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The Scottish Exhibition and Conference Centre Energy from Waste project: A sustainable viewpoint

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CONTENTS

ABSTRACT

The Scottish Exhibition and Conference Centre is planning to generate its own energy to cover its actual and future needs. The energy requirements are not only electricity but also heat and cooling. The generating proposal has to make use of renewable energy. Energy from Waste is one of the options that will be evaluated. There are two main drivers involved in the proposal to build an EfW plant: One is the need to comply with the waste diversion targets set by the Landfill Directive. The other driver is outlined in the Energy White Paper in which limits for Carbon Dioxide emissions are set for the UK in the mid-term future, thus promoting the development of renewable energy sources. Both drivers have a more sustainable development approach in which landfill is avoided and more efficient energy sources are used. Sustainable development indicators are in place too in order to measure the contribution of any project towards the sustainability goals.

The Scottish Exhibition and Conference Centre Energy from Waste plant will help to achieve the energy requirement that the development needs to attain. It will do so in a more sustainable manner when compared to other options.

Among the benefits that such a development will bring and which are discussed and quantified are the help to reduce the amount of waste that will be diverted to landfills, the much better economic performance when compared to the current and future landfill options, the Carbon Dioxide emissions avoided and the offset of non renewable resources. They all have a positive impact on Sustainable Development Indicators such as the Climate Change, Energy: Renewable and Waste: Landfilled. Finally, other issues related to the Energy from Waste project will be mentioned, such as the Renewable Obligation Certificates and the public perception towards incineration facilities.

INTRODUCTION

The Scottish Exhibition and Conference Centre (SECC) is aiming to be self-dependant in terms of energy consumption. The SECC is a landmark development for the city of Glasgow, therefore many actors are interested in making this an outstanding project, including Glasgow City Council and the Scottish Environment Protection Agency (SEPA).

The energy requirements of the SECC are not only electricity, but also include the use of heat in the form of either heating or cooling for the current and planned developments within the area.

The proposal has to make use of renewable energy sources to boost Scotland's image as a country devoted to make sensible use of them. Energy from Waste (EfW) is one of the options that will be evaluated to fulfil the SECC needs, based on a power plant to supply both the electricity and heat. The feedstock of the power plant will be Refuse Derived Fuel (RDF). This will be supplied by the plant that Glasgow City Council has commissioned to be in operation soon.

There are two main drivers involved in the proposal to build an EfW plant. One is the "National Waste Strategy: Scotland" which deals not only with ways to reduce the amount of waste produced, but also how to handle it. Subjacent is the need to comply with the waste diversion targets set by the Landfill Directive (99/31/EC), among others, such as developing this sector in order to ensure that it is sufficiently efficient to compete in the UK and European context and lastly as a response to the commitments of the United Nations Conference on the Environment and Development held in Rio (1992).

The other driver is to make use of renewable energy sources, framed within the more ample strategy outlined in the Department of Trade and Industry's (DTI) "Energy White Paper: Our Energy Future – Creating a Low Carbon Economy", in which limits for Carbon Dioxide (CO_2) emissions are set for the UK in the mid-term future. Among other ideas expressed in the document, some related to an EfW project, are that the UK will continue taking steps towards reducing Green House Gas (GHG) emissions and maximise the benefits arising from the Combined Heat and Power (CHP) schemes.

Advantages and disadvantages of Energy from Waste

The major advantages of EfW facilities can be summarized below:

- Electricity generated from waste becomes an income source and reduces the use of power from conventional sources such as gas or coal.

- If a CHP scheme is adopted, additional reduction of gas or oil used for space heating is also achieved together with additional economic benefits.
- The waste is diverted from landfills, which reduces the methane emissions from the site and in addition reduces the requirement for landfill space by approximately 70%.
- Ultimately, waste is a resource that deserves to be properly used and not just disposed of in a non-sustainable manner.

However, energy recovery from waste is far from being a faultless solution:

- An EfW process produces ashes that may need to be landfilled if not used in other industry (e.g. construction).
- Typical low conversion efficiency (17% to 21%). However, CHP schemes have much better efficiencies (ILEX Energy Consulting. 2005).
- Emissions are still frequently cited as a barrier to planning consent.

Sustainability issues

Since the Conference on Environment and Development in Rio, 1992 (known as the Earth Summit) and the World Summit on Sustainable Development in Johannesburg (2002), the UK government has been determined to make sustainability a core element in its domestic policy. In the document "One future–different paths. The UK's shared framework for sustainable development" (Department for Environment, Food and Rural Affairs, 2005), the UK Government and the Devolved Administrations agreed on the new framework goal for sustainable development:

> "The goal of sustainable development is to enable all people throughout the world to satisfy their basic needs and enjoy a better quality of life without compromising the quality of life of future generations.
> …that goal will be pursued in an integrated way through a sustainable, innovative and productive economy that delivers high levels of employment, and a just society that promotes social inclusion, sustainable communities and personal well-being. This will be done in ways that protect and enhance the physical and natural environment, and use resources and energy as efficiently as possible…"

A series of national indicators were defined in order to keep track on and evaluate the measures that were proposed. The indicators are based on the UK shared priority areas for immediate action:

- Sustainable Consumption and Production
- Climate Change and Energy
- Natural Resource Protection and Environmental Enhancement
- Sustainable Communities

The above mentioned priority areas will influence the SECC project. The regional authority guided by them, has created a series of indicators aiming to trace the development of the initiatives and in some way measure the Scottish path towards sustainable development. The document "Indicators for Sustainable Development for Scotland: Progress report 2004" by the Scottish Executive Environment Group outlines the main indicators and targets.

Other important issues

The Renewable Obligation is the Government's main mechanism for promoting the use of renewable energy sources, specifically designed for the energy generation sector. In Scotland, the Renewable Obligation (Scotland) is in place. Gasification and Pyrolysis are within the Renewable Obligation Certificate's (ROC) scope if the energy source is waste. However, conventional EfW is not covered and therefore, the electricity generated by these means will not benefit from this providence in the form of the tradable certificates although it is a renewable energy source. ROC extended eligibility will impact the economies of the conventional EfW projects and may become a valid decision criterion when compared to other waste management options. If the eligibility is extended, then it could also have a major impact on the renewable sources development as it could become less risky, in economical and technological terms, to develop EfW instead of other renewable sources.

Finally, as with any other mayor industrial project, the SECC project will undoubtedly have an impact on public perception. It is inevitable to be controversial when dealing with an EfW plant. Any large new industrial proposals face at least three challenging forces from the local inhabitants that will normally be against its development (Brown, T. 2001):

- The natural reluctance to any large industrial development. Even if the scale is small, the impact that the project will have on transport and property values is of considerable concern to the local residents.
- Fears about the health impact of emissions from incineration.
- Concerns about whether or not the plant will diminish the community recycling efforts.

Public involvement seems to be the ideal way to overcome the negative attitudes towards EfW, however, all parties involved in the project development need to make efforts in solving the situation. Current public understanding and awareness of waste issues is poor (Brown, T. 2001), which means that the government, environmental agencies, local authorities, environmental groups and the waste industry will need to play a more decisive role in improving the situation.

All the above mentioned elements provide an overall image of what the SECC project is about: a complex series of interdependent relations within a legislative frame that aims towards acheiving sustainable development in a demanding social context. For this particular study, sustainability will be tackled in four different areas: meeting the landfill targets, resources use, CO_2 emissions savings and offset of fossil fuels. The first will be limited to net space savings (tonnes of waste not landfilled) due to both the operation of the RDF plant and the incidence of the EfW project. The resource use will be viewed as an economic comparison of the current landfill option and the proposed SECC project. For this purpose a model will be built, compared and validated. A series of different case studies and recent literature figures will be presented and tested. In addition, the SECC project will be economically evaluated under different operational and financial alternatives in order to make it more attractive as a financial investment. As in any possible investment option, the attractiveness will be centered on the Net Present Value (NPV) and the Internal Rate of Return (IRR). In the section dealing with emissions savings, these will be calculated estimating how much CO_2 will not be released into the atmosphere if the EfW project is developed. This is because of the biogenic nature of the RDF that will serve as fuel for the plant. Savings will be calculated based on the estimated energy production of the project and compared to a conventional fossil fuel power plant and the current landfill option. Finally, the project impact on the offset of fossil fuels will also be estimated. For the last two sustainability issues, the comparison will be

mainly against a power plant delivering only electricity, as this is the most likely scenario.
The above mentioned items will have an effect on the Sustainable Development Indicators that the regional authority has developed. Thus the results will be projected into the Sustainable Development Indicators and therefore their theoretical impact assessed.

In summary, this thesis will try to quantify the impact that the SECC project will have on some sustainable development issues. These will be reflected in the local Sustainable Development Indicators. This is important because at first glance an EfW facility raises concerns about its benefits, and therefore demonstrating that it can be more sustainable that the current landfill option will certainly help to improve its image and facilitate its acceptance.

CHAPTER 1

SUSTAINABLE DEVELOPMENT AND AGENDA 21

In 1972 (Stockholm) the UN agreed on the need to respond to the problem of environmental deterioration. Twenty years later the protection of the environment, along with social and economic development were taken as fundamental to sustainable development during the Conference on Environment and Development held in Rio de Janeiro. The global programme called Agenda 21 in addition to the Rio Declaration on Environment and Development, were the results of such global effort. Ten years after Rio, during the Johannesburg Summit, the vision of sustainable development was further developed.

Some of the most challenging issues that affect the world are summarized in the "Johannesburg Declaration on Sustainable Development" (United Nations, 2002):

- Poverty eradication, changing consumption and production patterns and protecting and managing the natural resource base for economic and social development.
- Society division between the rich and poor and even worse, the increasing gap between the developed and developing worlds.
- Continued loss of biodiversity, desertification and the adverse effects of climate change, air, water and marine pollution.
- Globalization and the rapid integration of markets, with benefits and costs unevenly distributed.

A series of commitments were undertaken, among others:

- The world diversity to be used for constructive partnership for change and for the achievement of the common goal of sustainable development.
- Commitment to speedily increase access to basic requirements as clean water, sanitation, adequate shelter, energy, health care, food security and the protection of biodiversity.
- It is recognized that sustainable development requires a long-term perspective and participation in policy formulation, decision-making and implementation.

The Agenda 21 document is a comprehensive plan of action to be undertaken by governments and groups in every area in which humans impact on the environment. It was adopted by more than 178 Governments and reaffirmed in the Johannesburg summit in 2002. The original Agenda 21 document was divided in four sections:

1. Social and economic dimensions
2. Conservation and management of resources for development
3. Strengthening the role of major groups
4. Means of implementation

Every section has a series of chapters dealing with more specific issues in the relevant area. Each chapter contains programme areas divided in terms of the basis for action, objectives, activities and means of implementation. As stated previously, the document is not only a global consensus but also has the very important factor of commitment. One of the most important results is the proposal to use indicators in order to measure the extent of the current situation and use them as benchmarks for future goals.

AGENDA 21 IN THE SCOTTISH CONTEXT

Scotland has a history of social deprivation thus the implementation of sustainable development in the form of a local agenda 21 has become part of the government efforts to eradicate poverty and increase social justice (Scottish Executive 2002). In 1997, the then Prime Minister set a challenge to each UK local authority to have a Local Agenda 21 plan by the end of 2000, target that was met by all Scottish local authorities.

Since the creation of the Scottish Parliament and Scottish Executive, many of the strands of sustainable development were devolved. Environment, transport, waste strategy, education, housing, economic development, rural affairs, planning, health and encouragement of renewable energy were among those devolved. The Executive's commitment to sustainable development was expressed with the creation in January 2000 of the Scottish Ministerial Group on Sustainable Development which later became the sub-Committee of the Scottish Cabinet in which the First Minister is the chairperson (The Scottish Parliament, 2002). Membership comprises a number of senior Ministers with responsibility for key issues such as Social Justice, Enterprise, Transport and Life Long Learning, Finance and Public Services among others. Another important achievement that illustrates this commitment is that all Bills sent for consideration by the Scottish Parliament must include a statement on their effects on sustainable development.

The Scottish Executive has chosen 24 indicators following the Agenda 21 recommendation in order to monitor the sustainable development process and in some way measure the effectiveness of the actions. Any industrial facility project will have an impact on the sustainable development indicators. The nature of the impact, positive or negative, will undoubtedly affect the project fate in terms of acceptability. The SECC project cannot escape this. Among the indicators that do have targets and are related to the SECC project are:

- Waste landfilled: reduction from 1.7m tonnes biodegradable municipal waste landfilled to 1.25m tonnes by 2010. In the document "Indicators of Sustainable Development for Scotland 2004" the target was raised to 1.32 million tonnes.
- Renewable energy: 18% of electricity from renewable sources by 2010, from current base of 10.4%. Due to consult on 30% by 2020. The document "Indicators of Sustainable Development for Scotland 2004" shows an increased value of 40% by 2020.

Some other indicators do not have measurable values but equally concern the SECC project:

- Climate Change (million tonnes greenhouse gas carbon equivalent): the Executive "will make an equitable contribution to the UK Kyoto target", this is, 12.5% reduction in 1990 levels of UK greenhouse gas emissions by 2008-2012.

SUSTAINABLE DEVELOPMENT FOR THE CITY OF GLASGOW

Local Action 21 was launched during the second Earth Summit in Johannesburg and it is built upon the Local Agenda 21 but represents a move from plan or agenda to practice or action. The Local Action 21 for the City of Glasgow framework document and the related Environment Strategy are currently under review and a new combined "Environmental Sustainability" document will be published later in 2006 (Glasgow City Council web site, 2005)

Nevertheless, in another document named "City Plan" (Glasgow City Council, 2003), the city opens its vision to share with business entrepreneurs and outlines several areas of interest and policies in order to reach the proposed sustainable development goals. It is basically focused on the private investment sector and aims to amalgamate in one document the relevant public sector programmes that can converge to make a new development for the city not only possible but successful. The plan encourages sustainable development, as affirmed in the sustainability section of the plan. Concrete actions towards sustainability are focused on:

i. Renewable energy

"The City Council will continue to support innovative proposals which promote, or incorporate, the generation of power from renewable sources and supporting the Scottish Climate Change Programme by:

- encouraging proposals for the generation of power from renewable sources; and
- providing guidance and setting parameters for renewable energy development in the City."

It is stated that depending on the type, scale and impact of the proposal, the council will encourage developing opportunities in urban areas as some types of projects may offer the additional benefit of low cost heat and power. In other words, the council will favor the development of renewable energy sources within the city, except where some key matters could be affected.

ii. Waste disposal

The City Council aims to deliver an efficient and cost-effective waste management service. Following the recommendations of the National Waste Strategy (Scotland), the Glasgow and Clyde Valley Area Waste Plan was approved, in which there is no identified area in Glasgow for new landfill facilities. In addition, the quantities of biodegradable wastes that can go into landfill sites are limited by European legislation. Therefore, alternative treatment methods will necessarily need to be identified.

iii. Other areas

"There is no evidence to suggest that adequate provision cannot be made for any new proposals that come forward in the foreseeable future relative to the electricity, gas, telephone and cable networks."

Having reviewed this, it is clear that the city has a comprehensive sustainable development policy in place and that any project able to exploit these areas will have the local authority's approval. The sustainable development focus also guarantees a certain degree of acceptability and should not expect to be strongly opposed. The

SECC project encapsulates the priority areas set by the Glasgow City Council's sustainable view and therefore should anticipate receiving high respect and acceptability.

CHAPTER 2

ENERGY FROM WASTE FACILITIES

EfW plants have two main objectives, to generate useful energy and to ensure a safe disposal of Municipal Solid Waste (Miranda, M. L. and Hale, B. 1997). In the process, waste volume is reduced by up to 90% in volume and by 70% in weight (Daskalopoulos, O. et al. 1997).

The process of incineration must be strictly controlled to avoid emissions of pollutants to the environment, same as for any other industrial application but with limits and parameters set for the specific condition of waste as fuel. During the incineration process the organic material in the waste is destroyed, therefore eliminating the possibility of landfill gas generation when the residue is finally disposed.

The RDF process converts Municipal Solid Waste (MSW) into a fuel removing materials with low calorific value like glass and metals. The major benefit is that the fuel ends up having a relatively uniform characteristic, thus avoiding unwanted alterations in properties. In addition to better fuel quality, also better efficiency and significantly lower heavy metals content in the fly ash residue can be obtained. The fuel density will depend upon whether the RDF is pelletized or not, nevertheless the pelletizing process is energy consuming and therefore expensive. Heating value varies depending on the waste composition; however, a low calorific value of 4000 kcal/kg or 16.75 GJ/tonne is regarded as typical (Caputo, A. C. and Pelagagge, P. M.. 2002). As per Murphy, J. D. and McKeog, E., the energy value of the residual component of MSW after waste management in Ireland is 13.26 GJ/tonne. Some other values reported in the same document are for the Netherlands (13.5 GJ/tonne), Denmark (11.3 GJ/tonne) and Japan (12.6 GJ/tonne). The initial value seems to be high when compared to the other reported values; however, as stated before, this will depend very much on the waste composition.

In the first stage of a typical EfW exhaust gas cleaning layout, the fly ash is removed by means of a baghouse (Hartenstein, H. U. and Horvay, M. 1996). The removed fly ash will usually be treated by extraction or vitrification. The next stage is the acid wet scrubber in order to absorb only HCl and HF. The final product after further processing is a marketable hydrochloric acid, suitable for various industries. In the third stage, the SO_2 is removed using lime slurry to convert it into gypsum. The gypsum is later processed and can be sold to the gypsum industry. The final stages are designed to polish the flue gas, removing all residual pollutants. This is normally achieved by two different methodologies:

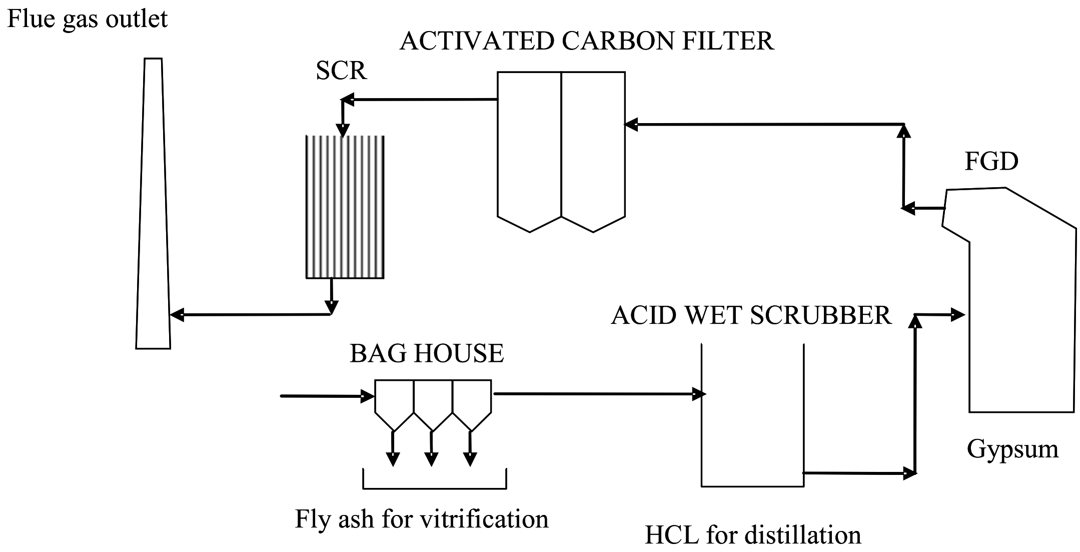

Figure 1. Flue gas cleaning system with Activated Carbon injection prior to the simplified SCR

Using an activated carbon filter and a simplified SCR system (Figure 1), the flue gas temperature can be set to 160-180 ºC thus resulting in a long lifetime for the SCR catalyst. The alternative is to design a cheaper layout at the final stage, adding operational difficulties to the process.

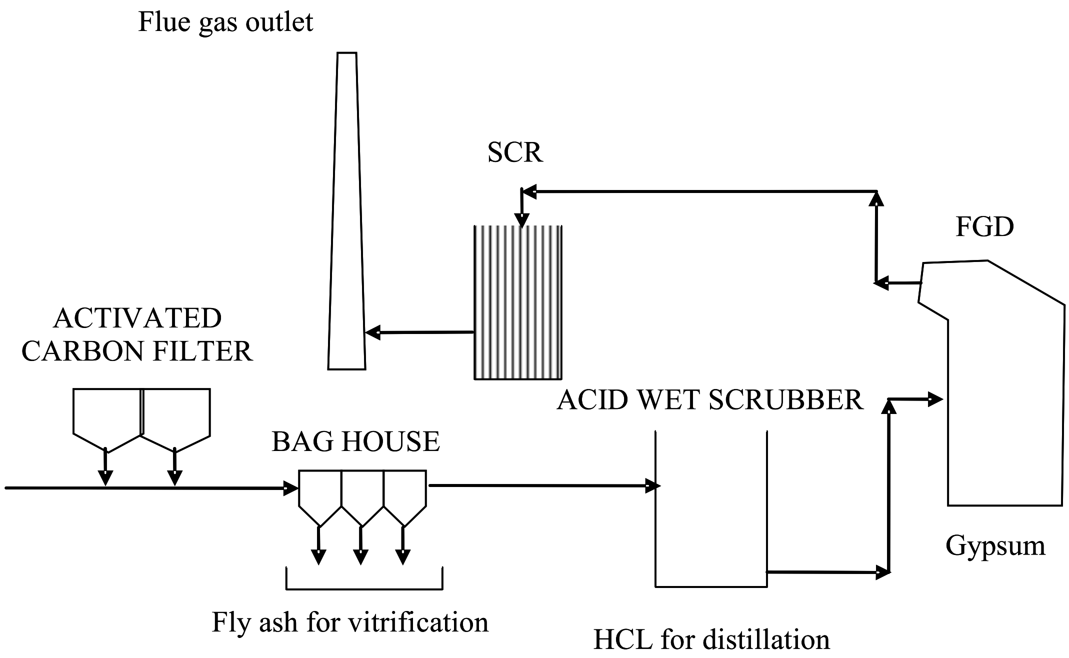

Figure 2. Flue gas cleaning system with Activated Carbon injection prior to the bag house

The use of a SCR as fourth stage (Figure 2) means that it should be operated at temperatures above 300 ºC.

