperatures at the inlet and outlet of the condenser, respectively.

4.6 Net Power Output and System Efficiencies

The net output power generated by the solar ORC system is defined as:

$$\dot{W}_{net} = \dot{W}_t - \dot{W}_p \tag{8}$$

The thermal efficiency of the ORC is the ratio of the net power output to the heat input in the evaporator. It can be expressed as:

$$\eta_{ORC} = \frac{\dot{W}_{net}}{\dot{Q}_e} \tag{9}$$

The overall efficiency of the solar ORC system can be defined as follows:

$$\eta_{sys} = \frac{\dot{W}_{net}}{G_t \cdot A_{col}} \tag{10}$$

In addition to the system efficiency, which is used to evaluate the system from a thermodynamic point of view, other parameters are needed to be defined to provide more insight into the technical feasibility and economic competitiveness of the solar ORC. These parameters include the total heat transfer surface area of the heat exchangers of the system and the volume flow ratio (VFR) between the outlet and inlet of the expander.

4.7 Calculation of the Heat Exchangers' Area

Based on the variation of heat transfer coefficient caused by different phase state, the evaporator is divided into three sections, namely, economizer (EC), evaporator (EV) and superheater (SH), while the condenser is divided into two sections, namely, de-superheater (DSH) and condenser (CON).

The logarithmic mean temperature difference (LMTD) method is used in the analysis of the heat exchangers and for the calculation of the heat transfer area [25]. The heat transfer rate in each section of the heat exchanger, i, is described as:

$$\dot{Q}_i = U_i A_i LMTD_i \tag{11}$$

where U_i and A_i are the overall heat transfer coefficient and the heat transfer area of each section, respectively. The values of the overall heat transfer coefficient for each section of the evaporator and condenser are listed in Table 3 [14]. The logarithmic mean temperature difference, $LMTD_i$, is defined as follows:

$$LMTD_i = \frac{\Delta T_{max,i} - \Delta T_{min,i}}{\ln \frac{\Delta T_{max,i}}{\Delta T_{min,i}}} \tag{12}$$

where $\Delta T_{max,i}$ and $\Delta T_{min,i}$ are the maximal and minimal temperature differences at each section terminals of the heat exchangers, respectively. The pinch point temperature differences of the evaporator and condenser used in this work are also listed in Table 3.

The total heat transfer area of the evaporator and condenser can be obtained as:

$$A_e = A_{EC} + A_{EV} + A_{SH} \tag{13}$$

$$A_c = A_{DSH} + A_{CON} \tag{14}$$

The total heat transfer surface area of the heat exchangers of the system is then given as:

$$A_{tot} = A_e + A_c \tag{15}$$

Table 3: The evaporator and condenser parameters

Evaporator		Condenser	
Parameter	Value	Parameter	Value
U_{EC}	250 W/m^2 K	U_{DSH}	125 W/m^2 K
U_{EV}	200 W/m^2 K	U_{CON}	225 W/m^2 K
U_{SH}	125 W/m^2 K		
ΔT_{ppe}	8 K	ΔT_{ppc}	5 K

4.8 The Volume Flow Ratio

The volume flow ratio (VFR) is defined as the ratio between the volume flow rates at the outlet and inlet of the expander. Increased VFR values are associated with large expander size and technical complexity [26].

$$VFR = \frac{\dot{V}_4}{\dot{V}_3} \tag{16}$$

The simulation of the proposed solar ORC system was developed using Thermolib 5.2 toolbox [27], by EUtech Scientific Engineering GmbH, in a MATLAB/Simulink environment. The working fluid properties were evaluated using the built-in thermos-physical properties database of Thermolib based on the real gas behaviour of Pen-Robinson Equation of State. The developed Thermolib model for the solar ORC system is illustrated in Fig 2.

5. Results and Discussions

A complete thermodynamic analysis was performed for the system shown in Fig. 1. The mass and energy balance equations are applied for each of the system components at steady state operation. The mass flow rates of the organic fluid, the corresponding HTF and cooling water were calculated. An analysis is conducted to investigate the effect of different operating parameters on the system performance (i.e. net power output, ORC efficiency and system efficiency). This parametric analysis results in achieving the optimal system performance for each working fluid. The ETC area of 180 m^2 was used for both cases of the working fluid in the parametric analysis.

5.1 Effect of Evaporation Pressure

The variations of system performance with the evaporation pressure for the two working fluids are shown in Figs. 3 and 4. The condensation temperature is fixed at 30 ^oC. As shown in Table 1, the maximum evaporation pressure is restricted to 30 bar, while the maximum value of the operating temperature is 100 ^oC.

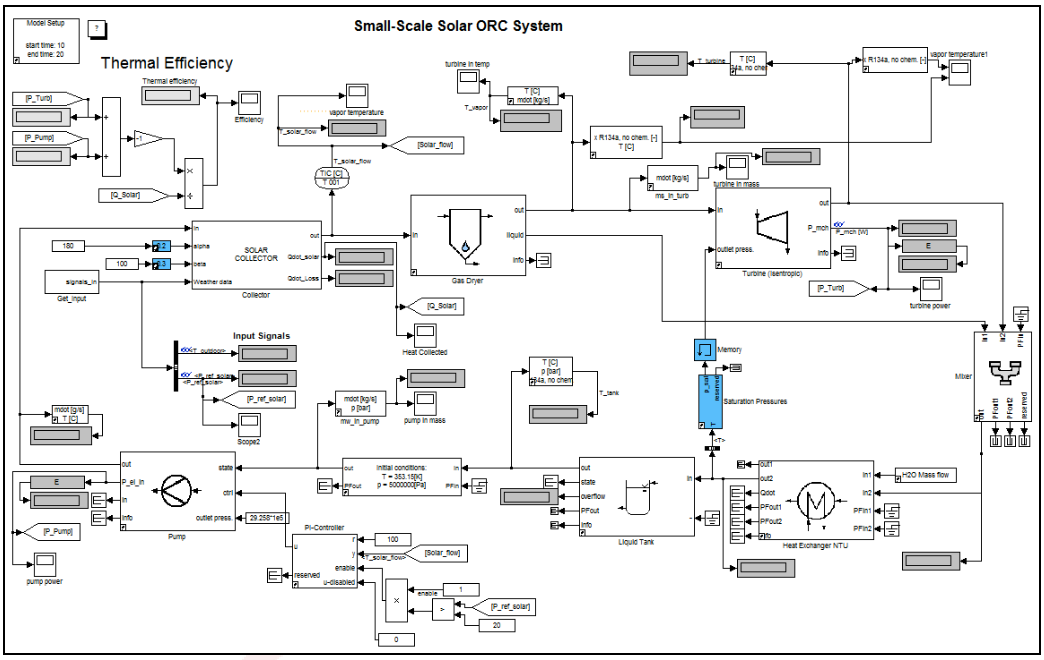

Figure 2: The developed Thermolib model for the solar ORC system

Fig. 3 shows that the net output power increases significantly with the increase of the evaporation pressure for both working fluids. The increase in the evaporation pressure yields an enthalpy increase in the expander and a decrease in the working fluid mass flow rate with domination of the former, and therefore the net output power increases. However, R245fa produces a higher net output power, compared to R134a, with lower values of evaporation pressure.
Similarly, as shown in Fig. 4, both ORC efficiency and system efficiency increase noticeably with the increase of the evaporation pressure. This is due to the significant increase of the net output power with the evaporation pressure. Also, R245fa provides higher values of ORC efficiency and system efficiency.

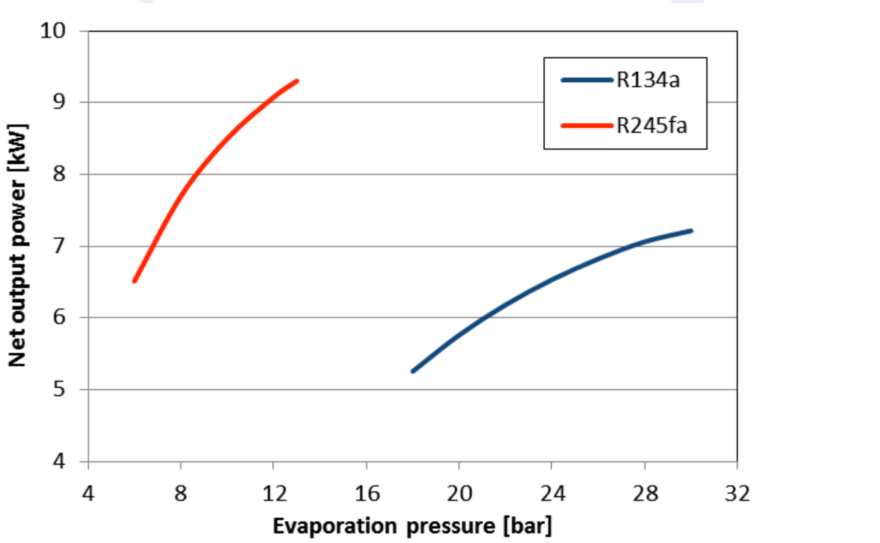

Figure 3: Variations of the net output power with evaporation pressure

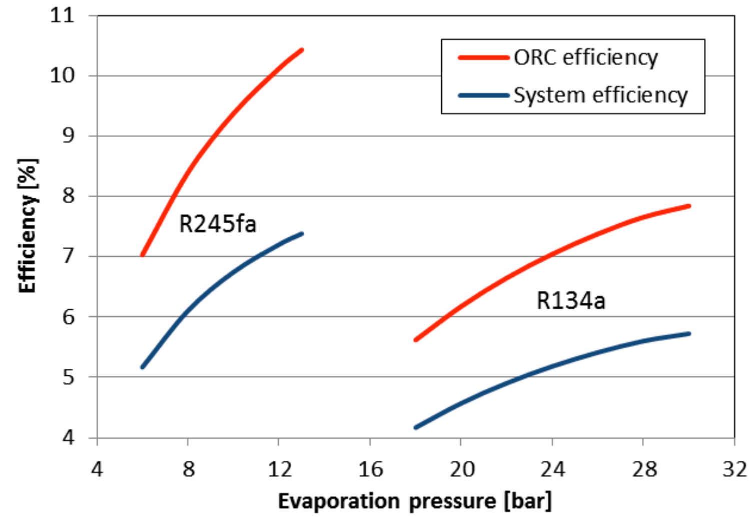

Figure 4: Variations of the ORC and system efficiency with evaporation pressure

5.2 Effect of Expander Inlet Temperature (Degree of Superheating)

Since the maximum cycle pressure is limited to 30 bar, during the superheating process, R134a should achieve the maximum cycle temperature of 100 ^{o}C. For R245fa, the maximum temperature of the cycle (100 ^{o}C) corresponds to an evaporation pressure of about 12.7 bar. The effect of degree of superheating on the system performance for R134a is illustrated in Figs. 5 and 6. The condensation temperature is set at 30 ^{o}C.

Fig. 5 presents the variation of the net output power with the degree of superheating. The net output power increases as the expander inlet temperature increases from the saturation conditions (zero superheat) towards the maximum cycle temperature of 100 ^{o}C. Fig. 6 shows a similar trend in terms of the ORC efficiency and system efficiency. These figures indicate that the net output power, ORC efficiency and system efficiency increase by about 5% with the superheating from the saturation temperature to 100 ^{o}C.

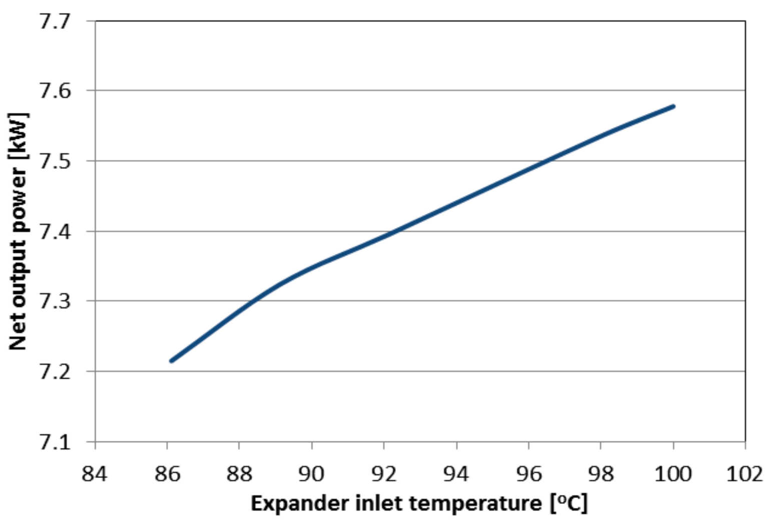

Figure 5: Variations of the net output power with expander inlet temperature (R134a)

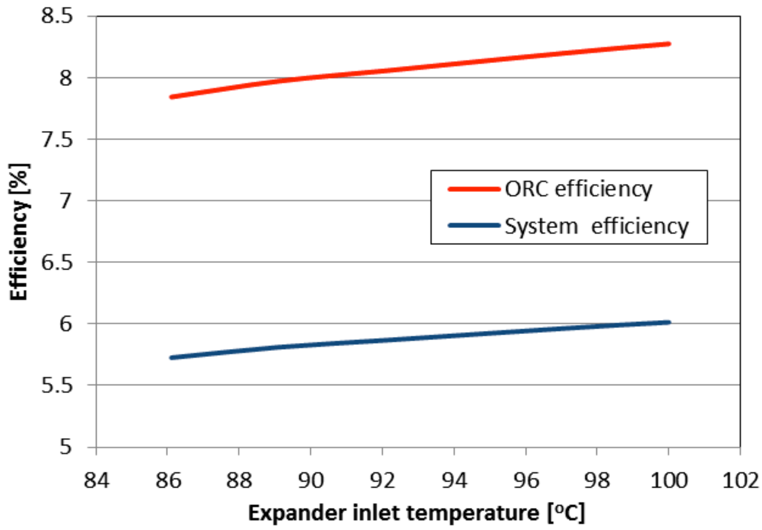

Figure 6: Variations of the ORC and system efficiency with expander inlet temperature (R134a)

5.3 The Effect of Condensation Temperature

Figs. 7 and 8 show the variations of the system performance with the condensation temperature at the optimum evaporation pressure of each working fluid. The pinch point temperature difference in the condenser is set to be 5 degrees and the condensation temperature is varied from 30 ^{o}C to 40 ^{o}C.

It can be seen in Fig. 7 that the net output power is decreasing with the rise in condensation temperature for both working fluids. R245fa produces higher values of the net output power (by about 2 kW). Fig. 8 shows that there is the same trend takes place for both the ORC efficiency and system efficiency. Decreasing the condensation temperature leads to an increase in the net output power which results in an increase in the efficiency. Also, the ORC efficiency and system efficiency are higher when R245fa is used.

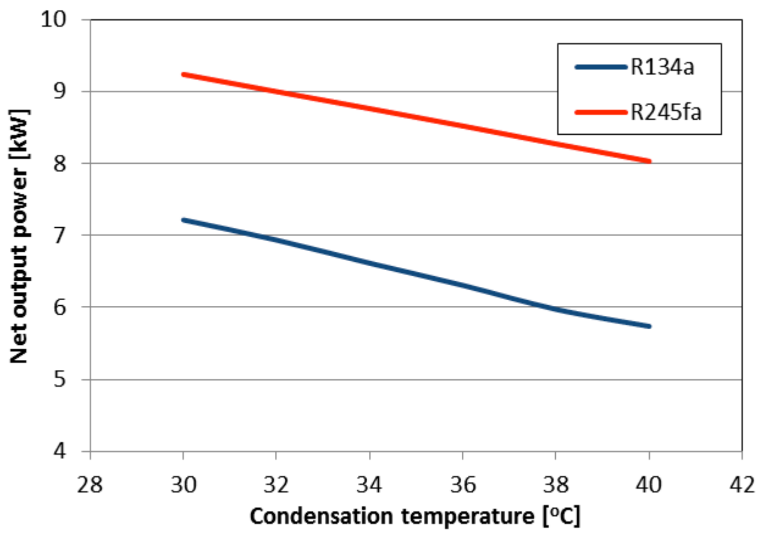

Figure 7: Variations of the net output power with condensation temperature

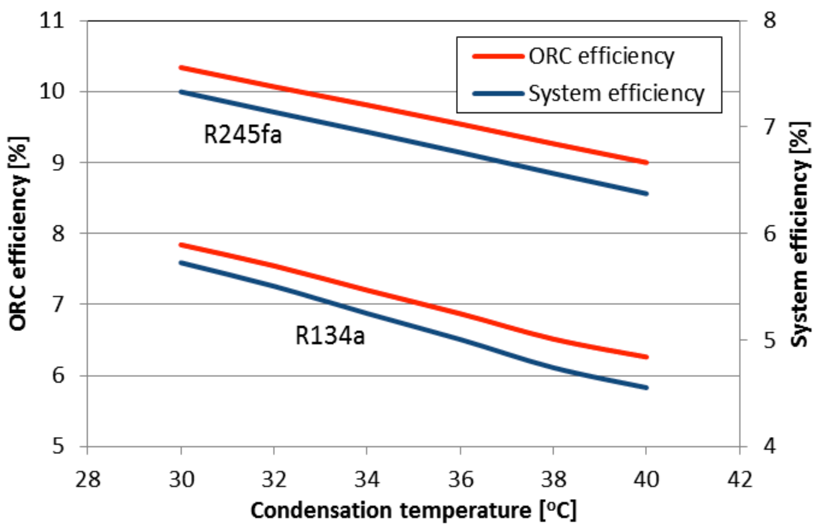

Figure 8: Variations of the ORC and system efficiency with condensation temperature

5.3 The Optimal System Performance

The optimal operating and design parameters of the 10 kW solar ORC with the heat source temperature of 120 ^{o}C are presented in Table 4 for each of the working fluids. These results were obtained at the maximum ORC operating temperature of 100 ^{o}C and condensation temperature of 30 ^{o}C. Table 4 lists thermal performance evaluation parameters and design parameters, including the total required solar collector area, total surface area of the heat exchangers and the VFR. The corresponding T-Q diagrams of the heat exchangers (evaporator and condenser) at the optimal operating conditions for R134a and R245fa are shown in Figs. 9 and 10, respectively.

It can be seen in Table 4 that the higher net output power (9.61 kW) is obtained with R245fa. This is because the system with R245fa requires less pumping power. In addition, higher ORC efficiency and system efficiency are achieved using R245fa and are equal to 10.34% and 7.33%, respectively. Also, using R245fa results in the smaller ETC area (187.2 m^2) and total heat exchanger area (72.20 m^2). However, application of R134a provides the lower VFR value (4.45) which indicates that a smaller expander size is needed.

Table 4: Optimal operating and design parameters

Operating and design parameter	R134a	R245fa
Gross power, kWe	10	10
Pump consumed power, kW	1.22	0.39
Net output power, kW	8.78	9.61
Evaporator pressure, bar	30	12.72
Condenser pressure, bar	7.81	1.74
ORC efficiency, %	8.27	10.34
System efficiency, %	6.01	7.33
Woking fluid mass flow rate, kg/s	0.523	0.393
HTF mass flow rate, kg/s	0.549	1.038
Cooling water mass flow rate, kg/s	3.093	2.523
Expander inlet volume flow rate, m^3/s	0.015	0.044
Expander volume flow ratio, -	4.45	8.22
Total ETC surface area, m^2	208.6	187.2
EC surface area, m^2	8.95	5.74
EV surface area, m^2	14.94	20.11
SH surface area, m^2	3.67	0.0
CON surface area, m^2	50.30	41.04
DSH surface area, m^2	5.18	5.31
Total heat exchanger area, m^2	83.03	72.20

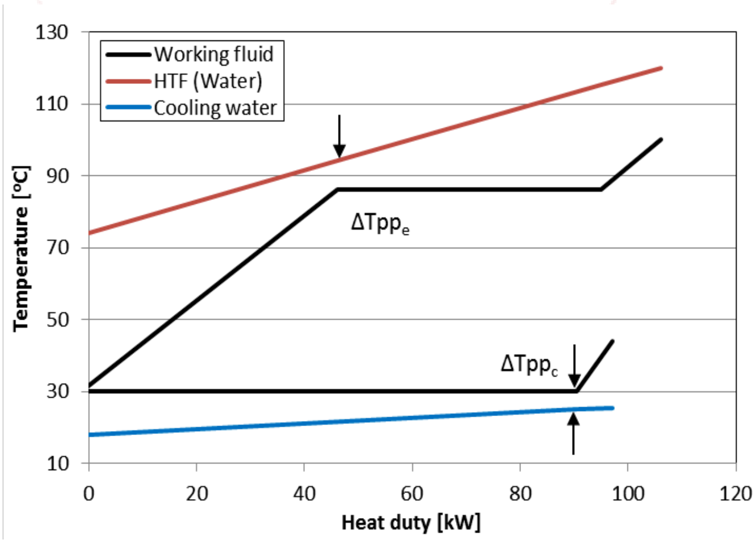

Figure 9: Evaporator and condenser T-Q diagram at optimal operating conditions (R134a)

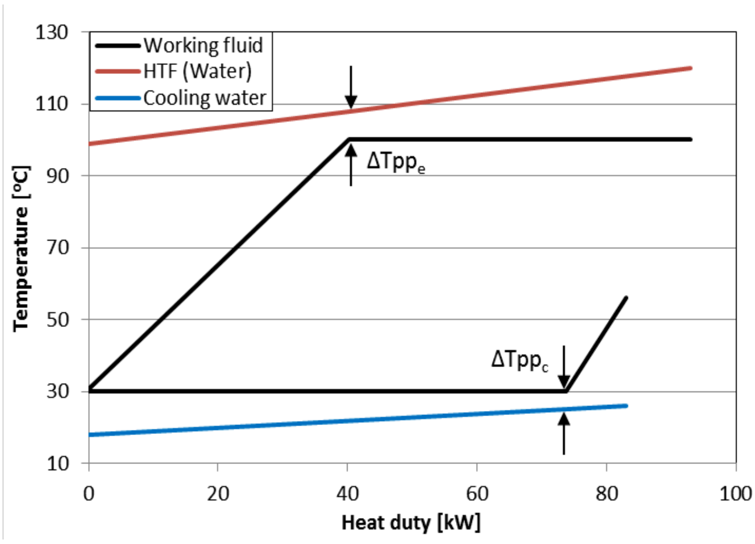

Figure 10: Evaporator and condenser T-Q diagram at optimal operating conditions (R245fa)

6. Conclusions

The performance and design parameters of the 10 kW solar ORC power system, connected to ETCs with heat pipes and to be used and operated in the UK climate conditions, were evaluated for two working fluids using thermodynamic analysis. A parametric analysis was conducted to investigate the effect of different operating conditions on the system performance in order to obtain the optimal operating and design parameters for each of the working fluids. The following are outcomes of this study:

- Both the evaporation pressure and condensation temperature have a significant influence on the system performance.
- ORC with R245fa provides higher net output power and overall system efficiency with values of 9.61 kW and 7.33%, respectively, under climatic conditions of Newcastle upon Tyne.
- ORC with R245fa requires the smaller ETC area (187.2 m^2) and total heat exchanger area (72.20 m^2). However, ORC with R134a has the lower VFR value (4.45), which indicates that a smaller expander size is required for the required output level.

Acknowledgment

The authors gratefully acknowledge the financial support provided by the Cultural Affairs Department of the Libyan Embassy in London.

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A Framework for the Governance of Socio-Technical Transitions in Urban Energy Infrastructures

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The European Conference on Sustainability, Energy & the Environment 2015
Official Conference Proceedings

Abstract
In this paper, a conceptual framework is proposed to analyze the dynamics of techno-institutional lock-in preventing urban energy infrastructures to change and the way a governance approach can affect these dynamics and direct urban energy transitions. In this respect, the framework hypothesizes that the relative power of different rationalities in urban energy infrastructure as a complex socio-technical system shapes its system inertia against transition effort. It is composed of the feedback dynamics between social, technological, economic and political dimensions of existing institutions, as well as the way a systemic governance approach can affect these dynamics of system inertia and shape transition pathways. Based on the current practices in urban energy transition projects, affecting part of this power structure is not sufficient for a successful transition, and may even have counterintuitive effects in long term. Based on the insights from this conceptualization, methodological guidelines are presented for modeling these power rationalities in the form of feedback structures causing system level inertia. This framework is the starting point for further research towards modeling techno-institutional lock-in, designing governance scenarios as well as evaluating the impact of these scenarios in energy transition in general, and urban energy transition in particular. Conceptualization of system inertia and the governance of energy transitions in urban energy infrastructures has practical applications to evaluate current low-carbon and energy transition efforts as well as different energy and climate change policies by urban authorities and other relevant actors aiming to contribute to urban energy transitions.

Keywords: urban energy transition, Socio-technical system perspective, lock-in, techno-institutional complex

Introduction

Cities and their energy systems are at the center of the most fundamental sustainability issues in the 21st century, as urbanization, climate change and the security of energy supply (Keirstead and Shah, 2013). Rapid urbanization has dramatically increased urban population as well as the need to basic goods such as energy. Indeed urban areas are responsible for around two thirds of the world energy consumption contributing to about 80% of global greenhouse gas emissions and climate change (IEA 2009, World Bank 2009; OECD 2009; Allix 2009; Bulkeley et al., 2015). Spatial concentration of activities, especially economic activities and energy services in cities is the main driver of economic growth, increase in urban population and energy consumption (Shah and Keirstead, 2013), which changes the patterns and trend of energy demand in urban areas as well. Considering the growing importance of local solutions for global challenges, such as the emergence of distributed energy systems to deal with climate change and energy transitions, cities are becoming the primary innovation locations, which need local institutions to exploit their local capital, skills, technologies and markets (Mancarella, 2013).
Energy infrastructures cannot be separated from the functionality other urban issues, since they are the backbone of urban infrastructure and are fundamental for urban activities (Chappin, 2011). Energy infrastructures (systems that satisfy needs for energy, Ajah, 2009) include environmental, economic, and social sustainability. These points address the fact that while cities are the source of many energy issues and problems in terms of their contributions to global energy consumption and global CO2 emissions, at the same time they are part of the solution to these issues (Rutherford and Jaglin, 2015). Therefore, changing the energy infrastructure systems is crucial for dealing with issues such as climate change through the massive introduction of renewable energy technologies and by reduction of energy use (Chappin, 2011).

In this respect, the so called ‘energy transition’, broadly defined as a radical, systemic and managed change towards ‘more sustainable’ or ‘more effective’ patterns of provision and use of energy (Rutherford and Coutard, 2015), is one of the major global challenges facing contemporary societies (see AGECC, 2010; Rifkin, 2011; WWF International, 2011). Cities as the main sites of energy consumption, are also a target as well as an instrument for energy transition (Rutherford and Coutard, 2014). Literature has already shown the role of cities in contributing to the transition of energy systems (International Energy Agency,2009; Bose,2010; WorldBank,2010 ;Commission for Environmental Cooperation, 2010; GDF Suez, 2010; Skanska, 2010; Greenpeace, 2005; Covenant of Mayors, n.d.; Harvey,2014; Droege, 2008; Newman et al., 2009; Troy,2012), but a systemic understanding of the relationship between cities and change in energy infrastructures is quite limited in literature. In order to understand the nature of this relationship and the potential for more elaboration, we need to consider three important issues: first, the conceptualization of the relationship between urban systems and energy transition; second, the systemic approach to analyze this relationship; and third, the best method to formulate and analyze specific problems such as system level inertia confronting change.

Governance of Energy System and Transitions at the Urban Level

Apart from the theories of the governance of energy transitions in general, context affects the process of energy transition at different political levels especially at the urban level. Urban energy transitions in developed and developing countries are different, as transitions in developing countries have a greater focus on the provision of basic commercial energy services. Moreover, in the developed world, the efforts are toward visions of low carbon futures (DTI 2007), but whereas in the developing country context, the dominant cause of energy transitions are rising levels of income and urbanization (Keirstead, 2013).
The literature on the governance of climate change and energy transitions, has considered city's role and the role of municipalities as actors within a multilevel, global system (Bulkeley et al., 2015). In the global environment domain, three distinct ways the term are used are analytical, normative and critical (Biermann and Pattberh 2008). In addition, in the climate change literature, the analytical way is the most common to identify and explain the ways in which climate change is governed. In the analytical approach, three related phenomena are central (Biermann and Pattberh 2008):

- Considering new types of agency rather than the national government
- New mechanisms and institutions of global governance to deal with energy issues
- Segmentation of the governance system and the transition from government to governance

Based on some observations, municipal governments take action in the absence of initiatives at the national level and in some cases such as the USA and Australia in spite of it (Bulkeley and Betsill 2003, Gore and Robinson 2009, Warden 2011). Therefore, there are reasons for considering cities as places critical for addressing climate change:

- Institutional reasons: the need to address policy problems at institutional levels as close as to citizens or the subsidiary principle (Bulkeley et al., 2015)
- The potential to implement climate change action: it addresses the role of municipal government intervention both through formal competencies and by enabling action plan. (Bulkeley et al., 2015)
- Effectiveness of responses: the potential of municipal government to tailor responses to local needs and to use local knowledge to support decisions (Corfee-Morlet et al. 2011, Henstra 2012).

A substantial strand of research on urban energy system transitions considers the role of cities in wider energy transitions. For example, there are studies that analyze national multi-level systems and the translation of national policy goals into local politics (e.g. Gupta 2007). Most of the literature in this respect, considers the activities aim to contribute to climate change action (e.g. Bulkeley and Kern, 2006; Kern and Alber, 2008). In this way, cities are the proper unit of analysis because from one hand, climate change is related to local governments in different way and with different logics; for instance, in it argued that an increasing portion of GHG is generated in cities, global change has a direct impact on cities which arises the issue of adaptation in cities and steers cities to be more innovative. In addition, cities can cooperate apart from compete and serve as focal point for the development of best practices used in different contexts or levels.

Looking at cities in this ways leads to the conclusion that actual response of local governments may vary due to different factors such as the impact of global change and the perception of this impact, city's competences and authority, national programs to support local initiatives, the involvement of cities in national and transnational networks, etc. (Kern and Alber, 2008). Therefore, these studies address the solutions developed by the governments to direct the climate change actions, including the climate change policies as the most common form.

Context strongly affects the process of energy transition at the urban level (Keirstead, 2013). For example, urban energy transitions in developed and developing countries are different, as transitions in developing countries have a greater focus on the provision of basic commercial energy services, while in developed world there is more room for considering sustainable energy solutions. In other words, in the developed world the efforts are toward visions of low carbon futures (DTI 2007), but whereas in the developing country context, the dominant cause of energy transitions are rising levels of income and urbanization (Keirstead, 2013). In addition, energy system structures in secondary cities is different from the primary cities in terms of the technologies, fuels, and the impact of the system configurations on the local environment. in developed countries, retrofitting and upgrading existing energy infrastructures and ensuring robust affordable performance are the issues, while in the developing world, expanding access to modern energy services in order to support economic and social development goals are necessary. Apart from these differences, both contexts of developing and developed countries highlight similarities in terms of the effect of technological improvements on the transition, the effect of new business models and financial issues.

Apart from efforts to address climate change at the urban level focused on the mitigation activities, recently the debate on climate change has been shifted to adaptation to the risks of climate change as a complementary paradigm. Adaptation is necessary since the effects of climate change become obvious and the effects are different from region to region (CEC 2007). Again the local and regional levels are optimal levels for adaptation, but adaptation is out of the scope of this research and therefore, we don't go into analyzing different adaptation activities here.

Urban Infrastructure, Complexity and a Systematic Approach to Un-Locking Techno-Institutional Complex

Changes in large technical systems, such as urban energy infrastructures, are the central topic of the scientific literature on transitions (Geels, 2002b) and transition management (Rotmans, 2003; Loorbach, 2007). An important premise for understanding and changing energy infrastructures is that these systems are complex. Indeed, infrastructure systems contain large number of elements that interact in a non-linear way (Simon, 1962). These systems are influenced by all sorts of actions taken and decisions made by multiple actors that are part of these systems. In other words, infrastructures are large, because they contain a whole hierarchy of systems which result in different feedback loops (Simon, 1973). This complexity of infrastructures has complications for both designing as well as intervening into the system by strategic decision makers. In their policy decisions, governments face deep uncertainty (Agusdinata, 2008).

Another facet of complexity in energy systems arises from their socio-technical nature. Indeed, transition in infrastructures is not only about technical aspects and technological transitions are much more than the technology alone (Keirstad, 2013; Chappin, 2011). Social and institutional aspects shape an important and including governance aspects are relevant in order to prevent the mal-functioning of markets and inefficient realization of long term public values (WRR, 2008)
Evans et al. (19999) analyzed the urban energy system for in the city of Newcastle-upon-Tyne for introducing combined heat and water and concluded that although the technology was ready, the necessary social networks couldn't be constructed to support the adoption of technology. In addition, by focusing on the price of new innovation, as the only determinant factor for adopting the technology, other important factors such as the partnership between universities and industry are neglected which limits the establishment of a coalition around the new technology.
In this respect, most of the research on energy and cities tend to divide between the social and the technical. It means that although they try to give importance to both dimensions, but in reality the research projects focuses on one of them (Rutherford and Coutard, 2014).
Each transition is emergent from a socio-technical system's perspective. A socio-technical approach to urban energy infrastructure transition considers both the institutional and technical dimensions of transition and their interactions. Socio-technical systems perspective points out to us that change in social elements and technological elements cannot be fully separated: in order to understand how infrastructure systems change, the relations between technical elements, between social elements and between social and technical elements need to be discussed (Chappin, 2011). Such an approach is necessary for analyzing and understanding the phenomenon because without understanding the social and institutional dimensions of any technological change, a sustainable and successful transition is not possible. For instance, in the case of combined heat and power in Newcastle-upon-Tyne, Evans et al. (1999) mentions that although the technology was ready, the necessary social networks could not be constructed to support the widespread adoption of the technology; or the well-known case of smart grid city in Boulder, Colorado was failed due to the lack of institutional capacity and facing social pressures.

In other words, rather than considering new technology and technical infrastructure, the entire relationship between consumers and produers might need to be redefined and modes of service provision adapted to meet new challenges (Keirstead, 2013). Transition requires a consistent policy framework and active market intervention to ensure the success of the network (Keirstead, 2013). In addition, our infrastructure systems are evolutionary, they show path-dependency and lock-in (Chappin, 2011). It means that options in the future are shaped by current behavior of the system and the return system is gaining by doing its current activities. As a result, the systems we observe today were not designed as such, they evolved to their present state (Nikolic et al., 2009; Herder et al., 2008).

The Theoretical Framework

In this paper, a theoretical framework is presented to analyze the process of urban energy transition to low carbon cities. By developing this framework, we try to answer the question that "How the assemblage of interventions in an urban energy system, leads to a transition to a low-carbon city?"

However, by analyzing this question in more details, three presumptions can be identified:

- An existing energy system
- An assemblage of interventions in the energy system
- Leading the system towards the final state of transition, namely a low carbon city

In fact, another approach is to consider the factors that prevent the system from a successful transition. In other words, a governance approach for a sustainable transition needs to investigate and overcome the barriers of transition in the existing system, as well as to promote the factors that facilitate the transition process.
In other words, these components can be classified as the following parts:

- Analyzing the underlying structure of a social system
- Capturing the operational environment in which the dynamics of interactions take place
- Observing the patterns of interaction and outcomes

In this respect, first we need to understand the dynamics of an urban energy system that shape the existing structure; then, the interventions take place in the operational environment and finally the outcomes of interventions and the resulting patterns of interactions should be identified and analyzed to evaluate the final state of the transition. Based on these parts, two main steps are proposed for understanding the governance of urban energy transitions:

1. System analysis for system-level inertia investigation
2. Governance by intervention in the urban energy system and evaluating outcomes

The main building blocks of this framework are depicted in Figure 1, briefly discussed in the following sections.

Step 1 - System Analysis for System-Level Inertia Investigation

In the first step, the current state of the energy system, its structure and the underlying dynamics should be investigated. The idea here is that the feedback processes and the underlying dynamics of interactions in the system are the sources of the obduracy and inertia of the system that are the barriers of transition towards a new system. This explanation has implications for the next steps of this framework. First, when the barriers to change are internal to the system, it means that the current structure cannot lead to the transition, and even the system might need a restructuring in order to define transition pathways. Second, the current actors are interacting in the existing structure and feedback processes of the system. Therefore, in order to have a transition, the current interactions between actors, incumbent technologies and governing institutions are not enough. In this respect, we need an intervention in the system aiming to change the structure and dynamics of the system and direct it toward the transition.
Indeed, the cities in different contexts show different dynamics, energy structures, objectives, and have different priorities based on their contextual factors. In other worlds, no one single solution fits all. In a city in the developed world, urban energy infrastructure can be analyzed as a complex socio-technical system. In this case, the objective of transition might be to mitigate the effect of energy system on climate

change by considering both technical and institutional factors. However, in a city in the emerging countries there might be a focus on the economic development and controlling rapid urbanization, which addresses the economic factors but again considers institutional changes as a required factor. The context of an underdeveloped infrastructure in an urban area however might be different, with the focus on the social objective such as accessibility and affordability of energy, as well as considering the urbanization process. Therefore, different contexts may share some characteristics but are different in terms of objectives, priorities and requirements.
Based on a socio-technical system perspective, in order to understand the underlying dynamics of the system, both the technical and institutional dimensions should be analyzed. The technical dimension constitutes the materiality of the system including its associated specifications. On the other hand, the institutional dimension addresses the rules of the game and the interactions in the human side of the system. This dimension can be decomposed further to economic, social/behavioral and political institutions, based on the different groups of stakeholders and their roles in shaping the system dynamics. Therefore, these four dimensions of the system dynamics are analyzed in the followings:

Technical Factors
Each urban energy system has a materiality manifested in the physical infrastructure and the flow of energy in the system. This physical infrastructure may have different degrees of maturity in different contexts as a mature or advanced infrastructure, a growing or developing infrastructure as well as an underdeveloping infrastructure, which needs to be developed to an advanced physical system. Based on the degree of maturity, the specifications and the complexity of the physical system might be different. The difference arises due to different standards, complexity in the physical network and its interdependencies.

Political Institutions
First set of the institutional factors, considers the rules of game as the formal and political institutions, which shape the relationship between all the actors involved in the system. These institutional factors have a multi-level and hierarchical nature, from international and national institutions that are external to the system dynamics, to the urban and local institutions that emerge based on the decision making process inside the juridical boundaries of the system . The primary assumption here is that the complex system of interactions between these institutions at different levels causes complex patterns that manifest themselves in terms of bureaucracies and legal complications. Based on the degree of formality, level of abstraction and their interdependency to the other factors in the system, political institutions have different weights in the obduracy of the system.

