

ENERGY CONSERVATION AND RENEWABLE ENERGY FROM SEWAGE TREATMENT IN THE UK

ENERJİ TASARRUFU VE İNGİLTERE'DE ATIK SULARDAN YENİLENEBİLİR ENERJİ ELDE EDİLMESİ

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ABSTRACT: This paper is an attempt to assess the performance and limitations of Biogas Combined Heat and Power (CHP) plants available to the water companies. This includes measuring the capacity of an average Sewage Treatment work (STW) for producing sludge and ultimately producing biogas. It also investigates the amount of electricity produced and the works self-sufficiency in terms of energy utilised.

Key words: Energy conservation, renewable energy, sewage treatment plants, water industry

ÖZET: Bu makale, su şirketlerinde bulunan biyogaz tesislerinin verim ve kısıtlamalarını değerlendirmeye çalışmaktadır. Bu da, ortalama olarak, üretilen çamur ve bunun sonunda elde edilen biyogaz üretim işlemlerinin kapasitesini ölçmekten geçmektedir. Aynı zamanda, üretilen elektriğin miktarı ile yapılan işin kullanılan enerji bakımından, kendi kendine yeterliliği incelenmiştir.

Anahtar Kelimeler: Enerji sakınımı (korunumu), yenilenebilir enerji, atıksu, arıtma tesisleri, su endüstrisi

Introduction

The study addresses one aspect of the ethical issues and highlights the responsibility of both the government and the industry for full commitment to the principles of the Brundtland Commission on Sustainable Development. In the late twentieth century following the Climate Change syndrome, the alarm was raised for the adoption of energy efficiency and utilisation of the renewable energy strategy by the energy intensive industries.

The Department of Energy (2001) advocated that renewable sources such as, wind, solar, hydropower and biomass could generate up to 70TWh (Terra Watt hour) of electricity per year and 20 million tonnes of coal equivalent of heat per year by 2025. The UK currently consumes about 250 Terra Watts hour (TWh) per year of electricity and a total of 330 million tonnes coal equivalent (mtce) per year of primary energy. A small fraction of this energy can be recovered by using biogas to provide electricity in the water industry (British Gas, 1990).

Today's world should, in principle, bear responsibility with respect to the needs of tomorrow's world, "the future generation". Energy conservation therefore is almost on every government's list of priorities. The recent environmental disasters are believed to be indicators of the intensified human consumption and waste since the

industrialization and more severe in the twentieth century. The Ozone depletion, global warming and climate change are believed by some experts, no longer to be scientific assumptions based on some hypothesis but facts in the twenty first century. To prevent further environmental catastrophe happening and reduce greenhouse gas emission into the atmosphere, both producer and consumer will have to look into the issue of energy conservation and limiting waste worldwide. One of the most dominant green house gases is methane. This study investigates methods of utilising the "biogas"(methane, carbon dioxide and hydrogen), naturally occurring from the fermentation of sewage sludge in the UK's sewage treatment works.

Since the water industry is the third most energy intensive sector (Journal of The Ends Report, 2002), therefore there is justification for some investment in the renewable energy technology. The biogas, mainly methane, is to be used as fuel for the combined heat and power. A comprehensive study was undertaken in this study, with respect to the renewable energy systems involving the utilization of biogas from sewage treatment at the sludge digestion stage. Today, the energy conservation, recycling, reuse and finally producing electricity from renewable sources are among the most important solutions to environmental issues.

This paper reflects the importance of the climate change convention and the global renewable energy programme. This follows the requirements of the Kyoto Protocol agreement, which sets a target to reduce emission of green house gases to 12.5% relative to 1990 emission levels. The study also incorporated the European Union directives, new renewable (2001/77/ec), renewable energy at EU level and the IPPC directive, Integrated Pollution Prevention and Control (96/61/EC), which is about minimising pollution from various point sources. The IPPC directive requires the industry to hold an installation permit, which is based on the concept of the Best Available Technique (BAT).

The water industry consists of ten major water companies in England and Wales. They treat raw sewage and supply potable water. On average, each company has about 350 sewage treatment plants. Most of these plants treat 500 to 600 litres per second throughput. They also supply approximately 235 litres of water per head per day (Twort et al, 1974).