The local regulation in charge of controlling EfW activities is the Waste Incineration Scotland Directive. The following table summarizes the limits set by the directive and the expected output with exhaust gas cleaning system.

Pollutant	Units	Waste Incineration Directive limit	Measured value (4)	Achievable Value (5)
Dust (1)	mg/m^3	50	0.9	<0.1
HCl	mg/m^3	-	20	<0.1
HF	mg/m^3	-	<0.1	<0.01
SO_2 (1)	mg/m^3	-	36	<0.1
NOx (1)	mg/m^3	-	274	<50
Cd + Tl (2)	mg/m^3	0.05	0.001(6)	
Hg (2)	mg/m^3	0.05	ND	<0.005
Sb + As + Pb + Cr + Co + Cu + Mn + Ni + V (2)	mg/m^3	0.5		<0.01
PCDD/F (3)	ng TE/m^3	0.1	0.006	<0.01
CO	mg/m^3	-	5	

Table 1. Waste Incineration Directive emission limits compared to measured values and achievable values.

(1) O_2 content 6 %. Daily average value. From the Waste Incineration Directive (WID).

(2) O_2 content 6 %. All average values over the sample period of a minimum of 30 minutes and a maximum of 8 hours. From the WID.

(3) O_2 content 6 %. All average values measured over the sample period of a minimum of 6 hours and a maximum of 8 hours. From the WID.

(4) O_2 content <11 %.. From Porteous, A. (2001). "Energy from waste incineration – A state of the art emissions review with an emphasis on public acceptability". *Applied Energy 70.* 157-167.

(5) O_2 content <11 %. From Hartenstein, H.U., Horvay, M. (1996) "Overview of municipal waste incineration industry in west Europe (based on the German experience)". *Journal of Hazardous Materials. 47*. 19-30.

(6) Cd only.

The existence of an European directive limiting the emissions of an EfW facility and the numerous examples of successfully developed and currently working experiences across Europe, should be taken as an indication that the air emissions of an EfW plant cannot be a limiting factor in its future development. This is especially important for the UK, which lags behind other countries in the European context regarding EfW plants.

WASTE MANAGEMENT IN THE NATIONAL AND LOCAL CONTEXT

Waste management in the UK is dominated by landfill. The reasons behind this bias are the widespread site availability and suitable geology for the function of stockpile waste underground, together with the low cost of this alternative. By the year 2000, only about 2 million tonnes of MSW were being incinerated in the UK, most with some kind of energy recovery, either via electricity generation or district heating. However, in order to comply with the EC directives (Directive on the Landfilling of Waste 1999/31/EC) and the UK National Waste Strategy in an increasing waste generation scenario, the UK will need to make use of additional alternatives. This vision is shared in other documents such as "Eligibility of Energy from Waste-Study and Analysis" (ILEX Energy Consulting, 2005) prepared on behalf of the Department of Trade and Industry and by the Scottish Environment Protection Agency (SEPA).

The following table is a picture of the total household waste produced and final destination in the UK for the year 2000 (The Parliamentary Office of Science and Technology, 2000):

Region	MSW (mtonnes /annum)	Landfill	Recycle and reuse	Incineration
England and Wales	28	82%	10%	8%
Scotland	3	90%	5%	5%
Northern Ireland	1	95%	5%	0%
Total	32	83%	9%	8%

Table 2. Municipal Solid Waste production in the UK and final disposal method (2000)

For large industrial facilities in the UK, the Pollution Prevention and Control Regulation 2000 (PPC) is a duplicate of the European Directive on this matter, the Integrated Pollution Prevention and Control 96/61/EC (IPPC). In these policies the fundamental guidelines are the waste hierarchy (See Figure 3), the use of the Best Practicable Environmental Option (BPEO) and the proximity principle. This is translated into a given priority over waste management options, in which that with the lowest environmental cost should be considered first. Thus, the first priority is to minimise the production of waste, followed by reuse, recycling and recovery and finally disposal. As a matter of fact, the recovery option is placed before the landfill or disposal option, always regarded as the least attractive method (Figure 3).

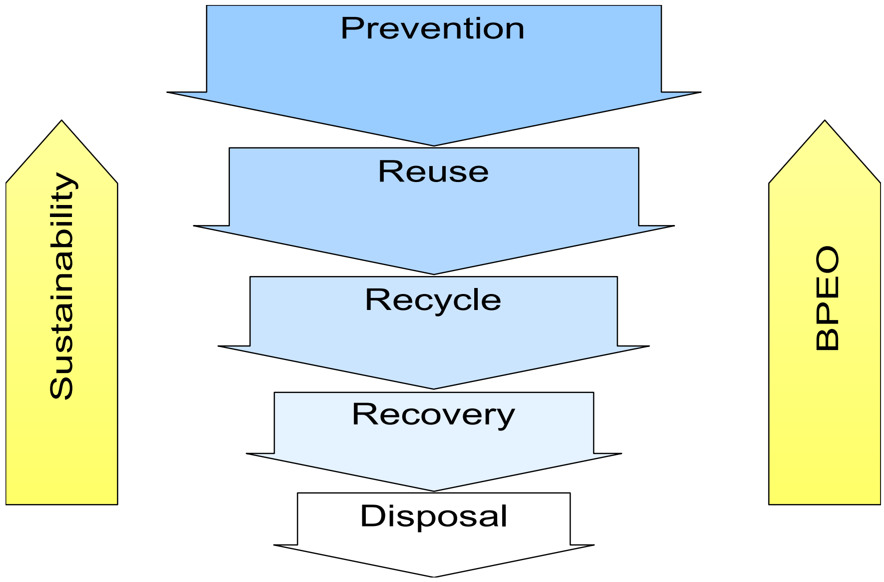

Figure 3. Waste hierarchy

The issue for an incinerator project is then to prove and demonstrate that options higher in the hierarchy have been exhausted, and perhaps more importantly, to demonstrate that the landfill option is worse in order to gain the support of the local waste planning authorities. This is especially important in view of some organizations or groups that allege that the commitment by local authorities to long-term contracts for supplying waste to incinerators will challenge efforts to work on higher hierarchy levels.

In the Scottish case, the SEPA National Waste Plan (SEPA, 2003) states that by 2020, Scotland could produce 4.6 million tonnes of municipal solid waste; this is 1.4 million tonnes per annum more than 2003 figures if waste production continues to grow at the current estimated rate of about 2% per year. The same source states that for the year 2002, in which 3.23 million tonnes of MSW were produced, the final waste destiny was:

MSW (mtonnes/annum)	Landfill	Recycle and reuse	Incineration
3.23	91%	7%	2%

Table 3. Municipal Solid Waste production in Scotland and final disposal method (2002)

The incineration capacity in Scotland is sustained by two incinerators with energy recovery. The installed capacity is depicted below:

Location	Capacity
Dundee	120,000 tpa of which 75,000 tpa is currently used for municipal waste
Lerwick (Shetland)	22,000 tpa of which 17,000 tpa is used for municipal waste

Table 4. Incineration capacity in Scotland (2002)

The data in Table 4 show that 64% of the Scottish 2002 installed incineration capacity is currently used for municipal waste with the balance being used for other types of waste.

SEPA's vision about EfW and its role in waste management is expressed in their web site:

> *"Scotland is facing some major decisions about how it deals with its rubbish. More than 89% of Scotland's waste goes to landfill, including nearly 12 million tonnes every year from Scottish homes and businesses - a practice that is unsustainable and unacceptable. John Ferguson, SEPA's National Waste Strategy Programme Manager, insists it's time for new thinking: Major progress in composting and recycling is needed in Scotland. A major increase in the use of energy from waste technology will be needed between 2010 and 2020 so that Scotland can meet its statutory targets for diverting waste from landfill"*

From the same web site, SEPA policy guidelines in relation to energy from waste plants are outlined:

- EfW must play an integrated role with other waste management methods in accordance with the "National Waste Strategy for Scotland", where the recovery of energy from waste is appropriate.
- Incineration of appropriate segregated waste may be an acceptable method for managing waste, especially with efficient energy recovery as CHP.
- SEPA will encourage research into cleaner technologies for energy recovery.

- Local authorities jointly developing appropriate energy from waste systems will be encouraged.

As can be seen again, the local regulatory framework is present and ready for any EfW project that may arise in the future. The need of EfW is constantly stressed throughout the different documents as an additional and effective way to handle the problems associated with waste, along with other alternatives higher in the hierarchy such as reducing and recycling in the waste management options that are available. The SECC project fits into this category.

CHAPTER 3

INTEGRATING SUSTAINABLE DEVELOPMENT, GLASGOW WASTE MANAGEMENT AND THE SECC PROJECT

As stated before, the Local Action 21 framework document and the related Environment Strategy are currently under review and a new combined "Environmental Sustainability" will be published later in 2006. However, a project like the one proposed by the SECC cannot wait until the framework is published in order to start the lengthy process from idea into reality.

Four fundamental thoughts inspire the sustainable idea for the SECC project:

- Meeting the waste reduction targets
- Efficient resources use (Economic approach)
- Environmental benefit in the form of CO_2 emissions reduction
- Offsets the use of non-renewable resources (coal, gas or oil).

Whatever alternative is proposed for the city waste management, it is a must that it has to deal with the waste reduction targets. The landfill reduction targets, as one of the main drivers of the local waste strategy, will be tackled by the SECC project. This can be contrasted with the no action from the other renewable energy sources willing to supply the SECC energy needs. The efficient resource use will be focused on economic benefits and how attractive the EfW alternative is when compared to the current and future landfill options. Yet the SECC project will not be necessarily attractive from the economic point of view, therefore a series of financial and operational aids will be in place in case the original alternative is not appealing. Emissions reductions will be concentrated on CO_2 savings when compared to a conventional fossil fuel power plant and the current landfill option, especially for the electricity production case. This may not seem to be the most beneficial perspective for the EfW option, however, even if the project is developed in a CHP scheme the gross emissions savings will be related to electricity production displaced. Finally, the savings from fossil fuels not being used will be estimated again in the particular electricity generation sector for the same reason mentioned above.

Modelling the project

In order to evaluate the attractiveness of the different alternatives, the first step is to build an initial model and validate the results for capital (Capex) and operations and maintenance (Opex) cost. After this has been done, a more detailed economical comparison can be made.

The initial model for Capex and Opex validation is similar to that presented by Murphy, J. D. and McKeog, E. in the 2004 paper "Technical, economic and environmental analysis of energy production from municipal solid waste" (*Renewable Energy*. 29. 1043-1057). It was selected because it was a recent document with data for the particular UK situation. The model created for this assessment is basically a newly built spreadsheet with some operational details and gross economic review of an EfW installation operating under both schemes: electricity production or CHP mode. An average value of 35% of the total waste input that a city generates was taken as an approximate figure in which base calculations can be made (Consonni, S., Giugliano, M. and Grosso, M. 2005 and Murphy, J. D. and McKeog, E. 2004). This can be considered as the output of the RDF plant planned by the city authorities. The remaining quantity is supposed to be treated and either reused or recycled. Unfortunately, on the economic side only two values are provided in the original model by Murphy and McKeog, therefore a curve was developed for both Capex and Opex figures depending on the plant size. This was done in order to be able to compare the model output with the reported values from different sources. The results are shown below:

Operational and economic comparison

	Model	Murphy and McKeogh (2004)	Published documents	Daskalopoulos et al (1997)		ILEX Energy Consulting (2005)	Real competed projects	Baldovie (1996)		Kirkless (2002)	Case study	SECC project	
Operations													
Waste figures		550000										339971	
RDF percentage		35.3%										35.3%	
Waste incinerated (tonnes)		194150		200000		200000		120000		125000		120010	
Waste feed rate (tonnes/hour)		22.2		22.8		22.8		13.7		14.3		13.7	
Heating value (GJ/tonne)		13.26		8.50		13.26		13.26		13.26		13.26	
Max power (MW)		81.6		53.9		84.1		50.5		52.6		50.5	
Efficiency		18%		21%		18%		21%		18%		18%	
Power (Electric) (MW)		14.7		11.6		15.1		10.5		9.5		9.1	
Load factor		85%		85%		85%		80%		85%		90%	
Electricity production (kWh)		109413233		86097917		112710000		73548800		70443750		71609826	
Elect. conversion factor (kWh/tonne MSW)		564		430		564		613		564		597	
Thermal efficiency		50%		50%		50%		50%		50%		50%	
Power (Thermal) (MW)		40.8		27.0		42.0		25.2		26.3		25.2	
Load factor		85%		85%		85%		80%		85%		90%	
Heat production (kWh)		253271372		167245370		260902778		147333333		163064236		165763485	
Cooling services (kWh)		50654274		33449074		52180556		29466667		32612847		33152697	
Ther. conversion factor (kWh/tonne MSW)		1565		1003		1565		1473		1565		1658	
Total conversion factor (kWh/tonne MSW)		2129		1434		2129		2086		2129		2254	
Estimated Capital Cost (£)													
Capital Cost (as per model)		69,281,166		71,025,968		71,025,968		45,427,524		47,137,311		45,430,896	
Estimated Operation and Mant.(£)													
O&M (as per model)		5,057,279		5,172,752		5,172,752		3,406,716		3,528,974		5,511,782	
Real values (£)													
Capital cost (Reported)		68,952,000	-0.5%	57,619,591	-23.3%	65,048,544	-9.2%	53,204,343	14.6%	44,557,800	-5.8%	**Average**	**-4.8%**
O&M (Reported)		5,509,400	8.2%	4,359,903	-18.6%	3,980,583	-29.9%					**Average**	**-13.5%**

Table 5. Model output and comparison with literature and completed projects

The validation process involved testing the model against other references from a diversity of published documents. This phase included the addition of four different estimates including two completed EfW projects, these are:

- Figures estimated by Daskalopoulos, O. et al. (1997)
- Figures reported by ILEX Energy Consulting. (2005)
- The Baldovie FBC project in Dundee, the most recent Scottish experience
- The Kirkless project in Huddersfield, England

The last two schemes are in the same size range as the SECC project; therefore of vital importance in order to establish a correct approximate cost for the SECC project.

All reported values were taken to the year 2004 using a 3% inflation rate and the corresponding time period. Reported electricity production figures were matched with small adjustments in either load factor or plant efficiency, the first in the range 80-85% and the second between 18 and 21%. Where the waste heating value was known, this was used; otherwise the nominal value of 13.26 GJ/tonne reported in the paper was used. A fixed thermal efficiency of 50% was set throughout the model.

In the Capex and Opex validations model both energy conversion factors match the results reported in the paper, i.e., the validation model outcomes are in accordance with those operational and economic results from the original paper; thus the model can be considered in working order.

As it can be seen in the model results, there is an average 5% underestimation in the Capex and a 13.5% underestimation in the Opex expenses. The average reported in the table takes into account the validation model results. As the capital cost average results represent a small deviation from the real figures, it was decided to make a new curve fitting this time for the original figures plus the reported values using average figures where needed. The new fitting will be used in the more detailed economic appraisal model that will follow. The opposite happens with the Opex cost in which the deviation from the original figures is greater; therefore, the model will stand with the figures reported in the paper. The resulting charts and trend lines are shown below:

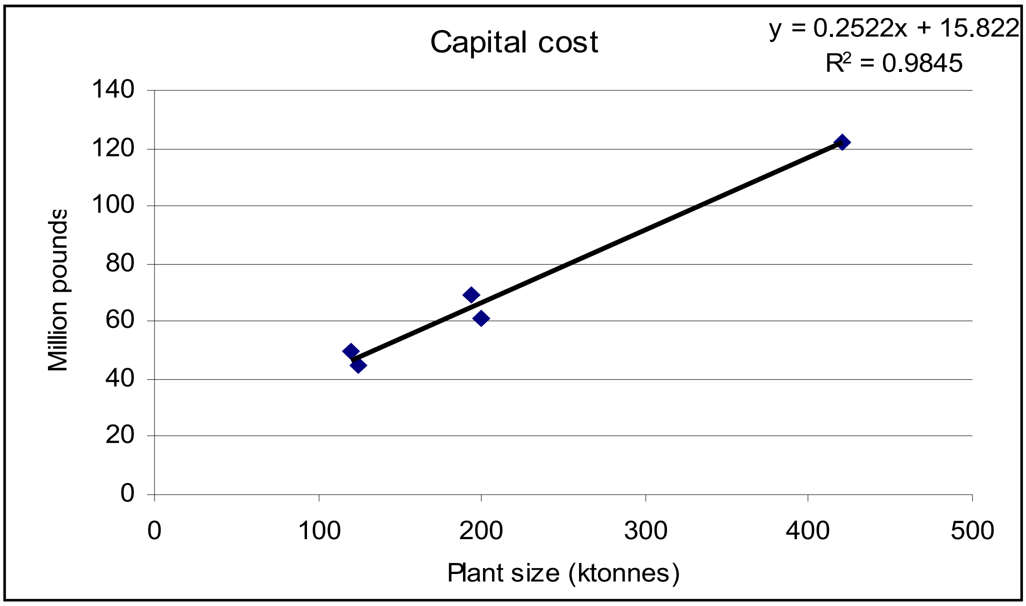

Chart 1. Capital cost fitting with original model, literature and completed projects figures

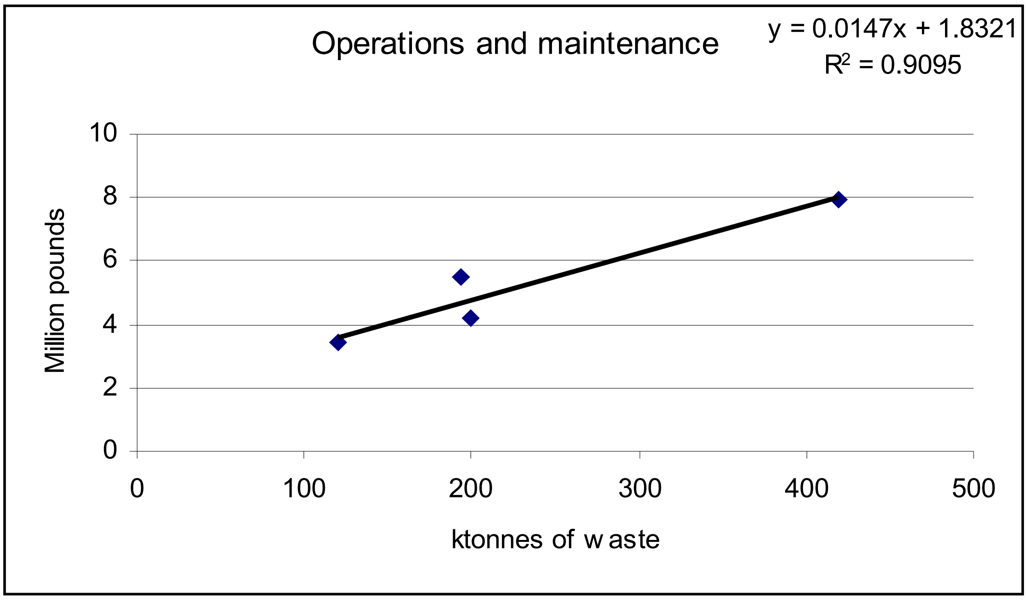

Chart 2. Operations and maintenance fitting with original model, literature and completed projects figures

In both charts the square of the trend line correlation factor is above 0.9 which denotes a very good fitting. However, as explained before, only the Capex will use the new trend and fitting while for the Opex the original figures will remain for subsequent calculations. Finally, it is important to note that the Capex and Opex costs of the SECC could be lower due to the absence of the waste preparation facilities as the fuel will be directly delivered as RDF.

One very important issue linked to the waste management strategy is the economic performance of any disposal option selected. If EfW plants are going to compete against traditional energy sources such as fossil fuels, then this comparison must be based on comparable energy prices. As for most other renewable energy sources, this is not the case and therefore most authors state that it is unlikely that the cost of incineration could be economically attractive. However, this depends on the specific location and market and if energy recovery in the form of heat is included in the project. The RDF manufacture process is not included in the evaluation since it is a decision already taken by the Glasgow City Council, therefore if the RDF is used as landfill capping material or as fuel for the SECC project this is irrelevant for the resulting economic evaluation.

The economic appraisal will be centered on the Net Present Value (NPV) and the Internal Rate of Return (IRR) methodology. This is, when the sum of the project initial cost plus the NPV through the project life is equal to zero then this represents the IRR of the option. The IRR calculated this way can be compared to a typical interest rate and therefore determines if the evaluated alternative is an attractive economic option. IRR values above the typical interest rate are attractive while those options with IRR values below the reference interest rate are not tempting. Different return rates will be estimated for each case and only positive IRR values denote a viable investment.

A spreadsheet with operational and economic data was developed and validated in order to perform a more detailed economical assessment estimating the cost of a development for the SECC project. A Microsoft Excel cash flow template was used. It was obtained from the web site http://office.microsoft.com/en-gb/templates/TC010175121033.aspx posted by the Service Corps of Retired Executives (SCORE®), modified accordingly to reflect the different EfW items and applicable parameters. It must be stressed that the above mentioned web site provided only the template as a frame on which to work, all the relevant information including formulae, was developed for this particular evaluation. In addition to the different SECC alternatives, two different landfill options were evaluated with the same model with the appropriate modifications to the input and estimation parameters. The different alternatives evaluated share some similar features:

- The total heat production is split into two separate items: 5/6 will be sold as heat and the remaining 1/6 will be sold as cooling services, following the same structure given by the Chartered Institution of Wastes Management.
- The loan was calculated as the capital cost plus 10%.
- Interest rate was assumed to be fixed at 3%.
- A common period of time of 20 years was supposed.
- IRR was calculated both using the embedded software formula and on a step-by-step basis, making it possible to generate charts.
- Tax was included at a 40% rate over the Net profit before tax.
- Depreciation is considered to be a straight line over a period of 17 years with a salvage value of 10% of the capital cost for the SECC project. Depreciation starts at the fourth year, when the plant starts the operation phase. Note however that for the landfill case, the depreciation was estimated using the same straight line procedure but for a lifespan of 19 years with no salvage value. This is because the landfill was considered operational during its second year and by law, the landfill is still responsibility of the authority 30 years after closure.