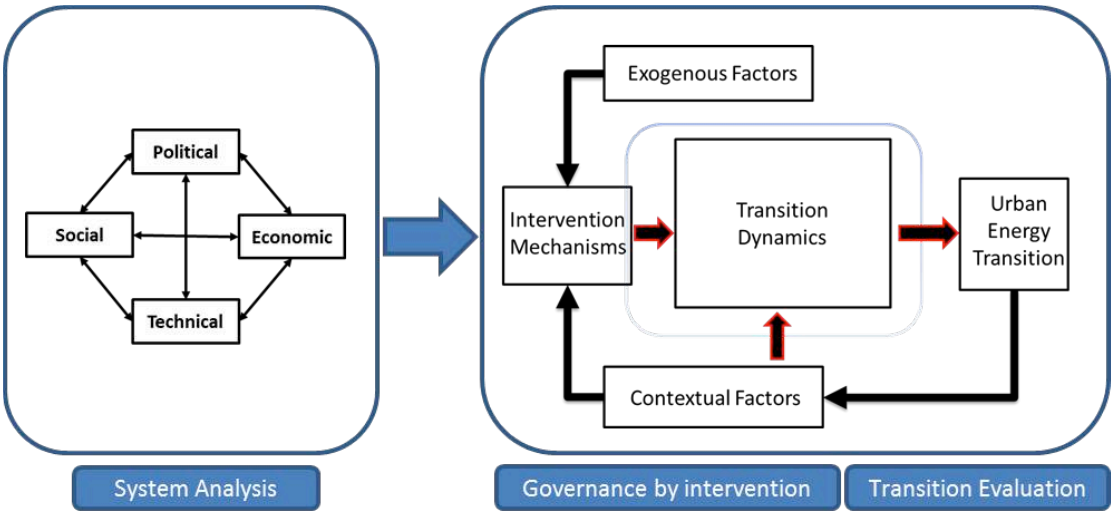

Figure 1: A framework for the governance of socio-technical transitions.

Economic Institutions

The second set of institutional factors, addresses the market dynamics, the relationship between business actors and their influences on the energy sector. The economic factors are important to understand both the dynamics of interactions between actors in the system and the sources of obduracy. On one hand, monetary interactions and economic transactions in the energy market are an important part of overall interactions in the system closely related to the political factors. On the other hand, in a capital-intensive sector such as the energy sector, investments are huge which affect the future behavior of the actors such as businesses and utility companies and are a big issue in changing the behavior of the investors and beneficiaries. Apart from these factors, at the micro-level, the purchasing power of the households and income affect the social and behavioral dynamics in the system.

Social Factors

The third set of socio-institutional factors are associated with the behavior of the end users, informal institutions that govern their behavior and the patterns that arise from these behaviors. The social factors have different effects on the obduracy of the system. In terms of the social institutions, like the case of the political institutions, they shape a hierarchy from cultural norms to day-to-day interactions. The degree of obduracy of social behaviors increases when they are affected with the institutions at the higher levels of this hierarchy. Social factors also influence the structure of the system by their position in the decision-making process and political priorities on one hand, and as the micro-factors for understanding the dynamics of the energy sector on the other. Many governments and strategic decision makers place a high priority for the social factors such as availability and affordability of vital resources such as energy. In addition, consumption and behavioral patterns as well as the effects of urbanization and demographic factors are the important factors, which affect the decision-making and planning processes such as the well-known demand management programs.

System Interdependencies

Considering these underlying dynamics, the importance of these dimensions vary greatly based on the contextual factors. Therefore, system configuration may differ according to these different priorities, which leads to different objectives, structures and mechanisms. Here I argue that these dynamics and their interactions cause the system level inertia and resistance to transition in the energy infrastructure. In this respect, it is needed to investigate the interdependencies in different contexts to identify the primary sources of system obduracy. Therefore, by considering these four dimensions, six types of mutual interactions can be formulated as depicted in figure 2.

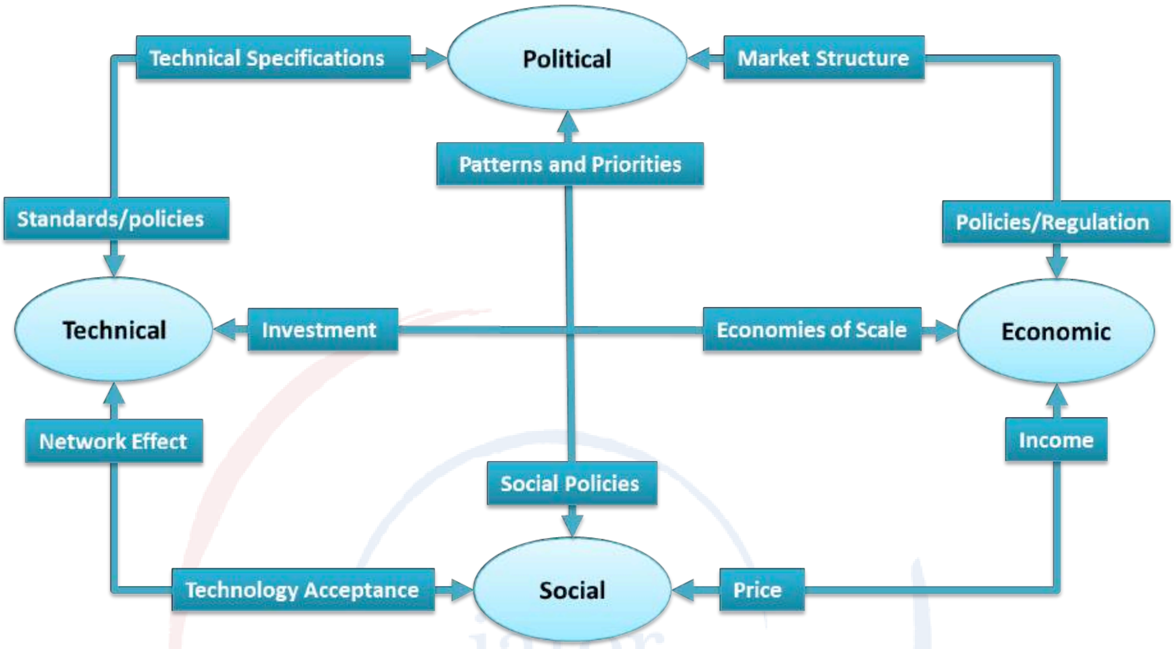

Figure 2 – System analysis to investigate system level inertia

Social-Technical

The interdependencies between social and technical factors can be explained by the dynamics of technology adoption. Technologies shape the social factors based on their level of acceptance, such as their ease of use and perceived usefulness. On the other hand, when the numbers of users increases, the benefit for potential users to use the same technology increases too; something commonly called as the network effect.

Economic-Political

The economic restructurings such as privatization, liberalization or re-regulation of markets are the primary effects of political institutions on the economy. At the urban level, these institutional effects manifest themselves in terms of new economic policies (such as urban energy policies and Feed-in Tariffs) and regulations. In the long run, these effects manifest themselves in the form of new market structure that shape a new institutional environment affecting the political decisions.

Social-Economic

Social and economic interdependencies arise from the purchasing power of actors in the system. The primary effect of economy on the end users emerges as the price of goods and services; while the level of income of the users and households explains the consumption behavior of the actors and its effect on the market economy.

Technical-Political
Technologies cannot function efficiently in a social system without well-established institutions. Standards and technical policies shape the development and diffusion of technologies in different societies. As a response, technical specifications are developed to satisfy these standards and constitute part of the broader institutional environment.

Social-Political
Actors' behaviors explain the relationship between social and political factors. On one hand, social policies affect the norms that shape the actors' behavior as the part of the institutional environment. On the other hand, actors' behavior in aggregate, shape the behavioral patterns such as the patterns of consumption that provide input for the emergence of new political institutions in future. The second mechanism for the influence of social factors on the political dimension is through the social priorities in the political agenda. These factors are important especially in the developing world and affect the political objectives in the transition process.

Economic - Technical
Finally, the interdependencies between technology and economy play a big role in the dynamics of inertia in urban energy system. The cost and benefit of technologies are the primary criteria for the businesses to evaluate the feasibility of investing in these technologies. Based on such analysis, investments on technologies by the economic actors, new dynamics of inertia emerge in the form of sunk costs and economies of scale.
Based on the four underlying dynamics of urban energy systems and their interdependencies, we can analyze the system level inertia and existing dynamics of different urban energy systems in various contexts. For this purpose, three steps are necessary in order to identify the prominent underlying factors and identifying the implications for the governance of urban energy systems:

- Analyzing the strengths of every pair of relationships between the four underlying dynamics
- Identifying the priorities of strategic decision makers involved in the governance of urban energy systems in terms of social, economic, technical and institutional objectives
- Formulating the potential opportunities for lock-out or leapfrogging in the system

Step 2 - Governance by Intervention in Urban Energy Systems

In the second part of the framework, a conceptual model is proposed for understanding the relationship between different interventions and the dynamics of urban energy transitions for low carbon cities. The primary idea here is that the governance manifests itself as a set of interventions in the dynamics identified in the first step.
The logic of this argument is that if we assume all the dynamics of energy systems in terms of social, political, technical and economic dimensions come from outside the urban boundaries, then there is no room for the urban governance to shape the transition and the future state of the energy system. However, in the real world there are factors at the urban level that influence the dynamics of transitions independent from the national and international forces or even in the absence of such forces.

Therefore, we hypothesize that governance at the urban level is meaningful and takes place in the form of interventions in the dynamics of the system.

Socio-Technical System Components

For formulating these interventions, in this part we propose a conceptual model for the governance of urban energy system transition as a set of interventions. For a system level analysis in a socio-technical system, we need to identify five different sets of factors as objectives, transition dynamics, intervention mechanisms, contextual factors and exogenous factors. Based on the underlying dynamics of system level inertia described in the first step, the contextual and exogenous factors can be decomposed to these four underlying dynamics; but the objectives, transition dynamics and intervention mechanisms are aggregate factors cause by nonlinear interactions between these underlying dynamics.

Objectives

Transition to a low carbon city is an emergent property of an energy system as a complex socio-technical system. Therefore, predicting the future state of the system is impossible and the role of governance is to steer the transition pathways towards a satisfactory state in future. In this respect, concrete objectives are needed in order to satisfied and direct the system toward them. In general, the objectives of transition can be classified into two broad categories as objectives to reduce the dependency of the system to unsustainable energy infrastructure; and promoting the new and sustainable system and energy sources.

Exogenous Factors

There are factors beyond the urban level that cannot be influenced by the dynamics of urban energy transition but affect these dynamics. Therefore they are classified as the environment and the landscape pressures which should be taken into account for formulating the intervention mechanism. Aligned with the dynamics of system inertia, we can classify these factors in the form of the four underlying dynamics. Technological changes beyond the urban boundaries are the primary technological factors which affect the urban energy system. Considering the social and political dimensions, national and international institutions as well as cultures and cultural norms are institutions that shape the behavior of actors at the urban level, but should be regarded as external forces. Economically, investments from outside the urban boundaries and external funding are another set of external factors, which affect the dynamics of transitions.

Contextual Factors

Another set of important factors affecting the transition dynamics are contextual factors. The underlying dynamics of energy system and its obduracy greatly affect the contextual factors and are important concepts for selecting intervention mechanisms. In terms of the underlying dynamics, contextual factors can be classified as the technological base and local resources, institutional and financial capacity of the city as well as the consumption patterns of the urban residents. These contextual factors affect the transition dynamics and intervention mechanisms, and take effect from the consequences of interventions in the system.

Intervention Mechanism

From the viewpoint of a strategic decision maker, intervention mechanisms are the only place that changing the system is possible. These mechanisms are tools to affect the dynamics of transition and steering the whole system towards transition. Therefore, at the center of this step is the selection or design of these mechanisms by combining different governance tactics and techniques (or government technologies in Foucault's terms) which address the dimensions of system inertia. In this respect, cultural learning programs are the primary mechanisms for changing the social dimension of the system. The institutional changes in the forms of designing new policies affect the political dimension of transition. For changing the technical dimension and its associated institutions, the is the need to either developing new technologies, which hardly takes place at the urban level, or transferring new knowledge and technology from outside the urban boundaries. Finally, investment in the form of direct investment or creating incentives for the private sector by mechanisms such as economic policies is the primary source of changing the economic dimension.

Transition Dynamics

Dynamics of the system transition are the results of interactions between all the actors involved in the system based on the effects of exogenous and contextual factors as well as the effect of intervention mechanisms. These dynamics are the pathways for the system to reach to the transition objectives and can be classified as three following dynamics:

Energy Efficiency

By assuming a constant amount of energy consumption in the system, the system efficiency can reduce the dependency to unsustainable energy sources through reducing the amount of energy supplied. Efficiency can be gained for instance by more efficient consumption at off-peak times, improving efficiency in the distribution and even more efficient types of energy production, inside the urban boundaries.

Energy Conservation

If we assume a constant efficiency of the energy system, then another dynamic is to reduce the level of energy demanded and consumed in the system. Behavioral changes, cultural learnings and demand side management programs address this part of the transition dynamics.

Renewable Energy Production

Finally, replacing the incumbent energy system with a sustainable and carbon-neutral energy system completes the transition process. Producing energy from renewable sources and diffusion of distributed energy technologies are the primary factors in this dynamic.

Based on these factors, the following conceptual model is proposed for analyzing the governance of urban energy transitions as the set of intervention mechanisms (Figure 3).

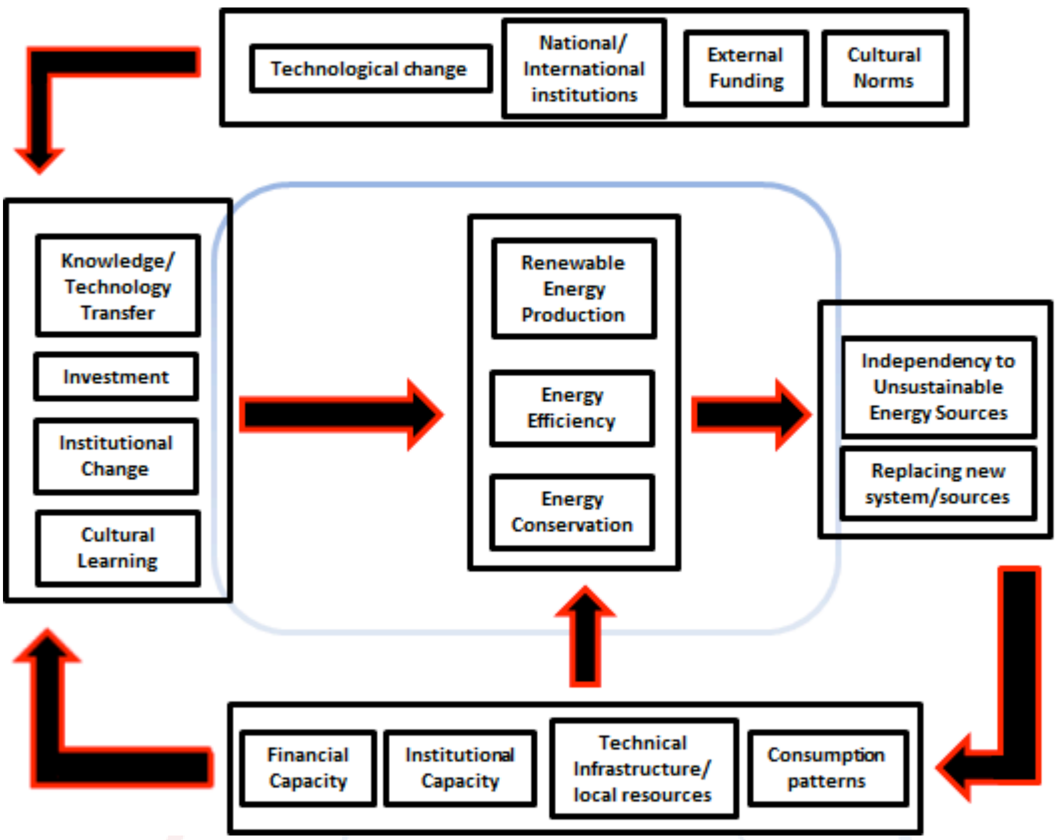

Figure 3 – The conceptual model of urban energy transition dynamics

System Intervention as the Governance Approach

Following this conceptual model and the dynamics of system inertia explained in the first part, the primary transition dynamics are formulated and intervention in the system can be designed by considering all the factors important in the governance of urban energy transition. The output of this step would be a combination of different intervention mechanisms as governance scenarios, which should be tested, in the third step. In this respect, three steps are necessary for designing different scenarios:

1. Identification of exogenous and contextual factors, setting transition objectives and formulating the possible transition dynamics
2. Formulating the effect of different intervention mechanisms on the transition dynamics
3. Selection and design of intervention mechanisms as the governance scenarios

The first step of this framework provides input for identifying the contextual factors involved in the energy system. In this step, a preliminary analysis is needed for the identification of the leverage points and designing the intervention mechanisms. This analysis provides input for understanding the effects of different scenarios in the system, which is the aim of the third step.

Conclusions

This paper proposed a conceptual framework for analyzing the dynamics of techno-institutional lock-in preventing urban energy infrastructures to change, and the way a governance approach is able to influence these dynamics and direct urban energy transitions. It formulated the relative power of different rationalities in urban energy infrastructure as a complex socio-technical system shapes its system inertia against transition effort. It is composed of the feedback dynamics between social, technological, economic and political dimensions of existing institutions, as well as the way a systemic governance approach can affect these dynamics of system inertia and shape transition pathways. Based on this framework, affecting part of this power structure is not sufficient for a successful transition, and may even have counterintuitive effects in long term. Based on the insights from this conceptualization, methodological guidelines were presented for modeling these power rationalities in the form of feedback structures causing system level inertia. Based on this framework, further research for modeling techno-institutional lock-in, designing governance scenarios as well as evaluating the impact of these scenarios are needed, especially using System Dynamics as a proper methodology for modeling feedback structures creating techno-institutional lock-in. Conceptualization of system inertia and the governance of energy transitions in urban energy infrastructures has practical applications to evaluate current low-carbon and energy transition efforts as well as different energy and climate change policies by urban authorities and other relevant actors aiming to contribute to urban energy transitions.

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Development of a Solar Cooling System Based on a Fluid Piston Convertor

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The Third European Conference on Sustainability, Energy & the Environment 2015
Official Conference Proceedings

Abstract
Solar water pumping and dynamic water desalination based on fluid piston converter were developed at Northumbria University. The fluid piston converter has a simple design and made of low cost materials. In water pump and desalination systems, the fluid piston converter works as an engine, driven by solar thermal energy absorbed by flat-plate or evacuated tube collectors. If in the same design of the converter, its fluid piston is driven using external source of energy without heat input, then such the converter works as a cooling device.

In this study, the solar fluid piston engine is coupled with the cooling unit with the fluid piston of the latter driven by the fluid piston engine. This results in production of cooling effect using solar energy. The operation of such system has been investigated theoretically and experimentally. The thermodynamic model, consisting of a system of ordinary differential equations, was developed in the MATLAB/Simulink environment to simulate the operation of such the thermal auto-oscillation system. The theoretical results confirm that it is possible to achieve the temperature of the working fluid in the cycle of the cooling unit, which is below the ambient temperature. The cooling effect depends on the operational parameters of both the engine and cooling parts of the system.

Keywords: solar cooling system, fluid piston engine

Nomenclature

Symbols
C_v - specific heat at constant volume
M - mass
P - pressure
$\dot{Q}$ - heat transfer rate
t - time
V - volume
γ - isentropic index
ω - angular velocity
C_P - specific heat at constant pressure
$\dot{m}$ - mass flow rate
p - denotes to fluid piston engine control volume
R - universal gas constant
T - temperature
X - displacement of the water level
ε - the cooler effectiveness

Indexes
c - denotes to the cooler control volume
e - denotes to cooling space control volume

Introduction

At present, a limited number of solar cooling systems are available commercially on the market and the scale of the practical applications is relatively small due to relatively high initial and running costs. Numerous studies have been carried out on different types of solar cooling systems including solar absorption and adsorption systems [1-5], the combined power and cooling [6, 7] and other types of solar cooling systems [8-10]. During the last few years, new test rigs for solar water pumping and dynamic water desalination unit were built and experimentally and theoretically investigated at Nortumbria University [11, 12]. These test rigs were built around the fluid piston converter/engine and solar evacuated tube collector with heat pipes. Heat input into the system was carried out using a solar simulator, made of 110 halogen floodlights, and controlled by an electrical three-phase transformer.

The concept of solar cooling system which has been built around the fluid piston engine and cooling machine is shown in Figure 1. The solar energy is used to drive the fluid piston engine which in its turn drives the cooling machine producing a cooling effect.

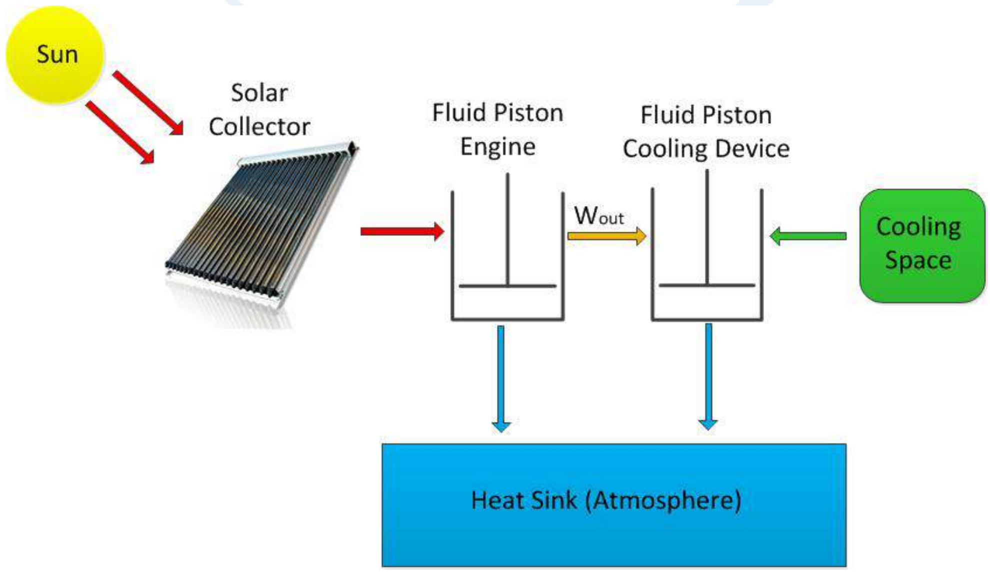

Figure 1: The concept of the solar cooling system.

Physical and Mathematical Model

Figure 2 shows a schematic diagram of the test rig with solar cooling system. It consists of two parts: engine and cooling machine parts. The engine part is made of the solar evacuated tube collector to heat water in the cylindrical evaporator and fluid piston engine. The evaporator is connected to the engine through the condenser. Steam produced by the solar collector drives the fluid piston engine. The fluid piston engine is made of two enclosed concentric plastic cylinders connected to each other in their bottom sections. The internal and external fluid columns act as a piston and fly wheel, respectively. The system is self-starting and the frequency of oscillations is about 1.5-3 Hz depending on the air volume above the external liquid column in the engine. The fluid piston is activated by the thermal energy generated in the evaporator. The pressure variation of air in the space above the external water column of the engine also drives the fluid piston of the cooling machine which has a U-shape. The condenser and cooler are used to reject the heat from the cycle of the engine and cooling machine.

The engine part and its mathematical model are described in details by Mahkamov et al. in [13].

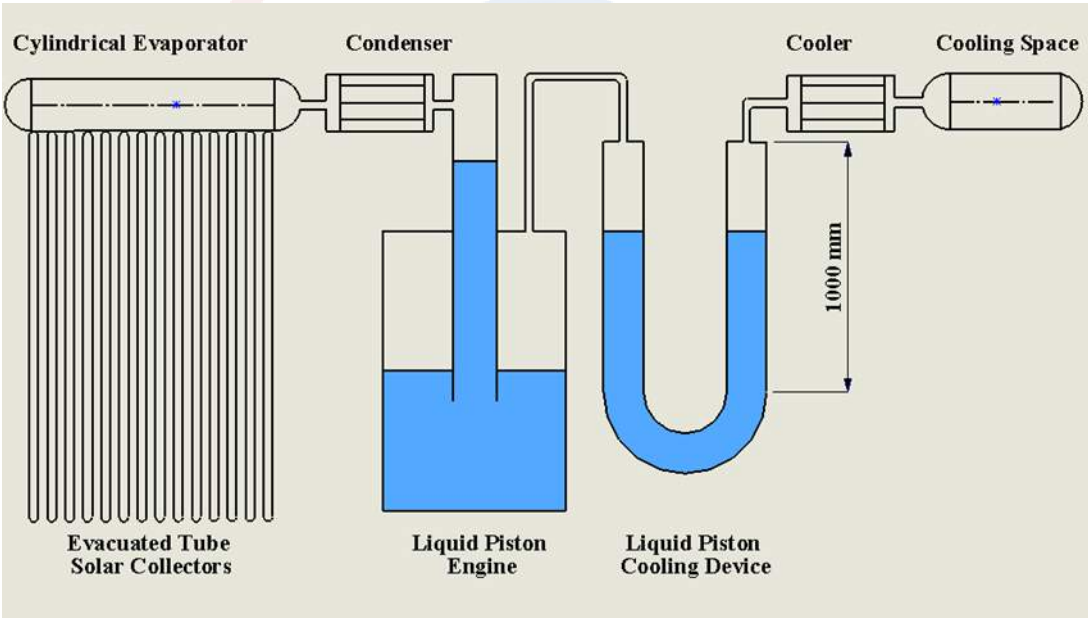

Figure 2: The fluid piston solar cooling system.

The calculation scheme for the mathematical modelling of the cooling part of the system is presented in Figure 3. It consists of three main control volumes, namely for fluid piston converter, cooler and cooling space. The working fluid in the system is air which is assumed to behave as an ideal gas. The pressure and temperature of the air in the system vary due to the change in the volume caused by oscillations of the fluid piston with the expansion and compression processes taking place in the cycle. The heat generated during the compression process is rejected in the cooler and the cooling effect generated in the cooling space during expansion process. The cold generated then can be transferred to the process heat carrier.

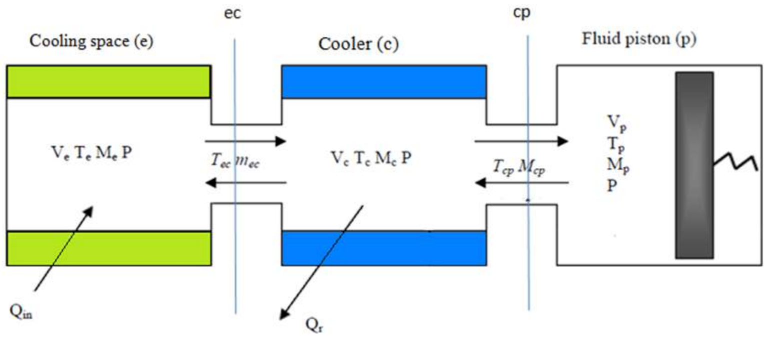

Figure 3: The calculation scheme of the cooling system.

The temperatures in the control volumes are affected by the direction of gas flow in interfaces between cooling space and cooler (denoted as ec) and cooler and fluid piston cylinder (shown as cp in Figure 3). For each of the control volumes mass and energy conservation equations are written.

The energy equation for the control volume can be presented as [14]:

$$\dot{Q} + (C_p \dot{m} T)_{in} - (C_p \dot{m} T)_{out} = P\frac{dV}{dt} + C_v \frac{d}{dt}(mT) \quad (1)$$

The displacement of the fluid piston is described as

$$X = X_0 \cos(\omega t) + L \quad (2)$$

where L is the starting position of the fluid piston.

The air pressure in the system is found by adding to each other energy equations (1) written for control volumes:

$$\frac{V_t}{\gamma - 1}\frac{dP}{dt} = -\dot{Q}_r - \frac{\gamma}{\gamma - 1}P\frac{dV_p}{dt} + Q_e \quad (3)$$

Here V_t is the total air volume in the system, Q_e are heat losses and $\dot{Q}_r$ is the heat rejected from the cooler, which calculated by applying the effectiveness-NTU method presented in [15].

MATLAB/Simulink environment

The above set of equations was solved in the MATLAB/Simulink environment. The developed Simulink model was built as a closed loop to simulate the proposed dynamic solar cooling system, as shown in Figure 4. After reaching the steady state condition, the variation in the fluid piston volume, the system air pressure and temperatures in every control volume are defined. The MATLAB/Simulink model also contains a set of criterion to establish whether the steady regime of operation is achieved during numerical integration. The heat losses in all three control volumes are calculated to produce more accurate results.

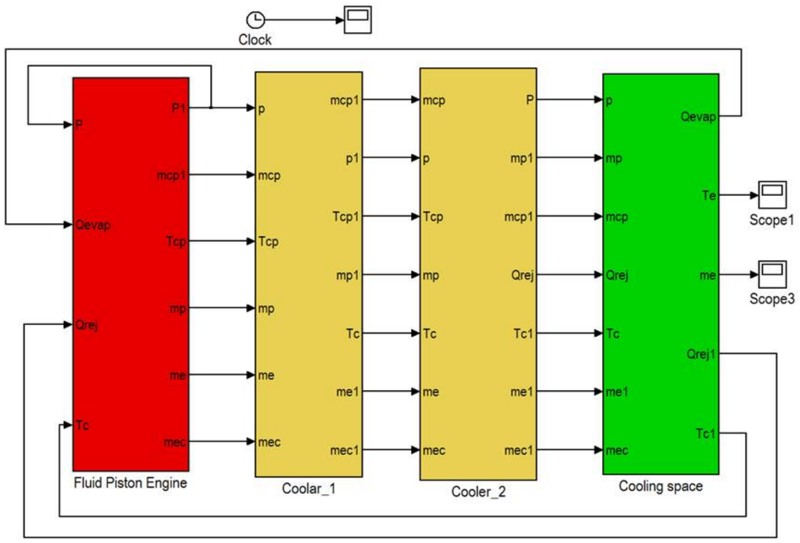

Figure 4: Simulink model of the solar cooling system.

Theoretical results

The operation of the cooling system was simulated for the specified amplitude of the fluid piston in the engine part and its frequency equal to 0.1 m and 3Hz, respectively. In addition, the temperature of the cooling water that enters the cooler was set to be 20° C. These conditions correspond to the operation of the fluid piston engine, tested experimentally in [11]. The displacement of the water column in cooling machine over the cycle is shown in Figure 5. Due to variation of the total volume of the cooling system the air pressure also periodically changes between 1.06 and 0.958 bar, see Figure 6.

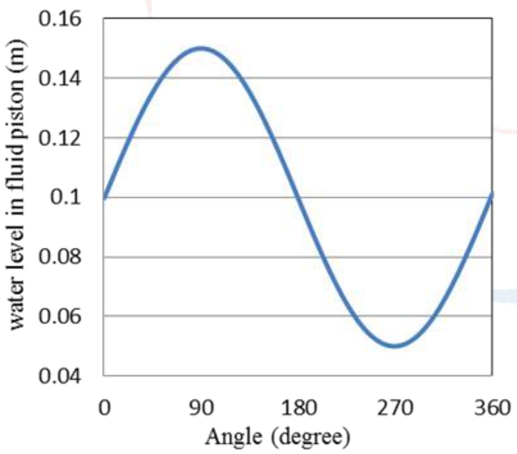

Figure 5: The liquid piston displacement.

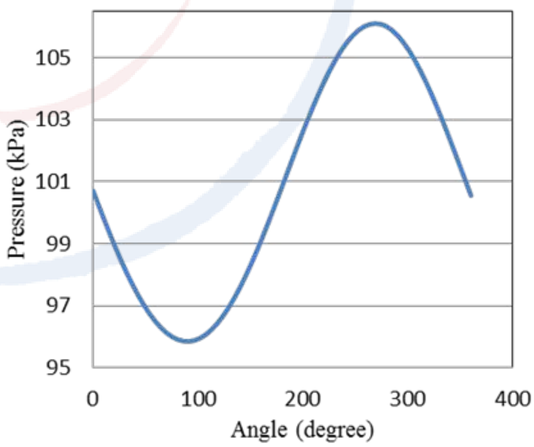

Figure 6: Air pressure variations.

Figures 7 and 8 demonstrate the variations of the temperature of air in the cylinder and cooling space, respectively. It can be seen in Figure 7 that the amplitude of the temperature variation in the cylinder is 15 degrees with maximum and minimum temperatures being 304 and 289 K. The range of the temperature variations in the cooling space are about 22 degrees with maximum and minimum temperatures being 303 and 281 K, respectively.

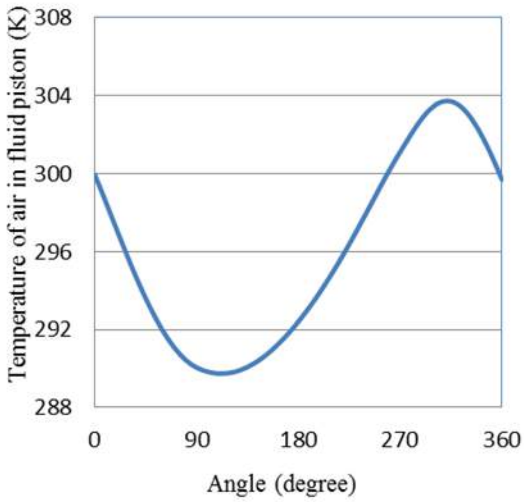

Figure 7: Air temperature in the cylinder.

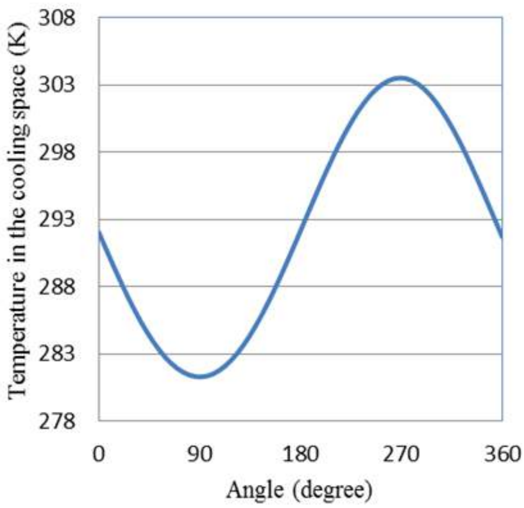

Figure 8: Air temperature in cooling space.

Experimental test rig

The engine test rig consists of the engine part with condenser, U-shaped cooling machine with cooler and heat pipe evacuated-tube solar collectors with the solar radiation simulator, see Figure 9

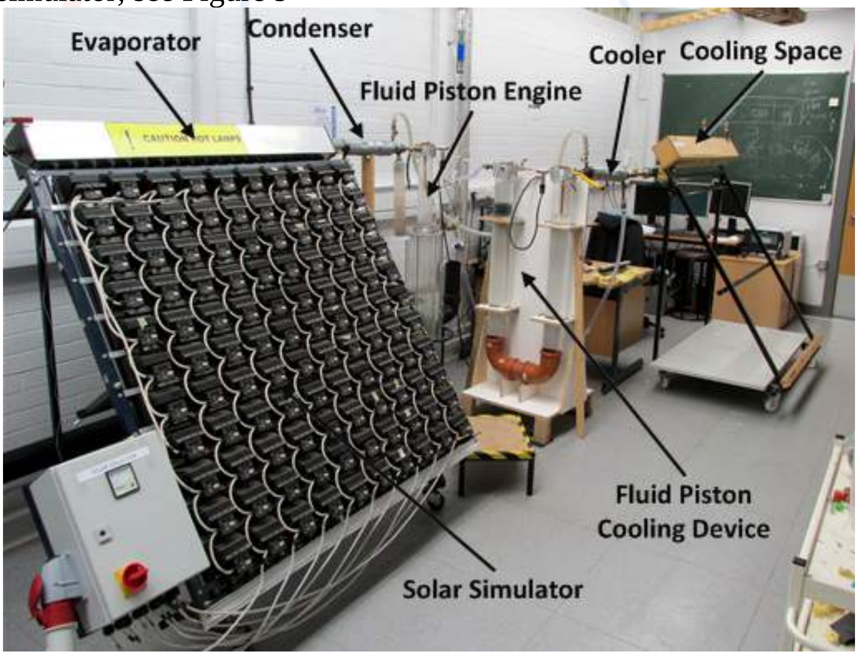

Figure 9: The test rig.

The evaporator is also the upper manifold of the solar collector which houses heads of heat pipes of the evacuated tube solar receivers. In this manifold the heat from head of heat pipes is transferred to the water and it is boiled producing steam. Generated steam is turned into the liquid in the condenser and returned back to the manifold. The pressure rise in the manifold initiates oscillations of water column (fluid piston) in the engine part. The solar simulator is made of 110 tungsten halogen lamps (150 W each) controlled by 3-phase variable transformer. The heat flux form halogen lamps onto the surface of the evacuated tubes was measured using a PMA 2200 photometer as a function of the 3-phas transformer voltage. The changes in the temperatures, pressures and levels of water columns were recorded using National Instruments DAQ, as shown in Figure 10. The types and specifications of sensors together with their locations are presented in Table 1.

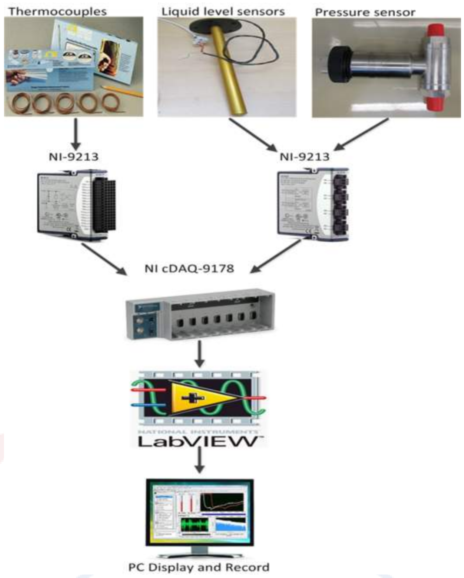

Figure 10: Data acquisition system.

Table 1: Specifications of the different sensors.

