Energy Performance improvement and Energy Cost reduction at Baltic Place commercial office complex

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Abstract- Day by day, energy demand keeps rising so that, it is essential to generate massive amounts of energy. Meantime, there are many changes have been introduced to make buildings or complex more energy efficient. It is very important to understand the energy sources used in buildings. The generation of renewable energy sources can be helpful to reduce their energy demands. Along with this, it is also helpful to reduce carbon Dioxide (CO_2) which is produced by the Buildings. Therefore, to achieve a sustainable energy building, it is essential to improve technologies in the buildings.

The main objective is to get a deep understanding of energy efficiency in overall commercial buildings; specifically in Baltic Place along with outlining what kind of the most feasible renewable and other energy efficient system or techniques to be adopted in the buildings to achieve most energy efficient buildings.

The outline of this project is to achieve a 6% reduction in annual consumption compared with last year (2014) and technologies to be adopted to make Baltic Place more efficient, intelligent and more sustainable building which will direct impact on rental income by building to the owner. At present, various renewable technologies are available such as a heat pump, solar heating etc. In this report, the water surface heat pump is explained in brief.

Index Terms- Energy consumption, commercial office building, District heating, weather normalisation, energy cost.

I. Introduction

Baltic Place is a joint partnership project between City & Northern. It consists of 131,000 sq. ft. of office space, including two eleven-storey tower blocks which are linked by a communal entrance and foyer. Beneath the building is a two storey underground car park with capacity for 100 vehicles. (GVA, 2014).

A. Aim:

Evaluate the energy use in the Baltic Place commercial office complex and determine energy saving improvements.

B. Objectives:

1. Evaluate current energy use and cost
2. Evaluate energy saving measures & proposed solutions to achieve energy consumption reduction by 6%.
3. Evaluate the use of renewable energy sources

C. Approach:

The main approach to this report is to give an overview of what energy efficiency is and the energy conservation history in Baltic Place. The main aspect is to define the problem on which the project is based.

D. Motivation:

About 33% ok UK carbon emissions are accounted for buildings. The UK thorough the Climate Change Act, have committed to cut carbon emissions and are targeting a reduction of at least 80% by the year 2050 with an interim target of 34% by 2020. These reductions will be benchmarked against on the UKs 1990 carbon levels. Additionally, the UK Government is aiming to have 15% of electricity produced from renewable sources by 2020. A further commitment is to aim for emissions from all building sectors to be as 'close to zero' by the year 2050.
To reduce carbon emissions produced from buildings, following points to be considered:

- Local planning authorities for making sure that new buildings are energy efficient
- From 2016, all new homes to be zero carbon and also all other existing buildings from 2019.
- Improvement in Energy Performance Certificate

(Policy Paper; "2010 to 2015 Government Policy: Energy Efficiency in Buildings" , May 2015)

II. Energy Review on the Current State of Art in Building Sector

A. Overview:

The cost of energy usage in the building sector has massively increased in recent years due to the increasing demand in energy which is primarily used for cooling and heating buildings. The building sector is responsible for 40% of the total energy consumption and 36% of the total CO_2 emissions in the EU. Generally, new buildings require less energy compared to those which are older. On average, about 35% of the EU's buildings are classified as old (over 50 years old). By improving the energy efficiency of these old buildings, the total EU energy consumption could be reduced by 5% to 6% and CO_2 emissions reduced by 5%. Building stock consists of commercial, residential, public and institutional structures. There are many factors which minimise energy requirements such as; building material, building design, cooling system, heating system, lighting and other appliances. The building envelope is one of the main factors impacting energy efficiency. The envelope is the building interface between the exterior and interior of the building such as: windows, walls, roof, doors, and foundations. All of these factors must work together to keep the building cool in the summer period and warm in the winter period.

The amount of energy used varies depending on the fabric design of the building and the systems in place and how effective they are. Most of the energy in a building is consumed by heating and cooling systems, however advanced controls such as programmable regulators or thermostats and building energy management systems (BMS) can significantly reduce the energy consumption of these systems if managed effectively.