The different alternatives that will be evaluated are the result of the manipulation of an operational parameter, some form of financial compensation or a combination of both. The operational parameter that will be evaluated in this document is the load factor as it is considered to be the most susceptible to a controllable variation in a normal basis. On the financial side, the allocation of a grant will be considered as a financial aid as well as price increases for electricity, heat and cooling services.

Heating and cooling services prices were taken from “Energy from Waste: A good practice guide” by the Chartered Institution of Wastes Management (2003). When the prices have an escalating factor, it is in the form of increments every 5 years on a 10% increase basis.

The gate fee is deemed to be the value of the landfill tax. Although this may be below the actual gate fee, this will represent the worst case scenario for any option. The landfill tax increase of £3/year from 2006, starting from an initial value of £18 up to £35 in 2012 is considered in all the evaluations shown here (an increase of £2 was assumed during the last year).

The residue disposal cost is assumed to be the result of multiplying the disposal cost per premise times the average waste production per premise, the first one taken at the constant value of £55.01/premise and the latter equally fixed with a value of 0.83

tonnes/premise as reported in the "Statutory performance indicators 2002-03 & 2003-04. Waste management" published by the Glasgow City Council.

$$\frac{55.01£}{premise} \times \frac{premise}{0.83tonnes} \Rightarrow \frac{66.28£}{tonne}$$

Although the average waste production per premise was assumed constant for this exercise, it should be mentioned that it may not remain the same over this long period of time either because the amount of waste per premise or the cost per premise change.

Meeting the waste reduction targets

The important issue is how to meet the targets and how the SECC project will contribute towards this objective. In the broad perspective and in order to meet the UK landfill objectives, current EfW capacity will have to grow by a factor of five by 2010. This is a dramatic increase that may not be easily acheived taking into consideration the lengthy planning permission process and the supply chain constraints (engineering, operations, equipment and capital funds). More locally, in the Scottish Executive Environment Group 2004, the aim is a reduction in municipal waste from 2.9 mtonnes in 2002 (compared with 3.23 mtonnes in the SEPA "National Waste Strategy 2003") to 2.6 mtonnes in 2010 and 2.3 mtonnes in 2020. However, in the latest review of the Indicators of Sustainable Development for Scotland in 2004 the target was set to zero growth by 2010. Whatever the figures and targets may be, there is no doubt that the use of EfW will contribute significantly to reach the goal.

It is obvious that a strategy based on reduce, reuse and recycle alone will not attain the landfill reduction requirements, as pointed out by the "National Waste Plan 2003" (SEPA, 2003) in which EfW has a growing importance starting from 2% in 2002 up to 14% in 2020, a 700% increase in 18 years. The City Council has already taken a step ahead in the sense that a RDF production plant will be in place soon, thus alleviating the amount of waste that ends up in a landfill. This is because the RDF obtained can be used either as a landfill capping material or as feedstock for an EfW plant. In this way, approximately 35% of the original waste will be transformed into RDF. If the RDF is used as capping material and thus as an inert substance, a significant reduction in the amount of waste to be disposed of in a landfill is achieved even in the worst case in which the remaining quantity is landfilled. The other option, to use the RDF as feedstock for the SECC project will, nevertheless, increase in some small degree the landfill space requirements. This is because from the original

RDF figures, a reduction of up to 90% in volume and 70% in weight can be obtained in the EfW process. In this way, the SECC project will make a negative contribution towards the waste reduction targets if the residue generated is not further used in the construction industry. Therefore, assuming that the waste transformed into RDF is used in an EfW plant but the fraction not transformed into RFD is landfilled, the amount of waste that will finally be disposed into a landfill will be as follows:

Annual waste produced by the city to be landfilled (tonnes)	**Annual waste transformed into RDF (tonnes)**	**Additional annual waste to be landfilled resulting from the EfW activities :70% reduction in RDF weight (tonnes)**
340,000	120,000	36,003

Table 6. Estimated waste figures for the City of Glasgow with the RDF and EfW plant in operation

This is, from the 340,000 tonnes of waste that the City of Glasgow produces every year, 120,000 tonnes will be transformed into RDF and used in the SECC project which will in turn generate a residue of 36,003 tonnes to be landfilled. This amount will be added to the fraction that, in the worst of situations, will not be recovered/recycled:

$$340{,}000 tonnes - 120{,}000 tonnes + 36{,}003 tonnes = 256{,}003 tonnes$$

It is important to note again that the SECC project will actually add material to be landfilled if no use is found for the ashes that the process generates, thus the major contributor to the landfill reduction targets is the RDF plant. This is a particular situation that arises with the RDF plant and in fact, if no RDF plant is in place then the waste diversion could be totally attributed to the EfW process. In addition, it is crucial again to stress that the previous numbers are assuming that the fraction of waste not transformed into RDF ends up in the landfill, which can be totally inaccurate because the waste will be segregated and ready for reuse and recycling purposes. The RDF process is designed to maximize the amount of material that can be recovered; thus the amount of waste to be landfilled will be considerably lower. Nevertheless, the numbers calculated as per the above simple calculation represent a 25% reduction in landfill space use. Having said this, the figures calculated are not likely to occur and will be substantially better. The implications of the current and future waste strategy are not only measured in terms of quantity of waste being disposed of and thus as mere compliance with the landfill diversion targets, but also in terms of space savings and life extension of the final disposal site that will be increased accordingly.

Economic evaluation of the landfill options

Current landfill

The current landfill option can be regarded as a money drain. Virtually no economic benefits are obtained from it, or at least in a reasonable scale as to recover the investment and make profits from the process. The main problem is that the income cannot match the expenses that are inherent to the safe operation of such a facility. The benefits of a landfill are, of course, encapsulated into the broader waste strategy and in the form of social return as it deals with the problems associated with no or poor waste management. The economic benefits of a landfill are subject to controversy especially when considering that at present, energy can be recovered from the organic material placed in a landfill in the form of landfill gas. As a matter of fact, in an already closed Glasgow City Council landfill site (Summerston) landfill gas is being recovered by a private company. The gas is used to run especially designed engines that deliver the power generated into the grid. However, as it is right now, only a small fraction of the electricity sales end up in the council's coffer while the larger portion is for the company, which, not only took the risk but also has the relevant know-how in the area. This option will therefore not be considered in more detail due to the reason exposed above and also because the long term perspective is to reduce the amount of biodegradable waste being diverted to landfill sites.

For the two alternatives evaluated in this document that involve a landfill economic evaluation, the site capacity was estimated to be the same as that currently being handled by the city council with no growth over the next twenty years. This could be considered optimistic due to the current waste commitments set up by the Scottish Executive, in which the region is aiming for zero growth from 2010 onwards. Thus the proposed alternative becomes a more favourable option from the landfill option point of view because less space is required and less cost is involved in dealing with the waste. Unfortunately, there is no information on current capital and operations and maintenance cost for a local landfill, thus they were estimated as a relative inexpensive option. The Capex or initial investment was supposed to be of £2 per tonne, an approach entirely theoretical and based on the low cost of land for this use, making it just 30% of the cost of a new EfW installation. Unfortunately, no Opex data is available, therefore it was assumed to be part of the disposal cost published by the Glasgow City Council in the document "Statutory performance indicators 2002-03 & 2003-04. Waste management" as shown in Table 7:

Item	Cost per premise (£)
Collection	59.46
Disposal	55.01

Table 7. Cost of waste collection and disposal for the City of Glasgow

Again, this is a totally speculative approach based on reference numbers. The disposal cost per tonne was already calculated and a figure of £66.28/tonne was established. The number of premises can be calculated using the same document knowing that the total amount of domestic refuse collected in the period was 240,950 tonnes at an average of 0.83 tonnes per household, this is:

$$\frac{240{,}950\,tonnes}{year} \times \frac{premise}{0.83\,tonnes} \Rightarrow \frac{290{,}301\,premises}{year}$$

The number of premises calculated in this way differs from the reported in the Environmental Protection Services report "Cleansing-Some Facts" (No year reported) of 285,231 premises, a difference of 5,070 premises or 2%. As the difference is small and the calculated values are bigger, these figures will be employed because they will represent the worst case for the economic evaluation.

Despite the fact that a period of 20 years could be considered extremely long for a facility like a landfill, it was chosen in order to make fixed period comparisons with the other cases possible.

As explained before, the depreciation was calculated with no salvage value for a 19 year period since it is assumed that the landfill can enter operation just one year after the go ahead and also because the local authority is responsible for the landfill site 30 years after it has been closed, thus limiting the potential activities that can be developed in the landfill area.

In the following table, the current landfill option without energy recovery in the form of landfill gas is shown:

Project ***Current landfill***

Select operational variables	
Load Factor (%)	80%
Electric efficiency (%)	18%
Thermal efficiency (%)	50%
Heating value (MJ/tonne)	13.26

Price variables	
Electricity price (£/kWh)	0.0476
Heat price (£/kWh)	0.0200
Cooling price (£/kWh)	0.0400
Heat share compared to cooling	5/6

Capital/O&M calculation	
Plant type	Landfill
Plant capacity (kt/y)	358
Capital cost (m£)	*14.32*
O&M (m£/y)	*0.00*
Grant (%)	0.00%
Grant (£)	*0*

Other variables	
Construction period (years)	1
Price increase (years)	0
Price increase (rate)	10%
Project starts (year)	2006
Gate fee max value (£/tonne)	35
Residual disposal cost (£/tonne)	66.28

Loan calculation	
Loan (Capital + 10%) (£)	*15,752,000*
Interest rate	3%
Period (Years)	20
Yearly repayment (£)	*1,058,782*

	2006	2007	2008	2009	2010	2011	2012	2013
Operations								
Waste incinerated (tonnes)	0	358000	358000	358000	358000	358000	358000	358000
Electricity production (kWh)	0	0	0	0	0	0	0	0
Heat production (kWh)	0	0	0	0	0	0	0	0
Cooling services (kWh)	0	0	0	0	0	0	0	0
Electricity price (£/kWh)	0.0476	0.0476	0.0476	0.0476	0.0476	0.0476	0.0476	0.0476
Heat price (£/kWh)	0.0200	0.0200	0.0200	0.0200	0.0200	0.0200	0.0200	0.0200
Cooling services price (£/kWh)	0.0400	0.0400	0.0400	0.0400	0.0400	0.0400	0.0400	0.0400
Gate fee (£/tonne)	18.00	21.00	24.00	27.00	30.00	33.00	35.00	35.00
Fuel cost (£/tonne)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Residue generated (tonnes)	0	0	0	0	0	0	0	0
Residue disposal cost (£/tonne)	66.28	66.28	66.28	66.28	66.28	66.28	66.28	66.28

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Incomes (m£)																					
Electricity sales	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Heat sales	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cooling sales	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gate fee income	0.00	7.52	8.59	9.67	10.74	11.81	12.53	12.53	12.53	12.53	12.53	12.53	12.53	12.53	12.53	12.53	12.53	12.53	12.53	12.53	12.53
Gross Profit	0.00	7.52	8.59	9.67	10.74	11.81	12.53	12.53	12.53	12.53	12.53	12.53	12.53	12.53	12.53	12.53	12.53	12.53	12.53	12.53	12.53
Expenses (m£)																					
O&M	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Residue disposal cost	0.00	23.73	23.73	23.73	23.73	23.73	23.73	23.73	23.73	23.73	23.73	23.73	23.73	23.73	23.73	23.73	23.73	23.73	23.73	23.73	23.73
Loan repayment	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06
Depreciation	0.00	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76
Total Expenses	1.06	25.55	25.55	25.55	25.55	25.55	25.55	25.55	25.55	25.55	25.55	25.55	25.55	25.55	25.55	25.55	25.55	25.55	25.55	25.55	25.55
Profits (m£)																					
Net profit before tax	-16.81	-18.03	-16.95	-15.88	-14.81	-13.73	-13.02	-13.02	-13.02	-13.02	-13.02	-13.02	-13.02	-13.02	-13.02	-13.02	-13.02	-13.02	-13.02	-13.02	-13.02
Tax	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Net profit after tax	-16.81	-18.03	-16.95	-15.88	-14.81	-13.73	-13.02	-13.02	-13.02	-13.02	-13.02	-13.02	-13.02	-13.02	-13.02	-13.02	-13.02	-13.02	-13.02	-13.02	-13.02

Table 8. Current landfill option (20 years cash flow)

As there is no landfill gas recovery, the only source of income is the gate fee supposed to be equal to the landfill tax. Incomes start at 7.5m£ and increase up to 12.5m£ in 2012, an increase of 40% following the same path of the landfill tax that rises from £21 to £35/tonne. On the expenses side, by far the most relevant is the residue disposal cost representing almost 93% of the total expenses. The amount of this item alone supersedes the income, thus sealing the fate of the landfill alternative. The net profit decreases (due to the increment of the landfill tax) until year the 2012 when it reaches a constant value of -£13 million. Chart 3 shows the gross profits, expenses and net profits after tax for the current landfill option.

Calculating the IRR of a money sink makes no logical sense, however, Chart 4 shows the estimation for the current landfill option:

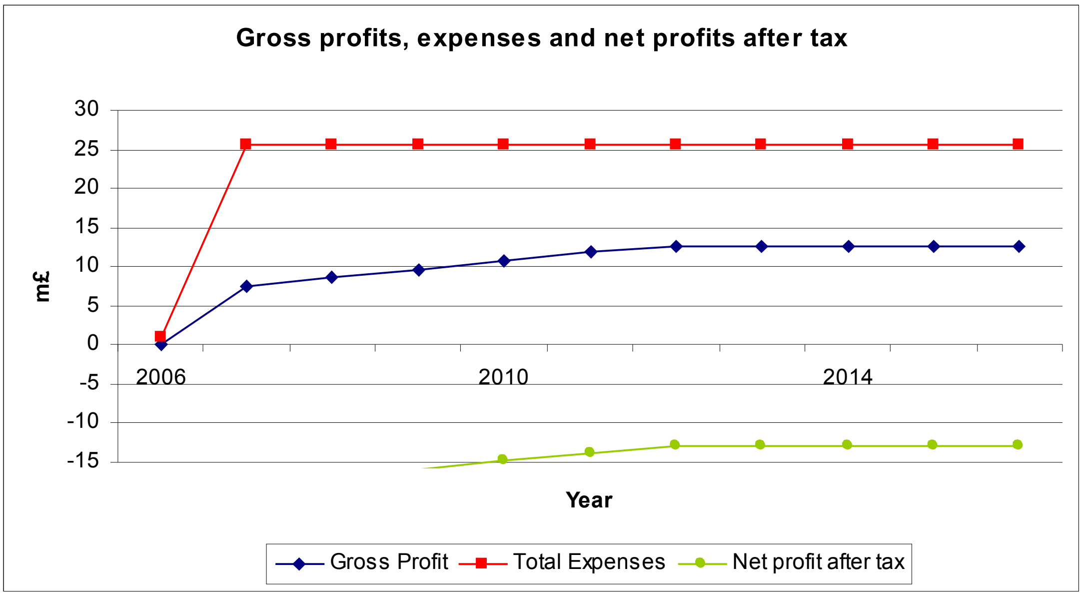

Chart 3. Gross profits, expenses and net profits after tax for the current landfill option

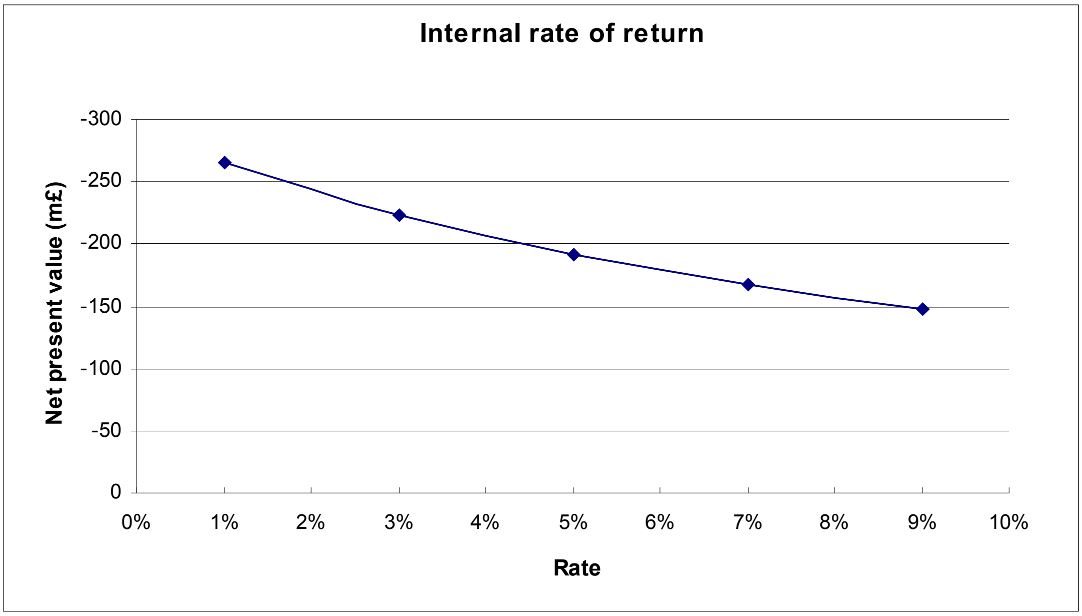

Chart 4. IRR estimation of the current landfill option

The Y axis is in reverse order for better visualization purposes. As it can be seen, there is no positive IRR as verified by the asymptotic shape of the curve. Even more, under this perspective the long term NPV for the same interest rate at which the money is borrowed is above the -£220m figure. The figure thus calculated will be used later along this document for comparison purposes.

The reason behind the economic performance of the current landfill option can be explained by saying that although the initial investment can be considered low when compared to other options, the constant drain of money over the years makes this option very expensive in the long term.

If the initial assumptions regarding the Capex and Opex costs are totally erroneous and in reality these figures are larger than those used here, then the results will be even worse. The main factors in the landfill economic evaluation are the sole source of income, i.e. the gate fee, and the largest expense, which in this case is the residue disposal cost. Only an increment of the first and a decrement of the second will improve the economical attractiveness of the current landfill option. As the residue disposal cost was estimated using real figures supplied by the city council, the only choice is to have a better estimation of the gate fee, which is not evaluated within the scope of this document.

Future landfill

It is worth mentioning that the Glasgow City Council is committed to transform the MSW into RDF, either to be used as landfill capping material or to feed any EfW project. As explained before, it is understandable that the landfill targets will be met in either use for the RDF.

In this exercise, the amount of waste transformed into RDF is used as landfill capping material and for the remaining fraction only half is landfilled, thus the other half is reused or recycled. The final figure for waste to be landfilled under these premises is 116 tonnes/year. This, however, is only a theoretical case in the sense that a larger amount of the non-RDF fraction is supposed to be recovered or recycled. Nonetheless, this does not mean that under this perspective this will be an economically attractive alternative.

Project ***Future landfill***

Select operational variables	
Load Factor (%)	80%
Electric efficiency (%)	18%
Thermal efficiency (%)	50%
Heating value (MJ/tonne)	13.26

Price variables	
Electricity price (£/kWh)	0.0476
Heat price (£/kWh)	0.0200
Cooling price (£/kWh)	0.0400
Heat share compared to cooling	5/6

Capital/O&M calculation	
Plant type	Landfill
Plant capacity (kt/y)	116
Capital cost (m£)	*4.64*
O&M (m£/y)	*0.00*
Grant (%)	0.00%
Grant (£)	*0*

Other variables	
Construction period (years)	1
Price increase (years)	0
Price increase (rate)	10%
Project starts (year)	2006
Gate fee max value (£/tonne)	35
Residual disposal cost (£/tonne)	66.28

Loan calculation	
Loan (Capital + 10%) (£)	*5,104,000*
Interest rate	3%
Period (Years)	20
Yearly repayment (£)	*343,069*

	2006	2007	2008	2009	2010	2011	2012	2013
Operations								
Waste incinerated (tonnes)	0	116000	116000	116000	116000	116000	116000	116000
Electricity production (kWh)	0	0	0	0	0	0	0	0
Heat production (kWh)	0	0	0	0	0	0	0	0
Cooling services (kWh)	0	0	0	0	0	0	0	0
Electricity price (£/kWh)	0.0476	0.0476	0.0476	0.0476	0.0476	0.0476	0.0476	0.0476
Heat price (£/kWh)	0.0200	0.0200	0.0200	0.0200	0.0200	0.0200	0.0200	0.0200
Cooling services price (£/kWh)	0.0400	0.0400	0.0400	0.0400	0.0400	0.0400	0.0400	0.0400
Gate fee (£/tonne)	18.00	21.00	24.00	27.00	30.00	33.00	35.00	35.00
Fuel cost (£/tonne)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Residue generated (tonnes)	0	0	0	0	0	0	0	0
Residue disposal cost (£/tonne)	66.28	66.28	66.28	66.28	66.28	66.28	66.28	66.28

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Incomes (m£)																					
Electricity sales	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Heat sales	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cooling sales	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gate fee income	0.00	2.44	2.78	3.13	3.48	3.83	4.06	4.06	4.06	4.06	4.06	4.06	4.06	4.06	4.06	4.06	4.06	4.06	4.06	4.06	4.06
Gross Profit	0.00	2.44	2.78	3.13	3.48	3.83	4.06	4.06	4.06	4.06	4.06	4.06	4.06	4.06	4.06	4.06	4.06	4.06	4.06	4.06	4.06
Expenses (m£)																					
O&M	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Residue disposal cost	0.00	7.69	7.69	7.69	7.69	7.69	7.69	7.69	7.69	7.69	7.69	7.69	7.69	7.69	7.69	7.69	7.69	7.69	7.69	7.69	7.69
Loan repayment	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34
Depreciation	0.00	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Total Expenses	0.34	8.28	8.28	8.28	8.28	8.28	8.28	8.28	8.28	8.28	8.28	8.28	8.28	8.28	8.28	8.28	8.28	8.28	8.28	8.28	8.28
Profits (m£)																					
Net profit before tax	-5.45	-5.84	-5.49	-5.15	-4.80	-4.45	-4.22	-4.22	-4.22	-4.22	-4.22	-4.22	-4.22	-4.22	-4.22	-4.22	-4.22	-4.22	-4.22	-4.22	-4.22
Tax	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Net profit after tax	-5.45	-5.84	-5.49	-5.15	-4.80	-4.45	-4.22	-4.22	-4.22	-4.22	-4.22	-4.22	-4.22	-4.22	-4.22	-4.22	-4.22	-4.22	-4.22	-4.22	-4.22

Table 9. Future landfill option (20 years cash flow)

Note that the amount of waste to be landfilled has been greatly reduced thus dropping the income from the current situation of £7.5 million during year 2007 down to £2.4 million. At the same time, the cost of the alternative has been lowered from the previous £27 to £8.2 million. The alternative remains as not economically appealing, however, the losses have by and large been reduced and the reference figure of the NPV using a 3% interest rate has been lowered to -£73 million. Chart 5 shows the gross profits, expenses and net profits after tax for the future landfill option.

