United kingdom energy survey considerations for enhancement of sustainable engineering

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Abstract. The UK is dedicated to dropping its greenhouse gas emissions by not less than 80% by 2050, compared to 1990 levels. Therefore, the economy of the UK should be changed while confirming secure, low-carbon energy supplies to 2050. In most organizations, energy is one of the most substantial manageable costs. Energy-saving expands profitability along with reducing CO2 emissions and dropping impact on the environment. In this study, to determine the current energy usage of the gymnasium building, an Energy Survey was conducted at the facility assessing the following areas: a. Lighting and switching. b. Heating and Insulation. c. Appliances. d. Water usage. e. Windows. f. Building structure. These features are taken into the current study considerations for green buildings: Efficiently use of energy, availability of renewable energy sources, water resources, reduction in the waste, usage of non-toxic materials, enable reuse and recycling, good indoor air quality, and consider the quality of life of the occupants. The study provided several recommendations to reduce the energy usage of the fitness center. The results achieved a significant reduction in energy consumption at higher financial savings. From assumptions made by replacing all fluorescent luminaire tubes with compatible LED, the annual savings in energy would be approximately 104,000 kWh and a cost saving of £16,500. Replacing a 3 kW water heater with a 3 × 2 kW power shower, the total energy saving per year is 31937.5 kW that equate to £5078.06 and so on to other facilities.

Keywords: Energy Saving, Survey, Profit, Greenhouse gas, sustainability.

1. Introduction
The United Nations evaluate 30%-40% of the world's energy use originates from the operation of premises, resulting in the release of a massive amount of CO2 into the atmosphere either directly through the burning of fuels or indirectly by the use of electricity generation [1]. The strategy and administration of the energy infrastructure for the cities must change to improve the use of resources in combination with energy efficiency. The UK is dedicated to dropping its greenhouse gas emissions by not less than 80% by 2050, compared to 1990 levels. Therefore, the economy of the UK should be changed while confirming secure, low-carbon energy supplies to 2050. The Department of Energy & Climate Change (DECC) works to establish the UK has the clean, safe, affordable energy supplies and encourages international achievement to mitigate the problem of climate change [2, 3]. As the EU ETS follows the 'cap and trade' principle, directives act with financial penalties to reach carbon budgets at certain times to countries who miss them [4, 2]. In the current year, emissions from different fieldworks protected by the system are reduced by 21% than in 2005. Therefore, the EU is following the right direction to surpass this target.

As stated in the World Green Building Council, 2019 [5], the building and construction sector is responsible for about 39% of the energy-related CO2 emissions. The Green building rule is being actualized within the development sectors and denotes both the construction and structure method that is ecologically friendly. The structure life cycle from planning, construction, operation, maintenance, and demolition is fixated on sustainability and diminishing the natural impact. These features are taken into the current study considerations for green buildings: Efficiently use of energy, availability of renewable energy sources, water resources, reduction in the waste, usage of non-toxic materials, enable reuse and recycling, good indoor air quality, and consider the quality of life of the occupants.

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Energy and Climate Change Secretary Huhne (2010) [2], says: "The challenge is ambitious but achievable. We are already on track to cut the UK’s emissions by 34% by 2020 and will do more if we can win the case for greater ambition across the whole EU. However, our line of sight needs to extend much further, through to the middle of the century". The Department of Energy & Climate Change (DECC) works to make sure the UK has secured, clean, affordable energy supplies and promotes international action to mitigate climate change.

The project is expected to achieve a considerable energy saving by MWh/year and reduce direct greenhouse gas emissions of millions of tonnes per year. Since the last decade, the development of the construction sector has become a priority area of development for the economies of the regions and the United Kingdom as a whole [6]. As energy consumption in the housing and utilities sector of the UK has been steadily increasing against the background of the general decline observed in the industrial sectors over the past decades, issues of improving the energy efficiency of buildings have become a priority in the formation of programs and plan to improve energy efficiency and energy conservation [1, 7]. With the adoption of the law of energy conservation and energy efficiency, organizational and legal conditions were created for qualitative improvement of the energy efficiency situation of buildings, including the scope of energy efficiency requirements in the housing sector.

2. The survey
The Fitness Centre, located on Brompton Area of MidKent College Training Services (MKCTS), is used by members of the college. In order to determine the current energy usage of the building, an Energy Survey was conducted at the facility assessing the following areas:

a. Lighting and Switching.
b. Heating.
c. Appliances.
d. Water usage.