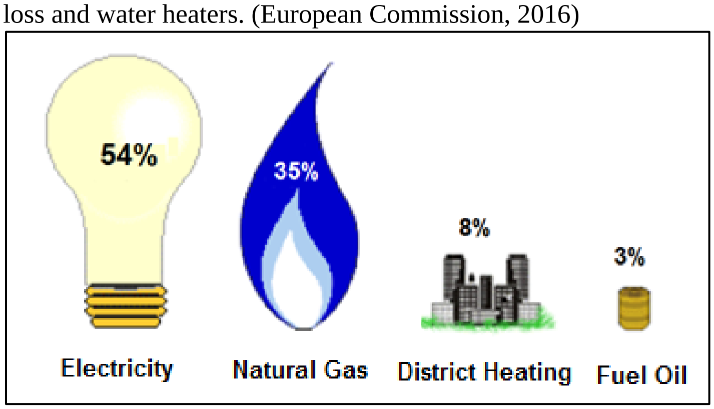
Energy reviews or audits can also be conducted as a suitable way of monitoring and determining how energy efficient the building is, as well as which changes can be made to improve efficiency. All relative tests should be completed to ensure that the cooling, heating, lighting and all energy systems work efficiently and effectively together.

Buildings produce less Carbon Dioxide (CO_2) emissions in comparison to other sources of pollution, such as industry and transportation. In addition to energy efficiency measures and energy conservation, the use of renewable energy would be beneficial. The energy produced from renewable sources can be used for cooling, heating, lighting or ventilation. Also, renewable energy would reduce carbon dioxide (CO_2) emissions. (European Commission, 2016)

B. Commercial Building Consumption

Commercial buildings consist of various buildings such as; schools, hospitals, offices, warehouses, workshops, hotels, police stations, shopping malls and libraries to name a few. All of these building types have their own unique energy requirements; however, commercial buildings consume more than half of their energy for lighting and heating purposes.

In commercial buildings or complex, water heating systems and integrated space can offer the best approach to energy-efficient heating. For example, the energy used for water heating can be reduced by insulating water pipes which helps to minimise heat loss and water heaters. (European Commission, 2016)



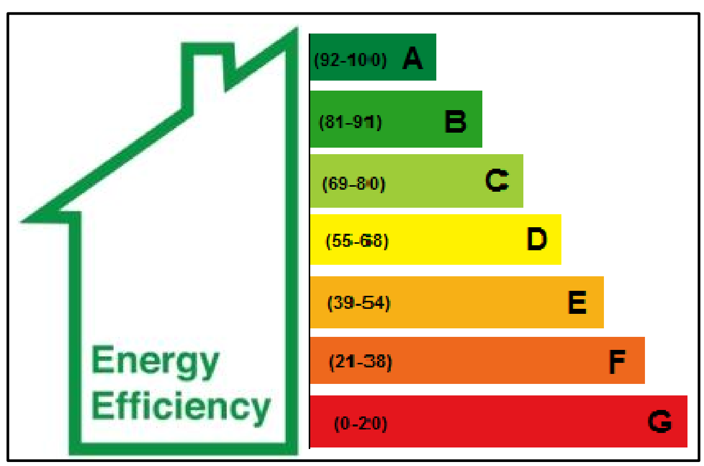
The above figure shows the energy usage distribution. Electricity and natural gas are the most common fuel type used in commercial building, however, other energy sources such as heat and power from district heating or locally generated groups are becoming more popular, this source is mostly applicable in a location where a number of buildings are found in close proximity to each other such as a university campus or big cities. In such cases, it is more beneficial to have a central heating and cooling system which provides energy in the form of hot water, steam or chilled water to the building. A district heating system is a good option for this as it is a more economical and efficient system, it also offers reduced equipment and maintenance costs.

It is easier to incorporate energy efficient systems into new buildings than it is in existing buildings, which consist of circa 99% of the building stock. It is these existing buildings which create a greater challenge for investigating energy efficiency, but offer the greatest opportunity for enhancing overall energy efficiency. Therefore, taking positive action towards energy efficiency for existing buildings can be seen as cost effective. There has been limited opportunity to convince large companies, organisations and building owners begin energy efficiency projects such as retro commissions and retrofits.