Component	Sensors	Description
Fluid piston engine	Water column level; Pressure; Temperature.	Level sensor: The aluminium R-series liquid level sensor by Gill Sensors (UK) with sampling rate of 80Hz. Pressure sensor: UNIK 5000 differential pressure transducer (-4 to +4 bar gauge), Druck Ltd Temperature sensor: The PFA insulated T-type thermocouples with thickness of 0.08mm.
U-Tube liquid piston cooling machine	Water column level; Pressure; Temperature.	
Cooling space	Temperature	

Experimental Results

The experimental results on oscillations fluid pistons in engine and cooling machine, cyclic variation in the air pressure and temperatures in the cylinders and cooling space are presented in Figures 11-15. It can be seen in Figures 11 and 12 that the amplitude of the fluid piston engine is about 5 cm whilst in the cooling machine this value is 1.6

cm. This difference is due to difference in diameters of plastic pipes used to make the engine and cooling machine (8.5 and 10 cm, respectively) frictional losses in the movement of the water columns in the internal and external cylinders of the fluid piston engine and the cylinder of the cooling machine. The changes in the air pressure in the engine and cooling parts over the cycle are shown in Figure 13.

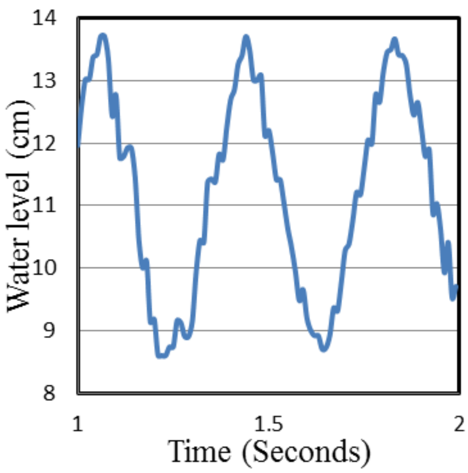

Figure 11: The engine liquid piston displacement.

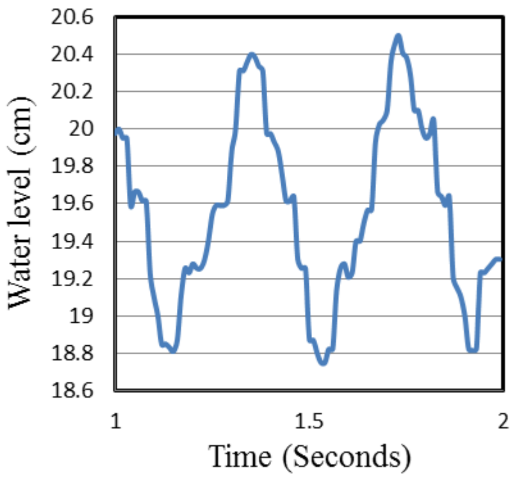

Figure 12: The cooling machine liquid piston displacement.

Before switching on the solar simulator, the air gage pressure in both the engine part and cooling part are set to be equal to the atmospheric pressure. By switching the set The oscillation of the air pressure and cooling parts is between 0.032 and -0.073 bar (gage) in the engine part and between 0.11 and 0.02 bar (gage) in the cooling machine.

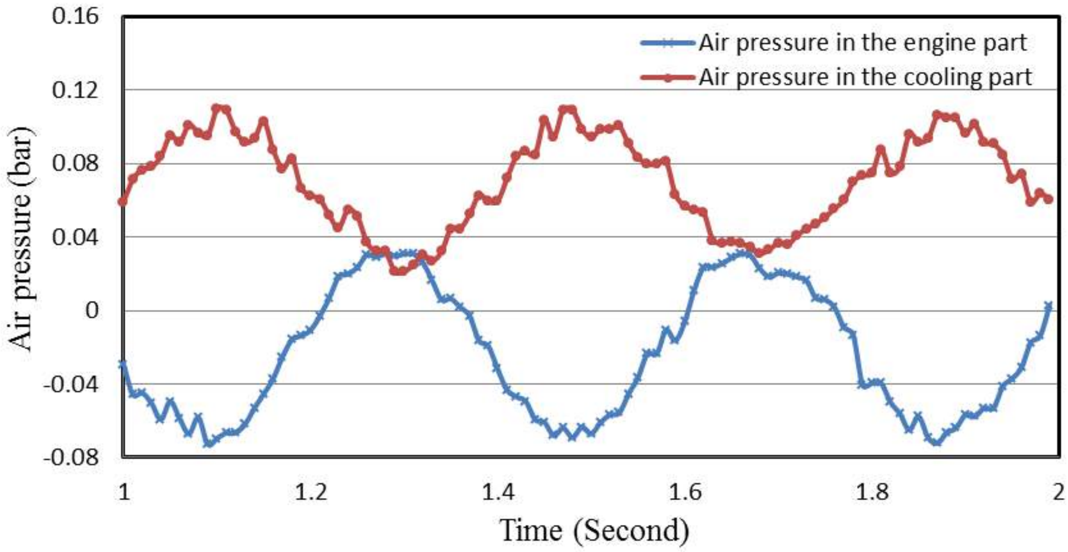

Figure 13: Air pressure in the engine part and cooling part.

Figures 14 and 15 show the variation in the air temperature in the cylinder of the cooling machine and in the cooling space. It can be seen that the average air temperature in the cylinder is 294.24 °K and this value in the cooling space is 292.7 °K. This demonstrates that the cooling effect takes place in the system with a 1.54 degrees reduction in the temperature of air.

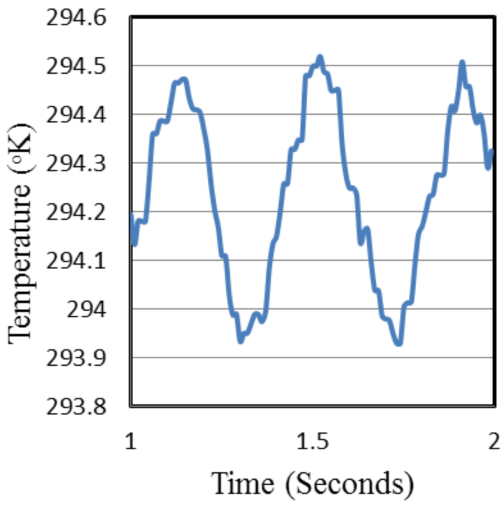

Figure 14: Air temperature in the cylinder of cooling machine.

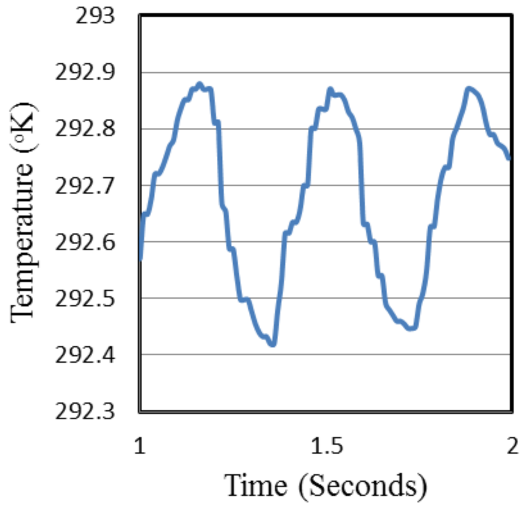

Figure 15: Air temperature in the cooling space.

Conclusions

In this study, the concept of the solar cooling system based on fluid piston converters is presented. The mathematical model of this cooling system was and numerical simulations were performed in MATLAB/Simulink environment. The possibility of producing the cooling effect in the system was demonstrated by means of numerical simulations and experiment. The theoretical reduction in the air temperature was about 3 degrees whilst in the experiment this value was found to be 1.54 degrees. The deviation between the theoretical and experimental results is due to unaccounted heat losses in the system.

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Piloting the CLIMASP -Tempus Interdisciplinary Minor in Climate Change and Sustainability Policy: Outcomes Achieved

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The European Conference on Sustainability, Energy & the Environment 2015
Official Conference Proceedings

Abstract
Higher education plays a unique and critical role, one often underestimated and/or neglected in building a more sustainable society. This paper deals with the piloting and validation of an interdisciplinary minor program in climate change and sustainability policy across 10 universities in Egypt, Jordan and Lebanon. It is a European Commission funded programme led by the University of Crete, Greece. A holistic and innovative assessment instrument was developed based on experiential, constructivist and transformative approaches to sustainability education. A pre-test questionnaire was given to assess: 1) previous teaching and learning practices; 2) sustainability education competences and 3) interdisciplinarity consisted of three scales- interdisciplinary skills, reflective behavior, and recognizing disciplinary perspectives as well as key learning pillars and critical skills. The same test was given at the end of the semester. The reliability tests performed showed that all the scales were valid for further statistical analysis. The pre-test and post-test analysis revealed statistically significant changes in students' performance as a result of the impact of the CLIMASP minor courses.

Keywords: Interdisciplinarity, climate change, sustainability policy, minor, higher education

Introduction

In recent years, we have experienced a number of environmental, social and economic problems that threaten the very existence of humankind. Problems such as extreme weather patterns and melting glaciers, deforestation and land degradation, habitat and biodiversity loss, air and water pollution, overuse of natural resources, poverty and violation of human rights, and global climate change, all pose critical challenges for people, communities and institutions across the world. Understanding sustainability problems, especially climate change, their causes, and their solutions is critical for building a sustainable global future. Dealing with sustainability problems there is need of shifting emphasis from disciplinary knowledge and skills to developing learners' interdisciplinary and action competence to participate actively in counteracting climate change and related problems. Higher education institutions (HEIs) play a unique and critical role, that is often overlooked, in making a healthy, just and sustainable society employing interdisciplinary perspectives (Makrakis & Kostoulas-Makrakis, 2014;2013ab). Blake et al. (2013) found that it appears to be raising demand for interdisciplinary understanding in relation to sustainability issues characterized by complexity and uncertainty, and this is likely to exert pressures on traditional disciplinary modes of teaching, content and organization in HEIs. They also found that programs which are promoting an interdisciplinary approach to sustainability are often seen as innovative, but still problems persist around the "uneasy fit between their cross-boundary integrative approaches and participatory pedagogies on the one hand, and discipline based university structures and methods on the other" (p. i). The higher education academic system is still very much structured on disciplines and the integration of interdisciplinary perspectives and programs have become unusual to the undergraduate fields of study (Davies et al. 2010). This necessitates a shift to new organizational and administrative forms that differ from traditional academic departments and faculties alongside with new curricula and teaching methodologies such as problem-based learning. Interfaculty and interdisciplinary collaboration are essential for modernizing higher education and it is a necessary condition for any transformation to meeting the challenges of climate change and sustainable development. Climate change and other sustainability problems require interdisciplinary approaches that can bridge the compartmentalization of knowledge and the isolation of academic fields in order to facilitate policy choices toward a path of ecologically sound and socially equitable solutions. There is, thus, a critical need for Middle Eastern universities, our focus here; in light of the climate change challenges their region is facing, to cultivate interdisciplinary expertise among their teaching staff and students.

Whilst the term 'interdisciplinarity' is often used flexibly to mean any approach that goes beyond a single discipline, the core characteristic of interdisciplinary approaches is their goal to analyze, synthesize and integrate concepts, methods and principles from different disciplines (Lawrence, 2010). This is different from what might be called a multidisciplinary subject which juxtaposes multiple perspectives on the same topic without integration and stays within their boundaries (Stock & Burton, 2011) while transdisciplinarity creates a unity of intellectual frameworks beyond the disciplinary perspectives (Domik, 2008; Choi & Pak, 2006). Based on a thorough literature review (e.g. Servant & Dewar, 2015; Brush & Saye, 2014; D'Ottavio & Bassan, 2014) we found that interdisciplinary students need to:

- Learn to interrogate multiple ways of knowing and methods and to talk critically but reasonably across these perspectives.
- Develop a reflective and explicit knowledge of how different disciplines work, the issues and problems they can address, and the strengths and limitations of each discipline.
- Balancing, weighing and accommodating a variety of disciplinary perspectives in order to reach a reasonable and creative decision or outcome.
- Understand that there are several important disciplinary perspectives that are relevant to every sustainability decision.
- Think critically, communicate effectively, and work collaboratively when addressing and solving the complex sustainability problems facing humanity.

It is, thus, crucial that education for sustainability leads in a deeply engaged interdisciplinary movement in HEIs, one which explicates the skills and practices enabling teaching staff, students and administrators to work meaningfully to this end. Education for sustainability is by itself an interdisciplinary field. The critical question to be raised is: how can we construct and embed an appropriate interdisciplinary paradigm in university curricula? Seeking interdisciplinary climate change education for sustainable development requires HEIs to:

1. Institutionalize sustainability methods and pedagogies based upon principles of social, environmental, economic and cultural justice.
2. Adopt interfaculty and interdepartmental cooperation for meeting demands of interdisciplinary cooperation within and between HEIs.
3. Encourage university-community partnerships through student practicum placements and service learning.
4. Develop to the maximum the potential of all students to play a leading and transformative role in their social and working roles.

The CLIMASP Minor

Our focus here is the Middle East and North African (MENA) region, and more specifically, Egypt, Jordan and Lebanon, countries that are heavily being threatened by climate change. Higher education institutions in the MENA region, in general, while recognizing that their region’s contribution to the damage of the global climate is much less when compared to developed regions; they do recognize the urgency for tackling the challenge of climate change (Makrakis & Kostoulas-Makrakis, 2014). Although, interdisciplinary teaching and learning is highly prioritized in most of the MENA region Higher Education Institutions (HEIs), in practice, there is lack of interdisciplinary perspective and motivation among teaching staff in undergraduate studies, with the exception of some interdisciplinary programs within Masters and Ph.D. programs (Khadri, 2014; Makrakis, 2014).

As a response to these challenges, the UNESCO Chair ICT in Education for Sustainable Development at the University of Crete has initiated and developed the CLIMASP project proposal that has been funded through the European Commission Tempus program. CLIMASP adopts a multi/inter-disciplinary and systemic approach that, at a wider level, aims to transform current unsustainable practices leading to climate change and promote interdisciplinary collaboration alongside with developing sustainable leadership in the partner countries' universities (Makrakis & Kostoulas-Makrakis, 2015). Specific objectives, within the aforementioned wider ones, include the:

- Development of capacity-building programs to train university teaching staff and key administrators for interdisciplinary collaboration and building partnerships with local/national/regional partners;
- Involvement of university staff and other key stakeholders (e.g., students, professionals, employers) in the development of an undergraduate interdisciplinary programs (minors) on climate change and sustainability policy in each partner country university;
- Integration and implementation of the interdisciplinary minors as an integral part to existing undergraduate academic degrees in disciplines like education sciences, applied sciences, technical sciences, economics/business sciences, and social sciences; and
- Monitoring, evaluation and review of the interdisciplinary programs on climate change and sustainability policy in each partner country institution.

The key outcome of the CLIMASP project is the development of interdisciplinary minors in 10 partner universities in the MENA region (Egypt, Jordan and Lebanon). Each partner university has mapped out 25-30 undergraduate courses from at least three academic faculties based on certain criteria. Among the criteria are those of relevancy, faculty and staff interest, and commitment. The interdisciplinary CLIMASP courses chosen have gone through a process of revising that aimed to embed sustainability into content and teaching methods. The CLIMASP courses are an integral part of the existing collaborating undergraduate disciplines such as education sciences, technical sciences, economics/business sciences and social sciences. The minor consists of core courses, elective courses and the required capstone course in three concentration areas: 1) Climate Change, Environment and Society; 2) Climate Change, Economics and Public Policy; and 3) Climate Change, Science and Technology. Each of the core and elective courses is equivalent of 6 ECTS and the capstone course of 10 ECTS. The capstone course is based on an internship that provides a strong mechanism for integrating academic coursework with practical experience. The amount of the minimum courses to be taken across the three concentration areas by undergraduate students to qualify for the CLIMASP minor is around 45-60 ECTS. This provides students a formal credential through transcript documentation adapting the Europass supplement diploma to certify that they have developed leadership in the field of CLIMASP.

The CLIMASP minor is framed on an interdisciplinary modular structure that enables each partner institution to tailor CLIMASP according to its specific needs. For a smooth transition from disciplinary to interdisciplinary curricula, a piloting stage started in the spring academic semester 2014-15 on a small number of CLIMASP courses. Piloting creates the opportunity to demonstrate what interdisciplinary learning and teaching looks like throughout the semester and allows faculty, students and evaluators to observe processes, methods and practices. Based on the pilot assessment, proper interventions to enhance content and methods will be applied to all the 240-300 CLIMASP course modules across the 10 partner universities.

A methodological framework for piloting the CLIMASP minor

Attempting to assess the CLIMASP courses piloted, an instrument was constructed that consists of five parts. In the first part, a number of student background variables were posed, including gender, faculty and discipline, study year and previous attendance of courses related to sustainable development. In the second part, we have framed a scale to measure teacher-centered (3 items) and student-centered (11 items) modes of teaching and learning. In the third part, the scale referred to the 10Cs, which is critical skills needed for the 21st century was framed. These skills and understandings are vitally important to support problem solving and sustainability decision-making. We have realized that there is a need to go beyond the 4Cs for workforce readiness in the 21st century - critical thinking & problem solving, communication, collaboration & team building and creativity & innovation (AMA, 2010; Partnership for 21st C. Skills, 2011; AT21CS, 2012). In a world of rapid change and expansion of human knowledge, along with sustainability crisis that threatens the very existence of humankind, education must extend beyond the focus on the 4Cs to what we have coined 10Cs (Makrakis & Kostoulas-Makrakis, 2014), namely:

1. Critical thinking and problem solving
2. Communication
3. Collaboration
4. Creativity and innovation
5. Connectivity
6. Critical consciousness
7. Critical reflection
8. Cross/inter-cultural competence
9. Co-responsibility
10. Constructing knowledge

Although there is some overlap among the 10Cs, each one has its own role in teaching and learning for problem solving. For example, critical thinking and problem solving refers to the ability to make decisions, solve problems and take appropriate action, using learning processes such as conceptualizing, applying, analyzing, synthesizing and/or evaluating information gathered by multiple means. Communication refers to the ability to synthesize and transmit ideas in written, oral and virtual formats. Collaboration refers to the ability to work effectively with others, including those from diverse groups and with opposing points of view. Creativity and innovation refers to the ability to apply new ideas in developing innovative applications and solutions. Connectivity addresses the complexity of human to human interaction as well as to society and nature. This is driven by the theory of connectivism- a response to a need to derive and express meaning, and gain and share knowledge, in an increasingly networked global society (Siemens, 2004; 2006). These connections occur on neural, conceptual and social levels (Siemens, 2008). Critical reflection refers to a complex process that strongly engages learners to critically reflect upon their reality, personal and social, and to transform it through action and reflection (Stanlick, 2014). Cross/inter-cultural competence requires that learners examine their own cultural backgrounds and identities to increase awareness of personal assumptions, values, and biases in order to work effectively in cross-cultural situations. Co-responsibility refers to a culture of sharing that necessitates shifting to less ego-centric principles and practices. Critical consciousness or concientization in Freire's (2000) terms denotes the process of developing a critical awareness of one's social reality through reflection and action. Constructing knowledge represents an attempt to shift from consuming information to constructing knowledge that merges with action.

In the fourth part, the scale consisted of 27 items referred to the six pillars of 21st century learning. The first four of these pillars (learning to know, learning to be, learning to live together and learning to do) were addressed in the 1996 report to UNESCO, Learning: The Treasure Within, The International Commission on Education for the 21st Century, "provide maps of a complex world in constant turmoil" as well as "the compass that will enable people to find their way in it" (Delors et al. 1996, p.85). At a later, stage, a 5th pillar of learning to transform oneself and society was added by UNESCO. We have added a 6th pillar of 'learning to give & share' in order to respond to the quest for merging volunteerism, social activism and learning (Fig.1).

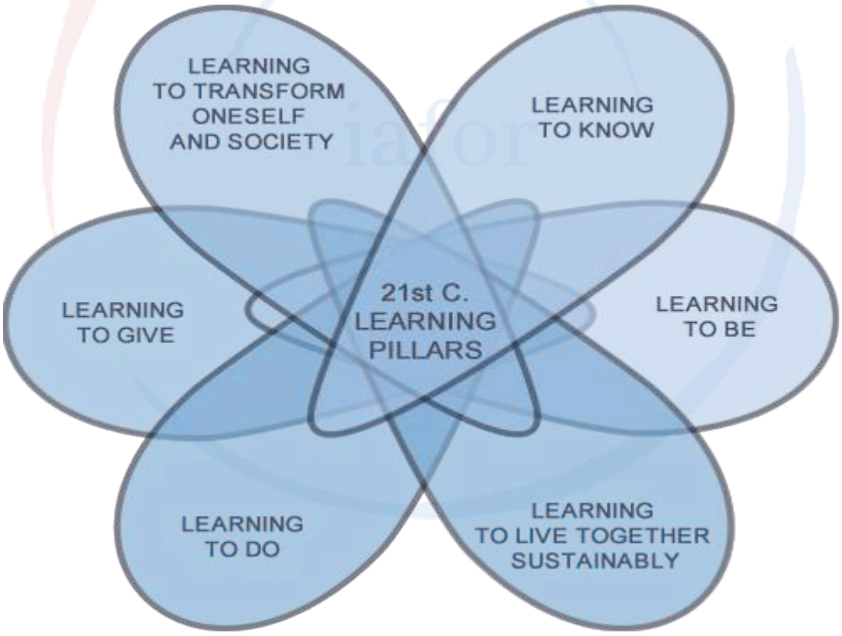

Figure 1: 21st Century Learning Pillars

Table 1: Definition of the 21st Century Learning Pillars

Learning to know	This type of learning concerns all the processes and practices that lead people to experience, construct and transform knowledge for making sustainability a mode of life and being.
Learning to be	This type of learning concerns all the processes and practices that lead to human self-actualization, self-regulation and cultivating a sense of being versus having.

Learning to live together sustainably	This type of learning concerns all the processes and practices that lead to a peaceful and non-discriminatory society and human co-existence with the natural world.
Learning to do	This type of learning concerns all processes and practices that lead to merging knowledge with action for building a sustainable future.
Learning to transform oneself and society	This type of learning concerns all the processes and practices to transform unsustainable values and behaviors and collectively engage to change society towards sustainability.
Learning to give and share	This type of learning promotes solidarity and caring attitudes to meet human needs as learners gain autonomy and purpose for their learning and civic engagement.

In constructing the six pillars of 21st learning scale, as far as the four learning pillars (learning to know, learning to be, learning to live together and learning to do) are concerned, the scale was based on the respective competences identified in the UNECE competence scale (cited in Dlouhá, Dlouhý & Barton, 2010). The other two sub-scales of learning to transform oneself and society and learning to give and share are based on our own measurement items.

Finally, the fifth part refers to the interdisciplinary problem-based learning scale that was modified from the one used by Lattuca, Knight & Bergom (2012). This scale has three key components: 1) interdisciplinary skills (8 items); 2) reflective behavior (2 items) and 3) recognizing disciplinary perspectives (3 items). As pointed by Lattuca, Knight & Bergom (2012), the Interdisciplinary Skills scale assesses students' perceptions of their abilities to think about and use different disciplinary perspectives in solving interdisciplinary problems or to make connections across academic fields. The Reflective Behavior scale includes items that operationalize the "reflexivity" dimension of interdisciplinarity. This scale includes items that reflect students' perceived ability to recognize the need to reconsider the direction of their thinking and problem-solving approaches. The final part of the scale, Recognizing Disciplinary Perspectives, measures students' perceived understandings of disciplinary knowledge, methods, expectations, and boundaries and how disciplinary knowledge might be applied in different situations.

Validating the CLIMASP course assessment scales

The validation process of the constructed measurement scales was based on the *Cronbach alpha* reliability analysis with a sample of 445 students from two CLIMASP partner universities (Jerash University (No= 326), Jordan and Suez Canal University (No= 119), Egypt). The *Cronbach's alpha* reliability analysis was based on the post-test items of the measured scales as the students participated in the survey were more familiar with the concepts that the items of the scales were composed. Table 1 shows the reliability analysis for the scale measuring student-centered and instructor-centered teaching methods. It has been revealed a very high reliability result equal to a=0.95 for the scale measuring student-centered teaching and learning methods and 0.90 for the instructor-centered teaching and learning methods. Similarly, the second scale concerned with the 10Cs, also based on our own conceptualization, exhibited a very high *Cronbach alpha* reliability value equal to 0.96 (Table 2).

Table 1: Student-centered and instructor-centred learning and teaching methods

Teaching and learning methods	**Items corresponding to student-centered and instructor-centered learning and teaching methods**	**Alpha if item deleted**	**Item Means**
Student-centered teaching (Alpha =.96) **Total items Mean= 2.8**	In classes, the discussion was led by both the instructor and students	0.96	3.7
	Connecting the course content with volunteering in the community	0.96	3.1
	Connecting the course content with practice outside the university.	0.96	2.6
	Connecting course content with online learning.	0.95	2.6
	Asked to reflect on what I have learned and think.	0.96	3.3
	Asked to do a project with real life issues/problems collaboratively	0.96	3.2
	Asked to make a presentation in class.	0.96	2.6
	Asked to solve a real life issue/problems and provide solutions.	0.97	2.8
	Asked to solve a real life issue/problem based on problem-based learning.	0.96	2.6
	Asked to review/criticize the work of other students.	0.97	2.3
	Asked to keep a portfolio for all class activities.	0.96	1.8
Teacher-centered teaching (Alpha= .93) **Total items Mean= 2.3**	In classes, the instructor led the course	0.90	2.8
	In classes the instructor led the discussion	0.92	2.7
	Asked to write down a final class exam.	0.90	1.6

Table 2. The 10Cs and their measurement items

Factor **10Cs (Alpha= .96)** **Items Mean= 3.4**	**Items corresponding to each critical skill**	**Alpha if item deleted**	**Item Means**
Critical thinking and problem solving	Making reasoned judgments that are logical, well thought out and reflective.	0.96	3.6
Communication	Sharing thoughts, questions, ideas and solutions effectively and efficiently.	0.96	3.5
Collaboration	Working together to efficiently and actively achieve a defined goal.	0.96	3.5
Creativity and innovation	Turning new and imaginative ideas into reality.	0.96	3.5
Connectivity	Linking to and communicate with others by using multiple means of communication.	0.96	3.5
Critical consciousness	Perceiving social, environmental, and economic oppression and take action.	0.96	3.4
Critical reflection	Questioning assumptions, presuppositions, and meaning perspectives.	0.97	3.6
Cross/inter-cultural competence	Communicating effectively and appropriately with people and cultures.	0.96	3.4
Co-responsibility	Being responsible, answerable or accountable for something within one's power, control or management.	0.96	3.5
Constructing knowledge	Constructing new knowledge and meaning upon previous experiences and ideas.	0.96	3.4

Regarding the sub-scales measuring the six pillars of learning, the Cronbach a reliability test exhibited very high reliability indices ranged from a= 0.84 to 0.94 (Table 3). Similar results were also obtained regarding the three sub-scales measuring the CLIMASP courses' interdisciplinbary dimensions. More specifically, as depicted in Table 4, the reliability test exhibited high *Cronbach's alpha* values ranging from .0.88 (Reflective behavior) to 0.90 (Recognizing disciplinary perspectives) and 0.95 (Interdisciplinary skills). Although, the scores are very high, it is our perception that there is need to enrich the scales with the fewer items with more items.

Table 3: The six learning pillars scale

Learning pillars	Items corresponding to each learning pillar	Alpha if item deleted	Item Means
Learning to know/learn (Alpha= .94) Total items Mean= 3.3	Posing analytical questions/critical thinking.	0.93	3.4
	Understanding complexity/systemic thinking.	0.92	3.0
	Overcoming obstacles/problem-solving.	0.93	3.4
	Managing change/problem-setting.	0.93	3.4
	Creative thinking/future-oriented thinking.	0.93	3.3
	Understanding interrelationships across disciplines/holistic approach.	0.92	3.3
Learning to be (Alpha= .92) Total items Mean= 3.5	Feeling self-confidence.	0.90	3.4
	Self-expression and communication.	0.90	3.5
	Coping under stress.	0.89	3.5
	Identifying and clarify values.	0.89	3.5
Learning to live & work together (Alpha= .94) Total items Mean= 3.2	Acting with responsibility (locally and globally).	0.94	3.6
	Acting with respect for others.	0.94	3.5
	Identifying stakeholders and their interests.	0.94	2.5
	Collaboration/team working.	0.93	3.3
	Participating in democratic decision making.	0.93	3.2
	Negotiation and consensus building	0.93	3.0
	Distributing responsibilities (subsidiarity)	0.93	3.2
Learning to do (Alpha= .94) Total items Mean= 3.4	Applying learning in a variety of life-wide contexts.	0.93	3.4
	Decision making, including in situations of uncertainty.	0.93	3.4
	Dealing with crises and risks.	0.92	3.4
	Acting responsibly.	0.93	3.5
	Acting with self-respect.	0.93	3,4
	Acting with determination.	0.93	3.4
Learning to transform oneself & society (Alpha= .90) Total items Mean= 3.5	Acting personally and collectively for the common good.	0.84	3.4
	Acting responsibly for social and economic injustices.	0.92	3.4
	Acting for environmental integrity.	0.83	3.6
Learning to give & share (Alpha= .84) Total items Mean=	Giving and sharing from own resources.	-	3.4
	Connecting learning with	-	3.1

3.25	volunteering.		

Table 4: Dimensions of the interdisciplinary scale and their measuring items

Factor	**Interdisciplinary items**	**Alpha if item deleted**	**Item Means**
Interdisciplinary skills (Alpha= .95) **Total items Mean= 3.5**	I value reading about topics outside of my own field/subject.	0.94	3.4
	I enjoy thinking about how different fields approach the same problem in different ways.	0.94	3.5
	Not all problems have purely technical solutions.	0.94	3.4
	In solving problems I often seek information from experts in other academic fields.	0.95	3.4
	Given knowledge and ideas from different fields, I can figure out what is appropriate for solving a problem.	0.94	3.5
	I see connections between ideas in my study/subject field and ideas in other study/subject fields.	0.94	3.5
	I can take ideas from outside my field and synthesize them in ways that help me better understand what I study.	0.95	3.5
	I can use what I have learned in one field in another setting.	0.94	3.4
Reflective behaviour (Alpha= .88) **Total items Mean= 3.4**	I often step back and reflect on what I am thinking to determine whether I might be missing something.	-	3.5
	I frequently stop to think about where I might be going wrong or right with a problem solution.	-	3.4
Recognizing disciplinary perspectives (Alpha= .90) **Total items Mean= 3.4**	If asked, I could identify the kind of knowledge and ideas that are distinctive to different fields of study.	0.83	3.4
	I recognize the kind of evidence that different fields of study rely on.	0.87	3.3
	I'm good at figuring out what experts in different fields have missed in explaining a problem/solution.	0.86	3.4

Outcomes achieved

One of the key aims of the CLIMASP pilot phase carried out in the spring semester of 2014-15 was to find out what changes have occurred as a result of the revised courses implemented. The change effects were measured through the use of paired-samples t-test by calculating the differences between the two measures. A pre-test/post-test evaluation is an assessment method that is administered at the beginning and at the end of a course. As pointed earlier, here we use the data collected from two partner institutions in Egypt and Jordan with a total sample of 445 students. When comparing pre-test and post-test class point scores for the whole group, the results show that significant changes occurred as a result of the course content and methods and teaching methods (Table 5).

Table 5: Pre-test and post-test comparisons of the interdisciplinary problem-based sustainability education scales and sub-scales

Scale	Type	Mean	t-test	d.f.	Sig.
Interdisciplinary Skills	Pre-test	2.87	-9.29	444	.000
	Post-test	3.45			
Reflective Behavior	Pre-test	2.98	-6.59	444	.000
	Post-test	3.44			
Recognizing disciplinary perspectives	Pre-test	2.87	-7.57	444	.000
	Post-test	3.36			
10Cs	Pre-test	2.12	-21.64	440	.000
	Post-test	3.45			
Learning to know	Pre-test	2.12	-18.99	439	.000
	Post-test	3.48			
Learning to be	Pre-test	2.96	-8.43	442	.000
	Post-test	3.48			
Learning to live Together	Pre-test	2.86	-5.04	441	.000
	Post-test	3.17			
Learning to do	Pre-test	2.75	-11.03	443	.000
	Post-test	3.42			
Learning to transform	Pre-test	2.93	-9.45	444	.000
	Post-test	3.53			
Learning to give & share	Pre-test	2.74	-7.05	444	.000
	Post-test	3.25			
Student-centered teaching methods	Pre-test	1.67	-17.88	445	.000
	Post-test	2.79			
Instructor-centered teaching methods	Pre-test	2.59	3.86	444	.000
	Post-test	2.35			

Examining the results in the interdisciplinay problem-based scale, we find that the average total pre-test Means ranged from 2.87 to 2.98 on a four-point scale [Strongly Agree, Agree, Disagree and Strongly Disagree] and the average post-test Means from 3.44 to 3.45, yielding an average statistically significant difference of + 0.52. In terms of the three sub-scales, the statistically significant difference measured through the paired-sample t-test were for: 1) interdisciplinary skills, $t(444)= -9.29$, at $p< 0.001$; 2) reflective behavior, $t(444)= -6.59$, at $p< 0.001$; and 3) recognizing disciplinary perspectives, $t(444)= -7.57$, at $p< 0.001$.

Regarding the scale measuring the 10Cs, the statistical analysis shows that the pre-test average total items Means was 2.12 on a four-point scale and the average post-test total items Means 3.45, yielding a statistically significant difference of + 1.36 with , $t(440)= -21.64$, at $p< 0.001$. This is the highest change effect, which shows clearly that the CLIMASP pilot courses did have a great effect across all the 10 critical skill, namely: Critical thinking and problem solving; communication; collaboration; creativity and innovation; connectivity; critical consciousness; critical reflection; cross/inter-cultural competence; co-responsibility and constructing knowledge. Looking into the results of the six learning pillars, it has been revealed that the average total pre-test Means ranged from 2.12 to 2.96 (Total Mean= 2.73) on the four-point scale and the average post-test Means from 3.17 to 3.48 (Total Mean 3.39), yielding an average statistically significant difference of + 0.66. The statistically significant differences across the six sub-scales were for: learning to know, $t(439)= -18.99$, at $p< 0.001$; learning to be, $t(442)= -8.43$, at $p< 0.001$; learning to live together, $t(441)= -5.04$, at $p< 0.001$; learning to do, $t(443)= -11.03$, at $p< 0.001$; learning to transform oneself and society, $t(444)= -9.45$, at $p< 0.001$; and learning to give and share, $t(444)= -7.05$, at $p< 0.001$.

Lastly, with respect to the scale measuring student-centered and instructor-centered learning and teaching methods, the pre-test/post-test analysis revealed a statistically significant difference in their Means. More specifically, on the one hand, the pre-test measurement of student-centered teaching and learning methods revealed a total average Mean equal to 1.67 and the post-test value reached to 2.79 on a four-point scale [Not at all, few times, often and very often], yielding a difference of + 1.12 with $t(444)= -17.88$, at $p< 0.001$. The second highest change effect among all scales and sub-scales. On the other hand, the results of the subscale measuring instructor-centered teaching and learning methods revealed a statistically significance difference but in different direction. The average pre-test score was 2.59 and the post-test score 2.35, yielding a slight but statistically significant decrease of -0.24. These two results show that besides adopting and implementing student-centered teaching and learning methods in the piloting of CLIMASP courses, the instructor-centered teaching/learning methods are clearly giving their way to more suitable sustainability education methods.

Conclusion

Presently, HEIs worldwide are seeking recognition through integrating the concept of sustainability to all disciplines and fields as well as to all other university functions. A major driver for more interdisciplinary approaches to teaching and learning is the dynamic and evolving concept of sustainability itself. Climate change education for sustainable development encompasses a new vision of education that seeks to empower people to assume responsibility for creating more sustainable futures, locally and globally. Through such a kind of education, human agency can lead to increasing people’s capacities to transform their visions for sustainability and a climate-free society into reality.

In piloting a number of the CLIMASP courses in the partner universities, we employed a pre-test/post-test instrument that reflects our teaching and learning methodologies conducive to sustainability education. Our aim was both to test reliability and validity of learning models as well as to examine possible changes during the implementation process. The statistical analyses show that the instruments are reliable, although improvement and enrichment is possible, despite the very satisfactory reliability values found. In terms of changes, starting from the apparent shift from instructionist to constructivist and critical pedagogy methods alongside with the significant changes occurred in students' interdisciplinary PBL sustainability skills and competences, it seems that the CLIMASP course revision process achieved its objectives.

Acknowledgments: This work has been developed within the framework of the CLIMASP (Development of an interdisciplinary program on climate change and sustainability policy) project that has been funded from the European Commission (European Commission, 543879-TEMPUS-1-2013-GR-TEMPUS-JPCR). The content of the paper reflects the views of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

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Perception of the Resident Population Towards Tourist Presence: A Survey Research in Alcossebre, Valencian Community Region, Spain.

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The European Conference on Sustainability, Energy & the Environment 2015
Official Conference Proceedings

Abstract
The objective of the survey was to analyze the attitudes that residents of Alcossebre have towards tourism, focused on their perception of the impacts on the community and on the natural and built environment. Alcossebre is located on the Mediterranean coast. It´s representative of the sun and beach tourism model that Spain has been offering since the 1960s. The resident population is 8218 inhabitants but in summer, due to the tourism, it increases by 150%.
So, residents feelings towards different, both positive and negative impacts, that tourism has had on their personal lives were observed. Sustainability requires residents to participate in the decision-making process for future development. Local perception of the social, economic and environmental impacts of tourism, allow to know the problems of the tourism phenomenon they detect, so planners can implement solutions, and as a result review and improve the most suitable responses.
For the survey development, 367 residents were categorized into four variables: Sex (Gender), Age, Occupation and Origin. A 13 mixed-item questionnaire was divided into two sections that used different calculation methods: one section used a Likert scale and the other, a ranking question type.
The results showed that residents have a favorable perception of tourism due to its economic and social benefits and highlights tendencies to minimize environmental costs attributable to visitors. Moreover, residents felt that government should prevent and resolve the possible impacts. This communication shows the variable Age results and discusses about the different perspectives about tourism impacts on their town and natural environment.

Keywords: Sustainable tourism, Urban planning, residents' perception, coastal tourist places, environmental impact.

1. INTRODUCTION

Tourism development has been identified as an effective way to revitalize the economy of a town or destination, whether rural or urban (Castelli & Cowboy Ortega, 2008; Chen & Chen, 2010; Suarez-Sanchez, 2007). However the tourism industry depends largely on the goodwill of the residents, their involvement and support (Andriotis, 2005; Long, 2012; Yoon, Gursoy, & Chen, 2001).
These authors refer the ideal practice, but when the planning decisions are taken, it is not done.