The study issue affects the stakeholders, which are water companies, customers, the public, regulators, pressure groups, etc. The study problem is in the area of the sewage treatment works and it occurs when sewage is treated. This area is chosen for this investigation because there seems to be an opportunity to save energy and reduce emissions of greenhouse gases. The problem occurs because of some constraints such as, costs, company culture, and low cost of energy is inhibiting adoption of new technology, which will have these advantages.

Biopower (electricity produced from renewable energy sources, sometimes referred to as green power) is now widely available and both the private and public utility companies are being encouraged to use the technology and reduce dependency on energy from fossil fuel. Support for renewable thinking seems to have removed some reservations by water companies about the adoption of green power. The scarcity of some raw material and rise in energy prices could soon put some pressure

on the water industry to further improve efficiency of resource use and invest in renewable energy. This may be achieved by using the sewage sludge for producing combined heat and power. This would also be an indicator for the renewable energy objectives as part of water companies' environmental management system (EMS).

At the sewage treatment works, all the wastewater from the domestic and industrial effluent is collected at the screen stage where large debris and other materials are separated. The incoming flow will then pass through the grit channel where grit is removed. The foul water will then flow first to the primary treatment tank and after to the secondary treatment tank. The settled sludge in both stages is pumped to the sludge treatment unit, and then into the digester tank. Through anaerobic digestion (without oxygen), bacteria digest the sludge, breaking down all organic wastes and produces biogas (White, 1978). This gas is a mixture of methane 55% to 75%, carbon dioxide 25% to 45%, and hydrogen 0.1% to 2%. The typical values are: 67%, 30% and 2.0% respectively. The presence of toxic waste results in destruction of the bacteria and hence stop the normal gas production (The Project Rosedale, 1999).

The sludge has to be heated (heat is provided by the combined heat and power plant) at a temperature of 68F or 37C for 2 to 3 weeks. The biogas from the digester, which contains about 60% methane gas, is then burned in the spark ignitions, which drive the alternator to generate electricity. The volume of gas produced in the digester is about 1 cubic metre per kilogram of volatile solids destroyed. The gas produced is also crudely estimated using per capital form and this amounts for up to 22 cubic metres per thousand persons per day. For example:- for an average town of 800,000 population (Bristol/Avonmouth) the figures show 640,000 cubic metres per day (Tchobanglous et al, 1981).

The combined heat and power plant at a sewage treatment works may generate up to 8 MW of electricity with electrical efficiency of 38%. The CHP installation costs £3.5 million (Wessex Water, 2001). The heat produced is in the form of hot water, which is used to heat the digesters and utilities on site. There are also other technologies available, for example: - Fuel Cell and the gasification. The cost of treating sludge and CHP plant installation together with the climate change levy, emission release compliances and EU directives and other regulators' impacts on water companies has been looked at. With respect to energy conservation, Some water companies are responding to the pressures from both public and government. The examples are the operations of CHP at Thames Water's Swindon Sewage Treatment Works and Wessex Water's Avonmouth Works Bristol England. The study suggests ways of reducing emissions by the utilization of biogas from the sludge treatment process to generate electricity.

The UK water companies treat millions of litres of raw sewage every day in their treatment works. As an example, Swindon Works receives 600 litres per second. With the adoption of appropriate technology there is in theory scope to generate 2 to 8 MW per year electricity in a large CHP plant (Wessex Water, 2001). Across the UK this would comprise a considerable amount of energy. The environmental problems facing the world are numerous, among them: the scarcity of non-renewable resources, impact of pollution on the environment and the needs of future

generations. The problem of not being able to fully utilise the by-products of processes, reuse of materials (from cradle to grave) and limitations of these kinds, in the interest of the public, and company profits needs analysing. These are organisational management limitations that could be interpreted as barriers that have an effect on progress and development.