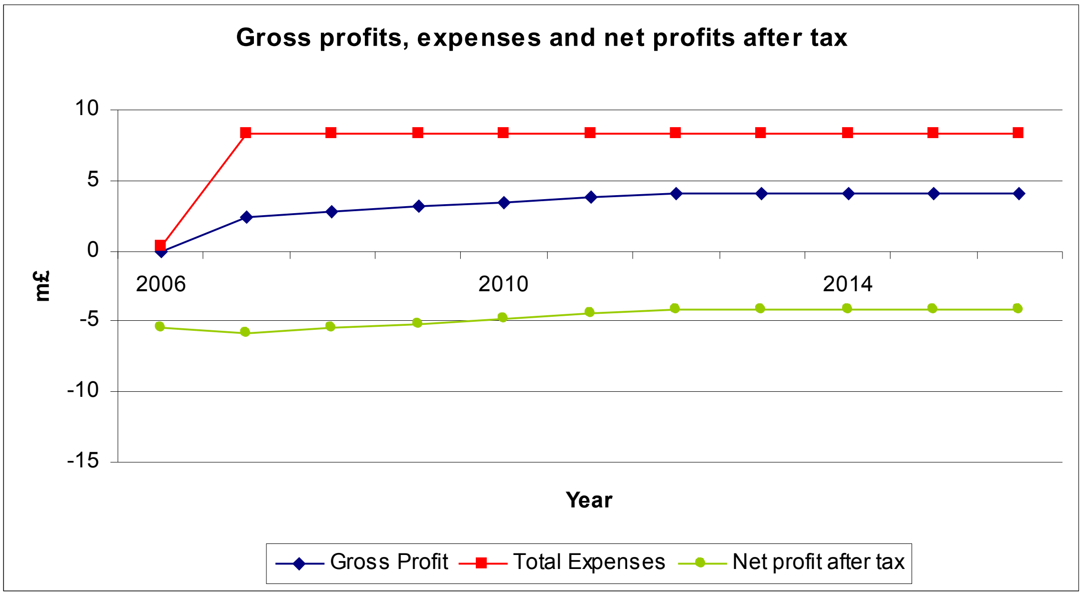

Chart 5. Gross profits, expenses and net profits after tax for the future landfill option

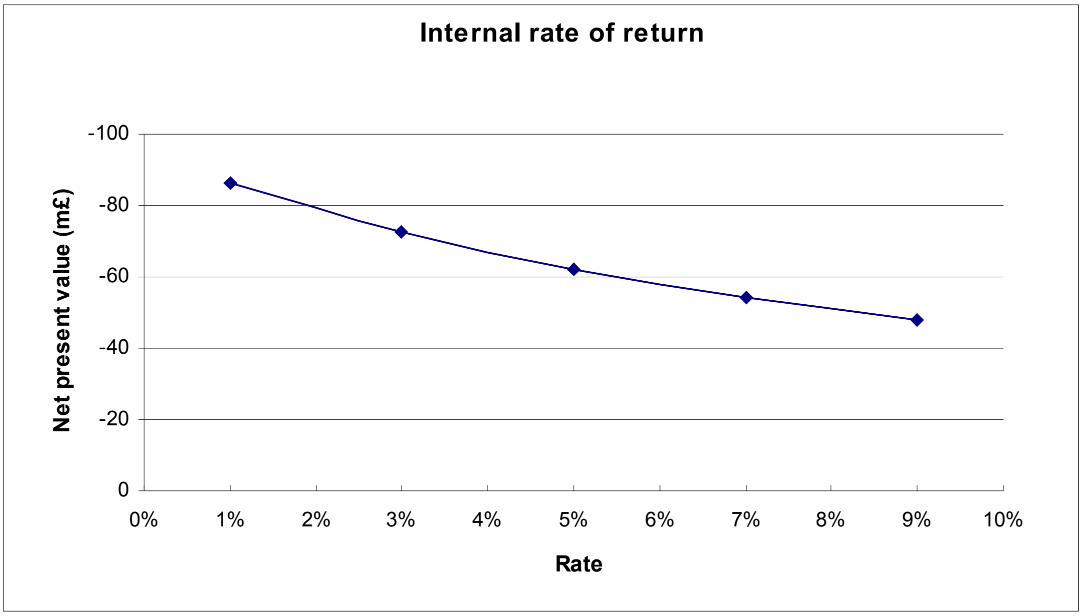

Chart 6. IRR estimation of the future landfill option

Chart 6 represents the IRR estimation.The future landfill still continues to generate no economic benefits, although the cost has been dramatically reduced. The reason explaining the economic performance of the future landfill option is that the constant drain of money has experienced a significant reduction.

As in the previous evaluation, even if the figures used for both Capex and Opex are incorrect, the intention is to show that this alternative is not sustainable from the point of view of efficient economic resource use unless the incomes, represented by the gate fees, are raised enough to make this happen.

Economic evaluation of the SECC project

As it is

The next table summarizes the results of the economic evaluation of the SECC project without operational or financial incentives. Both a 12 month cash flow statement projection and a 20 years cash flow exercise are estimated.

The estimation for the SECC project as it is has fixed electricity, heat and cooling prices; increasing gate fee following the landfill tax guidelines already discussed and constant residual disposal cost. It also has a fixed electricity efficiency of 18% and fixed load factor. The following table shows the results for the 12 month cash flow.

Twelve-month cash flow statement — **SECC project as it is**

	Jan-06	%	Feb-06	%	Mar-06	%	Apr-06	%	May-06	%	Jun-06	%
Operations												
Waste incinerated (tonnes)	10001		10001		10001		10001		10001		10001	
Electricity production (kWh)	5304442		5304442		5304442		5304442		5304442		5304442	
Heat production (kWh)	12278801		12278801		12278801		12278801		12278801		12278801	
Cooling services (kWh)	2455760		2455760		2455760		2455760		2455760		2455760	
Electricity price (£/kWh)	0.0476		0.0476		0.0476		0.0476		0.0476		0.0476	
Heat price (£/kWh)	0.02		0.02		0.02		0.02		0.02		0.02	
Cooling services price (£/kWh)	0.04		0.04		0.04		0.04		0.04		0.04	
Gate fee (£/tonne)	27.00		27.00		27.00		27.00		27.00		27.00	
Fuel cost (£/tonne)	0.00		0.00		0.00		0.00		0.00		0.00	
Residue generated (tonnes)	3000		3000		3000		3000		3000		3000	
Residue disposal cost (£/tonne)	66.28		66.28		66.28		66.28		66.28		66.28	
Revenue (£)												
Electricity sales	252,491	29%	252,491		252,491		252,491		252,491		252,491	
Heat sales	245,576	28%	245,576		245,576		245,576		245,576		245,576	
Cooling sales	98,230	11%	98,230		98,230		98,230		98,230		98,230	
Gate fee income	270,023	31%	270,023		270,023		270,023		270,023		270,023	
Gross Profit	866320	####	866320		866320		866320		866320		866320	
Expenses (£)												
O&M	283,913	37%	283,913		283,913		283,913		283,913		283,913	
Residue disposal cost	198,857	26%	198,857		198,857		198,857		198,857		198,857	
Loan repayment	283,972	37%	283,972		283,972		283,972		283,972		283,972	
Depreciation		0%										
Total Expenses	766742	####	766742	0	766742		766742		766742		766742	
Net Profit (£)	99579		99579		99579		99579		99579		99579	
Tax (£)												
Net Profit After Tax (£)	99579		99579		99579		99579		99579		99579	

	Jul-06	%	Aug-06	%	Sep-06	%	Oct-06	%	Nov-06	%	Dec-06	%	YEARLY	%
Operations														
Waste incinerated (tonnes)	10001		10001		10001		10001		10001		10001		120010	
Electricity production (kWh)	5304442		5304442		5304442		5304442		5304442		5304442		63653304	
Heat production (kWh)	12278801		12278801		12278801		12278801		12278801		12278801		147345611	
Cooling services (kWh)	2455760		2455760		2455760		2455760		2455760		2455760		29469122	
Electricity price (£/kWh)	0.0476		0		0.0476		0.0476		0.0476		0.0476		0.0476	
Heat price (£/kWh)	0.02		0.02		0.02		0.02		0.02		0.02		0.02	
Cooling services price (£/kWh)	0.04		0.04		0.04		0.04		0.04		0.04		0.04	
Gate fee (£/tonne)	27.00		27.00		27.00		27.00		27.00		27.00		27.00	
Fuel cost (£/tonne)	0.00		0.00		0.00		0.00		0.00		0.00		0.00	
Residue generated (tonnes)	3000		3000.25		3000		3000		3000		3000		36003	
Residue disposal cost (£/tonne)	66.28		66		66.28		66.28		66.28		66.28		66.28	
Revenue (£)														
Electricity sales	252,491		252,491		252,491		252,491		252,491		252,491		3,029,897	29%
Heat sales	245,576		245,576		245,576		245,576		245,576		245,576		2,946,912	28%
Cooling sales	98,230		98,230		98,230		98,230		98,230		98,230		1,178,765	11%
Gate fee income	270,023		270,023		270,023		270,023		270,023		270,023		3,240,270	31%
Gross Profit	866320		866320		866320		866320		866320		866320		10395844	####
Expenses (£)														
O&M	283,913		283,913		283,913		283,913		283,913		283,913		3,406,962	29%
Residue disposal cost	198,857		198,857		198,857		198,857		198,857		198,857		2,386,279	20%
Loan repayment	283,972		283,972		283,972		283,972		283,972		283,972		3,407,660	29%
Depreciation													2,439,981	21%
Total Expenses	766742		766742		766742		766742		766742		766742		11640881	####
Net Profit (£)	99579		99579		99579		99579		99579		99579		-1245036	
Tax (£)													0	
Net Profit After Tax (£)	99579		99579		99579		99579		99579		99579		-1245036	

Variables	
Load Factor	80%
Efficiency (Electric)	18%
Efficiency (Thermal)	50%
Heating value (MJ/tonne)	13.26

Loan calculation	
Loan (Capital + 10%)	50,697,374
Interest rate	3%
Period	20
Repayment (£)	3,407,660

Capital/O&M calculation	
Plant capacity (kt/y)	120.01
Capital cost (million £)	46.09
Opex (million £/y)	3.41
Grant (million £)	0.00

Table 10. SECC project as it is (12 months cash flow)

The 12 month analysis starts at the beginning of the fourth year from project initiation. This assumes that the construction phase will take three years starting from 2006; therefore no revenues are considered during this initial period of time. Three of the four income items share almost the same importance of about 30%: electricity sales, heat sales and gate fee income, but more importantly, heat and cooling services added together represent the greatest source of income for the case studied, highlighting the importance of a CHP scheme over the more simplistic electricity generation scenario. In fact, the heat and cooling services alone account for about 40% of the total income, a remarkable indication of the relevance of a CHP scheme in the SECC project.

Note that the profits are relatively low at about £100,000 per month, thus small variations in the expenses items could potentially unbalance the situation and transform the profits into losses. Therefore, the importance of reducing costs cannot be underestimated. Note also that the taxes are calculated at the end of the period, therefore although there is a positive net income every month for this particular year, at the end of the period when the depreciation is included, the balance moves towards negative values and as a result no tax is deducted. During the year two items of the expenses share the same relative importance, the loan repayment and the Opex expenses with 37% of the total expenses. This balance is altered when the depreciation is included. The relative importance of the residue disposal cost in this case can be taken directly from the model. Using the premises set up herein, it represents almost 26% of the total cost. In spite of being the smallest percentage, it is significant.

As for the twelve month cash flow statement, the twenty year projection estimation is based on fixed electricity, heat and cooling prices, increasing gate fee (as per the landfill tax) and constant residual disposal cost, fixed efficiency (18% for electricity generation) and fixed load factor. The table below shows the results:

Project ***SECC as it is***

Select operational variables	
Load Factor (%)	80%
Electric efficiency (%)	18%
Thermal efficiency (%)	50%
Heating value (MJ/tonne)	13.26

Price variables	
Electricity price (£/kWh)	0.0476
Heat price (£/kWh)	0.0200
Cooling price (£/kWh)	0.0400
Heat share compared to cooling	5/6

Capital/O&M calculation	
Plant type	EfW
Plant capacity (kt/y)	120.01
Capital cost (m£)	*46.09*
O&M (m£/y)	*3.41*
Grant (%)	0.00%
Grant (£)	*0*

Other variables	
Construction period (years)	3
Price increase (years)	0
Price increase (rate)	10%
Project starts (year)	2006
Gate fee max value (£/tonne)	35
Residual disposal cost (£/tonne)	66.28

Loan calculation	
Loan (Capital + 10%) (£)	*50,697,374*
Interest rate	3%
Period (Years)	20
Yearly repayment (£)	*3,407,660*

	2006	2007	2008	2009	2010	2011	2012	2013
Operations								
Waste incinerated (tonnes)	0	0	0	120010	120010	120010	120010	120010
Electricity production (kWh)	0	0	0	63653304	63653304	63653304	63653304	63653304
Heat production (kWh)	0	0	0	147345611	147345611	147345611	147345611	147345611
Cooling services (kWh)	0	0	0	29469122	29469122	29469122	29469122	29469122
Electricity price (£/kWh)	0.0476	0.0476	0.0476	0.0476	0.0476	0.0476	0.0476	0.0476
Heat price (£/kWh)	0.0200	0.0200	0.0200	0.0200	0.0200	0.0200	0.0200	0.0200
Cooling services price (£/kWh)	0.0400	0.0400	0.0400	0.0400	0.0400	0.0400	0.0400	0.0400
Gate fee (£/tonne)	18.00	21.00	24.00	27.00	30.00	33.00	35.00	35.00
Fuel cost (£/tonne)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Residue generated (tonnes)	0	0	0	36003	36003	36003	36003	36003
Residue disposal cost (£/tonne)	66.28	66.28	66.28	66.28	66.28	66.28	66.28	66.28

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Incomes (m£)																					
Electricity sales	0.00	0.00	0.00	3.03	3.03	3.03	3.03	3.03	3.03	3.03	3.03	3.03	3.03	3.03	3.03	3.03	3.03	3.03	3.03	3.03	3.03
Heat sales	0.00	0.00	0.00	2.95	2.95	2.95	2.95	2.95	2.95	2.95	2.95	2.95	2.95	2.95	2.95	2.95	2.95	2.95	2.95	2.95	2.95
Cooling sales	0.00	0.00	0.00	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18
Gate fee income	0.00	0.00	0.00	3.24	3.60	3.96	4.20	4.20	4.20	4.20	4.20	4.20	4.20	4.20	4.20	4.20	4.20	4.20	4.20	4.20	4.20
Gross Profit	0.00	0.00	0.00	10.40	10.76	11.12	11.36	11.36	11.36	11.36	11.36	11.36	11.36	11.36	11.36	11.36	11.36	11.36	11.36	11.36	11.36
Expenses (m£)																					
O&M	0.00	0.00	0.00	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41
Residue disposal cost	0.00	0.00	0.00	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39
Loan repayment	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41
Depreciation	0.00	0.00	0.00	2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44
Total Expenses	3.41	3.41	3.41	11.64	11.64	11.64	11.64	11.64	11.64	11.64	11.64	11.64	11.64	11.64	11.64	11.64	11.64	11.64	11.64	11.64	11.64
Profits (m£)																					
Net profit before tax	-54.11	-3.41	-3.41	-1.25	-0.89	-0.52	-0.28	-0.28	-0.28	-0.28	-0.28	-0.28	-0.28	-0.28	-0.28	-0.28	-0.28	-0.28	-0.28	-0.28	-0.28
Tax	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Net profit after tax	-54.11	-3.41	-3.41	-1.25	-0.89	-0.52	-0.28	-0.28	-0.28	-0.28	-0.28	-0.28	-0.28	-0.28	-0.28	-0.28	-0.28	-0.28	-0.28	-0.28	-0.28

Table 11. SECC project as it is (20 years cash flow)

As it can be noted, the income related to gate fee is increasing and its importance grows from 31.2% to 37% in 2012. It is the most important source of income. The result in income increase is a steady change in net profits that, starting as a loss of £1.2 million in 2009, it is transformed into a reduced loss of £284,956 in the sixth year, a reduction of 77%. Note again the importance of the combined heating and cooling services income, which together become a significant 36.4% by the end of the 20 years period. Despite the improvements, all net profits after taxes are negative, same as in both landfill alternatives, which means there is no possible IRR. Chart 7 below gross profits, expenses and net profits after tax for the SECC project as it is while Chart 8 gives a better idea of the IRR calculation.

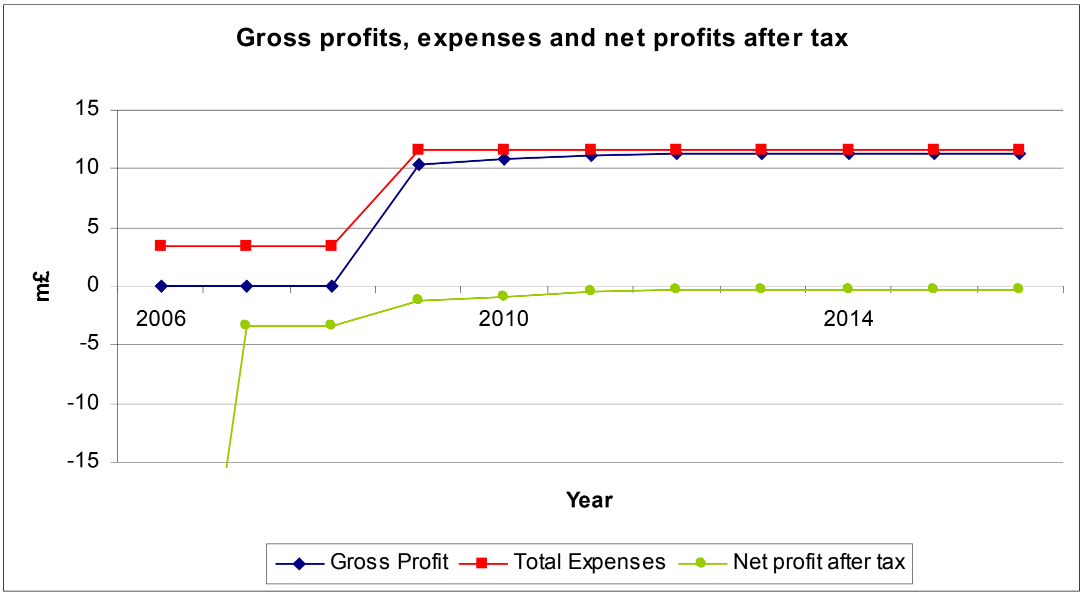

Chart 7. Gross profits, expenses and net profits after tax for the SECC project as it is

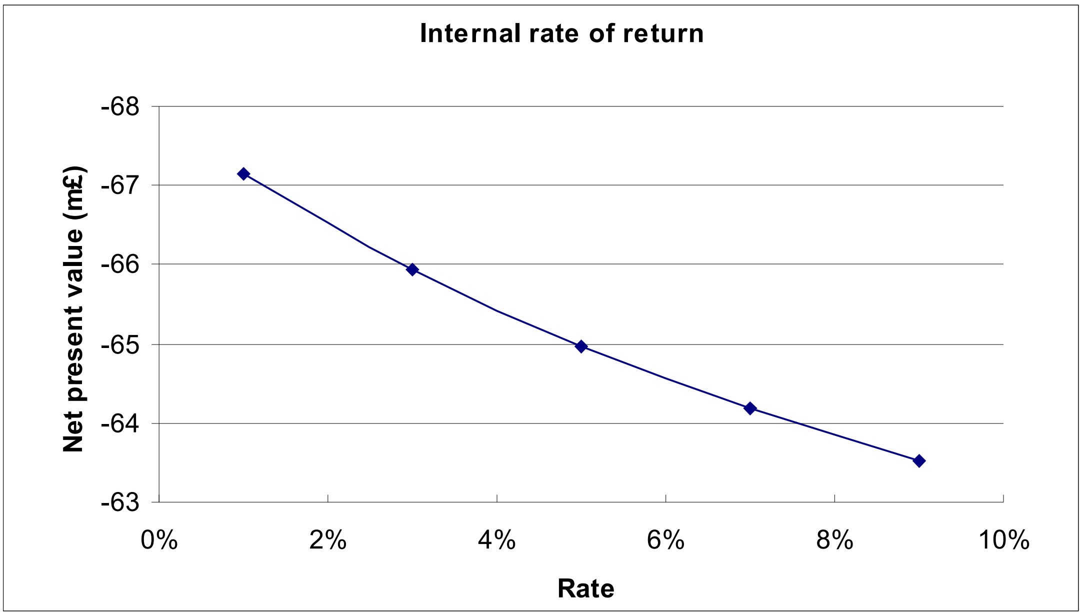

Chart 8. IRR estimation for the SECC project as it is

As for the landfill options, the Y axis is in reverse order just for illustration purposes. As there is no positive value, this means that the SECC project evaluated under the assumptions described above is not a viable alternative from the economic viewpoint as it is. When the NPV estimation is done at the 3% interest rate, the figure is of about -£66 million a good £23 million below the same reference when compared to the future landfill option in the long term. Note also that the yearly losses of the future landfill option will be of about £5.5 million and compare this to the yearly losses of £284,956 for this option. This last figure becomes a good indication that with a reasonable adjustment in operational or financial parameters, this situation could be reversed.