In the 60s, during the dictatorship of Francisco Franco, the Spanish State realized an opportunity to attract foreign investment, by offering good weather, beautiful beaches, landscapes and land from the Mediterranean shores to new investors as well as a cheap and abundant hand labor. Government favored the real estate development to create infrastructures in the short term, could meet the demands of accommodation, restoration and mobility of future visitors. At the beginning, new jobs were generated in the urban real estate industry and then, in the services sector, changing the way of life of the inhabitants of the coast, who used to be farmers, fishermen and masons. To adapt themselves to the emerging phenomenon of tourism, residents had to acquire knowledge that would enable them for tourist sector labors. Since then, that residents´ generation and the following ones, have been living with visitors and adapting their lifestyle to the changing needs of the tourism demand, in order to capitalize and maximize the profits for themselves.
Local economy is the main concern that drives a region to become a tourist destination, especially when it has some natural or cultural values that can attract visitors. Many Spanish regions with limited funding sources adopt tourism as a solution to their economic development problems and therefore in these destinations, the expected economic benefits make the local population reaction to be very favorable to tourism. (Cater, 1987) (Cardona, 2012; Dogan Gursoy, Jurowski, & Uysal, 2002; Haralambopoulos & Pizam, 1996).
In the Valencian coast, particularly Alcossebre, tourism has become the main engine of the local economy since the 80s. Therefore, it seems that the inhabitants of the small coastal towns should be very pleased with the presence of visitors and to ensure at all costs their enjoyment of the tourist experience for getting the maximum benefits for themselves.

1.1 Residents towards the tourist presence.

> *"Tourist activity in Spain has been the most important motor for the national economy growth and in particular for the Valencian coasts. It is one of the main activities which contribute to the development of many municipalities with attractiveness and other tourist destinations around these cities. However, for many years, this positive impact over society has overshadowed other aspects and implicit negative effects, such as environmental impacts or cultural ones in local populations ".*
> *García Pérez Mesanat & Sancho, 1999.*

It is not possible to propose an unlimited tourism development (Hwansuk Chris Choi & Murray, 2010; Garcia, Sancho, & Valencia, 1999; García Pérez Mesanat & Sancho, 1999; Giussani, Luengo, & Poujol, 2010). It should be found a balance between the level of demand from visitors and the absorption capacity which the tourist territory and its resources can withstand without being damaged (Vera Rebollo & Ivars Baidal, 2003).

Furthermore, there is a social carrying capacity or tolerance threshold in all destinations, beyond which tourism development levels are unacceptable and the presence of tourists is intolerable by the local population. If local people perceived more strongly impacts negative than positive, it can lead to taking a belligerent stance against tourism, as we might say that this activity would be exceeding its capacity (Blasco Peris, 2009).
Therefore, trying to analyze if the threshold is exceeded or not is interesting.
While the volume of tourists and cumulative negative impacts are kept within reasonable limits of carrying capacity, tourism is accepted by residents (Garcia Perez Mesanat & Sancho, 1999; Suárez Sánchez, 2015). However, if this threshold is exceeded, the local population begins to show frustration and discontent signs that are perceived by the visitor. It is therefore important to measure if, for example, the local population experiences a set of negative environmental impacts that they considered are produced by tourism and the importance that residents give to this fact.

2. ALCOSSEBRE. Case study Research
This small coastal town is the holiday destination with the tourist model of sun and beach prevailing on the Mediterranean coast since the profitable business of mass tourism was released in the early 70's. Alcala de Xivert municipality is located in a privileged area within the Mediterranean coast. Located between the Costa de Azahar and the interior Maestrat region, It surprises with an original landscape, rich, diverse and full of contrasts, where the plains and mountains alternate with beaches and rocky coastal areas.
There, surrounded by history, protected by the mountains of Irta and Murs, on a vast expanse of alluvial formation, belonging to the Alcala de Xivert municipal term, the town of Alcossebre is found.

Figure 1. Alcossebre location in the province of Castellon.

Along the more than 10 Km. coastline belonging to Alcala de Xivert-Alcossebre, it can be found a wide variety of beaches, from small secluded coves to large fully accessible beaches equipped with all the utilities necessary to rest and relax. They are beaches which have kept the blue flag (FEE, 2007) since its introduction.

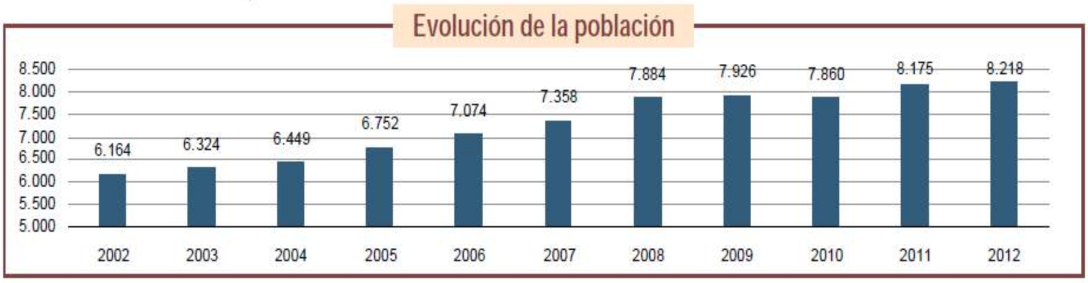
Also, the supply of both hotel accommodation and second homes is mainly in the first line of the coast. To complete this tourism model, nautical recreational activities at the Las Fuentes marina, such as diving, sailing, sailing and excursions to the nearby Columbretes Islands are offered.

Figure 2. Alcossebre. Romana Beach. August 2014.

This tourism model, associated to the real estate industry, has provided of secure employment in the services sector and construction to the people of Alcossebre and in general, to the population of the Mediterranean coastal region. They have reached a better quantity of life, but tourism involves the problem of saturation associated with the summer season.
This adds overhead natural habitat, an increased demand for resources in a short period of time each year, an overflow capacity of infrastructure services and therefore, a deterioration of the overall tourist experience and the local people quality of life.

2.1. Demography

Alcossebre has experienced a notable increase in its population in recent times. In 1996, the municipality had 4,902 inhabitants and in 2012, this number had almost doubled. Table 1 shows its evolution since 2002, according to the IVE (Statistics Valencian Institute):



http://www.ive.es/portal/page/portal/IVE_PEGV/CONTENTS/fichas_mun/cas/Fichas/12004.pdf

People from all over Spain and the entire world, have come to settle in this town and in the neighboring ones, searching the employment opportunities that offer tourism and real estate industries. Due to tourism, the resident population has gone from being mainly local (61.3%), to a set of Northern European (24.45 %), Maghreb (11.3%), Latin (1.6%) and Eastern European (1.5%) nuclei.

3. THE SURVEY

3.1 General

In this work, a study of a well-known aspect of tourist activity like the impacts that tourism may have on host populations is realized. To meet the feelings of people in Alcossebre (Castellón province) and their attitude towards tourism and visitors, to also know the problems faced as residents and their possible reaction to the solutions that could be implemented to solve them.

According to the extensive literature on tourism in recent years, the perception of residents is an added value to take into account in the decision-making towards sustainable tourism (Hwan Suk Chris Choi & Sirakaya, 2006; Miller & Louise Twining-Ward, 2006; Pine, 2001). Beyond join local Agendas21 programs, analyzes the feelings of the local people has not yet been implemented systematically towards sustainability in many localities.

The ways in which the inhabitants of Alcossebre perceive and feel towards the presence of visitors, in their role as host community, is explored. These purely subjective and difficult to measure effects which it also suffers to the problems associated with human and vehicular seasonal overloading were interpreted.

The methodology employed is based on a survey conducted in Alcossebre during the months August, September and October 2014, with a valid sample of 367 residents. The econometric treatment to quantify those unquantifiable aspects of tourism was through a questionnaire designed with such questions ranking and Likert scale.

3.2 Method of work

To measure the tourism impact experienced by the local population, it has chosen the direct method based on the first hand information provided by the local population, in order to know their perception about the advantages or disadvantages of the life in a tourist destination.

This is why it has used this method and no other type of indirect or observable. The simplest mechanism to figure out how to value the citizen resident tourism impacts is to ask them directly through a survey.

3.3 Technical details of the survey

Scope: Local, Spanish: Alcossebre, a town of *Alcalá de Xivert*, Castellón Province

Universe: Resident Population.

Data source: Questionnaires.

Sample: 459 residents / questionnaires completed. The response rate of valid questionnaires was 79.96%, corresponding to 367 questionnaires. The sample constituted 4.5% of a population of 8218 inhabitants, with a confidence interval of 5 and with a confidence level of 95%. The sample calculation was performed by the portal http://es.gmi-mr.com/solutions/sample-size-calculator.php

Data collection method: By questionnaire with thirteen items, realized by 5 identified residents.

Data processing: The answers were entered into a database created in Excel. First, the graphics and tables corresponding to the results of each question in each category percentages were performed. Then, using matrix functions (according to formula) the weighted average of each question for each category of the 4 variables chosen was obtained. The results provide insight into the likelihood of response or perception of the population towards each raised situation.

Undertaken Survey: August to October 2014.

3.4 Methodology

3.4.1 Questionnaire Design

The measuring instrument applied to surveys of residents was based on a 13-item questionnaire that addresses the demographic profile of residents in the sample, seeks commenting on the economic, cultural, social and environmental aspects in general (Jinx, Ma, 2012) they have observed about the impact of tourism in their environments. It ends with questions about his attitude and disposition toward tourist (Cardona, 2012; Vega Perez, 2011). This questionnaire has been adapted to the particularities of the case study, such as culture, rooted to the spot and socioeconomic status of the population, among other considerations.

Due to the length of the questionnaire and the objectives of the survey, blocks of questions were condensed into 13 items divided into 4 sections:
THEMATIC BLOCK I: The attractiveness tourists are looking for visiting Alcossebre (question 1)
THEMATIC BLOCK II: The benefits that tourist arrivals bring to residents (questions 2, 3, 4, 5, 6)
THEMATIC BLOCK III: The deterioration, problems and impacts that residents attribute to tourists (questions 7, 8, 9, 10, 11 and 12)
THEMATIC BLOCK IV: Predisposition to invite tourists to return (question 13)
Questionnaire design for a mixed approach, combining Ranking closed questions with other valuation was used. 9 questions are designed to be measured according to the Likert scale (1 = none, disagree, and 5 = Very much, totally agree, definitely Yes, completely satisfied) and 4 closed ones (Ranking) with different options for choosing from. These closed questions facilitate the respondent's answer and are easy to encode. Some have introduced the *Others* option. Thus, the respondent expressed if desired, in more detail its views (Sharpley, 2000; SurveyMonkey, 2008; Walonick, 2012).
The measurement method used for the valuation questions was the psychometric Likert scale (1932) (Cardona, 2012; Clason & Dormody, 1994; D. Gursoy et al, 2010; Hitchcock & Porter, 2004; Long, 2012; Sharpley , 2014), which specifies the level of agreement or disagreement with a statement or question. Unlike dichotomous questions with yes / no, the Likert scale measure attitudes and determine the degree of compliance of respondent with any of the statements or questions that are proposed. It has chosen to use it because the questionnaire raises situations in which it is intended that the person to tinge his/her opinion. In this regard, the response categories were used to capture the intensity of the feelings of the respondent to that statement or question.
The sample of 367 participants who answered the entire questionnaire was segmented in 4 groups of variables as proposed by Cardona (2012):
By sex (gender), by age (since 16 to 75), by occupation (officer, worker by their own, employed, retiree, housekeeper, student and others) and by place of origin, regarded as residents foreign immigrants with more than 7 years in the territory, because their belonging and integration sense.
As for the fieldwork, the amount of questionnaires, lack of funds and the need to have employees who could identify residents were major difficulties, which made the task of interviewing and data collection to be extended. On the other hand, the low response from groups with aversion to surveys, whatever their means of interview, was an added risk for the study.

3.4.2 Weighted Average

Calculate the weighted average is appropriate to obtain a measure of central tendency and when a data has a relative importance (or weight) related to other data, such as questions of valuation (scale Likert). It is obtained by multiplying each of the weighting data (weight) and then adding them, thereby obtaining a weighted sum. Then it is divided by the sum of the weights, resulting in a weighted average (Conceptual, 2010; Soler, Arias, & Pizarro, 2014). This survey data set taken was the number of participants in each category of the 4 variables and weights, from 5 to 1, according to the Likert scale.

3.4.2.1 Formula

$$WA = \frac{w_1X_1 + w_2X_2 + \ldots\ldots + w_nX_n}{w_1 + w_2 + \ldots\ldots + w_n}$$

Where:

(X_1, X_2,….., X_n) is the data set and (w_1, w_2, ……, w_n) the weights.

The result is the weighted weight of the response trend.

4. RESULTS and DISCUSSION

This study is immersed in the knowledge and the understanding of the residents' perceptions about the impacts of tourism over their lives. Their attitudes toward tourism development are critical to the success and sustainability of decisions and actions of planners, especially in heavily dependent on this phenomenon populations. Similarly, this research is getting to meet the problems that matter to local people, to what extent are to tourism attributed and the given importance.

The Age variable was the most significant for better knowing the feelings and attitudes. Youngest people, often as students and tourist sector employees were more condescending towards tourist presence and tended to minimize the potential environmental impacts.

4.1 Sociodemographic Profile

Table 2 shows the distribution of respondents by number and percentage, according to the 4 variables. By sex, by age, by occupation and by place of origin and their corresponding categories are shown.

Sociodemographic Profile					
Population 8.218 inhabs.				**Sample**	**367 questionnaires**
VARIABLE	CATEGORIES			Total of the category	PERCENTAGE
SEX		GENDER	**MEN**	156	**42,51**
			WOMEN	211	**57,49**
		MEN	**WOMEN**		
AGE	**16-25**	16	25	41	**11,17**
	26-35	27	33	60	**16,35**
	36-45	29	38	67	**18,26**
	46-55	32	42	74	**20,16**
	56-65	30	39	69	**18,80**
	66-75	22	34	56	**15,26**
OCCUPATION	Officer	11	16	27	**7,36**
	Worker with their own	26	9	35	**9,54**
	Employee	59	47	106	**28,88**
	Retiree	29	41	70	**19,07**
	Housewive	6	63	69	**18,80**
	Student	22	20	42	**11,44**
	Others	3	15	18	**4,90**
ORIGIN	Native	48	53	101	**27,52**
	Born in the region	35	76	111	**30,25**
	Born in Spain	54	50	104	**28,34**
	Inmigrant with over 7 years of residence	19	32	51	**13,90**

Table 2. Socio-demographic profile of the sample surveyed. 4 variables and their corresponding categories in which respondents were distributed is.

Of the 367 respondents, 156 were men and 211 women, of whom 168 were under 45 and 199 aged 46 to 75. The largest number of participants, 106, worked as an employee. Only 51 respondents were rooted immigrants, with 316 nationals. It was noted more willing to answer the questionnaire in women, people over 46 and Spanish residents as well as employees who are mostly engaged in tourism services.
The design of the questionnaire, to be short and direct (13 questions prepared by the mixed method), was a facilitating factor for the high survey response. The questions, being mostly valuation, were easily collected and calculated in an Excel spreadsheet for the trend of the answers.

4.2 Calculation of results

The questionnaire consists of 13 questions, 4 of them closed type ranking, that is to say that there are different options to choose from in order of importance to the respondent. This is the case questions 1, 9, 11 and 12 (see questionnaire). The rest of the questions were designed to be measured according to the Likert scale, that is, considering the following assessment:
5 =A lot; 4 = Pretty, Enough; 3 = Regular; 2 = Something or somewhat and 1 = little or nothing.

In these questions, the results showing the likely trend of the response is through the Weighted Average formula calculated. (section 3.4.2.1). That is, if the answer gets a score of 3.4 the result will be more tending to *Regular* and if 3.8, shall be construed to be more prone to *Pretty*.
The questions were designed according to this scale are the 2, 3, 4, 5, 6, 7, 8, 10 and 13. (See questionnaire in Table 6. Table Abstract).

4.2.1. Sample of calculation based on the type of question

Variable: Gender (Sex)
Categories: Men and Women
A breakdown of the calculation of the results according to the type of question, for example variable Gender, comprising two categories shown.
In the ranking type questions, you can see the result of the trend response, calculated in percentages by their characteristics. For example, in question 1, the requirement to mark *What are the reasons do you think attract tourists to visit Alcossebre?* The most chosen answer was *The beaches*. In the tables below you can note that it was chosen by 46.79% of men and 31.28% women.
You may also notice that as the second reason for visiting Alcossebre, the *Gastronomic offer* was selected by 27.49% of women while men felt that it was in *Real Estate Offer* 22.44%.

Calculation of the most probable trend of response in the survey "Perception of Resident Alcossebre towards tourism"					
Ranking closed questions	Options		GENDER		
			%Men	%Women	Response Trend
1. What grounds do you think attract tourists to visit Alcossebre? Please rank the following options.	1	The Beaches	46,79	31,28	The beaches
	2	The Gastronomic Offer	21,15	27,49	The Gastronomy
	3	To share cultural experiences with residents	5,13	11,37	
	4	For the supply of real estate products: holiday apartments	22,44	17,06	The real state products offer
	5	To visit markets and fairs (purchases)	-	7,11	
	6	By offering recreational activities naturalist: hiking, walking, diving, etc.	4,49	0,95	
	7	Others	-	4,74	

Table 3. Calculation of the most probable answer to the question type ranking. Question no. 1.

In the valuation questions, Likert scale, the results of the calculation of the weighted average can also be seen in the example of the Gender variable, along with the results for percentages of the responses of men and women.
In Question 2. *Do you think the visit of tourists benefits economically to Alcossebre residents*. It shows that 54.49% of men valuated it with the highest appreciation (5), as well as 45.50% of women.
Calculating the weighted average by categories and by the total population, a value of 4.10 is obtained, which is interpreted like most of people in Alcossebre, both men and women, believe that the visit of tourists benefits *pretty* or *enough* to the locals.

LIKERT type question	Weight	Interpretation	Gender % Men	Gender % Mujeres	Weighted Average Men	Weighted Average Women	Tdotal population Weighted Average
2. Do you think that the visit of tourists to Alcossebre benefits economically to its residents?	5	Much, A lot	54,49	45,50	2,72	2,27	2,50
	4	Pretty	23,08	28,91	0,92	1,16	1,04
	3	Regular	10,26	13,74	0,31	0,41	0,36
	2	Somethig	6,41	9,00	0,13	0,18	0,15
	1	Little	5,77	2,84	0,06	0,03	0,04
			100,00	*100,00*	4,14	4,05	**4,10**

Table 4. Calculation of the weighted average to determine the trend of the response to question Likert. Question no. 2.

The same procedure was performed to calculate other variables and categories, as described in the table in socio-demographic profile (section 4.1).

4.4 Overall results by thematic blocks and variables for the Age variable.

In the case of the variable Age, it specially determines the outcome of the response. Note that this variable has been the one that has produced the most interesting data from the survey and that it represents the feelings of the host community.

On the other hand, beyond the statistical measurement, feedback collected by pollsters as marginal notes of the answers given are presented. These comments reflect the opinions of the residents who felt motivated to provide more information about the current problems in Alcossebre and the natural environment, the reasons that cause them and some concerns about the regional development.

The overall results for the four thematic blocks into which the questionnaire (Section 3.4) are integrated considering the variables and their categories, are presented below:

THEMATIC BLOCK I

• The attractive to tourists looking to visit Alcossebre

QUESTION

1. Mark the reasons you think tourists would visit Alcossebre.

The most chosen option to this question was *the beaches*, as the main reason to visit Alcossebre with 46% of the total, regardless of variables (sex, age, occupation and origin). The second place was for the option *the gastronomy* with 23% and the third one, for *the supply of real estate products* with 17% of responses.

To this first question, young people between 16 and 25 years (11,17% of total sample), 63.41% responded that the beaches were the main reason for the visit to Alcossebre and for the overall result this assessment contributes to this attraction be the most likely answer; but also in this question, the youngest people was the only age group that said there were other reasons for the visit, as were the night clubs, parties in pubs and also the only group that did not mention the real estate offer as a reason, not surprisingly because of age, they believe not buy any property as an investment yet. Students and employed persons also gave more weight to the beaches as the main reason for the visit, with 60% of the answers the first ones, reinforcing the results by age and 56% the second ones, which generally have jobs in hospitality industry and restoration. Entrepreneurs more often chose *the cuisine or gastronomy* (40%) followed of retirees by 36%. Note that in this last group of occupation, more willing to respond enthusiastically, it was women who weighted the gastronomic value of the products of their land and traditional dishes to be devoted mostly to be housekeepers.

The third option most voted, *the real estate option*, residents over 36 years thought that it was another attraction to visit Alcossebre, since 90% chose.

THEMATIC BLOCK II

• The benefits that tourist arrivals bring to residents (questions 2, 3, 4, 5, 6)
QUESTIONS
2. Do you think that the visit of tourists benefits economically to Alcossebre residents?
3. Do you think that tourist arrivals ensures long-term socio-economic benefits among which is stable employment opportunities and social services to raise the quality of life of the residents?
4. Do you consider that tourism stimulates local culture?
5. Do you consider that tourist arrivals to the city have improved Alcossebre infrastructure services (roads, transportation, access to the beaches, information technology, businesses etc.)?
6. Are you satisfied with the arrival of tourists to the residential / developments Alcossebre areas?

Although no full unanimity in the response by groups of variables was observed, the weighted average of this answer is 3.83, suiting the trend towards *moderately satisfied*.

In this thematic block about the socio-economic and cultural benefits that tourism could bring to improve the quality of life for residents of Alcossebre, youngest people responded with a resounding *Much* (85%), followed by those between 26 and 35 (68%). The other options were only by the eldest people mentioned. Residents feel that tourism results on more employment opportunities than traditional productive activities.

Therefore, it is fair to say that the younger residents are hopeful about developing themselves professionally in their hometown. They have their employment and economic expectations set in the presence of tourists and the activities involved in tourism. They realise it's possible to achieve their own company in the sector at the medium and long term.

However, residents between 36 and 55 years were more conservative about the same questions, because at the time they were asked, they mentioned that they would like the city and the region in general, to have greater industrial, agricultural and livestock development and not rely both the dynamics of tourism as at present.

However, they acknowledged it would take to propel political will and a shift in the mentality of young people to engage in other economic activities away from the tourist sector.

Young people between 16 and 35 years responded most enthusiastically to the question *Do you think that tourism stimulates local culture?*, question 4, with 72% between the two groups (16-25 and 26-35). The other age ranges considered mildly stimulates tourism and precisely the answers of young people made the tendency for the overall opinion is that the stimulated *enough*.

As young people referred, tourism provides the late tendencies in fashion, technology and mainly in music. Besides, due to tourism they have the opportunity of meeting new people from other places and they feel encouraged to visit other countries and to learn another languages.

Adults and older residents were concerned about that tourism leaves a negative influence over the youth when local culture begins to be modified and impact the identity and traditions or, in some cases makes them to disappear.

They feared above all the emergence of new ways of thinking, foreign to local and national ones. However, they appreciated that the presence of tourists was a motivator item for young people in search of cultural experiences in other countries.

Another question that appreciates significantly the younger people satisfaction by the arrival and presence of tourists is in question 6. Residents between 16 and 25 mostly responded that they were very satisfied with this situation because they can get job stability and meet new people by 76%.

This enthusiasm shows in the weighted average of the age group that is the highest of all categories of this variable by far. Difference is especially noticeable with the responses of retired residents, who perceive in excessive tourist presence a source of oppression, scarcity of goods and rising prices, especially in the summer. 76% responded that they were *moderately satisfied* with this situation.

THEMATIC BLOCK III

• The deterioration, problems and impacts that residents attribute to tourists (questions 7, 8, 9, 10, 11, 12)

QUESTIONS

7. Please, remark what extent is it important to you as a resident of Alcossebre, beaches and natural surroundings to be respected as a tourist attraction.

8. Do you consider the natural landscape (beaches, Sierra de Irta Natural Park, etc.) is being degraded by effects of tourism?

9. How has the natural landscape been deteriorated due to tourism, in your point of view?

10. Have you noticed any urban environment deterioration due to tourism?

11. How has the urban environment been deteriorated due to tourism, in your point of view?

12. Where do you notice major problems due to tourism?

The satisfaction of 16 to 25 years old people about the presence of tourists is complemented by the importance given to respect the beaches and the natural environment, and that 72% thought so. The age groups of 26-35 and 36-45 years were the most concerned about, with 73 and 74% respectively, and were more alert. This can be seen in the weighted averages of these categories in Question 7 and while recognizing that there are environmental problems, not entirely attributed to tourists, but often attributed to the immigrants in their opinion, with no Environmental education and therefore they do not know how to care for the natural environment.

This question is also observed in adults between 46 and 65. These groups give slightly less importance to the behavior of tourists (67%), because they consider that currently the tourist has learned to care for the environment and helps to maintain it.

However, most respondents (82%) agreed that undoubtedly exists an environmental deterioration, mainly perceived in the lack of clean beaches, due to human overload summer, although the attribute more while the inefficiency of municipal cleaning and apologize greatly to tourism.

As for the deteriorating city center (question 10), the young people perceive minor damage, 48%, reaffirming their pleasure at the presence of visitors. The remaining age groups were more critical reaching 85% by summing responses and *pretty much* in the group of 36-45 years. Oldest population mostly complained that the effects of tourism were left particularly strong in increasing the *amount of waste, in the increase of people and vehicles in the center of town, as also as affecting its image*. They also regretted with younger ones about rising prices (23 and 22% of each group) at the peak tourist seasons. While this perception was widespread, it was further strengthened between these age groups because students or retirees have less economic resources.

THEMATIC BLOCK IV

• Predisposition to invite tourists to return (question 13)

QUESTION

13. Would you invite a tourist to return for another stay in Alcossebre?

Residents are proud of their landscapes and gastronomy mainly and mostly of them want the world to know and appreciate their natural beauties. They are also aware that tourism is currently the main driver of the local economy and it is essential for the survival of its inhabitants and the development of the region.
In the last 60 years tourism has occupied the leading place as a generator of local wealth, so the residents have already learned to live with tourists and with the advantages and disadvantages of their presence, so there are especially reluctant to keep coming on vacation to Alcossebre, but even they wish. The advantages obtained with this are largely weighted to the disadvantages and trust that tourists value the natural beauty and the services offered and respect them during your stay.

4.5 Summary Table

Below, in Table 6, the overall results of the completed questionnaire are summarized. These data refer to the weighted averages and percentages, obtained according to the type of question, the 4 variables (Sex (gender), Age, Occupation and Origin) and their corresponding categories.

SURVEY SUMMARY TABLE "Alcossebre Residents´perception toward tourism"			
Ranking closed questions	Question Type	Total Average percentage(TAP) %	Most voted response
1. What grounds do you think attract tourists to visit Alcossebre? Please rank the following options.	Options	46,08	The beaches
9. Under your point of view, check how the natural landscape has been deteriorated due to tourism.	Options	46,04	The cleanliness of the beaches
11. Mark please, how the urban environment has been deteriorated due to tourism.	Options	38,69	The cleanliness of the town
12. What items do you think are the best shown of the impacts or effects due to the tourist presence in Alcossebre? Rank them, please.	Options	31,53	The amount of garbage
LIKERT type Questions	Type of Question	Total Weighted Average (TWA)	Response trend
2. Do you think that the visit of tourists to Alcossebre benefits economically to its residents?	Likert escale 5-1	4,28	Pretty
3. Do you think that tourist arrivals ensures long-term socio-economic benefits such as stable employment opportunities and social services to raise the quality of life of the residents?	Likert escale 5-1	4,32	Pretty
4. Do you consider that tourism stimulates local culture?	Likert escale 5-1	3,40	Regular
5. Do you think the arrival of tourists to the area have been improved Alcossebre infrastructure services (roads, transportation, access to the beaches, information technology, businesses etc.)?	Likert escale 5-1	4,34	Pretty
6. Are you satisfied with the arrival of tourists to the residential areas in Alcossebre ?	Likert escale 5-1	3,65	Moderately satisfied
7. Check what extent is it important to you as a resident of Alcossebre that beaches and natural surroundings are respected as a tourist attraction.	Likert escale 5-1	4,45	Pretty important
8. Do you consider the natural landscape (beaches, natural park of Sierra de Irta, etc.) is being degraded by effects of tourism?	Likert escale 5-1	4,33	Pretty
10. Have you noticed about deteriorating urban environment (people) due to tourism?	Likert escale 5-1	4,17	Pretty
13. Would you invite any tourist to return for another stay in Alcossebre?	Likert escale 5-1	4,16	Probably YES
Likert scale: 5= A lot, much; 4= Pretty; 3=Regular, Moderatly; 2= Something; 1= Little			

Table 6. Summary table of the survey. The questionnaire are divided by questions type for better understanding of the results.

5. CONCLUSIONS

Having to rely heavily on tourism, it is not surprising that respondents put high hopes on it for their economic well-being and tend to have positive attitudes towards tourism. Despite the perception of some negative impacts, residents perceived as beneficial overall effects. They associate tourism with a significant industry that supports the local economy, giving employment opportunities, business and investment, a variety of cultural activities, cultural exchange with tourists, recreational activities and restoration of historic buildings. However, the local population blamed the tourism raising prices of real estate products, the cost of many goods and services, causing traffic congestion, waste, water pollution, air and soil, noise and decrease the availability of landscapes natural and farmland.

They indicated however, that tourism can help improve the quality of life of residents, making them proud of their land and local culture, bringing products and quality services to transport tourists and make Alcossebre visible at international level.

Therefore, they adapt or resign themselves to live with the negative consequences because the benefits have a greater weight. Respondents were fairly moderate further in attributing exclusively to tourism environmental costs and socio-cultural. The study suggests that respondents highly support tourism development, but were concerned about the roles of government and the local community in control and support tourism. The value of this study is that through knowledge generated by the responses of the local population in terms of the perceived problems, mainly environmental, it can help to consider the perception of the host community to the tourist presence as an important part in the decision making and implementation of actions and policies towards sustainable tourism development. Also, it is useful to understand the environmental, social and economic problems that residents are detecting on their area and day to day and contribute equally to decision-making to prevent negative reactions towards the tourist presence. Such is the case of human and vehicular overhead in summer, mainly in the urban environment, so it should take notice of the tourist volume control in arriving and about the seasonality.

Overall, resident people in Alcossebre have a quite satisfactory perception of tourism because the favorable impact on their welfare and the improvement of their quality of life. Tourism carries economic profits, employment and services improvement and residents tend to minimize the environmental impacts attributable to the presence of tourists. They blame the government to avoid the negative effects of tourism.

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Gypsum to Gypsum (GtoG): The European Life+ Project That Aims to Transform the Gypsum Waste Market

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The European Conference on Sustainability, Energy & the Environment
Official Conference Proceedings 2015

Abstract
The GtoG project is working for creating a recycling culture of gypsum products, changing the way this waste is usually treated in construction, renovation and demolition works, with the aim of achieving higher gypsum recycling rates in Europe and promoting selective deconstruction practices. For this purpose and under the leadership of Eurogypsum (the European Plaster and Plasterboard Manufacturers Association) five demolition companies, one demolition consultant, two gypsum waste processors, five plasterboard manufacturers and three academic partners, from 7 European countries, work together constituting the project consortium.

A preliminary study on current practices was completed in 2013. Subsequently in 2014, a set of demonstration activities on deconstruction, processing of gypsum waste and reincorporation of recycled gypsum were conducted. Finally, during this year 2015, different results have been delivered, such as the “European Handbook of best practices for controlled deconstruction of gypsum systems” and the “Report on best practice indicators for deconstruction, recycling and reincorporation practices". The final results will include an Inventory of best practices and the Roadmap for the future implementation of a sustainable value chain.

Keywords: GtoG project, gypsum recycling, selective deconstruction, plasterboard.

Introduction

The European Gypsum Industry is one of the fully integrated industries within the construction sector, covering the whole life cycle of the gypsum products from cradle to cradle as gypsum products are indefinitely and fully recyclable. For this reason, gypsum companies strive to effectively recycle the products at the end of their life cycle. Nevertheless, a large proportion of gypsum waste is still landfilled and backfilled worldwide (European Commission, 2011), including building plaster, gypsum blocks and plasterboard, being the later the most common recyclable gypsum waste generated.

Gypsum waste can be differentiated in three categories based on its origin:

- Production waste (e.g. plasterboards which do not meet specifications and waste resulting from the manufacturing process).
- Waste generated in new construction sites.
- Demolition waste. It includes both demolition and renovation waste and it is the most complex to address because it is usually mixed C&D waste.

Focusing on demolition waste, practices implemented nowadays represent the main barrier to create a recycling culture within the construction industry, leading to mixed C&D waste which is disposed of in landfills reducing the possibilities to recover valuable recyclable materials, and contributing to an increase in the environmental impacts. Therefore, when this product with such composition is disposed of in a landfill site in contact with organic matter, presence of water and absence of air, decay is induced as well as the generation of hydrogen sulfide gas, which is a toxic substance (Barbudo, Galvín, Agrela, Ayuso, & Jiménez, 2012; López & Lobo, 2012). Methane (CH_4) and carbon dioxide (CO_2) emissions are also generated, caused by the degradation of the paper content (WRAP and Environmental Resources Management Ltd (ERM), 2008).

Wherefore, in 2002 as part of the process of establishing criteria and procedures for the acceptance of waste at landfills, the EU reclassified gypsum products as high sulphate, non-hazardous non-inert waste (European Commission, 2010).

The Waste Framework Directive (WFD) is an important tool for driving C&D waste recycling. The EU has set an ambitious target in the WFD of 70% for the recycling of Construction and Demolition (C&D) waste. In this respect, although gypsum is only one of a number of C&D wastes, the European Gypsum Industry is determined to play its part in helping the EU to achieve this target. Moreover the Directive prioritizes recycling upon landfilling (European Parliament and Council, 2008). In addition, the Council Decision 2003/33/EC, establishes criteria and procedures for the acceptance of waste at landfills. Section 2.2.3 specifically addresses gypsum waste, and requires non-hazardous gypsum-based materials to be disposed of only in landfills for non-hazardous waste in cells where no biodegradable waste is accepted" (The Council of the European Union, 2003).

Lastly, in 2010, the European Gypsum Industry developed with the European Commission the Green Public Procurement (GPP) Criteria for Wall Panels, including Gypsum Plasterboard Wall Panels (European commission, 2008). GPP Criteria establishes that for the purchase of environmentally sound wall panels the gypsum content must be at least 5% recycled gypsum board and when higher percentages are possible they should be selected in preference.

The GtoG project

The GtoG project *"From Production to Recycling: A Circular Economy for the European Gypsum Industry with the Demolition and Recycling Industry*", is co-financed by the Life+ Programme of the European Commission. It started in January 2013 and will finish in December 2015. The participating consortium is coordinated by Eurogypsum, European federation of national associations of gypsum products manufacturers, and consists of 17 partners (2 universities- 5 demolition companies-1 consultant in deconstruction- 5 gypsum manufcaturers-1 laboratory- 2 recyclers) from seven European countries (Figure 1).

Figure 1. Representatives of the GtoG project consortium during the kick-off meeting.

The overall aim of the GtoG project is to transform the gypsum demolition waste market to achieve higher recycling rates of gypsum waste, thereby helping to achieve a resource efficient economy. The market transformation will start happening with the establishment of the project as a collaborative business model between the demolition industries, processing and manufacturing industries.
Such closed-loop recycling for gypsum products will only happen if:

- Deconstruction techniques are applied for all demolition or refurbishment projects;
- Sorting of waste is done at source - thereby avoiding mixed waste;
- Processing is carried out according to clear standards;
- Incorporation in the production process is carried out with innovative processes.

Thereupon, the GtoG project seeks to put in place an integrated approach in order to holistically manage construction and demolition waste, from gypsum products deconstruction to recycled gypsum reincorporation, via gypsum waste processing as a secondary raw material. The integrated approach proposed in the project, pleads for a multinational partnership involving all major stakeholders in the value chain (demolition companies, processing and manufacturing industries). This integrated approach could be extended, adapted and applied to any other type of construction material used in construction (Figure 2).

Figure 2: Plasterboard value chain integrated approach.

As specific objectives, the following must be highlighted:

- Diagnosis of the building. To achieve the overall objectives, it is necessary to focus first on the deconstruction practices and to demonstrate the feasibility and advantages of deconstruction versus demolition.
- Processing gypsum demolition waste. The major objectives of processing are separation of the gypsum from the paper and the size reduction of gypsum waste.
- Qualifying gypsum waste. The above-mentioned separation is done according to agreed specifications between the gypsum processors and the gypsum manufacturers in a contractual form.
- Incorporation of the processed gypsum into the manufacturing process, including an assessment of technical difficulties, options and solutions. By developing innovative techniques in manufacturing plants, GtoG aims to incorporate up to 30% of secondary gypsum in plasterboards.
- Production of European criteria for recycled gypsum to establish the end-of-waste (EoW) status and apply for a Council regulation to confirm these criteria under Directive 2008/98/EC.
- On the basis of the results of point 1 to 4, establish, if feasible, a recycling target for gypsum waste.
- Reassessment of the 5% of recycled gypsum in the Green Public Procurement Criteria for Wall Panels (i.e. plasterboard) developed by the European Commission.
- Assessment of the carbon footprint and the methods to mitigate it at the construction level, transport level, processing level and manufacturing level.

In order to achieve the aforesaid, it is necessary to analyse how the value chain operates in different countries. For this reason, the project targets and involves partners from the major EU gypsum product dismantlers, processors and producers.

Methodology

The European Gypsum Industry has global players but produces locally with high technical and environmental standards and with great respect for the local communities. The business and technical response of the large players responds to the culture, needs and legislative/technical requirements of the local economy. In that aspect, production processes are similar, but not the same. Initiative for greening the products are taken at plant level and differ from one plant to the other, from one country to the other, resulting in competition inside the same company.
On the other hand, the majority of demolition companies are SMEs focused on the local market, also with different approaches and initiatives.
Regarding the gypsum processing market, it mainly consists of two companies that act locally in each country with the process developed by the two companies. In the UK, some gypsum recycling companies are starting to develop for the UK market,

although recycling demolition gypsum waste is still concentrated because the market is still small.
In view of the above-mentioned, and following the structure of the Life Programme, the project develops its technical activities through three actions (Figure 3):

- Action A, which analyses and evaluates the current practices in deconstruction/demolition, C&D waste characterization, processing of the gypsum waste for the production of recycled gypsum and its reincorporation into the manufacturing process. This action represented a sort of introduction to GtoG, where a technical, economic, environmental and legislative analysis is carried out for deconstruction, recycling and manufacturing of plasterboard.
- Action B, the project implementation action, where 5 pilot projects implementing the deconstruction techniques, the processing and reincorporation in gypsum manufacturing plants is being carried out in Belgium, France, Germany and UK.
- Action C, where the outcomes of the pilot projects are being used to reassess the findings of the surveys carried out in action A. The end result will be a report on best practices to recycle plasterboard waste throughout the entire value chain.