Today energy issues are very controversial. For example: - as the latest technologies are available, using energy from fossil fuel becomes more and more unacceptable (as this is a dominant feature of twentieth century wind turbines, solar panels, CHP and hydroelectric plants). It is claimed that there is resource limitation and that this will affect supply. This in turn will cause price rises. The developing world will have to meet their internal demands as they go through their industrialization phase and it will limit their export of resources. To avoid conflict between developing and the developed countries, there will be a need for some degree of adaptation and review of energy policies by the OECD countries (The Open University, 2000). This will include compliance with the terms of recent guidelines and energy conservation, reuse, recycling, the utilization of the renewable resources and the climate change convention guidelines.

This study, therefore, seeks to some extent to suggest ways of removing the barriers, and highlights what may be done to reduce the problem of energy dependencies of water companies on imported power. In the second half of the twentieth century, it became evident that emissions of certain gases is forming a blanket-like barrier in the atmosphere which prevents reflected sun's heat from escaping into the space, and therefore, creating greenhouse conditions. Among these gases, carbon dioxide (CO₂) and methane are the more dominant.

In 1990 – 1991, 120,000 tonnes of carbon dioxide was emitted by one water company alone (Wessex Water, 2000). In 1999 – 2000, 80.236 tonnes of CO₂ from energy, 4386 tonnes of methane (106 t CO₂ equivalent) and 5460 t (tonnes) of CO₂ from transport were emitted by the same water company. Against this, measures have been taken to utilize almost all of the available biogas for power generation on major sites.

The UK's target is to reduce CO₂ emissions to 20% below 1999 levels by 2010 (European Commission, 2001). It must be said that the 'Kyoto' is not without criticism. According to Bjorn Lomborg (2001), 'economic analyses show that it will be far more expensive to cut carbon dioxide emissions radically than to pay the costs of adaptation to the temperature'. The water companies claim to have their own effective strategies to handle the integration of environmental protection into their policy. This study will contribute to a better appreciation as to whether such claims are warranted and whether such companies could do more. This study also supports the needs for environmental education. The following is pointed out in the British gas 1990 key environmental issue 14:

Environmental education is an important means to raise decision makers' awareness of sound and responsible decision-making, at all levels. The quality of our decisions will depend on our ability to understand the issues involved, and also on our willingness to consider the implications of those issues, however, uncomfortable they

may be. This applies particularly to those in business industry, and commerce; not just construction, oil, large scale farming, but everyone; the insurance companies, the PR people, the young men in front of the flickering index screens, the butcher, the baker, and the fibre-optic maker. In some ways the lesson has been well learned.

Definitions of terms such as energy conservation and renewable energy in the domain of the water industry would ease the understanding of the core issue related to the study problem. The energy conservation related to the reduction of imported energy and an increase to the production of electricity through the utilisation of sewage sludge gas at the sewage treatment works. The renewable energy is a term used in this study to relate to sewage sludge gas or Biogas, which is produced through the digestion process.

The study focuses on two issues, one is the prospects of expanding Biogas CHP development in the UK industry. The other issue is that the assessment of limitation (technology, the culture of the industry) that inhibit the development. Figure 1 shows the spray diagram adapted for the intended holistic approach in the study. Figure 1 as well as the other three presented in this paper are based on diagrams presented in Standard British Open University postgraduate modules, referenced accordingly as elucidated.

A number of CHP plants such as the Engine Generator and Fuel Cell are being used world wide in the waste treatment industries, but there are problems associated to the nature of the technology (cost, operational and maintenance) and the water industry's culture that has influence in the decision making process. This would include the unique nature of the private enterprises to base their decision - making on efficiency and the results of cost benefit analysis (Park, 1986).