2.1 Lighting
The building consists of 4 main areas; the cardiovascular (CV) gym area, the weight training area, hallway and offices and the changing rooms. All areas are lit using fluorescent strip luminaires and controlled by manual switches [8]. Each area has the following number of luminaires:

a. Cardiovascular gym area 32 x luminaires.
b. Weight training area 18 x luminaires.
c. Hallway and offices 3 x luminaires.
d. Changing rooms 8 x luminaires.

During the survey, the building had one occupant; however, the lighting was on throughout the building, therefore wasting energy lighting in unused rooms. Externally, security lights are present and appear to be LED [9]. The survey was unable to determine how they are controlled.

2.1.1 Energy Saving Recommendation for Lighting.
1. All fluorescent luminaire tubes are to be replaced with compatible LED tubes. From assumptions made, the savings in energy would be approximately 104,000 kWh and a cost saving of £16,500.
2. All manually operated light switches are to be replaced with PIR sensors. This is to reduce the daily usage of the lights and prevent lights from remaining on when the rooms are not being occupied. In turn, the building will comply with Part L of the Building Regulations, the conservation of fuel and power [10].
3. PIR sensors are to be connected to a manual override located in the Office. Staff training is to be conducted in order to educate personnel on the benefits of utilizing daylight where possible instead of using luminaires to illuminate an area [11].
4. Exterior lights and sensors are to be cleaned and serviced in order to maximize their efficacy.
5. All skylights and windows are to be cleaned and maintained to allow natural light to enter the gym areas.
Nevertheless, LED luminaires are proven to be efficient, and as the lights were not on, energy is not being wasted during daylight hours. The most considerable areas of the building are the gym areas, and both have sufficient windows and translucent roof panels that can allow daylight to enter, however, all of the windows and roof panels are dirty thus restricting the amount of daylight into these large spaces resulting in the lights being used during daylight hours. The current condition of the skylights can be seen in Figure 1.

![Figure 1. Skylight Condition](image)

2.2 Heating and Insulation

The heating system in the gym areas consists of large electrically operated fans that are controlled via a timer, seen in Figure 2. By using a timer, energy usage is controlled. Other heaters in the gym are electrically and thermostatically controlled, also saving energy as the heaters are not continually operating [7, 12].

![Figure 2. Heating System Timer and Thermostatic Control](image)

Windows are single-glazed and will allow large amounts of heat to be transferred outside the gym. However, doors are fitted with automatic closing mechanisms which will prevent heat from being lost and reduce draughts from other areas. The two fire exits in the CV area, however, allow many draughts through as the seals around the door have degraded. The material of the door is also inadequate for insulation, creating a cold bridge between the external and internal temperatures.
The main gym areas have large ceiling spaces created by the pitched roof. This additional space is not only an unused area, but also a large space that a lot of heat is collected and can be lost through the roof space as no roof insulation is apparent. No insulation is apparent on the external walls either. However, the depths of both the lower block wall and upper cladding wall suggests they are filled with a form of insulation or an air gap has been left. This would prevent heat loss if it was suitably constructed/installed [13].

2.3 Appliances

During the energy survey of the gymnasium, the following appliances were assessed:

1. **Hand dryers.** Hand dryers have been installed within the toilets as an alternative to hand towels which reduces paper waste. The hand dryers used within the toilets have a push-button operation which switches the dryer on for a 30 second period. A disadvantage of using this method of operation is that if the operator leaves the hand dryer, it continues to operate and consumes energy.

2. **Air conditioning.** Temporary air conditioning is used within the gymnasium throughout the summer months. A disadvantage of using temporary air conditioning is that the cooling effects have limited coverage. Gymnasium users are likely to open doors at the opposite end of the gymnasium due to the effects not being sensed, which in turn would reduce the efficiency of the air con unit5. Temporary air conditioners are also inefficient just by starting up they usually produce heat.

3. **Gym equipment.** Gym equipment such as treadmills, cross-trainers and stationary bikes are powered 24 hours a day through socket outlets. Although these machines are powered 24 hours a day, they are not in use, 24 hours daily, which means constantly powering them is inefficient.

4. **Ice machine.** There are two ice machines situated in the gymnasium, which are switched on 24 hours a day. These appliances are connected to the mains power and water supply and freeze water to create ice for the physio department and gym users. The gymnasium could centrally locate a single ice machine in an accessible location and still provide the necessary ice requirements.

5. **TV.** There are five televisions mounted to a wall within the gymnasium. The televisions are unused and left on standby 24 hours a day. Research has shown that even when a television is on standby, it still consumes electricity.

6. **Front door lock.** The main entrance to the gymnasium utilized an electromagnet for security purposes. Power to the electromagnet is controlled by a timer in order to save on energy during off-peak hours. Without the timer, the door would consume power 24 hours a day all year.