PREPARATORY ACTIONS: ECONOMIC AND TECHNICAL SURVEYS

In order to reach the main goal of the GtoG project, due to the strong regional orientation, current practices in deconstruction – demolition, C&D waste characterization, gypsum recycling and the reincorporation of the recycled gypsum into the plasterboard manufacturing process were firstly explored in the preparatory actions of the project. An analysis of practices and economics of the plasterboard value chain was conducted in 2013 in the major European member states gypsum product consumers. This academic survey –preparatory phase- covering Belgium, France, Germany, Greece, Poland, Spain, the Netherlands, and the United Kingdom, was mainly carried out by the two participating universities and the deconstruction consultant company.

Action A.1 Value chain analysis in terms of deconstruction methodologies, economics of logistics and recycling

This action is the core preparatory action of the project and aims to establish the technical and economic characteristics of the deconstruction chain of gypsum lightweight systems leading to recycling versus landfilling. It builds an inventory of current practices in deconstruction, processing and industrial use of recycled material.
Action A1 is divided in the following Sub-Actions:

- A1.1 Deconstruction practices - Economics of deconstruction & logistics
- A1.2 Recycling and plasterboard manufacturing practices
- A1.3 Technical-Economic-Legislative-Environmental criteria

IMPLEMENTATION ACTIONS: PILOT PROJECTS

A second phase is focused on demonstration activities on deconstruction, gypsum recycling and reincorporation of recycled gypsum, activities being part of the End-of-Life (EoL) stage of the gypsum plasterboard. The demonstration activities of the GtoG project have been carried out in, Belgium, Germany, France and The United Kingdom. The outcomes of these pilot projects are used to reassess the findings of the surveys carried out in 2013 and produce the Best practice report on gypsum recycling.

Action B.1 Eco-efficiency of deconstruction/segregation: Technical/economic/ market feasibility

This Action is the first implementation action of the project, dealing with optimization of current practices in the deconstruction/segregation of lightweight gypsum from C&D waste identified in Action A1. It involves the systematic recording of deconstruction procedures in the various EU countries, based on building typology and linking them to the existing legislation.

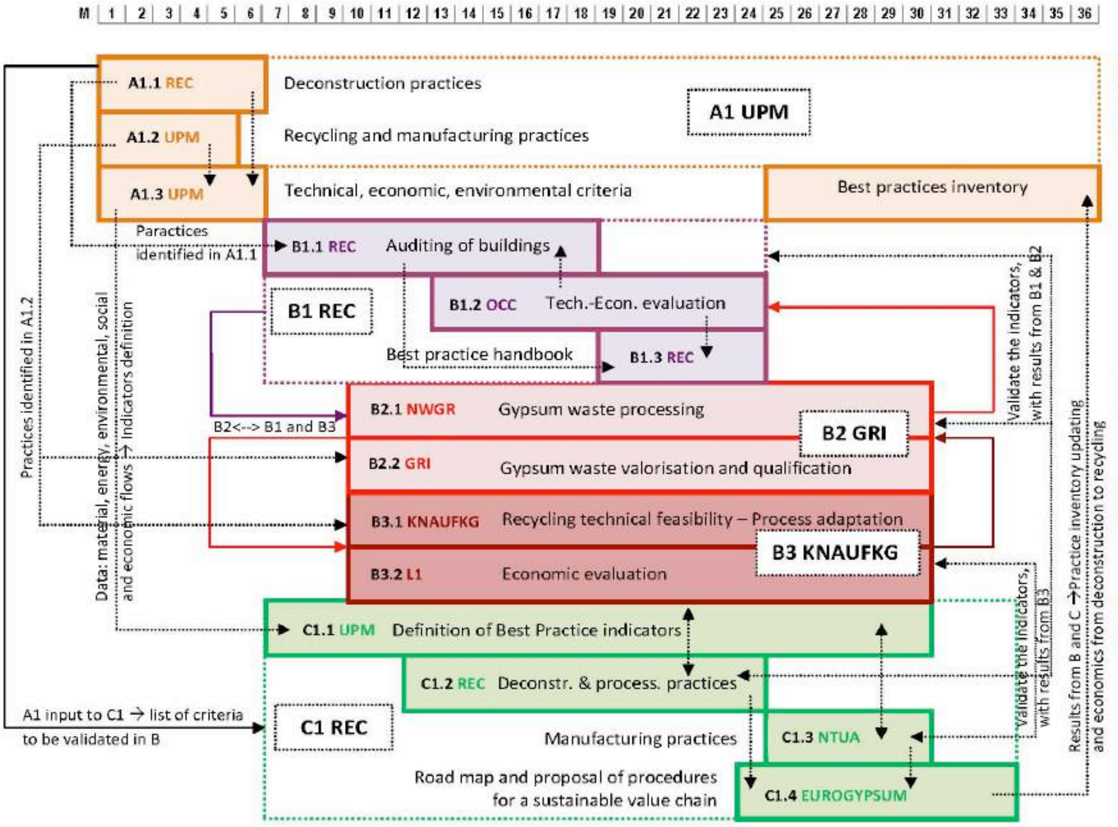

Figure 3. Structure of the GtoG project actions.

Action B1 aims to identify and elaborate the most appropriate procedures and practices for deconstruction of lightweight systems and to implement these on selected pilot projects. The action is divided in the following sub-actions:

- B1.1 Auditing of buildings – deconstruction projects
- B1.2 Technical-economic evaluation of deconstruction steps
- B1.3 Preparation of “best practice” handbooks

Action B.2 Valorisation of deconstruction waste

The second phase of the implementation activities has addressed the issues of optimization of methods and practices in order to obtain processed gypsum with properties that are 90% similar to natural gypsum. This, in turn, will enable easier incorporation of the gypsum into the manufacturing process and the establishment of the EoW status for recycled gypsum. After gypsum materials have been segregated from other products it is necessary to ensure that the secondary gypsum that will be obtained from the waste processing is suitable for ultimate reprocessing. For this reason, gypsum waste must be accurately qualified, and decontaminated.

In Action B2, the gypsum waste received from the four different deconstruction sites is qualified and re-assessed to ensure that the waste is suitable for reprocessing. The properties of the secondary gypsum are agreed between the waste processors and the manufacturers. The foreseen sub-actions within this Action B2 are:

- B2.1 Processing of deconstruction gypsum waste
- B2.2 Valorisation and qualification of deconstruction gypsum waste

Action B.3 Towards sustainable lightweight systems
After having defined the best practices for each step of the value chain in Actions B1 and B2, Action B3 integrates the achieved results to demonstrate, at industrial level, the optimized value chain and to support widespread dissemination routes through the following Sub-Actions:

- B3.1 Gypsum waste recycling. Technical feasibility-Process adaptation
- B3.2: Economic evaluation. Energy and raw material saving potentials

MONITORING OF THE DECONSTRUCTION, PROCESSING AND MANUFACTURING PROCESSES**.**
At the same time, the impact from the project actions is gathered the through a set of monitoring indicators that have been defined in the project.
Action C.1 Monitoring of impact in the value chain (cradle to cradle approach)
This Action constitutes the best waste management options for gypsum demolition waste (reuse and recycling versus landfilling). The results of the systematic and methodological improvements in all stages of the value chain (from Actions B1 to B3), are assessed by the best practice indicators. The validity of the best practice indicators is also verified by the monitoring activities where corrective actions are proposed if needed.
The following sub-actions have already been developed:

- C1.1 Definition of Best Practice indicators
- C1.2 Monitoring of deconstruction and processing practices
- C1.3 Monitoring of manufacturing practices

Results

The main result achieved during the first phase of the Preparatory Actions, has been an inventory of current practices for deconstruction, recycling and reincorporation in the manufacturing process of the recycled gypsum. This document establishes the technical and economic characteristics of the deconstruction chain of gypsum lightweight systems leading to recycling versus landfilling. It builds an inventory of current practices in deconstruction (diagnostic of the buildings, audit of the material to be deconstructed, deconstruction, decontamination, and segregation), processing and industrial use of the recycled material.
Furthermore, a framework for assessing the success of gypsum recycling, consisting on six indicators influencing closed-loop gypsum recycling, has been formulated. On the other hand, in relation to the Monitoring Actions, a set of technical-economic-environmental and social criteria in the form of monitoring indicators have been defined and used for gathering information from the pilot projects. Based on the analysis of the monitoring indicators, a report of Best Practice Indicators for deconstruction, recycling and reincorporation practices have been drafted. Within the second phase of the Preparatory Actions, an Inventory of best practices will be ready at the end of the GtoG project, as well as the roadmap for the future implementation of a sustainable value chain.
The outcomes of action B1, the first implementation action of the project have been the European handbook of best practices for controlled deconstruction of gypsum system and the European manual of best practices for the audit of building. These

documents summarize the actions and results of the deconstruction projects implemented in Belgium, France, Germany and the UK. In these countries, the partners have implemented audits to identify materials and wastes to be removed, created a catalogue with photos of the materials built 20-30 years ago and examined in detail the different gypsum-based systems deconstruction techniques. The handbooks collate and describe in detail the results from these pilot projects and also propose an assessment of the economics of deconstruction versus demolition. These handbooks also aim at becoming standard guidelines that will lead the European demolition companies to operate in an eco-efficient way, help Member States to achieve the goals of the Waste Framework Directive (WFD) and, finally, to contribute to the creation and promotion of a culture of deconstruction.
During the coming months, the GtoG Project is expected to deliver results related to the waste processing and reincorporation of recycled gypsum in the manufacturing process. For the first one, European specification/qualifications for recycled Gypsum and a handbook on waste acceptance criteria at the recycling facilities will be delivered. For the second one, the optimal European average percentage of recycled gypsum that could be incorporated in the production process, aimed at 30% in the pilot manufacturing plants, will be assessed.

Conclusions

The GtoG project is contributing to demonstrating that gypsum recycling rates can be increased and incorporated in the gypsum manufacturing process if deconstruction techniques are used in demolition and renovation works:

- The recyclability of the material at the end of its life highly depends on the way the building is deconstructed and how the material is segregated on-site.
- Local factors and criteria will determine the available options, demanding a substantial effort on behalf of the companies involved with regard to resources and investments, as well as requiring a high level of technical expertise and professionalism.
- Even if not representing additional cost or labour, changes in the stakeholders' implemented systems can be hard to accomplish. Consequently, training, education and dialogue are required.
- Selective demolition is compatible with all methods of demolition. Initial treatment and evaluation of the waste generated on-site might incur costs that will be recovered from savings on waste management and income from the recycled materials.
- Gypsum from plasterboard waste, if correctly managed, can always be recycled into new plasterboard.

Acknowledgement

This study has been performed under the framework of the GtoG project, supported by the European Commission – DG Environment through the Life + programme; under contract number LIFE11 ENV/BE/001039.

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Towards an Inventory of Best Practices for an Efficient Gypsum Recycling Value Chain

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The European Conference on Sustainability, Energy & the Environment 2015
Official Conference Proceedings

Abstract
In Europe, an increasing use of gypsum plasterboard began in the 1960s – 1970s, especially growing popularity from the mid-1980s. Ever since a large proportion of gypsum waste is being landfilled and backfilled worldwide, including building plaster, gypsum blocks and plasterboard, being the later the most common recyclable gypsum waste generated in Europe.

Considering a reference service life of 50 years, most of the buildings being currently renovated or demolished contain very few or inexistent plasterboard. However, in the coming years, the quantities of plasterboard waste are expected to substantially increase, and becoming a forthcoming issue.

This investigation presents the work conducted to develop an inventory of best practices towards an efficient gypsum recycling value chain, within the framework of the Life+ GtoG project. The study is based on three pillars: the crucial indicators for the effectiveness of the recycling route, relevant results from the monitoring of a set of European pilot projects, and conclusions regarding the life cycle effects on carbon emissions of different levels of plasterboard recycling. These best practices would not only help to minimize the construction and demolition (C&D) waste sent to landfills, but also to mitigate primary mineral resource depletion.

Keywords: Plasterboard, gypsum recycling, value chain, best practices, GtoG project

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Introduction

Gypsum products are used for partitions, ceilings and lining of walls in building construction and renovation, being plasterboard the most common recyclable gypsum product generated in Europe. Around 10.73 million tonnes of plasterboard were consumed in the EU-27 in 2013 (ELCD database 2.0, 2007; Eurostat, 2013; Williams, 2008), while an estimated amount of 1.9 million tonnes of post-consumer plasterboard waste was generated, of which 87% might have been landfilled (Eurostat, 2012; Gypsum to Gypsum project LIFE11 ENV/BE/001039, 2013). In the coming years, this amount is expected to substantially increase, as plasterboard grew in popularity in the mid 1980s (Eurogypsum, n.d.). Although gypsum is fully recyclable, recycling systems are only operating in 7 out of the 27 Member States (Belgium, Denmark, Finland, France, the Netherlands, the United Kingdom and Sweden).

The End-of-Life (EoL) of gypsum plasterboard comprises demolition or deconstruction of the building, transport of the plasterboard waste to recycling facility (either direct or via transfer station), waste processing operations and final disposal (European Committee for Standardisation (CEN), 2012). These processes can be grouped into two main routes: the gypsum recycling and the gypsum landfilling route, as shown in Figure 1.

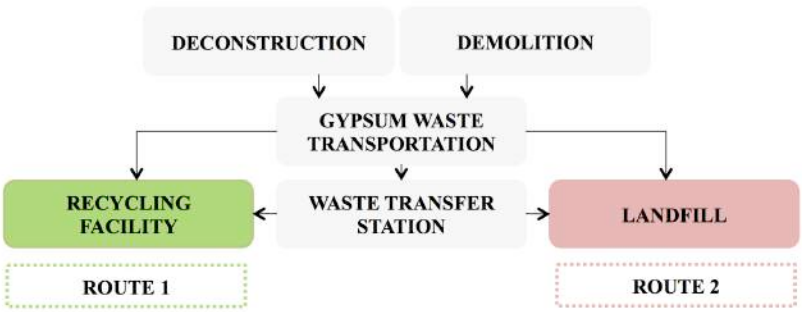

Figure 1: End-of-Life (EoL) of gypsum plasterboard main processes and routes.

If gypsum waste is landfilled, the combination of sulphate content of gypsum and biodegradable waste may break down, amongst other substances, into Hydrogen Sulphide (H_2S), a hazardous flammable gas with environmental and health effects when inhaled. This H_2S emission rate is variable and depends on different factors such as soil moisture, H_2S concentration and temperature (Xu & Townsend, 2014).

In a circular economy post-consumer gypsum waste is effectively collected, recycled and used to make new plasterboard (Figure 2), whereas natural gypsum is only used when secondary raw materials are not available. From January 2013 the European Life+ Gypsum to Gypsum (GtoG) project ENV/BE/001039 "From Production to Recycling, a Circular Economy for the European Gypsum Industry with the Demolition and Recycling Industry" is working for fostering the recycled gypsum market, by promoting deconstruction practices, standardized quality criteria and quantifying the environmental impact of the recycling and the landfilling route. The consortium is composed by 17 European partners, including gypsum recyclers, plasterboard manufacturers, deconstruction, consultancy companies and research institutions, being the coordinator of the project Eurogypsum, the European federation of national associations of gypsum products manufacturers[1].

Figure 2: GtoG project poster.

If best practices during building deconstruction, gypsum recycling (processing) and recycled gypsum reincorporation are not implemented; recyclable gypsum waste can turn into non-recyclable waste. This study presents three main pillars for formulating best practices associated to the EoL of gypsum plasterboard, towards an efficient gypsum recycling value chain.

Basis of the Inventory of Best Practices

Three pillars, further detailed in subsequent sections, are the basis of the Inventory of Best Practices:

- A number of indicators for assessing the success of closed-loop gypsum recycling in the European Union;
- Results from the monitoring of a set of European pilot projects on deconstruction, processing of gypsum waste and reincorporation of the recycled gypsum into the manufacturing process: Key Performance Indicators (KPIs) and Best Practice Indicators (BPIs);
- Conclusions regarding the life cycle effects on carbon emissions of different levels of plasterboard recycling.

In addition, previous and ongoing GtoG deliverables complement the study:

[1] Further information can be found in http://gypsumtogypsum.org/

- European Handbook on best practices for plasterboard deconstruction and Manual for best practices in audit prior deconstruction[2];
- Report on Production Process Parameters (on going);
- Guidance criteria recycled gypsum and recycled gypsum End-of-Waste (EoW) (on going).

Indicators for assessing the success of closed-loop gypsum recycling in the EU

Major indicators impacting the success of closed-loop gypsum recycling systems have been identified and tested in the 8 EU selected countries target of the GtoG project: Belgium, France, Germany, Greece, Poland, Spain, the Netherlands and the United Kingdom.

i. "Reach of the gypsum recycling system" assesses the distance from the gypsum waste source to the gypsum recycling facility.
ii. "Segregation of gypsum waste from other C&D waste" represents the amount of gypsum waste that is segregated from other C&D waste.
iii. "Competitiveness of the recycling solution compared to local landfills" shows the competitiveness of the gypsum recycling solution compared to landfill disposal.
iv. "Compliance with the existing regulation impacting gypsum waste" describes the amount of gypsum waste that complies with the existing regulation.
v. "Legal alternative destinations" estimates the amount of gypsum waste or recycled gypsum that does not follow other alternative routes.
vi. "Environmental focus" describes the share of gypsum waste market for which environmental factors determine the final destination.

Results from the monitoring of a set of European pilot projects: KPIs and BPIs

A total of 36 KPIs are applied in a set of European pilot projects (Table 1). After data collection and analysis, 29 Best Practice Indicators (BPIs), aiming to recognize and encourage best practices in the deconstruction, recycling and reincorporation processes are selected.

Figure 3: Plasterboard dismantling and segregation in different GtoG pilot projects. From left to right: strip-out activities in London (the UK), manual plasterboard dismantling in Graben (Germany), waste storage in Levallois Perret (France) and mechanical plasterboard dismantling in Brussels (Belgium).

Whilst for deconstruction and recycling there are several socio-economic BPIs that have not been selected, mainly due to their variability depending on the different

[2] Downloadable from http://ec.europa.eu/environment/life/project

market context, policies and competitive environments from the country under study, in the case of reincorporation all of them are considered.

Deconstruction - Performance Indicators		
Criteria	**Stage**	**Indicator**
TECH	Audit Deconstruction Traceability	TECH1. Existence and deviation of the audit for gypsum-based systems TECH2. Effectiveness of the deconstruction process TECH3. Effectiveness of the traceability
ENV	End route	ENV1. Gypsum waste sent to landfill ENV2. Transport emissions comparison between recycling and landfilling
SOC	Decon - Demol Deconstruction	SOC1. Labour time difference between dismantling and demolishing plasterboard SOC2. Productivity SOC3. Training of the deconstruction team SOC4. Follow-up of the waste management
ECO	Audit Deconstruction Traceability	ECO1. Audit cost ECO2. Plasterboard dismantling and loading cost ECO3. Gypsum block dismantling and loading cost ECO4. Cost difference between recycling GW and landfilling route

Recycling - Performance Indicators		
Criteria	**Stage**	**Indicator**
TECH	Reception Storage Processing	TECH1. Quality of the gypsum waste received TECH2. Gypsum waste rejected TECH3. Warehouse storage capacity for gypsum waste TECH4. Output materials of the recycling process
ENV	Processing and transport	ENV1. CO_2 emissions from the recycling process ENV2. Natural gypsum saved
SOC	Reception	SOC1. Recycler's satisfaction
ECO	Processing Transport	ECO1. Energy cost of the gypsum waste processing ECO2. Transport cost of the recycled gypsum

Reincorporation - Performance indicators		
Criteria	**Stage**	**Indicator**
TECH	Reception Storage Reincorporation Manufacturing	TECH1. Recycled gypsum rejected by the manufacturer TECH2. Recycled gypsum quality criteria TECH3. Warehouse storage capacity for recycled gypsum TECH4. Recycled gypsum content TECH5. Recycled content increase TECH6. Production waste
ENV	Preprocessing Manufacturing	ENV1. CO_2 emissions: business-as-usual compared to maximized recycled content in the preprocessing ENV2. CO_2 emissions: business-as-usual compared to maximized recycled content in the production process
SOC	Manufacturing	SOC1. Manufacturer's satisfaction
ECO	Reception Preprocessing Manufacturing	ECO1. Cost difference between business-as-usual and maximized recycled content quality check ECO2. Cost difference between natural gypsum and recycled gypsum ECO3. Cost difference between FGD gypsum and recycled gypsum ECO4. Energy cost difference between business-as-usual and maximized recycled content in the preprocessing ECO5. Energy cost difference between business-as-usual and maximized recycled content in the production process

Table 1: Developed KPIs. Most of them are selected as BPIs, with the exception of Deconstruction SOC1, SOC2, ECO1, ECO2, ECO3 and Recycling ECO1 and ECO2, which are variable depending on the country under study, skills of the workers and/or equipment performance.

Conclusions regarding the life cycle effects on carbon emissions of different levels of plasterboard recycling

A life cycle model is the basis of the assessment, from which the known mass flows are quantified using principles of mass balance. Three scenarios are defined: 2013 base case (5% recycled content) and two alternatives: low recycling case (0% recycled content) and high recycling case (nearly no gypsum waste sent to landfill, corresponding to 18.5% recycled gypsum in new plasterboard).

- When moving from the 2013 base case towards the high recycling case, greater impacts occur in the processes of transport of recycled gypsum, pre-processing stage, transport of plasterboard waste to recycling and waste processing, while lower impacts are observed in gypsum mining, transport of natural gypsum and final disposal.
- When plasterboard is landfilled, plasterboard's lining paper is degraded by anaerobic bacteria, producing GHG emissions.
- The total GHG emissions are smaller in the high recycling case, mainly due to the avoided methane released from facing paper degradation.

Conclusion

Best practices for an efficient gypsum recycling value chain would not only help to minimize gypsum waste sent to landfills, but also to mitigate H_2S and CH_4 emissions from landfill, landscape degradation and natural resources depletion.

The general GtoG action plan foresees the submission of the DA.2 deliverable, *Report: Inventory of Best Practices*, planned for December 2015.

Acknowledgement

This study has been performed under the framework of the GtoG project, supported by the European Commission – DG Environment through the Life + programme; under contract number LIFE11 ENV/BE/001039.

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The Role of Regional Strategies in Realising Energy Neutrality in Regions: Experiences from the EU-LEE Project SUSREG

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European Conference on Sustainability, Energy and the Environment 2015
Official Conference Proceedings

Abstract
The EU has high ambitions with respect to climate change mitigation and energy independence, and developed a broad range of instruments to realise these ambitions. SUSREG was a project within the IEE programme (Intelligent Energy Europe), where knowledge partners and local and regional authorities in six countries developed and implemented planning tools and strategies contributing to energy saving and renewable energy introduction. These strategies were set up to facilitate practical energy initiatives, like PV panels on dwellings or energy saving initiatives by housing corporations. The paper describes the main features of some of the regional strategies, and describes how and to which extent the strategies lead to practical energy initiatives.
The paper will focus on three regions: Greater Copenhagen (Denmark); the City Region of Arnhem and Nijmegen (the Netherlands) and Emilio Romagno (Italy). These regions give an impression of the diversity of cases within SUSREG, but also give the opportunity to draw some more general conclusions. One of the regions already show substantial progress in their process towards energy neutrality. Here the participation within SUSREG is one initiative within an existing regional strategy towards energy neutrality. Other regions are more in the beginning of the development of such a strategy. The participation in SUSREG helped the regions to speed up the process of development and implementation of the strategy. In these regions, it is too early to identify an increase in bottom up initiatives as a result of a regional strategy. The experiences in all regions support the importance of a broad vision on sustainability and quality. When improved energy efficiency is linked to other quality aspects of sustainability, the support among both the business sector and residents seems to increase. Strong partners in all three sectors of the triple helix (knowledge institutes, business and industry, government) can serve as an enabler for the development and realisation of ambitious plans.

Keywords: Sustainable development, energy neutrality, stakeholder engagement, triple helix cooperation

Introduction

The EU has high ambitions with respect to climate change mitigation and energy independence. These ambitions are described in the strategy 'Energy 2020'. The main objectives of this strategy are to reduce greenhouse gas emission by 20%, to increase the share of renewable energy to 20% and to make a 20% improvement in energy efficiency (European Union, 2011). This strategy is not only set up to mitigate climate change, but also to improve the energy security and energy independence of the EU. The strategy is formalised in the Energy Efficiency Directive (EED) (European Union, 2012) This directive asks member states to formulate National Renewable Energy Action Plans (NREAP's) and National Energy Efficiency Plans (NEEAP's). Local Strategic Energy Action Plans (SEAP's) describe the ambitions and activities of municipalities on a local level. Energy 2020 is considered as a first step, but more ambitious steps are necessary on a longer term. The EU roadmap 2050 describes the necessity to reduce greenhouse gas emissions in 2050 with at least 80% compared to the present levels, in order to limit the social and economic impact of climate change on the long term (European Commission, 2011).

The programme Intelligent Energy Europe (IEE) was set up to realise the ambitions of Energy 2020. IEE supported projects dealing with renewable energy, energy-efficient buildings, industry, consumer products and transport. The expectation was that by doing this, Europe would also boost its competitiveness, security of energy supply, and technological innovation (European Commission, 2015).
SUSREG is a project within the IEE programme that developed knowledge and tools to realise energy efficient buildings, cities and regions. Knowledge partners and local and regional authorities from six countries worked on the following objectives: to improve urban and regional planning processes, to support the use of sustainable energy resources and energy efficient building methods; and to improve the knowledge, attitudes and skills of planners with regard to sustainable energy. Partners came from Cyprus, Czech Republic, Denmark, Spain, Italy and the Netherlands (SUSREG, 2015).
The project was divided into three stages. In the first stage, existing planning tools for sustainable and energy efficient neighbourhoods were collected and described. This information was used to develop on the job training activities for officials within local and regional authorities. Each region applied the knowledge and skills acquired during the training sessions in a case study: an area where an intervention was prepared and if possible implemented, in order to improve the energy performance of the area. Finally, the overall results were disseminated by capacity building activities like workshops and presentations. The SUSREG project started in 2013 and finished in 2015. Saxion University of Applied Sciences , the institute where the authors work, took part in the development and execution of the training sessions, in the reflection on the case studies and in the national and international dissemination activities.

Energy neutral buildings and areas

The concept of energy neutrality of buildings and areas can be defined in many different ways. An overview of some of the definitions can be found in Schaefer et al (2014). In general, energy neutral buildings or zero energy buildings have no net use of fossil or nuclear energy. The energy needed in the building is from renewable sources on the building itself, like PV panels, small wind turbines or geothermal energy.

The European Energy Performance of Buildings Directive requires all new buildings to be 'nearly zero-energy' by the end of 2020. All new public buildings must be nearly zero-energy by 2018. The Buildings Directive limits the scope to building related energy: 'the calculated or actual energy that is consumed in order to meet the different needs associated with its typical use (…), heating energy needs, cooling energy needs (…) and domestic hot water needs' (European Union, 2010).

Energy neutral regions can be defined as regions that have no net use of fossil or nuclear energy. Not only the energy use in the built environment is considered, but also the energy use related to other sectors like transport, business and industry. For all the fossil energy that is used, the same amount of additional renewable energy is produced and made available outside the region.
Energy neutral buildings or regions are not necessarily autarkic or off grid. The total balance of energy use and (renewable) energy production is zero. Both local and (inter)national grids can help in transporting a surplus of produced energy to elsewhere, or importing energy from elsewhere in case of shortage of local production. The European Climate Foundation stresses the need for improvement of power grids on all levels, from local to European, to make them ready for a power supply dominated by renewables like wind and sun (Hewicker, Hogan and Mogren, 2011).

Within the SUSREG project, the Trias Energetica was used as an important framework for energy efficiency. The Trias Energetica identifies three steps: reduce the demand for energy by avoiding waste of energy and by implementing energy saving measures; use sustainable sources of energy instead of finite fossil or nuclear sources; as far as necessary, produce and use the needed fossil energy as efficiently and as clean as possible. (Roth, Alsema and Goud, 2014).

Energy neutrality and sustainability

Within the SUSREG cases, energy neutrality was usually not considered as an aim on itself. It was considered as one of the quality dimensions of sustainability, within a broader perspective, as described by De Vries et al (2013). They state that sustainable area development should focus on the realization of synergy between quality issues like environmental quality, social quality, economic quality and spatial quality. It combines quality 'here and now' with quality 'elsewhere and later', and prevents in this way transfer of problems from the present to future generations, or from one location or country to other places. And finally, they stress that sustainability only can be realized in a situation with careful communication and stakeholder involvement. A broad quality perspective helps to realize neighbourhoods that are attractive for all stakeholders, and thus helps in creating societal support for sustainability.

Cases

Three of the SUSREG cases with a strong regional focus were selected here for a further analysis. The national and regional context of the cases is described, and the specific activities executed within the project. An attempt is made to identify possible success factors within the different cases. Information was derived from internal reports from the SUSREG project, from interviews with partners and from discussions during project meetings. In addition to this, other available literature was studied.

City Region Arnhem – Nijmegen (The Netherlands)

The City Region of Arnhem and Nijmegen is located in the eastern part of the Netherlands and has around 740.000 inhabitants (De Stadsregio, 2015) and a size of around 1,000 km^2. The city region consists of 20 municipalities and has two main cities: Arnhem (150,000 inhabitants) and Nijmegen (175,000 inhabitants). For several years, this region had a regional council with decisive power on regional issues like spatial planning and transport and infrastructure. Since July 2015, this regional council has stopped and the cooperation between the municipalities only continues on an informal basis.

National context

The most recent Dutch energy ambitions and actions were described in the national Agreement on Energy for Sustainable Growth (2013). This is a voluntary agreement, signed by 47 different parties with a background in government, business and NGO's. The main goals are an annual improvement of the energy efficiency of 1.5%, from 2013 to 2020, and an increase of the share of renewables from 4.5% in 2013 to 14% in 2020 and 16% in 2023. The action programme is expected to create 15.000 additional jobs in 2020, e.g. in the building sector and in the renewable energy sector.

Even though the agreement was signed by many stakeholders, it also met criticism. The NGO 'Urgenda', a network of experts in sustainability, went to the court in The Hague to appeal against the agreement, since they considered the agreement insufficient. The court followed their line of reasoning and concluded that the Dutch government is required to take more effective action to reduce the Dutch share to global emissions of greenhouse gases. According to Urgenda, this the first time that a judge has legally required a State to take precautions against climate change (Urgenda, 2015).

Also evaluations of earlier versions of the Dutch Energy Efficiency Action Plan were critical. Schüle et al (2013) concluded that the NEEAP has, 'absence of ambition and enthusiasm, lack of funding, lack of legislation and lack of implementation'.

Regional context

In the beginning of the 21st century, many cities and regions in the Netherlands formulated strategies for energy or climate neutrality. An inventory by the NGO Urgenda in 2009 resulted in a list of more than 50 cities with the ambition to be energy neutral or climate neutral, between 2020 and 2050 (Urgenda, 2009). Both the cities of Arnhem and Nijmegen and the City Region Arnhem – Nijmegen formulated such strategies.

In Arnhem, the covenant 'Energy made in Arnhem' was signed in 2011 by 59 organisations ranging from housing corporations to universities, schools, hospitals and business parks (city of Arnhem, 2011). It contained a list of more than 100 projects, dealing with built environment, transport and infrastructure and research and development. The evaluation of this covenant in 2014 showed positive results. The number of partners had grown from 59 to 117. At the moment of the evaluation, over 200 projects were finished or still running. The energy consumption in households was in 2014 8.3% lower than in 2009, and in businesses 6%. The share of renewable energy increased from 3.6% in 2009 to 5.3% in 2014. According to the evaluation report, large scale projects for production of renewable energy were being prepared at the moment of evaluation (City of Arnhem, 2015a). A follow up of the first programme was published in May 2015 (City of Arnhem, 2015b).

Nijmegen published a road map for an energy neutral city in 2045, in June 2013 (City of Nijmegen, 2013). Both government and businesses set up several projects within the municipality. According to the monitoring results of the programme, the total energy use in 2015 was 15% lower than in 2008, and the share of renewables was 6.5%. Mid 2015, 5 wind turbines are under construction and will increase this figure very soon (Power2Nijmegen, 2015).

The City Region Arnhem and Nijmegen published a region wide strategy and related projects in 2013, with the name Groene Kracht (Green Power) (Lodder et al, 2013). This strategy focuses on the topics that need to be covered on a regional level: regional transport and infrastructure; location of large scale facilities for renewable like wind turbines and solar parks; large scale energy infrastructure like heat networks. This strategy also created a framework for the policy in the smaller municipalities, that do not have the skills, time or power to develop strategies like the two main cities in the region. The long term ambition of this strategy is, to be energy neutral as a region in 2050. For the shorter term, this is translated into and annual improvement of energy efficiency of 1.5% until 2020, and a total share of renewable energy of 16% in 2020. The regional project office of Green Power closed down, as the regional council stopped. The consequences for the running regional projects are not clear at the moment.

SUSREG cases: high standards of sustainability in urban expansion areas

The specific SUSREG cases in Arnhem dealt with energy efficient renovation of existing dwellings, and with the development of a strategy to trigger real estate developers to develop energy neutral dwellings in an urban expansion area. The difference with the previous expansion projects was, that developers received less binding conditions for the spatial quality, but were seduced to present bids that will meet high standards of sustainability. A so called 'Ambition document' was composed for the development of this neighbourhood, emphasizing sustainable ambitions on energy, water and green, mobility and building flexibility. Also a toolbox was presented with innovative solutions to meet these ambitions. The bids with the best scores on these ambitions will be invited to develop parts of this pilot-area. Not only real estate developers were approached in this way, but also housing corporations and individuals with plans to construct their own home. The city received positive response on this approach in a market consultation. After this, the procedure was formalized by the city council in July 2015 (Verwey, 2015). At date, results of this new procedure are not yet available.

The case study area in Nijmegen is part of a larger area designated for expansion of the city of Nijmegen. The original urban plans for this area were evaluated with GPR

Urban Planning, an integrated quality assessment tool for residential areas. Due to the economic crisis, the demand for new houses reduced significantly, thus causing a delay in the development process for the Grote Boel. This offered the opportunity to assess the plan again with GPR Urban Planning and evaluate different scenarios for this development.

The evaluation resulted in a plan with a better integration of sustainable energy in the urban design, a stronger emphasis on bicycle use, better balance in green spaces and a higher chance of success for implementation of the development as planned. The first tangible results of this new plan are some innovative nearly zero-energy initiatives from different developers. Under the name ‘GB4All’ (Green Building for All), 60 dwellings in a nearly zero energy concept will be developed. These buildings are not only very energy efficient, but also very flexible. The dwellings are constructed with standard dismountable parts, leading to a high level of flexibility in design and use. When house owners want to reconstruct their house after a few years, they can replace the building parts and give back the what they do not need anymore. This results in a building concept that is presented as 100% recyclable (GB4all, 2015). The use of the integrated assessment tool also resulted in an improved cooperation between experts with different disciplines. It also lead to a closer cooperation with the neighbouring town of Arnhem (van Ginkel, 2015).

Greater Copenhagen Region (Denmark)

The Greater Copenhagen Region includes the city of Copenhagen and 28 neighbouring municipalities in an area of 2570km^2. The number of inhabitants is around 1.7 million.

National context

Denmark has a long tradition with renewable energy, especially wind turbines and biogas plants. According to DTI (2004), the development of wind turbines and biogas started already in the 1980’s. National financial instruments like profitable feed-in tariffs stimulated both the realization of wind turbines and biogas plants.

The most recent plan in this respect is Danish Climate Policy Plan (Danish Ministry of Climate, Energy and Building, 2013). The target of this plan is to reduce the Danish greenhouse gas emissions with 40% in 2020, compared to 1990. It further states, that a reduction of 80 – 95% in 2050 is necessary, in line with the recommendations of climate scientists, to limit the impact of climate change to an acceptable level. The Danish government developed a Climate Change Act (2014) and a Climate Change Council (2015) to implement these ambitions. However, the government also states that the Danish emissions are strongly dependent on European policy instruments, especially a properly working system for Emission Trading (ETS). External assessors were very positive on the quality of the Danish National Energy Efficiency Action plan. It was considered of ‘extraordinary quality’, and the country ‘progressed very well’ in realizing its ambitions (Schüle et al, 2013). These observations show that the national context for ambitious climate and energy policy can be considered as very positive in Denmark.

Regional context

The city of Copenhagen hosted the last global Climate Change Conference within the United Nations Framework Convention on Climate Change, in 2009. Even though Denmark was already rather pro-active with respect to energy saving and renewable energy, this conference was an extra trigger for the Greater Copenhagen Region to put more effort on this topic. One of the results was the launch of Gate 21, a ‘partnership between local authorities, private companies and research institutions working together for a sustainable society and green business development’ (Gate 21, 2015). In the past years, Gate 21 developed several projects in the Greater Copenhagen Region, related to sectors like Energy and Resources, Transport, and Built Environment. Gate 21 was one of the initiators of the Danish participation in the SUSREG project. Gate 21 does not limit its work to the Greater Copenhagen Region, but has its office in Albertslund near Copenhagen. Therefore, a strong focus of the work can be found in this region.

SUSREG Case: Regional Strategic Energy Planning

The SUSREG project in Denmark concentrated on the realisation of a Regional Strategic Energy Plan in the Greater Copenhagen Region. The objective of the project was to achieve a consensus among all relevant stakeholders on the transition to a fossil-free society not later than 2050. To achieve this objective in the most cost-efficient way the stakeholders analysed a number of scenarios comprising various renewable energy supply options, including wind, biomass, solar energy.

The finally agreed scenario aims at a completely fossil free heating and power supply sector in 2035, and fossil free transport sector in 2050. The ambition is to reduce the gross energy demand in the region in 2020 with 6.3% compared to 2012, and to reduce the CO2 emissions with 27%. During the next years about 10-15 billion DKK (1.3 to 2.0 billion EUR) need to be invested in each year, by all stakeholders involved. The Energy Plan states that the total costs for the society in meeting the energy demand using renewable energy would be of the same magnitude as if the maintaining the supply using fossil fuels. Therefore, it is considered as cost effective to do this substantial effort.

The SUSREG project made it possible to organise training sessions and discussion meetings for several of the stakeholders involved in this process. Main stakeholders in this process were the 29 municipalities, the regional authority, knowledge institutes, businesses in the energy and waste sector and national and regional public transport companies.