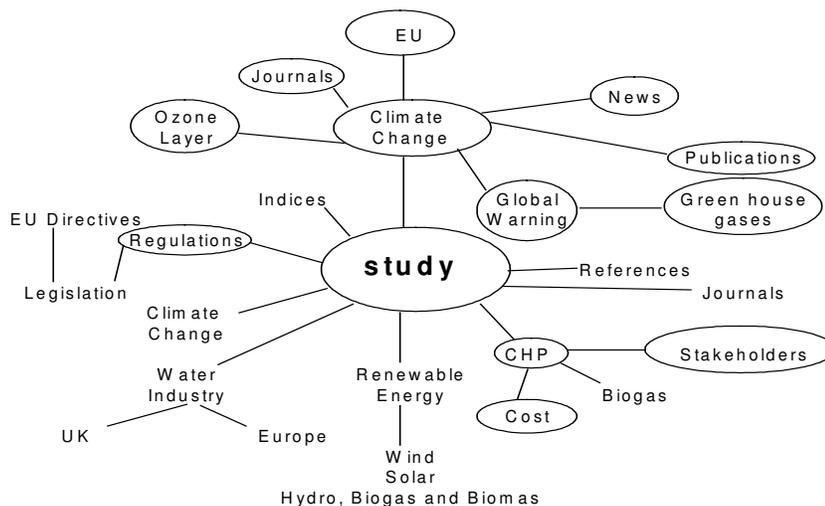


Figure 1. Spray diagram for studying holistic approach
(Environmental Decision making, Open University Publication, T 860, 2002, UK)

Figure 2 depicts the main stakeholders in the renewable energy areas of interest.

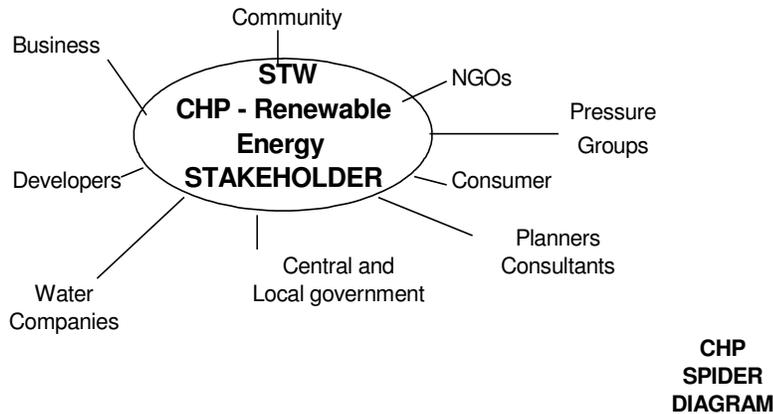


Figure 2. The Stakeholders

(Enterprise and the Environment, Open University T 830, 2002, UK)

Definition of scopes

The consumption of energy by various sectors is alarming. The demand for energy is so great that recently a £9 billion plan is being drawn by British energy and British nuclear fuels to build nine nuclear stations to replace the ageing advanced gas cooled reactors (Guardian, 27th February 2002). Despite the demand for energy, not all forms of energy generation are deemed acceptable. A week previous to this news, on 20th February 2002 the Guardian printed the following remark: - “The renewable energy, wind farms in mid Wales is the centre of controversy, for some the wind turbines are blights on a glorious landscape, for others, they mean clean energy and economic lifelines for rural communities”. This study focuses on the water sector to find ways of reducing its energy demands.

The water industry consumes 6000 GWh of energy each year. It is the third most energy intensive sector and only steel, cement and part of the chemical industry account for higher use of energy (Journal of The Ends Report, 2002). Some water companies such as Anglian Water argue that improved water quality and increased sewage treatment will call for higher levels of energy use. The study therefore is seeking to identify factors, which could reduce the overall energy consumption. It then focuses on the assessment of opportunities available to further extend the use of renewable energy and the operation of CHP at the sewage treatment works.

Under today’s political and economic climates, it seems that the public believe there is a case for supporting the expansion of the green power generation (Biogas CHP) and that the study is valid. During the course of the study many issues were noted related to the environment. These were brought to the public’s attention through the media worldwide. A diary was prepared and incidents heard or read (TV, radio and newspapers) were recorded. It is appropriate to look at the following materials

broadcast or published supporting the energy conservation and the environmental protection theme:

The BBC 1 news on Saturday 17 March 2002 informed the public that chemicals in waste (sewage) caused fish to change sex and become sterile. Water companies claim water and sewage treatment demand more energy and cost these days because of the nature of the throughput.