"Building Research Establishment Environmental Assessment Methodology" (*BREEAM*) is the world's running sustainability assessment process for developments of master planning, infrastructure and buildings. It reports a number of lifecycle phases like New Construction, In-Use and Refurbishment. Worldwide, there are about 2,215,000 buildings listed for assessment since BREEAM was introduced in 1990.

According to the "*Chartered Institution of Building Services Engineers*" (CIBSE) published in 2014, the government of the UK has agreed a target to minimise gas emissions of national greenhouse. Based on CIBSE 2015 latest edition, CIBSE has set 29 benchmarks for various categories. (Bruhns, et al., 2011)

The use of CIBSE benchmarks is an important factor which creates a point of reference and develops standards against which buildings can be compared, analysed and the performance can be monitored. For example, by comparing energy consumption per meter square (m^2) with the benchmark will allow the decision maker to judge the total amount of energy consumed and which are improvements can be made to reduce the consumption in that specific area.



The above figure describes energy efficiency rating of the building.(Energy Saving Trust, 2014). In the UK, all commercial and domestic building needs to have an Energy performance

Certificate (EPC) for buying or renting their property. By doing an energy performance survey of the building, it is easy to identify ways to save money on energy bills of the property as well as improve user comfort. Generally, an Energy performance Certificate is valid for 10 years from the date of issued.

C. Driving factors affecting energy consumption

Energy consumption depends on varies driving factors such as:

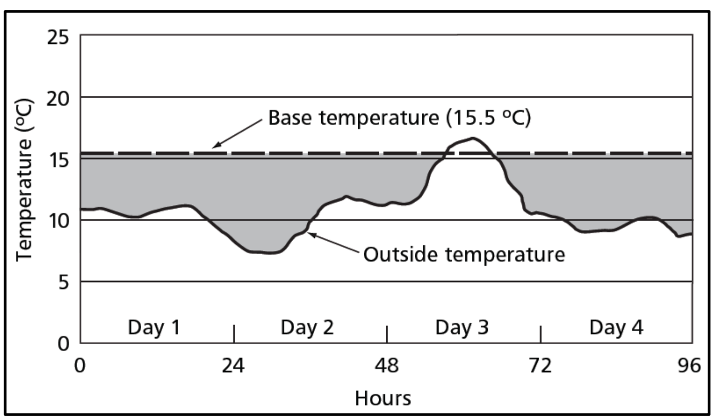
- Weather
- Occupancy
- Hours of operations

Weather is one of the dominant factors of building energy use. Weather patterns vary from day-to-day and year-to-year depending on location and a certain season may be warmer or colder. Energy used to keep warm or comfort is directly dependent on how it is cold. Along with this, occupancy is also an important factor in energy consumption. More occupant in property results more energy consumption. Hours of operations also matters for more energy usage.

Before analysing energy consumption, it is very important to know about degree day and weather normalisation of consumption.

D. Degree days and Weather normalised energy consumption

Degree days are commonly used in the energy industry to determine the effect of outside air temperature on building energy consumption. Degree day is a temperature difference between the reference temperature or base temperature and the actual outdoor temperature. (Day, T., 2006)



For UK, 15.5°c is the base temperature for general buildings such as commercial office buildings and schools while 18.5°c is generally used for hospitals as they use energy 24/7 to keep comfort level. For office building, if outdoor temperature is below 15.5°c, heating is required to reach comfort level (15.5°c). For example, if outdoor temperature is 7.5°c then degree days will be 8 (15.5-7.5) shown in above figure. While, if outdoor temperature exceeds 15.5°c, no heating is required which is set to zero degree days as it is not possible to have a negative value of degree day. (BizEE Software Limited, 2008)

The 20- years average heating degree days are also useful for comparing current use against long period consumptions or to fix budget against such situations. The 20- year average heating degree days (STD UK HDD) for the UK for a year are considered as 2463 for 15.5°c base temperature while 3422 for 18.5°c base temperature. The actual degree days are published on monthly basis for 18 different regions in the United Kingdom. The electronic sources of degree day data are also available for different locations with different temperature. For Baltic Place, nearest weather station is Newcastle.

Weather normalisation determines the effect of weather on energy consumption as well as enabling comparison of energy consumption from different places or periods with different weather stations.