According to the participants of the training sessions, these sessions played an important role for the preparation for the negotiation process. They brought the knowledge of the participants to a higher level and provided opportunities for interdisciplinary and cross sector exchange of knowledge and ideas. The experiences in the Greater Copenhagen Region are expected to serve as an example for other regions in Denmark that want to develop a strategic energy plan.

Since the plan was only recently approved (summer 2015), it is not yet possible to identify the specific impact of the plan and the preparation process. However, the support expressed for the contents of the plan is substantial (Terkelsen and De Vries, 2015).

Emilia Romagna / Romagna Forlivese (Italy)

Emilia Romagna is one of the regions in the Northern part of Italy. The total population is around 4.5 million inhabitants, and it covers an area of around 22.000 km2. Its capital is Bologna. The SUSREG partner was not this region as a whole, but the Union of municipalities Romagna Forlivese. This is a group of 15 municipalities with a total population of about 188.000 inhabitants.

National Context

Italy published its first National Renewable Action Plan and National Energy Efficiency Action Plan in 2010. The most recent national Energy Strategy was published in 2014. Italy intends to achieve and exceed the European 20-20-20 targets , work on security of supply and foster sustainable growth in the energy sector. The external assessment of the contents and implementation of the first edition of the NEEAP was rather negative: 'experts were critical about the plans', 'little or no progress seen in the last three years'(Schüle et al, 2013).

Regional context

The Union of municipalities of Romagna Forlivese is established in a process of administrative reform in the province of Emilia-Romagna. In this process, some responsibilities are transferred from the individual municipalities to the Union. One of these tasks is energy planning. Even before the administrative reform, the group of municipalities used to work together to develop common tools for urban planning and practices of involvement with local and regional stakeholders. In this period, the municipalities prepared a common SEAP (Sustainable Energy Action Plan), as agreed within the EU in the Covenant of Mayors.

The joint SEAP states targets to be reached by 2020, first of all almost a reduction of the CO_2 emission with 10,000 tons reduction compared to 2005, within the built environment. The municipalities prepared and revised a common local Regulation about energy efficiency and green building (including different kinds of incentives connected with renovations) that is going to be adopted by each of the 15 municipalities, as an addendum of the more general regulation about local urban building regulation. Moreover, they planned to prepare a common local urban building regulation, according to the regional and national law and their specific competencies.

SUSREG case: energy renovation of buildings in small historical urban centers

The SUSREG team focused on energy renovation of buildings in small historical urban centers. Romagna Forlivese is characterized by small urban communities built around ancient historical centers. The design of energy renovation in these buildings is strongly influenced and limited by regulation, conservation and structural safety needs, costs of materials, etc. The team developed "Guidelines for urban regeneration and energy renovation within the historical centers of Romagna Forlivese" (Tollari et al., 2015). These guidelines serve as a non-binding framework to create more coherence in initiatives connected with energy sustainability and urban planning in the area. They provide information on technical issues and solutions for several types of challenges in these historical buildings, but also pay attention to more soft skills like citizen participation.

The added value of the SUSREG project was the provision of training activities for professionals involved, and the facilitating of intensive communication between local businesses in the building and energy sector and the energy planners and urban planners of the Union of Municipalities. The work also resulted in an energy helpdesk for citizens.

The experience within the SUSREG project demonstrated that urban planning and urban regeneration initiatives can be integrated within local and regional energy planning, providing a very important added value. The participants experienced that discussing about practical local needs and interventions mobilizes knowledge, skills, ideas, supports a clear vision of tools to be adopted, and provides professional growth as well as business opportunities. Public officers within the region can maintain good relations with local stakeholders and also make a good fund raising job whenever it is needed; local and regional professionals can develop and extend their expertise focusing on the needs the context they belong to, SMEs and new entrepreneurs can rely on opportunities in the region to develop and test new technological and business solutions. It creates conditions where a transition to a low carbon economy can contribute both to business competitiveness and attractive areas (Filippi, de, 2015).

Conclusions and final observations

The cases discussed above are quite different, both in context and scale, and in aims and activities. Therefore, a comparison of the cases and a description of the lessons learned should be done with care. Nevertheless, it is valuable to reflect on the three cases and finish this paper with some observations about the possible role of regions in achieving energy neutrality, and the success and failure factors involved. These observations could serve as input for further in depth research.

The Dutch case is characterized by a relatively weak national policy context but a strong drive towards energy neutrality in the region itself. Possible stimulating factors for this strong drive could be the political context, the presence of strong knowledge institutes and the presence of strong players in business and industry. Both the cities of Arnhem and Nijmegen have a long tradition of pro-active local environmental policy. Knowledge institutes like the Radboud University Nijmegen and the University of Applied Sciences Arnhem – Nijmegen have faculties and departments focusing on environment, energy and sustainability. A third factor is the presence of strong players in the sector of business and industry related to energy and environment. Both cities have several highly qualified businesses in the energy sector, like electricity production companies and network companies, and firms involved in engineering and consultancy. In fact, all parts of the Triple Helix are well presented in the region and have a long tradition of cooperation. Even though the national policy context is relatively weak, the region manages to formulate high ambitions and implement these ambitions in successful projects. The involvement of the smaller municipalities in the region is possibly under pressure, as a result of the finalisation of the Regional Council. It is too early to determine the actual consequences, but this is an interesting field for further research.

The Copenhagen Region is characterized by a strong national policy and a strong drive towards energy neutrality in the region itself. Also here, all parts of the Triple Helix are well presented and communicate and cooperate intensively. Since the present regional plan was only very recently approved, it is not yet possible to determine the effectiveness of the strategy. However, the region and the country already have a long tradition with renewable energy.

The region Romagna Forlivese has a relatively weak national policy and until now a limited regional experience with energy strategies. The history of the region itself is one of relatively small municipalities, with an average population just above 10.000. This has consequences for the expertise and power of the local authorities. The region has SMEs in the building sector, but lacks strong businesses in sectors like energy and sustainability. This can also be a limiting factor in the formulation and implementation of ambitious policies regarding energy and climate. The formation of the Union of municipalities seems to help the region to expand its expertise and power, and gives room to ambitions in this field. The training activities of the SUSREG project also helped in acquiring up to date knowledge on energy and sustainability, and lead to closer cooperation and communication between different stakeholders in the region. This can be seen as an important success factor in the region.

The cases above show on the one hand, that energy ambitions and activities of regions are strongly influenced by national and EU policy. On the other hand, regions can develop firm climate strategies even in a situation with limited national ambitions, if the right local and regional conditions are available. The presence of a regional political body can help to make this happen.

Regions have a number of scale advantages, to realise energy neutrality. They are often a more suitable scale for optimising physical planning of renewable energy infrastructure like wind turbines, photovoltaics, biofuels or heat networks. Single cities can have more limitations in this respect, simply because they do not have enough open space for facilities like biofuels, wind parks or large scale solar parks. Regions can also be a more suitable scale for knowledge exchange and cooperation between stakeholders and sectors. This is especially the case if the region has strong players in the different sectors of the Triple Helix.

The coming years will make clear if these regions really manage to realise all of their ambitions towards energy neutrality. Monitoring of these and other regions can help in identifying success and failure factors more in detail, and in developing tools for a further improvement of the effectiveness of energy and climate policy in Europe.

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Additional Electricity Generator Model from Vehicle Movement within an Industry Area

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The European Conference on Sustainability, Energy & the Environment 2015
Official Conference Proceedings

Abstract

The purpose of this research was to create a method and design a generator model from vehicle movement in the industry area at a slaughter and food processing plant called CPF PCL., which is located in Bangkok, Thailand. The main concept of the design was sustainable energy harvesting. The design method consisted of 2 primary elements, the designing process and relevant criteria. The new designing process was applied using a logical framework approach and SWOT analysis. The criteria for the design were based on a life cycle assessment, which included raw materials, production, usage and disposal. The result of the new design model was an integration of the pressure between air and water to generate electricity by collecting energy from the movement of the 4 and more wheels on a vehicle.

Keywords: energy harvesting, electricity, generator model, vehicle movement

Introduction

Electricity is important for overall human life because it is one of the essential elements used in the production of consumer products and is critical for propelling the economy of the country. In industry, electricity is associated with a product life cycle, beginning from the extraction of raw material, to production, to use by customers and to the end of the cycle with waste disposal. By 2050, the world population is estimated to have risen to 9 billion and food demand will increase by 70% (United Nation, 2011). Thus, electricity will have a vital role for food production, which is used in most production processes for food high in demand. Base on Thailand’s energy consumption, as reported by the Energy Policy and Planning Office (Department of Alternative Energy Development and Efficiency, 2012), the business sector consumes the most electricity in Thailand. The food industry and fossil fuels are the major energy resources that are exhaustible. Therefore, the Thai government is aware of excessive use, resulting in the shortage of electrical power. The government and business sectors are currently interested in alternative energy, which relates to the Ministry of Energy’s renewable energy development plan over 10 years (2013-2021), and has established alternative/renewable energy as a goal of 25% for all energy requirements in the country (Department of Alternative Energy Development and Efficiency, 2013).

The food industry has a good opportunity for harvesting energy from vehicle movement through product and raw material transportation as well as the use of personal vehicles, which was recorded at a slaughter and food processing plant for CPF PCL., located in Bangkok, Thailand (study area). An average of 1000 vehicles/day moved in and out of this area (CPF PCL., 2013). Thus, an additional electricity generator model is an innovation that will help harvest and generate supplemental electricity from vehicle movement, which is used in several activities of industrial areas.

Energy harvesting from vehicle movement

Energy harvesting is the process of capturing energy from energy generating sources. Harvesting can be natural or artificial, such as using vibration, heat, light, air flow, water flow, piezoelectric, electromagnetic, mechanical etc. The energy is accumulated and stored using various means for supplying electronic or electrical appliances at a later time (Energy Harvesting, 2014).

Vehicle movement is one of the energy sources readily and abundantly available for energy harvesting. The existing products used to harvest energy from vehicle movement have a similar concept, which is comprised of a platform for embedding on the road to access vehicle movement, the mechanism which connects to a generator, and an electricity storage system. The differences for energy harvesting from vehicle movement machines are the characteristics of the platform and the mechanism for generating electricity. There are many types, such as cog, piezoelectric, water and air pressure, among others. A sample of an existing product currently in use is the cog KineticPower™, a proposed product of Kinergycarpet™ for roads with high traffic patterns. The efficiency of the generator depends on the overall capture volume and the weight of the vehicle at any particular site (KineticPower, 2013). Moreover, Innowattech Piezo Electric Generator (IPEG™) of Innowattech Company created an application for road or railway for harvesting the weight of vehicle, movement, vibration and temperature change from grating between the road and vehicle wheels to generate electricity by piezoelectrics (Innowattech Energy Harvesting Systems, 2007). Energy harvesting from pedestrian footsteps is illustrated by Pavegen. It has pioneered a floor tile which translates the energy from pedestrian footsteps into energy that can be used for powering traffic lights and other applications (Pavegen, 2014). Frontier Service Development Laboratory at Research & Development Center of JR East joint researched a “power-generating floor”, which is equipment for harvesting energy from footsteps that was installed in Tokyo at the railway station. The generated electricity is used for light bulbs (East Japan Railway Company, 2008). There are existing products in the market for harvesting energy, which is converted to electricity. In this research, the focus was on a new design model for harvesting energy from vehicle movement and specifically for industrial areas or vehicle speed control areas.

Objectives

There are two objectives in this study: 1) To propose an approach for finding an innovative design for sustainable energy harvesting and 2) To design a mechanism and characteristic model of an electricity generator from vehicle movement (EGM model).

Methodology

The entire process of this study referred to eco-design ISO/TR 14062 (2002) (International Organization for Standardization, 2002), starting from the planning, site survey and measurement to set the target of the EGM model efficiency. Subsequently, the design the conceptual details were devised, which were comprised of an elaborate innovation process for design criteria and solutions for the EGM model, such as an approach for finding an innovative design for sustainable energy harvesting and design of a mechanism and characteristics for a EGM model. This study only followed three steps of eco-design because it focuses on proposing an approach and design model, it does not deal with a prototype or the actual building of the machine.

The approach for finding an innovative design for sustainable energy harvesting was applied from a combination of 4 main approaches, including SWOT analysis, logical framework, life cycle assessment and sustainable concept. These were employed for setting the elaborate innovation process of design criteria and solution for EGM model.

The SWOT analysis (Humphey, 2005) is a useful technique for identification of strengths, weaknesses, opportunity and threats. The logical framework approach is a management tool mainly used for designing, monitoring, and evaluating international development projects (Gasper, D, 1997). In this research, both approached were applied for finding an innovative design for sustainable energy harvesting. The SWOT analysis was adopted to identify the desirable and undesirable characteristics of energy harvesting equipment from vehicle movement and used the logical framework’s technique to develop the equipment for better function, comfort and safety for users.

The life cycle assessment or LCA, referred to ISO 14040 (International Organization for Standardization, 2006), is a technique used to assess environmental impact associated with the various stages of a product's lifecycle, which covers raw material extraction, production, usage, transportation and waste disposal. The LCA is related to the sustainable concept (World Commission on Environment and Development, 1987) concerning three dimensions including environmental, social and economic. The LCA and sustainable concept were applied for the design criteria in the process of finding and developing the EGM model.

A proposed approach for finding an innovative design for sustainable energy harvesting

The proposed design process was applied from SWOT analysis and a technique used in the logical framework approach. The prominent process is a system to find the innovative characteristics of a product and use it for product development. In the first process, research of the information on EGM should be done, as well as which products are available in the market. Afterwards, research should identify the desirable and undesirable characteristics of all the existing EGM in 5 dimensions such as engineering, space, financial, environmental and social, which are related to the sustainable concept. The desirable characteristics were selected for optional characteristics in setting the model. When the researcher considered the existing characteristics, should proposed the new idea that they are different from the existing were been proposed characteristics and assumed that proposed characteristics will have undesirable characteristics for cross checking the innovation.

The existing and proposed desirable and undesirable characteristics which had their opposite meaning were removed. The remaining desirable characteristics were selected to be necessary characteristics. The remaining undesirable characteristics were changed to be desirable ones by improving to create a new model.

From the new approach, design of the specifications for the product was completed, with the detailed design consisting of the size of the machine, volume and pressure in the system, length of pipe, the number of pipe elbows etc. Finally, all processes helped to create a new sustainable energy harvesting product, as shown in Figure 1. The results are discussed in more detail in a later section.

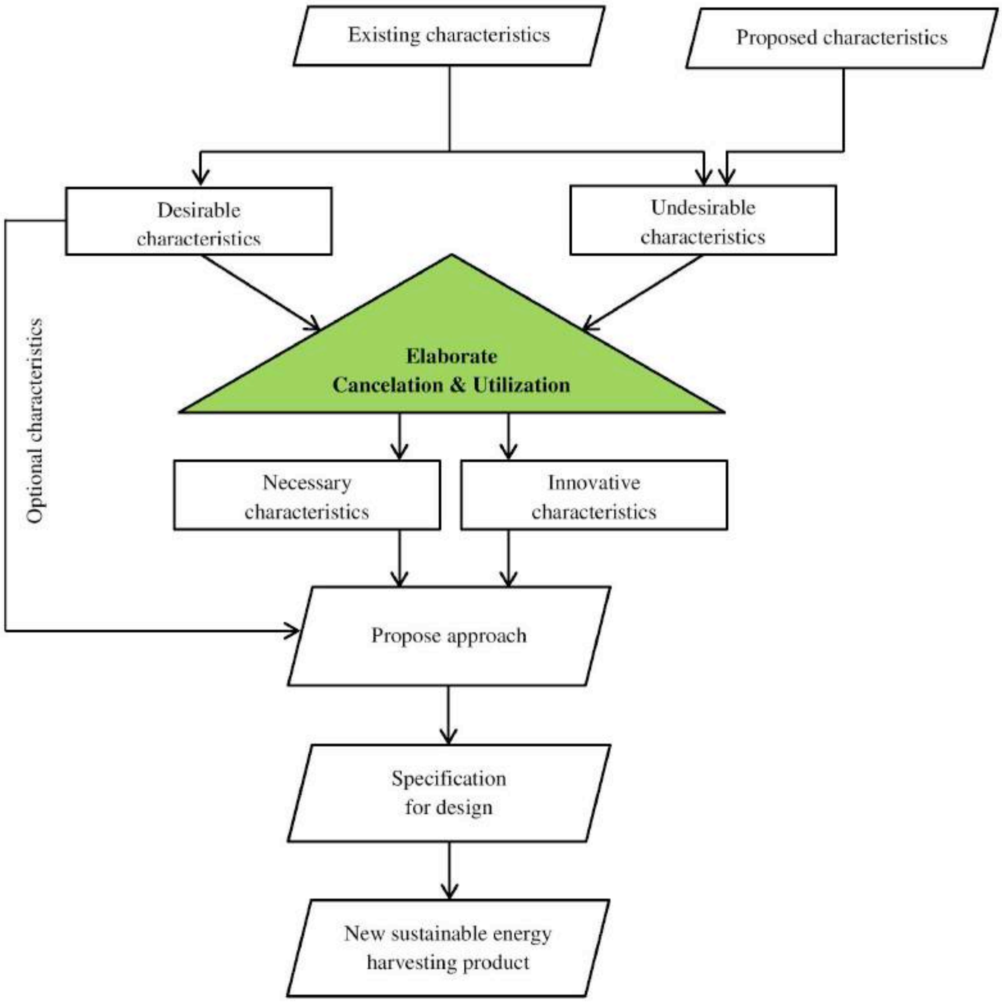

Figure 1: Schematic diagram of the design solution

Results and Discussion

The EGM model was designed with a new proposed approach. It had mechanism characteristics, as shown in Table 1. The EGM model had main parts for the machine, including a platform, one air tank, two water tanks, two generators, as well as water pipes and air pipes. The platform structure was made from metal for installation on the surface of a road. It was durable for 4 or more wheel vehicle movement and the surface platform was covered with rubber for smoother driving. The EGM model was combined between air and water pressure for the generation of electricity from vehicle moment. The prominent system was important input, which included ambient air. It is an inexhaustible resource and available everywhere. The EGM model used water pressure to rotate the generator with a closed loop. The water could circulate between water tanks I and II, so it had resource efficiency and safe water.

Table 1: EGM model mechanism characteristics

LCA	Necessary characteristics	Innovative characteristics	Optional characteristics
Material	- Metal structure for durability	- Water and air combination system: water has high momentum and air is an unlimited resource - Rubber surface platform for smoother driving	- Materials are locally available - Luminous sign in night time - Weather proof - Long-time useful life material
Production	- Slope platform suitable for vehicles	- Length of platform is less than 8 meters for smooth driving	- No dig on a surface road - Uses less time to assemble - Parts of machine can separate: comfortable for installation and movement
Usage	- Driver and vehicle must exercise safety when using machine	- Has two generators: comfortable for maintenance - Has two water tanks with a circulate system: saves water - Has a spare pipe: continues working when a generator breaks down or one water tank leaks - Smooth walk way for pedestrians	- Parts of machine can separate: comfortable for maintenance - Suitable for many types of vehicles
Waste disposal			- Materials can be reused or recycled - Reduction of waste to landfill
Transport			- Parts of machine can separate: comfortable for transport - Suitable package for protection of the parts of machine

The conceptual mechanism design of the EGM model

The electricity generation from the movement of vehicles with four or more wheels vehicle movement model required air pressure and water pressure. Air was generated through the movement of vehicles on the platform. A flexible raw material formed with a plastic bag and metal sheet was capable of creating pressure to activate the valve and turbine of the generator. The mechanism of the EGM model is shown in Figure 2. The working cycle of this model switched between water tanks I and II. When the air pressure in the air tank was released to water tank I, generator I would function to generate electricity. On the other hand, when the air pressure in air tank was released to water tank II, the generator II would function to generate electricity. The electricity was then generated and collected in a battery, directly or indirectly used for electronic appliances.

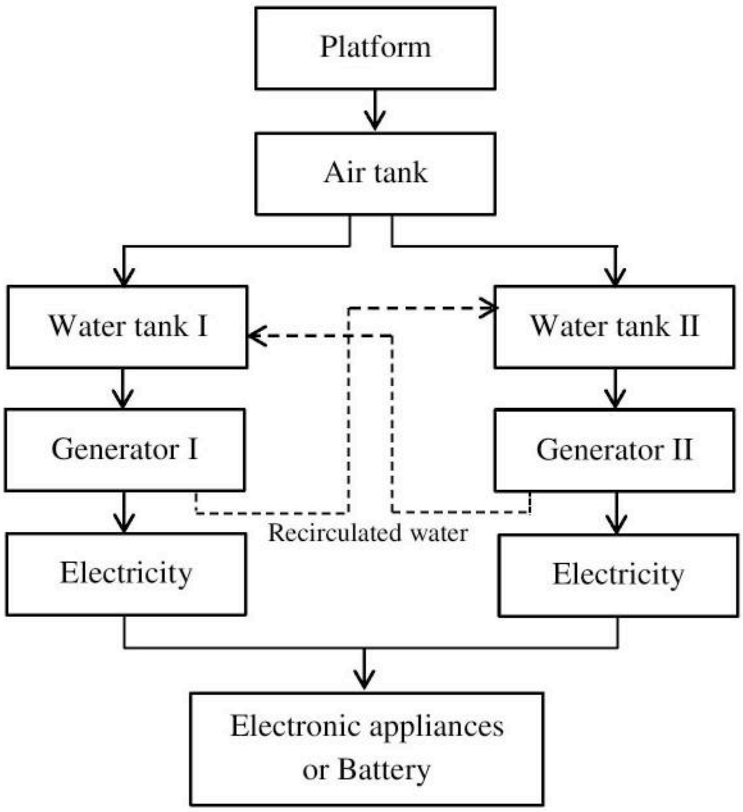

Figure 2: Schematic diagram of the conceptual mechanism design

Based on the condition of the study area, efficiency scenario of the EGM model's generator could generate as high as 60 kWh/day by installing of 3 sets of EGM model. The total length of platform was 240 meters with requirement of 60 pairs-wheel movements. Each set of EGM model generated 1 kWh as per one meter platform with 1,880 pairs-wheel movements.

This research focused on the design concept of the mechanism and conceptual characteristics of the EGM model. If the EGM model's prototype is established in the future, it should concern the specification of equipment and the conditions of each area. The efficiency of the model depends on the specification of equipment such as length platform, size of air tank, size of water tank, capacity of generator etc. Thus, choosing the equipment specification to suit electricity target is recommended. Construction and installation of the model needs to be adjusted properly in order to avoid energy loss. The example uses many elbow joints of air pipe and long pipe. It will lose air pressure, so there must be a valve in the pipe system. Future research must improve the hotspot of lost energy in the EGM model as a step to release surplus air pressure for water movement from one water tank to another. This will help to increase the efficiency of the generator and support resource consumption for high efficiency.

Conclusion

The approach proposed criteria and a solution, which can be used to design a new and more elaborate sustainable energy harvesting mechanism from vehicle movement. Innovation for an EGM model should be designed using an intentional combination of air pressures and water pressures.

Acknowledgments

The authors acknowledge the support received from the ECON fund of the Energy Policy and Planning Office, Ministry of Energy for research scholarship funding. We are also grateful for the study area support received from CPF PCL. Thank is extended to MR. Suphachai Aungsupakorn, for inspiration and encouragement provided. Finally, appreciation is extended to MS. Kularb Kimsri for teaching basic concept of LCA and for valuable suggestions.

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Development of a Behavioural Change Tool for Energy Efficiency in Buildings: A Case of Nigeria Office Buildings

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The European Conference on Sustainability, Energy & the Environment 2015
Official Conference Proceedings

Abstract

The increasing impacts of climate change and the building sector's contribution to increasing this impacts, has led to more urgent need and awareness to use energy more efficiently and consequently reduce CO_2 emissions from buildings. Inefficient operational practices and users' behavioural factor towards energy consumption in buildings, remains one of the most challenging areas in terms of reducing energy consumption in buildings. In a developing country such as Nigeria, energy use can be curtailed up to half of the energy currently consumed by building users if efficiently utilized. However, in spite of government efforts for increased consumer's energy efficiency, the concept appears to be poorly embraced. This paper aims to identify the potentials and barriers to improve energy efficiency in office buildings. The objective is to develop a tool that could positively influence end-user's energy consumption behavior. Drawing from the perspectives of the theory of planned behaviour (TPB); questionnaire survey instrument was developed and administered online to collect data on building energy use and behavioural pattern of end user in five office buildings in Nigeria. The findings indicate that end-users' energy efficiency awareness is high and their behavior and practices in respect of energy efficiency, can be improved. The paper concludes that this require a tool with integrated approaches to educate and motivate the end-users in taking responsibility and accountability towards improving energy efficiency and consequently reducing the carbon footprint of their building.

Keywords: energy use, energy efficiency, behaviour, carbon emissions, office buildings

1. *Introduction*

Global awareness on the efficient use of building energy is increasing due to greenhouse gas (GHG) emissions and climate change. Public awareness of climate change has proven to stimulate organisations to consider strategies for reducing energy consumption both for economic and environmental reasons (Shelly, 2011), (Lucon, 2014). However, behaviour, lifestyle, and culture still have major effects on building energy use. In the developed countries, it has been shown that, behaviour influenced by awareness of energy and climate issues can reduced demand up to 20% in the short term and 50% of present levels by 2050 (Lucon, 2014). Hence, it can be expected that increased awareness of building efficient energy use and climate change norms could help achieve a drastic reduction in use for sub-Sahara African. The desired 'step-change' to energy efficiency behaviour requires knowledge of behaviour, drivers and barriers that influences consumer's energy decision making, and application of this knowledge in intervention programmes (Stephenson J., 2010). The knowledge of systems and behavioural theories of decision making will assist in this respect, and understanding its drivers will help in adoption of more efficient energy practices. Since the 1970's oil 'bubble-burst' crises, Scientists have undertaken several interdisciplinary research on energy consumption behaviour, some of which are: technology assumption models (diffusion theories, theory of planned behaviour, social communication etcetera); and pro-environmental psychology (influences of information, pro-environment attitude, value-belief-norms); etcetera (Stephenson J., 2010). These various studies seek to understand human behaviour on energy use, identify motivations and hindrances for efficiency, improve awareness, and the importance of technological intervention programmes.

In this study, a literature review on barriers and drivers for energy efficiency in buildings has been carried out; and a behavioural change tool to influence energy use and CO_2 emission reduction has been developed. The study also examined the perceived behavioural control of occupants to office buildings' energy use, users' intention or willingness to change to more energy efficient habit, measured the level of perceived awareness and concerns for global environmental norms, and roles of attitude and intention in predicting occupants' energy consumption behaviour.

2. *Literature Review:*

2.1. Barriers and Drivers to Improve Energy Efficiency in Office Buildings

Behavioural change has been identified as one of the ways to tackle the inefficient use of energy in buildings. Lack of awareness by end-users and persistency of poor occupant's behaviour toward more efficient energy practices in sub-Saharan Africa have been identified as major barriers in a recent study (CREDC , 2009). Most respondents (68%) claimed they are not familiar with the term 'energy efficiency'. About 77% respondents identified lack of training, knowledge, and skills on energy management as barriers. The use of second-hand office and home equipment and appliances, poverty, lack of research and materials on energy efficiency, inefficient metering system, and low electricity pricing are also seen as barriers. Furthermore, Sambo (2007), cited other barriers as the lack of: policy to encourage, promote and incentivize energy consumption and energy efficiency; codes and regulations to groom energy efficiency and consumption programmes; adequate institutional frameworks (agency) for overseeing the formulation, coordination, implementation and monitoring energy conservation policies and programmes. Other barriers include lack of information on energy use data, public sensitization, enlightenment and awareness on the benefits of energy efficiency. In Nigeria, the availability of skilled manpower for energy management is a serious barrier for efficiency consumption, there is no trained manpower for an energy assessment, benchmarking and certification purposes. The skill required for low/ zero carbon building designs, constructions and operations is still grossly inadequate and constitutes a major hindrance to building energy efficiency measures, implementation and enforcement.

Furthermore, poverty and financial barrier are potent barriers and constraints which affect the achievement of low CO_2 emissions from buildings in Nigeria. World Bank classified Nigeria within the lower-middle income country with a poverty headcount of 46% as at 2010 (World Bank., 2015). It estimated Nigeria population at 178.5million with GDP of $521.8billion by 2014, and 46.0% of the population at poverty gap level of $2 per day. This presents a clear picture of her poverty level. The government cannot meet the electricity demand, and citizens are left with no choice than to struggle to meet only basic energy needs. This scenario has led to increasing use of generators both in domestic and office buildings. Most of the imported generators are sub-standard or fairly used and often characterized by very high emotions. The emissions from these onsite electricity generation are increasing and unstainable. The circumstance deepens energy poverty in Nigeria and other sub-Saharan African countries. Data from UNDP (GEF-UNDP, 2011), indicate that Nigerians spent approximately ₦769.6 billion (USD 89.5million) annually on fuelling generators as at 2011. About ₦450.9 billion (USD 69.2 million) was spent on diesel-powered generators, and ₦255.5 billion (USD 32.7 million) on petrol-powered generators respectively.

The dilapidating infrastructure for electricity generation and supply is another major barrier to building energy efficiency. The electricity generating capacity in the country dropped from 3,149MW in 2007, to 5,516MW in 2012 (E.C.N., 2009) and approximately 2,487MW presently. The citizens also experience 32times of electricity outage per month (World Bank., 2015), which further aggravate energy security issue in Nigeria and the sub-region. Therefore, the citizens are grasping for the short supply of electricity and not often interested in consumption efficiency. Finally, inappropriate pricing policy for electricity and prices of petroleum products is also a barrier, as it has been proven that subsidy discourages the efficient use of energy (Sambo, 2007). Nigeria electricity consumption is 40% fuel-based (NEP, 2005), hence subsidy on petroleum products affects energy consumption behaviour. Also, current electricity tariff in Nigeria is about ₦17.27/kWh (£0.06/kWh) national average. While UK's electricity tariff is £0.13/ kWh from grid and natural gas electricity is £0.04/kWh. The relatively cheaper prices of electricity, diesel and PMS in Nigeria may have contributed to the obvious inefficient behaviour of consumers.

Energy-efficiency best practices have been adopted as drivers for building energy use reduction worldwide. Standards and labels are a commonly used driver for promoting energy efficiency. It is now a common norm to see labels and standards specification on electric appliances worldwide (GEF-UNDP, 2011). This helps to inform potential buyers about the amount of energy a product can consume and the standard the product has met. There are two different kinds of labelling namely; endorsement label, which tells that a product meet a predetermined standard or eligibility criteria, and comparative label (linear, dial, and bar), which allow comparison of products efficiency by absolute scaling of their energy consumption through a simple numerical or ranking system (Harrington, 2004).

Energy performance standards are also used to drives energy efficiency in Europe and other developed countries. European's energy performance of building directive (European Commission Directive, (2002/91/EC)., 2009) and the UK building regulations 2013 part L (conservation of fuel and power) are few amongst the available examples. They set minimum energy performance standards for buildings energy consumption and associated emissions. The efficiency standards are mandatory and help reduce energy use and Carbon emissions from buildings in developed countries and also promote the efficient use of energy worldwide, (Lucon, 2014). This measure can be adopted for sub-Saharan African Countries.

Economic and fiscal incentives have also been identified as drivers for reducing energy consumption in Nigeria (Sambo, 2007). Soft loans (maximum of 5% interest rate), subsidies on energy efficient equipment (up to 30% initial capital cost), grants in form of designated bulk purchase of energy efficient appliances, tax rebate on purchases of energy-efficient equipment and appliances are some of the drivers that can help reduce energy use in Nigeria.

Institutional set up has been identified as incentives for energy efficiency. Sambo (Sambo, 2007) advocated the establishment of Nigeria Energy Efficiency and Conservation Agency, which will oversee energy conservation and efficiency issues in the country. The Department of Energy in the USA, the UK department of Community and Local Government etcetera oversees all building energy use policies in respective countries.

The creation of awareness through propaganda and enlightenment campaigns for building energy efficiency is also important. Ironically, the cost of energy to Africans especially Nigerians is soaring higher due to increasing standard of living, and use of fuel- or diesel-powered generators (GEF-UNDP, 2011). Often time, the cost data for fuel-electricity consumption is unavailable in contrast to the situation with grid electricity. Frequent power outage and social-economic lifestyle change, have led to the abuse of generators' use.

2.2.Current Models of Energy Consumption Behaviour

The most researched of all models of behavioural research are the Theories of Reasoned Action (TRA) and Planned Behaviour (Christopher, 2001). The theory of Planned Behaviour (TPB) is an extension of the TRA, which include the measure of control belief and perceived behavioural control. Ajzen (Ajzen, 2002), in the TPB, asserts that human's action is determine by three kinds of considerations: beliefs about the likely outcome of behaviour and the evaluations of these outcomes (behavioural beliefs); beliefs about the normative expectations of others and motivations to comply with these expectations (normative beliefs); and beliefs about the presence of factors that may encourage or discourage the performance of the behaviour and the perceived power of these factors (control beliefs). Behavioural beliefs are assumed to determine the attitude towards behaviour but are not assumed to determine the direct measure of attitude. Normative beliefs determine subjective norms but not a direct measure of subjective norms. While control beliefs determine perceived behavioural controls, but not the direct measure of perceived behavioural control. Attitude towards a behaviour is a person’s overall evaluation of performing the behaviour in question.

Stern’s Attitude-Behaviour-Context Model (ABC model) that excludes habits, was initially developed in 2002 (Martiskainen, 2008). ABC model of environmentally significant behaviour is based on the understanding that behaviour is a function of an organism and its environments. Behaviour (B) is an outcome of the interaction between personal attitudinal variables (A) and contextual variables (C). Our personal attitudinal variables include beliefs, norms, values, and a tendency to act in certain ways. Contextual factors include monetary incentives and cost, physical capacities and constraints, social norms, institutional and legal factors. In addition, the interaction between attitudinal variables and contextual factors is the fundamental dimension of the ABC model and hence it use for pro-environmental behaviour research like recycling.

While, Henry Triandis’ Theory of Interpersonal Behaviour was developed in 1977. It is based on the notion that intentions, habits, and external factors influence behaviour. In this Model, behaviour in any given situation is a function of what people intend, what his/her habits are, situational factors, and the condition in which the person operates. In addition, rational thought, social, normative, and emotional factors controls a person’s intention. Triandis’ Theory of Interpersonal Behaviour considered habits (Martiskainen, 2008).

Theory of Value-Beliefs-Norms was used by Ibtissem (Ibtissem, 2010), to explain energy conservation behaviour in the Tunisian context. He applied the principle of activation of personal norms by the values and beliefs of individuals. His Value-Belief-Norm was based on Schwartz’s theory of Norms Activation that is strongly inspired by the Altruistic Behaviour Model. The Model of Altruistic Behaviour is linear with positive/ negative consequences on other members of the environment. The research confirmed that the behaviour of energy conservation is positively, and also significantly connected to personal norms. This he said confirmed both Values-Belief-Norms and Norms Activation theories, which postulate that personal norms represent the determinant factor which is the closest to energy consumption behaviour.

Stephenson et al used energy cultures as a conceptual framework. The ‘energy culture’ framework provides a structure for solving the problems of multiple interpretations of behaviour because it is influenced by the interactions between cognitive norms, energy practices, and material culture. The culture-based approach to behaviour is drawn from lifestyles and systems thinking.

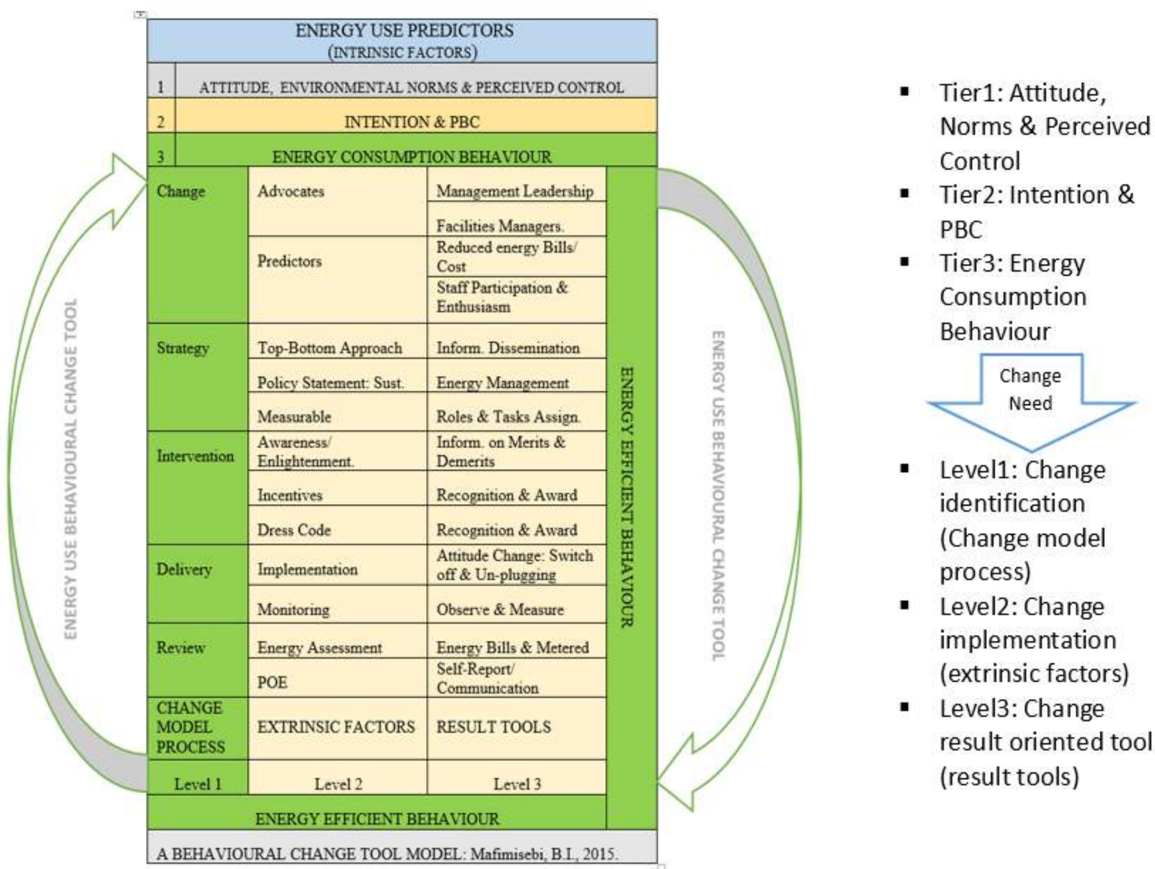
Finally, these theories and models serve as the basis for formulating a new behavioural change framework. A simplified, informative and incentivized model could help sub-Saharan Africans to change to energy efficient behaviour.