There may be several ways to improve the economic perspective of a project; however, this work will focus on some variables that could be easily controlled. One of the possibilities is to increase profits: operational enhancements such as an increase in the load factor could do so. But there are also financial options such as a grant or even the perspective of increase in the price of electricity, heat and cooling services or perhaps an extended landfill tax policy that lengthens its application for some years thus increasing the value of the gate fee. On the other hand, some operational measures such as cost reduction could be implemented, however, none of the options evaluated in this document will explore this side of the equation.

The following cases involve a study of modest variations of reasonable parameters in order to make the SECC project more economically attractive.

With a grant

If a grant is allocated to the project, the benefits will be a reduction in the amount of money that needs to be borrowed, therefore a lower capital cost and a reduced loan repayment. Note that in the evaluation of the SECC project as it is, this item represented almost 30% of the expenses. This has obviously a positive impact on the cash flow of the project and depending on the amount granted the impact will be greater. Three different grants are evaluated, covering 15, 20 and 30% of what the loan should have been without it, this is, the grants are of £7.6, £10.14 and £15.21 million respectively. Only the twenty year cash flow with the highest grant will be shown here:

Project ***SECC with grant***

Select operational variables	
Load Factor (%)	80%
Electric efficiency (%)	18%
Thermal efficiency (%)	50%
Heating value (MJ/tonne)	13.26

Price variables	
Electricity price (£/kWh)	0.0476
Heat price (£/kWh)	0.0200
Cooling price (£/kWh)	0.0400
Heat share compared to cooling	5/6

Capital/O&M calculation	
Plant type	EfW
Plant capacity (kt/y)	120.01
Capital cost (m£)	*46.09*
O&M (m£/y)	*3.41*
Grant (%)	30.00%
Grant (£)	*15,209,212*

Other variables	
Construction period (years)	3
Price increase (years)	0
Price increase (rate)	10%
Project starts (year)	2006
Gate fee max value (£/tonne)	35
Residual disposal cost (£/tonne)	66.28

Loan calculation	
Loan (Capital + 10%) (£)	*35,488,162*
Interest rate	3%
Period (Years)	20
Yearly repayment (£)	*2,385,362*

	2006	2007	2008	2009	2010	2011	2012	2013
Operations								
Waste incinerated (tonnes)	0	0	0	120010	120010	120010	120010	120010
Electricity production (kWh)	0	0	0	63653304	63653304	63653304	63653304	63653304
Heat production (kWh)	0	0	0	147345611	147345611	147345611	147345611	147345611
Cooling services (kWh)	0	0	0	29469122	29469122	29469122	29469122	29469122
Electricity price (£/kWh)	0.0476	0.0476	0.0476	0.0476	0.0476	0.0476	0.0476	0.0476
Heat price (£/kWh)	0.0200	0.0200	0.0200	0.0200	0.0200	0.0200	0.0200	0.0200
Cooling services price (£/kWh)	0.0400	0.0400	0.0400	0.0400	0.0400	0.0400	0.0400	0.0400
Gate fee (£/tonne)	18.00	21.00	24.00	27.00	30.00	33.00	35.00	35.00
Fuel cost (£/tonne)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Residue generated (tonnes)	0	0	0	36003	36003	36003	36003	36003
Residue disposal cost (£/tonne)	66.28	66.28	66.28	66.28	66.28	66.28	66.28	66.28

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Incomes (m£)																					
Electricity sales	0.00	0.00	0.00	3.03	3.03	3.03	3.03	3.03	3.03	3.03	3.03	3.03	3.03	3.03	3.03	3.03	3.03	3.03	3.03	3.03	3.03
Heat sales	0.00	0.00	0.00	2.95	2.95	2.95	2.95	2.95	2.95	2.95	2.95	2.95	2.95	2.95	2.95	2.95	2.95	2.95	2.95	2.95	2.95
Cooling sales	0.00	0.00	0.00	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18
Gate fee income	0.00	0.00	0.00	3.24	3.60	3.96	4.20	4.20	4.20	4.20	4.20	4.20	4.20	4.20	4.20	4.20	4.20	4.20	4.20	4.20	4.20
Gross Profit	0.00	0.00	0.00	10.40	10.76	11.12	11.36	11.36	11.36	11.36	11.36	11.36	11.36	11.36	11.36	11.36	11.36	11.36	11.36	11.36	11.36
Expenses (m£)																					
O&M	0.00	0.00	0.00	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41
Residue disposal cost	0.00	0.00	0.00	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39
Loan repayment	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39
Depreciation	0.00	0.00	0.00	2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44
Total Expenses	2.39	2.39	2.39	10.62	10.62	10.62	10.62	10.62	10.62	10.62	10.62	10.62	10.62	10.62	10.62	10.62	10.62	10.62	10.62	10.62	10.62
Profits (m£)																					
Net profit before tax	-37.87	-2.39	-2.39	-0.22	0.14	0.50	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74
Tax	0.00	0.00	0.00	0.00	-0.05	-0.20	-0.29	-0.29	-0.29	-0.29	-0.29	-0.29	-0.29	-0.29	-0.29	-0.29	-0.29	-0.29	-0.29	-0.29	-0.29
Net profit after tax	-37.87	-2.39	-2.39	-0.22	0.08	0.30	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44

Table 12. SECC project with grant (20 years cash flow)

The impact on the cash flow is noticeable when looking at the importance of the loan repayment. In the previous case, this amount represented 30% of the expenses, whereas now with the £15.21 million grant the amount has been reduced and the loan repayments are 23% of the total expenses. With this grant, the total expenses have been reduced in £1.0 million every year when compared to the previous case. This certainly helps the fact that since the plant began to operate, it is reporting increasing net profits after tax, starting from £82,375 up to £442,405 when the landfill tax reaches its peak in the year 2012. However, this enhancement is far from bringing the economical perspective into the positive side. Figure 9 shows the Gross profits, expenses and net profits after tax of the SECC project with a 15.21m£ grant while Figure 10 shows the IRR estimation of the SECC project with the same grant.

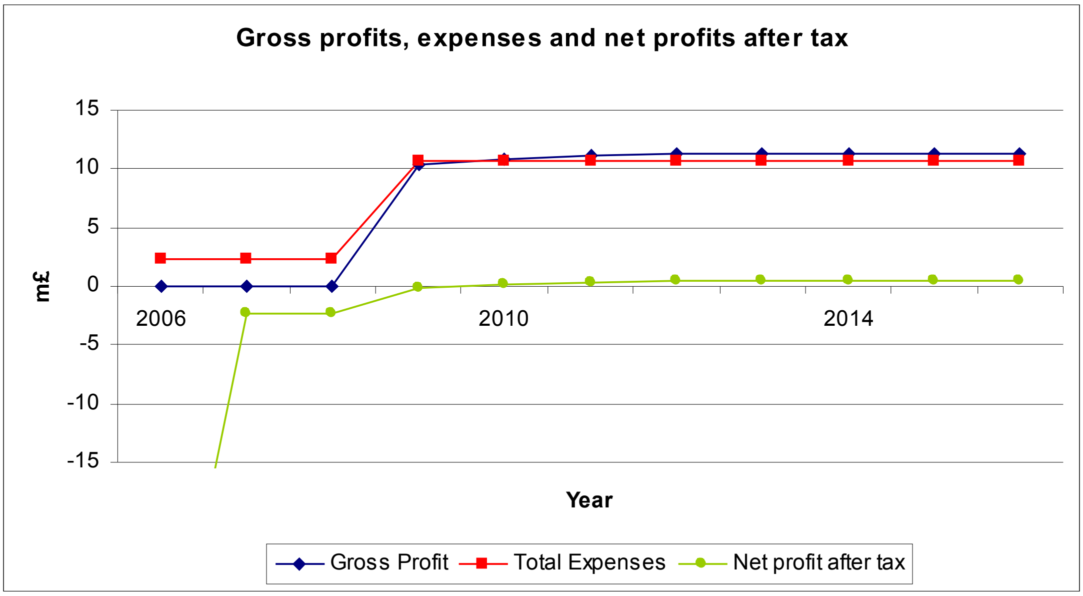

Chart 9. Gross profits, expenses and net profits after tax for the SECC project with a £15.21 million grant

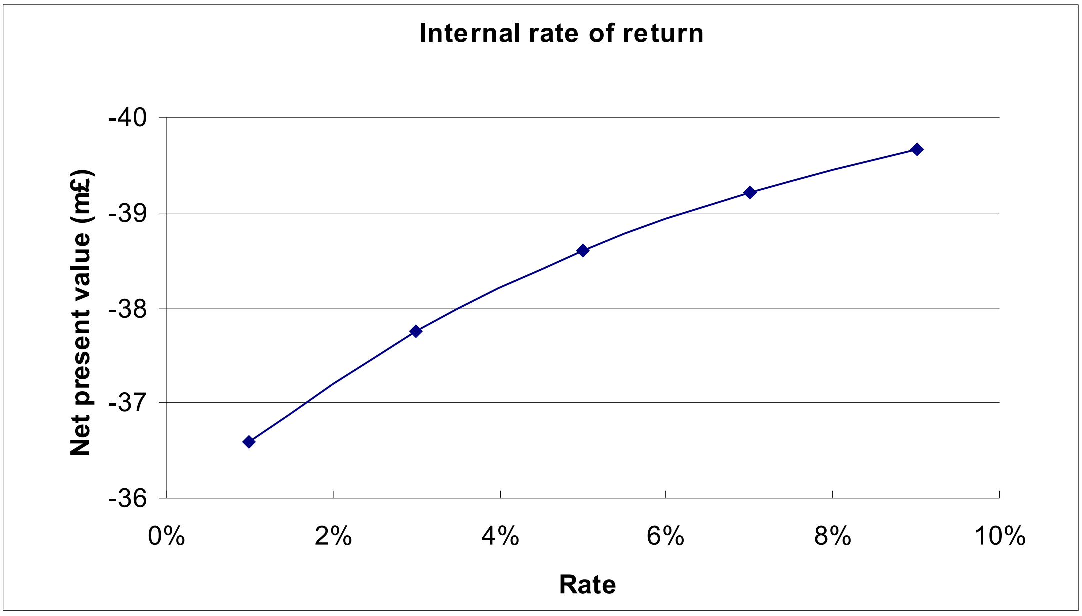

Chart 10. IRR estimation for the SECC project with a £15.21 million grant

Using the same reference of 3% interest rate for the NPV calculation, the effect of the grant is to reduce the figure from the values previously obtained to something around -38m£ in the best case of a £15.21 million grant. This is little above half the previous figure for the SECC project as it is. For the other grants evaluated, the situation is similar but with increased (worse) figures. The £10.14 million grant resulted in a -£47 million NPV whereas the £7.6 million grant is around -£51 million, certainly below the -£66 million figure but still negative. It seems obvious that the use of this financial help alone is not enough to make this an economically attractive option.

With increased load factor

The load factor could be manipulated in order to obtain more benefits from longer operation times throughout the year. This increases the amount of electricity, heat and cooling services generated and consequently available for sales. Estimations were done for load factor increase of 5, 7 and 10% from the original 80%. The following table has the twenty year projection for the case of a 90% load factor:

Project	***SECC with increased load factor***
Select operational variables	
Load Factor (%)	90%
Electric efficiency (%)	18%
Thermal efficiency (%)	50%
Heating value (MJ/tonne)	13.26
Price variables	
Electricity price (£/kWh)	0.0476
Heat price (£/kWh)	0.0200
Cooling price (£/kWh)	0.0400
Heat share compared to cooling	5/6
Capital/O&M calculation	
Plant type	EfW
Plant capacity (kt/y)	120.01
Capital cost (m£)	*46.09*
O&M (m£/y)	*3.41*
Grant (%)	0.00%
Grant (£)	*0*

Other variables	
Construction period (years)	3
Price increase (years)	0
Price increase (rate)	10%
Project starts (year)	2006
Gate fee max value (£/tonne)	35
Residual disposal cost (£/tonne)	66.28
Loan calculation	
Loan (Capital + 10%) (£)	*50,697,374*
Interest rate	3%
Period (Years)	20
Yearly repayment (£)	*3,407,660*

	2006	2007	2008	2009	2010	2011	2012	2013
Operations								
Waste incinerated (tonnes)	0	0	0	120010	120010	120010	120010	120010
Electricity production (kWh)	0	0	0	71609967	71609967	71609967	71609967	71609967
Heat production (kWh)	0	0	0	165763813	165763813	165763813	165763813	165763813
Cooling services (kWh)	0	0	0	33152763	33152763	33152763	33152763	33152763
Electricity price (£/kWh)	0.0476	0.0476	0.0476	0.0476	0.0476	0.0476	0.0476	0.0476
Heat price (£/kWh)	0.0200	0.0200	0.0200	0.0200	0.0200	0.0200	0.0200	0.0200
Cooling services price (£/kWh)	0.0400	0.0400	0.0400	0.0400	0.0400	0.0400	0.0400	0.0400
Gate fee (£/tonne)	18.00	21.00	24.00	27.00	30.00	33.00	35.00	35.00
Fuel cost (£/tonne)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Residue generated (tonnes)	0	0	0	36003	36003	36003	36003	36003
Residue disposal cost (£/tonne)	66.28	66.28	66.28	66.28	66.28	66.28	66.28	66.28

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Incomes (m£)																					
Electricity sales	0.00	0.00	0.00	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41
Heat sales	0.00	0.00	0.00	3.32	3.32	3.32	3.32	3.32	3.32	3.32	3.32	3.32	3.32	3.32	3.32	3.32	3.32	3.32	3.32	3.32	3.32
Cooling sales	0.00	0.00	0.00	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33
Gate fee income	0.00	0.00	0.00	3.24	3.60	3.96	4.20	4.20	4.20	4.20	4.20	4.20	4.20	4.20	4.20	4.20	4.20	4.20	4.20	4.20	4.20
Gross Profit	0.00	0.00	0.00	11.29	11.65	12.01	12.25	12.25	12.25	12.25	12.25	12.25	12.25	12.25	12.25	12.25	12.25	12.25	12.25	12.25	12.25
Expenses (m£)																					
O&M	0.00	0.00	0.00	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41
Residue disposal cost	0.00	0.00	0.00	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39
Loan repayment	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41
Depreciation	0.00	0.00	0.00	2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44
Total Expenses	3.41	3.41	3.41	11.64	11.64	11.64	11.64	11.64	11.64	11.64	11.64	11.64	11.64	11.64	11.64	11.64	11.64	11.64	11.64	11.64	11.64
Profits (m£)																					
Net profit before tax	-54.11	-3.41	-3.41	-0.35	0.01	0.37	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61
Tax	0.00	0.00	0.00	0.00	0.00	-0.15	-0.24	-0.24	-0.24	-0.24	-0.24	-0.24	-0.24	-0.24	-0.24	-0.24	-0.24	-0.24	-0.24	-0.24	-0.24
Net profit after tax	-54.11	-3.41	-3.41	-0.35	0.01	0.22	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37

Table 13. SECC project with increased load factor (20 years cash flow)

As explained before, the immediate consequence is an increase in the electricity generated from the initial 63,653 MWh produced at 80% load factor to 71,609 MWh with 90% load factor, an increase of 13%. The same happens with the combined heat and cooling services which varied from 176,814 MWh to 198,916 MWh. This, as anticipated, has a direct positive effect on the income and its relative importance or rank. Also as expected, the relative importance of electricity, heat and cooling sales increases while the importance of the gate fee income declines during the first year the plant operates when compared to the original alternative. However, this improvement is just a very small amount of less than 3 percent points.

In terms of net profit after tax, the situation is again vastly improved when compared to the EfW case without any manipulation in which a perpetual loss is obtained. In this case, very discrete earnings start to flow during the second year of plant operations and stabilize at around £365,694 later on. This, however, does not mean that this alternative is attractive, as can be confirmed in the following charts. Chart 11 shows the gross profits, expenses and net profits after tax of the SECC project with greater load factor whereas Chart 12 shows the IRR estimation for the same case.

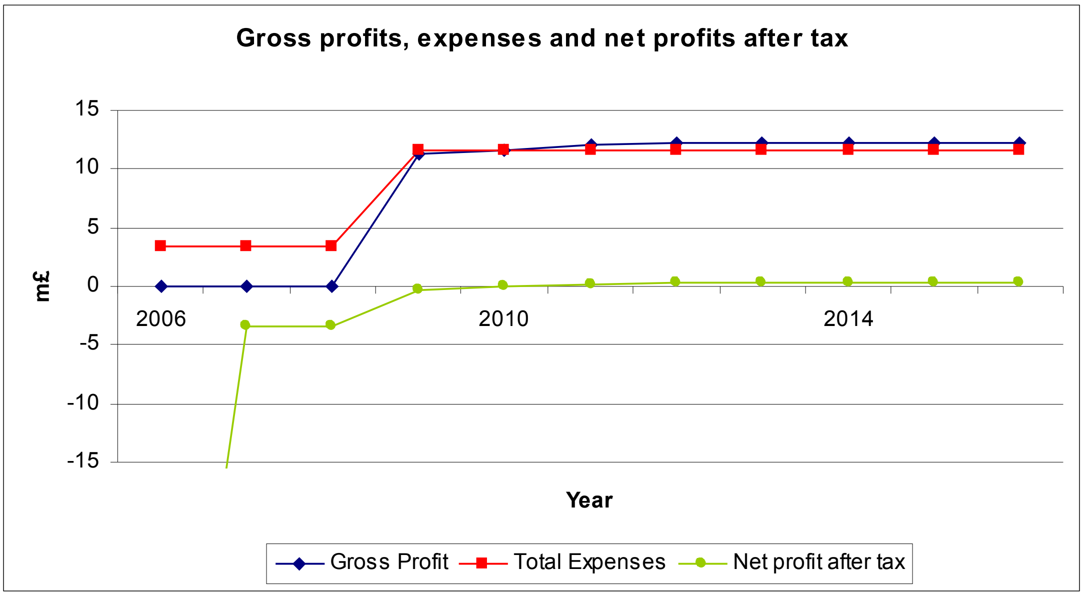

Chart 11. Gross profits, expenses and net profits after tax for the SECC project with greater load factor.

The results for the other load factor increments simulated are obviously lower when compared to the 90% load factor. Again the Y axis is in reverse order just for illustration purposes.

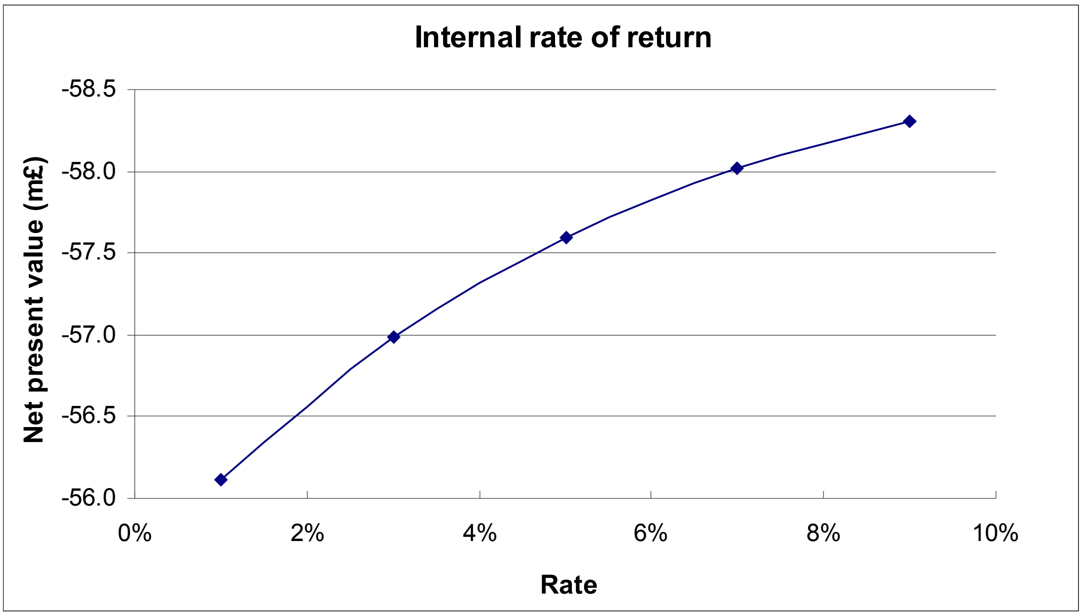

Chart 12. IRR estimation for the SECC project with greater load factor

As for all the alternatives studied so far, no IRR can be found. The NPV for the 90% load factor case is around the -£57 million figure when estimated using a 3% interest rate. For the remaining load factor increments of 85 and 87%, the results are -£61 million and -£59 million, respectively. Although it can be said that the increase in load factor is beneficial to the economic perspective of this alternative with the improvement in the yearly cash flow when compared to the SECC as it is, it is still not enough to make this an attractive option from the financial point of view and in fact a very large increase in load factor is needed in order to obtain minor benefits.