Comparing only energy consumption or the weather from a certain year to the next year would give only the change between those years. But, if energy consumption is "Weather Normalised" its enables to compare energy consumption over a normal weather period. Also, it adjusts energy usage, which helps to compare energy usage over a longer period.

Therefore, with the help of these weather normalised energy consumption; it can be measured expected or predicted amount of energy for each of the next 30 years. By comparing variations between weather normalised energy consumption profiles, it is easy to detect deteriorations in uncovering energy losses, heating plant efficiencies or show increased process demand. (Vesma, V., 2014)

III. INVESTIGATION OF ENERGY SOURCES & CONSUMPTION IN BALTIC PLACE

A. Energy Sources and consumption history:

In past years, SystemLink Energy Management software as well as bespoke excels spreadsheet were used to analyse the consumption data at Baltic Place. However, now-a-days there are many energy management software systems that are available on the market. Currently ZECO energy management software is used for analysis of consumption at Baltic Place. This software is more reliable and easier to understand. The quality of data and consequently the accuracy of the energy use and consumption has been improved by introducing this software in Baltic Place. The overall energy consumption of last year (2014) is based a mix of aMR (Automatic Meter Reading) data, invoice as well as manual meter readings routinely taken and recorded by the site manager. (ZECO Energy Ltd,2011)

2014		2015	
All figures are in kWh			
Electricity	Gas	Electricity	Gas
1,680,545	1,507,578	1,941,085	1,318,553

Based on the above data, heating degree days (HDD_{2014}=2330 and HDD_{2015}=2574) from the nearest whether station (Newcastle) and standard UK heating (2463), normalized consumption can be calculated as,

For 2014,

$$\text{Total Normalised} = \frac{\text{Heating fuel}}{\text{HDD}} \text{ x STD UK Heating}$$
$$= 3{,}24{,}178 \text{ kWh}$$

Normalised total kWh/m^2/annum= 202.48 kWh/m^2/annum

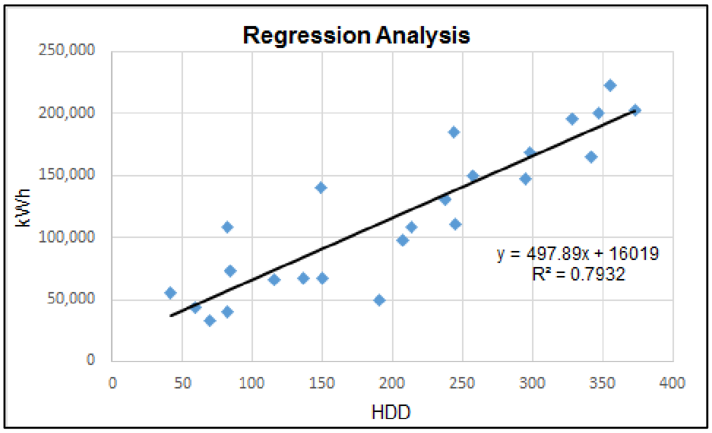
For 2015,

Total Normalised = 3,202,777 kWh

Normalised total kWh/m^2/annum= 198.07 kWh/m^2/annum

B. Regression Analysis and CUSUM Chart:

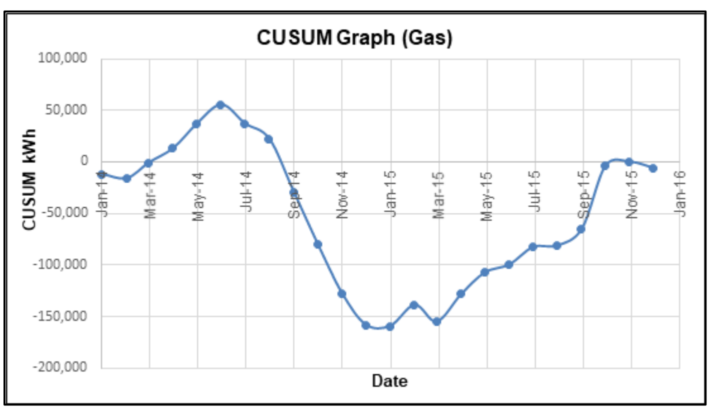
Regression analysis is based on the least squares method. Regression gives a clear correlation between heating fuel consumption and heating degree days. With the help of monthly consumption and HDD, regression graph has been tabulated as follows,