2.4 Energy Saving Recommendation for Appliances

The following recommendations have been made for the appliances used within the gymnasium:
1- **Hand dryers.** MKCTS are to install a hand dryer with a user's proximity sensor attached. Upon vacating the area, the machine will automatically switch off, which reduces energy consumption. Individually hand drying units are £200 with a payback period of 7.8 Years.

2- **Air condition.** MKCTS is to install a permanent fixed air conditioning unit to the gymnasium. The advantage of using this type of air conditioning unit is that it is more efficient as the unit can be placed outside, which will remove the waste heat produced by the unit inside the gymnasium.

3- **Gym equipment.** MKCTS is to install manually operated cardiovascular equipment at the cost of £42,000 with a payback period of 2.33 years.

4- **Ice machine.** MKCTS is to remove one of the ice machines and centrally locate the remaining ice machine for the entire gymnasium to utilize. This will reduce the amount of energy consumption in half with a saving of £49,000 per year with little to no payback period.

5- **TV.** MKCTS is to remove televisions from the gymnasium. By removing the televisions from the gymnasium, there is an estimated saving of £72.80 per year. It would take an estimated time of 1 hour for an engineer to remove the 5 televisions from the wall at the cost of £21 per hour as per SPONS 20191. The payback period for this improvement would be 0.29 years.

### 2.5 Water Usage

**2.5.1 Hot water – Shower and Basin.** From the survey conducted in the Brompton Fitness Centre (BFC), the hot water system is supplied from the hot water heater and a tank, which provides hot water when demanded, that can be used in the changing rooms and cleaner's cupboard. The water is systematically heated to keep it warm over a long duration of time. The drawbacks to a water heater with a tank are:

1. The container needs to refill and requires more time to heat the water.
2. Less energy-efficient, as they continuously run to preserve the water temperature up.
3. A water heater with a large tank takes up considerably more space.
4. Potential fire hazard due to heat if other objects are kept in close proximity.
5. Damage to structure and insulation should it leak.

**2.5.2 Cold Water.** This part includes:

1. Urinals. The urinal uses timer controls whereas the shower uses push-button valves to provide timed usage.
2. Basin. The basin in male and female ablutions uses a traditional rotating threaded controller valve water tap for hot and cold water.
3. Male/female lavatory. The lavatories (male and female) use a single flush system. Single flush toilets use just one mechanism for all kinds of waste (liquid and solid) and have a minimum tank capacity of 4-6 liters.

### 3. The Calculation for Profitability and Energy Saving

#### 3.1 Lighting Energy Plan.

The calculations have been made with the following assumptions:

- The fluorescent light strips currently being used are 58 W each with a lifespan of 8000 hours.
- The lights are in use for 16 hours per day, 7 days per week.
- The cost of electricity is in line with the Kent average of 15.9 pence per kWh.
- The calculation for the annual usage cost for current lighting is as follows:
  - 16 hours per day x 7 days = 112 hours per week.
  - 112 hours x 365 days = 40,880 hours per year.
  - 40,880 hours x (0.058 kW x 61 fittings) = 144,633.44 kWh per year.
  - 144,633.44 x £0.159 = **£22,996.72 annually.**
In order to reduce the daily usage of the lights, the manual controls of all luminaires could be removed and replaced with Passive Infrared (PIR) sensors. The amount of energy that this would save is dependent on the length of time the lights were to remain on after no occupants were detected and how often the areas were left unattended. For the calculation, it is assumed that:

a. The timer is set to 5 minutes in all areas.

b. The daily usage of the luminaires is reduced to 13 hours per day.

In order to reduce the amount of energy used, an LED strip light rated at 20 W, £7.80 per unit with a lifespan of 30,000 hours could be used to replace the current fluorescent lamps. By using the same assumption of kWh cost and daily usage, the savings would be as follows:

- 61 lamps x £7.80 PU = £475.80 purchase price.
- 33215 hours/yr x (0.020 kW x 61 fittings) = 40,522.3 kWh.
- 40,522.3 kWh x £0.159 = £6,443.05 annually.

From these calculations, the total energy saving per year is 104,111.14 kWh that equates to £16,553.67. Excluding the labor and access equipment costs, the initial purchase of the replacement LED tubes would be paid back in 11 days. Due to the extended lifespan of the LEDs, additional savings from maintenance would also become apparent as the current fluorescents would have to be replaced a minimum of 3 times before the LEDs needed replacing.

3.2 Heating and Insulation

1. Windows. All windows are to be replaced with UPVC double glazed windows in order to reduce the amount of heat lost.

2- Heating. All heaters, fans and controls are to be cleaned and serviced. This is to improve the efficiency of all components in order to reduce energy consumption.