In a price increase scenario

Another possibility envisaged in a twenty year life span of an EfW plant, is an increase in the prices of the services that the project is providing: electricity, heat and cooling services. From the possible alternatives to simulate this, a simple approach of a fixed increase of 10% starting from year 2014 was used. The price increments are supposed to occur with a five year interval gap before any further increment. The same percentage increase is assumed for all services, also applicable for the dates in which they will take place.

Project	***SECC with price increase scenario***
Select operational variables	
Load Factor (%)	80%
Electric efficiency (%)	18%
Thermal efficiency (%)	50%
Heating value (MJ/tonne)	13.26
Price variables	
Electricity price (£/kWh)	0.0476
Heat price (£/kWh)	0.0200
Cooling price (£/kWh)	0.0400
Heat share compared to cooling	5/6
Capital/O&M calculation	
Plant type	EfW
Plant capacity (kt/y)	120.01
Capital cost (m£)	*46.09*
O&M (m£/y)	*3.41*
Grant (%)	0.00%
Grant (£)	*0*

Other variables	
Construction period (years)	3
Price increase (years)	5
Price increase (rate)	10%
Project starts (year)	2006
Gate fee max value (£/tonne)	35
Residual disposal cost (£/tonne)	66.28
Loan calculation	
Loan (Capital + 10%) (£)	*50,697,374*
Interest rate	3%
Period (Years)	20
Yearly repayment (£)	*3,407,660*

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Operations											
Waste incinerated (tonnes)	0	0	0	120010	120010	120010	120010	120010	120010	120010	120010
Electricity production (kWh)	0	0	0	63653304	63653304	63653304	63653304	63653304	63653304	63653304	63653304
Heat production (kWh)	0	0	0	147345611	147345611	147345611	147345611	147345611	147345611	147345611	147345611
Cooling services (kWh)	0	0	0	29469122	29469122	29469122	29469122	29469122	29469122	29469122	29469122
Electricity price (£/kWh)	0.0476	0.0476	0.0476	0.0476	0.0476	0.0476	0.0476	0.0476	0.0524	0.0524	0.0524
Heat price (£/kWh)	0.0200	0.0200	0.0200	0.0200	0.0200	0.0200	0.0200	0.0200	0.0220	0.0220	0.0220
Cooling services price (£/kWh)	0.0400	0.0400	0.0400	0.0400	0.0400	0.0400	0.0400	0.0400	0.0440	0.0440	0.0440
Gate fee (£/tonne)	18.00	21.00	24.00	27.00	30.00	33.00	35.00	35.00	35.00	35.00	35.00
Fuel cost (£/tonne)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Residue generated (tonnes)	0	0	0	36003	36003	36003	36003	36003	36003	36003	36003
Residue disposal cost (£/tonne)	66.28	66.28	66.28	66.28	66.28	66.28	66.28	66.28	66.28	66.28	66.28

	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Operations										
Waste incinerated (tonnes)	120010	120010	120010	120010	120010	120010	120010	120010	120010	120010
Electricity production (kWh)	63653304	63653304	63653304	63653304	63653304	63653304	63653304	63653304	63653304	63653304
Heat production (kWh)	147345611	147345611	147345611	147345611	147345611	147345611	147345611	147345611	147345611	147345611
Cooling services (kWh)	29469122	29469122	29469122	29469122	29469122	29469122	29469122	29469122	29469122	29469122
Electricity price (£/kWh)	0.0524	0.0524	0.0576	0.0576	0.0576	0.0576	0.0576	0.0634	0.0634	0.0634
Heat price (£/kWh)	0.0220	0.0220	0.0242	0.0242	0.0242	0.0242	0.0242	0.0266	0.0266	0.0266
Cooling services price (£/kWh)	0.0440	0.0440	0.0484	0.0484	0.0484	0.0484	0.0484	0.0532	0.0532	0.0532
Gate fee (£/tonne)	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00
Fuel cost (£/tonne)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Residue generated (tonnes)	36003	36003	36003	36003	36003	36003	36003	36003	36003	36003
Residue disposal cost (£/tonne)	66.28	66.28	66.28	66.28	66.28	66.28	66.28	66.28	66.28	66.28

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Incomes (m£)																					
Electricity sales	0.00	0.00	0.00	3.03	3.03	3.03	3.03	3.03	3.33	3.33	3.33	3.33	3.33	3.67	3.67	3.67	3.67	3.67	4.03	4.03	4.03
Heat sales	0.00	0.00	0.00	2.95	2.95	2.95	2.95	2.95	3.24	3.24	3.24	3.24	3.24	3.57	3.57	3.57	3.57	3.57	3.92	3.92	3.92
Cooling sales	0.00	0.00	0.00	1.18	1.18	1.18	1.18	1.18	1.30	1.30	1.30	1.30	1.30	1.43	1.43	1.43	1.43	1.43	1.57	1.57	1.57
Gate fee income	0.00	0.00	0.00	3.24	3.60	3.96	4.20	4.20	4.20	4.20	4.20	4.20	4.20	4.20	4.20	4.20	4.20	4.20	4.20	4.20	4.20
Gross Profit	0.00	0.00	0.00	10.40	10.76	11.12	11.36	11.36	12.07	12.07	12.07	12.07	12.07	12.86	12.86	12.86	12.86	12.86	13.72	13.72	13.72
Expenses (m£)																					
O&M	0.00	0.00	0.00	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41
Residue disposal cost	0.00	0.00	0.00	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39
Loan repayment	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41
Depreciation	0.00	0.00	0.00	2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44
Total Expenses	3.41	3.41	3.41	11.64	11.64	11.64	11.64	11.64	11.64	11.64	11.64	11.64	11.64	11.64	11.64	11.64	11.64	11.64	11.64	11.64	11.64
Profits (m£)																					
Net profit before tax	-54.11	-3.41	-3.41	-1.25	-0.89	-0.52	-0.28	-0.28	0.43	0.43	0.43	0.43	0.43	1.22	1.22	1.22	1.22	1.22	2.08	2.08	2.08
Tax	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.17	-0.17	-0.17	-0.17	-0.17	-0.49	-0.49	-0.49	-0.49	-0.49	-0.83	-0.83	-0.83
Net profit after tax	-54.11	-3.41	-3.41	-1.25	-0.89	-0.52	-0.28	-0.28	0.26	0.26	0.26	0.26	0.26	0.73	0.73	0.73	0.73	0.73	1.25	1.25	1.25

Table 14. SECC project in a price increase scenario (20 years cash flow)

As expected, incomes stabilize in phases since the price increments take place every five years. When income reaches its final value for this alternative (2024), the electricity income raises its importance from 26.7% (SECC as it is) up to 29.3% of the total income. A similar situation arises with the other income items. Only the income due to the gate fee decreases as to balance the changes, from 37 to 30.6%. Note also that during the first five years of operation, the plant is suffering a loss equal to the EfW case as expected. However, from year 6 onwards, the income soon stabilizes and the net profits after taxes finish at an outstanding £1.3 million at the end of the evaluated period. This situation by itself does not, however, improve the economic perspective of the alternative. Chart 13 shows the gross profits, expenses and net profits after tax for the SECC project with electricity, heat and cooling services price increases.

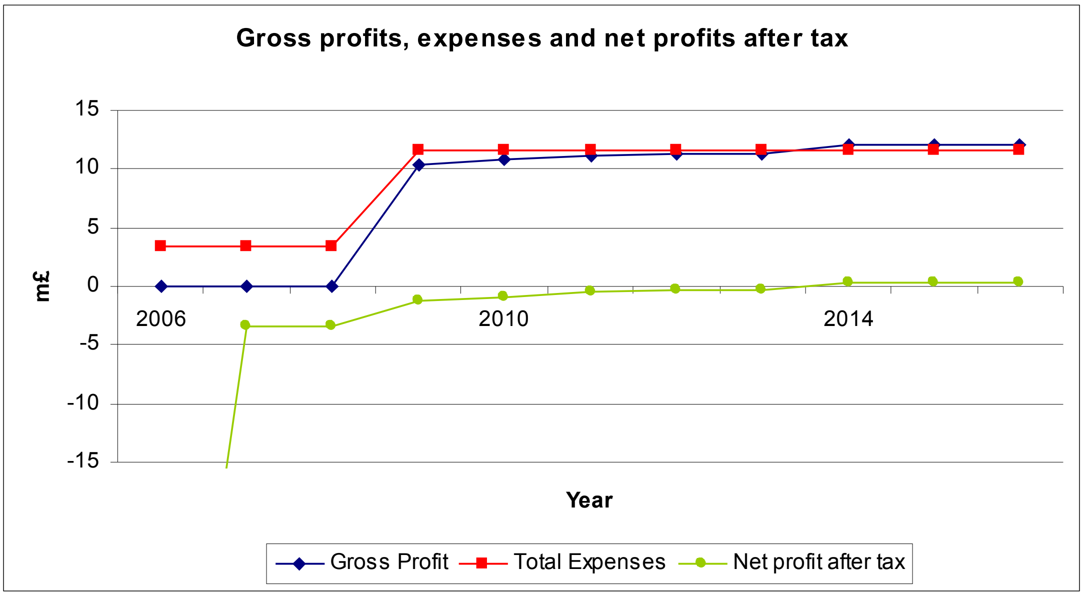

Chart 13. Gross profits, expenses and net profits after tax for the SECC project with electricity, heat and cooling services price increases

Chart 14 shows the IRR estimation for the SECC project with electricity, heat and cooling services price increases. The alternative of raising the services price fails to bring the project to positive numbers as in the previous options. The project does bring down the NPV reference to a figure of -£58 million at the assumed 3% interest rate.

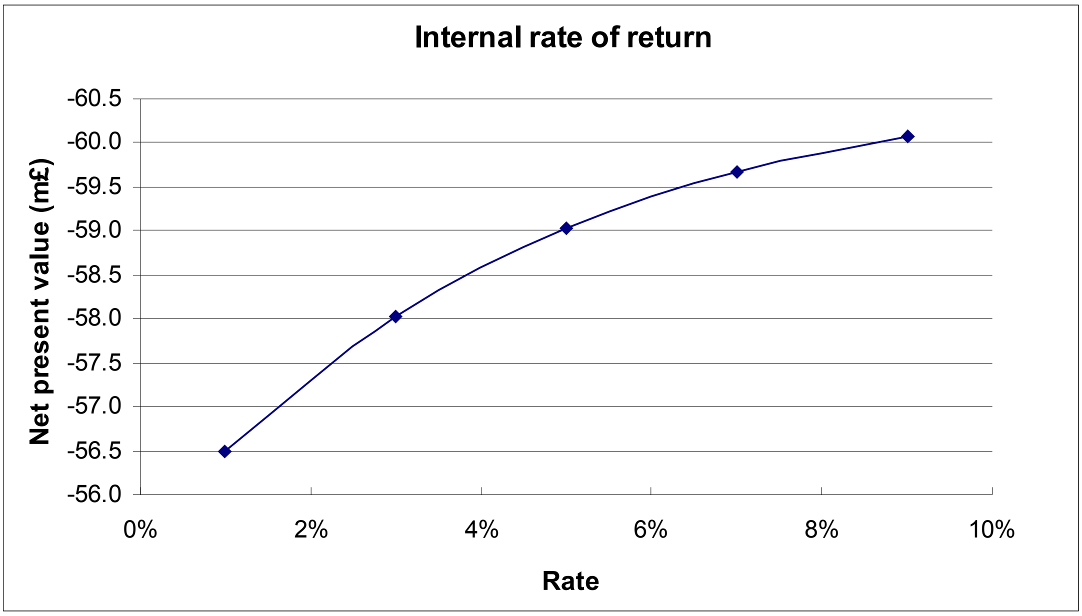

Chart 14. IRR estimation for the SECC project with electricity, heat and cooling services price increases

As in the previous cases, a sensible increase in the price variable results in minor improvements of the NPV although it does increase in a substantial way the yearly profits.

All the operational and financial measures studied here have failed to provide a positive IRR, even though they have lowered the long term losses of the project when compared to the landfill option. One last logical exercise is to make a new case study with all the previous enhancements combined.

With both financial and operational aids

In the following case the most rewarding alternatives studied so far will be combined in one, thus a grant of £15.21 million will be allocated, together with an increase in load factor and the already explained services sales price increase. The result is unfortunately not encouraging. Although the NPV value at 3% interest rate has decreased dramatically and is now closer to -£21 million, it is still not enough to make the project attractive from the economic viewpoint.

Having seen this, even when the SECC project is definitely a better option from the point of view of resource use, more is still needed in order to overcome the economic hurdles still present. This is, further steps need to be taken in order to help the project become more appealing. As an example, the next attempt will be based on lengthening the time in which the increase of the gate fee figures apply in order to increase the benefits that will arise from such a measure. Just as a guide, the period will be projected at the same current rate until it reaches approximately the same value of the residual disposal cost, this is approximately £66/tonne. This will happen during year 16 after the project start-up or equivalent to 2022. The resulting cash flow statement is shown below:

Project ***SECC with financial and operational aids***

Select operational variables	
Load Factor (%)	90%
Electric efficiency (%)	18%
Thermal efficiency (%)	50%
Heating value (MJ/tonne)	13.26

Price variables	
Electricity price (£/kWh)	0.0476
Heat price (£/kWh)	0.0200
Cooling price (£/kWh)	0.0400
Heat share compared to cooling	5/6

Capital/O&M calculation	
Plant type	EfW
Plant capacity (kt/y)	120.01
Capital cost (m£)	*46.09*
O&M (m£/y)	*3.41*
Grant (%)	30.00%
Grant (£)	*15,209,212*

Other variables	
Construction period (years)	3
Price increase (years)	5
Price increase (rate)	10%
Project starts (year)	2006
Gate fee max value (£/tonne)	66
Residual disposal cost (£/tonne)	66.28

Loan calculation	
Loan (Capital + 10%) (£)	*35,488,162*
Interest rate	3%
Period (Years)	20
Yearly repayment (£)	*2,385,362*

Operations	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Waste incinerated (tonnes)	0	0	0	120010	120010	120010	120010	120010	120010	120010	120010
Electricity production (kWh)	0	0	0	71609967	71609967	71609967	71609967	71609967	71609967	71609967	71609967
Heat production (kWh)	0	0	0	165763813	165763813	165763813	165763813	165763813	165763813	165763813	165763813
Cooling services (kWh)	0	0	0	33152763	33152763	33152763	33152763	33152763	33152763	33152763	33152763
Electricity price (£/kWh)	0.0476	0.0476	0.0476	0.0476	0.0476	0.0476	0.0476	0.0476	0.0524	0.0524	0.0524
Heat price (£/kWh)	0.0200	0.0200	0.0200	0.0200	0.0200	0.0200	0.0200	0.0200	0.0220	0.0220	0.0220
Cooling services price (£/kWh)	0.0400	0.0400	0.0400	0.0400	0.0400	0.0400	0.0400	0.0400	0.0440	0.0440	0.0440
Gate fee (£/tonne)	18.00	21.00	24.00	27.00	30.00	33.00	36.00	39.00	42.00	45.00	48.00
Fuel cost (£/tonne)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Residue generated (tonnes)	0	0	0	36003	36003	36003	36003	36003	36003	36003	36003
Residue disposal cost (£/tonne)	66.28	66.28	66.28	66.28	66.28	66.28	66.28	66.28	66.28	66.28	66.28

Operations	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Waste incinerated (tonnes)	120010	120010	120010	120010	120010	120010	120010	120010	120010	120010
Electricity production (kWh)	71609967	71609967	71609967	71609967	71609967	71609967	71609967	71609967	71609967	71609967
Heat production (kWh)	165763813	165763813	165763813	165763813	165763813	165763813	165763813	165763813	165763813	165763813
Cooling services (kWh)	33152763	33152763	33152763	33152763	33152763	33152763	33152763	33152763	33152763	33152763
Electricity price (£/kWh)	0.0524	0.0524	0.0576	0.0576	0.0576	0.0576	0.0576	0.0634	0.0634	0.0634
Heat price (£/kWh)	0.0220	0.0220	0.0242	0.0242	0.0242	0.0242	0.0242	0.0266	0.0266	0.0266
Cooling services price (£/kWh)	0.0440	0.0440	0.0484	0.0484	0.0484	0.0484	0.0484	0.0532	0.0532	0.0532
Gate fee (£/tonne)	51.00	54.00	57.00	60.00	63.00	66.00	66.00	66.00	66.00	66.00
Fuel cost (£/tonne)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Residue generated (tonnes)	36003	36003	36003	36003	36003	36003	36003	36003	36003	36003
Residue disposal cost (£/tonne)	66.28	66.28	66.28	66.28	66.28	66.28	66.28	66.28	66.28	66.28

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Incomes (m£)																					
Electricity sales	0.00	0.00	0.00	3.41	3.41	3.41	3.41	3.41	3.75	3.75	3.75	3.75	3.75	4.12	4.12	4.12	4.12	4.12	4.54	4.54	4.54
Heat sales	0.00	0.00	0.00	3.32	3.32	3.32	3.32	3.32	3.65	3.65	3.65	3.65	3.65	4.01	4.01	4.01	4.01	4.01	4.41	4.41	4.41
Cooling sales	0.00	0.00	0.00	1.33	1.33	1.33	1.33	1.33	1.46	1.46	1.46	1.46	1.46	1.60	1.60	1.60	1.60	1.60	1.77	1.77	1.77
Gate fee income	0.00	0.00	0.00	3.24	3.60	3.96	4.32	4.68	5.04	5.40	5.76	6.12	6.48	6.84	7.20	7.56	7.92	7.92	7.92	7.92	7.92
Gross Profit	0.00	0.00	0.00	11.29	11.65	12.01	12.37	12.73	13.90	14.26	14.62	14.98	15.34	16.58	16.94	17.30	17.66	17.66	18.64	18.64	18.64
Expenses (m£)																					
O&M	0.00	0.00	0.00	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41	3.41
Residue disposal cost	0.00	0.00	0.00	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39
Loan repayment	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39
Depreciation	0.00	0.00	0.00	2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44
Total Expenses	2.39	2.39	2.39	10.62	10.62	10.62	10.62	10.62	10.62	10.62	10.62	10.62	10.62	10.62	10.62	10.62	10.62	10.62	10.62	10.62	10.62
Profits (m£)																					
Net profit before tax	-37.87	-2.39	-2.39	0.67	1.03	1.39	1.75	2.11	3.28	3.64	4.00	4.36	4.72	5.96	6.32	6.68	7.04	7.04	8.02	8.02	8.02
Tax	0.00	0.00	0.00	-0.27	-0.41	-0.56	-0.70	-0.84	-1.31	-1.45	-1.60	-1.74	-1.89	-2.39	-2.53	-2.67	-2.82	-2.82	-3.21	-3.21	-3.21
Net profit after tax	-37.87	-2.39	-2.39	0.40	0.62	0.84	1.05	1.27	1.97	2.18	2.40	2.61	2.83	3.58	3.79	4.01	4.23	4.23	4.81	4.81	4.81

Table 15. SECC project with financial and operational aids (20 years cash flow)

It can be noted that from the beginning of its operational life the SECC project is generating profits. These are in the rise from the initial £0.4 million to £4.8 million in 2024 due to the increasing income while the expenses are fixed. It is important also to note the increasing weight of the gate fee income, which at the end of the 20 year period becomes the most important source of income amounting to 43% of the total. Finally a positive IRR can be calculated. Chart 15 shows the economic performance in terms of gross profits, expenses and net profits after tax while Chart 16 shows the IRR estimation for both cases, the original sum up of all aids and the alternative with gate fee increase.