From above figure, the performance line is y=497.89x +16019

i.e. Fuel consumption (kWh) = (497.89 x Degree days) + 16092

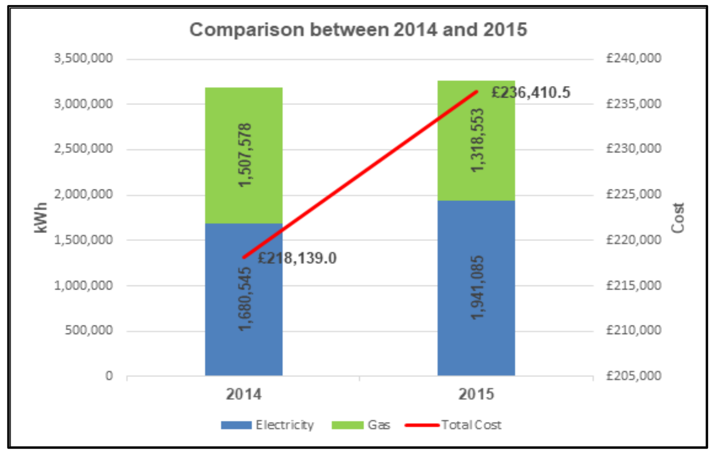
By putting degree days (monthly) in the above equations, a predicted or expected energy can be calculated.



In the above graph, 0 line is the baseline. The points which are above the baseline are over-consumed (more than expected) while points which are below baseline are under-consumed (less than expected). For Baltic Place, April 2014 to August 2014 was over-consumed months. While, other months were under-consumed.

C. Energy Cost Analysis

Average price for electricity 2015 is 10.3152 pence/kWh (off peak economy 7 [7.22 pence] and standard rate [14.05 pence]) while for gas, average price is 2.7442 pence/kWh.
Similarly, average Electricity price for 2014 was 10.2692 pence/kWh, while for gas 3.0222 pence/kWh.
Energy cost $_{2015}$ = (1,941,085 x 10.3152) + (1,318,553 x 2.7442)
= £236,410.50
Energy cost $_{2014}$ = (1,680,545 x 10.2692) + (1,507,578 x 3.0222)
= £218,139.04
From above calculation, Baltic Place consumed 2.18% less energy (weather normalised) in 2015 compared with 2014 year. But comparing with the cost, 2015 year spent 8.38% more money compared to 2014. (Energy Saving Trust, 2014)



D. Determination of Energy Significance Ranking

The main purpose of this analysis is to identify the sources, priorities them depending upon scoring and analyse new or existing opportunities for improving energy performance. The criteria consider related process, activities and associated energy consuming equipment which is used across the building as well as the time periods for which they are in use or operation.

Where the building has a capability for renewable energy and this is recognised within the matrix, an overall contribution factor is considered to specify the low carbon input into the overall contract significant ranking.

For example, Consumption of **Grid Electricity** for the contract is **2,000,000 kWh** for a year. And **CHP generated** from the same contract is **800,000 kWh** for a same year.
Ratio will be,

$$\text{Ratio}= \frac{\text{CHP generated (kWh)}}{\text{Grid Electricty (kWh)}} = \frac{800{,}000}{2{,}000{,}000} = 0.4 = \mathbf{(40\%)}$$

Now, say one of the activities/process and associated energy consuming equipment runs for the whole year. Also let us consider a maintenance period of 2 weeks is carried out for each year.
So total running hour will be,
= 24 X 7 X 50 (hours, days, weeks)

= 8400 hours

And, total running hours for the activities, process and associated energy consuming equipment which run occasionally or seasonally, say for example external or internal lights, catering facilities etc. which use as per requirement.
So let us consider the total running hours for the activities or equipment for the above condition is 4200 hours.