The BBC 1 news on the 15 July 2002 reported, “cancer cases are above the national average in Burnham On Sea, Somerset. This, it was stated to be related to Hinkley Point nuclear power station in Wales”. Here, 2 issues come to mind immediately, one is the danger from radioactive waste and the other is the cleaning up of beaches and the huge cost to the water companies. Another added problem was identified by the Friends of the Earth (1998), which states, ‘ nuclear is no solution to Climate Change, a mixture of energy efficiency and renewable energy offers a quicker, more realistic and sustainable approach to reducing carbon dioxide and that the nuclear power is one of the least cost effective ways in which to cut carbon dioxide emissions’.

On the subject of Climate Change, BBC radio news reported on the 20 March 2002 that an Ice Shelf as big as Cyprus broken off the glacier in Antarctica. On 21 February 2002, it broadcast the flooding in Bolivia, where people were drowning in the floodwater in the city centre and the rescue efforts failed. Today, all these are widely perceived warnings that reduction in greenhouse gas emissions and energy conservation are not just some policy issues for governments and industry (to be used as a distraction), but in reality, life and death matters. Therefore, the water industry’s plea for support in their efforts for emissions reduction and energy conservation could therefore be justified.

Wherever there is a sewage treatment plant there is sludge to be treated. In the small sewage treatment plants this sludge may be transported to a larger site for treatment. The biogas from the sludge digestion process could be fully utilised in energy conversion process to satisfy the latest environmental protection legislation and European directives.

The water industry is claiming that the consumption of energy is rising in line with tighter consent conditions (see tables 1 and 2)

Table 1. Energy use per mega-litre, KWh’s
(Journal of The Ends Report, 2002)

Year	1998/99	1999/00
Drinking Water Supplied	468	553
Sewage Treated	437	454

Table 2. Electricity use and generation by water companies 2000/01
(Journal of The Ends Report 2002).

COMPANY	CONSUMPTION MWh	RENEWABLE GENERATION MWh	% CONSUMPTION OFFSET BY GENERATION
Anglian	706,000	10,600	1.5
Northumbrian	643,000	9,000	1.4
Severn Trent	852,500	76,367	8.9
Southern Water	370,000	3,600	1.0
Thames	999,000	124,000	12.4
United Utilities	722,000	?	?
Welsh	373,000	?	?
Wessex	245,000	?	?
Yorkshire	493,000	9,000	1.8

The E.U directive for sludge disposal controls the disposal of sludge on agricultural land near the Sewage Treatment Works. The Council directive 86/278/EEC (1986) is for the protection of the environment when sewage sludge is used. The aim of the directive is to regulate the use of sewage sludge in agriculture and to prevent contamination of soil, vegetations, animals and human.

It is claimed that there are risks with respect to long period of wet weather and foot and mouth disease, and this is due to increasing phosphate and metal levels in soil. The need for transporting sludge to a remote area would require more energy and is therefore uneconomical.

Another issue is highlighted by The Journal of Ends Report (2002) is The New Electricity Trading Arrangement (NETA) implies, namely that, 'Water companies are unable to pass the levy costs on to customers at least until the next price review in 2004. However, their complaints that the levy has hit profits need to be seen in the context of wider industrial energy prices. Wholesale electricity prices have fallen by almost 20% since the introduction of the new electricity trading arrangement (NETA) In April 2001, and by considerably more over the past 4 years. Against these limitations, there are hopes for water companies to enter the greenhouse gas trading market via 'Project mechanism'. This means that those companies that carry out 'Approved Emission Projects' may sell emission credits. Also sectors regulated under 'Integrated Pollution, Prevention and Control' (IPPC) are offered 80% exemption from the levy if their "Agreed Emission Saving" targets are properly met. Taking advantage of new technologies is another way to save energy. One example is recognised as The Sonix System, which is utilised by 'Wessex Water' at Avonmouth Sewerage Treatment Works. Using this system, the sludge is passed through an ultrasonic sector to break down cell walls, which increases digestibility. The Sonix claims that 33% more breakdown of sludge causes a 55% increase in methane generation. Other cost saving could result by considering Reeds Beds and Stabilising Ponds (sewage farm lagoons for improving the final

effluent). Reeds plants have the capacity to transfer oxygen from the stem to the roots where biological action purifies the sewage. The treated effluent is almost clean when it is finally discharged into the watercourse. All these measures could make a difference in cost reduction, allowing water companies to invest in Renewable Energy despite their tendency to look to reducing Tariffs and checking billing (Journal of The Ends Report, 2002).