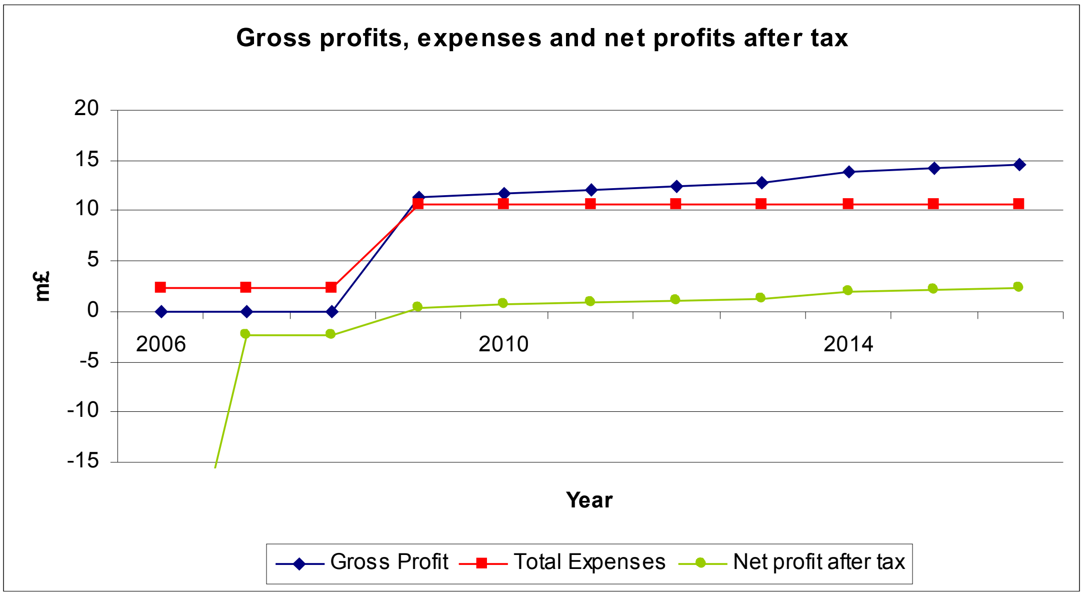

Chart 15. Gross profits, expenses and net profits after tax for the SECC project with a combination of financial and operational aids

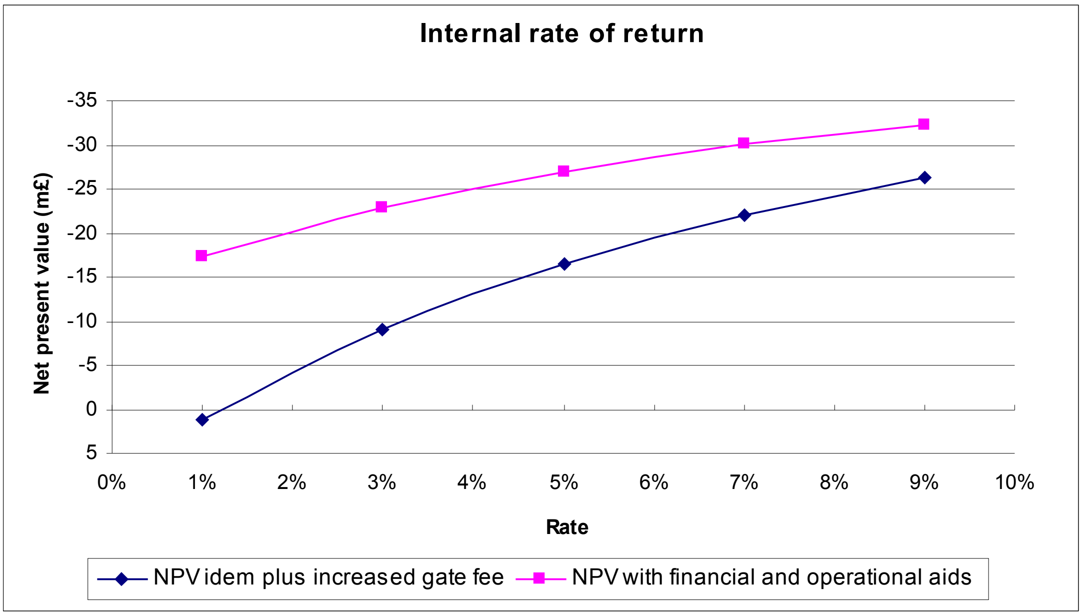

Chart 16. IRR estimation for the SECC project with a combination of financial and operational aids

Note that as explained before for the case of all aids combined, the resulting IRR is negative. The NPV at the reference value is -£23 million. Although, for the case of extended increase of the gate fee, the project has finally been brought down enough to cross the reference line, thus defining a positive IRR of 1.21%. This is a massive improvement when compared to any of the landfill alternatives or the previous SECC options, yet the resulting figure is below the 3% interest rate that the loan requires, therefore, and only taking into consideration economic variables, it is more reasonable to keep the funds secure in the building society than to invest in the EfW project. This is simply because without operational risks it is able to generate more profits. Obviously this is not a viable option since the waste managing problem would not be addressed.

All in all, the economic evaluation of the different financial and operational alternatives for the SECC project do improve its attractiveness when compared to the two different landfill options evaluated here, but it still needs more assistance in order to become more appealing to private investors. In other words, the EfW project is more sustainable than the current and future landfill options from the resource use point of view.

Environmental benefit in the form of CO_2 emissions reduction

It is well known that recovering energy from waste contributes to the goal of reducing CO_2 emissions. This is achieved because of two main reasons: the fuel from waste is carbon neutral or its origin is biogenic and also because of the avoidance of gases released from a landfill, in particular Methane which has an enhanced green house potential. This is important because the SECC project will add this feature as an additional benefit when compared to another energy source. An estimation of these savings will be presented in the following pages.

Biogenic origin of the fuel

Porteous, A. (2005) estimates the biogenic content of typical UK waste as 85%. Thus, burning waste in an EfW plant will add 15% of new CO_2 to the atmosphere. However, it is difficult to establish a fixed number for the savings since the Heating Value of the MSW can vary depending on its origin. Nevertheless, the figures for CO_2 savings can be calculated for both operations, either sole electricity production or in a CHP scheme. Evidently the CHP scheme is the most rewarding in this particular issue as can be seen below.

The chemical reaction involved in the combustion process is:

$$C + O_2 \Rightarrow CO_2$$

Using the molecular weight of the elements:

$$\begin{aligned} 12kgC &\rightarrow 44kgCO_2 \\ xkgC &\rightarrow 1{,}000kgCO_2 \end{aligned}$$

Where x is calculated as 273. This means, 273 kg of C are needed in order to produce 1 tonne of CO_2.

But C is only a fraction of the MSW. Same as in the Heating Value case, different waste sources will have different C content. The following table summarizes the findings in the area of C content. An average value will be used despite having a reported value for UK waste.

Author	Country	Carbon content in MSW (%)
Porteous, A. (2005)	UK	24
Murphy J. D. and McKeogh, E. (2004)	Ireland	22.5
Chan et al (1998)	Taiwan	20.11
Consonni et al (2005)	Italy	27.6
		Average = 23.55

Table 16. Carbon content of different MSW

Therefore:

$$273kgC \rightarrow 23.55\%$$
$$xkgC \rightarrow 100\%$$

Where x is calculated as 1,159. This is, 1,159 kg of MSW are needed in order to produce 1 tonne of CO_2. In other words, one tonne of MSW produces 863 kg of CO_2. But only 15% of the carbon in the MSW is non-biogenic, therefore, effectively only 130 kg of CO_2 are added to the atmosphere.

As per the initial modelling study detailed earlier in this thesis, one tonne of MSW produces 564 kWh if used for electricity production only and up to 2,129 kWh if in a CHP scheme. The corresponding conversions lead to:

$$564kWh \rightarrow 130kgCO_2$$
$$1kWh \rightarrow xkgCO_2$$

Where x is calculated as 0.23. This is, one tonne of MSW will produce 230 g of new CO_2 if only electricity is being produced. In a similar manner for the CHP scheme the numbers are:

$$2{,}129kWh \rightarrow 130kgCO_2$$
$$1kWh \rightarrow xkgCO_2$$

Where x results in 0.06 kg of CO_2 produced after burning 1 tonne of MSW. These numbers then show that burning MSW in an EfW under a CHP scheme adds only about 60 g/kWh of accountable CO_2. This compares well with the values reported by Murphy, J. D. and McKeog, E. (2004) which were 58 g/kWh for a CHP scheme and 220 g/kWh in sole electricity generation mode.

In order to compare the savings of GHG, a reference for different fossil fuels is needed under both operation schemes. Porteous, A. (2005) alluding to DTI (1999) and Kyte (1996) data state that the typical emissions of a coal and gas fired power plant with and without thermal energy recovery are:

Plant type	CO_2 emissions electricity only (g/kWh)	CO_2 emissions CHP scheme (g/kWh)
Conventional Coal fired	950	410
Conventional Gas fired	525	226

Table 17. CO_2 emissions of selected fossil fuel fired power plants

Therefore, based on the electricity production per year of 71,609,967 kWh for the SECC project alternative with all the financial and operational aids, the CO_2 savings for Scotland will amount to:

Plant type	CO_2 savings (g/kWh)	CO_2 savings (tonnes CO_2)	CO_2 savings (%)
Conventional Coal fired	720	51,599	76%
Conventional Gas fired	295	21,125	56%

Table 18. CO_2 emissions savings for the SECC project in electricity generation mode compared to conventional fossil fuel fired power plants

Correspondingly, based on the total energy produced by the SECC project per year of 270,526,542 kWh, the CO_2 savings for Scotland for the SECC project alternative with all the financial and operational aids will be:

Plant type	CO_2 savings (g/kWh)	CO_2 savings (tonnes CO_2)	CO_2 savings (%)
Conventional Coal fired	350	69,621	85%
Conventional Gas fired	166	33,020	73%

Table 19. CO_2 emissions savings for the SECC project in CHP scheme compared to conventional fossil fuel fired power plants

As a reference, Murphy, J.D. and McKeogh, E. (2004) reported savings of about 734 gCO_2/kWh and 240 gCO_2/kWh when compared to a conventional power plant powered by fossil fuels in electricity production and in thermal recovery schemes, comparable with the ones obtained in this document.

Avoidance of gases release from landfills

In addition to the CO_2 savings when compared to a conventional fossil fuelled power plant, further savings can be calculated because of the avoidance of the release of Methane from landfills. Methane is reported to be 21 times stronger than CO_2 as a green house gas by the US Environmental Protection Agency (Turning a liability into an asset: A Landfill Gas-to-Energy Project Development Handbook, 1996) and also by the European Union (Options to Reduce Methane Emissions, 1998). Methane also accounts for roughly 50% of all gases released by a landfill. Therefore estimating Methane release will be an estimation of the direct savings that the EfW plant can bring. Calculating Methane production from landfill is not an easy task because of the many factors involved in the calculations, however some figures will be obtained using the above mentioned US EPA document as reference.

The first Methane estimation tool is a rough average to be used when only the amount of waste in place is known. The rule establishes that, on average, 0.10 ft^3 of landfill gas is generated per pound of waste per year. As the waste composition is supposed to be standard, the Methane produced will account for 50% of the gases released. Because the waste ages in the landfill with time, this is only valid for the initial years of the landfill life if no further waste is added to the site. An additional drawback is that the amount of gas estimated in this way could easily have a 50% deviation from the original figure. The amount of gas produced is not the same amount that is actually recovered either to be used in a landfill gas facility or burnt, and very little information is available on recovery efficiency. For our example, the premises for landfill gas calculations under this methodology would be equivalent to assuming a new landfill cell opened and closed every year with a nominal capacity of 340,000 tonnes. The estimations here assume no RDF facilities or in other words, the current disposal situation in landfill.

$$\frac{0.10\,ft^3}{lb}\times\frac{2204lb}{tonne}\times\frac{340{,}000tonnes}{year}\Rightarrow\frac{74.9x10^6\,ft^3}{year}$$

Using the specific volume of gaseous Methane to convert it to tonnes (data from http://www.airliquide.com/en/business/products/gases/gasdata/index.asp?GasID=41)

$$\frac{74.9x10^6\,ft^3}{year}\times\frac{0.0283m^3}{ft^3}\times\frac{kg}{1.48m^3}\times\frac{tonne}{1{,}000kg}\Rightarrow\frac{1{,}433tonnesMethane}{year}$$

As explained before, a 50% deviation should be calculated for this methodology, placing the Methane production between the low 716 tonnes/year and the upper extreme of 2,149 tonnes/year. However, only a fraction of the Methane produced is effectively recovered and burnt. The best US EPA estimation is in the range of 50 to 90% when energy facilities are present. A more recent estimation for European landfill sites in the range of 340,000 tonnes of waste in place range is about 40% if a Methane recovery facility is in place (See http://www.esru.strath.ac.uk/EandE/Web_sites/04-05/landfill/home21.html). Thus, the nominal case using the estimated Methane production figure of 1,433tonnes/year, for which only 573 tonnes/year will be effectively recovered and burnt, will leave the remaining 860 tonnes/year of Methane to escape to the atmosphere. As stated before, the GHG potential of the Methane is 21 times that of CO_2, therefore the equivalent CO_2 savings for the Methane release alone are 21 times the 860 tonnes released:

$$\frac{860tonnesMethane}{year}\times 21timesCO_2effect\Rightarrow\frac{18{,}060equiv.tonnesCO_2}{year}$$

This is 18,060 tonnes of CO_2 extra that will not be thrown into the atmosphere if the SECC EfW plant is developed. Equally if no recovery facility is present and the Methane escapes entirely into the atmosphere without any restriction, the amount of equivalent CO_2 saved will increase to 30,093 tonnes.

Another alternative methodology to calculate the Methane production from a landfill is using a First Order Decay Model. This model is more accurate in the sense that it accounts for variable gas generation rates, which is not only more realistic because the gas is released at different rates during the landfill lifetime, but also critical if estimating cash flow for a landfill gas project. Additional information is needed in order to use this model, namely:

- the average annual waste acceptance rate;
- the number of years the landfill has been open;
- the number of years the landfill has been closed, if applicable;
- the potential of the waste to generate Methane; and
- the rate of Methane generation from the waste.

Estimation for the peak gas production will be done using the estimation tool provided by the US Environmental Protection Agency in the web site "Technology Transfer Network. Clean Air Technology Center" (Retrieved on September 5th, 2005 from http://www.epa.gov/ttn/catc/products.html#software). The estimation was based on the following:

- All waste placed in one cell during one year.
- At the end of the year the site is closed.
- 50% of the gas produced is Methane.
- The default model parameters were not modified, thus the potential of the waste to generate Methane and the rate of Methane generation from waste were assumed to be the Clean Air Act conventional factors.

The maximum Methane generation calculated using this tool was $2.826x10^6 m^3$. Using the appropriate conversions:

$$\frac{2.826x10^6 m^3}{Peakyear} \times \frac{kg}{1.48 m^3} \times \frac{tonne}{1{,}000 kg} \Rightarrow \frac{1{,}934 tonnesMethane}{Peakyear}$$

Again assuming that only 40% of the Methane produced is effectively recovered, this is, the remaining 60% is released into the atmosphere, then the final figures will be as follows:

This is, using the First Order Decay Model some 24,000 tonnes of CO_2 will not be released into the atmosphere if the SECC is developed. If there is no gas recovery facility in place, the amount of Methane released will increase to 40,614 tonnes of CO_2. The discrepancy with the initial estimation of equivalent tonnes of CO_2 savings is due to the differences in both methodologies. In addition to this, it must be remembered that Methane is supposed to be 50% of the total gas generated in the landfill, the other half being CO_2 thus adding a small additional amount of CO_2 to the total gas release from the landfill.

All in all, the most important message is to make sure that CO_2 savings are achievable when an EfW plant is installed instead of a landfill site. The savings are not only because of the biogenic nature of the feedstock, but also because of the avoidance of release of the powerful Methane gas that takes place at landfill sites. For the SECC case the savings could be between 56 and 85% when compared to a fossil fuel power plant or near 21,125 to 69,621 tonnes of CO_2 due to fuel change alone. In addition, between 18,060 and 24,368 equivalent tonnes of CO_2 could be further added to the equation in terms of Methane release savings from a landfill site.

All this points towards the fact that the SECC project is a more sustainable option from the CO_2 emissions perspective when compared to conventional fossil fuel electricity production and the current landfill alternative.

Offset of non-renewable resources

The idea of the SECC project is to make these installations less dependant on external energy sources. As energy will be produced using renewable energy sources, non-renewable energy sources will be displaced and therefore the dependence on fossil fuels will diminish. However, it is also true that the scale of this project is small compared to a conventional power plant, along with lower efficiencies for the EfW plant. The SECC project will produce about 9.1 MW of electricity, far below the more common output delivered by a typical fossil fuel power plant (low to mid hundred MW). Thus, the diverted amounts of coal and gas are expected to be reasonably small if contrasted to the typical fossil fuel power requirements.

Having said this, in the following lines a gross quantification of the benefits will be made in terms of coal and gas removed from the current energy mix, using as reference the electricity production. Electricity generation was selected because by far both fossil fuel sources studied are almost exclusively used for electricity production purposes. If the energy expected to be delivered by the project is known, estimations can be made in order to approximately compute the tonnes of coal and cubic meters of gas to be displaced depending, naturally, on the origin of the fuel.

Coal estimation

Two different coals will be used in these estimations as markers: A good South African coal and an average Australian coal. From "Steam, Its generation and use" (Babcock and Wilcox, 1992), the High Heating Values of the selected coals a:

Coal source	High Heating Value (Btu/lb)	High Heating Value (kJ/kg)
South African	12,170	28,307
Australian	9,660	22,469

Table 20. Selected coals heating values

Knowing the electricity production from the EfW plant, the savings can be estimated. For the South African coal:

$$\frac{9.1MJ}{s}\times\frac{tonne}{28{,}307MJ}\times\frac{3{,}600s}{hour}\times\frac{24hours}{day}\times\frac{365days}{year}\Rightarrow\frac{10{,}138tonnes}{year}$$

But this would be at 100% efficiency, which is far from true for a fossil fuel plant. With a nominal design efficiency of about 30% for a thermal power plant, the coal requirements would be 33,793 tonnes of South African coal per year.

The same procedure can be used to estimate the amount of Australian coal, resulting in a figure of 42,574 tonnes of Australian coal per year.

Gas estimation

The same procedure can be made for gas estimation. In this case, an average gas from South Carolina (US) will be used.

Gas source	High Heating Value (Btu/ft^3 @60F and 30in Hg)	High Heating Value (kJ/kg)
South Carolina	1,116	53,275

Table 21. Selected gas heating values

The figure of 5,386 tonnes/year of gas at 100% efficiency is obtained, however, the efficiency of such a power plant is around 45% and thus the amount of gas to be displaced would be 11,971 tonnes of gas or 17.7×10^6 m^3/year, assuming all gas is Methane.

As mentioned at the beginning of this section, the offset of fossil fuels may be low because the SECC project power output is small. Nevertheless, the reduction can be further analysed and accounted for because it has an effect on the Sustainable Development Indicators.

Albeit the savings being of a small scale, the benefits of the counterbalance of fossil fuels are apparent and as such are an asset for the SECC project. In this issue, the EfW plant has a more sustainable output when compared to the alternatives.

CHAPTER 4

SUSTAINABLE DEVELOPMENT INDICATORS

With the Agenda 21 as background, the Scottish Executive decided to build up reference Sustainable Development Indicators in order to guarantee that programmes and projects likely to be implemented are not in conflict with the sustainability goals that were established. The idea is that the indicators can provide a useful tool in order to measure and trace the progress in the long term. The Executive issued the second report on the status of the indicators in the document “Indicators of Sustainable Development for Scotland: Progress Report 2004” (Scottish Executive Environment Group, 2004). This report and its values will be used as a reference in order to measure the impact that the SECC project will have.

The SECC project will mainly influence energy indicators; more specifically, those related to emissions (Climate Change) and use of renewable energy (Energy: Renewable). However, being additionally an EfW project, it will also leave a mark on waste indicators, in particular, the amount of waste that ends up in landfills (Waste: Landfilled). Each indicator will be briefly explained and its more recent value shown. The estimated contribution of the SECC project will be quantified using the corresponding value.

Climate Change

The changing climate is connected directly with the emission of GHG. The reference or marker GHG is CO_2, a consequence of the combustion process (among other sources of CO_2). Other gases such as Methane have GHG potential and are referenced to the CO_2 common frame. For the case of Methane, the multiplying factor is 21. The Scottish Executive is convinced that action is needed in order to reduce emissions of GHG and thus reduce or avoid the damaging consequences of climate change. Values for the indicator in tonnes of equivalent CO_2 are shown in Table 22 below:

	CO_2 emissions (tonnes)				
Green House Gas	**1990**	**1995**	**1998**	**1999**	**2000**
Carbon Dioxide	17.0	16.9	17.1	16.7	16.5
Methane	2.0	1.9	1.8	1.7	1.6
Others	1.8	1.7	1.7	1.7	1.7
Total	20.8	20.5	20.6	20.1	19.8

Table 22. Climate Change indicator

This is one of those indicators in which there is no specific commitment to achieve the target. The target for this particular indicator is to make an equitable contribution to the UK Kyoto target of a 12.5% reduction in 1990 levels of UK greenhouse gas emissions by 2008-2012.

As seen earlier in this document, the SECC project will account for some CO_2 savings from displacement of fossil fuels and avoidance of Methane emissions from landfills. Such amount will depend on the source of energy that the SECC project displaces plus the CO_2 equivalent from the Methane release in landfills. Only electricity generation will be considered as previously stated in this document. Thus the impact of the EfW plant on the indicator can be calculated as follows:

	CO_2 savings (tonnes)		
Fossil fuel displaced	**Electricity generation**	**Landfill**	**Total**
Conventional coal fired	51,599	18,060	69,659
Gas fired	21,125	18,060	39,185

Table 23. SECC project CO_2 savings estimation

The table above was made considering the first methodology for Methane estimation in landfills using the nominal gas production and 40% recovery efficiency.

In the case where a conventional coal fired power plant is displaced, the results represent 0.35% of the CO_2 emissions figures whereas if the EfW plant displaces a gas fired power plant the savings only account for 0.2% of the 2000 CO_2 emissions. It may not seem to be significant, but it certainly is considering the scale of the EfW plant and that the indicator is for the entire Scottish region. A much better and more detailed perspective can be obtained if the indicator is plotted as the rate of change as shown in Chart 17:

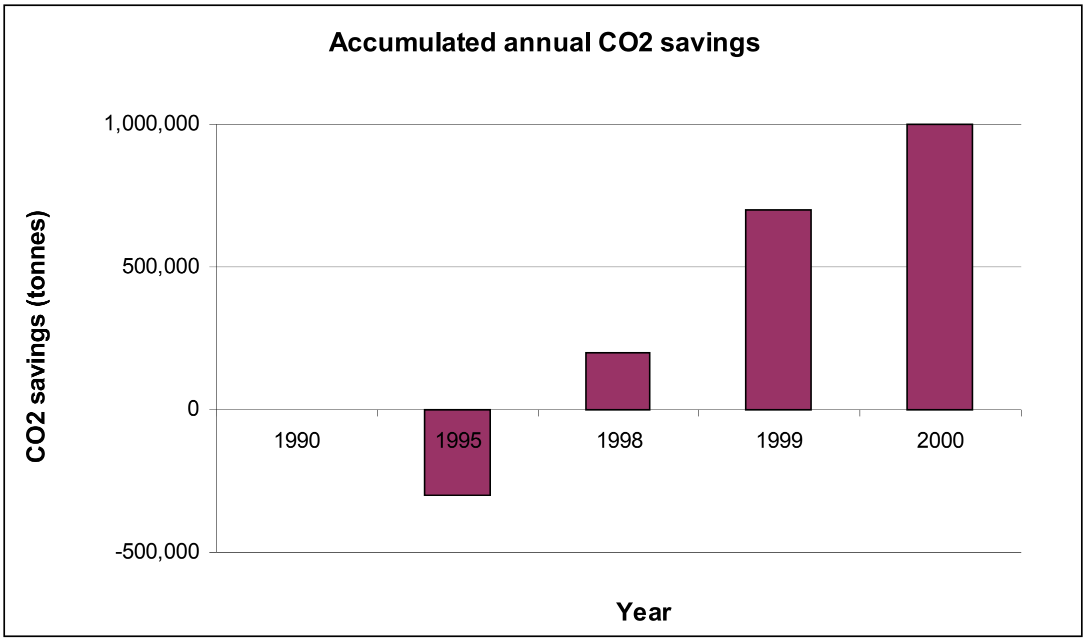

Chart 17. Accumulated annual CO_2 savings for Scotland

This charts shows that 1 million tonnes CO_2 have been saved in five years at an average of 200,000 tonnes of CO_2 per annum. Seen under this perspective, the 69,659 tonnes of CO_2 saved by the EfW plant calculated as it displaces conventional coal electricity generation, scales up to a 28% contribution. The same can be said if the project replaces a gas fired power plant used for electricity generation; in this case, the importance of the CO_2 reduction on the average saving figures will be as much as 16%. The SECC project importance seen like this is much more enhanced, especially when considering that it is a fairly small project and that in the real development this will be a CHP scheme, thus improving the figures even more.