- For catering facilities, consider 7 hours of continual use throughout a day, so that would be,
  = 7 X 5 X 50 (hours x days x weeks)
  So total running hour will be,
  = 1750 hours
- For external lighting, consider an average of 10 hours/day, so total hours will be,
  = 10 X 7 X 52 (hours, days, weeks)
  = 3640 hours

Grid supplied electricity is offset by electricity generated from our own renewable sources such as CHP, PV etc. Therefore to consider this in relation to the activities, process and associated energy consuming equipment which runs for the whole year is,

Operational hour = 8400 X 0.4
= 3360 hours.

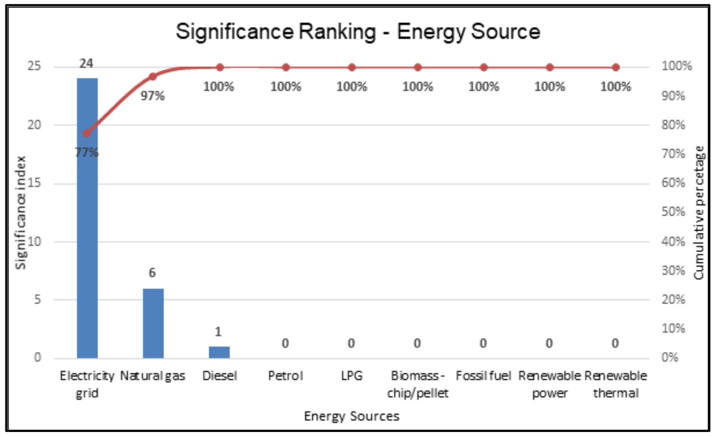
So, with reference to table below, the above figure is between 2501 and 5000 so score will be **3**.
Similarly,
The operational hours for the activities, process and associated energy consuming equipment which run occasionally or seasonally is,

Operational hour = 3640 X 0.4
= 1456 hours.

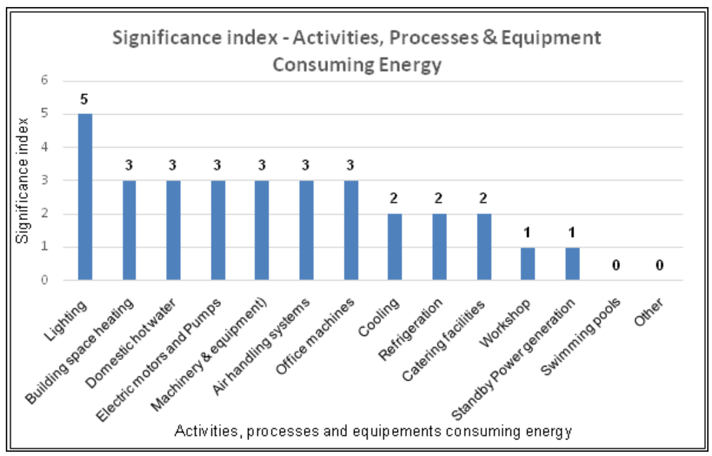
So, with reference to table below, the above figure is between 501 and 2500 so score will be **2**.

Score	Description	Limit
-1	Energy is generated entirely	-
1	Equipment or processes are occasionally or rarely used	No more than 500 hours
2	Equipment or processes are frequently used	501 to 2500 hours
3	Equipment or processes are used extensively	2501 to 5000 hours
4	Equipment or processes are in constant use	More than 5001 hours

Based on building survey about operating hours from site managers, scoring has been calculated. With the help of scoring, significance ranking was determined.



Based on the above analysis, electricity is main source which consuming more energy. Electricity is subdivided again to get more information about which activity or processes use more electricity. The figure below shows significance index for activities, processes and equipments consuming energy.



From above figure, it is clear that lighting is main energy consuming activity. There are also few other processes and activities such as domestic hot water, electric pump etc. which are also using more electricity. But, comparing with their investment cost, replacement of motors or development that is more expensive. So, it is better to replace light bulb which is a more reliable option.

E. Light Analysis

To improve overall energy performance of Baltic Place, it was very important to reduce electricity consumption. A review and investigation of current lighting, it was found that there were various types of bulb in use depending on various applications such as main area corridors, toilets, emergency lights etc. After considering all types bulbs, LED was the best option over existing traditional bulbs.

After lighting analysis, wattage of replacement light bulb having same lumens were calculated. Based on this calculation, if existing bulbs were replaced with LED as per application, it can be saved 277,914 kWh per year.