2.3. A case for a behavioural Change tool for Energy Efficiency in Nigeria office buildings

Information-based and incentive-based intervention programmes have been known to be good in changing consumption habit and attitude (De Bruijn, 2007). Hence, information and incentive are the bedrock of change tool for this study. People will change to more efficient energy consumption behaviour: if they believe it will benefits them (beliefs about the outcome); if the outcome of energy use and savings is visible, and provide clear goals and motives (evaluation of outcomes); and information is personalised and presented in a clear format (facilitating condition) (McMakin, 2002). Also, behaviour and lifestyle are crucial drivers for energy use in buildings. A building fitted with a central air conditioning unit will consume more energy than those with split units. However, energy use of similar functions and occupancy can vary by the impact factor of 2-10, depending on culture and behaviour. Hence, consideration for culture, norms, and occupants' behaviour for buildings and their energy infrastructure is crucial during design, construction and operations (Lucon, 2014).

The paper look at the behavioural change from perspective of the strategic change management process. The proposed model is based on the attributes of TPB, and Jones and White's model of Change (Jones K., 2008) for asset management. Drawing upon them, the new model deals with the peculiarities of Nigerian's energy consumption culture and concise behavioural change process.

The model used the direct measure method of TPB (Ajzen, 2002). It looked at intrinsic and extrinsic factors of energy consumption within office buildings in an organisation. The constructs of attitude/ habit, environmental norms, and perceived behaviour are the tier 1 level of influence. The Tier1 level of intrinsic factors determine energy consumption intention and PBC of users in an organisation (figure.2.4.1)



Occupants' attitude, their awareness on environmental issues, and power of their perceived control help formed their intention & PBC on energy use. Their intention and concern (Tier 2 level) for environmental norms has the strongest influence on their consumption behaviour (Tier 3). The totality of these intrinsic factors forms the individual energy consumption behaviour in office buildings.

Energy consumption behaviour is already formed at this stage, therefore, the need for change. The new model also contained a dynamic process for behaviour change, which involve; change identification (Change model process, level1), change implementation (extrinsic factors, level 2), and change result oriented tool (result tools, level 3). The change process model (Jones K., 2008), identified the change critical path: identifying change purpose, defining change strategy, drawing up intervention programmes, identifying deliverables, and reviewing change programme. The extrinsic factors (level 2) for efficient energy behaviour are; change advocates and predictors; top-bottom strategy, sustainability policy, and measurement; awareness and incentivised intervention programmes including dress code, deliverables through implementation and monitoring; and energy assessment and post-occupancy evaluation for review.

While the result-oriented tools for change (level 3) involve: management leadership style and FM being the advocates for change; reduced energy bills, staff participation and enthusiasm are identified predictors of positive change; information dissemination, energy management, and roles and tasks assignment are the strategy; and clear information on merits and demerits of energy use, recognition and awards for incentives and dress code compliance for inventions. Others include: attitude change, observations and measurement for implementing and monitoring change; energy bill, metered (data captured), POE (self-report) and two-way communications are the result tools needed for positive change to energy efficient behaviour.

Lucon O. et al, identified traditional behavioural approaches that support this model. The behaviour and local cultural factors, the way people adjust their thermostats during winter and summer or rainy and dry seasons, dress code (e.g. change in attire standards) and cultural expectations towards attires. The ‘cooling Biz’ initiative in Japan that relax certain business dress codes to higher thermostat setting is an exemplary tool (Lucon, 2014).

In Africa, it is noteworthy that, Nigerians put on suits and ‘agbada’ to offices during the hot dry season (with 27-41^{oC} range), it influences cooling load demand. The change of attires to the lighter dress code during the dry season can help reduce cooling energy demand. The study explored occupants perceived attitudes, environmental norms, and perception of behavioural control to develop the new change tool for energy efficient behaviour in office buildings.

3. *Research Methodology*

The paper looks at identified potentials and barriers to energy efficiency in office buildings through literature review; and predict occupants’ attitude and intention towards energy consumption behaviour through an online survey. It is a part of larger research project whose objective is to develop a tool that could positively influence occupants’ energy use behaviour. The research adopts a positivist and objectivist research paradigms, and used the quantitative method to deduce meanings and objective answers given to survey questions (Bryman, 2008). Similar studies carried out by Elmualim et al (Elmualim, 2010); and Akande (Akande, 2015), used survey method to gathered quantitative data on the perceptions of occupants’ in the UK. The survey questionnaire was piloted and accepted as the best tool for data collection based on discussions from stakeholder’s views.

An online self-administered questionnaire was developed and administered. The occupants of five selected case study buildings in Nigeria, and one in the United Kingdom were selected based on approval for use of buildings by the respective organisation. The questionnaire survey was considered the most suitable for examining the level of users’ knowledge, understanding, opinion and perception on office building energy use. The quantitative method has the advantage of eliminating bias on the part of the researcher in achieving the aim of the research by improving the overall strength of the study (Creswell, 2009 & 2013).

The online questionnaire was sent to 130 respondents in all case study office buildings and had about 82.0% (106) response rate. The behavioural data were collected based on occupants' energy use perception from self-report measurement for five office buildings in Nigeria, which were then analysed. The IBM's SPSS 20 version software package was used to analyse collected data (George, 2013). Drawing upon the TPB, four predictor variables that deal with the study topic were used to predict their energy consumption behaviour. These are occupants' perceived control (PC), concern for global environmental issues (norms), attitude/ habit towards energy use behaviour, and occupants' awareness. The direct measure and the use of TACT were adopted for all predictor variables, for the observation of compatibility.

4. *Results and findings*

A Cronbach's alpha reliability test was performed on all measured constructs to determine their consistency and reliability of the expected results (Rachad, 2013). Cronbach's alpha reliability coefficient normally ranges between 0 and 1, the closer it is to 1, the stronger the internal consistency of items measured in the scale. The result indicates the measure of occupants' perception on all four constructs having alpha's value of 0.824 and 0.852 on standardised items. It shows an acceptable strong reliability level at the acceptably alpha's value of 0.70 (Gliem, 2003).

4.1. Occupants' Perceived Behavioural Control.

Respondents were asked to rank their PBC exercised on services installations in respective buildings. A unipolar scale of 1-7 (from having no control to having full control) was used. Results for sampled population (N=91-95, valid N=84) as indicated in table4.1.1 below shows the statistical means (SM), standard deviation (SD), skewedness and kurtosis for PBC on mechanical heating installation, air-condition cooling equipment, daylighting, noise level, ventilation level, lighting installation and shading/ blinds in case office buildings:

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
Heating	91	1.00	7.00	3.6264	2.50177	.263	.253	-1.670	.500
Cooling	95	1.00	7.00	5.1368	2.33206	-.914	.247	-.855	.490
Day Light	92	1.00	7.00	4.8804	2.31499	-.683	.251	-1.129	.498
Noise level	95	1.00	7.00	4.2737	2.24766	-.155	.247	-1.482	.490
Ventilation	95	1.00	7.00	5.0316	2.17555	-.808	.247	-.790	.490
Lighting	94	1.00	7.00	5.4468	1.83524	-1.209	.249	.545	.493
Shading (Blinds)	91	1.00	7.00	5.1868	1.97153	-.853	.253	-.432	.500
Valid N (list wise)	84								

Table 4.1.1. Descriptive Statistics for PBC on Building Services Installation

Note:
Table 4.1.2 and Figures 4.1- 4.7 below, most respondent (53.9%) have no control on heating installation, and about 70.6% of occupants said they have control on cooling installations. Those that have control on daylight gain add up to 64.10%, and 48.4%

have control for noise level. Other variables are: ventilation, have control (66.30%), no control (23.20%), and neutral (10.50%); while for lighting, have control (76.50%), no control (12.80%), and neutral (10.60%); and shading, have control (66.00%), no control (18.70%), and neutral 18.70%.

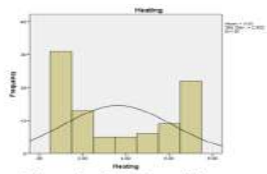


Fig.4.1: Heating

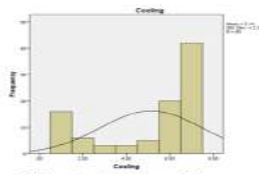


Fig.4.2: Cooling

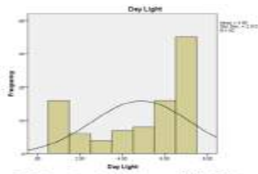


Fig.4.3: Daylight

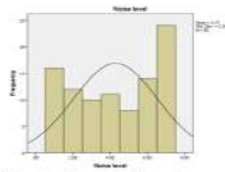


Fig.4.4: Noise level

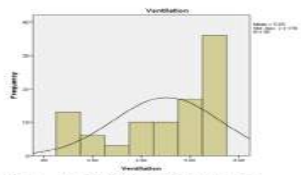


Fig.4.5: Ventilation

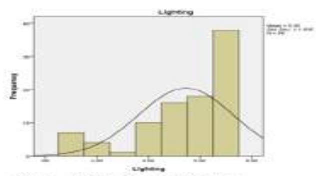


Fig.4.6: Lighting

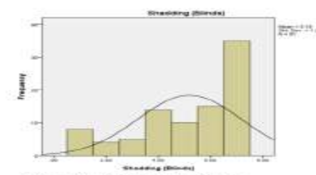


Fig.4.7: Shading

Occupant's Reponses for PBC on Service Installation in Buildings			
Frequency	Having control	Having Neutral control	Having No control
Heating	40.7%	5.5%	53.9%
Cooling	70.6%	2.8%	26.3%
Day light	60.1%	28.2%	7.6%
Noise level	48.4%	39.9%	11.6%
Ventilation	66.3%	23.2%	10.5%
Lighting	76.5%	12.8%	10.6%
Shading- Blinds	66.0%	18.7%	18.7%

Table 4.1.2 Occupant's Frequency Table for PBC

The finding shown in tables 4.1.1 and 4.1.2, reveals occupants PBC for lighting installations has the highest (77%) frequency with SM (5.45), indicating strong influence on lighting energy use. Next is cooling (71%) with SM (5.14). Other findings are: ventilation (66%) with SM (5.03); shading/blinds (66%) and SM (5.19); daylight recorded 64% and SM (4.88), noise level scored 48% and SM (4.27), and heating scored 41% on PBC and SM (3.63). Most of the staff (71% of respondents) agreed they influenced and controlled the use of cooling and lighting installations in these buildings. This indicates that building lighting and cooling energy use in these offices are influences by at least 71% by the occupant behaviour.

The degree to which any two of these variables have linear relationship was tested with two-tailed Spearman's Rank correction coefficient test [26]. Respondents' PBC for cooling to cooling (N=90- 95) was positively perfect at 1.000. Results for cooling to heating (.469**), cooling to daylight (.494**), cooling to noise level (.514**), cooling to ventilation (.691**), and cooling to lighting relationship (.663**) are positive with strong perfect linear relationship at 1% (0.01) level of significant.

4.2. Occupants' Energy Efficiency Habit and Attitude.

Occupants were asked to rank their energy efficiency habit/ attitude on a 5-point Likert scale from strongly disagreeing to strongly agree. The result (N=88-99), as shown in tables 4.2.1 & 4.2.2 and figures 4.8- 4.12 revealed, the SM, SD, skewness and kurtosis for: I do switch off (light and plug-in-loads) in fig4.8; I do switch off (my computer and other appliances) in fig4.9; I switch off often (generally) in fig4.10; I switch off sometimes (generally) in fig4.11; and I don't switch off (generally) in fig4.12 below:

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
I do switch off: Light and Plug-in Loads	91	1.00	5.00	4.1538	1.18249	-1.418	.253	1.035	.500
I do switch off: My Computer and other Appliances	95	1.00	5.00	4.5579	.97540	-2.590	.247	6.277	.490
Shading (Blinds)	91	1.00	7.00	5.1868	1.97153	-.853	.253	-.432	.500
I switch off often: Generally	89	1.00	5.00	3.6966	1.41746	-.766	.255	-.782	.506
I switch off some times: Generally	87	1.00	5.00	2.2644	1.35938	.783	.258	-.716	.511
I don't switch off: Generally	88	1.00	5.00	1.8182	1.34374	1.417	.257	.494	.508
Valid N (list wise)	81								

Table 4.2.1. Descriptive Statistics for Habit & Attitude

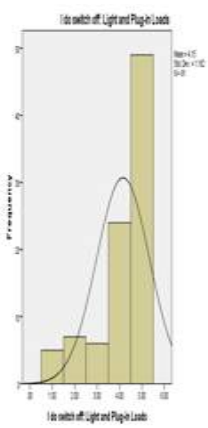


Fig.4.8

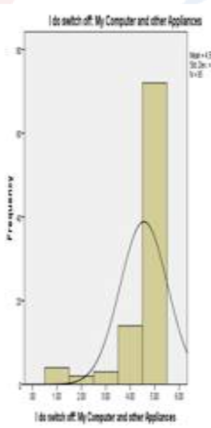


Fig.4.9

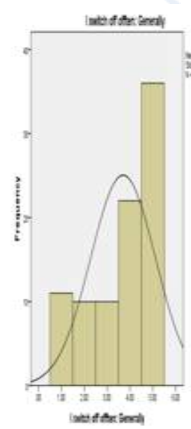


Fig.4.10

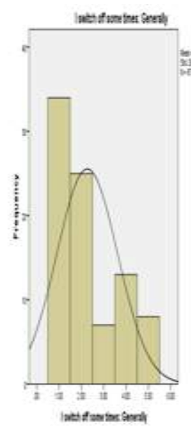


Fig.4.11

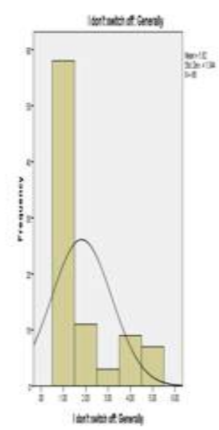


Fig.4.12

Occupants' Energy Efficiency Habit and Attitude			
Frequency	Agreed	Neutral	Disagreed
I do switch off (light and plug-in-loads)	70.2%	6.5%	13.2%
I do switch off (my computer and other appliances)	90.0%	3.2%	6.3%
I switch off often (generally)	65.0%	11.2%	13.6%
I switch off sometimes (generally)	24.3%	8.0%	67.8%
I don't switch off (generally)	28.2%	3.4%	78.4%

Table 4.2.2 Occupant's Frequency Table for Energy Efficiency Habit & Attitude.

Findings for occupants' habit / attitude shown in tables 4.2.1 and 4.2.2 above, indicate rate of response as thus: I do switch off (light and plug-in-loads) add up to 70.20% (agreed) and SM (5.45). Those affiliated with I do switch off (my computer and other appliances) had the highest (90.00%) response rate and SM (5.14). It revealed strong occupants' habitus and positive attitude towards electrical energy use. Others are: I switch off often (generally) with 65.00% (agreed) and SM (3.70); and I switch off sometimes (generally) have 67.80% (disagreed) and SM (2.26). It confirmed that most occupants do have the habit of switching off generally and positive attitude toward efficiency. While responses to I don't switch off (generally), 78.40% (disagreed) and SM (1.82), correlate with earlier result confirming occupants' positive attitude towards switching off.

Two-tailed Spearman's correction coefficient test for ranked data was performed for linear relationship as thus:

I do switch off (my computer and other appliances) to I do switch off (light and plug-in-loads) indicates rs value of .591** with p value= .000 at 1% level of significance. This is a strong positive linear relationship, which confirmed that they have both habit, and their attitude to the two variables is the same.

I do switch off (my computer and other appliances) to I switch off often (generally) has r_s value = .298** with a p-value of .005 significant level. The result emphasised weak positive linear relationship at 1% significant level between them.

I do switch off (my computer and other appliances) was compared to I do switch sometimes (generally), the r_s value was -.069 with p-value =.523 level of significant. This is a weak negative correlation.

I do switch off (my computer and other appliances) to I don't switch off (generally) was also compared. Result shows r_s = -.306 and value = .004 significant level. It also a weak negative linear relationship.

Finally, the linear relationship of two extreme opposite variables, I switch off often (generally) was compared to I don't switch off (generally). The result indicates the r_s value of -.231** and p-value of .031, which is a strong negative linear correlation at 1% significance level.

4.3. Respondents' Awareness on Environmental Norms (Issues).

Respondents were asked to rank their awareness level on global environmental norms. The 5point Likert scale (strongly disagreeing to strongly agree) for direct measure of awareness (N=94-95) was adopted. Table 4.3.1, & 4.3.2 and figures 4.14 to 4.20 (normal distribution curves) below, revealed results as follows:

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Climate Change	95	3.00	5.00	4.2842	.63015
Sustainable Development	95	1.00	5.00	4.1158	.87352
Global Warming	94	1.00	5.00	4.2766	.69413
Carbon Dioxide Emission	94	2.00	5.00	4.1809	.81601
Energy Efficiency	94	1.00	5.00	4.1170	.90228
Carbon Footprint	94	1.00	5.00	3.4787	1.15217
Building Energy Efficiency Performance	94	1.00	5.00	3.7340	1.08930
Valid N (list wise)	91				

Table 4.3.1. Descriptive Statistics for Awareness on Environmental Norms

Respondents' Awareness on Environmental Norms (Issues)			
Frequency	Awareness	Unawareness	Unsure
Climate Change	90.5%	0.0%	9.5%
Global Warming	91.5%	1.1%	7.4%
Sustainable Development	84.2%	5.3%	10.5%
Carbon Dioxide Emission	83.0%	12.8%	4.3%
Energy Efficiency	83.0%	4.3%	12.8%
Carbon Footprint	55.3%	22.3%	22.3%
Building Energy Efficiency Performance	64.0%	13.9%	21.3%

Table 4.3.2 Occupant's Frequency Table for Awareness on Environmental Norms.

About 90.50% are awareness of Climate Change with SM (4.28), SD (0.63) and only 9.50% are unsure of it awareness. Global Warming is the highest (91.50%) with SM (4.28), SD (0.69), unaware (1.10%) is low, and 7.40% (unsure); Sustainable Development awareness level add up to 84.20% with SM (4.128), SD (0.87), 5.30% (unawareness), and 10.50% (unsure). Also, 83.00% are aware of CO_2 emissions with SM= 4.12, SD= 0.82 and few (12.80%) are unaware, and 4.30% (unsure). 83.00% are aware of Energy Efficiency with SM= 4.12, SD = 0.90 and few respondents, 4.30% (unaware), and 12.80% (unsure). While Building Energy Performance scored relatively low awareness (64.90%) with SM of 3.73, SD= 1.09, and increasing unaware (13.90%) and unsure (21.30%) levels. Relative awareness level (55.30%) also decreased as it relate Carbon Footprint to buildings with SM (3.48), SD = 1.12, and increased level of unaware (22.30%) and those unsure of it awareness (22.30%).

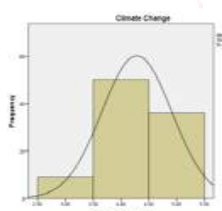
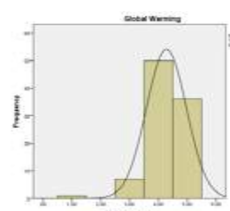
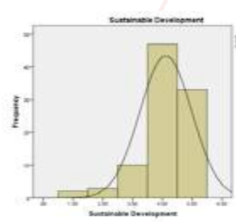
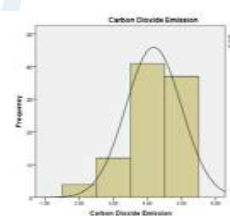





Fig.4.13: Climate C. Fig.4.14: Global Warm. Fig.4.15: Sus. Dev. Fig.4.16:CO_2Emission

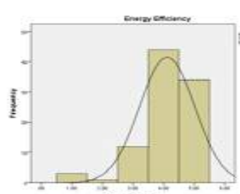
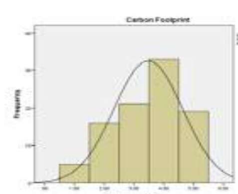
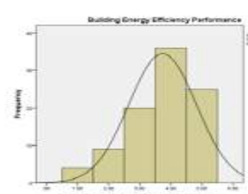




Fig.4.17: Energy Eff. Fig.4.18: Carbon Ft. print Fig.4.19. Bldg. Eff. Perfm.

Finally, results for all four variables reveal that awareness on global environmental issues among corporate staff is high generally also shown in figures 5.13 to 5.19 on their normal distribution curve above. However, it was observed that awareness on environmental norms decreases comparatively in relation to building energy performance and carbon emissions from it. The level of unawareness for these two variables (at 24.55% and 33.45% respectively) was high compared to the other variables.

4.4. Occupants' Willingness (indicated Intention).

Finally, respondents were asked to rank their concerns on a willingness to change to more energy efficient behaviour, reduce building energy use, carbon footprint, and global warming. A direct measure of intention (N=93-95) was adopted, using the Likert 5point scale of not fully concern to fully concern, and the result as shown in table 4.4.1 and figures 4.20- 4.23 below indicates the following:

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
Willingness to change to more energy efficient Habit	95	2.00	5.00	4.3053	.71569	-.883	.247	.776	.490
Willingness to Reduce Carbon footprint of this building	93	2.00	5.00	4.1505	.82021	-.891	.250	.545	.495
willingness to Reduce this building's energy Consumption	95	2.00	5.00	4.2105	.83659	-1.085	.247	.919	.490
willingness to reduce Global warming	93	2.00	5.00	4.4194	.82518	-1.516	.250	1.870	.495
Valid N (listwise)	92								

Table 4.4.1. Descriptive Statistics for Occupants' Willingness (Indicated Intention)

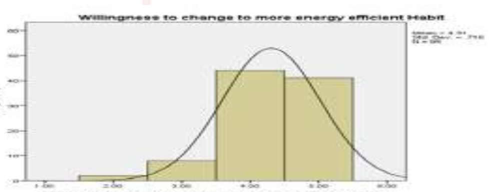


Fig. 4.20
Willingness to Change to E.E. Habit

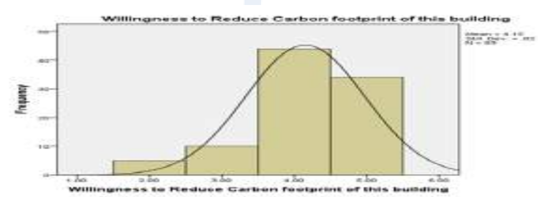


Fig. 4.21
Ditto to Reduce Carbon Footprint

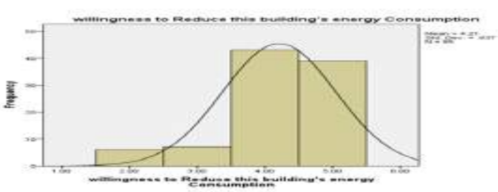


Fig. 4.23
Ditto to Reduce this Bldg. Energy Use

Fig. 4.24
Ditto to Reduce Global Warming

Respondents' willingness to change to more energy efficient habit have statistical mean (SM) of 4.31, SD= .716, skewness= -.883 and kurtosis = .776. Their level of concern and willingness add up to 89.50%, just a few (8.40%) are neutral and are not willing (2.10%).

Occupants' willingness to reduce carbon footprint of building have SM = 4.15, SD= .820, skewness= -.891 and kurtosis = .545. Response indicates that majority, about 83.90% (concern), 5.40% (unconcern), and 10.80% (neutral) to issue of carbon footprint

Willingness to reduce case study building energy consumption SM is = 4.20, SD = .837, skewness = -1.10, and kurtosis = .919. It concern scored high with 86.40% (concerned), 6.30% (unconcerned) and 7.40% (neutral). It correlate with staff's willingness to change to better energy efficient habit with same SM (4.20).

Willingness to reduce global warming have SM of 4.42, SD of .825, skewness= -.1.512, and kurtosis of 1.87. The highest response with 89.30% are concerned for global warming, 6.30% (unconcerned) while 7.40% (neutral).

5. *Discussions and Conclusion.*

The literature emphasised the need for creation of awareness and vigorous campaign to drive building energy efficiency. It also stressed the possible need for information-based and incentive-based intervention programmes for the change based tool. The study reveals that the majority of respondents (83.00% and above) are aware of Climate Change, Global Warming, Sustainable Development, Carbon Dioxide Emissions, and Energy Efficiency. However, the awareness level decreased with Building Energy Performance (64.90%) and buildings' Carbon Footprint (55.30%). This trend indicates a low appreciation of environmental norms relationship with building energy use. This is due to lack of information and enlightenment on building energy use and carbon emissions.

Drawing from the TPB, the study deployed the direct measure, belief on various constructs was not considered. Therefore, direct measurement of occupants' attitude, norms and controls combined to inform their intention towards energy consumption behaviour. The findings revealed that most occupants' (66-77%) have strong perceived behavioural control on service installations (lighting, cooling ventilation, and shading/blinds). There is also a perfect positive linear correlation between cooling systems and other services at 1% (0.01) level of significant. The level of perceived control for their habit is high and strong due likely to energy conservation.
Moreover, more than 70.00% of occupants have the habit of switch-off for electrical equipment (lights, plug-in-loads, computer and other appliances). This revealed strong occupants' habitus and positive energy efficiency attitude. About 65.00% agreed they switch-off often (generally) in correlation with 78.40% who disagreed that they don't switch off (generally). Their linear relationship (extreme opposite variables) when compared, resulting r_s value of -.231** and p-value of .031, which is a strong negative linear correlation at 1% significance level. This clearly indicates that respondents have a switch-off habit and their consumption attitude is energy efficient.
Furthermore, 89% respondents and above are concerned and willing to change to more energy efficient habit and reduce global warming. While their intention and concern decreased (84.00-86.00%) for reducing building energy use and carbon footprint. The result clearly show the intention of occupants on the issue of building energy consumption. Their intention for energy efficiency based on environmental norms is already strong, but weak for buildings and CO_2 emission.
Relatively, low awareness on building energy use and associated CO_2 emissions was identified. The case study occupants did actually satisfied the direct measure for attributes of attitude towards their habit, subjective norm and PBC based on TPB model. Also, their strong intention for energy efficient behaviour is based on environmental norms rather than building energy performance. This can be harnessed for building energy efficiency through the formulated behavioural change tools for organisations using commercial buildings in Nigeria.

Finally, the model advocate information- and incentive-based intervention programme within a TPB based strategic change process for corporations. A change in dress code standard, for example dressing lighter during hot seasons can help reduce cooling energy demand in Nigeria. Also, simple switch-off stickers and posters on a computer, table desks' top, entrance wall near switch's points, etcetera can be useful. While sensitization programmes (competitions like energy efficient staff of the month, the green staff of the month) can help improve awareness. These can change staff energy behavioural attitudes and drives stronger intentions toward building energy use efficiency.

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Fog: An Important Water Source in Arid Zones

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The Third European Conference on Sustainability, Energy & the Environment 2015
Official Conference Proceedings

Abstract
In semiarid and arid zones, fog is considered an important alternative water source. The southeast Pacific anticyclone, the cold Humboldt Current and the prominent coastal topography that characterize the north of Chile promotes the formation of low stratocumulus along the coastline. The thermally induced winds move these low clouds eastwards and, in the hills of the Coast Range higher than 600 m, persistent fog episodes can be observed.

The goal of this work was to characterize fog water collection and its relation with atmospheric variables. To achieve this, an experimental station equipped with a meteorological station and a Standard Fog Collector (SFC) was installed in El Sarco, a coastal hill located in the semiarid area of Chile known as Norte Chico. Near the station, a large fog collector of 150 m^2 designed by an engineer team in Chile was installed. The collected water was used to restore a selected area with relict vegetation.

We found that the wind regime was compatible with a land-sea circulation, where the wind speed was stronger during the day than at night. Fog water (FW) collection increased with wind speed and occurred when the wind came from the ocean, as well as when it came from the opposite direction. The shape of the diurnal cycle of the mean FW collection was dependent on the season, and on average, it had two maximum peaks at 07:00 LT and 20:00 LT. The daily average per month ranged between 1.7 l day^{-1} and 5.0 l day^{-1} and occurred in August and January, respectively.

Keywords: fog water collection, meteorology, arid zones

Introduction

Because of its influence on human life, fog has been the focus of many scientific studies. On the one hand, it represents a hazard to air, road and marine traffic with significant economic loss, but on the other hand, fog is an important hydrological resource for replenishing aquifers, for promoting reforestation and for human needs (Gultepe et al., 2007, Möller D., 2008, Klemm et al., 2012). However, the intensive study of fog, as well as its formation and dynamics, are complex processes that require further understanding.

Many studies and field experiments have demonstrated that the coast of South America exhibits geographical and topographical characteristics that make it suitable for the presence of fog most of the year. The interaction between the Humbolt current and the Southeast Pacific anticyclone favors the presence of well-formed stratocumulus clouds (Sc) that are transported inland by the trade winds and a sea-breeze circulation. When these clouds intercept the coastal topography, advection fog events can be observed. Furthermore, when air rich in humidity is forced by the wind to rise to the prominent relief of the Coast Range, the air cools and promotes the formation of orographic fogs (Garreaud et al., 2008).

Fog water (FW) is a sustainable water resource for reforestation and human needs (Domen et al., 2014). During the last century, experiments to measure FW collection have been performed in many places around the world using various prototypes of mainly different kinds of mesh. For example, in Lanai (Hawaii), several hundreds of Norfolk Pine trees were planted in the mountain summits to collect fog water and replenish aquifers (Olivier, 2004).

Chile is a pioneer in using fog to obtain fresh water for human needs. In 1992, a system of 100 large fog collectors (LFG) were installed in El Tofo, a hill of 700 m altitude located in the Coastal Range of the semi-arid Coquimbo Region in Chile. The water harvested from fog was used to provide fresh water to Chungungo, a fishing village with 300 inhabitants. During more than 8 years, fog was the only water source for this village.

This experience has been replicated in different parts of the world where water is scarce and the occurrence of fog events happen often enough to make the collection of fog water convenient (Cereceda et al., 2003; Marzol, 2008; Marzol & Sanchez, 2008; Marzol, 2010; Oliver 2004; Oliver & Rautenbach, 2002, 2007; Oliver et al., 2012; Schemenauer et al., 1987, 1988, 2004; Cereceda & Schemenauer, 1991; Schemenauer & Cereceda, 2013). Currently, Morocco and Guatemala are communities in which the only water source is from fog collected by LFC. The location of sites where fog has been or is actually used as a fresh water source can be found in Klemm et al., 2012.

Fog is defined as a cloud that touches the Earth´s surface leading to a reduction in visibility less than 1 km (Fessehaye et al., 2014). With regards to visibility, fog can be characterized as dense, thick, moderate and light which pertains to ranges of 40 - 70 m, 10 – 250 m, 250 – 500 m and 500 – 1000 m, respectively (Awan et al., 2009).

Technologies to collect fog water are simple. The working principle is to expose a mesh to a foggy environment. Water droplets carried by the wind are pushed through the mesh where they condense. With successive impacts, the droplets grow until they are large enough to fall by gravity and the water can be collected (Klemm et al., 2012).

The quantity of water that can be collected from fog is measured by a Standard Fog Collector (SFC), a square Raschel mesh with an area of 1 m^2 that is installed 2 m above ground level (agl) (Schemenauer and Cereceda, 1994). This system allows the comparison of potential FW collection in different sites.

Experiences carried out in different parts of the world show that it is possible to collect considerable quantities of water by artificial devices or Large Fog Collectors (LFC) (Schemenauer et al., 1987, 1988; Cereceda et al., 2003; Schemenauer & Cereceda, 1991; Klemm et al., 2012, Marzol et al., 2008; Marzol, 2010; Olivier et al., 2004, 2012).

The collection of FW depends not only on the presence of fog, but also on meteorological variables such as wind direction, relative humidity, dew point depression, and most importantly, wind speed (Hiatt et al., 2012, Caceres et al. 2007). Other factors that influence FW collection are the orientation of the mesh and its collection efficiency.

In this paper, we analyze the relationship between FW collected by a SFC and meteorological variables. The study was based on results obtained from an experimental station located in the Coastal range 15 km south of El Tofo where the first successful project was performed in Chile.

Study site

The study site was located on a hill called El Sarco (29.51ºS, 71.27º W and 700 m altitude) in the Coast Range of the semi-arid Coquimbo Region in Chile, 7 km from the coast, 43 km north of the city La Serena, the main city of the region (Figure 1).

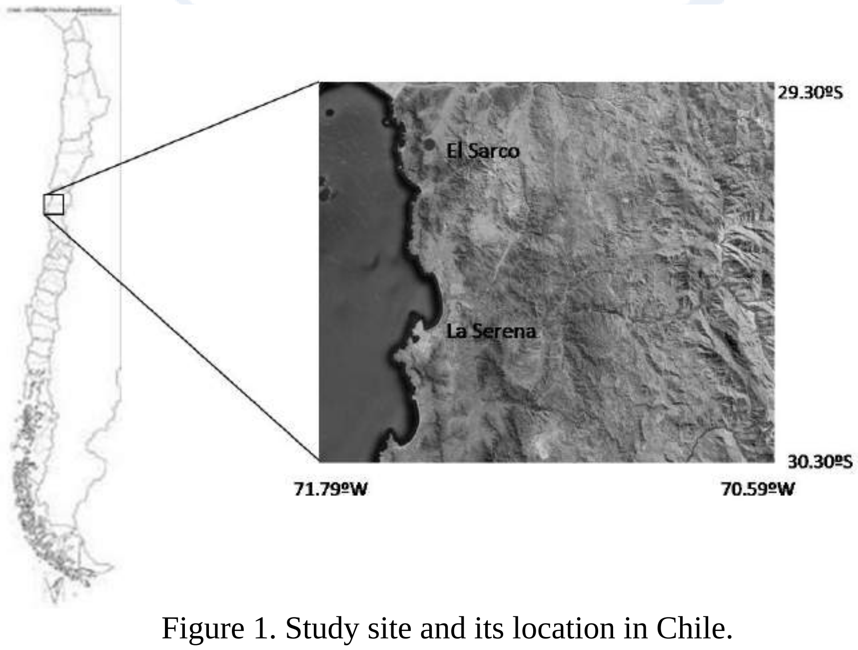

Figure 1. Study site and its location in Chile.

The climatic characteristics are influenced by the cold Humboldt Current which moves northwards along the Chilean coast and the southeast Pacific high pressure area that produces a light southerly wind. The site is a saddle point of two mountains of around 1000 m altitude forcing the moist air masses coming from the sea to converge, increasing the probability of the occurrence of fog events.

Experimental design

The experimental station, shown in figure 2, consisted of a Campbell meteorological station equipped with sensors for wind speed, wind direction, temperature and relative humidity (RH) at 2.5 m and 10 m above ground level (agl), and a rain gauge. Near the meteorological station, a SFC oriented in a SW direction (230°) was installed. The water collected by the SFC was measured by a second rain gauge. Both meteorological data and water collected were registered each 3 seconds and stored each 10 minutes.

Figure 2. Experimental station. Left: meteorological station and SFC. Right: Large Fog Collector

Near the experimental station, a LFC of 150 m^2 area designed by an engineer team in Chile was installed. The water harvested from fog was used to restore an area with relict vegetation.
The results presented in this work are from data collected for one year from June 18, 2014 until June 17, 2015. For the purposes of this article, only meteorological variables registered at 2.5 m agl were analyzed.

Results

Air temperature and humidity

Both temperature and RH experiments demonstrated important day to day variations. If fog was present, the RH achieved near saturation values and the amplitude of the diurnal cycle of temperature was small. The higher variations in temperature occurred in winter where the minimum and maximum temperatures were reached. The lowest and highest temperature at 10 minute averages were 29.6° C and 3.74° C achieved on the 17^{th} of August at 10:30 LT and the 1^{st} of July at 04:40 LT, respectively.

The high fluctuations in temperature in the winter time can be observed in figure 3, where the mean daily and monthly temperatures are shown. The minimum and maximum mean daily temperatures were 6.7° C and 25.6° C achieved in July and August, respectively.

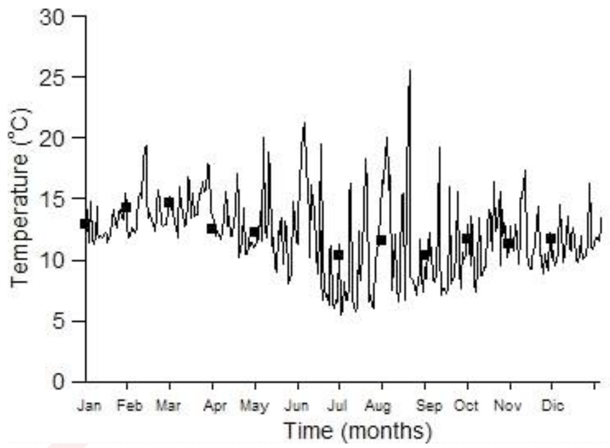

Figure 3. Daily (solid line) and monthly (squares) average temperatures.

The monthly temperature average demonstrated small variations during the year. The values ranged between 10.4° C, reached in July and September, and 11.7° C observed in October and December.
The behavior of RH was opposite to the temperature. It ranged between 5% and near saturation values. The minimum and maximum mean monthly averages were 70.6% and 92.2% obtained in August and April, respectively (not shown).

Wind speed and direction

The wind characteristics of the site were compatible with a land-sea circulation. During the day, the wind blew from the land to the sea (S-W) and at night it blew in the opposite direction (N-E). The wind direction distribution shown in figure 4 reveals that there are two predominant wind directions corresponding to the day and night winds.

The wind speed ranged between calm and 13.1 m s^{-1} stronger during the daytime than at night. The higher fluctuations in wind speed occurred during the winter months of June, July, and August (Figure 4). The monthly wind speed average exhibited small variations during the year. The minimum monthly averages was 2.9 m s^{-1} achieved in in July and August, and the maximum one was 3.9 m s^{-1} reached in December.