The SECC project will undoubtedly add a valuable contribution towards the CO_2 emissions reduction and enhance the Climate Change sustainable development indicator value.

Energy: Renewable

The use of renewable energy sources usage is seen as directly linked with sustainable development. As the Scottish Executive has introduced legislation that requires electricity suppliers to increase the amount of electricity generated by renewable means, this indicator is a guideline in order to measure its success and progress. The latest figures are shown in Table 24:

	% electricity generated using Renewable sources		
Source	**2000**	**2001**	**2002**
Hydro	9.4	7.6	8.9
Wind, wave and solar	0.4	0.5	0.8
Others	0.2	0.4	0.5
Total	10.0	8.6	10.3

Table 24. Energy: Renewable indicator

Scottish electricity suppliers are obliged to provide 10% of the electricity generated from new renewable sources by 2010. Following a further consultation, the Scottish Ministers announced in March 2003 the adoption of a generation target of 40% from renewable sources by 2020. In the same document the total amount of electricity consumed is reported as 34.7 TWh for 2002 and thus will be used as a reference. This comparison will give a good idea of the expected change in the indicator.

Using the total figure of 34.7 TWh for the last reported year, the 10.3% that accounts for all renewable energy sources is 3,574,100 MWh and the 0.5% contribution of the "Other" sources is 173,500 MWh. The electricity generation of the SECC project will add 71,610 MWh that would be classified as "Other" renewable sources, a very positive 41% to the current values. The next chart shows the increase rate for "Other" renewable sources for the years in which data is available.

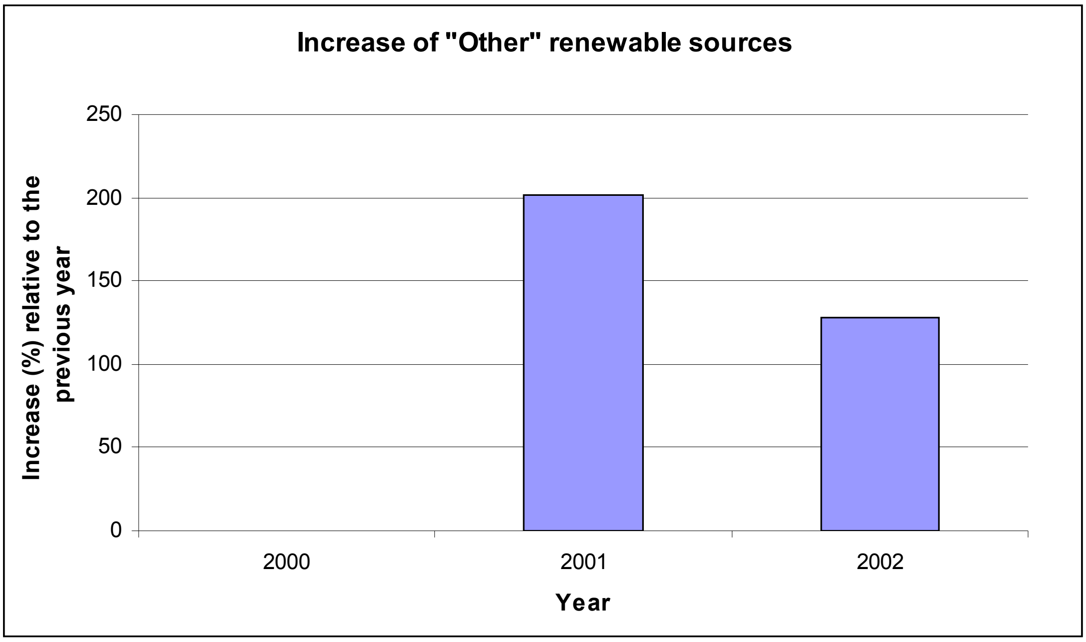

Chart 18. Increase of other sources of renewable energy.

Chart 18 shows the increase of the "Other" renewable energy sources relative to the previous year. Year 2001 represented a massive increase of 200%. Even though 2002 denoted a decrease in the growth rate, it is still a very considerable 128% increase when compared to the initial year. The EfW plant secures a 41% generated by one single project over the past figures, thus if the previous years maintain the current trend a steady growth is feasible. The SECC project therefore is among the projected contributing developments that will enhance the Energy: Renewable indicator.

Waste: Landfilled

The priority is to reduce landfilling of biodegradable waste because this is not an efficient use of resources and the landfill diversion targets need to be met. The indicator is defined as the amount of biodegradable municipal wastes landfilled assuming that 60% of municipal solid waste is biodegradable. A summary of the figures in the 2004 report are as follows:

	1997	**1998**	**1999**	**2000**	**2001**
Biodegradable MSW landfilled (million tonnes)	1.7	1.7	1.9	1.8	1.8

Table 25. Waste: Landfilled indicator

The target is to reduce the amount of biodegradable municipal wastes landfilled to 1.32 million tonnes by 2010, based on the 2010 Landfill Directive to reduce biodegradable municipal wastes landfilled to 75% of the reported 1995 levels (2.8 million tonnes) and the assumption that 60% of municipal waste is biodegradable.
It must be recalled now that the amount of feedstock to the EfW plant is a fraction of the total MSW arising. The value of 35% was used for the feedstock calculations, as stated earlier in this document. The remaining 65% is supposed to undertake further processing to be reused or recycled. In fact, most, if not all, the biodegradable waste (carton, paper, etc.) will be converted into RDF along with the plastic fraction of the waste. This will leave only non-biodegradable material to be landfilled and in fact, as the RDF can be alternatively used as capping material, it is supposed to be inert. Again, all the waste reduction is due to the RDF plant contribution and thus the impact of the SECC project will be nil. Using the 2001 values as a reference, the indicator figures change as follows:

$$1{,}800{,}000\,tonnes - 0.6 \times 340{,}000\,tonnes \Rightarrow 1{,}596{,}000\,tonnes$$

This represents a 11.3% reduction on the 2001 values. The real decrease of the indicator will have to be assessed with real figures when the EfW plant starts operation but should be close to the above estimated reduction.

CHAPTER 5

OTHER ISSUES RELATED TO THE SECC PROJECT

The SECC project and its relation with other environmental initiatives

The Renewable Obligation is the Government's main mechanism for supporting and encouraging the use of renewable energy in the electricity generation sector. It was introduced in April 2002 and it is basically a market incentive for some forms of renewable energy. The scheme requires suppliers to generate an annually increasing percentage of their sales from renewable energy sources. For each megawatt hour of renewable energy generated, a tradable certificate called a Renewable Obligation Certificate (ROC) is issued.

Suppliers can meet their obligation by:

- Acquiring ROC's
- Buying them at a price of £30/megawatt hour
- Combining the previous options

When there is a payment in order to buy ROC's, the money is put into the buy-out fund that is recycled to ROC holders at the end of the 12-month period. In Scotland, the Renewable Obligation (Scotland) is in place.

Advanced technologies such as Gasification and Pyrolysis are within the ROC's scope if the energy source is waste, however, conventional EfW is not covered and therefore, the electricity generated by these means will not benefit from this providence. This seems to contradict the spirit of the norm because, being covered by the same Waste Incineration Directive regulations, all the EfW technologies such as Gasification/Pyrolysis and conventional EfW will limit their emissions based on the same principles that guide the directive, hence there is no advantage of one technology being selected over another from the environmental point of view. In the same train of thought, if the biogenic content of the feedstock is 85%, at least the same proportion of the electricity produced using waste should be considered as renewable regardless of the technology involved in the conversion process.

The document "Eligibility of Energy from Waste-Study and Analysis" (2005) by ILEX Energy Consulting on behalf of The Department of Trade and Industry, suggests that EfW with mechanical separation to pre-sort the waste will become the preferred option for local authorities.

Predicting the EfW growth is a complex task because of all the uncertainty involved:

- It is driven, among others, by the EU directive on waste diversion
- Energy needs and future developments play an important part in its evaluation
- The waste growth and population increase are another factor that adds uncertainty to the evaluation.
- Finally, the waste strategy that the local authorities will follow.

The extended eligibility of ROC's will impact mainly the economies of the projects and may become decision criteria when compared to other waste management options. Even more, if the ROC eligibility is extended to cover conventional EfW, then the effects on this type of facility will be noticed as an increased capacity. This could have a significant impact on the renewable sources development as it could become less risky, in economical and technological terms, to develop EfW instead of other renewable sources. This is, perhaps, the major threat that conventional EfW posses to renewable energy sources development.

Public acceptance of EfW plants

In documents such as the "National Waste Strategy: Scotland" (SEPA 1999) and the "Incineration of Household Waste" (The Parliamentary Office of Science and Technology, 2000) it is recognized that the public tends to view incinerators as "bad neighbours". Opposition to EfW is more likely to appear if people feel excluded from the decision making process and have decisions imposed upon them instead of being consulted. Acceptability is increased if local people are involved early in the planning process.

The "National Waste Plan 2003" (SEPA, 2003) has taken this into consideration and the stakeholders had a significant involvement in the development of the Waste Area Plans. Among the participants were local authorities, non-governmental organisations, waste management industry, local community groups and even individual members of the public. However, support may become extinct when communities are confronted by the actual development proposal. This is aided by the fact that some environmental groups oppose incineration as part of broader campaigns: to promote higher recycling targets or encourage other renewable energy sources.

Different institutions have issued recommendations in order to successfully handle the opposition that an EfW plant will create. Among them, the National Society for

Clean Air and Environmental Protection (NSCA) published the document “Public Acceptability of Incineration” (2003) in which the main recommendations are:

- They should only be developed where there is a proven environmental need. The Landfill Directive has stressed the need to divert waste from the common landfill practice, and, as explained earlier in this document, higher steps in the waste hierarchy will not be enough. Therefore there is a real need to develop the project.
- Incineration should include energy recovery. As it has been conceived, the SECC project has been planed to make use of the CHP scheme, not only because it is an imposed requirement but also because it is more economically attractive in this way.
- It should be sized for local waste (Thus reducing transport cost and public resistance to waste ‘imports’). The sizing of the project is constrained only to local waste and therefore waste imports should not be an issue.
- It must have environmental management systems with emphasis in public reporting of performance. Finally, the reporting procedure and waste management disclosure can be guaranteed as early as in the planning stages to make sure the community is well informed.

The SECC project must make sure that all the above mentioned issues are covered. In terms of relationship with the public, the consultation processes should, among other topics, improve the public’s understanding of the issues, be open and genuinely participative and be aimed at building understanding and trust, not just at achieving planning permission.

In the local context, SEPA issued a guideline to approach EfW plants (Babtie Group, 2002). Additional concerns rose during the consultation, in particular:

- There is not enough research into advanced EfW technologies such as Pyrolysis and Gasification
- The problem of lack of information showing that EfW will not deter waste management options above in the hierarchy.
- There will be problems if, in order to make a reasonable plant size, the need to import waste becomes a reality.

- As the development is based on the BPEO and these are revised on a regular basis, there is the fear that regular changes will have a negative impact on the investors as this could impose greater risk.
- Lastly but not least important, the consultation showed a big bias from the public perspective towards landfill above thermal treatment as alternative for waste that cannot be reused or recycled, although EfW would be more acceptable if waste is segregated thus ensuring no reuse or recycling discouragement.

All in all, the issues of ROC's extended eligibility and bad public perception are questions that are part of the problem when trying to develop a complex project like the proposed SECC EfW installation. The efforts in determining the sustainability of this alternative when compared to the current situation and its impact on the sustainable development indicators, will help to reduce the apprehension that it is normally surrounding this delicate matter.

CONCLUSIONS

The Scottish Exhibition and Conference Centre energy from waste plant will help to achieve the energy requirement that the development needs to achieve. It will do so in a more sustainable manner when compared to other options.

The SECC project will not contribute in reducing the amount of waste that will be diverted to landfills and help to achieve the targets set by the Landfill Directive. The RDF plant due to be in operation soon will cover this issue. This is a particular situation because both initiatives were not designed together. However, if the SECC project was standing alone without the help of the RDF plant, then the waste reduction figures and its impact on the Waste: Landfilled sustainable development indicator, should be attributed to the EfW project.

From the economic viewpoint and evaluated under the premises outlined here, the project certainly needs a reasonable amount of financial and operational enrichment in order to make it attractive. The options evaluated here point towards the securing of a substantial grant together with a tough operational performance and greater services income from increased prices for electricity, heating, cooling services and landfill tax. Even under these considerations, the IRR is positive but below the market reference. However, the sole economic aspect is still much better that the economic performance of the current and future landfill options. The social benefits, quantified in economic terms, will make a substantial addition to the evaluation shown here.

Carbon dioxide emissions will be avoided if the SECC project has the permission to be developed. Both reasons, the biogenic nature of the fuel and the avoidance of gases emissions from landfills, are responsible for the savings that can be estimated from 56% to 85% depending on the fuel source supplanted (coal or gas) and the operation mode (electricity alone or CHP mode) using the fuel replacement as reference. Clearly the savings increase when the avoidance of Methane release is added to the previous figures. However, the estimation of gases release from landfills is not an accurate science.

If the project displaces a fossil fuelled power plant, the offset of non renewable resources could be in the order of 33,800 tonnes/year or 42,800 tonnes/year of coal depending on its heating value or 17.7×10^{6} m^3/year of gas. Certainly small figures when compared to the typical electricity generation power plant, but nevertheless savings that correspond to the small scale of the SECC project.

Finally, the project has a positive impact towards sustainable development in two of the three indicators evaluated in this document. Its impact on the Waste: Landfilled indicator is nil due to the operation of the RDF plant. The influence on the Climate Change indicator will be of small significance if seen as a national figure, but a significant 28% of the rate of change of the past years if a coal power plant electricity production is displaced. The same figure drops to 16% if a gas fired plant electricity generation is replaced by the SECC project. For the Energy: Renewable indicator the trend is towards a benefit or increased use of energy from non fossil fuels, with a 41% contribution of the SECC project when compared to the latest available figures in the "Other" sector. Therefore, in these particular items, the project can be considered more sustainable than the current waste management alternative.

On the negative side, two aspects are relevant to the SECC project: On the one hand the current situation of EfW excluded from the Renewable Obligation scheme. It seems to be hindering its growth, and as shown by some research it may become the preferred renewable energy source if the ROC eligibility is extended. On the other hand there is the natural predisposition to the harmful consequences that such a project could bring, especially from the public and organized environmental groups. This can be avoided with proper care taken by local authorities and the active participation of the general public. In this sense, the SECC project will not be the exception.

REFERENCES

AEA Technology Environment (1998) "Options to Reduce Methane Emissions". A report for DGXI. Retrieved on 5/09/05 from http://europa.eu.int/comm/environment/enveco/climate_change/methane_emissions.pdf

Babcock and Wilcox (1992) "Steam, its generation and use". Edited by the Babcock and Wilcox Company, Barberton, Ohio, USA.

Babtie Group (2002). "Guidelines and approach to thermal treatment plants and energy from waste". *Scottish Environmental Protection Agency.* SEPA Consultation: Final report.

Brown, T. (2001). "Burning issue: the public acceptability of incineration". *The Chemical Engineer*. Issue 720. 22-23.

Caputo, A.C. and Pelagagge, P. M. (2002). "RDF Production Plants II: Economics and Profitability". *Applied Thermal Engineering*. 22, 439-448

Chartered Institution of Wastes Management (2003) "Energy from Waste: A good practice guide". *IWM Business Services Ltd.*

Consonni, S. Giugliano, M. and Grosso, M. (2005). "Alternative strategies for energy recovery from municipal solid waste Part A: Mass and energy balances". *Waste Management*. 25. 123-135.

Daskalopoulos, O. et al. (1997). "Economic and Environmental Evaluations of Waste Treatment and Disposal Technologies for Municipal Solid Waste". *Applied Energy*. Vol 58. No 4. 209-255.

Department for Environment, Food and Rural Affairs (2005) "One future–different paths. The UK's shared framework for sustainable development". *Department for Environment, Food and Rural Affairs.*

Department of Trade and Industry (2003). "Energy White Paper: Our Energy Future – Creating a Low Carbon Economy". *Department of Trade and Industry*. Retrieved on 3/08/2005 from http://www.dti.gov.uk/energy/whitepaper/ourenergyfuture.pdf

Department of Trade and Industry. "Policy. The Renewable Obligation". Retrieved on 15/07/2005 from http://www.dti.gov.uk/renewables/renew_2.2.htm

Glasgow City Council. (2005). "City Plan". *Glasgow City Council.* Retrieved on 29/07/05 from http://www.glasgow.gov.uk/en/Business/City+Plan/

Glasgow City Council. (2005). "City Plan. Part 1. Development Strategy. Infrastructure. Renewable Energy. Promoting Renewable Energy". Retrieved on 28/06/2005 from http://www.glasgow.gov.uk/en/Business/City+Plan/Part+1+-+Development+Strategy/Infrastructure/Renewable+Energy/Promoting+renewable+energy/

Glasgow City Council. (2004). "Statutory Performance Indicators 2002/03 and 203/04. Waste Management". *Glasgow City Council.*

Glasgow City Council. (2005). *"Sustainable Development"*. Retrieved on 29/07/2005 from http://www.glasgow.gov.uk/en/Business/Environment/Sustainabledevelopment/

Hartenstein, H. U., Horvay, M. (1996). "Overview of municipal waste incineration industry in west Europe (based on the German experience)". *Journal of Hazardous Materials*. 47. 19-30.

ILEX Energy Consulting. (2005). "Eligibility of Energy from Waste-Study and Analysis". *Department of Trade and Industry*.

Miranda, M. L. and Hale, B. (1997). "Waste not, want not: the private and social cost of waste-to-energy production". *Energy Policy.* Vol. 25. No 6. 587-600.

Murphy, J. D. and McKeog, E. (2004). "Technical, economic and environmental analysis of energy production from municipal solid waste". *Renewable Energy*. 29. 1043-1057.

National Association for Clean Air and Environmental Protection (2001). "Public Acceptability of Incineration. Summary and Conclusions". *National Association for Clean Air*. Retrieved on 5/09/2005 from http://nscaorguk.site.securepod.com/assets/PAI%204-page%20summary%20web.doc

Porteous, A. (2001). "Energy from waste incineration – A state of the art emissions review with an emphasis on public acceptability". *Applied Energy.* Vol 70. 157-167.

Porteous, A. (2005). "Why Energy from Waste Incineration is an Essential Component of Environmentally Responsible Waste Management". *Waste Management.* 25. 451-459.

Scottish Environment Protection Agency (2004). "Glasgow and Clyde Valley Area Waste Plan. Annual progress report 2003-2004". *Scottish Environment Protection Agency.*

Scottish Environment Protection Agency (1999). "SEPA National Waste Strategy Scotland". *Scottish Environment Protection Agency.*

Scottish Environment Protection Agency (2003). "The National Waste Plan 2003". *Scottish Environment Protection Agency.*

Scottish Executive (2002).”Sustainable development in Scotland - Rio, Johannesburg and beyond”. *Scottish Executive*. Retrieved on 15/07/2005 from http://www.scotland.gov.uk/consultations/environment/rio.pdf#search='SUSTAINABLE%20DEVELOPMENT%20IN%20SCOTLAND%20rio%20and%20beyond'

Scottish Executive (2005) “Waste Incineration (Scotland) Regulations 2003. Practical guidance. Edition 2”. *Scottish Executive*.

Scottish Executive Environment Group. (2004) “Indicators of Sustainable Development for Scotland”. *Scottish Executive*.

The Parliamentary Office of Science and Technology (2000). “Incineration of Household Waste”. *The Parliamentary Office of Science and Technology* Number 149. December 2000.

The Scottish Parliament (2002) “Sustainable Development (Updated)” Retrieved on 28/07/2005 from http://www.scottish.parliament.uk/business/research/pdf_res_brief/sb02-47.pdf#search='SUSTAINABLE%20DEVELOPMENT%20IN%20SCOTLAND'

United Nations. U. N. Department of Economic and Social Affairs. Division of Sustainable Development. Documents. “Agenda 21”. *United Nations.* Retrieved on 14/07/2005 from http://www.un.org/esa/sustdev/documents/agenda21/

United Nations. U.N. Department of Economic and Social Affairs. Division of Sustainable Development. Documents. “Johannesburg Declaration on Sustainable Development”. *United Nations.* Retrieved on 14/07/2005 from http://www.un.org/esa/sustdev/documents/WSSD_POI_PD/English/POI_PD.htm

US Environmental Protection Agency (2005). “Benefits of Landfill Gas energy”. *US Environmental Protection Agency.* Retrieved on 15/07/2005 from http://www.epa.gov/lmop/benefits.htm

US Environmental Protection Agency (1996). “Turning a liability into an asset: A Landfill Gas-to-Energy Project Development Handbook”. *US Environmental Protection Agency*.