After working on Net Present Value (NPV) and Simple Payback, capital investment can be recovered in 3 years with profitability index 182%.

F. Boiler Consideration

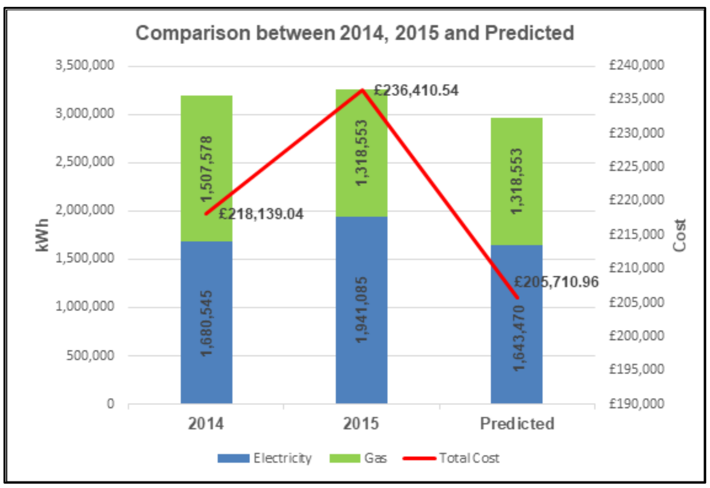
The boiler efficiency is a crucial factor in a domestic heating system. In Baltic Place, there were 4 boilers in which 2 boilers were installed at both the west side of the building and 2 in east side of the building. All 4 boilers were of Remeha Gas 310-6 eco pro. (Broag-Remeha, 2005)

The Energy Technology Product List (ETL or ETPL) is a government approved list of energy efficient machinery, equipment and plant. This is a Government scheme of the Enhanced Capital Allowance (ECA) tax for business.

Remeha Gas 310-6 eco pro was an energy efficient boiler as per ETPL. So, there was no need to replace existing boiler. (Climate Change and Energy – guidance, 2015)

IV. Results and Evaluations

Based on the above table, it is an opportunity to save energy in the form of electricity by replacing the existing bulb with LED. The consumption figure for 2014 and 2015 is taken from above calculations. Predicted consumption for electricity 2015 is calculated by subtracting saving consumption from actual electricity use (1,941,085 – 297,615.4).



From above calculation, it is clear that if an existing bulb is replaced with LED which gives overall **11.27%**savings over 2014 year.

Based on 2014 and 2015 consumption, CO2 emissions produced by electricity and gas are explained below,

	Electricity	Gas	CO2 emissions ($TonneCO_2$)
Conversion factor	0.44548	0.18404	-
2014 (kWh)	1,680,454	1,507,578	1,026.1
Predicted 2015 (kWh)	1,643,470	1,318,553	974.8

From the above table, it is clear that CO_2 emissions reduced **5%** by replacing light bulbs.

V. Recommendations

A. District Heating

The district heating systems deliver hot water and heat to the multiple dwellings or buildings from ‘energy centre’ or a central boiler unit. This system delivers cooling or heating thought a network. The energy centre with low carbon energy will distribute both heat and power to the consumers via new underground heat pipes and high voltage electricity cables which will be funded by Gateshead Council.

The Gateshead energy centre has a set backup source. The CHP unit does not run when customers do not require heat energy or it is being repaired or serviced. In this case, heat is provided to the consumers from conventional gas boilers, which operates as a backup. (Gateshead Council, 2015) (Renewable Energi Partnerships Ltd, 2011) (Cube Housing Association, n.d.)

B. Surface Water Heat Pump

The UK government has set a target of 15% electricity generation from renewable sources by 2020. Heat pumps are one of the technologies that can help achieve this target. The main purpose of heat pump is to transfer low-grade heat from a source having low temperature to a body or object at a high temperature. Heat transferred to or from a surface of the water body is used for cooling or heating buildings. For example, home refrigerator in which heat is taken out from the cold item inside the fridge and is released to the outside environment (the kitchen).