In most of the UK's large sewage treatment works there are combined heat and power plants, which use the biogas from sludge treatment process and produce electricity and hot water. At present there is evidence (Clarke Energy, 2001 and Energy User News, 2002) that in the USA and the UK the CHP installations provide sufficient electricity to run the treatment processes. The examples of these for the UK are the sewage treatment works at Avonmouth - Bristol and Thames Water at the Swindon site.

In Figure 3, CHP operation at a Sewage Treatment Works (STW) is shown to identify main components. Figure 4 using a Sankey diagram elucidates the flow of energy in typical CHP and the potential for investment.

Two issues need to be considered here. First, what we know about the appropriate technology or technologies and second what we don't know about them. So far, there had been some introduction of the technology. But, what is not known is the culture of the water industry. They may claim that they are a waste management and a water supply company and not a power supply company. Its management may also argue that it is not cost effective to consider extensive investments in renewable energy. This is due to the limitations such as cost of installation and maintenance plus the insufficient sludge volume. In addition the lack of real support from the government and the public reduces the pace of progress.

The study assesses the prospects for expanding energy conservation and renewable energy for sewage treatment in the UK water industry. What is important to know is the technological, costs, organisation-cultural reasons that inhibit the adoption of technology and also the actual opportunities (in terms of the amount of gases produced, amount of energy saved, degree of reduction of greenhouse gas emissions and scope for operating cost reductions) offered by adoption of this technology on a wide spread scale by the water industry. To enhance the investigation and improve the assessment, also experiences outside the UK has also been considered.

The hypothetical view in the study is that there are compelling technological, environmental, organisational-cultural and economic reasons in support of expanding energy conservation and generation of renewable energy from sewage in the UK water industry.

In the past each water company had to deal with its sludge disposal by treatment and through dumping at sea before the legislation prohibiting dumping at sea was enforced in 1998.

Each company therefore has its dewatering and digester system for the treatment of sludge. Recently, the combined Heat and Power operation formed part of the

renewable energy programme. It then called for the expansion of digestion area and production of electricity.

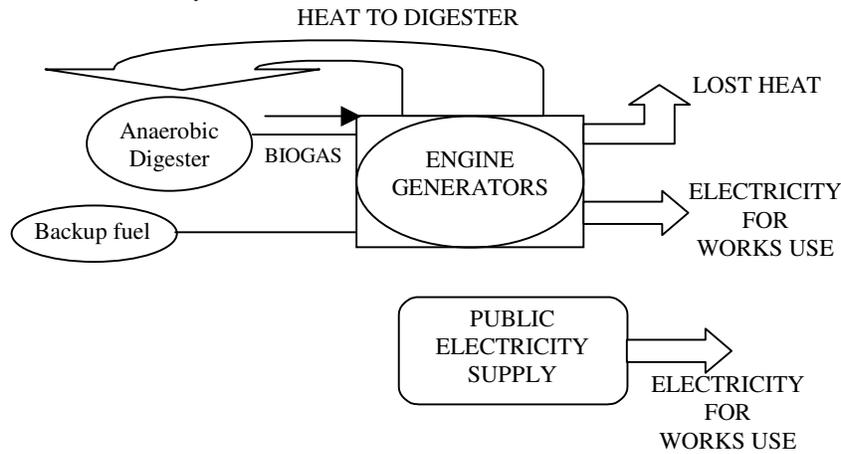


Figure 3. CHP Operation at the STW

(Capacity for Managing Development, Open University, TU 870, 2002, UK)