3- Insulation. Fire exit doors are to be replaced with new UPVC doors with appropriate door seals. UPVC doors are well insulated, and good door seals will reduce heat loss.

As the labor required to create a flat false ceiling is extensive, insulated plasterboard is to be installed on the ceiling of the Cardiovascular and weight training areas. It is to follow the angle of the pitched roof.

4. Appliances

4.1 Hand dryers.

An assumption has been made that the current hand dryer is operated on average 25 times per day for a period of 30 seconds per turn. The dryer is rated at 2600 W, and a kWh in Kent on average is rated at 14p. The calculation for annual usage and cost is as follows:

- 25 operations x 30 secs = 750 secs per day
- (750 secs x 365 days) / 3600 secs = 76.04 Hours per year
- 76.04 hours x 2600 W = 197.71 kWh
- 197.71 kWh x £0.14 = £27.66 per year

If an upgraded model such as the one shown in figure 4-B were to be installed, the savings would be as follows, assuming the same amount of operations and kWh cost. The new model is a 500w model that operated for 15 seconds.

- 12 second operation time x 25 operation = 300 secs per day
- 300 / 3600 = 0.0833 hours per day
- 0.0833 x 365 = 30.42 hours per year
- 30.42 x 0.5 kW = 15.21 kWh per year
- 15.21 x £0.14 = £2.12 per year
This equates to an annual saving of £25.5 per year. The cost of the recommended hand dryer is in the region of £200. The payback period for this improvement would be 7.83 years.

![A. Gymnasium hand dryer](imageA) ![B. Recommended hand dryer](imageB)

**Figure 4:** A. Gymnasium hand dryer  B. Recommended hand dryer

### 4.1.1 Gym equipment

There are currently ten treadmills, five stationary bikes, and five cross trainers in the gymnasium all powered from socket outlets. The Wattage rating or these machines are as follows:

- a. Treadmill = 1000W
- b. Stationary bike = 750W
- c. Cross trainer = 750W

It is estimated that each piece of equipment is used for 1 hour per day 7 days a week. The calculation for annual usage and cost is as follows:

\[
\text{Annual usage} = (10 \times 1000W) + (5 \times 750) + (5 \times 750) = 17.5 \text{ kWh}
\]

\[
\text{Cost} = 17.5 \text{ kW} \times 7300 = 127750 \text{ kWh}
\]

\[
\text{Annual cost} = 127750 \times £0.14 = £17,885.00 \text{ Per year}
\]

It is recommended that the gymnasium utilize manually operated cardiovascular equipment. The cost to implement this recommendation is shown in the calculations below:

- Assault runner cost = £3,369
- C2 Bike cost = £980
- Manually operated cross-trainer = £600

\[
\text{Total cost} = 3369 \times 10 + (980 \times 5) + (600 \times 5) = £41,590.00
\]

\[
\text{Payback period} = £41,590 / £17,885 = 2.33 \text{ years}
\]

### 4.1.2 Ice machine

The two ice machines situated in the gymnasium are in operation 24 hours a day and are rated at 4kW. The calculation for annual cost and usage is as follows:

\[
\text{Annual usage} = 2 \text{ machines} \times 24 \text{ hours' operation a day} = 48 \text{ hours}
\]

\[
\text{Annual usage} = 48 \times 365 \text{ days per year} = 17520 \text{ hours per year}
\]

\[
17520 \times 4 \text{ kW} = 70080 \text{ kWh per year}
\]

\[
70080 \text{ kWh} \times £0.14 = £9811.20
\]

The recommendation is to remove one of the ice machines and centrally locate the remaining ice machine so as the physio department and Gym users can utilize it. The savings for implementing this recommendation are shown below:

\[
\text{Annual saving} = £9811.20 / 2 = £4905.60 \text{ per year}
\]

There would be a negligible cost for the removal of the ice machine which could be recuperated by selling the unit to an interested party. The recuperation of funds would be almost instantaneous.
4.1.3 **TV.** There are five televisions situated in the gymnasium, which are underutilized / not in use. The use of televisions is not essential to achieve the expected benefit of using the gym. Due to this, the recommendation is to remove all the televisions. The televisions are 200W LCD. The usage of TVs is estimated to be 2 hours per day, five days a week.

The calculation for annual cost and usage is as follows:

- 2 hours x 5 days a week = 10 hours per week
- 10 hours x 52 weeks per year = 520 hours per year
- 520 hours x 5 Televisions = 2600 hours per year
- 2600 x 200 W = 520 kWh
- 520 x £0.14 = £72.80

By removing the televisions from the gymnasium, there is an estimated saving of £72.80 per year.