Coefficient of Performance is the ratio of energy (heat) removed or added (which is depend on cooling or heating weather) from the object or system to electricity used for operation. It is expressed as,

$$COP=\frac{\text{Heat removed or added to the system}}{\text{Workdone by the system}}$$

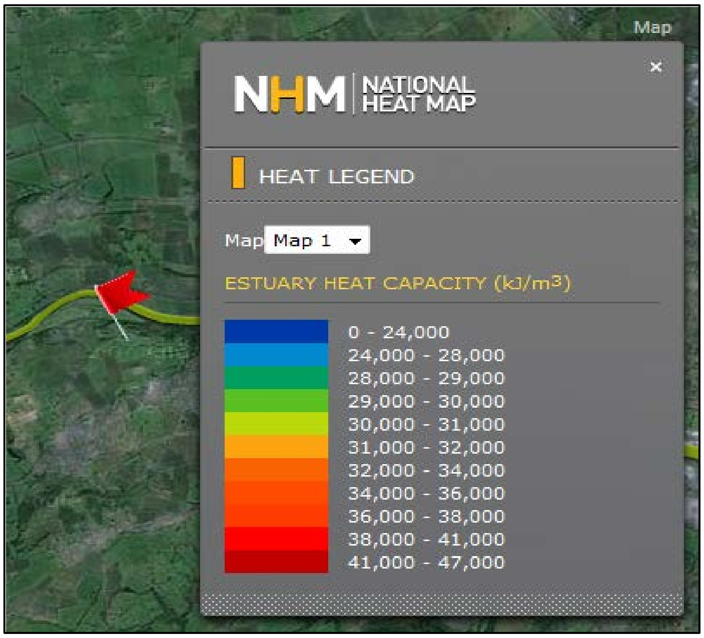
The average coefficient of performance of the heat pump is 3 to 4 which means it is about 300% to 400% efficient and average CO_2 emissions is 0.09 – 0.10 kg/kWh. (Heat Pump Association, 2014)

The water source i.e. Tyne river is closer to Baltic Pace which is about 500 meters. For heat pump system installation, there are enough water sources. Also, it is important to check the heat capacity of water, which will give an idea about whether water source heat pump installation is possible in that area or not.

The National Heat Map tool gives a bundle of electronic map which shows heat requirements for buildings throughout

England. This tool provides information about low carbon heat projects to the planners and developers to identify priority areas. Local authorities can be used this map as the beginning stage for developing Energy Master Plans. (Heat Pump Association, 2014)

The Settlement Heat Capacity (KW) layer illustrates the total heat available from the Tyne River. Generally, Estuary Heat Capacity (KJ/m^3) available for extraction by water source heat pump which is equal to kW at a rate of abstraction rate (1 m^3/s). The figure shows the heat capacity of the Tyne River. (Department of Energy and Climate Change, 2012)



C. Energy Consumption Profile

With reference to the figure below, there are 7 spikes each week. In general, it should be five as offices are closed on weekends. It should be investigated for better overall performance. Even if this is a weekend, it consumed 2/3rd of normal weekday. Also, from 26th to 28th December, it was holiday period, but still this consumed more electricity. (ZECO Energy Ltd, 2011)

With the help of this profile, it is easy to find out where and when energy is consuming more. By properly monitoring and investigating these energy consumptions, it can be helped to reduce overall consumption.

D. Boiler Replacement

As discussed in the boiler consideration chapter, there is possibility of energy improvement by replacing the boiler after 2-3 years. As this existing boiler is 7 years old, efficiency normally goes down year by year. So, it's better to replace it after 2-3 years.

VI. Conclusions

From above evaluation of energy consumption, it is clear that there are signs of energy savings and introduction of renewable energy sources which are now being more considered and appreciated by the public. As day by day CO_2 emissions are increasing, it is very important to design a building with optimisation of energy use without compromising building performance in terms of comfort condition and air quality.

In Baltic Place, overall energy consumption as well as CO_2 emissions can be reduced effectively by adopting energy saving opportunities such as replacement of light bulb, introduction of renewable sources such as surface water heat pump and district heating scheme. By replacing an existing bulb to LED can be reduced **11.27%** electricity consumption in kWh along with a **5%** reduction in CO_2 emissions. Also,the introduction of district heating will help to save energy cost.

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