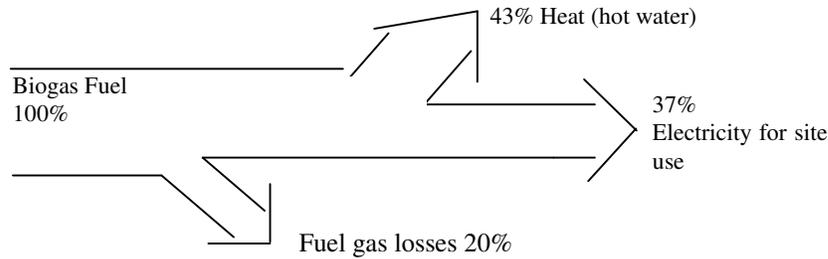


Figure 4. Sankey diagram showing energy flow at STW

(Capacity for Managing Development, Open University, TU 870, 2002, UK)

Since dumping at sea is illegal, most companies invested in treating sludge for cropland and grazing land or alternatively, in some cases in UK, burned through the incinerators. Treatment of sludge is vital if it is to be used as fertilizer. Raw sludge contains pathogenic organisms that are harmful to flora and fauna when these are in contact with soil. These bacteria are destroyed through some chemical treatment and then through fermentation, which produces biogas.

In summary, benefits and costs determined by Wessex Water Plc are as follow:

Benefits

- Government energy premium is £500 per day for energy efficiency measures.
- When Green power produced on site is used for site operations, it displaces imported electricity from the supplier.
- Exemption of green power from the CCL (0.43ppKWh) can be counted.
- ROC worth 3ppKWh, is taken into account.
- Value of the heat recovered (30% of energy input into the CHP plant).

- f) Renewable energy can be exported at 4.53ppKWh (1.7+0.43+2.4pence)

Costs

- g) Installation costs (£3 million)
- h) The maintenance costs 1.6ppKWh
- i) The plant service period causing 15% loss in operation time
- j) Increase in payback periods (more than 3 years)

There is still a strong feeling towards the quality of river water (where water is extracted for treatment and supply) and other environmental domains, such as farming lands (where treated sludge is spread for soil improvement) and air (eliminating odour and release of green house gases). There is also an obligation by the water companies under the environmental protection act, IPPC and pressure from the regulators and directives to promote a green culture. This approach is very much evident from the literature and annual reports produced by the water companies, their performance of biogas – CHP, and energy efficiency on site.

Sewage Treatment Work at Avonmouth (Bristol)

At Avonmouth, five spark engines (model 3516 caterpillar) are used, and each with capacity of 1.15 MW and total power of 5.8 MW per year. The average demand is 2 to 3 MW (2 MW power demand per year for an average STW). The works therefore is self-sufficient. The Swindon site on the other hand produces approximately 23 tonnes of sludge and 4400metre cubed of biogas each day. This is not adequate for self-sufficiency of the works. The site demand for power is about 2 MW per year. The electricity produced is about 1.5 MW per year, which is not quite sufficient to meet the demand. The CHP and its building require 4 KW/hr which should be taken into account when running costs are considered. The heat is used for heating digesters in both sites (Wessex Water, 2001).

Conclusions

The study focused on an issue, which has attracted the attention of both the consumer and supplier of energy and alarmed the industry and the government about the consequences for the lack of commitment to the principles of the sustainable development. The energy crisis gained ever-increasing controversy and demanded a solution to the problem. Consumption and energy use since industrialisation lead to today's globalisation and commercialisation. Some believe this was inevitable and it is human nature to learn and develop. Here the hypothesis for a brighter future and benefits to all nations in a democratic environment is that successful development could take place if environmental protection is also considered as a theme and integrated in any business activity.

The trends show that as the new culture (green culture) is being evolved the industry has been working towards the fulfilment of its responses to the change. The cost of technology is reducing each year (3 years payback periods are reasonable) and with government incentives, it is to an extent possible to promote the renewable energy programme at most Treatment Works. One may conclude here that the expansion on some sewage treatment works is foreseeable under the existing economical and political climate.

The implications warn the industry and the government about the consequences of lack of commitment to the principles of sustainable development in business policy and operations without the environment policy. Further work is required to promote the development of renewable energy programmes in the water industry. This could be done through incentives, and government assistance. The services of energy prices and taxes seem necessary to spur on the renewable energy.

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