5. **Water Energy Plan.**

There are several water-saving devices available to reduce water energy use from fixtures substantially. Table 1 below shows a few recommended options available and potential water savings per year from the building.

5.1 **Water Usage Recommendation**

The following recommendation has been made to minimize water consumption in BFC:

a. **MKCTS** is recommended to replace the water heater with a tankless water heater, units that have an inner heating mechanism to heat the water to a specific temperature on-demand only. Tankless hot water consists of small boxlike, usually slighter size than boilers and possesses a little risk of dripping or becoming a fire hazard.

b. **MKCTS** is recommended to conduct annual inspection and maintenance for a water heater and drain hot water tank to eliminate deposited materials which collect at the bottom of the container. The sediment may cause corrosion in the chamber; therefore, it becomes less effective and possibly starts leaking.

c. **MKCTS** is recommended to replace single flush with dual flush toilet, which structures of two buttons on the container lid that is pushed in either half flush-for clearing liquid and full flush-for pushing down solid waste. Flushing lavatory uses more water than any other household item totaling 30% of all consumed water. With a dual flush system, it saves plenty of water besides having an eco-friendly urinal and cheaper in a long time.

The calculation shown below for the water heater has been made with the following assumptions:
- kW water heater operated 7.5 hours a day × 7 days per week = 157.5 kWh
- 157.5 kWh × Annually (365 days) = 57487.5 kWh
- 57487.5 kWh × £0.15913 = £9140.50 annually.

By replacing 3 kW water heater with a 3 × 2 kW power shower, the annual operating cost assuming at least 30 people showering 10 minutes per person will be:
- 30 people × 10 minutes = 300 minutes = 5 hours a day
- kW × 5 hrs a day × 7 days a week = 70 kWh
- 70 kWh × Annually (365 days) = 25550 kWh
- 25550 kWh × £0.159 = £4062.50 annually.

Figure 6. Electric shower heater unit.

From the above calculation, by replacing the water heater with the power electric shower, the total energy saving per year is 31937.5 kW that equate to £5078.06. Similarly, a significant amount of water can be saved by installing cheap and easy retrofit devices on showers, taps and flushing units. The cost estimate shown in Table 1 is based on 24 hours a day, 365 days a year.

Table 1. Water energy-saving plan

| Device                  | Recommendation                                                      | Replacement cost | Estimated annual saving | Payback period |
|-------------------------|---------------------------------------------------------------------|------------------|-------------------------|----------------|
| Water heater with a tank (3 kW) | Replace with electric shower heater (tankless water heater) - instantaneous | £600             | £5078                   | 2-3 months    |
| Urinals                 | Upgrade by installing PIR sensor control                             | £960             | Reduces water use by 70% | 9 months      |
| Basin taps              | Install tap aerator to control the                                   | £10              | Reduces flow rate between 2-8 liters/minute (50%) | -             |
| Male/female toilet      | Dual flush or Cistern volume adjuster (reduces the amount of water per flush by up to 2 liters) | £200             | £500                    | 3-4 months    |
| Shower                  | Install aerating shower head to control the flow rate (between 6-8 liters/minute) | £25              | £30                     | -             |

Recommended aerating shower head and tap aerator to reduce flow rate.
6. Conclusion

The transition to a low carbon economy requires technology to be deployed at every level from business operation, building design, distribution. In addition to technological fixes, it is essential to consider the business and human aspects. Measures are required to incentivize people and organizations to invest in the new low carbon technologies. Intensives can be financial, legal, or regulatory. Ultimately, it is how people behave as individuals and within organizations that will deliver a low carbon economy building operation, and energy supply. In order to effectively harness new technology, we need to create a system that encompasses demand, distribution and supply.

Over time the system must deliver a low carbon supply utilizing the full available resources in a commercially sustainable manner. The system is not solely technical; it must also include mechanisms that motivate people to choose the environmentally sustainable option. It must encourage building development to construct energy-efficient buildings, enable suppliers to offer appropriate tariff structures, and enable occupiers to operate buildings efficiently. It must ensure that electricity suppliers minimize their carbon emissions and maximize the energy conversion process whilst proving a high-quality service to customers. In doing so, not only infrastructure become more sustainable but so can our cities.

The paper has proved that by applying the energy saving on a building, the overall annual saving was £31155.27 in addition to ecologically friendly living. The average unit rate per kWh in the southeast of the UK is £0.2; therefore, the energy saving is 155.776 MWh annually.

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Figure 7: A. Recommended tap aerator. B. Existing shower head (left) and recommended shower head aerator.
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