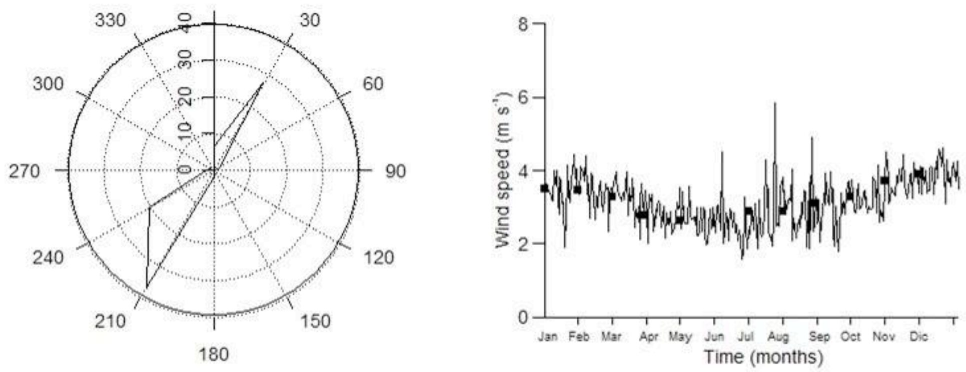

Figure 4. Left: Wind direction distribution. The labels are in degrees and indicates where the wind is blowing from. Right: daily (solid line) and monthly (squares) wind speed average.

Water collected by the SFC

In order to analyze the water collected (WC) from fog and its relation with meteorological parameters, meteorological data were averaged at 1 hour intervals. In the case of FW collected, the accumulated value in the same period was calculated.

We found that the maximum FW collection was 4.2 L m^{-2} h^{-1} and occurred on July 22 at 090:0 LT during a precipitation event. Regarding precipitations, the highest harvest of fog water was 2.6 L m^{-2} h^{-1} and occurred on September 21 at 18:00 LT.

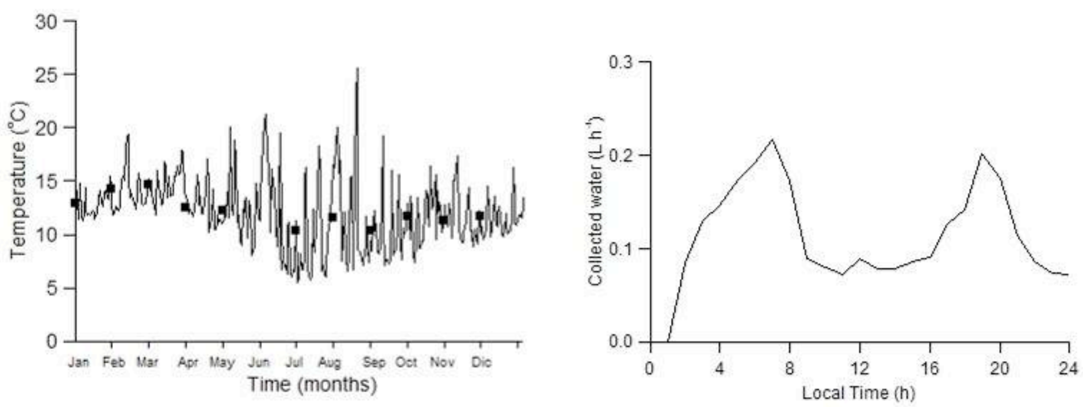

Figure 5. Water collected by the SFC. Left: one day intervals (solid line) and monthly daily average. Right: mean diurnal cycle in a one-year period.

Figure 5 displays the daily and the daily monthly average of water collected by the SFC. We found that the mean daily FW collected was 2.7 L m^{-2} day^{-1}. The maximum daily FW collected was 19.5 L m^{-2} day^{-1} on July 22 during the precipitation event mentioned above. Excluding this value, the highest collection was 16.0 L m^{-2} day^{-1} and occurred on October 8. The monthly daily FW collection was higher in the summer than in winter. The months with the lowest and highest FW collection were August and January with 1.7 L m^{-2} day^{-1} and 5.0 L day^{-1}, respectively.

The mean diurnal cycle of FW collected by the SFC showed two maximum peaks at 07:00 and 20:00 LT, with values of 0.23 L m^{-2} h^{-1} and 0.20 L m^{-2} h^{-1}, respectively (Figure 5). During 09:00 LT and 16:00, the mean water harvest from fog was approximately constant and equal to around 0.08 L m^{-2} h^{-1}.

Fog water collection and meteorological variables

Figure 6 displays the relation between FW collection and wind velocity (speed and direction). We found that the FW collection increased with wind speed, which can be explained because the liquid water flow incident on the mesh increases with wind speed. The right panel in figure 6 shows that FW collection occurred with both S-W winds, when the wind blew inland from the Pacific Ocean, and with N-E winds, when the wind blew in the opposite direction.

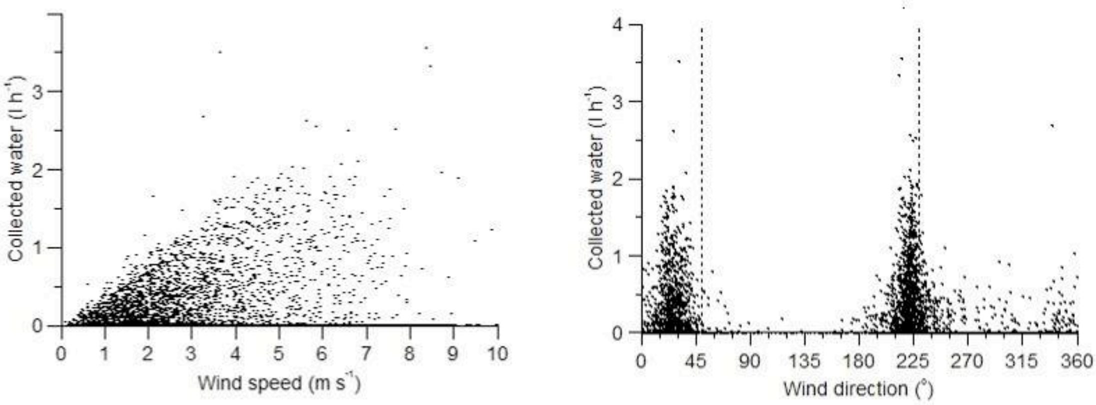

Figure 6. Relation between water collection and wind speed (left) and wind direction (right). The vertical dashed lines represent the orientation of the mesh

Summary and discussion

In this paper we analyzed FW collected by an SFC and its relation with meteorological conditions.

The principal findings were:

- There are variations in FW collection during the year. In the summer when water is normally scarcer, WC is higher than during the winter months. The daily monthly average ranged between 0.7 L m^{-2} day^{-1} and 5.0 L day^{-1} obtained in August and January, respectively. On average, the FW collection was 2.7 L m^{-2} day^{-1}.

- The highest fluctuations in temperature and RH occurred in the winter and autumn months. During fog events, the RH remained near saturation values, whereas the temperature stayed approximately constant.

- The wind behavior was compatible with land-sea circulation. During the day, the wind blew from the southwest in the direction from the ocean to inland, and during the night it blew in the opposite direction.

- FW collection increased with wind speed. This fact can be explained because more water droplets condense onto the mesh when there is more wind.

- FW collection occurred when the wind was coming from both the ocean (southwest direction) and the opposite direction (northeast).

Finally, we would like to emphasize that if the mean FW collected in El Sarco was 2.7 L m^{-2} day^{-1}, the quantity of water that could be harvested from fog using an LFC of 150 m^{-2} area similar to the one installed in our experimental site, would be almost 400 L day^{-1}. A system of several ATN would have the capacity to harvest a large quantity of water to be used for different purposes. Therefore, the results from our study confirm that fog represents a sustainable water resource.

Acknowledgments

This research was funded by Project Dominga of Andes Iron, SpA, and it is attached to the Plan de Mejoramiento Institucional en Eficiencia Energética y Sustentabilidad Ambiental ULS-1401.

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Residual Biomass: A Silver Bullet to Ensure a Sustainable Bioeconomy?

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The Third European Conference on Sustainability, Energy & the Environment 2015
Official Conference Proceedings

Abstract
The transition to a bioeconomy is generally considered as a step towards increased sustainability. However, increased biomass production can have several negative impacts and as a consequence, many cultivated biomass resources are unsustainable, thereby counteracting the sustainability objective of the bioeconomy. One proposed alternative is the use of residual biomass: biomass that is not cultivated for the use in a bioeconomy directly, but is a waste product of other processes. Since residual biomass is not produced on agricultural land it appears to be a silver bullet for sustainable biomass supply. But is that really the case? This paper discusses conditions that determine whether the use of residual biomass is indeed sustainable. Based on an extensive literature review we conclude that residual biomass is not a silver bullet, but can contribute to sustainability under certain conditions. Most importantly, the consequences for sustainability of changing current use have to be evaluated. Residual biomass is only seldom purely waste and regularly fulfils other functions, such as maintaining soil quality or providing habitats. The benefits of extracting residual biomass for new applications, thus causing a resource use change (RUC), have to outweigh the loss of their former function. Furthermore, not all residual biomass uses contribute to sustainability equally. Applications should be optimized to achieve various sustainability goals. Advances can be achieved through adapting technologies and logistics and increasing synergies between biomass-processing sectors.

1. Introduction

Global challenges, such as reducing human dependence on fossil resources and emissions of greenhouse gases (GHG) causing human-induced climate change, are drivers for the development of a bioeconomy, in which biomass replaces fossil resources in various supply chains. The importance of sustainability in the development of a bioeconomy is broadly recognized (Pfau, Hagens, Dankbaar, & Smits, 2014). However, it is heavily debated whether an increased use of biomass resources contributes to a more sustainable situation. If biomass demands cannot be met in a sustainable way, the sustainability objective of the bioeconomy cannot be reached. Especially negative effects on GHG emissions and ecosystems of land use change in favour of increased biomass production are noted (e.g. Searchinger et al., 2008). One strategy that is often proposed by researchers and policy makers to avoid negative impacts of increased production is the use of residual biomass. Since residual biomass does not have to be produced on agricultural land, the initial assumption is that through avoiding land use change it is a sustainable alternative to biomass crops. Furthermore, it is generally assumed to be cheaper than cultivated biomass. All in all, residual biomass use appears to be an effortless, immediate and fail-safe solution to a complex problem for sustainable biomass supply. But can residual biomass really be the “silver bullet” enabling a sustainable bioeconomy?

The goal of this paper is to discuss conditions that determine whether use residual biomass contributes to sustainability. First, biomass supply and demand and their consequences on sustainability are discussed, reflecting shortly on the historical perspective of biomass use. Subsequently, Section 3 reflects on proposed strategies to mitigate these consequences, focusing on residual biomass. One important aspect of residual biomass use, called resource use change, is highlighted in Section 4. Section 5 discusses how different applications of residual biomass are related to sustainability. Reflecting on currently handled sustainability criteria the paper finally elaborates on conditions for the sustainable use of residual biomass.

2. Biomass supply and demand in the past and present: consequences for sustainability

Before the Industrial Revolution, biomass-based energy and other renewable energy sources dominated energy supplies (Meredith, 2013; Stern & Kander, 2012; Wrigley, 2013). These were mostly replaced by fossil energy carriers during and after the Industrial Revolution in Europe, initially dominated by burning coal instead of wood (Wrigley, 2013). Biomass applications as materials have undergone similar developments around a century later. Chemical research was initially driven by the potential to convert biomass into fuels and chemical products, and until the beginning of the 20th century many chemical materials were based on biomass. Petroleum-based products later gradually displaced most of these biomass-based products with the rise of the petrochemical industry in the 1950s (Pawelzik et al., 2013; Ragauskas et al., 2006; van Wyk, 2001; Veraart, van Hooff, Lambert, Lintsen, & Schippers, 2011).

For various reasons, efforts are currently being made to reduce or even abandon our consumption of fossil resources. These developments have stimulated the expansion of applications and modern technologies for biomass use. Contemporary applications accompany traditional biomass uses and include both new sources of energy and materials, for example biofuels and bioplastics. The new opportunities to replace fossil resources with biomass have contributed to the vision of the so-called bioeconomy. Where in the past biomass inputs for non-food applications were gradually exchanged for fossil resources, it is now attempted to reverse this development. The bioeconomy is thus in fact a *renaissance* of biomass use.

However, achieving a switch back to biomass-based production brings with it a fundamental problem. Before the Industrial Revolution, biomass enabled, but also constrained economic growth: the available energy was limited to the annual regrowth (Wrigley, 2013). Before this limitation was overcome by the use of fossil resources, various countries around the world had already experienced shortages of biomass supply to fulfil their growing demands for energy (Reijnders, 2006). Overexploitation of resources created problems and triggered the switch to the use of fossil resources. In Britain, fossil material use soon exceeded what could have been supplied by sustainable biomass exploitation from woods, pastures or cropland (*ibid.*). Today, our energy demands are higher than ever and still predicted to rise. The fact that biomass resources could not supply sufficient sustainable energy before the Industrial Revolution provides an daunting perspective on current efforts to engage in a transition *back* to an economy driven by biomass. Paradoxically, the availability of fossil resources seemed practically unlimited during the Industrial Revolution, in contrast to “fresh” biomass, though fresh biomass regrows fast in comparison with virtually non-renewable fossil resources. Today we face the finite nature of fossil resources and the negative impacts of their exploitation and turn back to renewable, fresh biomass.

If renewable resources are to supply enough commodities to replace human consumption of fossil-based goods, this will have serious consequences for the demand for raw materials (van Dam, de Klerk-Engels, Struik, & Rabbinge, 2005). Improved agricultural techniques, modern processing technologies, and more efficient resource use may help to tackle this problem. However, land availability is considered a limiting factor for biomass supply for a bioeconomy (Alvarenga, Dewulf, & Van Langenhove, 2013; Brehmer, Struik, & Sanders, 2008; De Meester, Callewaert, De Mol, Van Langenhove, & Dewulf, 2011; Østergård, Markussen, & Jensen, 2010; Paula & Birrer, 2006). Global population growth and higher per capita consumption create a double rising pressure on raw materials and natural resources. Even with modern technologies and highly increased efficiency, the question remains whether humankind can fulfil its demands for resources in a sustainable way.

Rising demands for biomass resources can lead to undesired consequences. If the demands for material and energy applications were to be met with cultivated biomass while at the same time producing more food for a growing and increasingly prosperous world population, agricultural production would have to increase strongly. This would require either increased yields on the same area of land currently used for agricultural production, or an expansion of cultivated land.

A proposed alternative for biomass production is the cultivation of aquatic biomass, mainly algae, making use of the vast areas of the globe covered with water, thus avoiding competition for land areas. Cultivation and processing techniques have been under development for years and are currently further advanced, aiming for example at the production of biofuels (Bharathiraja et al., 2015; Chen, Zhou, Luo, Zhang, &

Chen, 2015; Trivedi, Aila, Bangwal, Kaul, & Garg, 2015). Nevertheless, use of land-based biomass resources is currently dominant and therefore chosen as focus in this paper.

Criticism of biofuels, and bioenergy in general, often refers to their effectiveness in reducing GHG emissions relative to fossil fuels. Proponents of bioenergy argue that the carbon uptake by plants makes biomass a carbon neutral resource, in contrast to fossil resources. Use of biomass for energy requires several processing steps consuming energy and materials, but the total sum is argued to be favourable in comparison with fossil fuels, due to the initial carbon uptake. However, changes in land use or expansion of land use can cause emissions of carbon that counteract the benefit of carbon uptake by plants. In 2008, Searchinger et al. published a study analysing the effects of direct and indirect land use changes on the overall GHG emissions of biofuel production in the USA. Since then, land use change (LUC), and especially indirect land use change (iLUC), dominate debates on the carbon footprint of bioenergy. Land use change can be defined as any change of one type of land use to another (Wicke, Verweij, van Meijl, van Vuuren, & Faaij, 2012). Biomass production can cause GHG emissions through land use change directly or indirectly. Direct LUC causes emissions if land harbouring carbon-rich ecosystems such as forests is converted specifically for the purpose of biomass production on that same land. GHG emissions from iLUC occur if land formerly used for the production of other feedstock (e.g. food production) is used for the production of biomass for energy or materials instead. As a consequence, carbon-rich land elsewhere is converted to make up for the feedstock no longer grown on the original land (Koh & Ghazoul, 2008; Plevin, O'Hare, Jones, Torn, & Gibbs, 2010; Searchinger et al., 2008; Wicke et al., 2012).

Both types of land use change can cause significant GHG emissions during and following the initial land use conversion. GHGs are emitted rapidly through slash and burn of natural land cover and microbial decomposition of plants, and over a prolonged period of time through the decay of roots (Fargione, Hill, Tilman, Polasky, & Hawthorne, 2008). In many cases the time before the initial emissions of carbon are offset by carbon savings of biofuels (carbon payback time) is long (Fargione et al., 2008; Gibbs et al., 2008; Lamers & Junginger, 2013), which is problematic for the mitigation of climate change in the short term.

Land use change furthermore has adverse effects additional to GHG emissions. The conversion of pristine ecosystems such as forests and grasslands, but also of diverse agroforestry systems, causes habitat destruction and may lead to biodiversity losses (Centi, Lanzafame, & Perathoner, 2011; Fargione et al., 2008; Koh & Ghazoul, 2008). While land use change effects have mostly been described for biofuels, they are also reflected in the scientific debate regarding the broader bioeconomy. Competition for land, competition for resources, and the uncertainty of emission reductions are the three most described problems regarding the contribution of a bioeconomy to sustainability (Pfau et al., 2014).

In summary, land use changes as a consequence of the renaissance of biomass for the production of materials and energy can lead to negative effects on carbon emissions, biodiversity, and food production, which counteract the sustainability objective of a bioeconomy.

3. Advantages and disadvantages of residual biomass use

To avoid the negative effects associated with land use change two strategies are often suggested: the use of degraded or marginal land for the production of biomass, and the use of residual biomass for the production of energy and materials (e.g. Fargione et al., 2008; Hatti-Kaul, 2010; Jenkins, 2008; Keijsers, Yılmaz, & van Dam, 2013; Lamers & Junginger, 2013; Landeweerd, Surette, & van Driel, 2011; Plevin et al., 2010; van Dam et al., 2005; Voll & Marquardt, 2012). While the advantages and disadvantages of marginal land in comparison to productive land have been discussed by some (e.g. Lamers & Junginger, 2013; Raghu, Spencer, Davis, & Wiedenmann, 2011; Vanholme et al., 2013), not much is known about the relationship between residual biomass and sustainability. Therefore this paper focuses on the strategy of using residual biomass.

Generally, two types of biomass resources for contemporary applications can be distinguished: cultivated biomass and residual biomass (see Figure 1). While Hoogwijk (2004) distinguishes between energy crops and biomass residues, the term “cultivated biomass” is chosen here to include all biomass produced specifically for non-food purposes. Next to energy crops, this includes for example biomass produced in forests or cultivated algae. Residual biomass is biomass that not produced for its use as for example energy source directly, but is a waste product of other processes. It is also referred to as "biomass residues" or "waste biomass". Hoogwijk (2004) distinguishes four types of residual biomass resources: agricultural residues, forest residues (incl. material processing residues), animal manure and organic wastes (e.g. waste wood of municipal solid waste). Here, the term “landscape residues” instead of forest residues is chosen to include biomass released during landscape maintenance activities in various types of landscapes. Next to forests, this includes half-natural landscapes influenced by humans, for example pastures or floodplains, but also roadside vegetation (see Figure 1).

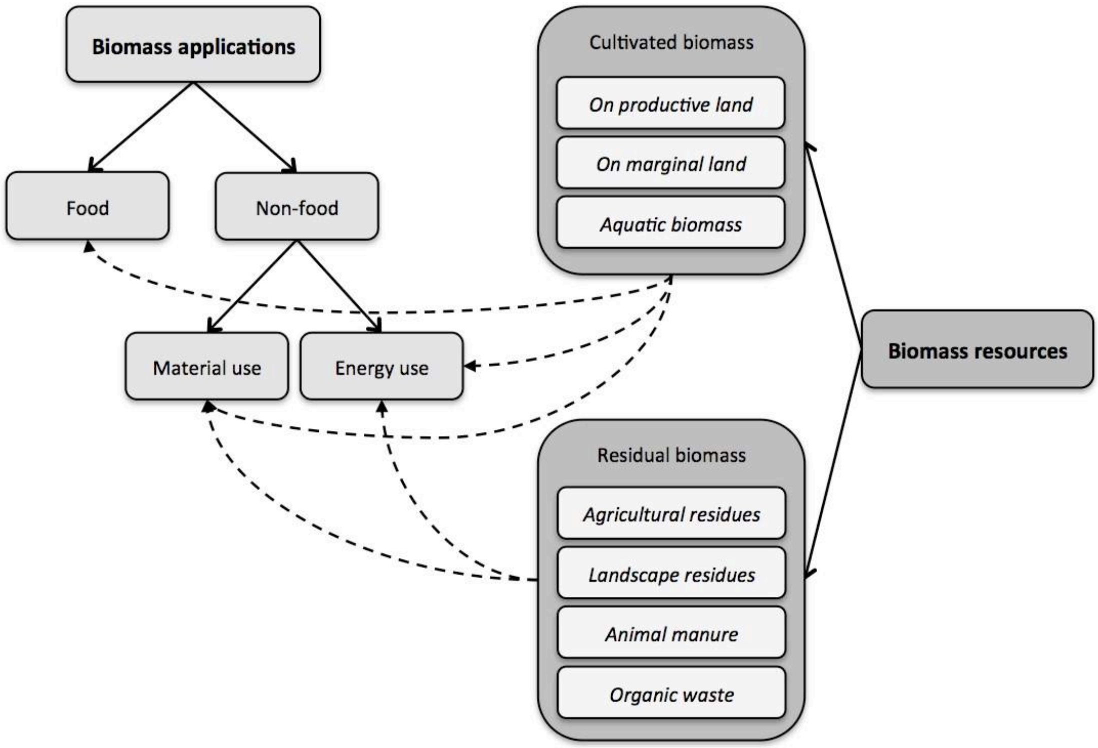

Figure 1: Contemporary biomass applications and resources

Using residual biomass as input for new production chains offers several sustainability advantages (Table 1). First, no additional land is required to produce biomass, which foregoes land use change. Second, applying otherwise unused material as input for new production chains reduces waste. Third, biomass that is left to rot may emit GHGs. Using this biomass will in the end still lead to GHG emissions, but by re-using this biomass other energy sources or materials can be substituted, reducing overall emissions. Finally, using residues increases the overall efficiency of resource use and can contribute to a "circular" resource use or a no-waste society, concepts closely related to sustainability.

However, residual biomass also poses a number of challenges (Table 1). Quantitative potentials of biomass supply from residual biomass are limited and much smaller than potentials from crops (Hoogwijk, 2004). It is therefore all the more important to use these streams in a sustainable way. It is questionable if potentials from residual biomass are high enough to fulfil demands in Europe, even in combination with biomass production on marginal land and increased efficiency.

Another challenge is the spatial availability and accessibility of residual biomass. Since the residues are by-products of other processes, they are initially situated in different, possibly widespread or difficult to reach locations. While cultivation of biomass is optimized for harvest and preservation of desired qualities, residues are not necessarily collected and stored appropriately. Collection and transportation for further use result in costs and emissions. Furthermore, processing, external impact, storage and transport can all lead to quality losses. These effects strongly influence the efficiency and sustainability of using residual biomass for applications within the bioeconomy. Ideally, processes would have to be optimized for reuse of waste streams by, for example, collecting residues on site and storing them appropriately or directly processing them further. Essentially, residues should then be treated as by-products or secondary products instead of waste. It could be advantageous to adapt technologies to be efficient on a small scale to avoid long distance transport and storage, which is associated with problems of odours and volatile organic compounds (Centi et al., 2011).

The quality and characteristics of residual biomass pose an additional challenge. Coming from a variety of sources, residues are far more heterogenic than cultivated biomass sources, especially waste streams like organic waste in urban areas (Keijsers et al., 2013). Many studies argue that to achieve an efficient use of resources all components of any biomass resource should be used (Binder, Cefali, Blank, & Raines, 2010; Bramsiepe et al., 2012; Charlton, Elias, Fish, Fowler, & Gallagher, 2009; de Jong, Higson, Walsh, & Wellisch, 2012; De Meester et al., 2011; FitzPatrick, Champagne, Cunningham, & Whitney, 2010; Galvez et al., 2012; Hatti-Kaul, 2010; Pfau et al., 2014; Vanholme et al., 2013). This may refer to the use of all parts of crops, including parts that would otherwise be residues, or to specific components of plants, such as sugars, cellulose, or lignin. To use residual biomass resources efficiently, technology has to be adapted to cope with the variety and heterogeneity of different types of biomass and with all the different components.

Carbon payback times of substituting fossil resources with residual biomass differ between regional circumstances. Lamers & Junginger (2013) compared three different scenarios of substituting different fossil energy carriers with forest residues, showing that carbon payback times differ between 0 and 44 years. Thus, while some options offer almost immediate carbon benefits, the mitigation potential is not only determined by the feedstock and not all applications of residual biomass are equally successful. Case specific assessment is thus of great importance.

Finally, novel applications may disrupt existing functions of residual biomass. This aspect is rarely addressed when new applications of residual biomass are considered. Therefore the next Section elaborates on this challenge of a change in resource use.

Table 1: Expected advantages and challenges of residual biomass use.

Expected sustainability advantages	Challenges
No additional land required	Availability and accessibility
Waste reduction	Quality and components
GHG emission reduction	Carbon payback times dependent on regional circumstances
Circular resource use	Impact of resource use change (RUC)

4. Resource use change

When residual biomass is considered as waste, using it for a new purpose may appear to offer only advantages. However, even though residual biomass is not produced directly for a specific application, in many cases it does fulfil a function nonetheless.

Residues are seldom unused waste streams and even abandoned or treated waste can provide functions. If these resources are then used for new applications, this has consequences on the former function. I refer to this phenomenon as resource use change (RUC) in this paper, to demonstrate the resemblance with LUC. Where (i)LUC represents a change to current land use, RUC refers to new uses of resources that are provided by this current land use. These changes may or may not lead to LUC in consequence.

Table 2 shows several functions of residual biomass in different situations, illustrating them with examples, and referring to possible consequences of a RUC. Three current situations are distinguished. First, residual biomass can be extracted to serve as input in other supply chains. Second, biomass that is left behind – for example in the field or in an ecosystem – often fulfils a function. It may serve to sustain soil quality or provide ecosystem services. Soil organic matter is an important factor in both ecosystems and agricultural production. Biomass left behind is decomposed and provides important nutrients for renewed growth (Bot & Benites, 2005; Schils, 2012). Both fine and coarse debris provide habitats for various species and are therefore important for ecosystem health and biodiversity (CBS, PBL, & Wageningen UR, 2014; Jagers op Akkerhuis, Moraal, Veerkamp, Bijlsma, & Wijdeven, 2006; Nordén, Ryberg, Götmark, & Olausson, 2004; Sullivan et al., 2011). Third, biomass that is not used and enters waste treatment can still fulfil a function. Biomass residues such as organic or green waste are often treated and provide compost or energy.

Table 2: Functions of residual biomass and consequences of RUC.

	Function	Examples	Possible consequence RUC
Extraction	Input supply chains	• Wood residues for pallets • Wood residues for composite materials • Straw for fodder	• Disturbance of supply chains • Increase of market prices • Replacement with cultivated biomass
Left behind	Sustaining soil quality	Agricultural residues or straw mixed in soil	Soil degradation
	Ecosystem services	• Provision of food, nutrients or habitats • Input for trophic interactions • Enabling biodiversity	• Loss of ecosystem services • Disturbance of ecosystem functioning • Biodiversity loss
Waste treatment	Provision of energy	Energy from waste incineration	Reduced energy provision; increased use of fossil energy
	Provision of compost	Compost for soil organic matter re-nourishment	Reduced availability of compost; increased use of fossil fertilizers

Novel applications of residual biomass result in RUC because they alter the current situation. RUC may have undesired consequences. Similar to LUC, these can occur either directly or indirectly. Direct consequences are the losses of the current functions, as shown in Table 2. This can result in disturbed supply chains, degraded agricultural soils, disturbance of ecosystems or loss of ecosystem services. Indirect consequences do not influence the biomass function directly but occur due to the replacement of a current function. For example, if residues used as animal fodder are devoted to new applications, the fodder has to be replaced with other sources, which may in turn lead to displacement effects such as iLUC (Asveld, van Est, & Stemerding, 2011; Tonini, Hamelin, & Astrup, 2014). If residues are used with the goal to avoid iLUC, as it is often argued, some applications may thus indirectly have the opposite effect.

Although RUC of residual biomass may have undesired consequences, it is worth considering. In some cases additional value may be achieved in combination with retaining the current function, while in others novel applications may achieve higher benefits than the current use. Especially low quality and waste streams may benefit from new processing. Biogenic waste that is currently incinerated may for example yield more energy through modern biogas installations. Other residues can be used first to produce energy or materials and subsequently extract nutrients for soil re-nourishment. In some cases, a compromise between current and new functions may be established, for example by applying mosaic landscape management allowing for different functions in different locations (Sullivan et al., 2011).

These examples show that residual biomass use for modern bioenergy or bio-based material production can be worthwhile. In some cases, it can achieve its promise as sustainable alternative to cultivated biomass, thereby avoiding land use change and negative consequences related to it. However, the above-described challenges show that this strategy is not a silver bullet. It requires case-specific evaluation, determining the potentials and consequences of a changed resource use.

5. Biomass applications and sustainability issues

Next to the RUC impact, the overall contribution of biomass use to sustainability is also determined by the aspired application itself. This Section discusses the relation between applications of residual biomass and sustainability.

Efficiency of resource use is an often-discussed aspect regarding biomass applications. Generally, more efficient use of resources is associated with greater sustainability (cf. Pfau et al., 2014). There are different views on what efficiency entails. While some argue that all components and by-products of any given biomass resource should be used, including the re-use or recycling of waste streams, others refer to choosing the best application for each quantity of resource (*ibid*). Different concepts address the optimization of biomass applications, for example cascading principles, biorefinery concepts or prioritization according to the value of the end product. They consider various applications, either prioritizing between them, or aiming at producing multiple products. All three concepts generally favour the production of (higher value) bio-based materials. For energy production, mainly lower value or otherwise unusable residues or by-products are considered. Through re-use of by-products and waste streams, residual biomass has the potential to link up different sectors. One sector can use the residual streams of another, thus creating synergies. Residual biomass is then seen as another raw material flow, rather than a waste stream (Commissie Duurzaamheidsvraagstukken Biomassa, 2014).

Even though increased efficiency of resource use may be advantageous, it does not necessarily lead to increased sustainability. The determination of efficiency is dependent on the objective of the application. Biomass is used to achieve a variety of different objectives, for example replacing fossil fuels, reducing GHG emissions, producing renewable energy, creating economic benefits or stimulating rural development (Pfau et al., 2014). However, not all goals are necessarily related to increased sustainability. Consequently, efficiency in reaching some of these objectives does not necessarily lead to increased sustainability. Different applications should be weighed against one another in order to define how residual biomass use can best achieve a contribution to sustainability. Sustainability is then not only a boundary condition for biomass use, but the actual main goal. Efficiency of biomass applications can then be measured in terms of reaching a more sustainable situation.

Potentials to contribute to sustainability not only lie with the reduction of GHG emissions, although that is one of the main drivers of the bioeconomy and an important sustainability goal. Another important sustainability challenge is the disturbance of global biogeochemical flows resulting, for example, from agricultural activities applying artificial fertilizers. Especially Phosphorus and Nitrogen distributions across the globe are dangerously disturbed, and biogeochemical flows have been identified as one of the planetary boundaries (Steffen et al., 2015). Recovery of minerals from biomass as an additional processing step offers the potential to reallocate minerals and replace artificial fertilizers, thereby counteracting this disturbance. Another chance lies with the production of environmentally friendly products. Although not all products that are bio-based are necessarily beneficial, new processes have the potential to create products that are for example less toxic or biodegradable, contributing to solving pollution problems.

6. Conditions for sustainable residual biomass use

The use of residual biomass as alternative for cultivated biomass offers several advantages, but it cannot be considered a silver bullet for a sustainable bioeconomy. Changing current use of resources, even if it means sourcing previously unused biomass residues, can have negative impacts outweighing the advantages. Whether residual biomass use contributes to sustainability depends on a variety of conditions, often influenced by regional differences. In this Section conditions for sustainable use of residual biomass are discussed, considering existing sustainability criteria and building on the previous sections.

One approach to set boundary conditions for sustainable use of biomass resources has been the development of sustainability criteria or standards. Such criteria mainly demand that biomass applications achieve GHG savings in comparison to their fossil-based alternatives, and that biomass is not produced on land with high biodiversity or high carbon stocks (Commissie Duurzaamheidsvraagstukken Biomassa, 2009; European Parliament, 2009). Regarding residual biomass a distinction is made between agricultural, aquacultural, fisheries and forestry residues on the one hand, and all other waste and residues on the other hand. Criteria for the latter group are less strict, essentially reduced to GHG emission reductions (European Parliament, 2009). Some argue to include a criterion ensuring that the extraction of residual biomass does not negatively influence soil quality (Commissie Duurzaamheidsvraagstukken Biomassa, 2009). Sustainability criteria are criticized for their restriction to certain bioenergy applications and the exclusion of impacts that are difficult to measure, such as iLUC (Asveld et al., 2011; Plevin et al., 2010). Universal application to all resources and all applications as well as consideration of all effects would be beneficial to enable a level playing field.

The previous sections have shown that additional to the aspects addressed by current sustainability criteria it is crucial to consider the origin and current use or function of residual biomass. New applications always present a RUC. Both GHG emissions and influences on soil quality are valid concerns, but RUC can have additional environmental impacts such as biodiversity loss or iLUC, as well as influences on other supply chains currently using the residual biomass. To maximise the benefits, different potential applications, or combinations of applications, should be compared since they may contribute to sustainability in varying degrees. It has to be thoroughly investigated what the effects of RUC are, in comparison with the current use or function.

Table 3 presents a checklist that can be used by public or private actors considering the use of residual biomass to evaluate and compare the contribution to sustainability of different resource and application options. It is divided into three sections addressing the current use of residual biomass, the potential application, and the impact of RUC.

Table 3: Checklist for sustainable residual biomass use.

Topic	Relevance	Checkpoint
Current Use	Residual biomass may already be in use for another application or fulfil a function when left behind. Examples: Wood residues are used for the production of composite materials and landscape residues may fulfil ecosystem services when left behind, e.g. maintaining soil quality or offering habitats.	Is the biomass currently being used or does it fulfil any function?
		Do the residues currently fulfil ecosystem services when left behind?
		Can the current use be replaced sustainably?
Potential Application	Depending on sustainability goals, residual biomass can be used for a variety of applications. The measure of efficiency depends on these goals. If residual biomass is to contribute to sustainability, several aspects should be considered to weigh different application options. Furthermore, applications should be adapted to use residual biomass optimally.	Does the envisaged application contribute to sustainability efficiently? Consider the following aspects: • Reduction of GHG emissions • Replacement of fossil resources • Mitigation of disturbance of biogeochemical flows (e.g. N, P recovery) • Production of environmentally friendly products (e.g. non-toxic, biodegradable)
		Are technologies, organization and logistics adapted to use residual biomass optimally?
		Are synergies between biomass processing sectors optimized?
Impact of RUC	Changing current use may cause negative impacts. Current supply chains may be disrupted, causing a switch to other resources and (i)LUC. Removing biomass from ecosystems can have negative impacts on the provision of ecosystem services.	Are ecosystem services reduced or lost as a consequence of RUC?
		Are current supply chains interrupted?
		Does the RUC cause (i)LUC?
		Is the transition cost and energy efficient?
		Do the benefits of new applications outweigh the negative impacts of RUC?

To determine the potential impacts of RUC, current uses and functions have to be identified and valued. The consequences of loss or modification of these uses must be determined, considering possible sustainable alternatives. Next, different applications must be weighed, comparing their contributions to sustainability and determining the most beneficial application. They should be valued according to their potential to reduce GHG emissions, replace fossil resources, mitigate disturbance of biogeochemical flows and produce environmentally friendly products. Applications must be adapted to the specifics of residual biomass to maximize the resource efficiency. As discussed in Section 3, residual biomass can be difficult to access and of lower quality than cultivated biomass. Technologies and logistics should be adapted to minimize these disadvantages so that residual biomass can effectively replace fossil resources. Biomass processing in all relevant sectors should be adapted to enable optimal use of residual biomass and waste or by-products arising during processing. Striving for an efficient use of residues and waste streams furthermore has the potential to create synergies between different biomass applications and sectors. What is considered waste in one sector may well serve as input for other uses.

Increased synergies provide great potential to increase sustainability in a bioeconomy and cope with competition for various applications. Efficient use of residual biomass links up well with sustainability concepts considering the reuse of waste as resources (e.g. circular economy, cradle to cradle). Finally, the impacts of the RUC have to be determined.

How benefits and costs of RUC are valued largely depends on the sustainability goals of the envisaged biomass application. The comparison should not be based solely on monetary terms. Current sustainability criteria only require a GHG emission reduction for certain residual biomass resources and are restricted to liquid bioenergy applications. However, RUC of all types of residues can have additional impacts that should be evaluated. The GHG emission impact and the potential to replace fossil resources are quantifiable, but impacts on soil fertility, iLUC, and ecosystem services such as habitats and biodiversity are more difficult to value. Their consideration is, however, important to estimate all costs.

7. Conclusion

The transition to a bioeconomy can offer important steps towards a more sustainable situation, like the reduction of the unsustainable exploitation of fossil resources, reduction of GHG emissions, and the provision of more environmentally friendly products. However, if land use changes are required to produce biomass, negative impacts often outweigh the benefits. Production on marginal land and the use of residual biomass are often proposed as strategies for sustainable biomass supply. But the assumption that residual biomass use is always sustainable because it does not cause (i)LUC is inappropriate; it is not a silver bullet to ensure a sustainable bioeconomy.

When it comes to cultivated biomass, competition for land, (i)LUC and carbon payback times are some of the main concerns which should be addressed through sustainability criteria. Residual biomass is a different type of resource and requires different considerations. It is false to generalize that residues are waste streams that are currently unused, assuming their exploitation is always beneficial and applying less strict sustainability criteria. RUC to realize new applications always has consequences, whether the resource is currently used, left behind or enters waste treatment. Therefore, the sustainability of new applications has to be evaluated based on the effects of the RUC.

It is recommended that public and private parties considering the use of residual biomass include all potential impacts of RUC in the evaluation of new applications. These potential impacts furthermore show the complexity of interactions between different supply and demand systems for biomass. Choices between resources and applications should be weighed based on their contribution to sustainability in order to reach the objectives of a bioeconomy. Reliable methods to assess impacts that are difficult to quantify at the moment, such as iLUC or biodiversity, should be developed. Facing a great demand for biomass all resources that can be supplied sustainably are helpful. Residual biomass should not be considered waste but a potential resource, applying above-discussed conditions to ensure that it contributes to a sustainable bioeconomy.

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